LONG POINT REGION

TIER THREE WATER BUDGET AND LOCAL AREA RISK ASSESSMENT

Report Prepared for:
LAKE ERIE SOURCE PROTECTION REGION

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We certify that this report is accurate and complete and accords with the information available during the site investigation. Information obtained during the site investigation or provided by third parties is believed to be accurate but is not guaranteed. We have exercised reasonable skill, care, and diligence in assessing the information obtained during the preparation of this report.

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EXECUTIVE SUMMARY

This report describes a Tier Three Water Budget and Local Area Risk Assessment (Tier Three Assessment) completed for the municipal drinking water systems of the Towns of Waterford, Simcoe, and Delhi, located within Norfolk County in the Province of Ontario, Canada. The purpose of this project is to evaluate the Water Quantity Risk Level and identify potential water quantity threats to these municipal drinking water systems. This assessment is a requirement under the Ontario Ministry of the Environment's *Clean Water Act* (MOE 2006).

The Province of Ontario introduced the *Clean Water Act* (Bill 43) to ensure that all residents have access to sufficient, safe drinking water. Under the *Clean Water Act*, Source Protection Regions are required to conduct technical studies to identify existing and potential water quality and quantity threats to municipal drinking water. Through the development of community-based Source Water Protection Plans, actions will be implemented to reduce or eliminate Significant Drinking Water Threats.

As one component of the required technical studies, Tier One and Tier Two Water Quantity Stress Assessments have been completed for many subwatersheds across the province. The purpose of a Water Quantity Stress Assessment is to compare available groundwater and surface water supply to the demand from existing, future, and planned drinking water systems. Where the ratio of water demand to water supply is high, subwatersheds have been classified as having a Moderate or Significant potential for water quantity stress. Source Protection Regions are required to complete a Tier Three Assessment when municipal water supply wells are located within a subwatershed that was classified by a Tier Two Study as having a Moderate or Significant potential for water quantity stress.

The water supply system of the Town of Delhi consists of a surface water intake and two groundwater wells completed within the overburden aquifer, while the populations of Waterford and Simcoe rely entirely upon groundwater for their potable water supplies. The system in Waterford uses two overburden wells, while that of Simcoe uses nine overburden wells within three well fields, along with a shallow infiltration gallery. The surface water intake at Delhi is located within the North Creek Subwatershed, whereas the wells in Delhi, Waterford, and Simcoe are located within the subwatersheds of Big Creek, Nanticoke Creek, and Lynn River, respectively. The Tier Two Water Quantity Stress Assessment completed for Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities (AquaResource 2009b) identified these subwatersheds as having a Significant or Moderate potential for surface water or groundwater stress. This identification led to the requirement of municipal systems located within these watersheds to be assessed under a Tier Three Assessment. To date, the Towns of Waterford, Simcoe, and Delhi have not had any issues meeting their water quantity requirements.

During the initial Tier Two Assessment, Otter at Tillsonburg subwatershed was also assigned a Moderate potential for stress. However, due to the uncertainty of this stress classification, the assessment of this subwatershed was re-examined during the initial stages of the Tier Three Assessment using the refined groundwater flow model. The updated results of that assessment lead to the classification of a Low potential for stress for the Otter at Tillsonburg subwatershed, resulting in the removal of the Town of Tillsonburg from the Tier Three Assessment.

This report details the Tier Three Assessment carried out for the Waterford, Simcoe, and Delhi municipal water supply systems. It summarizes the process and results of the Local Area Risk Assessment. Two technical appendices summarize the development of the conceptual model (**Appendix A**: Physical Characterization Report) and the numerical hydrologic and hydrogeologic models (**Appendix B**: Model Development and Calibration Report) used to complete the assessment.

Scope of Work

The scope of work completed in this Tier Three Assessment and documented in this report follows the Province's *Technical Rules: Assessment Report, Clean Water Act, 2006* (*Technical Rules*; MOE 2009) and *Water Budget and Water Quantity Risk Assessment Guide* (AquaResource 2011).

The following tasks were completed for this study:

- developing the conceptual understanding of the Tier Three Study Area
- updating the groundwater flow model, originally developed for the Tier Two Assessment, with the latest hydrostratigraphy and calibrating it with a focus on the Tier Three Focus Area
- developing and calibrating a regional integrated surface water / groundwater flow model of the Tier Three Focus Area to simulate hydrological components, as well as groundwater recharge and flow
- developing and refining four local-scale, integrated surface water / groundwater flow models, that are nested within the regional integrated model, near municipal water wells and intakes that obtain potable water from surface water sources, or a mixture of groundwater and surface water sources (i.e., Lehman Reservoir, and wells in Waterford and two areas of Simcoe)
- completing a Local Area Risk Assessment for the municipal wells and surface water intake located in the Tier Three Focus Area using the groundwater flow model and local integrated models
- applying the calibrated groundwater and integrated models to assess the water budget components in the Study Area and near municipal wells and intakes (Local Areas)
- completing Significant Groundwater Recharge Area delineation and mapping

Conceptual Model

Appendix A contains a detailed description of the conceptual understanding of the Tier Three Study Area, which includes characterization for the entirety of Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities, as well as characterization of the more localized Tier Three Focus Area, including the lands immediately surrounding the Towns of Waterford, Simcoe, Delhi, and Tillsonburg. The following sections provide a brief overview of the conceptual model.

Topography and Physiography

Regionally, ground surface elevation in the Tier Three Study Area varies through the three Conservation Authorities from a high of approximately 340 m above sea level (asl) north of Tillsonburg, along the St. Thomas Moraine, to a low of approximately 174 m asl to the south, along the Lake Erie shoreline. Near the Tier Three Focus Area, ground surface topography varies from 307 m asl on the St. Thomas Moraine, to 190 m asl to the south, along the valleys of Big Otter Creek, Big Creek, and Lynn River. Other regional topographic highs are associated with other various moraines in the area including the Westminster, Norwich, Tillsonburg, Courtland, Mabee, Paris, Galt, and Moffat Moraines.

The area represented by the three Conservation Authorities is located within portions of five physiographic regions, including Norfolk Sand Plain, Mount Elgin Ridges, Horseshoe Moraines, Haldimand Clay Plain, and the Ekfrid Clay Plain, as defined by Chapman and Putnam (1984). The Tier Three's Focus Area includes all of these regions except for Ekfrid Clay Plain, which is found further to the west. The Towns of Delhi, Simcoe, and Waterford are found within the Norfolk Sand Plain, which is the predominant region in the Focus Area and is characterized by relatively flat, glaciolacustrine coarse sand and, to a lesser extent, silt deposits.

The Mount Elgin Ridges physiographic region is located north of Tillsonburg and is characterized by alternating ridges and valleys, representing the various moraines in the area (Chapman and Putnam 1984; Barnett 1982). The Tillsonburg and Paris Moraines are part of the Horseshoe Moraines region and are located just east and north of Delhi. These two moraines are characterized by irregular ridges composed of Wentworth Drift, as well as outwash, glaciolacustrine, and stratified drift deposits (Barnett 1982).

The Haldimand Clay Plain is present along the eastern side of the Focus Area and larger Study Area, east of Waterford and Simcoe. This area is characterized by a relatively flat, glaciolacustrine clay; however, the clay thins and is interbedded with till closer to the moraine features to the north (Chapman and Putnam 1984; Barnett 1978). The physiographic region known as the Ekfrid Clay Plain is located west of Tillsonburg within the Catfish and Kettle Creek Conservation Authority boundaries. Similar to the Haldimand Clay Plain, the Ekfrid Clay Plain is predominantly flat, fine-grained clay deposits; however, the deposit thins and is characterized by boulders in the St. Thomas area (Chapman and Putnam 1984).

Surface Water Features

The Tier Three Focus Area includes various important surface water features. Within the Town of Tillsonburg, in the western portion of the Focus Area, Stoney Creek flows from the northwest and feeds into Big Otter Creek. Big Otter Creek flows from the northeast, through Tillsonburg and continues southwest, eventually draining into Lake Erie. Tributaries to these creeks are small with the exception of Little Otter Creek, which flows south of the Town of Courtland and feeds Big Otter Creek southwest of the Focus Area.

Near Delhi, in the central portion of the Focus Area, Big Creek flows from the north, through the northwestern part of Delhi, and continues south, where it ultimately enters Lake Erie. The Big Creek tributaries of North and South Creeks converge from the west and are dammed to form the Lehman Reservoir before entering Big Creek. This five hectare reservoir supplies a portion of the municipal water supply for the residents of Delhi and Courtland (AECOM 2010) and is included in this Risk Assessment. Further details regarding the construction of this reservoir can be found in **Appendix A**. Several kilometers south of Delhi, Stony Creek feeds into Big Creek, originating from the northeast and passing to within 500 m of the two groundwater municipal supply wells for Delhi and Courtland.

Major surface water features in the northeastern part of the Focus Area include Nanticoke Creek, which flows southward where it flows into and beside the Waterford Ponds and subsequently turns east, through the Town of Waterford, before continuing southeast and into Lake Erie. The two Waterford groundwater wells are located adjacent to these ponds, which are former gravel pits now used for recreation (Chapman and Putnam 1984). The coarse-grained texture of the pond/lake substrate is interpreted to allow surface water infiltration during municipal pumping (Lake Erie SPRTT 2008) from these two wells classified as Groundwater Under Direct Influence (GUDI) of surface water.

In the southeastern portion of the Focus Area, Patterson and Davis Creeks flow southward and converge to form the Lynn River in the northern extent of the Town of Simcoe. Lynn River flows southwards, through Simcoe, where it is fed by Kent Creek, originating from the west. Lynn River continues through Simcoe and southeastward until it reaches its terminus at Lake Erie. The municipal wells of the Northwest Well Field lie adjacent to former sand and gravel pits (that have formed ponds), as well as adjacent to the upper reaches of Patterson Creek. The infiltration gallery and groundwater wells of the Cedar St. Well Field lie adjacent to Kent Creek.

Wetland complexes classified as Provincially Significant Wetlands (PSWs) make up the bulk of the wetlands found in the Focus Area. In the areas surrounding Tillsonburg, identified PSWs include the Dereham Wetland and Hughes Tract found to the north of Tillsonburg, as well as small pockets of PSWs and other mapped wetland complexes located east and southeast of Tillsonburg. In the central part of the Focus Area, small PSWs are found along the entire length of Big Creek, including a small area less than 200 m from the Lehman Reservoir intake. PSWs located nearest to the Delhi groundwater wells include the Nixon Ellaton Wetlands and Kent Creek Complex located to the north and southeast, respectively. The Waterford groundwater wells found in the northeastern portion of the Focus Area are surrounded by a PSW (NC2) that follows Nanticoke Creek and its southern tributaries and surrounds the Waterford Ponds. Three PSWs are found near Simcoe including: LR13, which follows the upper reaches of Patterson Creek and runs adjacent to the Northwest Well Field; the Kent Creek Complex, which follows Kent Creek and lies close to or encompasses the Cedar St. Well Field and infiltration gallery; and the LR16 Complex, which follows Lynn River as it flows to the southeast away from Simcoe.

Paleozoic Bedrock Geology

Beneath the greater Tier Three Study Area, bedrock geology consists primarily of gently dipping Paleozoic shale, limestone, and dolostone units, which are buried beneath a thick veneer of overburden sediments for much of the regional area. Outcropping Paleozoic bedrock has been observed in just a few areas in the east near Hagersville. The Paleozoic formations, which have been identified and included in the regional conceptual model include, from oldest to youngest, the Salina Formation, the Bass Islands / Bertie Formation, the Bois Blanc Formation, the Onondaga Formation, the Amherstburg Formation, the Lucas Formation, the Dundee Formation, and the Marcellus Formation. A description of the lithology of each formation can be found in **Table I**.

TABLE I. Bedrock Geology Summary from the Paleozoic Era

Formation	Lithology
Marcellus	• Black, organic-rich shales, interbedded with grey shales and carbonates • Interbeds are very fine to medium grained and fossiliferous (limestone), and somewhat calcareous (shale)
Dundee	• Light brown-grey, fossiliferous limestone and minor dolostones • Medium to thickly bedded and microcrystalline
Lucas	• The Anderdon Member of the Lucas Formation consists of an upper medium-grained, fossiliferous sandy limestone, and a lower fine-grained locally fossiliferous limestone
Amherstburg	• Brown limestone and dolostone. Commonly fossiliferous, bituminous and cherty
Onondaga	• Cherty, fossiliferous limestones
Bois Blanc	• Grey-brown, crystalline, cherty, fossiliferous limestones and dolostones • Often thin- to medium-bedded and fine- to medium-grained
Bass Islands / Bertie	• Brown-grey, dolostones and minor shales • Often argillaceous, bituminous, crystalline, variably laminated, and contains minor fossil content
Salina	• Brown-buff-grey, characterized by evaporates (i.e., halite, gypsum, and anhydrite), shales, and carbonates (dolostone and limestone)

Yakutchik and Lammers 1970; Barnett 1982; Armstrong and Carter 2010

Quaternary Geology

A major unconformity separates Paleozoic bedrock from overlying Quaternary overburden deposits across Ontario. This unconformity represents the period of extensive weathering and erosion of exposed bedrock before the deposition of overlying Quaternary sediments, which occurred approximately 200 million years following bedrock sedimentation (Johnson et al. 1992). The Quaternary sediments found in the Study Area are dominated by the results of glacial ice lobe advances and retreats during the Late Wisconsinan. Deposits from older glacial stages are often reworked and overprinted by more recent glacial activity. Laterally extensive sheets of till commonly serve as regional lithological markers that help reconstruct the glacial history of the area. The Quaternary deposits, which have been identified regionally in the area, from youngest (top) to oldest (bottom), are listed in **Table II**. These sediments represent fine- to coarse-textured tills, glaciolacustrine deposits, recessional moraines, deltaic sands, and silts, as well as more recent processes, which have formed modern alluvial deposits, dunes, and the Long Point Spit.

TABLE II. Quaternary Geology Summary

Age (ybp)	Glacial Period	Associated Deposit
Present to 12,500	Post-glacial	Modern alluvium, organic deposits, Long Point Spit, eolian, sand dunes
13,000 to 13,500	Port Huron Stade	Wentworth Drift, Norfolk Sand Plain, Haldimand Clay Plain, and intervening coarse-grained sediments
13,500 to 14,000	Mackinaw Interstade	Paris / Galt Moraines
14,000 to 15,500	Port Bruce Stade	Port Stanley Drift, fine-grained glaciolacustrine deposits, coarse-grained intervening deposits, several end moraines (e.g., St. Thomas, Norwich, Ingersoll, Westminster, Tillsonburg, Courtland, and Mabee Moraines)
15,500 to 16,500	Erie Interstade	Fine- and coarse-grained glaciolacustrine deposits
18,000 to 25,000	Nissouri Stade	Catfish Creek Till

YBP – years before present
After Barnett 1992

Regional Hydrostratigraphy

Hydrostratigraphic units are derived from the bedrock and overburden stratigraphic units based on their general hydrogeologic properties. The delineation of hydrostratigraphic units based on geologic descriptions from borehole logs is an approximation; however, the available information is used in conjunction with interpretations of the regional and local spatial distribution of geologic units. Units composed primarily of coarse-grained overburden materials (e.g., sands and gravels) or higher transmissivity bedrock units are referred to as aquifers and units composed of lower permeability overburden (e.g., clay or fine-grained tills) or poorly transmissive bedrock units are referred to as aquitards.

The regional hydrostratigraphic unit structure for the Study Area was developed in an earlier phase of this project and builds upon previous studies in the area, as well as more recent, high-quality corehole data collected as part of this Tier Three Assessment (**Appendix A**). A total of 11 overburden and 1 bedrock hydrostratigraphic layers were conceptualized (**Table III**). While some of the units are regional in extent, many are restricted to certain areas due to the spatial variability of the depositional environments. The Norfolk Sand Plain is one such thick and spatially extensive unconfined aquifer and is found in the central portion of the regional area. Below the Norfolk Sand Plain exists an intermediate aquifer, which is confined by the Wentworth or Port Stanley Drift. Further to the east, the Haldimand Clay Plain is found at surface and is not interpreted to overlie any overburden aquifer units. In this area, the carbonate bedrock aquifers of the Dundee and Onondaga Formations are used for domestic water supply. Bedrock aquifers exist in other parts of the regional area (e.g., Dundee, Lucas, and Amherstburg

Formations); however, water quality can be sulphurous (Armstrong and Carter 2010) and these bedrock aquifers may not be used due to the availability of transmissive overburden aquifers at shallower depths.

TABLE III. Hydrostratigraphic Units within the Regional Area

No.	Geologic Unit	Glacial Period	Aquifer / Aquitard
1	Haldimand Clay Plain/ Surficial Clay	Holocene	Aquitard
2	Norfolk Sand Plain/ Interstadial Sediment	Mackinaw Interstade / Port Huron Stade	Aquifer
3	Wentworth Drift		Aquitard
4	Coarse-grained Interstadial Sediment (Sand, Gravel)		Aquifer
5	Wentworth Drift		Aquitard
6	Coarse-grained Interstadial Sediment (Sand, Gravel)		Aquifer
7	Port Stanley Drift	Port Bruce Stade	Aquitard
8	Coarse-grained Interstadial Sediment (Sand, Gravel)		Aquifer
9	Port Stanley Drift		Aquitard
10	Coarse-grained Interstadial Sediments (Sand, Gravel)	Erie Interstade	Aquifer
11	Catfish Creek Drift	Nissouri Stade	Aquitard
12	Paleozoic Bedrock		Aquifer / Aquitard

The conceptual hydrostratigraphic framework presented in **Table III** was used as the basis for the development of the numerical model layers. As several of the hydrostratigraphic units described in **Table III** are discontinuous across the regional area, and to reduce the total number of layers represented in the numerical models, the hydrostratigraphic model was subdivided into three geological zones. Each zone represents three distinct, more localized, depositional environments, including Port Stanley Drift Plain (west), Norfolk Sand Plain (centre), and Haldimand Clay Plain (east). As a result, the number of overburden hydrostratigraphic layers in any one zone was reduced from 11 layers to 7 (**Table IV**). The updated model was constructed with two layers to represent bedrock based on the inclusion of weathered and unweathered bedrock layers used in the Tier Two Model. There was not enough evidence to support the existence of a continuous highly weathered zone of bedrock at a regional-scale in the Tier Three model; therefore, layers eight and nine in the updated model are considered the same hydrostratigraphic unit: Paleozoic Bedrock.

TABLE IV. Hydrostratigraphic Framework

Layer	Geologic Unit	Glacial Period	Aquifer / Aquitard
ZONE 1: Haldimand Clay Plain Zone (zone extends approximately from the Galt Moraine in the west, across the Haldimand Clay Plain to the eastern model boundary)			
1	Haldimand Clay Plain / Surficial Clay	Holocene	Aquitard
2	Norfolk Sand Plain / Interstadial Sediment	Mackinaw Interstade / Port Huron Stade	Aquifer
3	Wentworth Drift		Aquitard
4	Interstadial Sediment (Sand, Gravel)		Aquifer
5	Wentworth Drift		Aquitard
6	Interstadial Sediment (Sand, Gravel)		Aquifer
7	Port Stanley Drift	Port Bruce Stade	Aquitard
8	Paleozoic Bedrock	Paleozoic	Aquifer / Aquitard
9			
ZONE 2: Norfolk Sand Plain Zone (zone extends approximately from the Tillsonburg Moraine in the west, to the Galt Moraine in the east)			
1	Surficial Clay	Holocene	Aquitard
2	Norfolk Sand Plain / Interstadial Sediment	Mackinaw Interstade / Port Huron Stade	Aquifer
3	Wentworth Drift		Aquitard
4	Interstadial Sediment (Sand, Gravel)		Aquifer
5	Port Stanley Drift	Port Bruce Stade	Aquitard
6	Interstadial Sediment (Sand, Gravel)		Aquifer
7	Port Stanley Drift		Aquitard
8	Paleozoic Bedrock	Paleozoic	Aquifer / Aquitard
9			
ZONE 3: Port Stanley Drift Plain (extending from the Study Area boundary in the west, approximately to the Tillsonburg Moraine in the east)			
1	Surficial Clay	Holocene	Aquitard
2	Surficial Interstadial Sediment (Sand, Gravel)	Mackinaw Interstade	Aquifer
3	Port Stanley Drift	Port Bruce Stade	Aquitard
4	Interstadial Sediment (Sand, Gravel)		Aquifer
5	Port Stanley Drift		Aquitard
6	Interstadial Sediment (Sand, Gravel)	Erie Interstade	Aquifer
7	Catfish Creek Drift	Nissouri Stade	Aquitard
8	Paleozoic Bedrock	Paleozoic	Aquifer / Aquitard
9			

Local Hydrostratigraphy in the Vicinity of Municipal Water Systems

The municipal groundwater wells in Waterford are interpreted to obtain water from both a subsurface aquifer and surficial water sources. Groundwater is extracted from a 6 m thick intermediate aquifer, which is overlain by the Wentworth Drift; however, well logs reveal windows in this lower permeability unit and these are interpreted to create hydraulic connection between the production aquifer and the Waterford Ponds, which were constructed in the upper Norfolk Sand Plain. These wells have been classed as GUDI.

The Town of Simcoe is serviced by three well fields that lie at the transition zone between the Norfolk Sand Plain in the west and the Haldimand Clay Plain in the east, resulting in a complex aquifer/aquitard system in this area. Near the Northwest Well Field, the production aquifer is a 14 m thick sand aquifer, overlain by a discontinuous Wentworth Drift confining layer. Similar to Waterford, boreholes logs reveal windows in the drift that are interpreted to connect adjacent, shallow, ponds (from aggregate extraction) to the deeper municipal production wells that have been classified as GUDI. The groundwater wells and shallow infiltration gallery of the Cedar St. Well Field draw water from the intermediate sands, as well as the surficial Norfolk Sand Plain aquifer where the intervening lower permeability Wentworth Drift is absent. In the area of Chapel St. Well 3, the municipal overburden aquifer is overlain by approximately 10 m of fine-grained Wentworth Drift and the well is located far from sensitive surface water features. The production aquifer in this area is observed to fine upward and consists of interbeds of fine-grained material reaching up to 5 m thick.

The municipal supply aquifer in the Delhi Well Field consists of fine- to coarse-grained sand, which is overlain by approximately 17 m of Wentworth Drift and approximately 18 m of sand and gravel at surface. Cross-section analysis reveals windows in the drift unit that are interpreted to potentially hydraulically connect the municipal aquifer to the shallow surficial aquifer. This is evidenced by the classification of the two Delhi wells as GUDI.

The Town of Tillsonburg obtains potable water from two well fields located northwest and southeast of the Town. The wells of the Northwest Well Field are completed within a relatively thin (3 m on average) sand aquifer that consists of silty fine-grained to pebbly gravel and reaches up to 14 m thick in the northernmost well. Three of the four wells in the Northwest Well Field are classed as GUDI wells (Wells 4, 5, and 7). The municipal aquifer is found at surface east and south of Tillsonburg Well 5 and is interpreted to be hydraulically connected to Stoney Creek and its tributaries located nearby. The wells of the Southeast Well Field in Tillsonburg are completed within a sand aquifer that is approximately 8 m thick on average, but thickens towards the northwest. Windows identified in the overlying aquitard of the Port Stanley and Catfish Creek Drift and the lack of vertical hydraulic gradients in these areas indicate a hydraulic connection between the Norfolk Sand Plain aquifer (8 m thick) found at surface and the production aquifer found at depth. Four of the wells in the Southeast Well Field are classed as GUDI wells (Wells 1A, 2, 9, and 10).

Water Budget Tools

As part of the Tier Three Assessment, numerical modelling tools were developed to assess the sustainability of the municipal water sources. To represent the complex hydrological and hydrogeological conditions present in the Study Area, both a regional-scale groundwater flow model, and regional- and local-scale integrated surface and groundwater flow models were developed. A dedicated groundwater flow model is required to provide an efficient method for the calibration and parameterization of groundwater flow in the region. The models were developed based on the above hydrostratigraphic model, a detailed characterization of the groundwater, and surface water systems, and were refined around wells and intakes to a level supported by available data. **Appendix B** of this report describes the development and calibration of the groundwater and integrated models in detail; a brief summary of each are provided below.

Groundwater Numerical Model

With the development and refinement of a detailed conceptual model of the geologic, hydrologic, and hydrogeologic systems for the Study Area, a numerical model of groundwater flow that was previously developed for the Tier Two Stress Assessment using FEFLOW (DHI Water & Environment; DHI 2012a), was updated with the most recently collected data. While the entire model domain was updated, greater refinement and attention during calibration was given to the Tier Three Focus Area where the municipal water supply systems of interest are located.

Once a hydrogeologic parameter set that reasonably replicated observed groundwater conditions was obtained, the hydrostratigraphic structure and calibrated parameters were provided to the regional-scale, integrated MIKE SHE model (DHI 2012b) of the Focus Area, which was then calibrated against observed hydrological conditions (e.g., streamflow). The integrated model was used to estimate groundwater recharge for the Focus Area, which was provided back to the groundwater flow model for re-calibration. Calibration of both the integrated model and the groundwater model proceeded iteratively as both models moved towards calibrated solutions.

The groundwater flow model was calibrated at the municipal well field-scale to both steady-state (long-term average) and transient (time-varying) conditions. Calibration targets included high-quality hydraulic head data from the field program and provincial and municipal monitoring wells; groundwater discharge estimates from streamflow gauges; and transient hydraulic head response data from municipal and provincial wells. The calibrated groundwater model, using groundwater recharge estimates from the regional integrated model, was used to complete scenarios as part of the Tier Three Assessment for the municipal supply wells of Delhi, as prescribed by the *Technical Rules*. These wells are interpreted to have minimal interaction with surface water features and therefore, use of an integrated model was not necessary.

Integrated Numerical Models

A regional-scale MIKE SHE integrated model was developed for the Focus Area to simulate the regional flow system and four local-scale integrated models were constructed at a higher resolution in the areas of Delhi, Waterford, and Simcoe to simulate well field-scale hydrologic and hydrogeologic features that influence the reliability of the municipal wells and intake in these areas. Model parameters, as well as surface and subsurface boundary conditions, were provided from the regional-scale model to the local-scale models.

The integrated models had reasonable water budgets demonstrating that precipitation was realistically partitioned into the various hydrologic components. Additionally, the groundwater calibration within the integrated models showed a match to the observed high quality data that was comparable to the FEFLOW model calibration, demonstrating the robust linkages between the models. Calibration and verification of the integrated models was achieved using observed streamflow data from eight Water Survey of Canada (WSC) gauges.

Most natural components of the hydrologic cycle were explicitly included in the integrated models (i.e., precipitation, evapotranspiration, snow melt, overland flow, channel flow, unsaturated flow, interflow, and saturated flow), as well as some of the effects of human activity (i.e., land use, irrigation, and water usage).

The four calibrated, local-scale MIKE SHE models were used to complete scenarios as part of the Tier Three Assessment for the municipal supply wells of Waterford and Simcoe, and the Lehman Reservoir in Delhi.

Consumptive Water Demand

Consumptive water demand is defined as the amount of water that is removed from a water source and not returned to the same water source within a reasonable amount of time. Consumptive water takers within the Study Area including both municipal and non-municipal permitted water takings were compiled for this study. The permitted consumptive water takings were simulated directly in the numerical models as they have the potential to influence water levels and affect the model calibration.

Other water uses that rely on groundwater and/or surface water within the subwatersheds were also identified in this assessment. These additional water uses include surface water features that rely on groundwater discharge for sustaining coldwater fisheries and wetlands (and similar environmental / ecological communities), for recreational use and for wastewater assimilation.

Current and historical surface water and groundwater pumping and monitoring data were also compiled as part of this study, and it was found that the water supply systems of Waterford, Simcoe, and Delhi have not experienced water quantity limitations.

Local Area Risk Assessment

Six Local Areas (Local Areas A, B, C, D, E, and F) were delineated surrounding the municipal supply wells, infiltration gallery, and surface water intake in the Tier Three Focus Area. These areas were delineated as outlined in the Province's *Technical Rules* and Ontario Ministry of Environment (MOE) Guidance (MOE 2014) based on a combination of the following:

- the cone of influence of the municipal wells
- land areas where recharge has the potential to have a measurable impact on water levels at the municipal wells
- the surficial drainage areas, which may contribute water to the Lehman intake
- the surface water bodies that contribute significant amounts of recharge to municipal wells

A set of Risk Assessment Scenarios were required and the municipal Allocated Quantity of Water (Existing plus Committed Demand up to the current lawfully permitted rate) was established for this Assessment. The calibrated groundwater and local-scale integrated flow models were used to estimate the changes in water levels in the municipal supply aquifer (and wells) and Lehman Reservoir under average and drought conditions. Changes in the water table near Provincially Significant Wetlands and the impacts to groundwater discharge under average climate conditions were also assessed. The impact of takings by the Lehman intake on downstream water uses was assessed by simulating the decline in reservoir water level relative to the reservoir overflow structure. The Risk Assessment Scenarios predicted that there is a Low Risk Level associated with the operation of the Lehman intake and the wells in Waterford, Delhi, Simcoe Northwest, and Simcoe Chapel St.; however, there is a Moderate Risk Level in the Cedar St. Well Field, due to simulated impacts to baseflow and a PSW near Kent Creek and the Cedar St. Well Field. This Risk Level was upgraded to a Significant Risk due to simulated drawdown exceeding the amount of Safe Additional Available Drawdown (SAAD) in Wells 2A, 3, 4, and 5 of the Cedar St. Well Field during all groundwater risk scenarios.

Significant Groundwater Recharge Areas

As required by the *Technical Rules*, Significant Groundwater Recharge Area mapping was updated as part of the Tier Three Assessment. The threshold recharge rates for the watersheds that was calculated in the Tier Two Assessment using Rule 44(1) of the *Technical Rules* was maintained for this assessment as per provincial guidance (AquaResource 2012). The threshold of 115% of the average groundwater recharge rate determined for each watershed in the Tier Two Study was applied against the groundwater recharge rates estimated by the regional MIKE SHE integrated model for the Focus Area. Land areas within the Focus Area, which had groundwater recharge estimates that were greater than the specified thresholds were identified as Significant Groundwater Recharge Areas. Similar to the Tier Two Significant Groundwater Recharge Area mapping exercise, a 1 km^2 filter was applied to remove small, isolated, identified areas, or to infill small, non-identified areas that were surrounded by identified areas.

Conclusions

Based on the results of the Risk Assessment modelling scenarios, Local Area A was assigned a Significant Risk Level, with High certainty, while Local Areas B, C, D, E, and F were assigned a Low Risk Level with High certainty.

Following the *Technical Rules*, all consumptive water users and potential reductions to groundwater recharge within Local Area A were classified as Significant Water Quantity Threats. These consumptive water users include the permitted water demands (e.g., municipal pumping) and non-permitted water demands (e.g., domestic water wells).

Recommendations

The following recommendations are made based on results of this Tier Three Assessment:

- Maintain and enhance monitoring programs:
  - Monitoring and reporting programs associated with Permits to Take Water are already in place and should be continued. Continuously recorded groundwater levels from monitors throughout each town and production wells would be beneficial in better understanding the seasonal and inter-annual variability of the groundwater flow system, as well as the influence of surface water features on production aquifers.
  - Flow gauging and other assessments of key surface water features near the Cedar St. Well Field should be maintained to monitor potential baseflow reduction and wetland impacts during times of high demand. In particular, two continuous stream gauging stations of Kent Creek upstream and downstream of the well field should be maintained. These data could be used to better characterize the stream and its interaction with PSWs and the groundwater flow system.
  - Ongoing collection of climate data will be vital for developing future water budgets. It is recommended that the existing climate monitoring network be maintained and enhanced as resources allow. As modelling software and computing power improves, more detailed, local-scale transient analysis will be possible and will benefit from local-scale climate data.
- Update Risk Assessment, as needed:
  - In the event that new significant water takings are proposed within the delineated Local Area, the Tier Three Risk Assessment should be updated to determine the impact of the proposed water taking on municipal water supply reliability, and possible changes to the level of risk.
- Rehabilitate and maintain wells routinely:
  - The Risk Assessment Scenarios analyzed well drawdown assuming constant well performance. As drawdown in the municipal wells and the ability of the wells to pump at their Allocated rates

is a key metric determining the level of risk assigned to a Local Area, any increase in drawdown due to declining well performance must be mitigated to ensure the validity of the Risk Assessment results. Issues with declining well performance have been addressed in the past with routine rehabilitation efforts and it is recommended that the towns continue their efforts to this end.

- Maintain and enhance water conservation programs:
  - Current water conservation programs should be maintained to ensure that per-capita water demand does not increase and to encourage decreases. Opportunities to reduce water demand within the towns should be considered. Any reduction in the per capita water use will enhance water supply reliability and local ecosystem health.
- Update regional water budget models:
  - The Lake Erie Source Protection Region maintains water budget modelling tools to help manage and protect the water resources across the watersheds. Hydrogeologic, hydrologic, and operational insights gained from this Tier Three Assessment should be incorporated into the models maintained by the Lake Erie Source Protection Region. These modelling tools should be updated periodically as new information is gathered and insights evolve within the watersheds.
- Assessment of Cedar St. Well Field:
  - Ongoing assessment of conditions at the Cedar St. Well Field, including any well performance testing, should be supported by focused modelling analyses. The model should be verified against the results of these studies and the model updated as required.

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1 INTRODUCTION

The Province of Ontario introduced the *Clean Water Act* (Bill 43; MOE 2006) to ensure that all residents have access to sufficient, safe drinking water. Under the *Clean Water Act*, Source Protection Regions are required to conduct technical studies to identify existing and potential water quality and quantity threats to municipal drinking water. Through the development of community-based Source Water Protection Plans, actions will be implemented to reduce or eliminate any Significant Drinking Water Threats.

Under the requirements of the *Clean Water Act*, municipalities may be required to complete a Tier Three Water Budget and Local Area Risk Assessment (Tier Three Assessment) to assess the ability of the municipal water sources to meet Committed and Planned water demands. Tier Three Assessments are required where municipal wells or intakes are located in subwatersheds that were classified as having a Moderate or Significant potential for hydrologic stress under a Tier Two Subwatershed Stress Assessment completed under the requirements of the *Clean Water Act*. The Tier Three Assessments identify municipal water sources that may be unable to meet Existing, Committed, and Planned water demands.

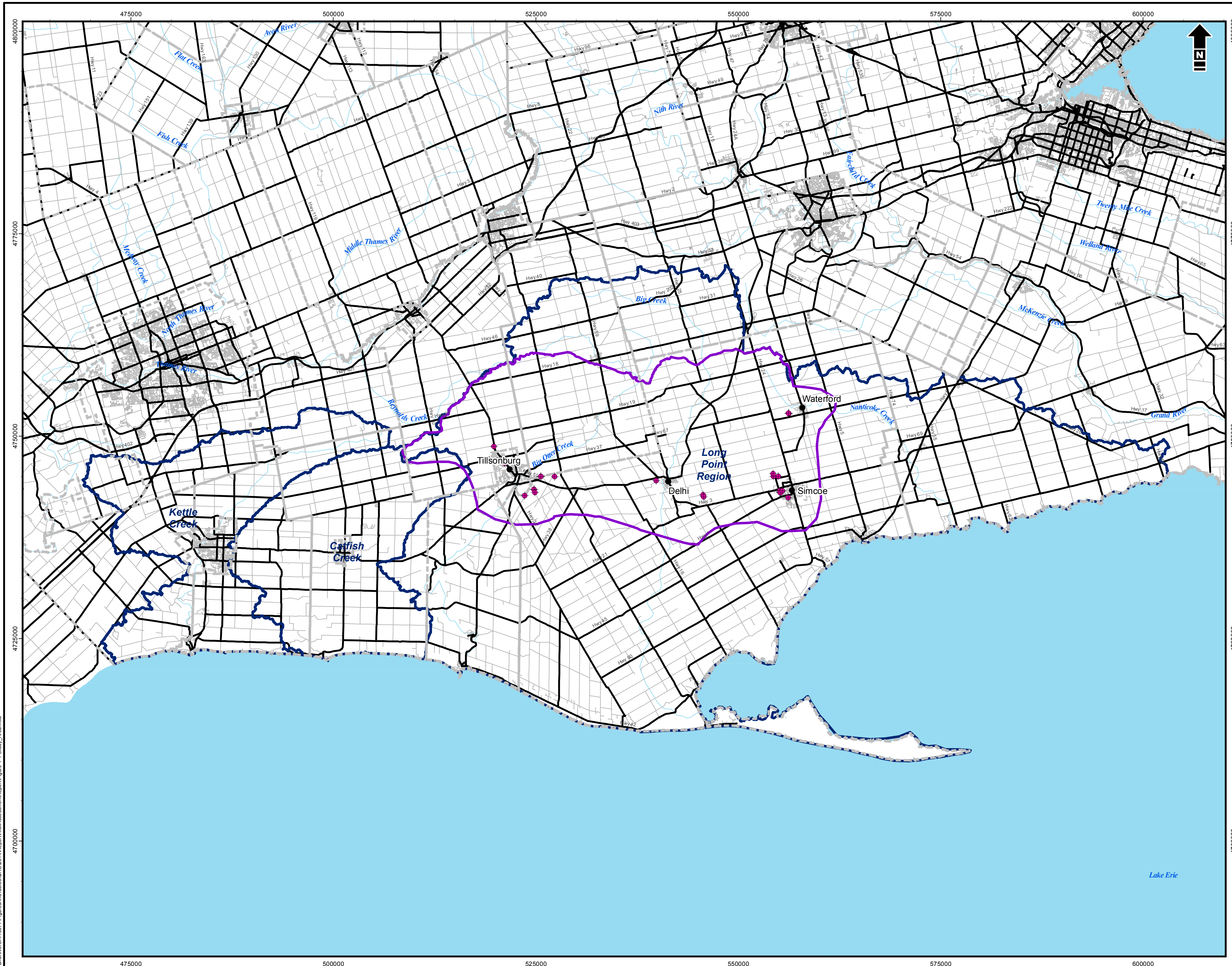
A Tier Two Water Budget and Water Quantity Stress Assessment was completed for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities (AquaResource 2009a, 2009b). This Tier Two Assessment identified the following municipal water supplies in subwatersheds that have a Moderate or Significant potential for hydrologic stress:

- Waterford (Nanticoke Upper Subwatershed identified in the Groundwater Stress Assessment), Simcoe (Lynn River Subwatershed identified in the Groundwater Stress Assessment), and Delhi (Big Above Minnow Creek Subwatershed identified in the Groundwater Stress Assessment and North Creek Subwatershed identified in the Surface Water Stress Assessment) in Norfolk County
- Tillsonburg (Otter at Tillsonburg Subwatershed identified in the Groundwater Stress Assessment) in Oxford County

As a result, a Tier Three Assessment was required for the Waterford, Simcoe, Delhi, and Tillsonburg water supply systems (**Figure 1.1**). While there are no documented issues with respect to the municipal sources not being able to meet demand, the municipalities are required to complete a Tier Three Assessment.

Otter at Tillsonburg subwatershed was classified as having a Moderate potential for stress under future conditions and was assigned a high level of uncertainty in the Tier Two Assessment. To address this uncertainty, the subwatershed stress assessment was re-examined during an earlier phase of the present study (**Appendix B**) using the refined regional groundwater flow model before proceeding with the Local Area Risk Assessment for the Tillsonburg water supply system. The Percent Water Demand calculation was updated for the subwatershed based on a reduced water demand forecast from Oxford County and the subwatershed stress assessment was repeated. The updated results of that stress assessment showed that a classification of a Low potential for stress should be assigned to the Big Otter at Tillsonburg subwatershed, reflecting the changing water consumption conditions within the Tillsonburg municipal water supply system. As a result of this revised subwatershed classification, the Tillsonburg water supply system was no longer required to be assessed under the Tier Three Assessment and therefore, the remainder of this report only assesses the water supply systems of Waterford, Simcoe, and Delhi.

This report details the Tier Three Water Budget and Local Area Risk Assessment carried out for the above municipal water supplies and summarizes the process and results of the assessment. Two companion reports detailing the milestones of this project are included as appendices, including the Long Point Region Physical Characterization Report (**Appendix A**) and Long Point Region Model Development, and Calibration Report (**Appendix B**).



Tier Three Study Focus Area
Conservation Authority Boundary
Watershed Boundary
Municipality
Water Body
Highway
Road
Municipal Well / Intake / Infiltration Gallery
Municipal System

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Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Study Area

Date: 29 Apr 2015		Project: 15077-527
Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 1.1

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1.1 Study Team

The project team was directed by a technical team of members from the following organizations:

- Long Point Region Conservation Authority
- Catfish Creek Conservation Authority
- Kettle Creek Conservation Authority
- Norfolk County
- County of Oxford
- Ministry of Natural Resources (MNR)
- MOE

A peer review team reviewed all documents produced as part of this assessment:

- Rob Schincariol, P.Geo. (University of Western Ontario)
- David Rudolph, P.Eng. (University of Waterloo)
- Hugh Whiteley, P.Eng. (University of Guelph)
- Christopher Neville, P.Eng. (S.S. Papadopulos & Associates, Inc.)

The project consultant team responsible for the completion of this Tier Three Water Budget and Local Area Risk Assessment was Matrix Solutions Inc. (Primary Consultant), Stantec Consulting Ltd., (Field Program), and Blackport and Associates (Field Program).

1.2 *Clean Water Act* Water Budget Framework

The *Clean Water Act* requires that each Source Protection Committee prepare an Assessment Report for their Source Protection Areas in accordance with Ontario Regulation 287/07 (General Regulation) and the *Technical Rules: Assessment Report, Clean Water Act, 2006* (*Technical Rules*; MOE 2009). A requirement of the Assessment Report is the development of water budgets that assess the threats to water quantity sources under a tiered framework. Tier One and Tier Two Assessments of this framework evaluate the subwatershed's hydrological stresses, while the Tier Three Assessment examines threats to water quantity sources and evaluates the ability of the sources to meet a community's current and planned drinking water needs.

Water budgets developed under the *Clean Water Act* provide a quantitative measure of the hydrologic cycle components and a conceptual understanding of the processes and pathways by which surface water and groundwater flow through a watershed or subwatershed. Key deliverables of the water budget analysis include the surface water and groundwater flow models, which are available for future use and application.

The Tier One and Tier Two Subwatershed Stress Assessments estimate the hydrologic stress within a subwatershed and identify those subwatersheds, which have the potential for local stresses to result in local water shortages at municipal wells and intakes. The subwatershed stress assessment is dependent on hydrologic parameters estimated in the water budget.

A Tier Three Assessment is completed for two reasons:

1. To estimate the Risk Level associated with a municipality being able to sustain its Allocated (Existing and Committed) water supply pumping rates.

2. To identify water quantity threats that may influence the municipality's ability to meet their Allocated pumping rates.

The Tier Three Assessment is completed for all municipalities where their drinking water sources are located within a subwatershed having a Moderate or Significant potential for water quantity stress as determined in the Tier Two Stress Assessment.

In general, Tier Three Assessments provide a consistent approach for evaluating the long-term reliability of the Province's drinking water sources, and they identify drinking water quantity threats located within local vulnerable areas where Moderate or Significant risks have been identified.

1.2.1 Tier Three Water Budgets and Local Area Risk Assessments

The objective of the Tier Three Assessment is to evaluate the risk associated with a municipality not being able to meet its future water quantity requirements, considering increased municipal water demand, future land development, drought conditions, and other water uses. The Tier Three Assessment uses refined surface and groundwater flow models and involves a more detailed study of the available groundwater or surface water sources than previous tiers. Various scenarios are evaluated with the models assessing the groundwater and the surface water flows and levels, and the interactions between them.

The ratio of water demand to water supply used to assess stress for Tier One and Tier Two is not used for the Tier Three Assessment. Instead, the Tier Three Risk Assessment evaluates the potential that a community may not be able to meet its current or planned water demands from a water source (e.g., stream, lake, or aquifer).

Estimates of consumptive water demand are a major component of a Tier Three Assessment. Consumptive water demand refers to the amount of water taken from a water source (e.g., surface water or groundwater) and not returned to that water source. The Tier Three Assessment identifies water uses (e.g., municipal and industrial) and estimates consumptive demand for each use.

Tier Three Assessments use detailed numerical groundwater and/or surface water models on a local scale. Models are developed with the accuracy and refinement needed to evaluate hydrologic or hydrogeologic conditions at a water supply well (or intake) and, whenever possible, should be refined from the Tier Two Assessment models. The models developed for the Tier Three Assessment need to be scaled with enough refinement to evaluate the potential impacts of planned water demands on other water uses. Water budget models are also developed to represent a refined conceptual hydrologic or hydrogeologic model and are calibrated to the best extent possible to represent average annual and drought conditions.

Numerical groundwater and surface water models are used to delineate the "Local Area" for groundwater wells and surface water intakes. In the Tier Three Risk Assessment, numerical models are used to estimate the impact of increased water demand, variable climate, and land use development on a well or surface water intake using a variety of modelling scenarios. Where these scenarios identify the potential that a well or intake will not be able to supply their Allocated rates, the Local Area is assigned a Moderate or Significant Water Quantity Risk Level. Once the Risk Level is assigned to the Local Area, activities within the Local Area that remove water from an aquifer or surface water body without returning that water to the same aquifer or surface water body (i.e., consumptive water uses) are identified as drinking water threats. Similarly, activities that reduce groundwater recharge to an aquifer within the Local Area are also identified as drinking water threats. The drinking water threats within the Local Area are then classified as Moderate or Significant depending on the Risk Level assigned to the Local Area. If the Risk Level is Significant, all consumptive water uses and reductions in recharge are classified as Significant Drinking Water Threats. The Risk Assessment modelling scenarios also considers the need to meet the water demand requirements of other uses.

Rules and technical guidance for completing Tier Three Assessments are provided in Part IX of *Technical Rules,* the *Technical Bulletin: Part IX Local Area Risk Level* (MOE and MNR 2010; MOE 2013), and the *Water Budget & Water Quantity Risk Assessment Guide* (AquaResource 2011).

1.2.2 Tier Three Methods

The following steps were completed for the Long Point Region Tier Three Assessment:

- develop the conceptual and numerical Tier Three Assessment Models
  - The first step in the Tier Three Assessment is the development of a conceptual water budget. Additional detailed hydrogeologic and/or hydrologic characterization is undertaken within and surrounding the municipal wells and intakes as part of the Tier Three Assessment. These conceptual models form the basis for the development of numerical models that are then calibrated to represent typical operating conditions under average and variable climate conditions.

- characterize municipal wells
    - The Tier Three Assessment requires a detailed characterization of wells and intakes, specifically identifying the low water operating constraints of those wells and intakes.
- estimate the Allocated and Planned Quantity of Water
    - This task compiles and describes Existing, Committed, and Planned demands for municipal wells.
- characterize future land use
    - An evaluation of the potential impact of future land use changes on drinking water sources is included. This task typically involves a comparison of Official Plans (OPs) with current land use and incorporates assumptions relating to imperviousness for future developments.
- characterize other water uses
    - The Assessment should identify other uses (e.g., ecological flow requirements) that might be influenced by municipal pumping and identify water quantity constraints according to those other uses.
- delineate vulnerable areas
    - The Groundwater Quantity Vulnerable Areas, Well Head Protection Areas, WHPA-Q1 (for Water Quantity) and WHPA-Q2, are delineated using the Tier Three Water Budget Model. The Surface Water Quantity Vulnerable Area, IPZ-Q, is delineated for surface water intakes. The IPZ-Q is the drainage area that contributes surface water to the intake. In this Tier Three Assessment, the point of interaction between surface water features and the municipal production aquifer have also been defined as a "Surface Water Contributing Area" (Waterford and Simcoe-Northwest Well Field) and can be delineated using GIS tools.
- evaluate risk scenarios
    - A series of scenarios will take into account the Allocated Quantity of Water for each well and intake, average, and drought conditions, and future land use. The scenarios should be evaluated in terms of the ability to pump water at each well or intake along with the impact to other water uses.
- assign Risk Level
    - A Risk Level (Low, Moderate, or Significant) will be assigned to each of the vulnerable areas based on the results of the risk scenarios. A certainty level (e.g., High, Low) will accompany each Risk Level.

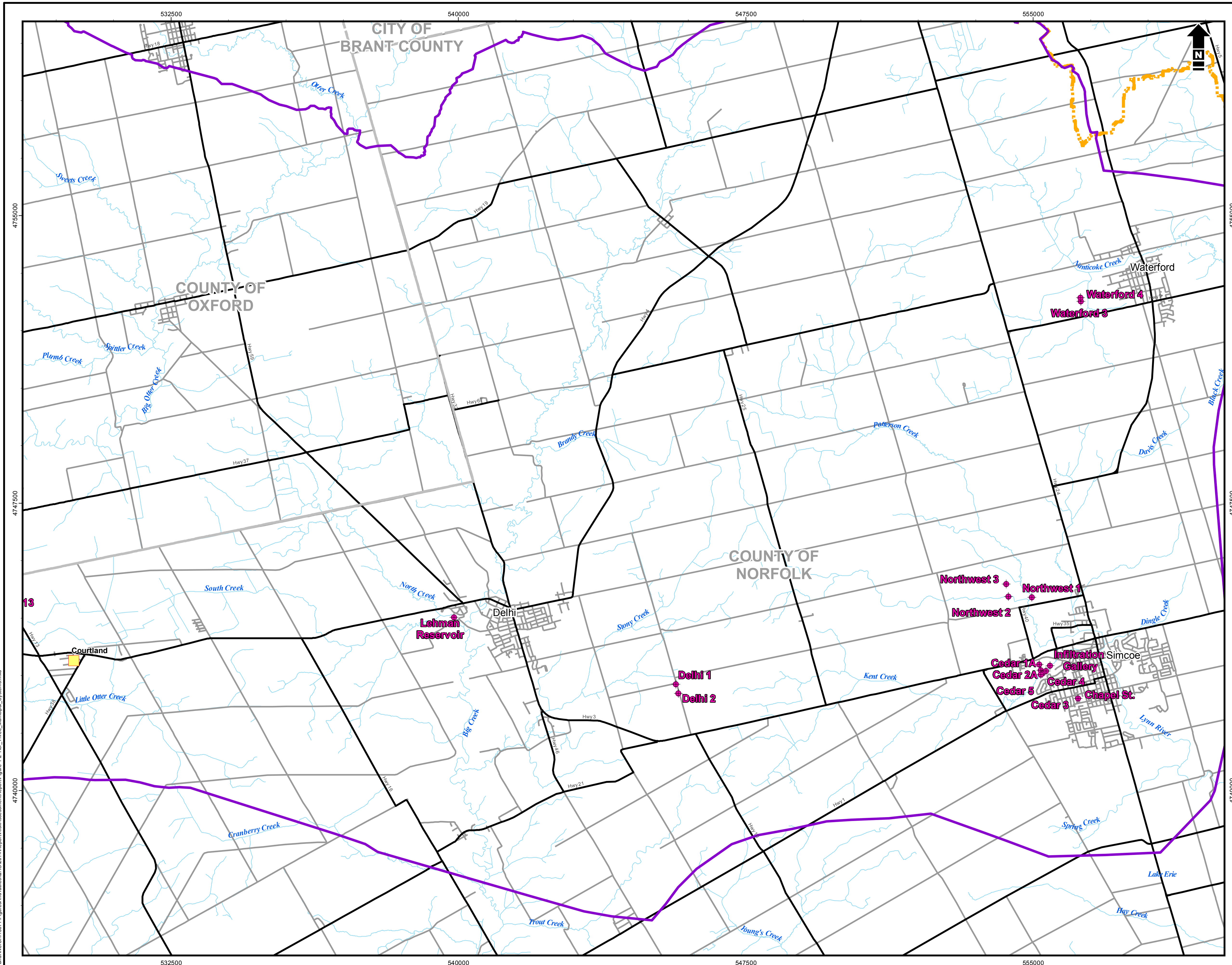
- identify drinking water quantity threats and areas where they are Significant and Moderate
  - Drinking water quantity threats as consumptive uses or reductions in recharge within the vulnerable areas are identified.

1.3 The Study Area

The Study Area is located in southwestern Ontario, within a portion of the Lake Erie Source Protection Region, encompassing the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities (**Figure 1.1**). Land use within the Study Area is predominantly agriculture-based, with additional minor occurrences of various natural heritage features (e.g., wetlands), forests, and urban areas. Within the Study Area, the lands immediately surrounding the Towns of Waterford, Simcoe, Delhi, and Tillsonburg in Norfolk and Oxford Counties were delineated as the Tier Three Study Focus Area (**Figure 1.1**) for the purposes of evaluating municipal pumping on a smaller, well field-scale during this Tier Three Assessment. As mentioned above, the water supply system of Tillsonburg has since been exempt from the Tier Three Assessment.

The important watercourses that flow in the vicinity of the Tier Three municipal water supply systems within the Focus Area include Big Creek, South Creek, North Creek and Stony Creek which flow in and near the Town of Delhi; Nanticoke Creek which flows through Waterford; and Patterson Creek, Davis Creek, Kent Creek and Lynn River which flow through Simcoe (**Figure 1.2**). Various tributaries feed these larger creeks and numerous wetland complexes can be found along the creek and river valleys.

The communities of Waterford and Simcoe rely entirely upon groundwater resources for potable water, while the Town of Delhi uses groundwater and, to a lesser extent, surface water. The Waterford system comprises two overburden wells located adjacent to various surface water features (i.e., aggregate ponds, wetlands, and creeks). The water supply system in Simcoe includes nine overburden wells within three well fields and one shallow infiltration gallery. The majority of this infrastructure is also constructed adjacent to surface water features. The system in Delhi consists of an intake at the Lehman Reservoir where North and South Creeks converge and are subsequently dammed, as well as two overburden wells, which are not in the immediate vicinity of surface water features. Water from the Lehman Reservoir is blended with water from the wells, and delivered to the population as a single system (AECOM 2010). This system also provides potable water to the community of Courtland, located approximately 10 km west of Delhi. Municipal well and intake locations are illustrated on **Figure 1.2**.



Tier Three Study Focus Area
Conservation Authority Boundary
Watershed Boundary
Municipal Boundary
Water Body
Watercourse
Community
Highway
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Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Tier Three Municipal Systems

Date: 29 Apr 2015	Project: 15077-527	
Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 1.2

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1.4 Project Scope

The scope of work completed in this Tier Three Assessment and documented in this report follows the Province's *Technical Rules*. The following tasks were completed for this study:

- characterizing the physical setting, including ground surface topography, hydrology, hydrogeology, and the municipal and non-municipal water demands in the Study Area (**Appendix A**)
- updating, refining, and calibrating a groundwater flow model with sufficient detail in the Focus Area to simulate groundwater flow near wells, intakes, and streams (**Appendix B**)
- developing and calibrating integrated surface water and groundwater flow models on regional and local scales to simulate surface water and groundwater flow, as well as estimate groundwater recharge rates in the Focus Area (**Appendix B**)
- delineating the vulnerable areas for the municipal wells and intake and complete a Local Area Risk Assessment for those systems
- applying the groundwater and integrated models to assess the water budget components in the Focus Area and near municipal wells and intakes
- updating Significant Groundwater Recharge Area (SGRA) mapping using the numerical models developed as part of the Tier Three Assessment

1.5 Organization of This Report

This report is organized into the following sections:

Section 1: Introduction - outlines the *Clean Water Act* water budget framework and the scope of this project

Section 2: Land Use and Land Use Change - summarizes the available land use data and describes the anticipated land use change in the assessed communities in the Focus Area

Section 3: Water Demand - outlines the consumptive water uses within the Study Area and estimates demand for those uses

Section 4: Local Area Risk Assessment - outlines the delineation of vulnerable areas, the Local Area, and the model scenarios and results; assigns the Local Area Risk Level; and presents an assessment of uncertainty of this Risk Level

Section 5: Water Quantity Threats – discusses water quantity threats identified in this study

Section 6: Tier Three Water Budget - outlines the Water Budget results compiled using the output of the calibrated groundwater and integrated flow models; details of these models are contained within **Appendix B**

Section 7: Significant Groundwater Recharge Areas – delineates and discusses the methods and results of the SGRAs

Section 8: Conclusions - summarizes the key components of the study; outlines the study conclusions, and provides recommendations for future work

Section 9: References - lists resources used to provide information in this document

Appendix A: Physical Characterization Report - provides a detailed description of the Study Area and development of the conceptual model

Appendix B: Model Development and Calibration Report - describes the development and calibration of the numerical hydrogeologic and integrated hydrologic and hydrogeologic models used to carry out the Risk Assessment

Appendix C: Municipal Wells and Intake – Summary Hydrographs - summarizes the important well and intake construction details, water levels and pumping data that were used in the Risk Assessment

Appendix D: Tier Three Assessment Peer Review Comments and Responses - provides a summary of the peer review comments and responses to those comments for **Appendix A** and **B** and this Tier Three Risk Assessment Report, as well as provides the peer reviewer sign-off letters for each report.

2 LAND USE AND LAND USE CHANGE

In addition to consumptive water uses, the *Technical Rules* identify reductions in groundwater recharge as potential water quantity threats. As such, the Tier Three modelling scenarios must consider the impact of future land development on groundwater recharge and consequently, the impact on municipal water sources. As the *Technical Rules* require the assessment of unmitigated threats as part of the Risk Assessment, the potential impact of stormwater management measures and low impact development techniques was not considered when estimating recharge reduction for future land use.

2.1 Land Use Data

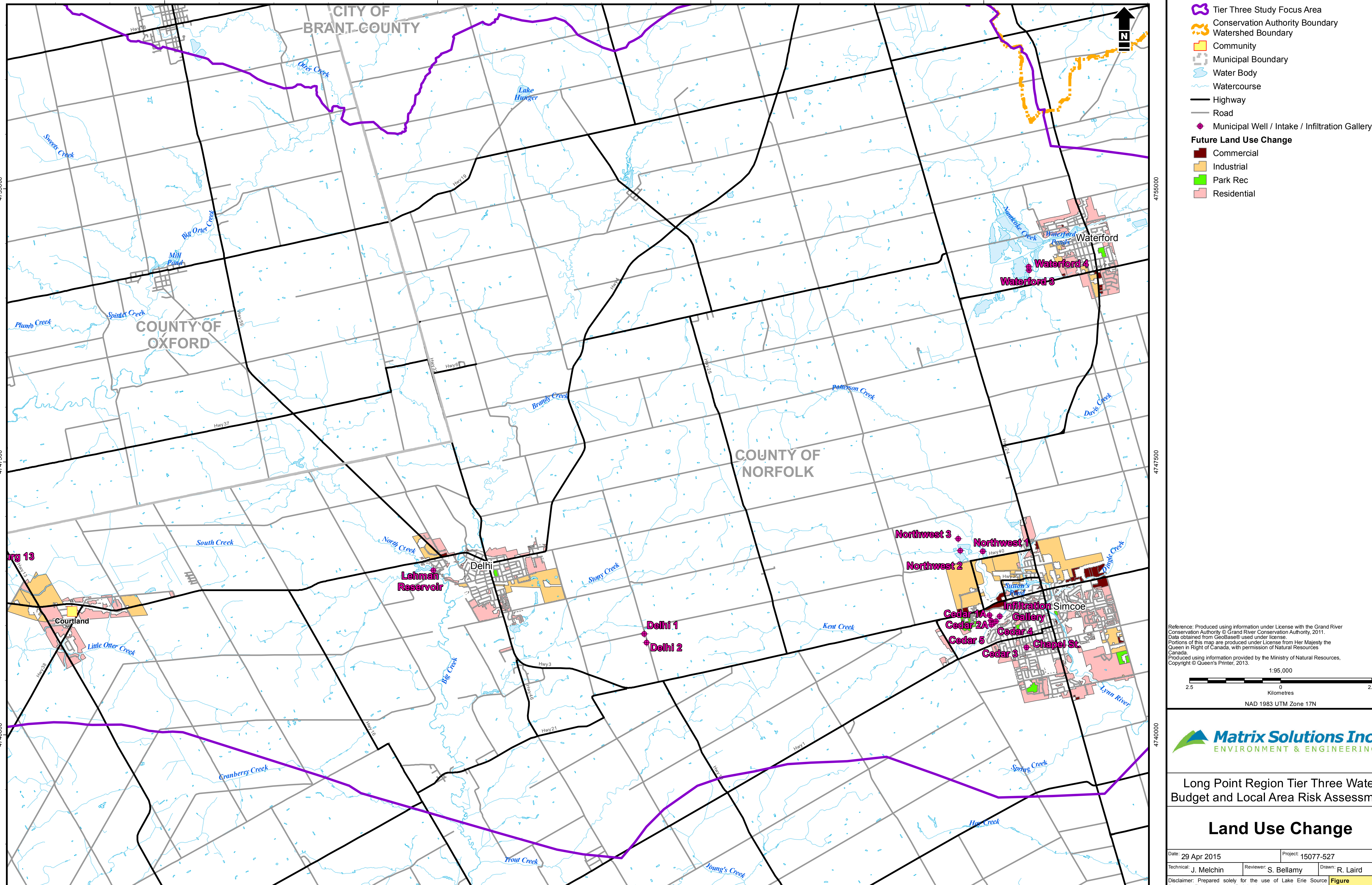
To identify potential changes in land use within the Focus Area, existing land use mapping data were compared to mapping of proposed future land use. Existing conditions land use was created using data from the Land Information Ontario (LIO), Southern Ontario Land Resources Information System (SOLRIS) dataset (LIO 2008) and was used during the development of the integrated surface water / groundwater numerical models, which is further discussed in **Appendix B**.

Future land use mapping was available for Waterford, Simcoe, and Delhi/Courtland from the Norfolk OP (Norfolk County 2011) and represents the maximum potential extent of these urban boundaries within the County. These land use maps, which indicated future urban development for each community in the assessment, was provided to Matrix in a digital format to facilitate additional map creation and comparison with existing digital land use data using GIS software.

2.2 Land Use Change

Figure 2.1 illustrates land areas where land use may change according to the OP as compared to current land use. This figure was created by digitally overlaying future land use with current land use using GIS, and selecting the areas where the proposed land use differed from the existing land use.

The most significant changes that may potentially occur are located around the outskirts of the current urbanized areas in Waterford, Simcoe, Delhi, and Courtland. In Waterford, land use change will primarily entail urban residential development, with small industrial/business park and commercial areas in the western and southern parts of the town. In Simcoe, most of the residential development will occur along the outskirts of the southern portion of the town, whereas land use along the northern parts of the town is predicted to change to industrial/business parks and, to a lesser extent, commercial land uses. In the community of Delhi, development will primarily be residential in the northern and southern parts of town, whereas development towards industrial/business park land uses is anticipated to occur in the eastern and northwestern parts of town. Commercial development is anticipated to be minor with limited areas of land located in the northern part of Delhi identified for development. In the community of Courtland, land use is predicted to change to residential uses in the central and southern parts of the town, whereas areas to the east and northwest are predicted to change to more industrial/business park uses.



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Matrix Solutions Inc.
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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Land Use Change

Date: 29 Apr 2015	Project: 15077-527	
Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 2.1

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2.3 Recharge Reduction

Land use change is represented in the FEFLOW model by reducing groundwater recharge proportionally to the amount of impervious area. In the MIKE SHE integrated models, land use change is represented by updating the vegetation and overland flow characteristics of the area of change. Updating the vegetation involves a change to the transient rooting depth and leaf area index, which indirectly alters evapotranspiration (ET). Updating overland flow involves a change to depression storage, surface roughness, and the impervious fraction. Impervious areas in MIKE SHE reflect directly connected impervious areas. A fraction is applied to ponded water available within a cell to determine water removed by directly connected impervious areas to stormwater conveyance systems. The recharge reduction related to land use change for the Risk Assessment Scenarios assumes that mitigation measures such as recharge or infiltration ponds, or similar best management practices, are not taken into consideration (as specified in the *Technical Rules*).

There are no specific impervious cover percentages associated with the land use designations contained within the OP. As such, each land use designation was assigned a percent impervious value based on literature values (Brabec et al. 2002). **Table 2.1** summarizes the assumed percent impervious value applied to each land use designation. Where there were multiple, similar land uses in OP data (e.g., commercial, shopping centre commercial and central business district), land uses were grouped together into one category (e.g., commercial). With some land uses, additional investigation was completed to select an appropriate percentage impervious value. For example, satellite imagery was used to discover that the majority of institutional land uses were not highly impervious surfaces, but rather the recreational fields of schools, which likely will not be paved over in the future. These areas were assigned a relatively lower percentage impervious value.

TABLE 2.1 Recharge Reduction Estimates Applied for Future Land Use Areas

Official Plan Land Use	Simplified Land Use	Assumed Percentage Impervious
Institutional	Parks and Recreation	10%
Hamlet	Residential	30%
Urban Residential		
Commercial	Commercial	70%
Shopping Centre Commercial		
Central Business District		
Industrial / Business Park	Industrial	70%

The percentage impervious values listed in **Table 2.1** were applied in the FEFLOW model to assess the Delhi system by multiplying the areal recharge distribution determined during numerical model calibration (described in **Appendix B**) with the percentage impervious values in areas with future land use changes. The remaining municipal systems were assessed using MIKE SHE models where the percentage impervious values were applied as the directly connected impervious fraction (an overland flow characteristic) of the area of land use change.

3 WATER DEMAND

This chapter outlines the consumptive water uses within the Study Area. Consumptive water demand refers to the amount of water removed from a surface water or groundwater source and not returned to that source within a reasonable amount of time. Estimates of consumptive water demand are necessary in water budget assessments to identify areas that may be under hydrologic stress. All municipal water takings within Delhi, Waterford, and Simcoe were considered consumptive in this study because water is pumped from either the Lehman Reservoir or aquifers, and is discharged to surface watercourses via water pollution control plants. In the case of the Town of Courtland, groundwater from Delhi is piped to Courtland and discharged to the shallow flow system via septic systems. The pumped water for these three municipal systems is not returned to the original sources within a reasonable amount of time and as such, is considered 100% consumptive.

The following sections outline the consumptive water takers within the Study Area, including the municipal (Section 3.2) and non-municipal, large permitted and non-permitted water takings (Section 3.4). These large (permitted) consumptive water takings were simulated as groundwater and surface water takings within the groundwater and integrated flow models as they have the potential to influence simulated water levels and impact model calibration.

In addition to the consumptive water takings, there are several non-consumptive water uses that also rely on the groundwater supplies within the subwatershed (Section 3.5). These include surface water features that rely on groundwater discharge for sustaining coldwater fisheries (and similar environmental / ecological communities), wastewater assimilation, and recreational uses. These water uses rely on a minimum flow or variation in water levels provided by the groundwater and surface water systems, and therefore, are part of the overall Risk Assessment (Section 4).

3.1 Municipal Water Systems

Other than the Town of Delhi, which uses a mixture of groundwater and surface water for municipal water supply, the Towns of Simcoe and Waterford rely entirely on groundwater for their municipal drinking water needs. The municipal water supply systems for these communities are outlined below and locations are illustrated on **Figure 1.2**.

3.1.1 Waterford

The Town of Waterford is located approximately 10 km northeast of Simcoe and is the smallest settlement included in this Tier Three Assessment. It currently draws its municipal water supplies from two groundwater supply wells (Wells 3 and 4) completed within the overburden aquifer (**Table 3.1**). The wells are located adjacent to former aggregate extraction pits that have filled with water creating ponds. Both wells are classified as Groundwater Under Direct Influence (GUDI) of surface water. Withdrawals for each well are limited by permitted daily maximums as outlined in the Permit to Take Water (PTTW). **Table 3.1** summarizes the maximum withdrawal rate and average pumping rate. Well construction details are provided in **Appendix A**.

TABLE 3.1 Town of Waterford Water Supply Wells

Well Name	Permit Number (Expiry)	Maximum Permitted Capacity (m^3/day)	Average Reported Taking (2008-2012) (m^3/day)
Thompson Rd. Well 3	0356-79SPVH (5/31/2017)	3,270	529
Thompson Rd. Well 4		2,946	507
	Total	6,216	1,036

3.1.2 Simcoe

The Town of Simcoe is the largest urban area in Norfolk County and is located in the southeastern part of the Focus Area, approximately 10 km southwest of Waterford and 17 km southeast of Delhi. The community is supplied with potable water from nine groundwater wells (Northwest Wells 1, 2, and 3; and Cedar St. Wells 1A, 2A, 3, 4, and 5; and Chapel St. Well 3) and one shallow infiltration gallery all completed within the overburden aquifer (**Figure 1.2**). The infiltration gallery, and all wells except Chapel St. Well 3, are designated as GUDI due to inferred hydraulic connection with the shallower water system and the close proximity to aggregate ponds, creeks, and wetland features.

Norfolk County is facing various challenges with the water supply systems in Simcoe, which will influence how the system will be managed to accommodate future growth. The biggest challenges relate to water quality concerns and associated treatment requirements at the well fields (e.g., nitrate and iron concentrations, iron fouling, and suspected elevated ammonia) and the age and susceptibility of the infiltration gallery to shallow contamination (Fields 2014, Pers. Comm.). It is important for this Tier Three Assessment to understand which of these challenges may potentially prevent a water supply source from taking on additional demands. According to staff at Norfolk County, Northwest Well 1 is used only for emergency purposes and has challenges related to ammonia treatment. Northwest Well 2 may be decommissioned in the future due to significant iron fouling, whereas the Cedar St. infiltration gallery may be decommissioned due to age of infrastructure and potential shallow contamination concerns (Fields 2014, Pers. Comm.). This information was used to direct the assignment of future (Allocated) pumping rates for numerical model scenarios as described in Section 3.2.2.

Table 3.2 summarizes the permitted and average withdrawals at each groundwater well and infiltration gallery, and detailed well construction details are found in **Appendix A**.

TABLE 3.2 Town of Simcoe Water Supply Wells

Well Field	Well Name	Permit Number (Expiry)	Maximum Permitted Capacity (m^3/day)	Average Reported Taking (2008-2012) (m^3/day)
Northwest	Northwest Well 1	8337-83TQ4C (10/31/2019)	2,292	100
	Northwest Well 2	1153-8RFRSX (5/31/2022)	2,292	1,025
	Northwest Well 3	2316-6Y8PQD (12/31/2016)	2,292	976
Cedar Street	Cedar St. Well 1A	8003-5XCR4H (3/31/2014)	6,819	401
	Cedar St. Well 2A			257
	Cedar St. Well 3			447
	Cedar St. Well 4			282
	Cedar St. Well 5			374
	Infiltration Gallery	1707-7L6GXD (6/30/2014)	5,236	569
Chapel Street	Chapel St. Well 3	6833-8RGQM6 (5/31/2022)	3,437	1,482
		Total	22,368	5,913

3.1.3 Delhi

The Town of Delhi is located in the south-central part of the Tier Three Focus Area, approximately 17 km northwest of Simcoe and 22 km southwest of Waterford. The Town supplies municipal water to both the populations of Delhi and the community of Courtland, located approximately 10 km to the west. This water is sourced from two GUDI groundwater wells screened within the overburden aquifer (Wells 1 and 2), as well as a surface water intake at the Lehman Reservoir. Reliance on the Lehman Reservoir has significantly declined since the mid-1990s and is predominantly used in a back-up capacity. Discussions with Norfolk County staff indicate that this source may be decommissioned in the future due to water treatment costs associated with surface water sources (Fields 2014, Pers. Comm.). Withdrawals for each well and intake are limited by the permitted maximum takings, as outlined in the PTTW. **Table 3.3** summarizes the maximum and average withdrawal rates at each well and intake, and a summary of well construction details is provided in **Appendix A**.

TABLE 3.3 Town of Delhi Water Supply Wells

Well Name	Permit Number (Expiry)	Maximum Permitted Capacity (m^3/day)	Average Reported Taking (2008-2012) (m^3/day)
Well 1	6681-96PL2G (5/31/2023)	2,300	487
Well 2		2,300	976
Lehman Reservoir	6423-89RPHE (10/31/2020)	6,815	195
	Total	11,415	1,658

3.2 Municipal Water Demand

As part of the Local Area Risk Assessment, the Allocated and Planned quantities of water need to be estimated for each existing and planned groundwater well or intake. The Allocated Quantity of Water is estimated based on the Existing and Committed municipal water demands, and the Planned Quantity of Water is the amount of water that meets the criteria of a planned system (MOE 2013).

As outlined in the *Technical Rules* and relevant technical guidance (MOE 2013), the Existing, Committed, and Planned Demand for this Assessment needed to be established. The definitions of these terms, as outlined in the revised technical guidance document, are below.

- Existing Demand refers to the amount of water determined to be currently taken from each well/intake during the Study Period.
- Committed Demand is an amount greater than the Existing Demand that is necessary to meet the needs of the approved Settlement Area within an OP. The portion of this amount that is within the Current Lawful PTTW Taking is part of the Allocated Quantity of Water. Any amount greater than the Current Lawful PTTW Taking is considered part of the Planned Quantity of Water.
- Planned Demand from an Existing Well/Intake is a specific additional amount of water required to meet the projected growth identified within a Master Plan or Class Environmental Assessment (EA), but is not already linked to growth within an OP.
- Planned Demand from a new Planned Well/Intake is a specific amount of water required to meet the projected growth identified within a Master Plan or Class EA, but is not already linked to growth within an OP.

For the municipal supply systems in Delhi, Waterford, and Simcoe, none of the demands associated with these wells/intake are considered to be Planned Demand.

3.2.1 Existing Demand

Existing municipal demand for Waterford, Simcoe, and Delhi is calculated based on the average demand from 2008 to 2012 for each municipal well and intake. This time frame incorporates the most recent average demands, while avoiding misrepresenting short-term trends in demand, which might occur over a single year, but are not representative of average conditions (e.g., a well shutting down for maintenance). Existing municipal demand rates are shown in **Table 3.4** for the three municipalities.

TABLE 3.4 Municipal Water Demand

<table>
<tr><th>Well / Intake Name</th><th>Maximum Permitted Rate (m^3/day)</th><th>Existing Rate (m^3/day)</th><th>Committed Rate (m^3/day)</th><th colspan="2">Allocated Rate – Existing plus Committed (m^3/day)</th></tr>
<tr><td colspan="6">Waterford</td></tr>
<tr><td>Thompson Rd. Well 3</td><td>3,270</td><td>529</td><td>197</td><td colspan="2">726</td></tr>
<tr><td>Thompson Rd. Well 4</td><td>2,946</td><td>507</td><td>197</td><td colspan="2">705</td></tr>
<tr><td>Total</td><td>6,216</td><td>1,036</td><td>395</td><td colspan="2">1,431</td></tr>
<tr><td colspan="6">Simcoe</td></tr>
<tr><td>Northwest Well 1</td><td>2,292</td><td>100</td><td>0</td><td colspan="2">100</td></tr>
<tr><td>Northwest Well 2</td><td>2,292</td><td>1,025</td><td>0</td><td colspan="2">1,025</td></tr>
<tr><td>Northwest Well 3</td><td>2,292</td><td>976</td><td>102</td><td colspan="2">1,078</td></tr>
<tr><td>Cedar St. Well 1A</td><td rowspan="5">6,819</td><td>401</td><td>102</td><td>503</td><td rowspan="5">Total = 2,270</td></tr>
<tr><td>Cedar St. Well 2A</td><td>257</td><td>102</td><td>359</td></tr>
<tr><td>Cedar St. Well 3</td><td>447</td><td>102</td><td>549</td></tr>
<tr><td>Cedar St. Well 4</td><td>282</td><td>102</td><td>383</td></tr>
<tr><td>Cedar St. Well 5</td><td>374</td><td>102</td><td>476</td></tr>
<tr><td>Infiltration Gallery</td><td>5,236</td><td>569</td><td>0</td><td colspan="2">569</td></tr>
<tr><td>Chapel St. Well 3</td><td>3,437</td><td>1,482</td><td>102</td><td colspan="2">1,584</td></tr>
<tr><td>Total</td><td>22,368</td><td>5,913</td><td>713</td><td colspan="2">6,626</td></tr>
<tr><td colspan="6">Delhi</td></tr>
<tr><td>Delhi Well 1</td><td>2,300</td><td>487</td><td>132</td><td colspan="2">619</td></tr>
<tr><td>Delhi Well 2</td><td>2,300</td><td>976</td><td>132</td><td colspan="2">1,108</td></tr>
<tr><td>Lehman Reservoir</td><td>6,815</td><td>195</td><td>0</td><td colspan="2">195</td></tr>
<tr><td>Total</td><td>11,415</td><td>1,658</td><td>264</td><td colspan="2">1,921</td></tr>
</table>

3.2.2 Population Growth and Committed Demand

As part of the Tier Three Assessment, a water demand assessment was completed to quantify future water supply needs in Waterford, Simcoe, and Delhi/Courtland. Norfolk County provided estimates of the number of unconnected lots (e.g., lots that are registered, draft approved or committed) for each of these communities, which represent the growth that the municipality plans to provide water for in the near term (NCPEDS 2013). The number of unconnected lots for the community of Courtland was included in the Delhi total as potable water in Courtland is provided by the Delhi water supply system. Using the total number of unconnected lots and an estimate of the number of people per dwelling, the population increase was estimated for each community (**Table 3.5**).

TABLE 3.5 Population Growth

<table>
<tr><th>Community</th><th colspan="2">2011 Population</th><th>Unconnected Lots[D]</th><th>People / Lot</th><th>Population Increase</th><th colspan="2">Future Population</th></tr>
<tr><td>Waterford</td><td colspan="2">3,119[A]</td><td>495</td><td>2.4[A]</td><td>1,188</td><td colspan="2">4,307</td></tr>
<tr><td>Simcoe</td><td colspan="2">14,777[B]</td><td>810</td><td>2.2[B]</td><td>1,782</td><td colspan="2">16,559</td></tr>
<tr><td>Delhi</td><td>4,172[C]</td><td rowspan="2">Total = 5,203</td><td>356</td><td>2.2[C]</td><td>783</td><td>4,955</td><td rowspan="2">Total = 6,030</td></tr>
<tr><td>Courtland</td><td>1,031[D]</td><td>20</td><td>2.2[E]</td><td>44</td><td>1,075</td></tr>
<tr><td colspan="8">[A] Statistics Canada 2012a
[B] Statistics Canada 2012b
[C] Statistics Canada 2012c
[D] NCPEDS 2013
[E] Data not available, assumed to be same as Delhi</td></tr>
</table>

Assuming the current per capita water use remains constant, the anticipated increase in water demand (i.e., Committed Demand) from the population increase was determined (**Table 3.4**). Anticipated increases in pumping over average 2008 to 2012 demand was determined to be 12% (713 m^3/day) in Simcoe, 16% in Delhi/Courtland (264 m^3/day) and 38% in Waterford (395 m^3/day).

For the purposes of the Risk Assessment Scenarios, the Committed increase in each community was distributed according to the anticipated future condition of the water supply infrastructure. For Waterford and Delhi, the Committed increase was distributed equally among the two groundwater wells in each community at approximately 197 and 132 m^3/day/well, respectively. The increase in demand was not allotted to the surface water intake at the Lehman Reservoir as takings from this source are traditionally low and used primarily for emergency backup.

In the Town of Simcoe, the Committed increase in demand was distributed equally between seven of nine municipal wells at 102 m^3/day/well. Future demands were not partitioned to Northwest Well 1 or Well 2, as well as the Cedar St. infiltration gallery. As mentioned in Section 3.1.2 above, these supplies may not be available for future additional use due to challenges associated with ammonia (Northwest Well 1), iron fouling (Northwest Well 2), and the age and susceptibility of the Cedar St. Infiltration Gallery to shallow contamination.

Since there are no planned water supply systems in any of the communities which have successfully completed an Environmental Assessment, there is no Planned Demand for each system. Therefore the total Allocated demand (Existing plus Committed Demand) is 1,431 m^3/day in Waterford, 6,626 m^3/day in Simcoe, and 1,921 m^3/day in Delhi (**Table 3.4**). For all three municipal systems, the total Allocated demand is well below the total permitted rate.

3.2.3 Other Municipal Water Use

The only other communities within the Tier Three Focus Area that obtain potable water from a municipal water supply are Tillsonburg, Norwich, Otterville, Springford, and Dereham Centre; other communities that fall within the Focus Area obtain water supplies from private drinking water systems.

While these wells are not evaluated in the Tier Three Assessment scenarios, the permitted and average withdrawals associated with these wells were characterized in **Appendix A** and the demands associated with these wells have been incorporated into the numerical models (**Appendix B**).

3.3 Safe Additional Available Drawdown

Safe Additional Available Drawdown (SAAD) is defined as the additional decline in water level within a pumping well that can be allowed while maintaining normal well operations. It is calculated as the additional drawdown that is available over the drawdown measured under recent historic pumping conditions. The following components were determined to establish the SAAD for each municipal pumping well within the Focus Area that was assessed:

- **Safe water level elevations:** the lowermost elevation within the municipal pumping well, or adjacent aquifer that must be maintained to safely pump a well. This elevation may be related to the well screen elevation, pump elevation, or similar operational limitations.

- **Existing water level elevations in the pumping wells:** the elevation of the observed average pumped water level within each municipal well from 2008 to 2012.

- **Estimated non-linear well losses at each well:** drawdown within the well in response to well inefficiencies (e.g., entrance losses and turbulent flow around pump fittings) created during groundwater pumping.

3.3.1 Safe Water Level Elevation

The safe water level elevation at each municipal water supply well was developed in consultation with Norfolk County staff. As all of the groundwater municipal supply wells in this assessment are screened overburden wells, safe water levels were defined based on the elevation of the top of screen plus 1 m above the screen (as a safety factor). If, during the Risk Assessment Scenarios, water levels were simulated to drop below the designated safe water levels (i.e., near or into the well screen), then a risk threshold was triggered.

Since the Cedar St. Infiltration Gallery is not a well but a series of connected manholes, the safe water level for this structure was determined to be the average floor elevation of all the manholes. If the water level decreased below the manhole floors, no water would be able to infiltrate into the gallery and no water would be able to be pumped. In this case, a risk threshold would be triggered.

Safe water elevations are summarized in **Table 3.6** and illustrated, along with relevant well construction details on **Figures C1** through **Figure C14** (**Appendix C**).

TABLE 3.6 Safe Additional Available Drawdown

Name	Ground Surface Elevation (m asl)	(A)	(B)	(C)	(B – C)	Safe Water Level Based On
		Top of Pump Elevation (m asl)	Average Pumped Water Level (m asl)	Safe Water Level (m asl)	Safe Additional Available Drawdown (m)	
		Depth Below Ground Surface (m)				
Waterford						
Thompson Rd. Well 3	231.8	224.8 [7.0]	228.7[1] [3.1]	225.2 [6.6]	3.5	Top of Screen
Thompson Rd. Well 4	232.3	223.4 [8.8]	227.9[1] [4.4]	223.2 [9.1]	4.7	Top of Screen
Simcoe						
Northwest Well 1	220.0	N/A	213.8[1] [6.2]	201.0 [19.0]	12.8	Top of Screen
Northwest Well 2	222.4	N/A	208.8[2] [13.5]	204.2 [18.2]	4.7	Top of Screen
Northwest Well 3	224.8	N/A	214.5[3] [10.3]	207.5 [17.3]	7.0	Top of Screen
Cedar St. Well 1A	217.1	206.7 [10.4]	211.4[1] [5.7]	206.2 [10.9]	5.2	Top of Screen
Cedar St. Well 2A	216.2	N/A	209.0[1] [7.3]	209.6 [6.6]	-0.6[4]	Top of Screen
Cedar St. Well 3	215.3	209.1 [6.3]	209.3[1] [6.0]	209.5 [5.7]	-0.2[4]	Top of Screen
Cedar St. Well 4	214.4	N/A	207.6[1] [6.8]	208.4 [6.0]	-0.8[4]	Top of Screen
Cedar St. Well 5	215.6	208.9 [6.7]	210.0[1] [5.6]	210.2 [5.4]	-0.2[4]	Top of Screen
Infiltration Gallery	214.7[5]	N/A	212.9[6] [1.8]	211.1[7] [3.7]	1.9	Avg. Gallery Floor Elevation [211.1 m asl]
Chapel St. Well 3	224.5	206.2 [18.3]	210.6[1] [13.9]	206.4 [18.1]	4.2	Top of Screen
Delhi						
Well 1	237.3	215.1 [22.2]	222.2[2] [15.1]	207.2 [30.1]	15.0	Top of Screen
Well 2	238.0	211.2 [26.8]	220.3[2] [17.7]	206.2 [31.8]	14.1	Top of Screen

[1] average pumped water level calculated using available data from 2009 to 2012
[2] average pumped water level calculated using available data from 2008 to 2012
[3] average pumped water level calculated using available data from July to October 2013
[4] negative Safe Additional Available Drawdown indicates average pumped water level elevation is lower than safe water level
[5] ground elevation for the infiltration gallery represents the average manhole lid elevation
[6] average pumped water level calculated using available data from June to September 2011
[7] safe water level for the infiltration gallery represents the average floor elevation of the manholes
N/A – data not available
asl – above sea level

3.3.2 Existing Water Level Elevations

The average pumped water level represents the average water level elevation in a well from available 2008 to 2012 data when the operator has identified the well as being under pumping conditions.

This “pumping” status does not indicate the length of time that the well has been pumping before a water level measurement and so it may represent a falling level immediately following the pump cycling on, or it may represent a steady-state pumped level following long-term pumping. Similarly, if the level is identified as “non-pumping,” this could mean either the pump was recently turned off and the water level represents a rising level, or the pump has been off for a longer period and the level is truly a static level. Where available water level data do not distinguish between pumping and non-pumping conditions, pumping conditions were inferred for the purposes of this assessment. Existing average pumped water level elevations are presented in **Table 3.6,** and these data, as well as more detailed water level and pumping data, are illustrated on **Figures C1** through **Figure C14.**

In the Towns of Waterford and Simcoe, some water level data from municipal pumping wells were only available starting in 2009; therefore, average pumped water levels in these cases represent a 4-year average, rather than the 5-year (2008 to 2012) average (**Figures C1** through **C12**). Further, in some circumstances, water levels that were identified as “pumping” clearly did not represent fully pumping conditions when compared to “non-pumping” water levels. To prevent skewing the average pumped water elevation estimates towards levels that were assumed to be shallower, non-pumping conditions, measurements judged to represent non-pumping conditions were excluded from the averaging calculation (e.g., the shallowest group of water level data points on **Figure C1**).

Special attention was given to Simcoe Northwest Well 3 (**Figure C5**) where Norfolk County staff identified faulty water level measurements before July 2013. For this well, the Existing water level elevation was calculated based on water level data from July to October 2013. This elevation data were deemed acceptable to use in concert with 2008 to 2012 Existing pumping data because the average Existing (2008 to 2012) pumping rate (976 m^3/day) falls within the range of pumping recorded during time period from July to October 2013 (881 to 986 m^3/day). Further, water levels were observed to stay relatively constant during July to October 2013, providing confidence in the use of these measurements as Existing-condition pumped levels for the Tier Three Assessment.

At the Cedar St. Infiltration Gallery, the average pumped water level was determined from a detailed water level elevation dataset of a 2-month period during the summer of 2011 for two gallery manholes (J and F). The observations were inferred to represent variable pumping conditions and therefore, to get a single representative pumped water level, all observations were averaged (**Figure C11**).

Groundwater levels in Delhi were measured relative to a reference point that has changed over time. Therefore, elevations of these points had to be measured or estimated (where no historical documentation exists) to convert all depths into elevations to create a continuous record of water levels from 2008 to 2012. Hydrographs for Delhi Wells 1 and 2 are presented on **Figures C13** and **C14**.

3.3.3 Calculated Safe Additional Available Drawdown Values

The SAAD is a measure of the additional available drawdown within a well, regardless of the non-linear head losses at each well that are due to turbulent flow of water through the well screen and casing to the pump intake. The SAAD is calculated as the difference between the average pumped water level and the safe water level. SAAD values are summarized in **Table 3.6**, along with relevant elevations and depths in the wells. These elevations are also illustrated on **Figures C1** through **Figure C14**.

As shown in **Table 3.6** and **Figures C7** to **C10**, four wells of the Simcoe Cedar St. Well Field have Existing average pumped water levels, which are lower than the identified safe water levels. While there have been no documented historical issues with meeting municipal demands in Simcoe, average water levels at Cedar St. Well 2A, 3, 4, and 5 are already approaching or exceeding the depth of the top of the well screen. Norfolk County staff has confirmed this observation during regular well operation at the Cedar St. Well Field.

3.3.4 Non-Linear In-Well Losses

Well losses refer to the difference between the theoretical drawdown in a well and the observed drawdown and are due to factors such as turbulence in the well itself as water flows into the pump. These well losses need to be considered in the Tier Three Assessment as the SAAD refers specifically to the water level in the well and not the average water level in the aquifer near the well, which is predicted by the groundwater and integrated flow models. The in-well losses are calculated as the additional drawdown that is expected within the pumping well due to the incremental increase from the Existing pumping rates to the Allocated pumping rates (Existing plus Committed Demand).

The two components of observed additional drawdown in a given pumping well are described in **Equation 1** (Bierschenk 1963; Hantush 1964; Jacob 1947);

$$s = BQ + CQ^2 \qquad \textbf{Equation 1}$$

Where *s* is drawdown, *Q* is the pumping rate, *B* is the aquifer loss coefficient (Theis 1935), and *C* is the well loss coefficient, which is constant for a given pumping rate. The first term in the equation (*BQ*) describes the linear component of the drawdown (i.e., doubling the pumping rate leads to a doubling of the drawdown). This term accounts for the drawdown in the formation near the well. The second term of the equation (CQ^2) describes the non-linear well-loss component of drawdown (Jacob 1947) in the well itself; this is the additional component that was quantified in this assessment.

Well losses were estimated using step test results. Step tests are hydraulic tests where a well is pumped at a series of different pumping rates and the drawdown throughout the test is recorded. Non-linear well loss coefficients were estimated using the step test results presented in well rehabilitation and maintenance reports (report references are provided in **Table 3.7**).

The loss coefficient, *C*, was calculated directly from step test data following the technique developed by Kasenow (1998):

$$C = \frac{s_2\, Q_1 - s_1 Q_2}{Q_1 Q_2^2 - Q_2 Q_1^2}$$ **Equation 2**

Where: s_1 is the total stabilized drawdown at the end of pumping step 1
Q_1 is the pumping rate for step 1

s_2 is the total stabilized drawdown at the end of pumping step 2
Q_2 is the pumping rate for step 2

For each step test, these coefficients were calculated for consecutive steps and then averaged to determine the loss coefficient for the well at the time of the step test. **Equation 3,** after Jacob (1947), was used to calculate drawdown due to in-well head losses for the increased pumping from Existing to the Allocated Rates:

$$\Delta S_{inwell} = C\,[(Q_{EC} + \Delta Q)^2 - Q_{EC}^2]$$ **Equation 3**

Where: C is the well loss coefficient determined from step-test data
Q_{EC} is the Existing Conditions (2008 - 2012) pumping rate used in the base case steady-state model
ΔQ equal to the increase from Existing Conditions (2008 - 2012) pumping rate to the Allocated municipal pumping rate used in the Risk Assessment Scenarios

Pumping rates, the calculated well loss coefficient, and the estimated non-linear head losses related to the Allocated increase for each well are summarized in **Table 3.7**.

TABLE 3.7 Estimated Drawdown due to Non-Linear Head Losses

Well Name	Existing Rate (2008-2012)	Allocated Rate	Pumping Rate Increase (ΔQ)	Drawdown due to Non-Linear Head Losses	Well Loss Coefficient (C)	Date of Step Test	Step Test Reference
	m^3/day	m^3/day	m^3/day	m	m/(m^3/day)^2		
Waterford							
Thompson Rd. Well 3	529	726	197	0.01	5.81E-08	24/06/2009	IWS 2009b
Thompson Rd. Well 4	507	705	197	0.01	4.47E-08	20/05/2009	IWS 2009b
Simcoe							
Northwest Well 1[A]	100	100	0	0.00	3.82E-07	-	Walton 1962
Northwest Well 2	1,025	1,025	0	0.00	1.20E-07	10/6/2010	IWC and IWS 2010
Northwest Well 3	976	1,078	102	0.00	6.59E-09	10/11/2011	IWC 2012a
Cedar St. Well 1A	401	503	102	0.00	4.64E-08	2/4/2008	IWS 2008
Cedar St. Well 2A	257	359	102	0.03	4.26E-07	20/03/2008	IWS 2008
Cedar St. Well 3	447	549	102	0.02	2.09E-07	16/05/2008	IWS 2008
Cedar St. Well 4	282	383	102	0.00	2.79E-08	14/10/2010	IWS 2010
Cedar St. Well 5[A]	374	476	102	0.03	3.82E-07	-	Walton 1962
Chapel St. Well 3	1,482	1,584	102	0.02	6.44E-08	18/01/2012	IWC 2012b
Delhi							
Well 1	487	619	132	0.02	1.59E-07	22/06/2009	IWS 2009a
Well 2	976	1,108	132	0.01	5.07E-08	4/06/2009	IWS 2009a

[A] Reliable step test data were not available for this well. Therefore a C-value of 3.82E-07 m/(m^3/d)^2 was selected based on the assumption that the well is mildly deteriorated (Walton 1962).
- Data not available

As the estimated drawdown from non-linear head losses represents the condition of the well at the time of the step test, this drawdown represents what would be expected if the well maintained that efficiency. Over time, however, wells lose efficiency (e.g. due to effects of biofouling and mineral precipitation) and the drawdown would be expected to increase. Water supply operators combat declining efficiencies by keeping production wells on routine maintenance schedules, which may include rehabilitation work. If operators find that drawdown due to well inefficiencies is occurring ahead of predefined maintenance scheduling, they may intuitively decrease withdrawals at the inefficient well and increase production at more efficient wells, which have greater capacities for additional drawdown. For the purposes of this Risk Assessment, it is assumed that the wells are maintained by the municipalities in current conditions and that drawdown due to non-linear head losses will remain constant through time.

3.3.5 Convergent Head Losses

The MIKE SHE integrated flow models use a finite-difference formulation for the groundwater portion of the models. Thus, they calculate the average water level in the grid block that contains the municipal well and not the water level in the well. Since a well is relatively small compared to a typical grid block, MIKE SHE underestimates the drawdown within a pumping well. Model results from MIKE SHE need to be adjusted in order to compare simulated drawdown at a well against safe available drawdown. The additional head losses that occur between the average water level in a grid block and the simulated pumping well are referred to as the convergent head losses. For each municipal production well in Simcoe and Waterford, the additional drawdown due to convergent head losses can be approximated using the following equation (Peaceman 1983):

$$\Delta s_{well-block} = \frac{\Delta Q}{2\pi T} \ln \left\{ \frac{0.208\ \Delta x}{r_w} \right\} \quad \ldots \qquad \textbf{Equation 4}$$

Where: *ΔQ is the increase in the pumping rate with respect to Existing (2008 2012) condition*
T is the cumulative transmissivity of the model layers across which the well is screened
Δx is the MIKE SHE grid spacing
rw is the radius of the pumping well

Table 3.8 below summarizes the additional drawdown due to convergent head losses calculated for each of the municipal wells in Waterford and Simcoe, where there is an increase in pumping from the Existing to the Allocated system rates. (Note: in the MIKE SHE models, each municipal pumping well lies within a 25 m × 25 m grid cell).

TABLE 3.8 Calculated Convergent Head Losses

Well Name	Existing Rate (2008-2012) (m^3/day)	Allocated Rate (m^3/day)	Pumping Rate Increase (ΔQ) (m^3/day)	Transmissivity[1] (m^2/day)	Well Radius (m)	Convergent Head Losses (m)
Waterford						
Thompson Rd. Well 3	529	726	197	627	0.20	0.16
Thompson Rd. Well 4	507	705	197	574	0.20	0.18
Simcoe						
Northwest Well 1	100	100	0	1,640	0.13	0.00
Northwest Well 2	1,025	1,025	0	1,679	0.13	0.00
Northwest Well 3	976	1,078	102	1,308	0.15	0.04
Cedar St. Well 1A	401	503	102	733	0.15	0.08
Cedar St. Well 2A	257	359	102	673	0.13	0.09
Cedar St. Well 3	447	549	102	464	0.20	0.11
Cedar St. Well 4	282	383	102	508	0.20	0.10
Cedar St. Well 5	374	476	102	423	0.20	0.13
Chapel St. Well 3	1,482	1,584	102	805	0.18	0.07

[1]Transmissivity simulated in the integrated model at the pumping well

Therefore, the simulated water levels predicted by MIKE SHE have to account for the sum of the non-linear head loss (Section 3.3.4) and the convergent head losses when assessing whether the pumping well can sustain pumping at the Allocated rates.

3.4 Non-Municipal Water Demand

3.4.1 Permitted Water Uses

In addition to the municipal water withdrawals within the Focus Area, there were a number of large, non-municipal permitted water takers with MOE PTTWs. A total of 70 non-municipal, non-agricultural permitted water takings within the Focus Area were assessed as reported in **Appendix A** (Tables 9 and 10) and included in the numerical models (**Appendix B**). Water use associated with agricultural irrigation represented the most significant water taking in the Study Area and these permitted takings were estimated using the integrated numerical model as described in **Appendix B** (Section 3.8.1).

The methods used for estimating the consumptive water demands ("water which is consumed and not returned to the pumped aquifer within a reasonable amount of time respective to that source") is described in **Appendix A (**Section 6.1). Consumptive demands were used as they could be considerably less than the permitted water use rates and thus, were vital to estimate for inclusion in the numerical models.

3.4.2 Non-Permitted Water Uses

Water takings, which do not exceed 50,000 L/day, do not need a PTTW. Among other purposes, non-permitted takings are used for supplying rural residences with potable water in areas where municipal systems do not exist. These domestic water demands were not simulated in the numerical flow models as the majority of the withdrawn water for domestic water takers is returned to the groundwater system via private septic systems. Consumptive water demands associated with this water use sector are relatively insignificant. As such, consumptive use for this water use sector was considered negligible and not included in the numerical models or water budget calculations.

3.5 Other Water Uses

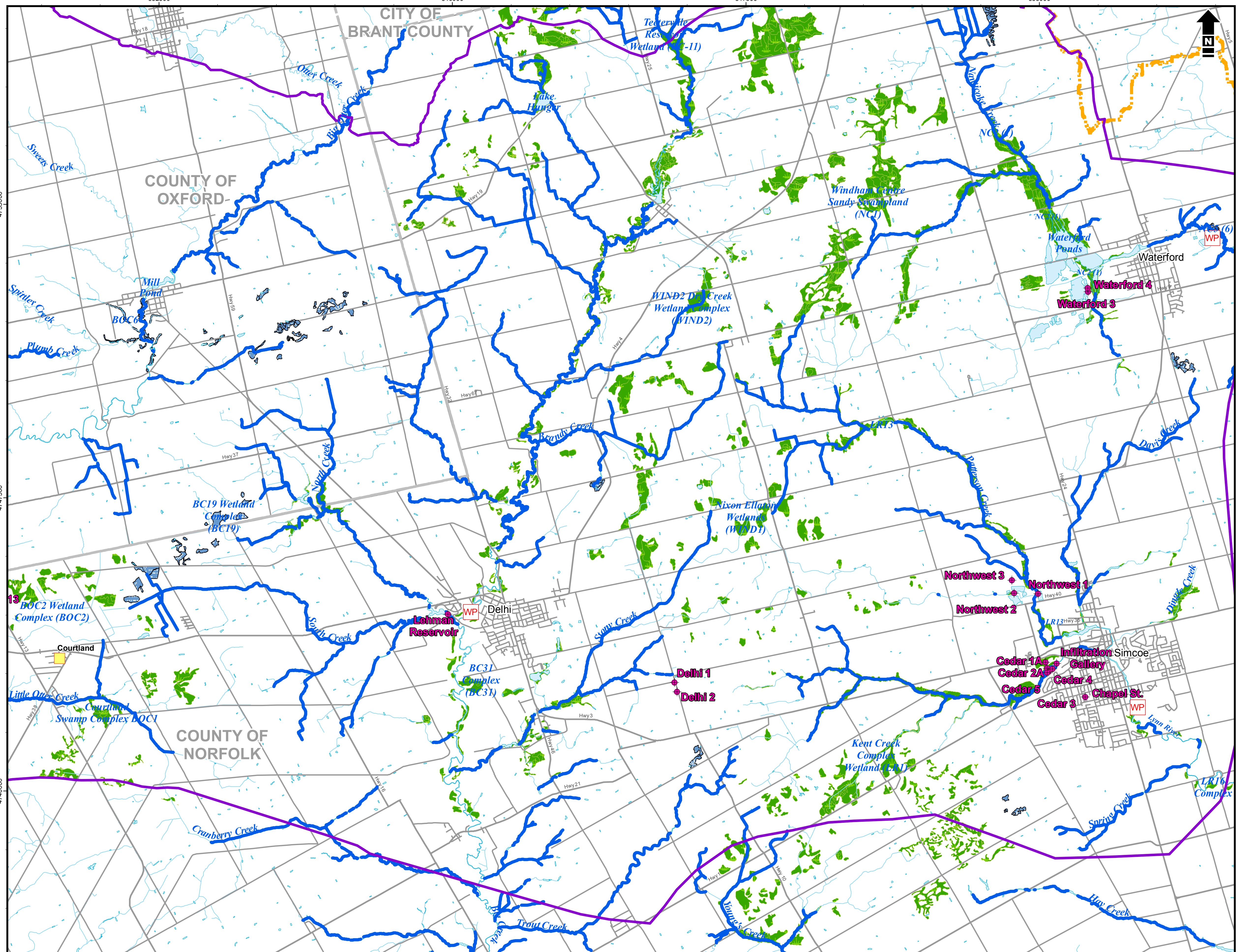
The Tier Three Assessment should identify other major water uses and consider possible impacts to those as a result of the Allocated municipal pumping. Other water uses that are relevant to the Focus Study Area include non-municipal groundwater takings (discussed in Section 3.4), and aquatic habitat, Provincially Significant Wetlands (PSWs), wastewater assimilation, and recreational uses (discussed in Sections 3.5.1 to 3.5.4) shown on **Figure 3.1**.

Establishing the quantity of water required by other water uses is difficult because of the following:

- System function is often not well enough understood to generate definitive flow rate estimates (e.g., the impacts of a reduction in groundwater discharge into the aquatic habitat are not easily defined due to a lack of characterization of local groundwater / surface water interactions or aquatic needs).

- System function is not always tied to a change in the flow rate of water (e.g., the health and ecological integrity of a PSW may be more dependent on the timing of changes in the water table elevation).

The Province has therefore introduced the use of thresholds to evaluate certain water uses. Thresholds for this Tier Three Assessment are introduced in Section 4.4.



- Tier Three Study Focus Area
- Conservation Authority Boundary
- Watershed Boundary
- Community
- Municipal Boundary
- Provincially Significant Wetlands
- Wetland
- Water Body
- Watercourse
- Coldwater Stream
- Highway
- Road
- WP Waste Water Treatment Plant
- Municipal Well / Intake / Infiltration Gallery

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Other Water Uses

Date: 29 Apr 2015	Project: 15077-527	
Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 3.1

3.5.1 Aquatic Habitat

As groundwater withdrawals typically affect aquatic habitat by reducing groundwater discharge to specific habitat features, Tier Three Assessments focus on possible impacts to coldwater fisheries that are particularly sensitive to changes in groundwater discharge. **Figure 3.1** illustrates the fish community mapping within the Focus Area (LIO 2010) that identifies coldwater streams near the municipal supply systems.

In the area of the Delhi wells, the coldwater and non-coldwater streams that were included in the assessment of baseflow reduction include Big Creek and smaller named and unnamed feeder streams including Stony Creek and Trout Creek. These streams in the Delhi area were evaluated using the calibrated Tier Three FEFLOW model that was well calibrated with local data.

In the areas west and southwest of the Town of Waterford, coldwater, and non-coldwater tributaries of Nanticoke Creek were assessed using the Waterford local-scale MIKE SHE model. Near Simcoe, Lynn River and segments of its tributaries (e.g., Patterson Creek and Kent Creek) exist as coldwater and warm water streams, which were examined as part of the Tier Three Assessment using the local-scale Simcoe North and Simcoe South MIKE SHE models. The local-scale MIKE SHE models were refined from the regional MIKE SHE model that was calibrated to both Water Survey of Canada (WSC) stream gauges and high quality hydraulic head observations.

3.5.2 Provincially Significant Wetlands

The *Technical Rules* also identify PSWs as another water use that should be considered as part of the Tier Three Assessment. Evaluated wetlands are classified under a standard methodology, taking into account the biological, hydrological, and socio-economic features and functions of a wetland. Based on this system, wetlands can be identified as PSWs and these are protected under the wetland component of the *Provincial Policy Statement* (Government of Ontario 2005). A total of 24 PSWs are located in the Tier Three Focus Area. Of those, the closest PSWs to the water supply systems of this Tier Three Assessment include NC2, located along the Nanticoke Creek near Waterford; Kent Creek Complex, LR13, and LR16 Complex located near and surrounding Simcoe; and Nixon Ellaton Wetlands and BC31 Complex located near the supply systems of Delhi (**Figure 3.1**). Evaluation of wetland features was limited to water level changes beneath a wetland and the impact of such water level changes on the function of the wetland (e.g., are discharge conditions maintained).

3.5.3 Wastewater Assimilation

There is a Wastewater Treatment Plant (WWTP) located in each of the Tier Three Assessment communities (**Figure 3.1**). In Waterford, the WWTP discharges treated water into Nanticoke Creek within a couple kilometers east of the Town. In Simcoe, treated water is released into Lynn River in the south-central part of town, approximately 2 km south of the confluence with Kent Creek. Within the Town of Delhi, the WWTP is located within 1 km east of the Lehman Reservoir intake and treated water discharges into Big Creek. The municipal intake and wells in this Assessment have the potential to reduce the baseflow from groundwater to Nanticoke Creek, Lynn River, Big Creek, and/or their tributaries, which would effectively reduce the assimilative capacity of those watercourses. Even though the magnitude of decreased groundwater discharge is anticipated to be small in comparison to the total flows of these watercourses, the impact of municipal pumping on these water bodies and their ability to assimilate waste from the WWTPs was a consideration in this Tier Three Assessment.

3.5.4 Recreational

Groundwater discharge to local water bodies can also maintain water levels during low flow periods. Where local waterways are used for recreational activities, groundwater inputs support those activities. Within the Study Area, recreational use of groundwater-supported water bodies likely occurs on both private and public lands. Public use includes recreational users along the larger creeks and rivers for canoeing and fishing, as well as users of ponds and lakes, such as those present in the Waterford North and Sutton Conservation Areas, where recreational activities may include fishing, swimming, and boating. Private recreational use may also be common on watercourses where these features run through privately held lands.

4 LOCAL AREA RISK ASSESSMENT

As described above, a Tier Three Assessment evaluates the risk that a municipal well or intake may not be able to meet its Allocated Quantity of Water. To do so, the Tier Three Assessment uses numerical models summarized in preceding sections to evaluate a number of scenarios, and compares outcomes from those scenarios to a set of circumstances. Based on those circumstances, a Risk Level of Low, Moderate, or Significant is assigned to the Local Area.

Municipalities typically implement physical solutions (e.g., storage reservoirs and peaking / backup intakes) and water conservation measures to reduce the amount of instantaneous water demand required from a primary drinking water source or to reduce the community's overall water demand. These types of measures are implemented to increase a municipality's "Tolerance" to short-term water shortages. Tolerance effectively reduces the potential that a municipality will face short- or long-term water quantity shortages and is considered when evaluating Risk.

The following chapter describes how the Risk Assessment Scenarios specified by the *Technical Rules* were applied using the FEFLOW model for the Delhi water supply wells and using MIKE SHE for the Waterford and Simcoe water supply wells and the Lehman intake to complete the Tier Three Assessment.

4.1 Delineation of Vulnerable Areas

The term "Local Area" was introduced in the *Technical Rules* (Part III.2) to link the Water Quantity Risk to an area surrounding the drinking water wells or intakes where a competing demand for water (land use development or pumping) may alter the sustainability of the municipal supplies. The water budget models are used to delineate the "Local Area" for groundwater wells and intakes, which form the basis for the Local Area Risk Assessment.

There are typically two components to the Local Area for groundwater systems: the Well Head Protection Area for Water Quantity (WHPA-Q), WHPA-Q1 and WHPA-Q2. For surface water intakes, an IPZ-Q is delineated and included in the Local Area. For surface water features contributing recharge to groundwater wells, the points of interaction are delineated and also included in the Local Area. The WHPA-Q1, WHPA-Q2, and IPZ-Q / Contributing Areas are discussed in the following sections.

4.1.1 WHPA-Q1

The WHPA-Q1 is defined in the *Technical Rules* and water budget guidance document (AquaResource 2011) as the "combined area that is the cone of influence of the municipal well and the whole of the cones of influence of all other wells that intersect that area." In the FEFLOW model, for the area surrounding the Delhi municipal wells, the WHPA-Q1 was delineated by examining the change in model-predicted heads between two model scenarios:

1. Steady-state model simulating existing land use and no pumping, which established water levels that would exist without pumping.

2. Steady-state model simulating existing land use, existing pumping for all non-municipal permitted and non-permitted water takings, and Allocated municipal pumping rates (Scenario G[2]).

In the integrated MIKE SHE models, for the areas surrounding Waterford and Simcoe, the WHPA-Q1 was delineated by examining the change in minimum model predicted heads between two model scenarios:

1. The long-term transient model simulating existing land use and no pumping, which established water levels that would exist without pumping.

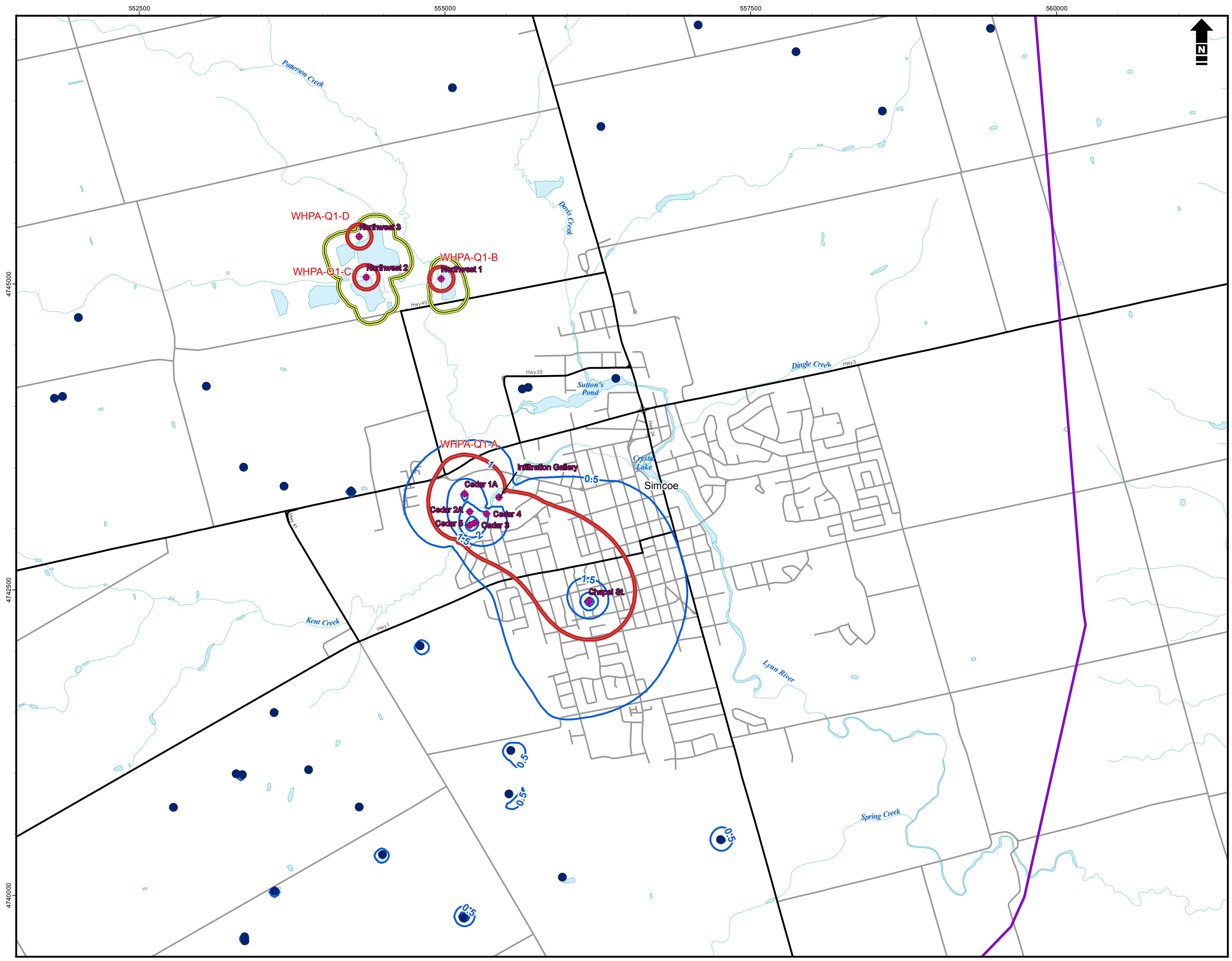
2. The long-term transient model simulating existing land use, existing pumping for all non-municipal permitted and non-permitted water takings, and Allocated municipal pumping rates (Scenario G[2]).

The difference between model-predicted heads for pumping and non-pumping scenarios was taken and the resulting drawdowns were projected to the ground surface (**Figures 4.1**, **4.2,** and **4.3**). The water budget guidance document (AquaResource 2011) recommends the consideration of seasonal water level fluctuations in the aquifer when selecting an appropriate drawdown threshold for the WHPA-Q1. Seasonal water level changes within the Provincial Groundwater Monitoring Network (PGMN) wells located furthest from the municipal production wells vary by approximately 0.6 to 2 m with the majority around 1.5 m (see Appendix B of **Appendix B**), As the water budget models are calibrated against a large amount of water level data that span a number of years, it is unlikely that the models can achieve a level of accuracy in water levels that is less than the natural variations in the calibration targets. Based on these factors, a 1 m decline in water levels was selected for use in delineating the WHPA-Q1 areas (**Figures 4.1**, **4.2,** and **4.3)**.

In Simcoe, there are four WHPA-Q1s; the largest (WHPA-Q1-A) encompasses the municipal wells of the Cedar St. Well Field and the Chapel St. Well (**Figure 4.1**). In the Northwest Well Field, drawdown was predicted to be less than 0.8 m and as such, no 1 m drawdown contour exists. Therefore, the WHPA-Q1 in this area is represented by three smaller zones (WHPA-Q1-B, WHPA-Q1-C, and WHPA-Q1-D), each consisting of a 100 m buffer area centred on the three municipal wells. None of the WHPA-Q1 areas include drawdown associated with other non-municipal permitted consumptive water users.

In Waterford, maximum drawdown was predicted to be 1.0 and 0.9 m for Wells 3 and 4, respectively. However, as this drawdown only exists immediately surrounding each well, the WHPA-Q1 in Waterford is represented by a single zone (WHPA-Q1-E) consisting of a combined 100 m buffer area surrounding each well (**Figure 4.2**). There are no other non-municipal consumptive water users that contribute to the WHPA-Q1-E.

In Delhi, the WHPA-Q1 consists of a single circular zone (WHPA-Q1-F), which encompasses Delhi Wells 1 and 2. It is slightly elongated in the north-south direction and has a radius of less than 1 km (**Figure 4.3**). WHPA-Q1-F includes the predicted drawdown related to permitted agricultural water takings.



Tier Three Study Focus Area
Water Body
Watercourse
Highway
Road
WHPA-Q1
100 m Buffer
Drawdown Contour (0.5m)
Municipal Well / Intake / Infiltration Gallery
PTTW - Excluding Tier Three Municipal Supply

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Simcoe - WHPA-Q1

Date: 29 Apr 2015	Project: 15077-527

Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 4.1

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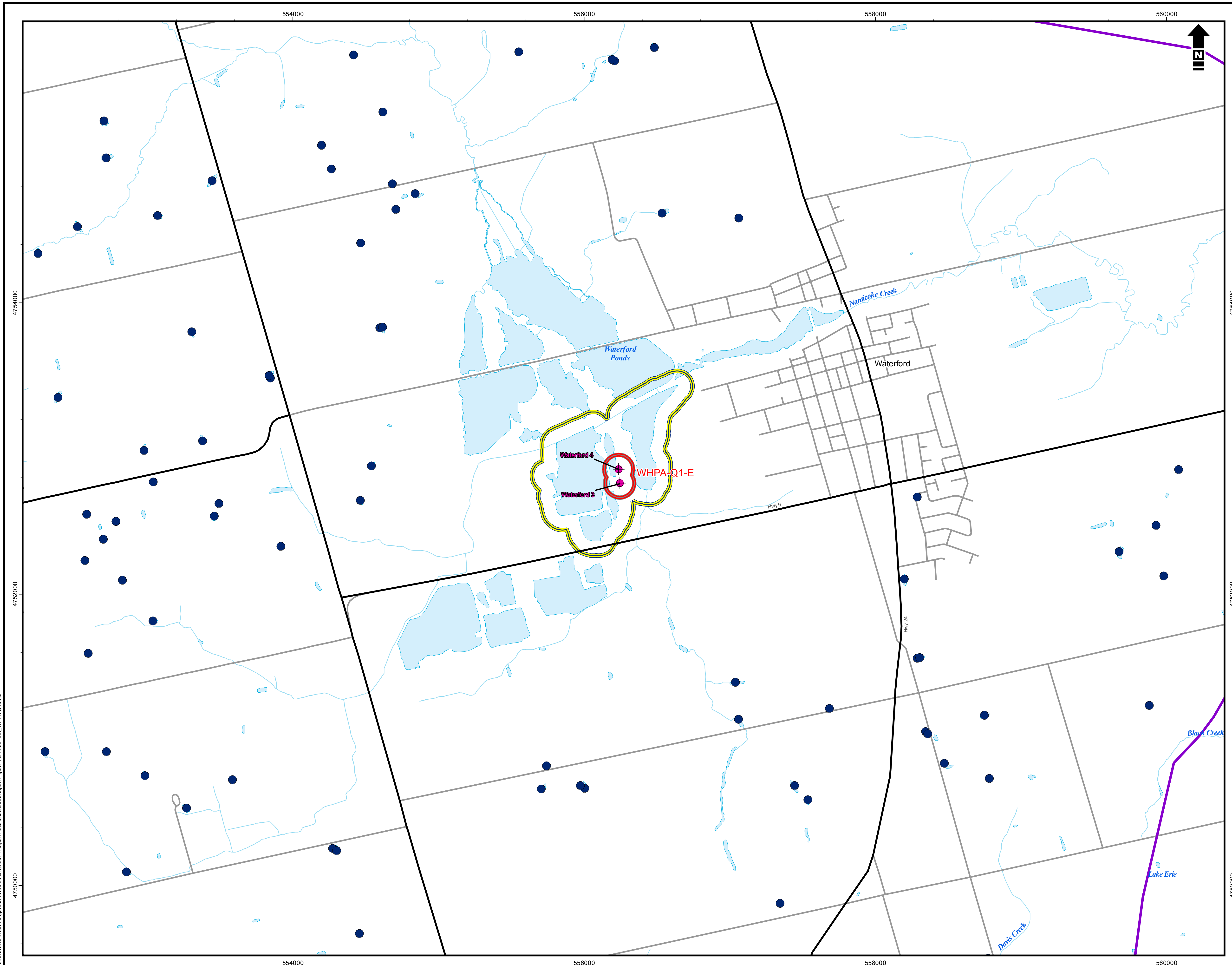

Tier Three Study Focus Area
Water Body
Watercourse
Highway
Road
WHPA-Q1
100 m Buffer
Municipal Well / Intake
PTTW - Excluding Tier Three Municipal Supply

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Waterford - WHPA-Q1

Date: 29 Apr 2015 | Project: 15077-527

Technical: J. Melchin | Reviewer: S. Bellamy | Drawn: R. Laird

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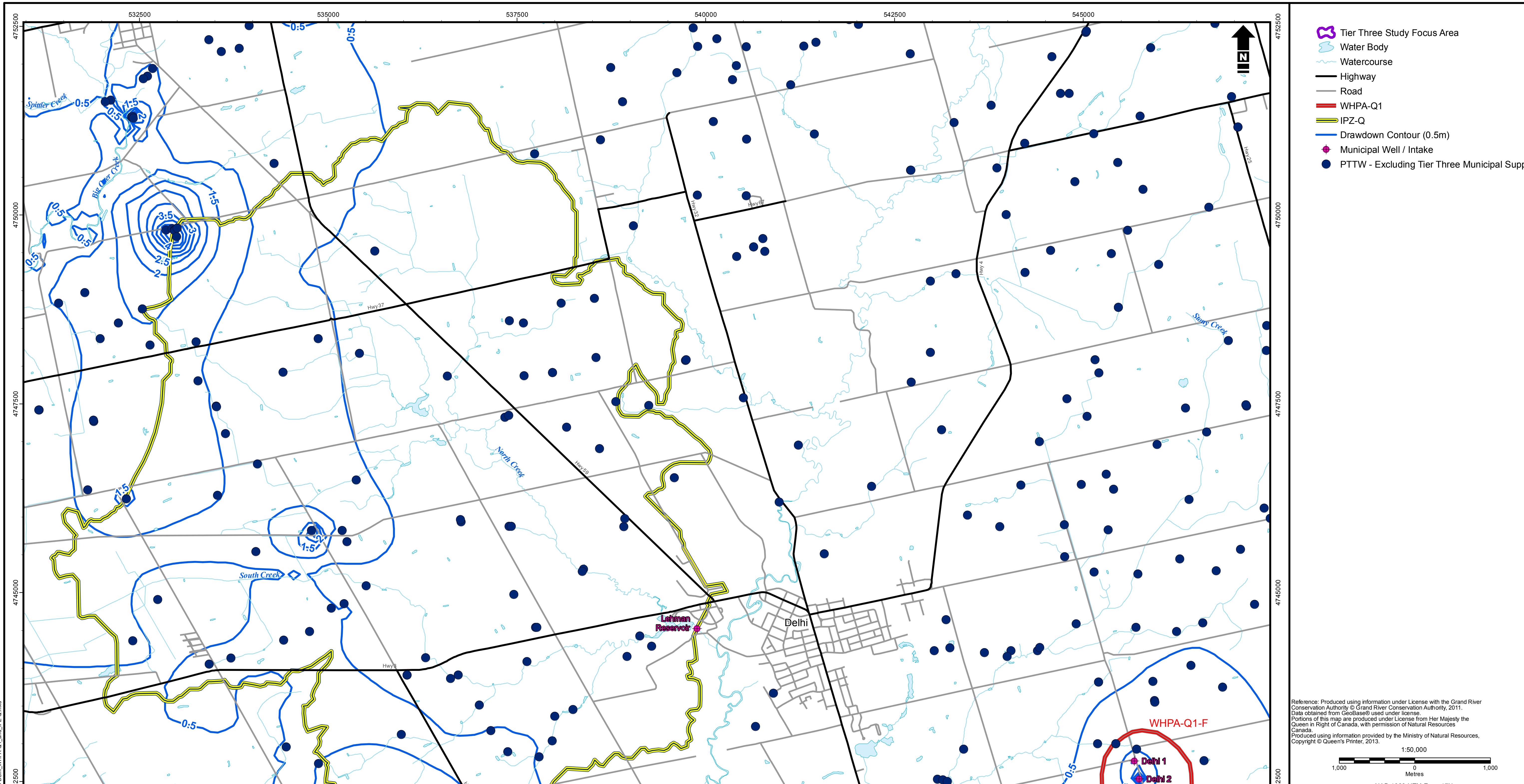
Figure 4.2



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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Delhi - WHPA-Q1 and IPZ-Q

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Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 4.3

4.1.2 WHPA-Q2

The WHPA-Q2 is defined in the *Technical Rules* and water budget guidance document (AquaResource 2011) as the WHPA-Q1 area, plus any additional areas outside the WHPA-Q1, where a future reduction in recharge may have a measurable impact on the reliability of the municipal wells. Proposed land development areas that could reduce the available drawdown in a municipal well, were considered for this assessment. **Figure 2.1** shows the urban development areas (as discussed in Section 2).

There are potential land use developments that extend beyond the WHPA-Q1 areas in this assessment (i.e., all proposed development in Delhi and Waterford, as well as the majority of the proposed development in Simcoe). To assess the impact of land use changes on the reliability of the municipal supply wells, the groundwater and integrated flow models were run with existing land use and existing pumping, and the head at the municipal wells (in the production aquifer) was recorded (Risk Assessment Scenario C; Section 4.4). The models were then updated to reflect future land use, and the models were re-run (Risk Assessment Scenario G[3]; Section 4.4). The reduction in hydraulic head due to the proposed development was predicted to be 0.1 m or less in the aquifers at the municipal wells.

For municipal wells that have available drawdown (i.e., all wells except Cedar St. Wells 2A, 3, 4, and 5), the predicted drawdown of Scenario G(3) represents less than 4% of the SAAD calculated for the wells. Since the magnitude of this drawdown is considered low (e.g., less than 10% of the remaining available drawdown) the drawdown is not anticipated to significantly affect the reliability of the municipal wells.

For the four wells of the Cedar St. Well Field, which have negative SAAD (i.e., do not have available drawdown), impacts due to future land use for these wells were assessed by considering Scenario G(3) drawdown relative to seasonal fluctuations in water levels in the aquifer. Since the predicted drawdown is 0.1 m or less, and less than 10% of the seasonal fluctuations in the aquifer (approximately 1.1 to 1.6 m at the nearest PGMN well [W170-2]; **Appendix B**), the drawdown associated with reduced recharge is not considered to have a significant impact on the reliability of the municipal wells.

Therefore, the reduction in recharge outside of the WHPA-Q1 was not considered to be significant and, as a result, each WHPA-Q2 (WHPA-Q2-A, WHPA-Q2-B, WHPA-Q2-C, WHPA-Q2-D, WHPA-Q2-E, and WHPA-Q2-F) is delineated as the same areas as the WHPA-Q1. In summary, there are no future land use developments that are expected to have a significant impact on the reliability of the municipal wells.

4.1.3 IPZ-Q and Surface Water Contributing Areas

The Surface Water Quantity Vulnerable Area, IPZ-Q, corresponds to the drainage area that contributes surface water to an intake, and the area that provides recharge to an aquifer that contributes groundwater discharge to the drainage area. Part VI.7 of the *Technical Rules* specifies the rules with respect to the delineation of IPZ-Q.

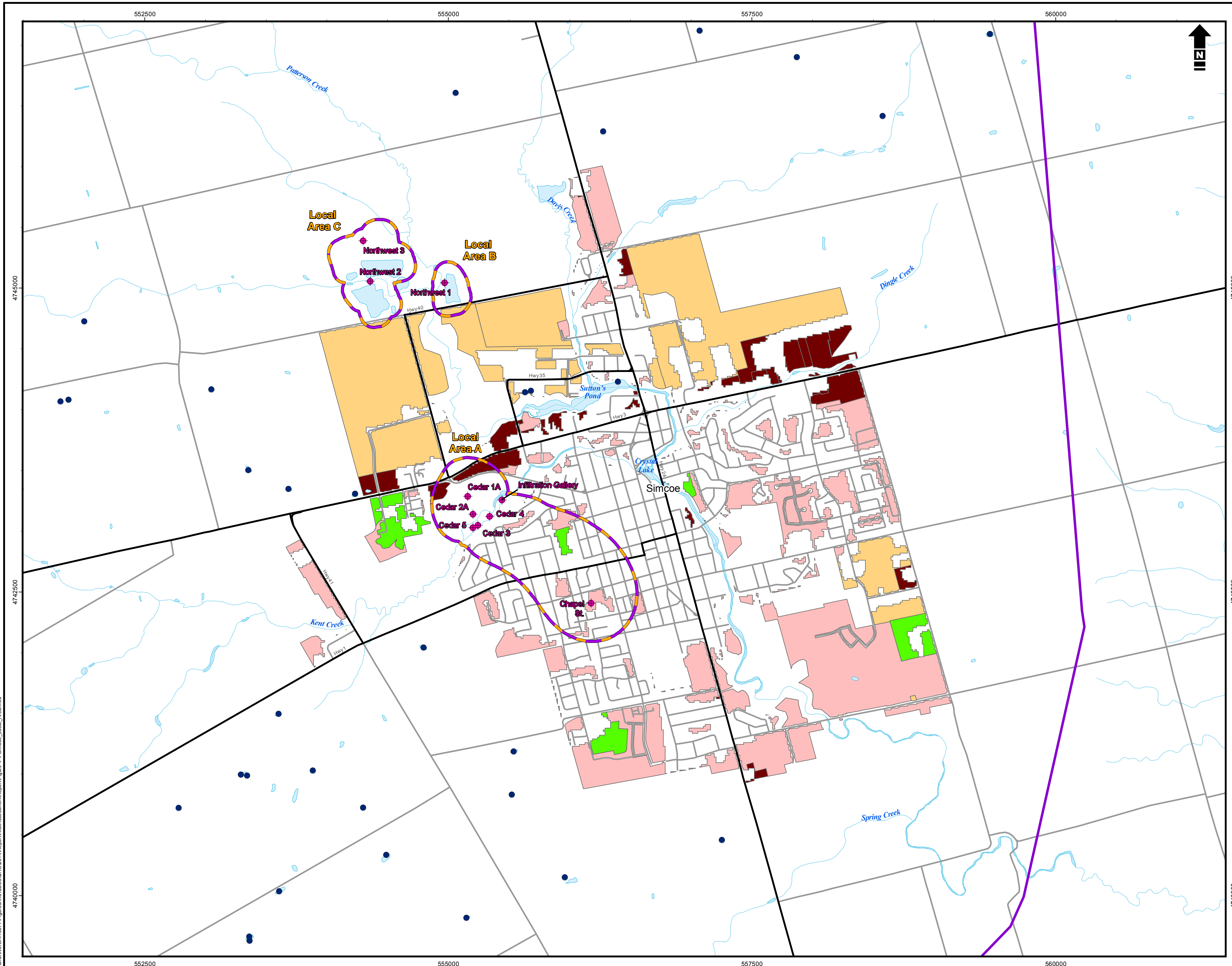
In the case of the surface water intake located at the Lehman Reservoir in Delhi, the drainage area contributing to the intake includes the reaches and tributaries of North Creek and South Creek west of Delhi. Reverse particle tracking in the groundwater model was used to determine if there is an additional area that provides recharge to the aquifer that contributes groundwater discharge to the drainage area. A limited volume of groundwater discharging in the streams is predicted to come from outside the catchment area. Subsurface travel times from the border of the catchment to the stream are in excess of 60 years. Therefore, the IPZ-Q is delineated as the drainage area of the Lehman Intake (**Figure 4.3**).

Although no municipal surface water intakes exist in the Towns of Waterford and Simcoe, GUDI studies reveal hydraulic connections between the surface water ponds and the municipal wells of Waterford and Simcoe Northwest that lie adjacent to those ponds. Such a connection is thought to be due to the presence of windows in the confining layer, which separates the shallow and deeper aquifer systems, causing leakage from aggregate ponds that contribute to sustaining groundwater municipal withdrawals. Reductions in levels in these ponds could reduce leakage to the underlying aquifers and impact well production.

As per the MOE Guidance (MOE 2014), in cases where a municipal supply aquifer derives a significant portion of its recharge from a surface water feature, the area upstream of the point of interaction between the groundwater and surface water systems should be included into the WHPA-Q1. As a result of this, areas around surface water ponds that may provide water to the Waterford and Simcoe Northwest Well Fields were delineated using a 100 m buffer around the ponds (**Figures 4.1** and **4.2**). Near the Cedar St. Well Field, similar large bodies of water are not found close to the wells and infiltration gallery. While the municipal supplies are hydraulically connected to the shallow flow system and Kent Creek (i.e., they are GUDI), based on the water balance for the WHPA-Q1 (Section 6.1 below), groundwater is discharging to Kent Creek and the surface water contribution of recharge to the aquifer is predicted to be minor in nature and therefore, an additional area was not delineated for this WHPA-Q1.

4.1.4 Local Area

The Local Areas for Simcoe, Waterford, and Delhi are illustrated on **Figures 4.4**, **4.5,** and **4.6**, respectively. The Local Areas are delineated by combining the cone of influence of the municipal supply wells (WHPA-Q1; **Figures 4.1**, **4.2,** and **4.3**), the areas where a reduction in recharge would have a measurable impact on the cone of influence of the wells (WHPA-Q2; **Figures 4.1**, **4.2,** and **4.3**), the drainage area contributing surface water to the Lehman Reservoir intake (IPZ-Q: **Figure 4.3**) and the areas around the ponds at the Waterford and Simcoe Northwest Well Fields (**Figures 4.1** and **4.2**). As a result, there are six Local Areas in this Assessment: Local Areas A, B, and C in Simcoe (**Figure 4.4**), Local Area D in Waterford (**Figure 4.5**), and Local Areas E and F in Delhi (**Figure 4.6**).



Tier Three Study Focus Area
Water Body
Watercourse
Highway
Road
Local Area
Municipal Well / Intake / Infiltration Gallery
PTTW - Excluding Tier Three Municipal Supply

Future Land Use Change

Commercial
Industrial
Park Rec
Residential

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Simcoe - Local Area

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Figure 4.4

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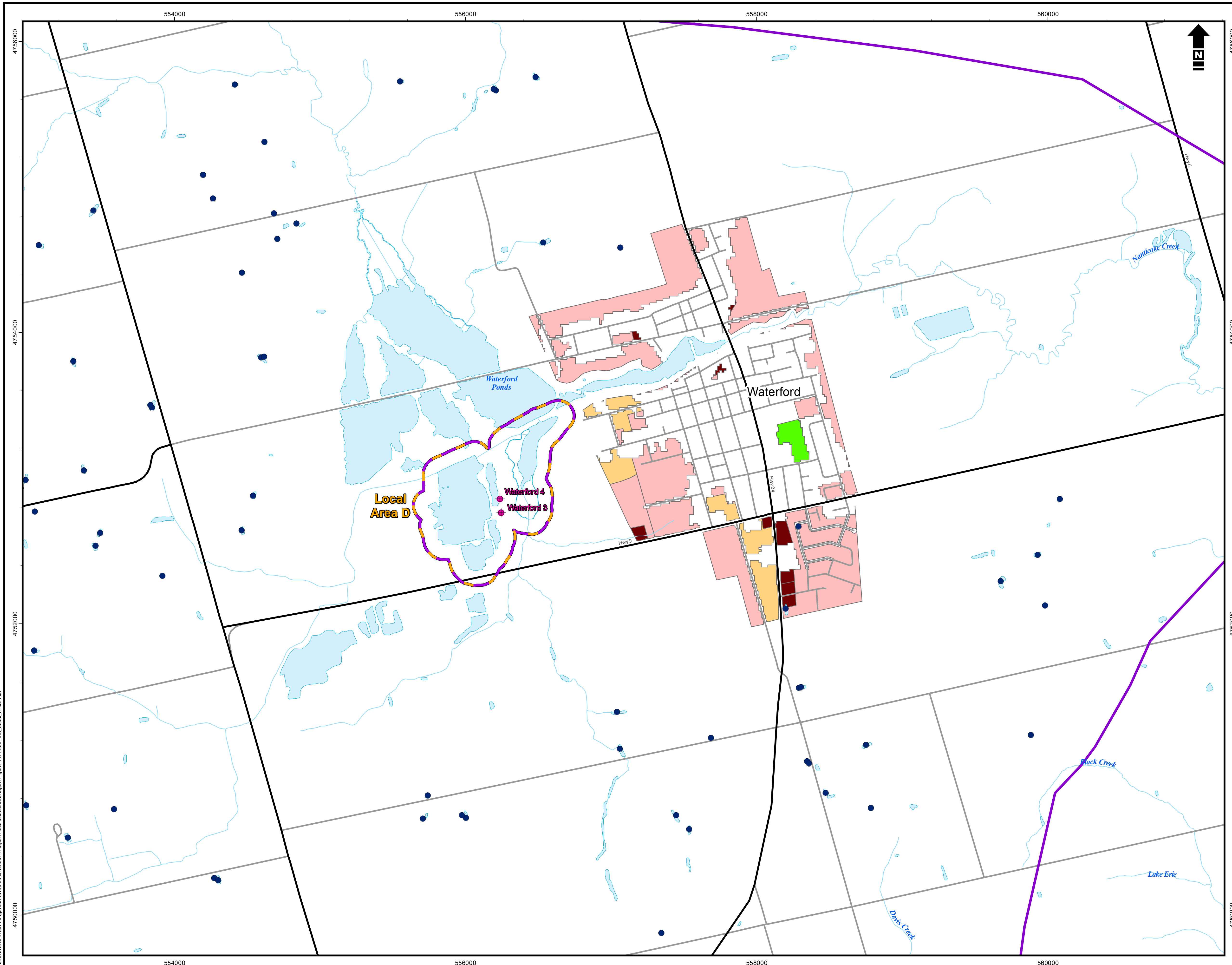

Tier Three Study Focus Area
Water Body
Watercourse
Highway
Road
Local Area
Municipal Well / Intake / Infiltration Gallery
PTTW - Excluding Tier Three Municipal Supply

Future Land Use Change

Commercial
Industrial
Park Rec
Residential

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Waterford - Local Area

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Figure 4.5

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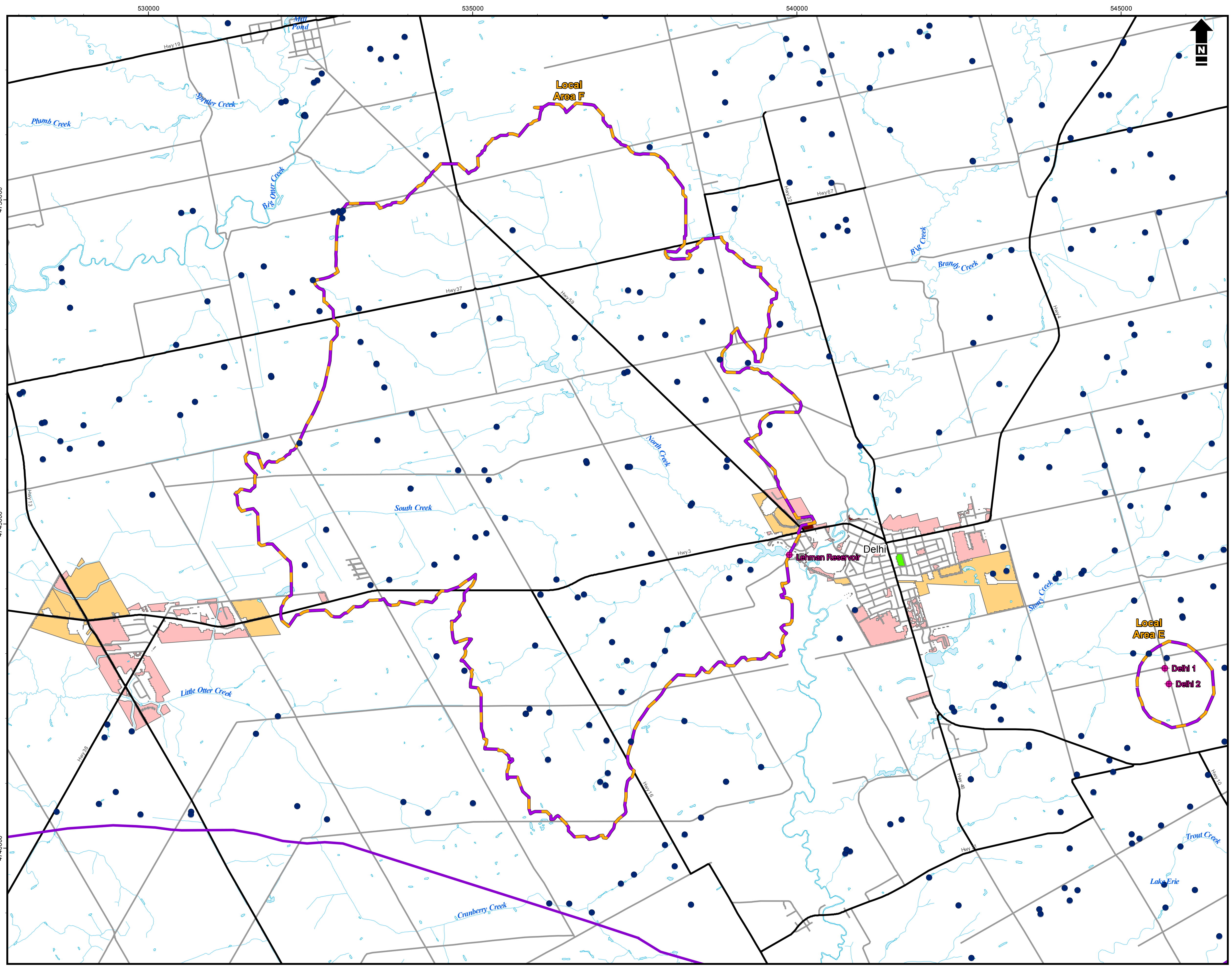

Tier Three Study Focus Area
Water Body
Watercourse
Highway
Road
Local Area
Municipal Well / Intake
PTTW - Excluding Tier Three Municipal Supply

Future Land Use Change

Commercial
Industrial
Park Rec
Residential

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Delhi - Local Area

Date: 29 Apr 2015 | Project: 15077-527

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Figure 4.6

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4.2 Risk Assessment Scenarios

The Tier Three Assessment requires that a series of scenarios be evaluated as listed in the *Technical Rules* and the water budget guidance document (AquaResource 2011). These scenarios, summarized in **Table 4.1**, are designed to identify the potential impacts from increased municipal water demand, land use changes, and drought on current hydrological and hydrogeological conditions. The water budget guidance document (AquaResource 2011) recommends that anticipated future takings for permitted non-municipal water demands also be incorporated into the scenarios, but in this case, there were no anticipated increases within the Study Area. The data required for each of the model scenarios are outlined in Section 4.4.

TABLE 4.1 Risk Assessment Model Scenarios

Scenario	Time Period	Model Scenario Details		
		Land Cover of the Local Area	Water Demand	Model Simulation
Surface Water Risk Scenarios				
A	MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Existing	Existing	Simulate transient water levels using hourly climate and monthly pumping. Assess using average water levels.
B	MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Existing	Existing	Simulate transient water levels using hourly climate and monthly pumping. Assess using minimum water levels.
E(1)	MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Planned, reduction in recharge	Allocated	Simulate transient water levels using hourly climate and monthly pumping. Assess using average water levels.
E(2)		Existing	Allocated	
E(3)		Planned, reduction in recharge	Existing	
F(1)	MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Planned, reduction in recharge	Allocated	Simulate transient water levels using hourly climate and monthly pumping. Assess using minimum water levels.
F(2)		Existing	Allocated	
F(3)		Planned, reduction in recharge	Existing	
Groundwater Risk Scenarios				
C	FEFLOW: Average of Climate Record (1960 to 2010) MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Existing	Existing	FEFLOW: Steady-state, simulate water levels using average annual recharge and average pumping MIKE SHE: Transient, simulating water levels using hourly climate and monthly pumping. Assess using average water levels.

Scenario	Time Period	Model Scenario Details		
		Land Cover of the Local Area	Water Demand	Model Simulation
D	FELFOW and MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Existing	Existing	FEFLOW: Transient, simulating water levels using bi-monthly recharge and monthly pumping MIKE SHE: Transient, simulating water levels using hourly climate and monthly pumping. Assess using minimum water levels.
G(1)	FEFLOW: Average of Climate Record (1960 to 2010) MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Planned, reduction in recharge	Allocated	FEFLOW: Steady-state, simulate water levels using average annual recharge and average monthly pumping MIKE SHE: Transient, simulating water levels using hourly climate and monthly pumping. Assess using average water levels.
G(2)		Existing	Allocated	
G(3)		Planned, reduction in recharge	Existing	
H(1)	FELFOW and MIKE SHE: Full Climate Record (1960 to 2010), Including Drought Periods	Planned, reduction in recharge	Allocated	FEFLOW: Transient, simulating water levels using bi-monthly recharge and monthly pumping MIKE SHE: Transient, simulating water levels using hourly climate and monthly pumping. Assess using minimum water levels.
H(2)		Existing	Allocated	
H(3)		Planned, reductions in Recharge	Existing	

The time periods in **Table 4.1** were interpreted as follows:

- Scenarios representing average climate (i.e., A, E, C, and G) were simulated using long-term transient scenarios for MIKE SHE, while a steady-state approach was used for FEFLOW.

- Scenarios representing drought conditions (i.e., B, F, D, and H) were simulated transiently using the full climate record (1950 to 2010) for both MIKE SHE and FEFLOW.

- Three versions of Scenarios E, F, G, and H are provided to evaluate the impact of Allocated pumping rates separate from the impacts of changes in land cover.

Impacts to other uses (e.g., wetlands and coldwater fisheries) are not evaluated for the drought Scenarios (B, F, D, and H). The drought scenarios only serve to identify the potential for water levels to fall beneath a minimum operating elevation for each municipal well or intake. For the groundwater municipal wells, this minimum operating level represents the safe water level as described in Section 3.3. For the Lehman Reservoir, where there are two intake openings, the minimum operating level is the elevation of the upper intake at the reservoir (214.58 m above sea level [asl]). This opening has been identified as the only one being used in normal operation (AECOM 2010). Impacts to other uses for groundwater wells are evaluated by estimating water table reduction beneath wetlands and reduced groundwater discharge to coldwater fisheries. At the surface water intake, impacts to other water uses are considered if the reservoir water level drops below the overflow structure (215.27 m asl).

4.3 Risk Circumstances

Output from the scenarios presented in **Table 4.1** is evaluated to identify specific circumstances that may be predicted to occur by the numerical models. Based on the occurrence of these circumstances, various Risk Levels are assigned to the Local Area. The circumstances vary depending on the scenario evaluated, and are as follows:

Circumstances of Significant Risk:

- Scenarios A or C – The municipal intake or well is not able to withdraw the Existing quantity of water.
- Scenarios B or D – The municipal intake or well is not able to withdraw the Existing quantity of water under drought conditions.
- Scenarios E(1), E(2), E(3) or G(1), G(2), G(3) – The municipal intake or well is not able to withdraw the Allocated Quantity of Water.
- Scenarios F(1), F(2), F(3) or H(1), H(2), H(3) – The municipal intake or well is not able to withdraw the Allocated Quantity of Water under drought conditions.

Circumstance of a Moderate Risk:

- Scenarios E(2) or G(2) – The municipal intake or well is able to withdraw the Allocated Quantity of Water, but results in either of the following impacts to other uses:
    - A reduction to flows or level of water that creates a measurable and potentially unacceptable impact based on professional judgement and the context of the specific use.
    - For an aquatic habitat classified as a coldwater stream, there is a reduction in groundwater discharge to that area in an amount greater than 10%.

Recent technical guidance (MOE 2013) allows for a Significant Risk Level to be assigned, provided that the difference between the Allocated Quantity of Water and the Planned Quantity of Water (as defined in Section 3.2) would result in an unacceptable impact to other uses. This same guidance (MOE 2013) states that a reduction of groundwater discharge greater than 20% would constitute an unacceptable impact to aquatic habitat. However, as Waterford, Simcoe, and Delhi do not have a Planned Quantity of Water, assigning a Significant Risk Level based on impacts to other uses is not possible.

4.4 Development of Risk Assessment Scenarios

The following sections describe how the Risk Assessment Scenarios presented in Section 4.2 were developed for application in the Tier Three Assessment.

4.4.1 Surface Water Risk Assessment Scenarios

4.4.1.1 Scenario A – Existing Demand, Average Climate

Scenario A evaluates the ability for the existing municipal water supply intake to maintain existing average monthly pumping rates over long-term climate conditions. This scenario was simulated transiently in the MIKE SHE integrated model using the estimated average 2008 to 2012 (Existing) monthly pumping rates simulating seasonal demand variability (**Table 4.2**) and hourly precipitation from 1960 to 2010. Transient intake pumping rates for the existing conditions scenario vary from a low of 75% of the average rate, to a high of 143% of the average rate, with peak demand generally from June to September.

The integrated flow model was used to predict the long-term average water level in the reservoir at the municipal intake.

TABLE 4.2 Existing Transient Rates Applied in the Risk Assessment Scenarios

Well / Intake Name	Existing Rate (2008 to 2012) (m^3/day)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Waterford												
Thompson Rd. Well 3	507	511	491	522	711	524	576	603	503	472	452	475
Thompson Rd. Well 4	491	467	490	499	584	616	656	410	497	450	503	425
Simcoe												
Northwest Well 1	210	207	185	21	173	187	15	17	125	28	21	15
Northwest Well 2	1,078	979	853	1,112	1,012	966	1,240	1,146	1,044	1,032	881	951
Northwest Well 3	1,017	919	813	912	899	974	1,097	1,040	986	902	1,038	1,121
Cedar St. Well 1A	310	318	313	336	428	529	586	671	438	356	292	239
Cedar St. Well 2A	222	198	210	273	306	319	329	288	286	242	211	196
Cedar St. Well 3	380	359	392	389	424	575	657	541	513	424	344	363
Cedar St. Well 4	235	240	242	272	324	341	422	343	254	225	238	241

Well / Intake Name	Existing Rate (2008 to 2012) (m^3/day)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cedar St. Well 5	325	313	318	410	435	445	562	448	343	283	318	291
Infiltration Gallery	351	374	725	660	782	862	603	573	616	671	299	308
Chapel St. Well 3	1,300	1,668	1,588	1,508	1,521	1,573	1,675	1,684	1,355	1,417	1,435	1,063
Delhi												
Delhi Well 1	394	458	520	497	585	613	518	440	497	495	310	518
Delhi Well 2	972	971	917	888	1,006	1,031	1,252	1,155	1,033	794	950	745
Lehman Reservoir	168	166	198	192	182	279	193	203	217	208	183	146

4.4.1.2 Scenario B – Existing Demand, Drought

Scenario B aims to evaluate whether the intake is able to pump at Existing Rates during a drought period. This scenario was simulated using the MIKE SHE integrated model in transient mode for the period of 1960 to 2010. Any drought periods from 1960 to 2010 were included to provide the lowest simulated water level. Average monthly pumping rates were applied to simulate seasonal demand variability (**Table 4.2**).

The *Technical Rules* refer to a minimum 2-year period to define drought conditions for the scenarios. However, this assessment went beyond the requirements of the Technical Rules and examined two longer drought periods that occurred within the 50-year climate period examined (i.e., 1960s and late 1990s). The transient model included the two drought periods as well as periods where precipitation (and in turn, recharge) were above normal.

As outlined in the *Technical Rules*, the impacts of municipal pumping on other uses were not considered in this drought scenario. The model was used to predict the minimum water level at the intake for the full 50-year climate period.

4.4.1.3 Scenario E – Allocated Demand, Future Land Development, Average Climate

Scenario E evaluates the ability for existing intakes to maintain Allocated pumping rates under average climate conditions, future development conditions, and with other permitted water takings. Monthly pumping rates for this scenario are presented in **Table 4.3**. This scenario was simulated using the integrated MIKE SHE model in transient mode using the same time period as Scenario A: 1960 to 2010. The average water level at the intake is calculated from the simulated results and compare to the SAAD.

Scenario E is subdivided into three Scenarios: E(1), E(2) and E(3). The purpose of multiple scenarios is to isolate the impacts of municipal pumping from impacts related to land developments. The E(2) scenario, which independently evaluates municipal pumping changes, is the only surface water scenario considered when evaluating the impact of the scenarios on other water uses. The E(1) and E(3) scenarios, which evaluate the impact of land use change, are not evaluated with respect to other water uses. Impacts due to land use change are more appropriately addressed under the *Planning Act*. Scenarios E(1) and E(3) are evaluated to ensure the municipal intake can withdraw its Allocated Quantity of Water.

TABLE 4.3 Allocated Transient Rates Applied in the Risk Assessment Scenarios

Well or Intake Name	Allocated Rate (2008-2012) (m^3/day)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Waterford												
Thompson Rd. Well 3	704	708	689	719	908	721	773	801	700	669	649	673
Thompson Rd. Well 4	688	664	688	697	782	813	853	608	694	648	701	622
Simcoe												
Northwest Well 1	210	207	185	21	173	187	15	17	125	28	21	15
Northwest Well 2	1,078	979	853	1,112	1,012	966	1,240	1,146	1,044	1,032	881	951
Northwest Well 3	1,119	1,021	915	1,014	1,001	1,076	1,198	1,142	1,088	1,004	1,140	1,223
Cedar St. Well 1A	411	420	415	438	529	631	688	773	540	457	394	341
Cedar St. Well 2A	324	300	311	375	407	421	431	390	388	344	313	298
Cedar St. Well 3	482	461	494	491	526	677	759	642	614	526	446	465
Cedar St. Well 4	337	342	344	374	426	443	524	445	355	327	340	343
Cedar St. Well 5	426	414	420	512	537	547	664	550	445	385	420	393
Infiltration Gallery	351	374	725	660	782	862	603	573	616	671	299	308
Chapel St. Well 3	1,402	1,770	1,690	1,610	1,623	1,674	1,777	1,786	1,456	1,519	1,537	1,165
Delhi												
Well 1	526	590	652	628	717	745	650	571	629	627	442	649
Well 2	1,103	1,103	1,048	1,020	1,138	1,163	1,384	1,287	1,165	926	1,082	876
Lehman Reservoir	168	166	198	192	182	279	193	203	217	208	183	146

Scenario E(1) – Cumulative Effects

This scenario evaluates the cumulative impact of increased municipal pumping rates (Allocated rates), reductions in recharge (due to increases in imperviousness) due to planned land use changes defined in the OP. **Table 4.3** lists the Allocated water demands applied to evaluate this scenario. **Figure 2.1** illustrates the land areas where recharge was reduced in the model.

Scenario E(2) – Isolated Pumping Effect

This scenario evaluated only the impact of increased municipal pumping rates (to Allocated rates) on the intake and other water uses. The existing conditions land use was simulated in this scenario to isolate the influence of municipal pumping from land development. Only this scenario is considered when evaluating the impact on other water uses (e.g., assessing whether the reservoir water level drops below the overflow structure, thereby reducing flow downstream of the reservoir). Impacts arising from land use development are independent from increased pumping, and only those impacts associated with pumping (e.g., Scenario E[2]) should be used to evaluate the Water Quantity Risk Level relating to the impact to other uses.

Scenario E(3) - Isolated Recharge Effect

This scenario evaluated the impact of reductions in recharge (due to increases in imperviousness) due to planned land use changes defined in the OP, on the municipal intake. Existing municipal pumping rates were used in this scenario to isolate the influence of land development.

4.4.1.4 Scenario F - Allocated Demand, Future Land Development and Drought

Scenario F evaluated the ability of the intake to maintain Allocated municipal pumping rates through a drought period (same temporal period as Scenario B: 1960 to 2010). The transient integrated model was used to examine the combined impact of drought conditions, land use development, and additional municipal pumping on the water level at the intake. Impacts to other water uses are not considered in Scenario F.

Average monthly pumping rates were applied to simulate seasonal demand variability (variability based on existing pumping trends from 2008 to 2012). These transient intake pumping rates for the Allocated Demand Scenario are found in **Table 4.3.**

Similar to Scenario E, this scenario was subdivided into Scenarios F(1), F(2), and F(3) to evaluate the relative contribution of municipal water takings and land use development at the municipal intake under drought conditions. The minimum water level at the intake was calculated from the simulated results and compare to the SAAD.

Scenario F(1) – Cumulative Effects

This scenario evaluated the cumulative impact of increased municipal pumping rates (Allocated rates), reductions in recharge (due to increases in imperviousness) due to planned land use developments defined in the OP and drought conditions on the municipal intake. As noted above, the impact was only evaluated at the intake and not on other water uses.

Scenario F(2)- Isolated Pumping Effect

This scenario evaluated the impact of increased municipal pumping rates (Allocated rates) on the municipal intake during a drought period. The existing conditions land use and existing non-municipal water withdrawals were simulated in this scenario.

Scenario F(3)- Isolated Recharge Effect

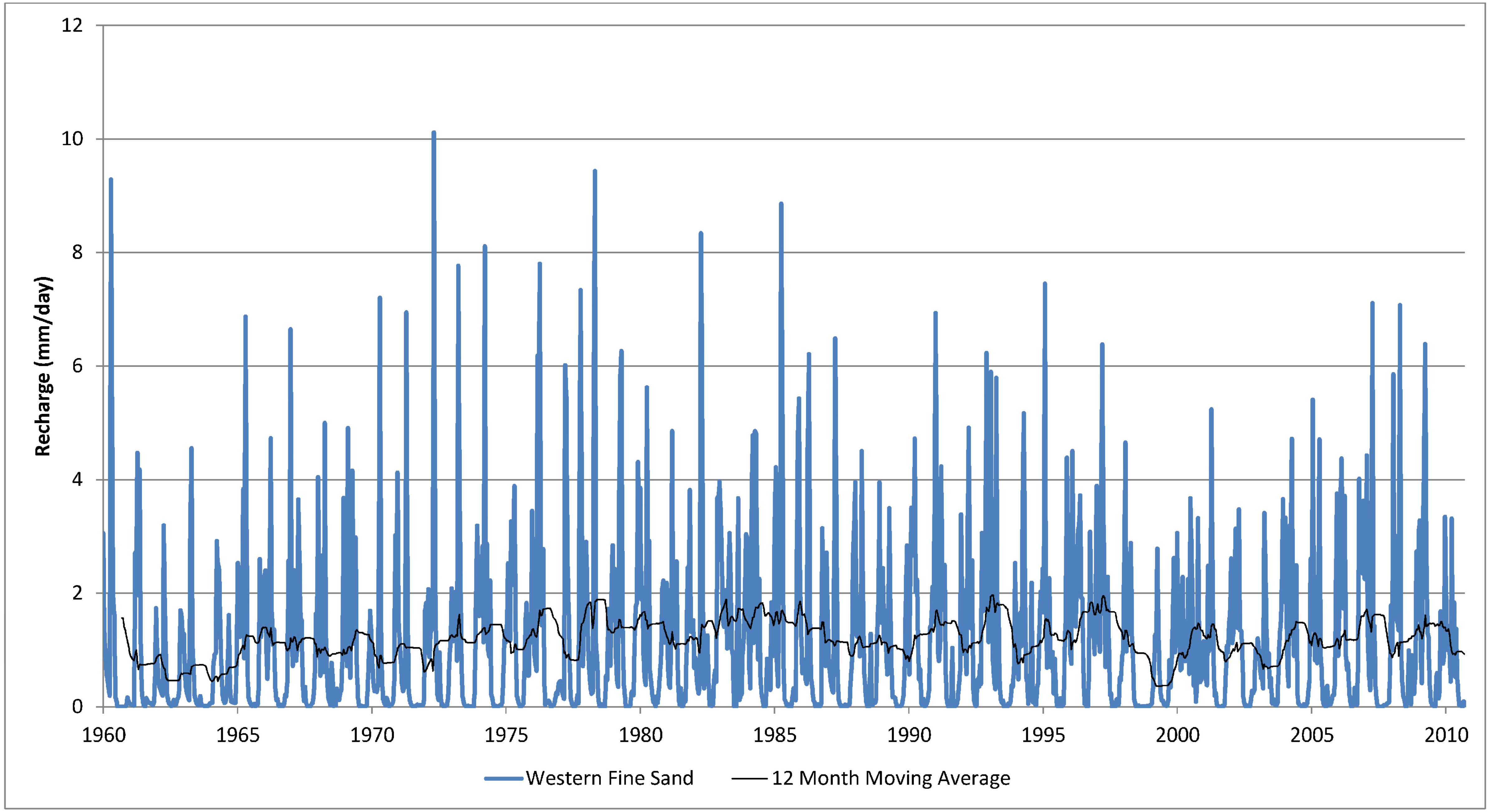
This scenario evaluated the impact of reductions in recharge (due to increases in imperviousness) due to planned land use developments defined in the OP and drought conditions on the municipal intake. As noted above, the impact was only evaluated at the intake and not on other water uses.

4.4.2 Groundwater Risk Assessment Scenarios

The design of the groundwater Risk Assessment Scenarios is analogous to the surface water Risk Assessment Scenarios (e.g., Scenarios A≈C, B≈D, E≈G, and F≈H) except for the following differences:

- Numerical model used
    - Where all surface water scenarios are performed using a local MIKE SHE integrated flow model, groundwater simulations were performed using the FEFLOW groundwater flow model for the Delhi municipal wells, and local integrated MIKE SHE flow models for the Waterford and Simcoe wells.
- Type of model simulation performed
    - Where all surface water scenarios are modelled in transient mode, groundwater Scenarios C and G in FEFLOW are simulated in steady-state mode using average annual recharge (from the regional MIKE SHE integrated model), average 2008 to 2012 pumping for Existing Rates, and annual average Allocated Rates (**Table 3.4**). In MIKE SHE, Scenarios C and G are simulated in transient mode using hourly climate and monthly pumping rates (Existing Rates - **Table 4.2**; Allocated Rates - **Table 4.3**).
    - In FEFLOW, groundwater Scenarios D and H are simulated in transient mode using average bi-monthly recharge (from the regional MIKE SHE integrated model) and monthly pumping (Existing Rates - **Table 4.2**; Allocated Rates - **Table 4.3**). In MIKE SHE, Scenarios D and H are also simulated transiently, but with hourly climate and monthly pumping. **Figure 4.7** illustrates an example of transient recharge rates generated in MIKE SHE for the western fine sand soil class, including the drought periods of the 1960s and late 1990s. This transient recharge was used as input for the FEFLOW model.

- Time period simulated
  - Where all surface water scenarios were modelled using the full 1960 to 2010 climate record, Scenarios C and G used an average of the climate record in FEFLOW. The full climate record was used in MIKE SHE for all groundwater scenarios and Scenarios D and H with FEFLOW. All drought periods during the 1960 to 2010 time period were included, which goes beyond the 10-year requirement for the groundwater Assessment.
- Type of parameter predicted
  - Where all surface water simulations predicted reservoir water levels at the Lehman intake, groundwater simulations predicted groundwater levels in the aquifer at the municipal pumping wells.
- Impacts to other water uses
  - Where the surface water Scenario E(2) assessed impacts to other water uses by assessing the decline in the reservoir water level relative to the overflow structure, the groundwater Scenario G(2) evaluated impacts to other water uses by quantifying reduced groundwater discharge to stream reaches and water table reduction below wetlands.



Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Long Term Recharge Variability

Date: 17 Sep 2014		Project: 15077-527	
Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird	

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Figure 4.7

4.5 Model-Predicted Scenario Results

As described above, the surface water model scenario results are evaluated with respect to the estimated water level at the Lehman Reservoir intake. Impacts to other uses will be evaluated through the assessment of water level decline relative to the overflow structure for surface water Scenario E(2). If the water level falls below the overflow structure, there will be no downstream contribution from the reservoir, which will affect downstream flow and other uses dependant on that flow.

4.5.1 Surface Water Level Decline

The simulated water level decline at the Lehman Reservoir for each of the surface water Risk Assessment Scenarios was compared to the available amount of decline at the intake and is summarized in **Table 4.4**. The available water level decline (0.76 m) is the difference between the normal reservoir water level (215.34 m asl) and the upper intake elevation (214.58 m asl; AECOM 2010).

For Scenarios A and E, the simulated water level decline was calculated using the long-term average reservoir water level elevation, whereas simulated water level decline for Scenarios B and F were calculated using the minimum water level elevation recorded in the 1960 to 2010 period. In either approach, water level decline was assessed relative to the simulated water level elevation from Scenario A (**Table 4.4**).

Simulations are compared to Scenario A as this scenario represents baseline, average existing conditions. The intake is not considered able to sustain its Allocated pumping rate when the simulated water level decline is greater than the available amount of decline (0.76 m). The minimum simulated water level elevation of the reservoir, representing the maximum simulated water level decline of all the scenarios is shown on the summary hydrograph presented on **Figure C15**. To maintain a common reference point on this figure, this simulated water level elevation has been calculated by subtracting the simulated water level decline (**Table 4.4**) from the normal reservoir water level (215.34 m asl).

4.5.1.1 Scenario A

Scenario A examines the predicted change in reservoir water level under Existing Demand at the surface water intake, under average climate and existing land use conditions. This scenario is the base case scenario representing existing conditions and water level decline from each subsequent surface water scenario has been calculated relative to Scenario A.

4.5.1.2 Scenario B

Scenario B examines the predicted water level fluctuations at the intake through variable climatic conditions including drought periods, existing transient variation in pumping, and existing land use. The lowest water level predicted by the model during this scenario was recorded for the intake. The differences between the lowest predicted water level and the water level predicted under Scenario A were tabulated and compared to the amount of available water level decline (**Table 4.4**).

As outlined in **Table 4.4,** the model predicted water level decline is less than the available decline amount, as such, the intake is predicted to maintain Existing Demand pumping throughout simulated drought periods with current land use.

4.5.1.3 Scenario E

Table 4.4 contains the model simulated water level decline under Scenarios E(1), E(2), and E(3) for the intake. Under average climatic conditions, the average model predicted water level decline is less than the available decline amount, for each of the three Scenarios. This suggests that under Allocated demand (Scenario E[2]), or if reductions in recharge were to take place (Scenario E[3]), or both (Scenario E[1]), the intake would be able to pump sustainably under average climatic conditions. Note that for the Lehman intake, the Allocated demand (in Scenario E[1] or E[2]) is equivalent to Existing Demand.

4.5.1.4 Scenario F

Scenario F examines the model-predicted fluctuations in water level at the intake under drought conditions. Scenario F(1) evaluated the cumulative impact of Allocated demand and reductions in recharge, while Scenario F(2) only evaluated the Allocated demand, and Scenario F(3) evaluated only the reductions in recharge.

The lowest water level predicted by the model during each of the model scenarios was recorded. The difference between this water level and the water level under Scenario A were tabulated and compared to the estimated amount of available decline (**Table 4.4**).

As outlined in **Table 4.4**, the minimum model predicted water level decline for the Lehman intake is less than the available decline amount. As such, the intake is predicted to be able to maintain Allocated pumping rates throughout drought periods and future land use changes.

4.5.2 Impacts to Downstream Flow

The impact to downstream flow, which may impact other downstream water uses, was also considered for the Lehman Reservoir using the results of Scenario E(2). The threshold for maintaining downstream flow is ensuring that the reservoir water level does not decline below the overflow structure (215.27 m asl; i.e., decline greater than 0.07 m below the normal reservoir water level [215.34 m asl]).

As summarized in **Table 4.4**, the simulated water level decline under the Scenarios E(2) is 0 m. Therefore, there is no additional risk associated with impacts to downstream flow and other water uses.

TABLE 4.4 Risk Assessment Water Level Decline Results

Intake Name	Available Water Level Decline (m)	Average Climate				Drought			
		Water Level Decline (m)				Water Level Decline (m)			
		A	E(1)	E(2)	E(3)	B	F(1)	F(2)	F(3)
		Existing Demand / Recharge / Water Takings	Allocated Demand, Reduced Recharge	Allocated Demand	Reduced Recharge	Existing Demand / Recharge / Water Takings	Allocated Demand, Reduced Recharge	Allocated Demand	Reduced Recharge
Lehman Reservoir	0.76	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1

4.5.3 Groundwater Drawdown

The simulated drawdown for each of the groundwater Risk Assessment Scenarios was compared to the estimated SAAD at each municipal well and is summarized in **Table 4.5**. For ease of comparison, the additional drawdown due to non-linear head losses (related to the Allocated increase for each well; **Table 3.7**) has been incorporated into the SAAD estimates originally presented in **Table 3.6**.

For the steady-state scenarios (Scenario G[1], G[2], and G[3]), the difference between the Scenario C water level within the municipal well, and those at the end of each scenario simulation, were recorded as the simulated drawdown in FEFLOW (**Table 4.5**). In the MIKE SHE model, the simulated drawdown is the difference between the long-term average water level for each scenario and the water level for Scenario C. For the transient scenarios (Scenarios D, H[1], H[2] and H[3]), the simulated drawdown was calculated as the minimum water level elevation recorded in the 1960 to 2010 period, subtracted from the simulated water level elevation from Scenario C (**Table 4.5**).

Simulations are compared to Scenario C as this scenario uses the average 2008 to 2012 pumping conditions that corresponds to the water levels used to calculate the SAAD values. Wells that may not be able to sustain their Allocated pumping rate are identified as those where the simulated drawdown is greater than the SAAD.

The minimum simulated water level elevation for each well, representing the maximum simulated drawdown (including non-linear well losses) of all the scenarios is shown on the summary hydrographs presented on **Figures C1** to **C14**. To maintain a common reference point on these figures, this simulated water level elevation has been calculated by subtracting the simulated drawdown (**Table 4.5**) from the average pumped water level for 2008 to 2012 (**Table 3.6**). The maximum drawdown for each scenario, for each well, is summarized on **Figure 4.8**.

4.5.3.1 Scenario C

Scenario C examines the predicted change in water level under Existing Demand at each of the municipal wells under average climate and existing land use conditions. This scenario is the base case scenario representing existing conditions. Drawdown from each subsequent groundwater scenario has been calculated relative to Scenario C. While the drawdown for Scenario C is zero for each municipal well, the amount of SAAD is negative for Cedar St. Wells 2A, 3, 4, and 5 (**Table 4.5**) as the safe water level elevation has already been exceeded at these locations (**Table 3.6**). Therefore, while these wells have not historically been identified as being unable to meet demands by Norfolk County staff, the exceedance of safe water levels in these four wells under existing, average climate conditions, results in a Water Quantity Risk Level of Significant for Local Area A.

4.5.3.2 Scenario D

Scenario D examines the predicted water level fluctuations at each of the municipal wells through variable climatic conditions including short and long-term drought, existing transient variation in pumping, and existing land use. The lowest water level predicted by the model during this scenario was recorded for each well. The differences between the lowest predicted water level and the water level predicted under Scenario C were tabulated and compared to the SAAD estimated for each municipal well (**Table 4.5**).

As outlined in **Table 4.5,** the model predicted drawdown is less than the estimated SAAD for all of the wells, except Cedar St. Well 2A, 3, 4, and 5 where the SAAD is exceeded. As such, a Significant Risk Level is assigned to Local Area A. This prediction assumes normal well performance and existing land use.

4.5.3.3 Scenario G

Table 4.5 contains the model simulated drawdown under Scenarios G(1), G(2), and G(3) for the municipal wells. Similar to Scenario D, the model predicted drawdown is less than the SAAD for all municipal wells, for each of the three Scenarios, except for Cedar St. Well 2A, 3, 4, and 5. This suggests that if municipal pumping were to increase to the full Allocated demand (Scenario G[2]), and reductions in recharge were to take place (Scenario G[3]), or both (Scenario G[1]), all municipal wells would be able to pump sustainably under average climatic conditions, except for those four Cedar St. Wells. As such, a Significant Risk Level is assigned to Local Area A.

4.5.3.4 Scenario H

Scenario H examines the model-predicted fluctuations in hydraulic head measurements for each of the municipal wells under drought conditions. Scenario H(1) evaluated the cumulative impact of Allocated demand and reductions in recharge, while Scenario H(2) only evaluated the Allocated demand (increased pumping), and Scenario H(3) evaluated only the reductions in recharge.

The lowest hydraulic head predicted by the model during each of the model scenarios was recorded. The difference between this water level and the water level for each well under Scenario C were tabulated and compared to the SAAD estimated for each municipal well (**Table 4.5**).

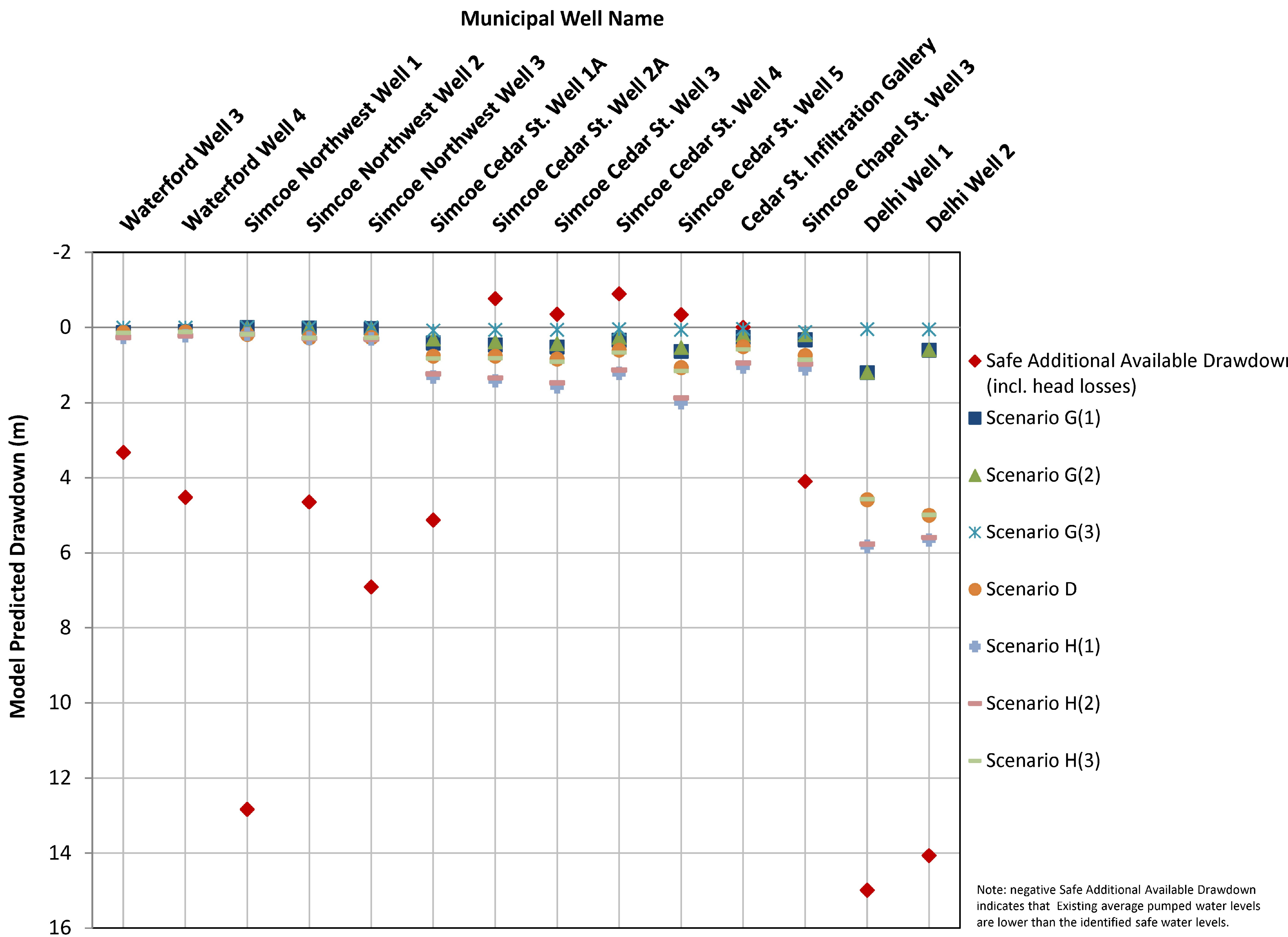
As outlined in **Table 4.5**, the model predicted drawdown for most of the municipal wells is less than the estimated SAAD for the wells. Simulated drawdown at Cedar St. Wells 2A, 3, 4 and 5; however, exceed the SAAD. Therefore, a Significant Risk Level is assigned to Local Area A.

TABLE 4.5 Risk Assessment Groundwater Drawdown Results

Well Name	Safe Additional Available Drawdown (m)	Safe Additional Available Drawdown, incl. Head Losses[A] (m)	Average Climate (Steady-State)				Drought (Transient)			
			Drawdown (m)				Maximum Drawdown (m)			
			C	G(1)	G(2)	G(3)	D	H(1)	H(2)	H(3)
			Existing Demand / Recharge / Water Takings	Allocated Demand, Reduced Recharge	Allocated Demand	Reduced Recharge	Existing Demand / Recharge / Water Takings	Allocated Demand, Reduced Recharge	Allocated Demand	Reduced Recharge
Waterford										
Thompson Rd. Well 3	3.50	3.33	0.0	0.1	0.1	0.0	0.1	0.3	0.3	0.1
Thompson Rd. Well 4	4.71	4.52	0.0	0.1	0.1	0.0	0.1	0.2	0.2	0.1
Simcoe										
Northwest Well 1	12.84	12.84	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2
Northwest Well 2	4.65	4.65	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
Northwest Well 3	6.96	6.91	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
Cedar St. Well 1A	5.21	5.13	0.0	0.4	0.3	0.1	0.8	1.3	1.2	0.8
Cedar St. Well 2A	-0.65	-0.77	0.0	0.5	0.4	0.1	0.8	1.4	1.3	0.8
Cedar St. Well 3	-0.22	-0.35	0.0	0.5	0.4	0.1	0.8	1.6	1.5	0.9
Cedar St. Well 4	-0.79	-0.89	0.0	0.3	0.3	0.0	0.6	1.2	1.1	0.7
Cedar St. Well 5	-0.18	-0.34	0.0	0.6	0.5	0.1	1.1	2.0	1.9	1.2
Infiltration Gallery	1.87	n/a	0.0	0.3	0.2	0.0	0.5	1.1	0.9	0.6
Chapel St. Well 3	4.18	4.10	0.0	0.3	0.2	0.1	0.8	1.1	1.0	0.9

Well Name	Safe Additional Available Drawdown (m)	Safe Additional Available Drawdown, incl. Head Losses[A] (m)	Average Climate (Steady-State) Drawdown (m)				Drought (Transient) Maximum Drawdown (m)			
			C	G(1)	G(2)	G(3)	D	H(1)	H(2)	H(3)
			Existing Demand / Recharge / Water Takings	Allocated Demand, Reduced Recharge	Allocated Demand	Reduced Recharge	Existing Demand / Recharge / Water Takings	Allocated Demand, Reduced Recharge	Allocated Demand	Reduced Recharge
Delhi										
Delhi Well 1	15.01	14.99	0.0	1.2	1.2	0.0	4.6	5.8	5.8	4.6
Delhi Well 2	14.08	14.07	0.0	0.6	0.6	0.0	5.0	5.7	5.6	5.0
shaded cells denote where Safe Additional Available Drawdown is exceeded										

Notes: [A] Safe Additional Drawdown including non-linear well losses (Table 3.7) and convergent head losses (Table 3.8).
Negative Safe Additional Available Drawdown indicates that Existing average pumped water levels are lower than the identified safe water levels.



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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Model Predicted Drawdown in Risk Assessment Scenarios

Date: 29 Sep 2014	Project: 15077-527	
Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

Figure 4.8

4.5.4 Impacts to Groundwater Flux/Baseflow

In the Province of Ontario, streams are classified as being cold, cool, or warm water based on temperature measurements and habitat and species observations. Cold water streams are of particular importance in that they support a diverse range of fish and plant life that exist in the natural thermal and water quality conditions. Cold water streams exist primarily due to a large portion of baseflow sustained by groundwater discharge. Under the Tier Three Risk Assessment, when considering only the Allocated Quantity of Water, any reduction in baseflow from groundwater to cold water streams using the G(2) scenario (increased demand) of 10% or more will result in a Water Quantity Risk Level of Moderate for the Local Area (MOE 2013).

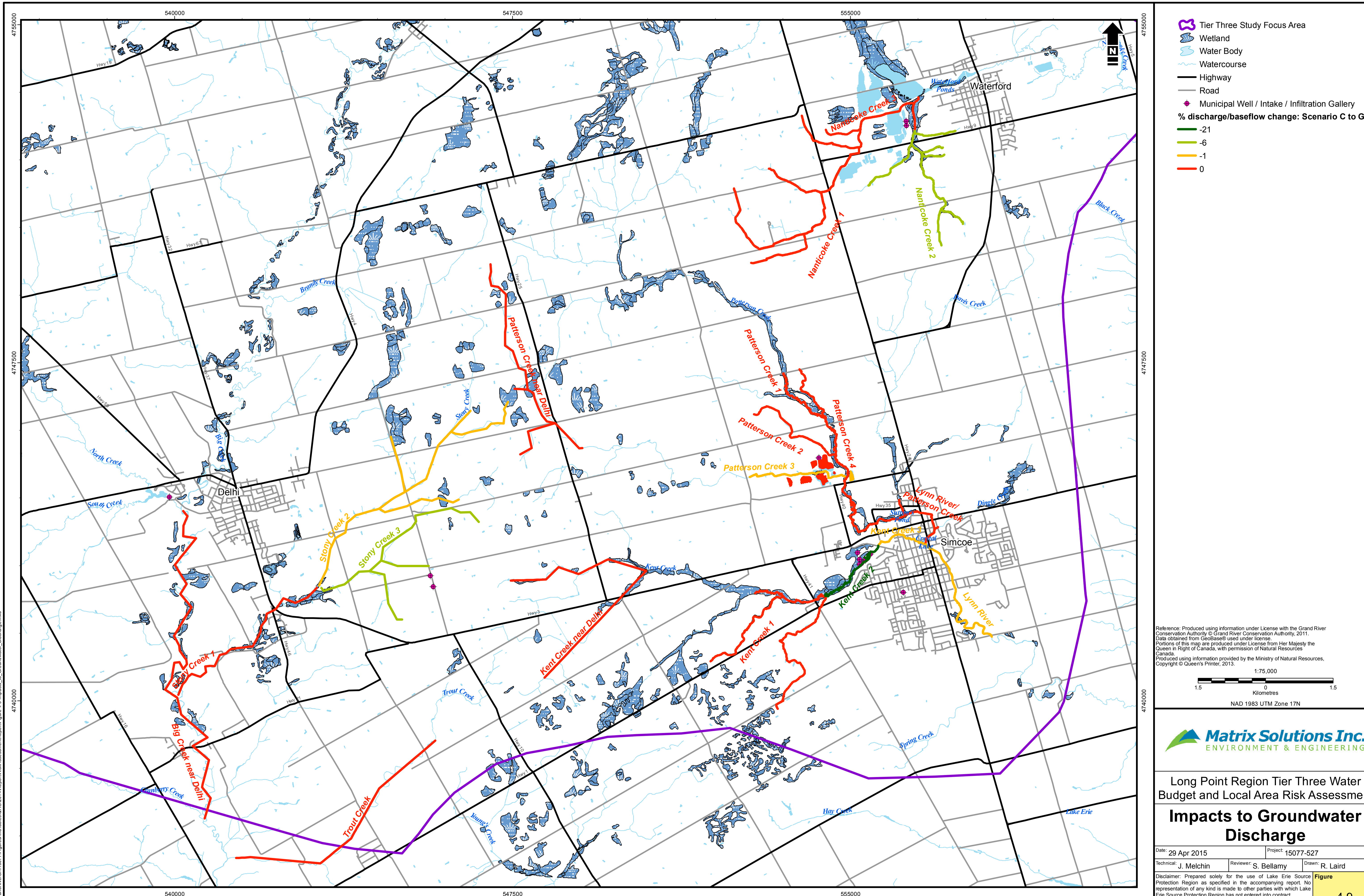
The simulated impact on groundwater flux (using the FEFLOW model for Delhi) and baseflow (using the local-scale MIKE SHE models) to rivers and streams of interest within the numerical modelling domains were assessed for Scenario G(2) by comparing the simulated groundwater flux or baseflow under Scenario G(2), relative to the baseline conditions represented in Scenario C. This exercise went beyond the requirements of the Risk Assessment, as simulated flux and baseflow were quantified for both coldwater and non-coldwater surface water features near the municipal wells. Streams and ponds were grouped together for this calculation to quantify the total combined effect on streams, which are in close proximity to one another. The modelled average annual groundwater flux (FEFLOW) and average baseflow (MIKE SHE) for each stream reach, for Risk Assessment Scenario C and G(2), as well as the percentage reduction between the two, is summarized in **Table 4.6. Figure 4.9** presents a map of the reduction in groundwater discharge and baseflow across the model domains.

TABLE 4.6 Impacts to Groundwater Discharge – Scenarios C and G(2)

Stream / Reach	Scenario C	Scenario G(2)	% Change
	Baseflow (mm/year)		
Waterford			
Nanticoke Creek 1	2	2	0%
Nanticoke Creek 2	16	15	-6%
Nanticoke Creek 3	25	25	0%
Simcoe			
Kent Creek 1	95	95	0%
Kent Creek 2	250	198	-21%
Kent Creek 3	961	951	-1%
Lynn River/Patterson Creek	847	845	0%
Lynn River	968	963	-1%
Patterson Creek 1	364	364	0%
Patterson Creek 2	29	29	0%
Patterson Creek 3	387	385	-1%
Patterson Creek 4	862	861	0%
Northwest Pond 1	0	0	0%
Northwest Pond 2	0	0	0%
Northwest Pond 3	179	178	-1%
Stream / Reach	**Scenario C**	**Scenario G(2)**	**% Change**
	Groundwater Flux (m^3/day)		
Delhi			
Stony Creek 1	658	658	0
Stony Creek 2	-5,272	-5,238	-1%
Stony Creek 3	-1,645	-1,544	-6%
Trout Creek	-23,290	-23,280	0
Big Creek Delhi	-64,215	-64,214	0
Patterson Creek near Delhi	-3,868	-3,864	0
Kent Creek near Delhi	-9,062	-9,034	0
shaded cells denote where change in baseflow or groundwater flux exceeds 10%			

Negative Groundwater Flux = Groundwater Discharge
Positive Groundwater Flux = Groundwater Recharge
Negative % Change = Reduced groundwater discharge or increased leakage to groundwater system

As summarized in **Table 4.6** and on **Figure 4.9**, simulated groundwater discharge and baseflow reductions for all of the modelled reaches due to Allocated pumping range from 0% to 21%. The Kent Creek 2 reach is the only reach simulated to have a reduction in baseflow by 10% or more (21%). As the creek is classified as a cold water stream in this area, this degree of impact is sufficient for a Moderate Risk Level to be assigned to Local Area A (Cedar St. Well Field). However, as Local Area A was assigned a Significant Risk Level based on safe available drawdown, the assessment of impacts to other uses cannot affect the final Risk Level. Other reaches do not display reductions in groundwater discharges (<6%) that are sufficient to affect other water users.



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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Impacts to Groundwater Discharge

Date: 29 Apr 2015 | Project: 15077-527

Technical: J. Melchin | Reviewer: S. Bellamy | Drawn: R. Laird

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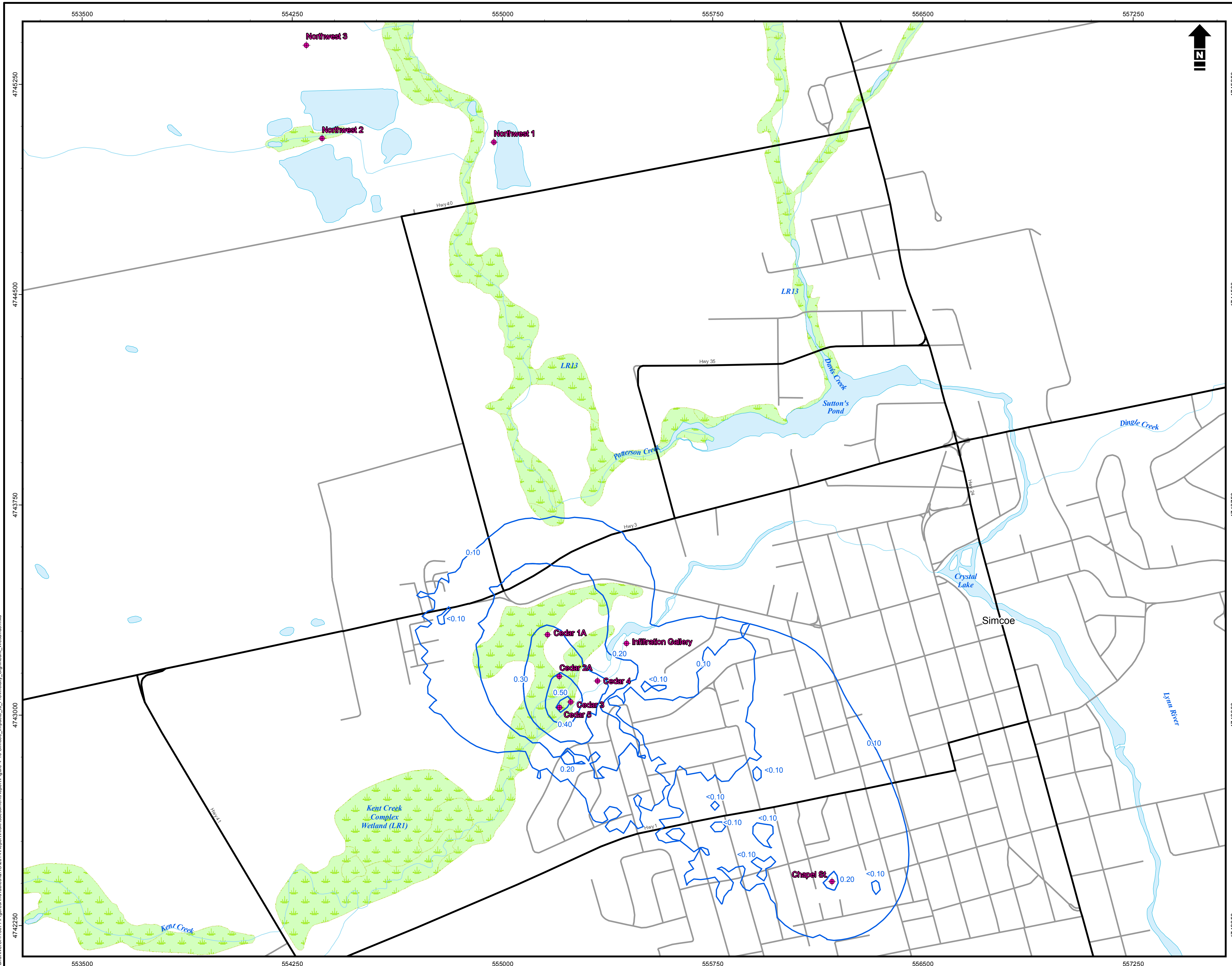
Figure 4.9

4.5.5 Impacts to Provincially Significant Wetlands

The simulated impact on PSWs within the numerical modelling domain was assessed by comparing the water table at PSW locations, under Scenario G(2), relative to the water table at PSW locations under the baseline Scenario C. Similar to impacts to groundwater discharge (Section 4.5.4), simulated water level change for Scenarios G(1) and G(3) were not assessed. Impacts to PSWs were evaluated using the local MIKE SHE models for Waterford and Simcoe and the FEFLOW model for Delhi.

Figure 4.10, **4.11,** and **4.12** illustrate the water table reduction contours predicted under Scenario G(2) as compared to the water table predicted under Scenario C for Simcoe, Waterford, and Delhi, respectively. The increase in municipal pumping to the Allocated rates (Existing plus Committed Demand) is predicted to cause a water table reduction of less than 0.3 m near Delhi and Waterford and less than 0.6 m near the Cedar St. and Chapel Well Fields in Simcoe. In Delhi and Waterford, none of the predicted drawdown is predicted to occur below identified PSWs. In Simcoe, less than 0.2 m of drawdown is simulated below PSW LR13, north of the Cedar St. Well Field, and less than 0.6 m is predicted below PSW Kent Creek Complex (LR1), near Cedar St. Wells 3 and 5. Less than 0.1 m of water table change is predicted to occur below PSWs located near the Simcoe Northwest Well Field.

As the predicted water table decline below Kent Creek Complex coincides with a predicted reduction in baseflow of 21% in Kent Creek, there is the potential that the function of the wetlands may be affected. This meets the requirement for a Moderate Risk Level to be assigned to Local Area A based on impacts to PSWs. Across the remainder of the Study Area, groundwater discharge conditions (including discharge to wetland features) is predicted to change by less than 10% and the maximum change in the water table below PSWs is predicted to be less than 0.3 m; therefore, the function of the wetlands is expected to be maintained in these areas and no additional risk is associated with impacts on these wetlands.



Provincially Significant Wetland

Water Body

Watercourse

Water Table Drawdown (m) : Scenario C - Scenario G(2)

Highway

Road

Municipal Well / Intake / Infiltration Gallery

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Simcoe - Impacts to Provincially Significant Wetlands

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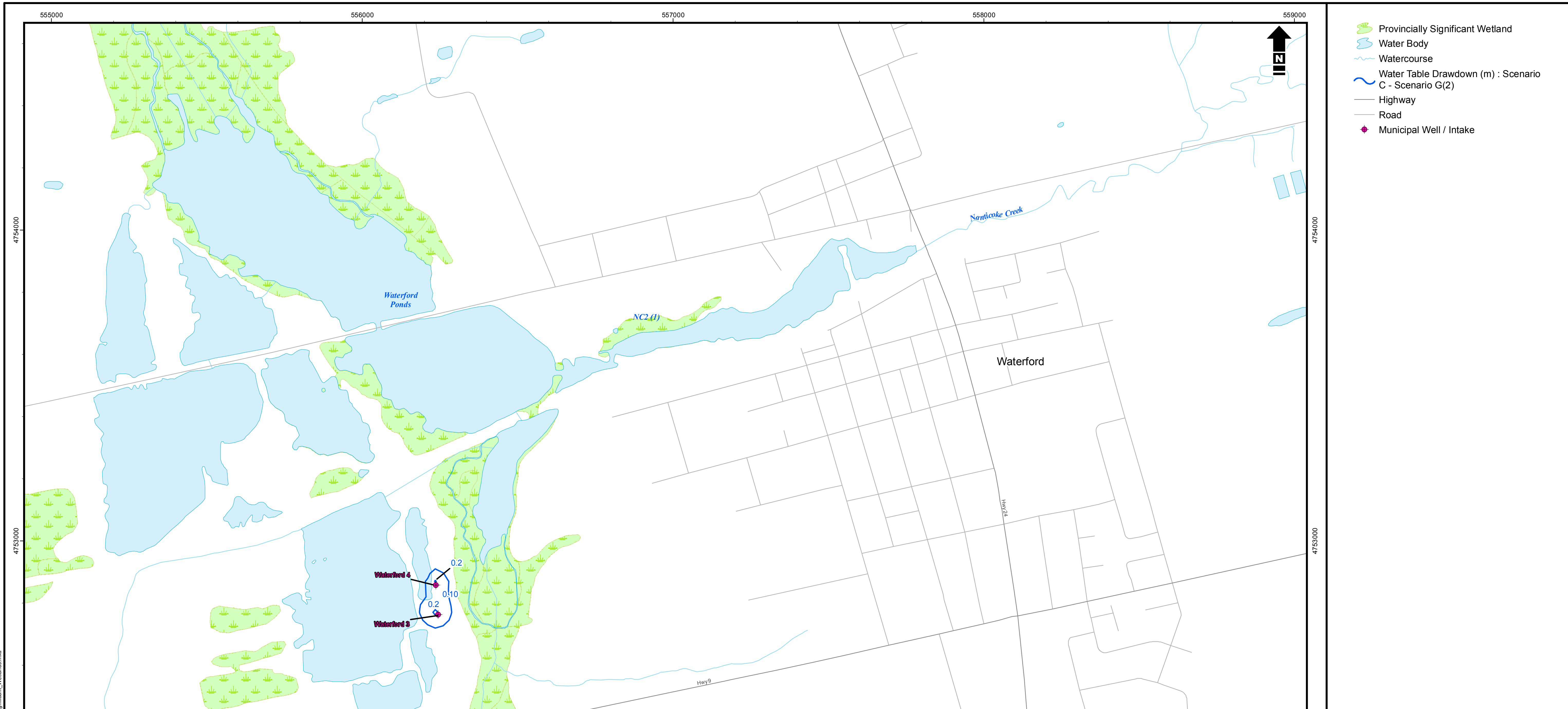
Figure 4.10



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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Waterford - Impacts to Provincially Significant Wetlands

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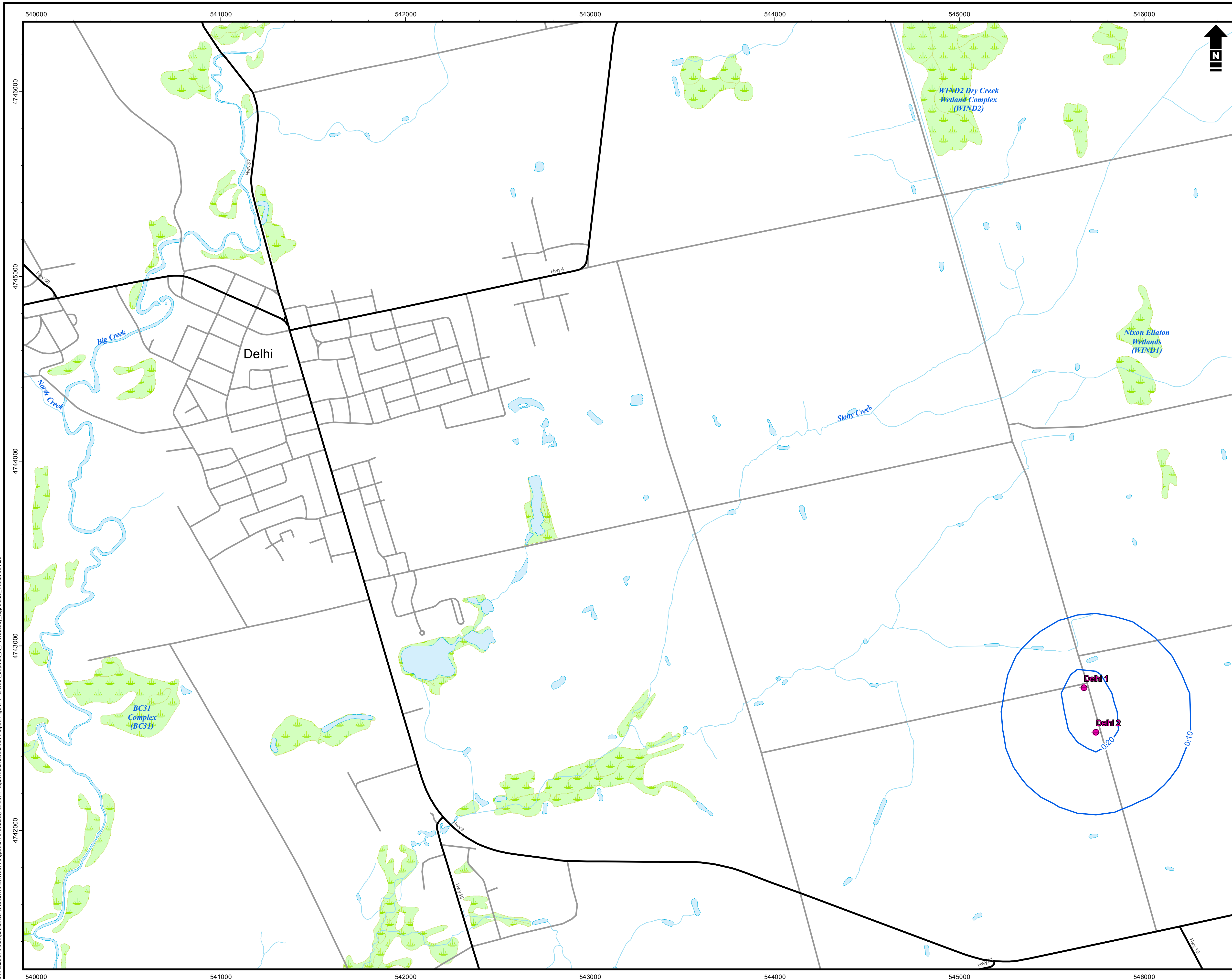
Figure
4.11



Provincially Significant Wetland
Water Body
Watercourse
Water Table Drawdown (m) : Scenario C - Scenario G(2)
Highway
Road
Municipal Well / Intake

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Delhi - Impacts to Provincially Significant Wetlands

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Figure 4.12

\\matrix-solutions.com\public\Gis\GrandRiverCA\15077\FiguresAndTables\GIS\2014\Report\RiskAssessmentReport\Figure-4-12-Delhi_Impacts_to_Provincially_Significant_Wetlands.mxd

4.6 Local Area Risk Assessment Results

The Local Areas for the Towns of Waterford, Simcoe, and Delhi are illustrated on **Figures 4.4**, **4.5,** and **4.6**. The Water Quantity Risk Level was assigned to the Local Areas based on the ability to meet peak demand ("Tolerance") as well as the results of the scenarios listed above (Risk Level).

4.6.1 Tolerance

Municipalities typically implement physical solutions (e.g., storage reservoirs and peaking / backup wells) and water conservation measures to reduce the amount of instantaneous water demand required from a primary drinking water source. These types of measures are implemented to increase a municipality's "Tolerance" to short-term water shortages. Tolerance effectively reduces the potential that a municipality will face short- or long-term water quantity shortages. A municipality's existing water supply system may be designed such that the wells or intakes alone cannot meet peak water demands, but existing storage systems are in place for this purpose.

The *Technical Rules* (Part IX.1) specify that if the municipality's system is able to meet existing peak demands, the Tolerance level for the existing system is assigned as High; otherwise, the Tolerance is Low. Since the municipal water supply systems of Simcoe, Waterford, and Delhi have never experienced water shortage issues, have a redundancy of supply with pairs of wells in each town and an intake in Delhi with a capacity that exceeds demand, and have existing storage systems in place to meet peak demand (e.g., a water standpipe in Simcoe, Delhi, and Waterford), the Tolerance of the systems is High.

4.6.2 Risk Level

As discussed in Section 4.3, Risk Level is assigned based on whether a set of circumstances are met within each evaluated Scenario. The circumstances are repeated below:

Circumstances of Significant Risk:

- Scenarios A or C – The municipal intake or well is not able to withdraw the Existing quantity of water.
- Scenarios B or D – The municipal intake or well is not able to withdraw the Existing quantity of water under drought conditions.
- Scenarios E(1), E(2), E(3) or G(1), G(2), G(3) – The municipal intake or well is not able to withdraw the Allocated Quantity of Water.
- Scenarios F(1), F(2), F(3) or H(1), H(2), H(3) – The municipal intake or well is not able to withdraw the Allocated Quantity of Water under drought conditions.

Circumstance of a Moderate Risk:

- Scenarios E(2) or G(2) – The municipal intake or well is able to withdraw the Allocated Quantity of Water, but results in either of the following impacts to other uses:

    - A reduction to flows or level of water that creates a measurable and potentially unacceptable impact based on professional judgement and the context of the specific use. (i.e., in this study the maintenance of downstream flow from the Lehman Reservoir).

    - For an aquatic habitat classified as a coldwater stream, there is a reduction in groundwater discharge to that area in an amount greater than 10%.

In addition to those circumstances, should the Tolerance of the drinking water system be found to be Low, a Risk Level of “Significant” is assigned to the Local Area.

For the surface water intake at Delhi, all surface water risk scenarios result in water level decline estimates that can be accommodated within the available amount of decline for the Lehman Reservoir (**Table 4.4**). Further, simulated water levels do not decline below the reservoir overflow structure under Scenario E(2). Therefore, downstream flow will be maintained and water uses are not predicted to be impacted. Based on these results, a Low Risk Level was assigned to Local Area F (**Figure 4.6**).

For the groundwater wells in Simcoe, Waterford, and Delhi, the simulated drawdown exceeds the amount of SAAD at Cedar St. Wells 2A, 3, 4, and 5 for all groundwater risk scenarios. Drawdown at all other wells in Simcoe, Waterford, and Delhi is predicted to be within the SAAD for each scenario. As a result, a Significant Risk Level was assigned to Local Area A.

Impacts to streamflow, as a result of the Allocated rate increase at municipal wells, are presented in **Table 4.6**. The maximum decrease in baseflow is 21% at the Kent Creek 2 reach due to pumping from the Cedar St. Well Field. This is the only stream reach that exceeded the 10% threshold (MOE 2013), and as a result, a Moderate Risk would be applied to Local Area A.

Impacts to PSWs, as a result of Allocated rate increases, are presented on **Figures 4.10**, **4.11,** and **4.12**. The maximum water table decline occurs beneath the Kent Creek Complex and is predicted to be less than 0.60 m. As this predicted drawdown coincides with a 21% reduction in baseflow in Kent Creek, there is the potential for wetland function to be affected; therefore, a Moderate Risk would be applied to Local Area A. The function of all other PSWs is predicted to be maintained with simulated drawdown under 0.30 m and less than 10% change in baseflow.

While a Moderate Risk Level would be assigned to Local Area A based on simulated impacts to baseflow and PSWs, a Risk Level of Significant, based on the magnitude of simulated drawdown, supersedes that. Therefore, Local Area A was assigned a Significant Risk Level and a Low Risk Level was assigned to Local Areas B, C, D, E, and F (**Figures 4.4**, **4.5,** and **4.6**).

4.7 Uncertainty Assessment of Risk Level Assignment

The structure, input parameters, and calibration of the groundwater and integrated flow models applied in the Risk Assessment are documented in **Appendix B**. The representation of the groundwater and surface water flow systems was calibrated to available hydrogeologic and hydrologic data using a set of parameters (e.g., recharge and hydraulic conductivity) that are consistent with the conceptual model. While the numerical models are considered appropriate for the Tier Three Assessment, it is useful to assess the certainty of the Risk Level assignments based on a number of factors observed throughout the completion of this Tier Three Assessment. For Waterford and Delhi, these factors include:

- High capacity – While demands are expected to increase by 38% in Waterford and 16% in Delhi/Courtland, water use trends suggest that the current capacity of the wells (i.e., represented by the amount of SAAD) is sufficient (3.5 m or greater) to meet future growth projections.

- Flexibility of the water supply systems – The water supply systems of Waterford and Delhi are such that if increased demand caused an undesirable amount of drawdown in a municipal well, or if the surface water intake in Delhi had to be taken offline, the operator has sufficient flexibility to re-proportion the increased demand to one or more of the remaining wells. This ability to optimize the performance of the water supply system is already occurring in these municipalities (e.g., when a well is turned off for maintenance or rehabilitation) and is expected to continue.

- Proximity to water bodies – Wells associated with Waterford and the Simcoe Northwest Well field are located immediately adjacent to large ponds. Due to the size of the ponds, as well as the fact that they are well connected to the water supply aquifer, the ponds are able to effectively mitigate water level drawdown caused by the municipal wells and other water takings. This results in a reliable water level within the municipal production wells, and a high certainty that the wells will be able to produce the Allocated Quantity of Water.

These factors contribute to a High level of confidence in the Low Risk Level that was assigned to Local Areas B, C, D, E, and F.

For Local Area A surrounding the Cedar St. and Chapel Well fields, the following factors contribute to the High level of confidence in the Significant Risk Level assignment:

- Low capacity – Demands in Simcoe are expected to increase by 12% due to future development and Cedar St. Wells 2A, 3, 4 and 5 do not have any available drawdown under current conditions to accommodate additional demand. This is supported by operator observations of water levels in wells drawing down into the well screens.

- Water sources at risk – The Town of Simcoe is facing water quality issues with wells in the Northwest Well Field, which may force the decommissioning of some wells. Further, the Cedar St. infiltration gallery may be decommissioned in the future due to its age and potential to be impacted by shallow contamination. The loss of this water supply may limit the future ability of operators to re-allocate demand away from the Cedar St. Wells in times of increased demand.

5 WATER QUANTITY THREATS

As outlined in the *Technical Rules,* for Local Areas assigned a Significant or Moderate Risk Level, drinking water quantity threats that may limit the sustainability of the municipal water supply wells or intakes need to be identified. The definition of a drinking water quantity threat is the following:

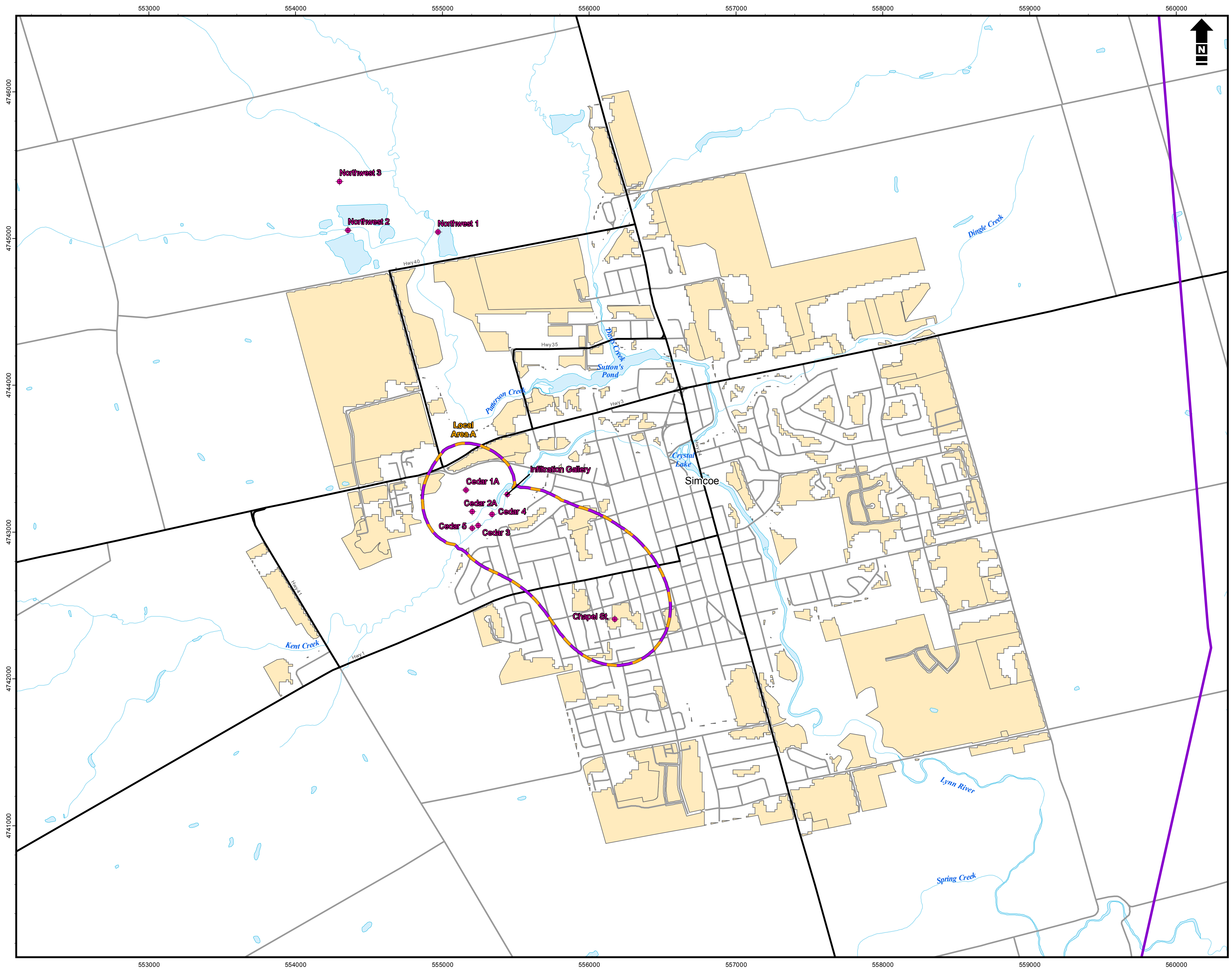
- an activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body (i.e., a consumptive demand)
- an activity that reduces the recharge to an aquifer.

    - Since Local Area A was assigned a Risk Level of Significant, all consumptive demands or areas of recharge reduction within this area are classified as Significant Water Quantity Threats.

5.1 Consumptive Water Demands

Figure 5.1 illustrates the consumptive water demands within Local Area A, which are classified as Significant Water Quantity Threats. This includes the municipal wells (1A, 2A, 3, 4, and 5) and infiltration gallery of the Cedar St. Well Field, as well as the Chapel St. Well. No other non-municipal permitted demands are found within Local Area A.

All non-permitted water uses, including rural domestic water uses, that lie within Local Area A are also classified as Significant Water Quantity Threats.



- Tier Three Study Focus Area
- Recharge Reduction Activities
- Water Body
- Watercourse
- Highway
- Road
- Local Area
- Municipal Well / Intake / Infiltration Gallery

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Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Water Quantity Threats - Local Area A

Date: 29 Apr 2015	Project: 15077-527

Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

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Figure 5.1

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5.2 Reductions in Groundwater Recharge

The *Technical Rules* specify that reductions in groundwater recharge are a potential water quantity threat within the Local Areas. The Tier Three Scenarios considered the impact of existing and future land development on groundwater recharge and the resulting impact on water levels in the municipal aquifer at the wells. All activities that have the potential to reduce groundwater recharge that are occurring in and around Local Area A are also classified as Significant Water Quantity Threats and are presented on **Figure 5.1**.

5.3 Significant Water Quantity Threat Enumeration

A summary of the number of Significant Water Quantity Threats from municipal and non-municipal permitted uses, lying within various management area categories (i.e., Local Area, Source Protection Area, and Municipal Area), is provided in **Table 5.1**. Seven threats from permitted municipal uses have been identified. Two Significant threats from non-municipal, non-permitted (e.g., domestic wells) uses are also enumerated in **Table 5.1**.

Significant threats represented by areas of reduced groundwater recharge are also summarized in **Table 5.1**. To avoid the subjective nature of grouping and counting individual polygons of land area, which may or may not be related, these threats are presented as the area of recharge reduction contained within the areas of interest. The recharge reduction areas cover 0.14 km^2 and represents less than 11% of the total area of Local Area A, less than 1% of the urban area of the Town of Simcoe, and a negligible amount of the total area of the Long Point Region Source Protection Area.

TABLE 5.1 Count of Significant Water Quantity Threats by Threat Group[1]

Threat Group	Local Area		Source Protection Area		Municipal Area	
	Local Area A		Long Point Region Source Protection Area		Town of Simcoe (Urban Area)	
Municipal	7		7		7	
Non-municipal Permitted	0		0		0	
Non-Municipal, Non-Permitted	2		2		2	
Recharge Reduction[2]	0.14 km^2 (10.6% of Local Area A)		0.14 km^2 (0.0% of Long Point Region Source Protection Area)		0.14 km^2 (0.9% of Urban Area of Town of Simcoe Area)	
Total[3]	Total number of Significant threats identified within all Local Areas of the Water Quantity Risk Assessment	9	Total number of Significant threats identified within all Source Protection Areas of the Water Quantity Risk Assessment	9	Total number of Significant threats identified within all Municipalities of the Water Quantity Risk Assessment	9

[1]This table does not include non-municipal, non-permitted uses other than water supply wells (e.g., test wells, remediation wells)
[2]Recharge reduction threats are summarized by identifying the total area represented by recharge reduction polygons and as a percentage of the total area of interest
[3]Total number of Significant threats does not include individual Recharge Reduction Polygons as those threats have been identified on a per-area basis.

6 TIER THREE WATER BUDGET

One component of the Tier Three Assessment is an improved estimate of the water budget components included in the hydrologic cycle. The calibrated groundwater and integrated surface water / groundwater flow models (**Appendix B**) developed for the Tier Three Assessment were used to estimate average annual values for the various components of the hydrologic cycle. While the MIKE SHE models and FEFLOW model were separate and independent models, the modelling was linked through the groundwater recharge component.

The combined results of the two water budget models produce an improved understanding of the hydrologic and hydrogeologic flow systems. The following sections outline and quantify the water budget components within the Local Areas.

6.1 Local Area Water Budget

Table 6.1 presents the water budget for the six Local Areas (Section 4.1.4) delineated in Simcoe (Local Areas A, B, and C), Waterford (Local Areas D and E), and Delhi (Local Areas E and F). The primary water budget components include precipitation and cross-boundary groundwater flow as inputs and ET, streamflow and pumping as outputs. In Local Area A (Simcoe Cedar St. and Chapel St. systems), 963 mm/year of precipitation falls and approximately 40% is removed from the system as ET. A higher proportion of precipitation is predicted to be lost due to ET for all other Local Areas (52% to 62%), likely as a result of a lower proportion of urbanization in these areas. In addition to ET, a significant amount of water is predicted to leave each Local Area via streamflow (171 to 3,552 mm/year) and pumping (34 to 1,065 mm/year). Other than precipitation, a significant source of water input includes subsurface flow into each Local Area (414 to 3,322 mm/year), except at Local Area F (Lehman Reservoir), where a net groundwater outflow of 66 mm/year occurs.

Some Local Areas have water budget component values that exceed precipitation (e.g. subsurface boundary flow for Local Areas B and C). Where this occurs, it is indicating that the Local Area is experiencing a large groundwater inflow. This water budget characteristic is a distinctive feature of the topographic and geological setting of the Local Area and these Local Areas represent a relatively small portion of a considerable larger flow system.

The water budget components that are relatively minor in each Local Area include the contribution of overland flow across the Local Area boundaries and the change in storage. A small net outflow is predicted in Local Areas A, C, E, and F, ranging from 1 to 47 mm/year. Conversely, a net overland boundary inflow is simulated for Local Area D and B (22 to 107 mm/year). The change in storage over the long-term is minimal (up to 1 mm/year).

The correct summation of the terms in the Local Area water budgets is provided as the following Water Budget Equation:

$$\Delta S = P + E + Q_{SO} + Q_{SB} + Q_P + Q_{BO} + Q_{BS} \qquad \textbf{Equation 5}$$

Where:
ΔS is the Storage change
P is Precipitation
E is Evapotranspiration
Q_{SO} is Overland flow to streams
Q_{SB} is Baseflow to streams (includes drain flow)
Q_P is Pumping
Q_BO is Overland boundary Flow
Q_{BS} is Subsurface boundary flow

TABLE 6.1 Water Budget – Local Areas

MIKE SHE Integrated Model - Average Annual Water Budget – 1960 to 2010 (mm/year)						
Water Budget Component	**Local Area A *(Cedar St. & Chapel St. Wells)***	**Local Area B *(NW 1 Well)***	**Local Area C *(NW 2 & 3 Wells)***	**Local Area D *(Waterford Wells)***	**Local Area E *(Delhi Wells)***	**Local Area F *(Lehman Reservoir)***
Precipitation	963	963	963	913	951	948
Evapotranspiration	-384	-517	-501	-565	-521	-527
Total Streamflow	-439	-3,553	-483	-518	-171	-320
(Overland Flow To Streams)	*-322*	*-2,801*	*-292*	*-505*	*-4*	*-50*
(Baseflow To Streams)	*-117*	*-752*	*-191*	*-13*	*-167*	*-270*
Pumping	-1,065	-323	-1,786	-543	-670	-34
Overland Boundary Flow	-4	107	-47	22	-3	-1
Subsurface Boundary Flow	930	3,322	1,853	691	414	-66
Storage Change	1	-1	-1	0	0	0

Note: negative values indicate a net loss of water out of the water budget domain and positive values indicate a net gain of water into the water budget domain

7 SIGNIFICANT GROUNDWATER RECHARGE AREAS

The *Technical Rules* and *Delineation of Significant Groundwater Recharge Areas: Supplemental Technical Guide* (AquaResource 2012) require that SGRAs be delineated for each Source Protection Area. The role of SGRAs is to support the protection of drinking water across the broader landscape. SGRAs delineated using the water budget tools are one of four types of vulnerable areas that are used in water quality vulnerability assessments; the other vulnerable areas are wellhead protection areas, intake protection zones, and highly vulnerable aquifers.

Recharge is the hydrogeologic process described by the flow of water moving from the ground surface through the unsaturated zone to the underlying saturated groundwater zone. Groundwater recharge occurs across a watershed at a range of rates depending on precipitation, ET, land use and vegetation, surficial soil type (geology), and physiography, but does not occur in areas of groundwater discharge. As described in **Appendix B**, within the Tier Three Focus Area, the MIKE SHE integrated model was developed using these components, calibrated to observed streamflow conditions, and applied to estimate groundwater recharge. A map of MIKE SHE estimated groundwater recharge rates is included in **Appendix B** (**Figure 3-45**).

SGRAs have previously been defined as part of the Long Point Region, Catfish Creek, and Kettle Creek Tier Two Water Quantity Stress Assessment (AquaResource 2009b). The *Technical Rules* and Provincial SGRA Guidance (AquaResource 2012) require that the SGRA mapping be updated at each successive tier of study. As such, the following chapter discusses how SGRAs were delineated using recharge rates estimated through the Tier Three regional MIKE SHE model.

7.1 Methods Used to Delineate Significant Groundwater Recharge Areas

The *Technical Rules* provide the following instructions for the delineation of SGRAs:

> ***Part V.2 - Delineation of significant groundwater recharge areas***
> *44. Subject to rule 45, an area is a significant groundwater recharge area if,*
>
> *(1) the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or*
>
> *(2) the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.*
>
> *45. Despite rule 44, an area shall not be delineated as a significant groundwater recharge area unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system.*
>
> *46. The areas described in rule 44 shall be delineated using the models developed for the purposes of Part III of these rules and with consideration of the topography, surficial geology, and how land cover affects groundwater and surface water.*

The Tier Two Assessment (AquaResource 2009b) used Rule 44(1) to define the thresholds for SGRAs for each of the three Conservation Authorities. For the Tier Two Study, the "related groundwater recharge area" identified in Rule 44(1) was taken as the entire conservation authority areas. This was consistent with guidance, which recommends that the assessment is performed at the watershed scale (AquaResource 2012). The average annual recharge rates for each conservation authority area were calculated and multiplied by 1.15 to arrive at the SGRA thresholds. These are summarized in Table 6.2

TABLE 6.2 Significant Groundwater Recharge Area Thresholds

Conservation Authority	Average Annual Recharge Rate (AARR) (mm/year)	Threshold Recharge Rate (AARR * 115%) (mm/year)
Long Point Region	224	257
Catfish Creek	157	180
Kettle Creek	143	164

Provincial guidance indicates that when the Tier Three study only considers a portion of the previous study's domain, SGRA thresholds from the previous study, and the updated groundwater recharge rates from the Tier Three study should be used to refine the SGRA mapping (AquaResource 2012). The Tier Three Focus Area does not include the Norfolk Clay Plain in the east of the Long Point Region Conservation Authority. This area of low recharge was included in the calculation of the SGRA threshold in the Tier Two as it is part of the "related groundwater recharge area." In order to maintain consistency with calculating SGRA thresholds on a conservation authority area basis, this Tier Three Assessment used the same thresholds established in the Tier Two Assessment to delineate SGRAs within the Tier Three Focus Area. Outside of the Focus Area, the SGRAs delineated in the Tier Two Study were retained and these were combined with the current results.

Areas within each conservation authority with recharge rates higher than the calculated threshold were identified as an SGRA. Also, similar to the Tier Two delineation (AquaResource 2009b), a filter was applied to remove small, isolated SGRAs, as well as infill small, non-SGRA areas that were fully contained within a larger SGRA polygon. As in the Tier Two delineation (AquaResource 2009b), SGRA polygons that were less than 1 km^2 were removed from the final map, while gaps that were less than 1 km^2 and within SGRA polygons were infilled and assigned as an SGRA. Any areas that were mapped as sand or gravel by the Ontario Geological Survey (OGS 2003) were not removed in this process.

7.2 Significant Groundwater Recharge Area Delineation Results

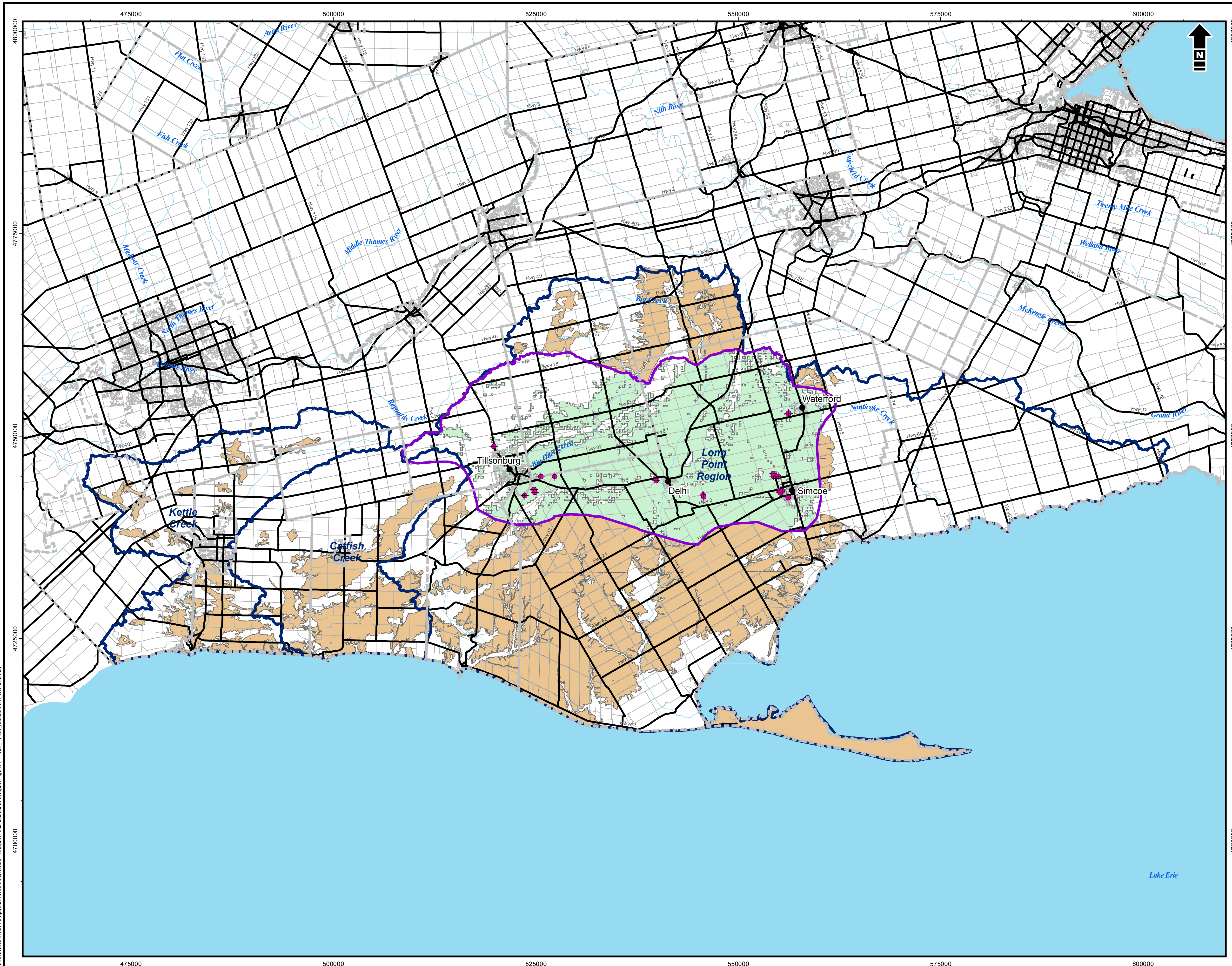
Groundwater recharge rates within the Tier Three Focus Area range from a median of 82 mm/year on the Port Stanley Drift, which is a silty to clayey till (22% of the Focus Area), to 411 mm/year on the fine sand of the Norfolk Sand Plain (62% of the area). Due to the Focus Area comprising mostly of the sand plain, the average groundwater recharge rate for the Focus Area was 310 mm/year. Discussion and comparison of the recharge rates determined in the Tier Two and Tier Three assessments is found in **Appendix B** (Section 3.10).

The Tier Two SGRA thresholds were applied to the Tier Three MIKE SHE predicted groundwater recharge distribution and the results were filtered as previously described. The combined Tier Three (inside the Focus Area) and Tier Two (outside the Focus Area) SGRAs are presented on **Figure 7.1**.

Within the Focus Area, the SGRAs mainly coincide with the fine sand of the Norfolk Sand Plain, and this is similar to the previous Tier Two results. The Tier Three refinement added four main areas to the Tier Two SGRAs: the sand plain to west of Waterford (the western half of the Nanticoke Upper Subwatershed) and areas of sand within the Town borders of Tillsonburg, Delhi, and Simcoe. Two main differences in the modelling approaches can explain these additions.

The Tier Two modelling results (AquaResource 2009a) found that watersheds primarily composed of sandy soils had higher simulated ET rates than clay or silt-dominated watersheds. This discrepancy was identified as an uncertainty that warranted additional future investigation. The Tier Three results indicate that the soil water parameters used in the Tier Two Model may not have accurately represented the reduced soil water characteristics of pervious soil types.

The second factor that introduced a discrepancy between the Tier Two and Tier Three groundwater recharge estimates is the treatment of overland runoff. In MIKE SHE, if overland runoff is generated on an individual cell, and flows onto a neighbouring cell, that water is made available for infiltration within the neighbouring cell. Factors such as land slope, surface roughness, soil water content, and infiltration potential, will determine the proportion of overland runoff that is infiltrated into downgradient cells. This is in contrast to the GAWSER model (used in the Tier Two Study), where once overland runoff is generated from a land segment, the model assumes that overland runoff will reach a watercourse. In watersheds with low topographic relief and that are highly pervious, models that assume all overland runoff will reach a watercourse likely overestimate overland runoff, and as a consequence, underestimate infiltration and groundwater recharge. This was a factor in the Tier Two modelling of recharge in the urban areas of Tillsonburg, Delhi, and Simcoe that would have been defined as areas with higher overland runoff due to increased imperviousness.



- Tier Three Study Focus Area
- Conservation Authority Boundary Watershed Boundary
- Tier 3 SGRAs
- Tier 2 SGRAs
- Municipality
- Water Body
- Highway
- Road
- Municipal Well / Intake / Infiltration Gallery
- Municipal System

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Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Long Point Region Tier Three Water Budget and Local Area Risk Assessment

Tier Three Assessment SGRAs

Date: 29 Apr 2015	Project: 15077-527

Technical: J. Melchin	Reviewer: S. Bellamy	Drawn: R. Laird

Disclaimer: Prepared solely for the use of Lake Erie Source Protection Region as specified in the accompanying report. No representation of any kind is made to other parties with which Lake Erie Source Protection Region has not entered into contract.

Figure 7.1

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8 CONCLUSIONS

The Province of Ontario introduced the *Clean Water Act* (Bill 43; MOE 2006) to ensure that all residents have access to safe drinking water. Under the *Clean Water Act*, Source Protection Regions are required to conduct technical studies to identify existing and potential water quality and quantity threats to municipal drinking water. Through the development of community-based Source Water Protection Plans actions will be implemented to reduce or eliminate any Significant Drinking Water Threats.

Under the requirements of the *Clean Water Act*, municipalities may be required to complete a Tier Three Assessment to assess the ability of the municipal water sources to meet Committed and Planned water demands. Municipalities that are predicted to be unable to meet their Allocated demands will be required to identify the Significant threats that may prevent them from meeting their Allocated demands.

This report details the Tier Three Assessment carried out for the Towns of Waterford, Simcoe, and Delhi. The report summarizes background information relating to the geology, hydrology, and hydrogeology of the area, water demands, and the process and results of the Local Area Risk Assessment. Companion reports (**Appendices A** and **B)** summarize the development of the conceptual and numerical hydrogeologic and integrated models used to complete this Tier Three Assessment.

8.1 Summary of the Water Budget Tools and Results

The Tier Two Assessment completed for Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities (AquaResource 2009b) identified the North Creek, Big Above Minnow Creek, Nanticoke Upper, Lynn River, and Otter at Tillsonburg subwatersheds as having a Significant or Moderate potential for groundwater or surface water stress. This identification of stress potential led to the requirement of a Tier Three Assessment for the municipal supply wells of the Towns of Tillsonburg, Waterford, Simcoe, and Delhi. To date, none of these systems have had any issues meeting their water quantity requirements. Due to the uncertainty of the assignment of a Moderate potential for stress to Otter at Tillsonburg, the subwatershed stress assessment was re-examined as part of this current study using the refined groundwater flow model. The updated results of that assessment led to the assignment of a Low potential for stress for the Otter at Tillsonburg subwatershed resulting in the removal of the Town of Tillsonburg from the Tier Three Assessment.

The Tier Three Risk Assessment involved a detailed review and representation of the physical system within the area of Simcoe, Waterford, and Delhi in Norfolk County. The conceptual model used within the Tier Three Assessment was refined and enhanced from an earlier conceptualization from the Tier Two Assessment.

A regional groundwater flow model that was previously developed for the Study Area in the Tier Two Assessment using FEFLOW was updated and refined in the Tier Three Focus Area. This approach provides an efficient method for calibration and parameterization of groundwater flow in the Focus

Area. Refinement was focused around municipal pumping wells to assess groundwater flow and the potentiometric surface impacts at a well field scale around the Delhi municipal wells. The groundwater flow model was calibrated to a fine level of detail with close attention to the following:

- observed water levels at both a local (municipal well field scale) and regional (regional groundwater model domain) scale
- stream baseflow estimates
- recharge estimates from the regional integrated MIKE SHE model
- municipal pumping and high quality water level observations

The Tier Three model was calibrated at the municipal well field-scale to both steady-state (long-term average) and transient (time-varying) conditions.

One regional and four local-scale MIKE SHE integrated surface water and groundwater models were developed for this assessment to simulate the regional flow system and simulate well field-scale hydrologic and hydrogeologic features, respectively. Model calibration involved the use of data from eight WSC stream gauges in the Study Area. Model parameters and boundary conditions from the regional model were provided to the local-scale models so that Risk Assessment simulations could be performed in the area of the Lehman Reservoir intake, as well as the municipal supply wells of Waterford and Simcoe. The groundwater supplies in these areas were interpreted to be more directly hydraulically connected to surface water features and therefore, use of integrated models was considered more appropriate in these areas.

As the groundwater and integrated models were satisfactorily calibrated to observed, steady-state, and transient water levels and stream flows, they were considered to be reliable tools for water budget estimation.

8.2 Local Area Risk Assessment Summary

Six Local Areas (Local Areas A, B, C, D, E, and F) were delineated surrounding the municipal intake and supply wells in the Focus Area (**Figures 4.4**, **4.5**, and **4.6**). The areas were delineated following the *Technical Rules* and MOE Guidance (MOE 2014) based on a combination of the cone of influence of each municipal well, land areas where recharge has the potential to have a measurable impact on the municipal wells, the surficial drainage areas, which may contribute water to surface water intakes and the surface water bodies that contribute significant recharge to municipal wells.

A set of Risk Assessment Scenarios, consistent with the *Technical Rules,* was developed to represent the municipal Allocated Quantity of Water (Existing plus Committed pumping rates), and current and future land uses. The calibrated groundwater and local-scale, integrated flow models were used to estimate the changes in water levels in the Lehman Reservoir and in the municipal supply aquifers under average and drought conditions. Impacts to other water uses under average climate conditions were evaluated with the groundwater model through the assessment of impacts to groundwater discharge and water table decline beneath PSWs. In the MIKE SHE model, impacts to other water uses were evaluated by assessing streamflow impacts downstream of the Lehman Reservoir overflow structure.

The estimates of drawdown in all scenarios were based on the assumption that wells are maintained in their current conditions to ensure constant well performance with no deterioration over time. The results from the Risk Assessment Scenarios are only valid if this level of maintenance is continued.

The Risk Assessment Scenarios predicted that there was a Low Risk Level associated with the operation of the Lehman intake and wells in Waterford, Delhi, and Northwest, and Chapel St. wells in Simcoe. However, there was a Moderate Risk Level in the Cedar St. Well Field (Local Area A) due to simulated impacts to baseflow and a PSW near Kent Creek and the Cedar St. Well Field. This Risk Level was upgraded to a Significant Risk due to simulated drawdown exceeding the amount of SAAD in Wells 2A, 3, 4, and 5 of the Cedar St. Well Field under all groundwater risk scenarios.

The confidence associated with the Low Risk Level in Local Areas B, C, D, E, and F is considered High for the Simcoe Northwest, Waterford, and Delhi water supply systems, because of the relatively high capacity of the systems to accept additional demand. Further, there is flexibility in the water supply systems for operators to increase pumping at wells with an abundance of SAAD to offset demands on wells with declining performance, or wells with low amounts of SAAD.

The confidence associated with the Significant Risk Level of Local Area A is also considered High due to the lack of capacity of Cedar St. Wells 2A, 3, 4, and 5 and the fact that water quality issues at other wells and age of infiltration gallery infrastructure may limit the ability of operators to re-allocate the demand to other wells during times of high use.

8.3 Conclusions

Based on the results of the Risk Assessment modelling scenarios, Local Area A was assigned a Significant Risk Level, with High certainty, while Local Area B, C, D, E, and F were assigned a Low Risk Level with High certainty.

Following the *Technical Rules*, all consumptive water users and potential reductions to groundwater recharge within Local Area A were classified as Significant Water Quantity Threats. These consumptive water users include the permitted water demands (e.g., municipal pumping) and non-permitted water demands (e.g., domestic water wells).

8.4 Recommendations

The following recommendations are made based on results of this Tier Three Assessment:

- Maintain and enhance monitoring programs:

    - Monitoring and reporting programs associated with PTTWs are already in place and should be continued. Continuously recorded groundwater levels from monitors throughout each town and production wells would be beneficial in better understanding the seasonal and inter-annual variability of the groundwater flow system, as well as the influence of surface water features on production aquifers.

    - Flow gauging and other assessments of key surface water features near the Cedar St. Well Field should be maintained to monitor potential baseflow reduction and wetland impacts during times of high demand. In particular, two continuous stream gauging stations of Kent Creek upstream and downstream of the well field should be maintained. These data could be used to better characterize the stream and its interaction with PSWs and the groundwater flow system.

    - Ongoing collection of climate data will be vital for developing future water budgets. It is recommended that the existing climate monitoring network be maintained and enhanced as resources allow. As modelling software and computing power improves, more detailed, local-scale transient analysis will be possible and will benefit from local-scale climate data.

- Update Risk Assessment, as needed:

    - In the event that new water takings are proposed within a delineated Local Area, the Tier Three Risk Assessment should be updated to determine the impact of the proposed water taking on municipal water supply reliability and possible changes to the level of risk.

- Rehabilitate and maintain wells routinely:

    - As noted in Section 8.2, the Risk Assessment Scenarios analyzed well drawdown assuming constant well performance. As drawdown in the municipal wells and the ability of the wells to pump at their Allocated rates is a key metric determining the level of risk assigned to a Local Area, any increase in drawdown due to declining well performance must be mitigated to ensure the validity of the Risk Assessment results. Issues with declining well performance have been addressed in the past with routine rehabilitation efforts and it is recommended that the towns continue their efforts to this end.

- Maintain and enhance water conservation programs:

    - Current water conservation programs should be maintained to ensure that per-capita water demand does not increase and to encourage decreases. Opportunities to reduce water demand within the towns should be considered. Any reduction in the per capita water use will enhance water supply reliability and local ecosystem health.

- Update water budget models:
  - The Lake Erie Source Protection Region maintains water budget modelling tools to help manage and protect the water resources across the watersheds. Hydrogeologic, hydrologic, and operational insights gained from this Tier Three Assessment should be incorporated into the models maintained by the Lake Erie Source Protection Region. These modelling tools should be updated periodically as new information is gathered and insights evolve within the watersheds.
- Assessment of Cedar St. Well Field:
  - Ongoing assessment of conditions at the Cedar St. Well Field, including any well performance testing, should be supported by focused modelling analyses. The model should be verified against the results of these studies and the model updated as required.

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