CREDIT VALLEY CONSERVATION

LAKE ONTARIO INTEGRATED SHORELINE STRATEGY BACKGROUND REVIEW AND DATA GAP ANALYSIS

APPENDIX F
Hydrogeology
Final Report

Prepared By:

Credit Valley Conservation

September 12, 2011

TABLE OF CONTENTS

List of Figures

1 INTRODUCTION

Groundwater flow systems are largely controlled by topographic relief and the permeability of the subsurface geologic materials. Assuming at least minimal permeability of surficial sediments, some precipitation (more where surficial sediments have higher permeability) will infiltrate to the water table and flow within the groundwater system. Groundwater flows both laterally and vertically depending on soil and bedrock permeability and the presence of surface water features, which can either add or remove water from the groundwater system. In areas where streams intersect the water table, groundwater typically discharges to the stream or river and contribute baseflow to the surface water feature.

The primary ground water function within the Lake Ontario Integrated Shoreline Strategy (LOISS) Study Area is assumed to be supportive of surface water features and aquatic habitat, and contributions to stream baseflow in particular. Groundwater discharge to streams helps to maintain flow even during prolonged dry periods, and thereby contribute to aquatic habitat. As groundwater is generally of better quality than surface runoff, and is also a more consistent temperature, groundwater also adds to the overall quality of stream flow as well.

Groundwater discharge to streams, and groundwater flow in general, are controlled by: topography; permeability of the subsurface media; and the hydraulic gradient of flow. Where groundwater moves through a low permeability medium, such as competent (i.e., unfractured) bedrock or clay, then the volume and rate of groundwater movement is very slow, and the potential for groundwater discharge to surface water features is correspondingly low. Where groundwater moves through a high permeability medium, such as sand or highly fractured bedrock, the rate of groundwater movement can be very high, with a similarly high potential for discharge to surface water features.

Considering the factors described above that govern groundwater flow and discharge to surface water features, there would appear to be a potential for groundwater discharge to streams to occur across much of the LOISS Study Area. There would likely be two different settings within the Study Area where significant groundwater discharge to surface water features could occur: to streams that overly the glaciolacustrine sand deposit associated with the historical Lake Iroquois shoreline; and to the main Credit River where it intersects the Acton-Mississauga buried bedrock valley feature in the northern portion of the Study Area. These conditions are further described below.

2 BACKGROUND

The following sources of information were reviewed to prepare this section of the Background Report.

***Integrated Water Budget Report – Tier 2 Credit River Source Protection Area* (AquaResource, 2009) (referred to as the *Tier 2 Report* in this section):**

The CVC's water budget modelling framework – primarily CVC's groundwater (FEFLOW) and surface water (HSP-F) flow models - was updated as part of a water quantity risk assessment, which was one of several studies in the watershed required by Ontario's Clean Water Act. A key component of this effort was the development of a watershed-based water budget, which documents and accounts for the movement of surface water and groundwater, and the demands placed on the water resources.

Some of the tasks completed for the *Tier 2 Report* are summarized below:

- Estimated consumptive surface water and groundwater use within the watershed;
- Refined and Calibrated Water Budget Models. Refine the CVC's existing numerical models including HSP-F (Hydrological Simulation Program–FORTRAN; surface water) and FEFLOW (groundwater) to improve the simulation and representation of long-term hydrologic processes; and
- Integrated Water Budget. Using the calibrated surface models, develop and present a subwatershed-based water budget including key hydrologic parameters; groundwater recharge, groundwater discharge, municipal pumping, and lateral flow into and out of subwatersheds.

The *Tier 2 Report* focuses on a watershed-scale assessment of groundwater flow conditions, and the results from the *Tier 2 Report* that are presented in this section should be viewed as such. While the *Tier 2 Report* results do give a sense of how the study are fits into the watershed-scale groundwater flow system, a more refined and local-scale assessment of conditions should be conducted through the later phases of this study.

For the LOISS, the *Tier 2 Report* provided most of the information about the geological and hydrogeological conditions and the figures included in this section. The *Tier 2 Report* should be consulted for a detailed description of the numerical and water budget development process.

Groundwater Resources of the Credit River (Davies and Holysh, 2007):

Under the Province of Ontario's Clean Water Strategy, the Ontario Geological Survey (OGS) of the Ministry of Northern Development and Mines (MNDM) established a program of groundwater mapping to delineate and characterize the major groundwater aquifers in southern Ontario. The program is intended to generate geological and hydrogeological information in support of initiatives such as watershed management, land use planning and source water protection. One of the projects under this program is the generation of a series of watershed-based Groundwater Resources Studies (GRSs), including this study of the Credit River watershed.

For the Davies and Holysh study, geological, hydrogeological, and stream flow data were reviewed and geological and hydrogeological conceptual models for the Credit River were developed. Particular attention was paid to the geological model, including refinement of the buried bedrock valley system that occurs throughout much of the watershed, including the Acton-Mississauga valley that transects the LOISS Study Area from north to south.

For this section of the LOISS Background Report, the Davies and Holysh study was used for details of deeper sedimentary deposits and details of the buried bedrock valley that transects the Study Area from north to south.

York Peel Durham Toronto – Conservation Authorities Moraine Coalition (YPDT-CAMC) Database:
The geological and hydrogeological database was developed by the York-Peel-Durham-Toronto (YPDT) coalition and the Conservation Authorities Moraine Coalition (CAMC). The YPDT database contains most water well records and additional exploration and geotechnical borings within the Credit River Watershed. These data include updates from the Ministry of the Environment (MOE) Water Well Record database, municipal supply wells, and geotechnical wells. The YPDT database is the main data source for the both the CVC *Tier 2 Report* and the Davies and Holysh report.

Currently, the database incorporates:

- 135,000 water well records from the MOE's Water Well Record database
- 49,000,000 water-level measurements
- 810,000 geological descriptions
- 45,000 consultant-drilled geotechnical and monitoring wells
- 2000 surface-water monitoring stations and 8,000,000 flow measurements
- 200 municipal supply wells, with 290,000 pumping rate measurements
- 520 climate stations, with 3,000,000 meteorological readings

(http://www.ypdt-camc.ca/Home/tabid/171/Default.aspx)

Sheridan Creek and Cooksville Creek Characterization Reports (CVC, 2010):
CVC has completed the Characterization Reports for subwatershed studies for both the Cooksville Creek and Sheridan Creek systems, including an assessment of hydrogeological conditions. The hydrogeological assessment for the Cooksville and Sheridan studies included an assessment of:

- Geology (including drilling several boreholes in each of the subwatersheds);
- Groundwater discharge to surface water features (including installation and monitoring of shallow piezometers in and around wetlands and collection of spot low flow measurements); and
- Collection of groundwater samples to assess water quality.

In addition, the field measurements of stream baseflows collected by other disciplines for the LOISS were reviewed and compared to results available from the studies described above.

Technical Assessment - Water Well Records

Figure 1 presents the locations of MOE Water Well Records and CVC groundwater monitoring wells within the Study Area and surrounding area up to Highway 403. MOE water well records are the most abundant source of geological and groundwater level information in the Credit River watershed. For the past several decades, whenever a water well record was drilled a driller's record of the geological deposits and depth to static groundwater level was submitted to MOE. The locations of both bedrock and overburden wells are shown. Review of Figure 1 indicates that there are few MOE water well records and CVC monitoring wells within the Study Area. Considering the current and/or historical reliance on the lake and Credit River for water supplies in this part of the watershed, it is not surprising that there are relatively few MOE water well records compared to other parts of the watershed where groundwater is a more significant source of water supply.

Higher quality well records, such as municipal wells or Provincial Groundwater Monitoring Network (PGMN) wells offer higher quality data and reliability. CVC installed several monitoring wells for the Cooksville and Sheridan studies, although only one well in each of the subwatersheds is located within the Study Area. The CVC monitoring wells installed within the Study Area generally confirm the mapping of bedrock and overburden units presented in Figures 2 and 7, respectively.

As discussed later in this section, bedrock is at or near ground surface across much of the Study Area, and therefore MOE water well records for bedrock wells are more common within the Study Area. Overburden wells may be more prevalent where the Iroquois glaciolacustrine sand deposit is present, and where the Acton-Mississauga buried bedrock valley is interpreted to be present.

Geology

Figure 2 is taken from the *Tier 2 Report* and presents the bedrock geology in the vicinity of the Study Area. The bedrock mapping indicates that the two uppermost bedrock formations in the vicinity of the Study Area are the Queenston and Georgian Bay Shale Formations. The Georgian Bay Formation
underlies the entire Study Area, while the Queenston Formation underlies the area to the northwest of the Study Area, overlying the Georgian Bay Formation.

Georgian Bay Formation:

The Georgian Bay Formation is the oldest bedrock formation to occur near ground surface within the Credit River watershed. The Georgian Bay Formation was deposited in a deep water marine environment, and typically occurs as a grey shale with fracturing limited to the upper few metres of the Formation. The Georgian Bay Formation is not considered to be an aquifer within the Credit River watershed, and it is expected that only minimal groundwater flow and/or groundwater discharge would occur through the

Formation, although some localized groundwater discharge may occur where the Formation is significantly fractured near ground surface.

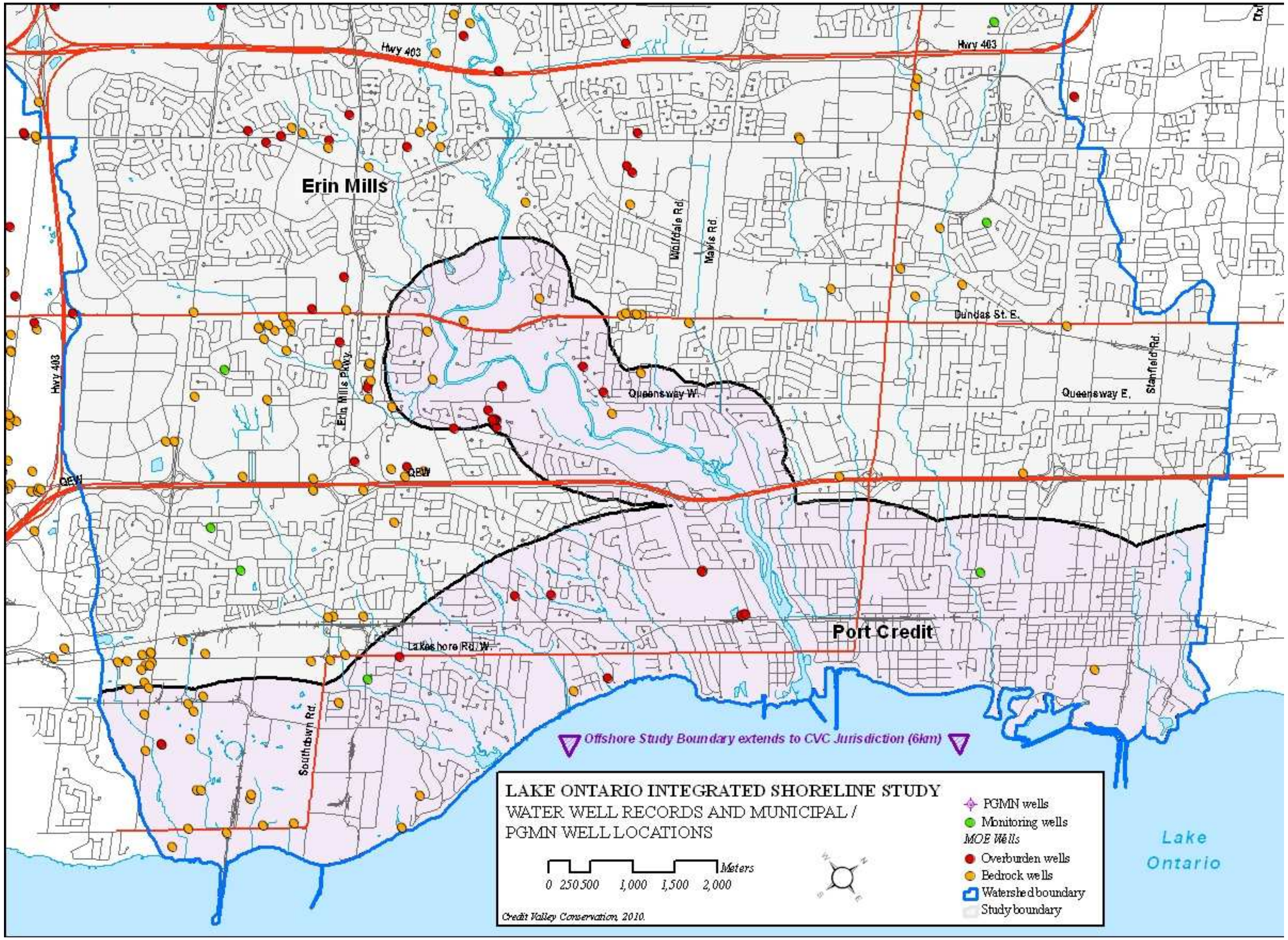


Figure 1: Water Well Records and Municipal PGMN Well Locations

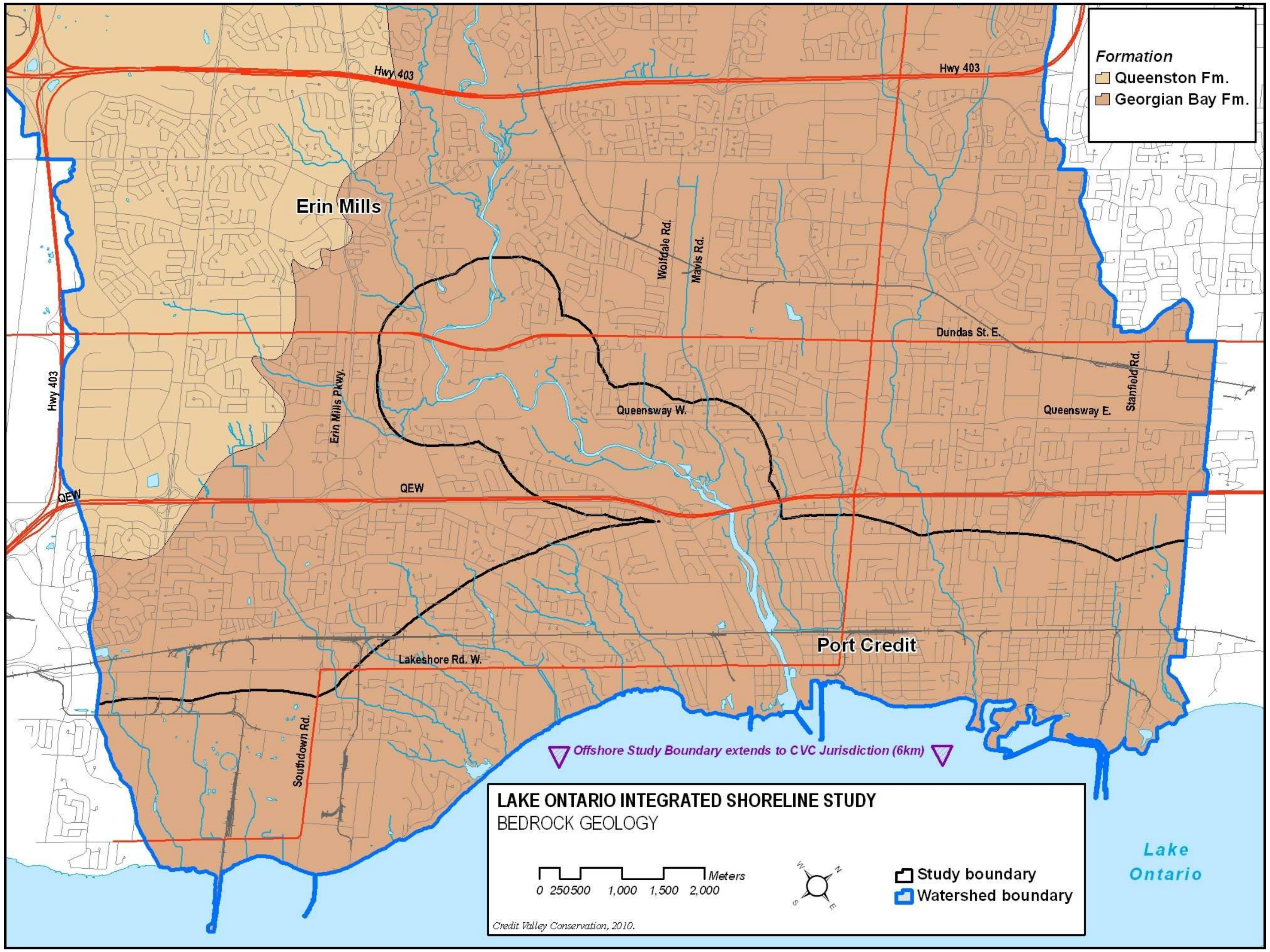


Figure 2: Bedrock Geology

Queenston Formation: Further north in the Credit River watershed, the Queenston Formation underlies the younger bedrock formations that make up the Niagara Escarpment. The Queenston Formation is a red shale that reaches a maximum thickness below the Escarpment of up to 150 m thick (Singer et al., 1994). The Queenston Formation is often used for domestic water supply by homeowners below the Escarpment, as productive overburden aquifers are not as abundant in the lower watershed as they are above the Escarpment. The upper fractured portion of the Queenston Formation can be moderately permeable and may be used for domestic supply, and groundwater discharge to surface water features overlying the Queenston Formation supports moderate amounts of baseflow in some areas of the watershed.

Figure 3 is taken from the Tier 2 Report and presents the bedrock topography in the vicinity of the Study Area. Figure 3 also shows the interpreted location of the Acton-Mississauga buried bedrock valley that trends from north to south through the Study Area, generally following the path of the present Credit River through the northern half of the Study Area, and then occurring to the west of the Credit River closer to Lake Ontario. Review of Figure 3 indicates that the bedrock surface tends to slope downward from the northwest towards the interpreted buried bedrock valley, and that the direction of slope of the bedrock surface to the east of the interpreted buried bedrock valley is generally north to south.

Where buried bedrock valleys are infilled with permeable overburden deposits, such as sand or gravel, they can act as very productive aquifers. Conversely, where buried bedrock valleys are infilled with fine grained deposits, such as silt and clay, the buried valleys do not convey large amounts of groundwater. In the upper and middle zones of the Credit River watershed buried bedrock valley aquifers are significant sources of potable water for municipal and private supplies. Based on review of the permitted water takings in the Study Area (described later in this section), and consideration of the lake-based servicing in the vicinity of the Study Area, the buried bedrock valley does not serve as a significant source of private or municipal water.

Both the *Tier 2 Report* (AquaResource, 2009) and the Davies Holysh study (2007) presented similar interpretations of the origin and infill material for the buried bedrock valley; however, due to the low number of water well records across the Study Area and in the vicinity of the buried bedrock valley, there is considerable uncertainty in terms of the precise location, alignment, depth, and infill material of the buried bedrock valley. Better understanding of the properties of the buried bedrock valley would require field investigation and detailed review of site-specific consultants reports for other projects (e.g., municipal infrastructure).

Figure 4 presents the locations of two interpreted geological cross-sections through the Study Area that were prepared by a consultant using the geological information contained in the YPDT database. Figure 5 shows the north-south cross-section that generally follows the alignment of the buried bedrock valley, and Figure 6 shows the west-east cross-section that approximately follows Lakeshore Blvd through the Study Area. Both cross-sections show that the depth of overburden within the Study Area, and in the

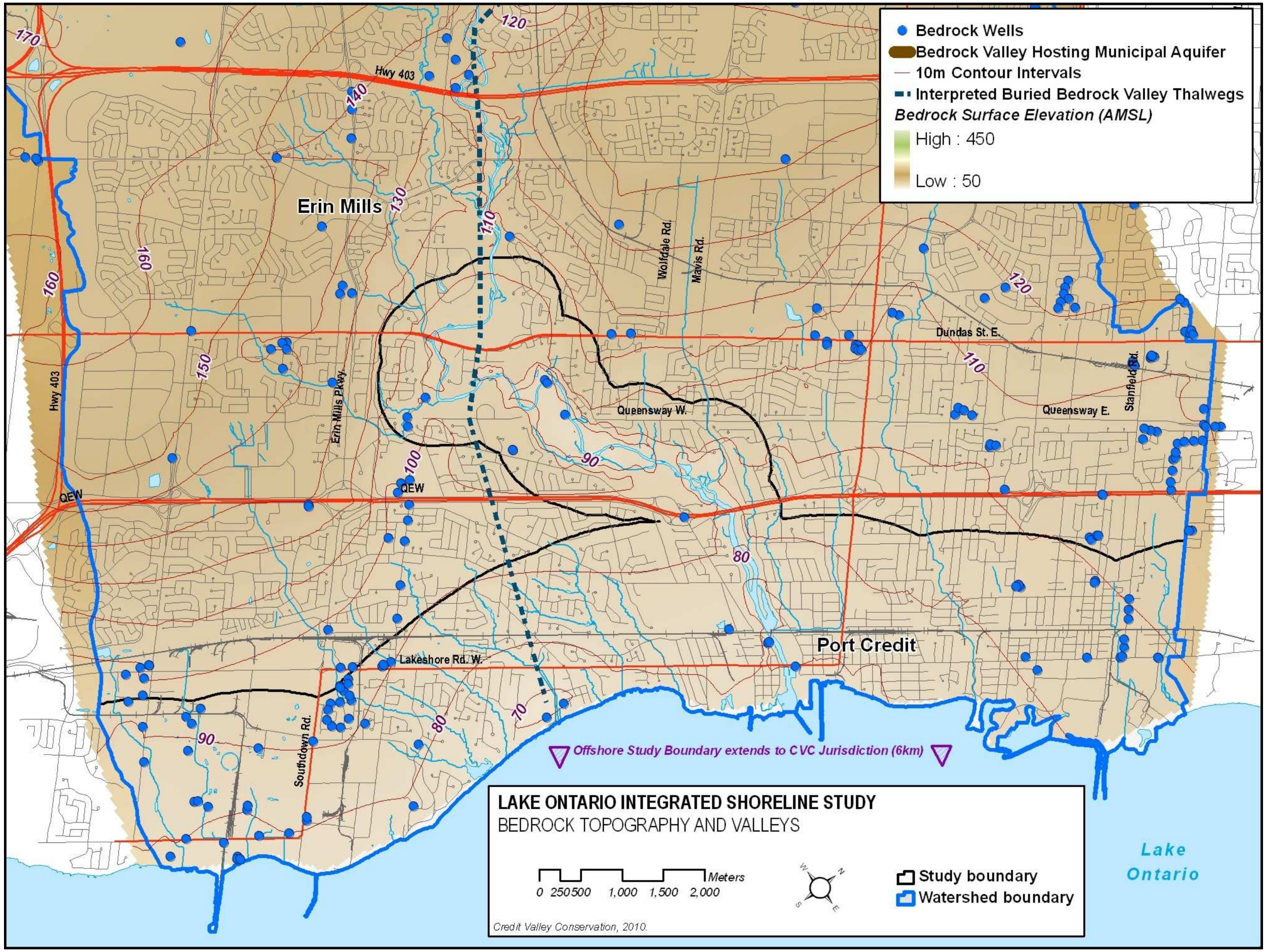
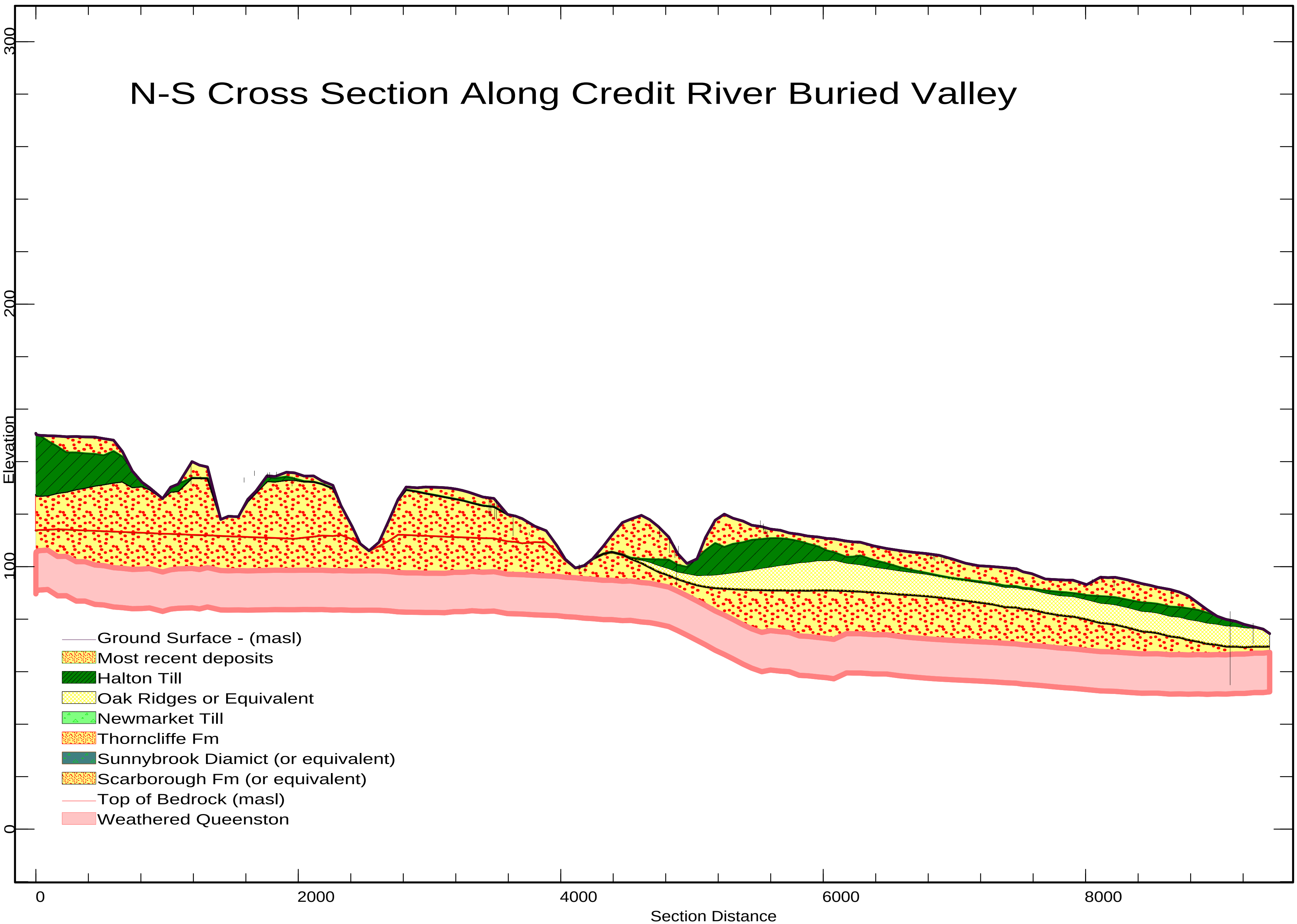
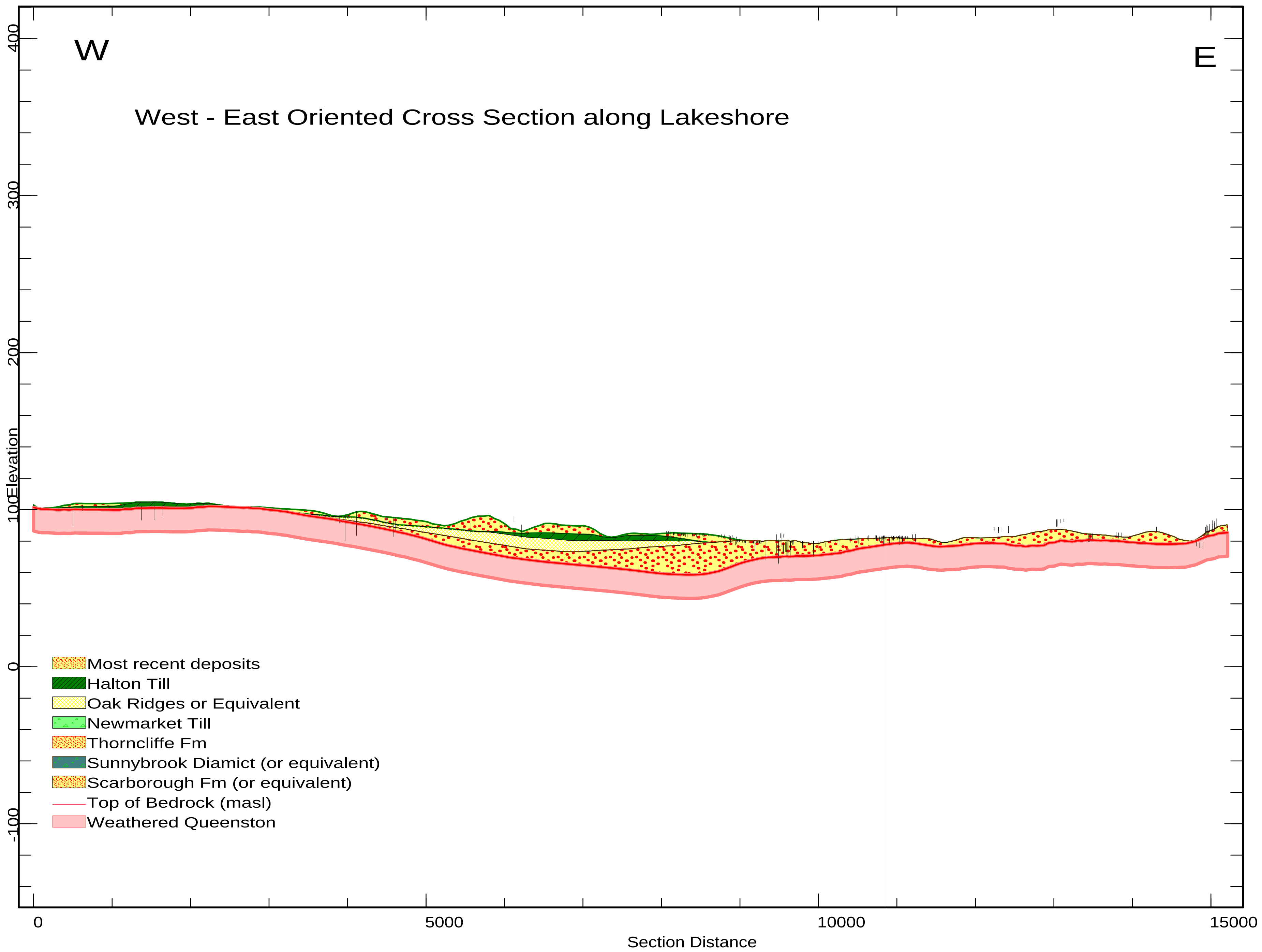


Figure 3: Bedrock Topography and Valleys

Cross Section Location Map



N-S Cross Section Along Credit River Buried Valley
Elevation
300
200
100
0
0
2000
4000
6000
8000
Section Distance
Ground Surface - (masl)
Most recent deposits
Halton Till
Oak Ridges or Equivalent
Newmarket Till
Thorncliffe Fm
Sunnybrook Diamict (or equivalent)
Scarborough Fm (or equivalent)
Top of Bedrock (masl)
Weathered Queenston



W
E
West - East Oriented Cross Section along Lakeshore
400
300
200
100
0
-100
Elevation
0
5000
10000
15000
Section Distance
Most recent deposits
Halton Till
Oak Ridges or Equivalent
Newmarket Till
Thorncliffe Fm
Sunnybrook Diamict (or equivalent)
Scarborough Fm (or equivalent)
Top of Bedrock (masl)
Weathered Queenston

vicinity of the buried bedrock valley in particular, is up to 50 metres. The cross-sections show that the buried bedrock valley is interpreted to be infilled by overburden materials, and these units are further described below. Further investigation of the exact nature of the valley infill deposits would be required to determine whether the valley deposits convey significant amounts of groundwater flow.

Figure 7 is taken from the *Tier 2 Report* and presents the Surficial Geology in the vicinity of the Study Area. Review of Figure 7 indicates that there are three prevalent surficial geological units in the vicinity of the Study Area: bedrock or bedrock drift; Halton Till; and glaciolacustrine sand. Each of those three units is further described below.

The **Halton Till** generally occurs to the north of the Study Area, and is the most prevalent surficial geological unit in the Credit River Watershed below the Niagara Escarpment. The Halton Till is a red clay to clayey silt till that is found in the Credit River watershed between the Niagara Escarpment and the Lake Iroquois shoreline (Karrow, 1991). In other parts of the watershed, the Halton Till is described as having fine-grained sand interbeds or lenses (Karrow, 1991). The Halton Till is generally considered an aquitard with low hydraulic conductivity, although it may serve as a source of limited water supply for private wells in the watershed, particularly where more permeable sand lenses are present.

The **Lake Iroquois Glaciolacustrine Sand** deposit associated with the shoreline of the former Lake Iroquois extends approximately 2 to 3 km northward from the present shoreline of Lake Ontario. This unit represents the youngest glacially-derived sediments within the Credit River watershed (Davies and Holysh, 2007),
and is characterized as a sand plain underlain by deeper fine-grained Glaciolacustrine (shoreline) silt to sand deposits (Karrow 1991).

Despite the coarse-grained nature of much of the Iroquois Glaciolacustrine Sand deposit, review of Figure 1 indicates that there are not many overburden water well records within the Study Area where this deposit is the surficial unit. While the paucity of water well records within the Iroquois Glaciolacustrine Sand may be evidence that the unit is not a very productive aquifer that could be utilized for potable water, one should also consider that the availability of Lake Ontario, as well as the Credit River and other tributaries, may have discouraged the drilling of water supply wells in this part of the Study Area in the latter half of the twentieth century, when the MOE began to maintain a record of water wells in the province.

The buried bedrock valleys within the Credit River watershed are infilled by different sediments that exist deeper than the surficial overburden deposits described above. The three principal deeper overburden deposits that may occur within the Study Area and vicinity are:

- Oak Ridges Moraine (or equivalent) Deposits;
- Thornecliffe Formation Deposits; and
- Sunnybrook Drift and Scarborough Formation Deposits.

These deeper deposits are described as follows.

Oak Ridges Moraine Deposits
Within the Credit River watershed most of the shallow coarse-grained sediments are interpreted to be more or less contemporaneous or equivalent to the Oak Ridges Moraine sediments, and are frequently collectively termed the Oak Ridges Moraine Aquifer Complex. These deposits are also referred to as the *Mackinaw Interstadial Deposits* in the CVC Tier 2 Report (AquaResource, 2009). In some locations in the Credit River watershed, the Oak Ridges Moraine deposits consist of interbedded fine sands and silts, and also with interbedded coarse sands and gravels. These sediment types reflect the range of depositional environments within the Oak Ridges Moraine (e.g., subaqueous channel, fan and delta; glaciolacustrine) (Davies and Holysh, 2007). However, while these deposits are interpreted to infill the Acton-Mississauga buried bedrock valley that trends through the Study Area, it appears that the Oak Ridges Moraine deposits in the Mississauga area are predominantly finer grained sediments (e.g., silt) (Davies and Holysh, 2007), and therefore may not convey significant groundwater flow. Occurrences of the Oak Ridges Moraine Deposits in the Study Area are shown on the cross-sections on Figures 3.b and 3.c.

Thorncliffe Formation Deposits
The Thorncliffe Formation deposits can include sand and silty sand, but typically is comprised of silt, sand, and clay closer to the Study Area (Davies and Holysh, 2007). The Thorncliffe deposits only occur below the Niagara Escarpment within the Credit River watershed, and typically in deeper bedrock valley settings. These deposits are not likely found within the Study Area, but may be present to the north within the Acton-Mississauga buried bedrock valley.

Sunnybrook Drift and Scarborough Formation Deposits
The Sunnybrook Drift and Scarborough Formation deposits are interpreted to be the oldest overburden sediments in the Credit River watershed (Davies and Holysh , 2007), and therefore underlie other deposits that infill the Acton-Mississauga buried bedrock valley. The Sunnybrook Drift deposit is a fine-grained silt and clay deposit (Karrow 1967), and is interpreted to function as an aquitard within the hydrostratigraphy of the Credit River watershed (Davies and Holysh, 2007 and AquaResource, 2009).

The Scarborough Formation deposit is typically comprised of sands and overlies the bedrock surface at the bottom of the buried bedrock valleys below the Escarpment, including the Acton-Mississauga buried bedrock valley below Huttonville (Davies and Holysh, 2007). Due to its coarse grained composition, the Scarborough Formation deposits are considered to function as an aquifer within the hydrostratigraphy of the Credit River watershed (Davies and Holysh, 2007 and AquaResource, 2009).

These deposits are present in the buried bedrock valley within the Study Area (as shown on Figures 5 and 6), as well as to the north of the Study Area.

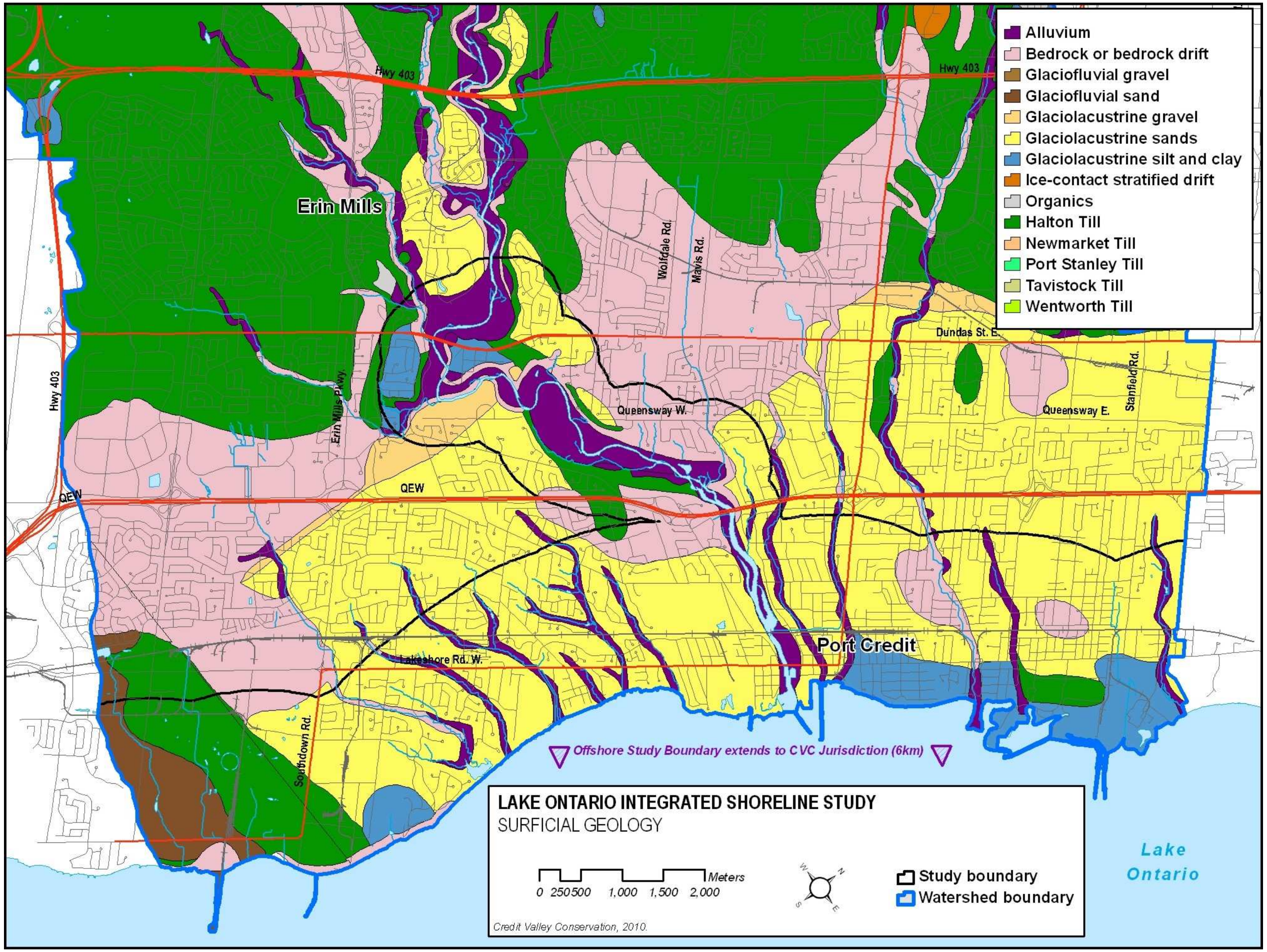


Figure 7: Surficial Geology

Groundwater Levels

Figure 8 is taken from the *Tier 2 Report* and presents the deep groundwater surface for the Study Area and vicinity. The deep groundwater surface was generated using the static groundwater level data from MOE water well records for wells with depth greater than 25 m. The deep groundwater level surface was generated using data from across the watershed, and therefore may not represent actual conditions at the local scale. Review of Figure 8 indicates that there are relatively few MOE water well records for wells deeper than 25 m in the Study Area and vicinity, and therefore the deep groundwater level surface presented on Figure 8 should be considered to be only an approximation of the actual deep groundwater level surface in the vicinity of the Study Area. Additional refinement required to make the deep groundwater level surface more representative of local conditions would need to include a search for additional sources of deep groundwater level measurements and extending the groundwater level contours to the shoreline.

Review of the deep groundwater level surface contours on Figure 8 indicates that the highest deep groundwater levels occur to the northwest of the Study Area, where Highway 403 turns to the south and also intersects the western boundary of the Credit River watershed. Deep groundwater levels are up to 180 m AMSL to the northwest of the Study Area, but are somewhat lower (150 m AMSL) to the northeast of the Study Area. Deep groundwater surface contours indicate that deep groundwater flow is generally towards the interpreted buried bedrock valley that runs from north to south through the Study Area. South of Dundas Street the deep groundwater surface contours generally suggest that deep groundwater flow is from north to south towards the Lake Ontario shoreline.

Review of Figure 9, which is taken from the *Tier 2 Report*, indicates that there are more MOE water well records for wells less than 25 m depth in and around the Study Area than there are well records for wells with depth greater than 25 m; however, much of the Study Area does not have any MOE water well records. The shallow groundwater level surface was generated using data from across the watershed, and therefore may not represent actual conditions at the local scale. Additional refinement required to make the shallow groundwater level surface more representative of local conditions would need to include a search for additional sources of shallow groundwater level measurements and extending the groundwater level contours to the shoreline.

Similar to the deeper groundwater surface contours shown on Figure 8, the highest shallow groundwater levels are found to the northwest of the Study Area, and the overall direction of shallow groundwater flow appears to be towards the interpreted buried bedrock valley and towards the Lake Ontario shoreline.

Water Takings

Figure 10 is taken from the *Tier 2 Report* and presents the locations of the long term Permits to Take Water (PTTWs) within and near the Study Area. The MOE requires that most non-domestic water takings that exceed a rate of 50,000 L/day have a PTTW, and the water taking locations shown on Figure 10 represent the locations of the known

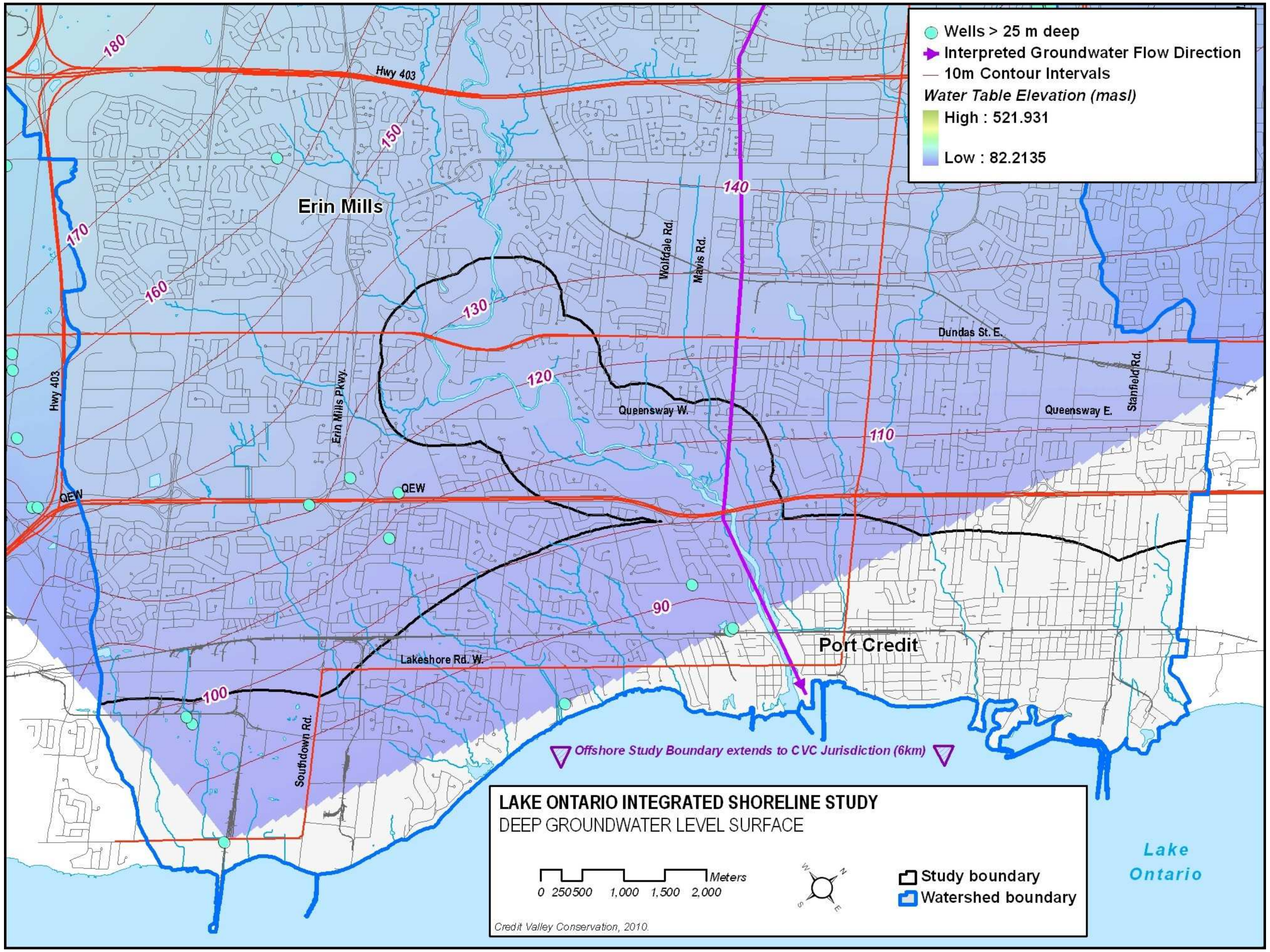


Figure 8: Deep Groundwater Level Surface

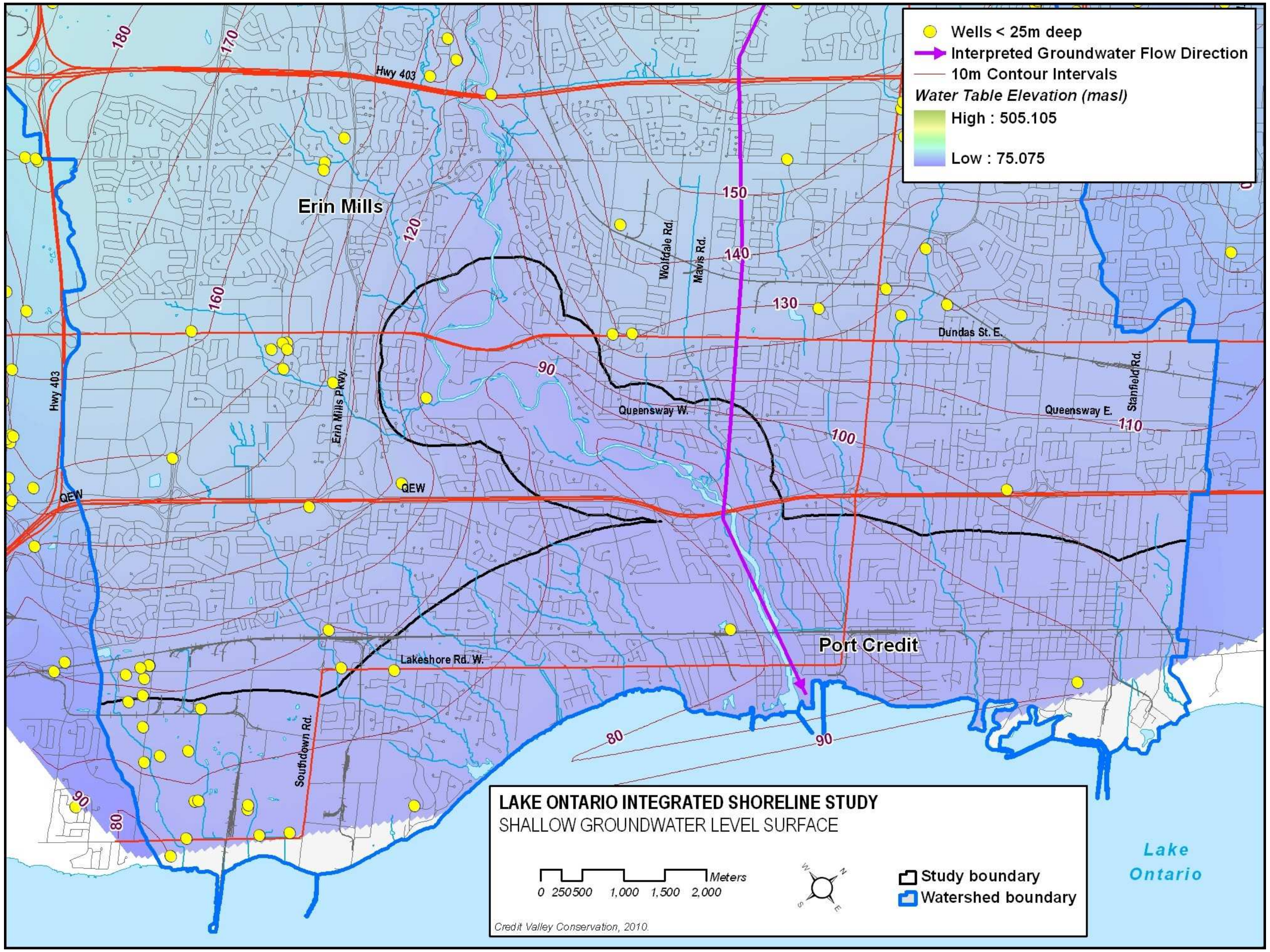


Figure 9: Shallow Groundwater Level Surface

long term PTTWs within and near the Study Area. Both of the PTTWs shown on Figure 10 are for surface water takings from the main Credit River for the purposes of golf course irrigation.

There are no known long-term groundwater takings within or near the Study Area; however, it is likely that short-term groundwater takings for construction dewatering will occur from time to time in the Study Area. The PTTWs for these short term groundwater takings would be issued by MOE only after technical review to confirm that there would be no impacts to key groundwater functions, such as discharge to streams.

Groundwater Recharge

Figure 11 is taken from the *Tier 2 Report* and presents the estimated recharge rate in the vicinity of the Study Area. Groundwater recharge is the portion of precipitation that infiltrates to the groundwater system. The *Tier 2 Report* describes the process of estimating recharge rates as follows:

- Average recharge rates estimated by the HSP-F model for a 1961-2004 simulation were applied across the watershed for each hydrologic response unit (HRU).
- The recharge map was interpolated to the model mesh within the watershed to apply recharge based on slope, soil (surficial geology), and land use. Outside the watershed, values were applied based on slope and soil type (surficial geology). The HSP-F values were not modified during the groundwater model calibration process.

Review of the recharge rates indicates that the recharge rates across most of the Study Area is in the range of 25 to 150 mm/year, with a zone of higher recharge rate along the northern boundary of the Study Area. North of the Study Area, the estimated recharge rate is lower, which is in part due to the presence of the lower permeability Halton Till at surface. The Iroquois glaciolacustrine sand and the upper weathered Georgian Bay Formation shale are more permeable than the clay-rich Halton Till, which contributes to the higher estimated recharge rate across much of the Study Area.

Groundwater Discharge

Baseflow in streams is generated by groundwater discharge and anthropogenic inputs (e.g., foundation drain discharges, leaking buried servicing). Groundwater discharge to streams occurs when the water table intersects the stream, and where upward vertical hydraulic gradients occur (indicating the potential for an upward flux of groundwater). Another important factor in determining the potential for groundwater discharge to streams is the permeability of the stream bed, which typically reflects the surface, or near surface, geological medium. High permeability material, such as sand and gravel, would allow for greater groundwater discharge to streams, while less permeable material, such as clay or competent bedrock, would allow for much less groundwater discharge, even in locations where upward vertical hydraulic gradients were present.

Both the *Tier 2 Report* (AquaResource 2009) and the Davies and Holysh report (2007) indicate that upward vertical hydraulic gradients occur in the lower watershed, with

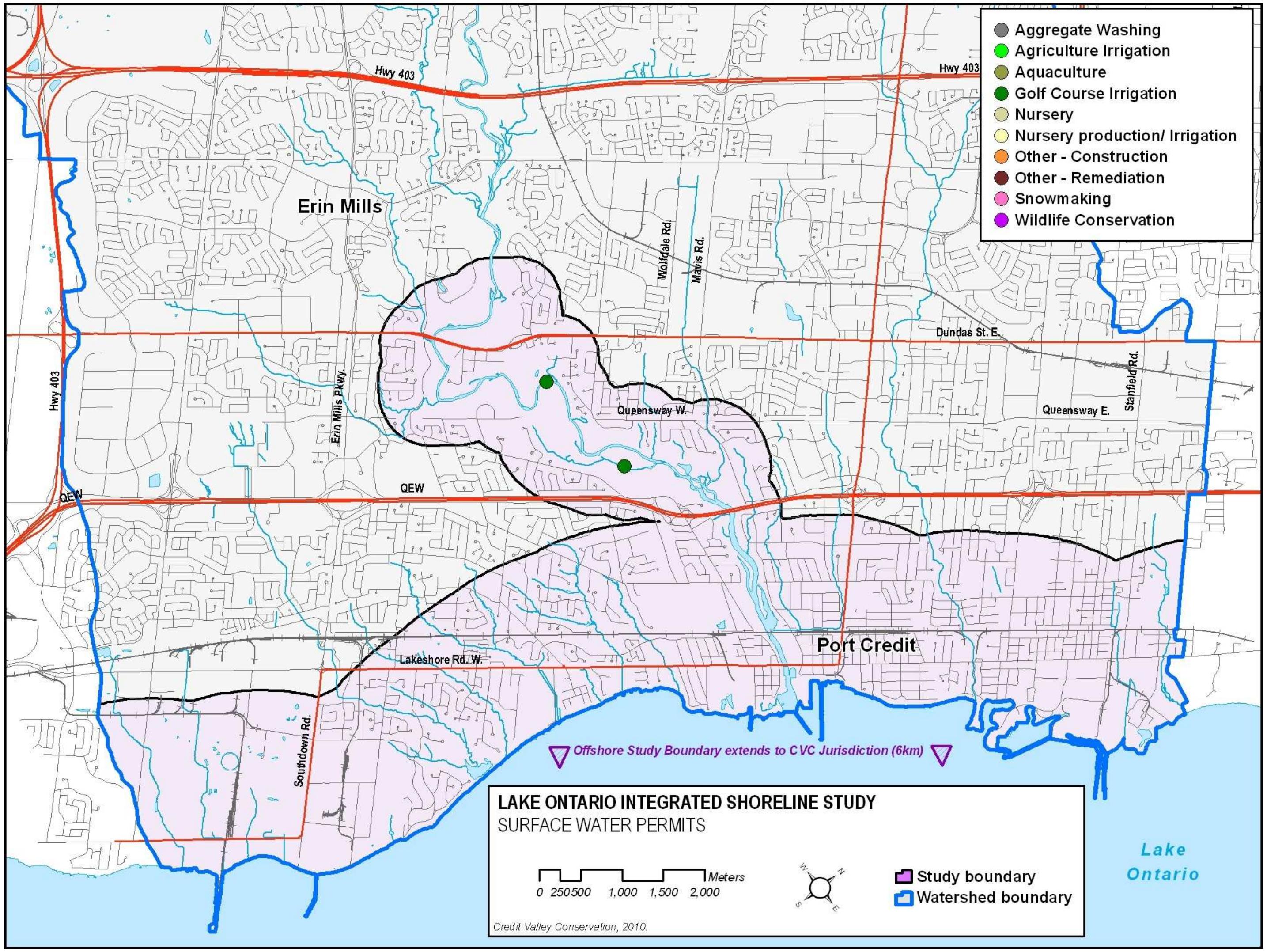


Figure 10: Surface Water Permits

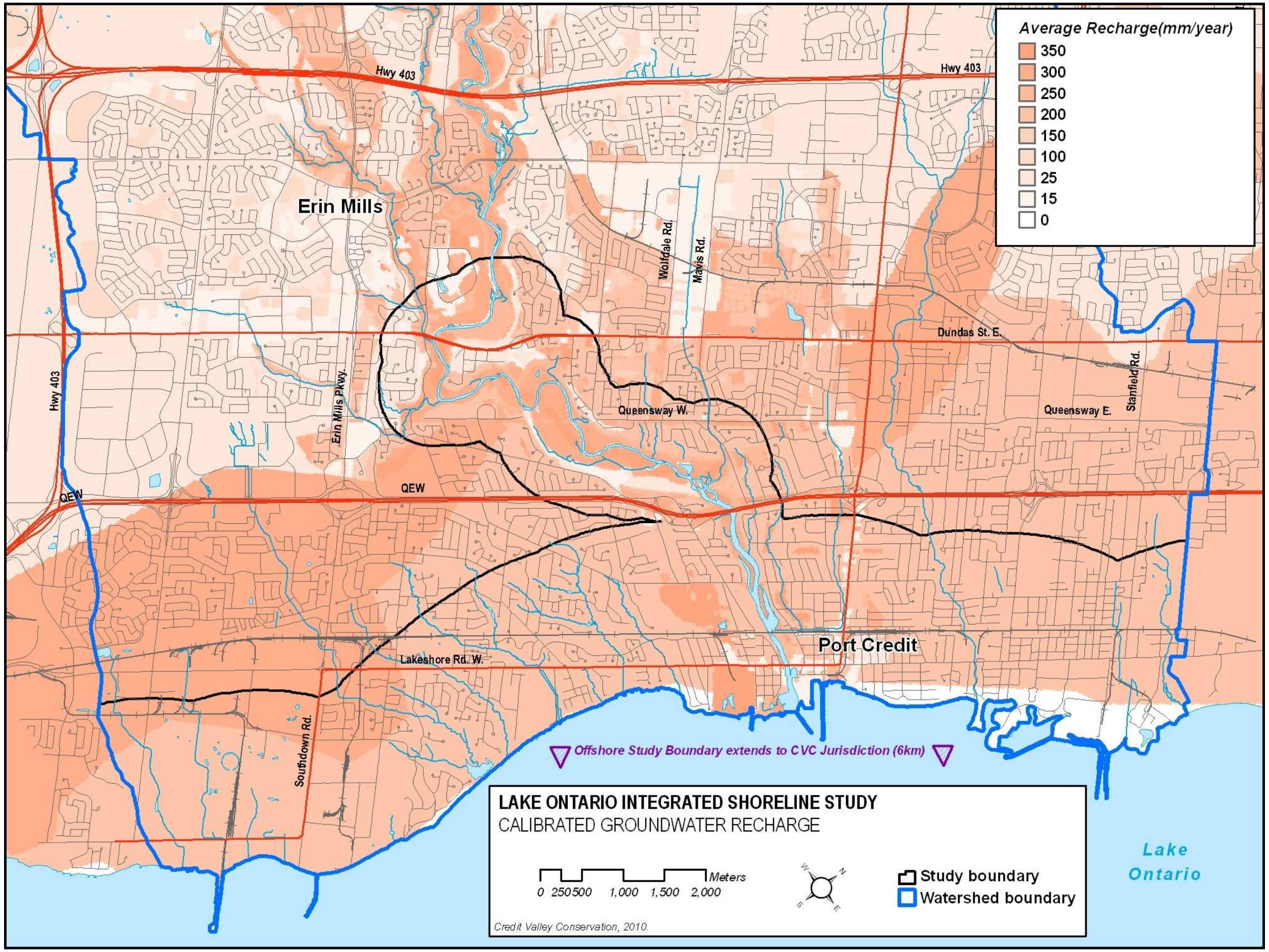


Figure 11: Calibrated Groundwater Recharge

Davies and Holysh also noting that vertical hydraulic gradients are predominantly upward within the Acton-Mississauga buried bedrock valley close to Lake Ontario. Therefore, vertical hydraulic gradients that are supportive of groundwater discharge to streams occur within the vicinity of the Study Area, and in areas where the streams are underlain by moderately to high permeability material, some significant groundwater discharge would be expected. Review of the surficial geology in the Study Area presented on Figure 7 indicates that the prevalent glaciolacustrine sand would be sufficiently permeable to allow significant groundwater discharge to streams, while the upper fractured Georgian Bay Formation shale could also allow groundwater discharge to occur. Lesser amounts of groundwater discharge would be expected in areas where the Halton Till or other fine grained deposits are present near ground surface.

Stream flow measurements collected after at least a few days without precipitation or snowmelt are typically considered to represent baseflow conditions. Stream flow under such conditions would not represent contributions from runoff, but would instead reflect groundwater discharge to the stream, and potentially other inputs such as anthropogenic sources. Baseflow measurements collected in support of the LOISS and Cooksville and Sheridan Creek studies appear to confirm that groundwater discharge to streams is occurring within the Study Area. The baseflow measurements collected in the Cooksville and Sheridan Creek subwatersheds ranged from approximately 2 L/s to 87 L/s (moving from the upper subwatersheds to lower subwatersheds). While some discharge was observed from sewer outfalls even after several days without precipitation, these contributions were estimated to be minimal relative to the overall baseflow in Cooksville and Sheridan Creeks at the time that the flow measurements were collected. Therefore, it is expected that groundwater discharge comprised most of the observed baseflow at that time.

Baseflow measurements were also collected from a number of the other streams in the Study Area in support of the Fluvial Geomorphology section (Table 3.5) of this report. While these measurements were collected at a single point along each stream, and there were no observations of potential discharge from sewer outfalls provided, it is possible that the majority of the measured flow represents groundwater discharge to the streams. The baseflow measurements to the monitored streams ranged from 0.2 L/s to 32 L/s, which are similar to measurements collected along Cooksville and Sheridan Creeks.

The rates of groundwater discharge to the streams estimated by the *Tier 2 Report* are lower than the measured baseflows described above. The *Tier 2 Report* estimates total groundwater discharge to streams and wetlands in the Lake Ontario tributary catchments (excluding the Credit River) to be approximately 10,000 m^3/day (115 L/s), which is about half of the measured stream flows described above.

The rates of groundwater discharge to streams in the Study Area as predicted by the *Tier 2 Report* are presented on Figure 12. Review of Figure 12 indicates that rates of groundwater discharge to streams were generally in the range of 1L/s per kilometer of stream length, which would be equivalent to approximately 2 to 3 L/s for most of the

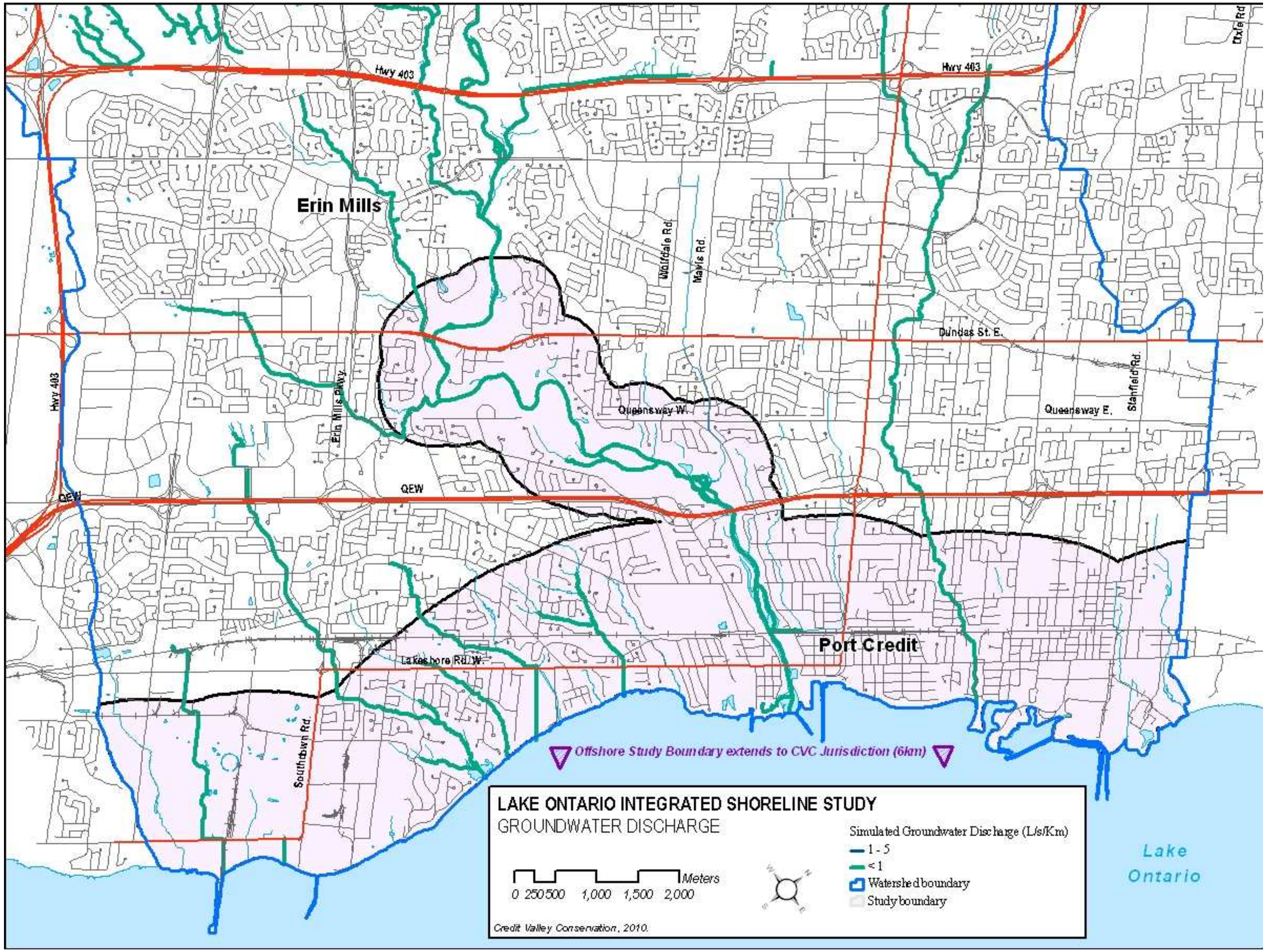


Figure 12: Groundwater Discharge

streams. The modeled rate of groundwater discharge from the *Tier 2 Report* is therefore an order of magnitude less than the measured baseflows described above.

The calibrated groundwater model results described in the *Tier 2 Report* may be less than the measured baseflows; however, for a groundwater model that was intended for analysis at the watershed and subwatershed scale, and considering the lack of an extensive database of hydrogeological and flow data for the Lake Ontario tributary catchments, the model-estimated groundwater discharge is a reasonable match to the measured flows. Also, the groundwater flow model discharges are intended to represent average annual conditions, which may have not been accurately captured by the baseflow measurements.

CVC's calibrated groundwater model estimates that there is about 17,000 m^3/day of direct groundwater discharge to the lake. Based on the comparison of the model-estimated stream baseflows to measured flows, it is reasonable to expect the model estimates of direct groundwater discharge to the lake to be accurate to the correct order of magnitude. Presently CVC does not monitor direct groundwater discharge to the lake, and it likely would be difficult to measure in the field. It may be possible to verify the presence of groundwater discharge to the lake that was previously identified by other means, such as by the presence of a certain type of aquatic habitat or by a water temperature survey that could show the difference between lake temperature and the temperature of direct groundwater discharge.

Groundwater Quality

CVC does not have long term groundwater quality monitoring data for the vicinity of the Study Area; however, the monitoring wells installed in the Cooksville and Sheridan Creek subwatersheds were sampled for general water quality parameters shortly after installation. The Cooksville and Sheridan monitoring well samples did not indicate any anthropogenic groundwater quality impacts; however, the ambient water quality is influenced by the composition of the overburden and bedrock units in which they are completed.

It is expected that there may be at least localized impacts to groundwater quality from urbanization, spills, etc. (historical and/or recent). A search for property-specific environmental assessment reports for the Cooksville and Sheridan studies discovered that there is a large database of reports, some of which could indicate historical or existing contamination of soil or groundwater.

3 CONCLUSIONS

The primary ground water function within the Study Area appears to be support of surface water features and aquatic habitat, and contributions to stream baseflow in particular, through groundwater discharge. Baseflow measurements suggest that groundwater discharge supports baseflow in streams across the Study Area. Additional baseflow measurements should be collected to confirm the groundwater contributions to baseflow and to improve our understanding of where the discharge occurs within the Study Area.

The *Tier 2 Report* modelling predicts that the amount of direct groundwater discharge to the lake is greater than the amount of discharge to the Lake Ontario tributaries other than the Credit River. Based on the generally close comparison between the model-estimated groundwater contributions to baseflow and measured stream baseflow, it would be a reasonable expectation that the actual rate of groundwater discharge to the lake is comparable to the rate predicted by the *Tier 2 Report* modelling.

Both the *Tier 2 Report* (AquaResource, 2009) and the Davies Holysh study (2007) presented similar interpretations of the origin and infill material for the buried bedrock valley; however, due to the low number of water well records across the Study Area and in the vicinity of the buried bedrock valley, there is considerable uncertainty in terms of the precise location, alignment, depth, and infill material of the buried bedrock valley. Better understanding of the properties of the buried bedrock valley would require field investigation and detailed review of site-specific consultants reports for other projects (e.g., municipal infrastructure).

A preliminary assessment of groundwater quality information does not indicate any significant impacts; however, urbanization may have caused localized impacts that would only be discoverable through an extensive review of environmental assessment reports within the Study Area.

3.1 Data Gaps

- Groundwater-surface water interactions are not well understood at a local scale. Additional rounds of baseflow measurements should be collected, with more locations to allow for better identifications of discharge locations.
- Properties of the buried bedrock valley are not well understood, and this increases the uncertainty of the characterization of groundwater system. A further review of available geological information, and a scoped field investigation, would be required to significantly improve our understanding of the buried valley properties.
- It would be difficult to quantify groundwater discharge to the lake solely through a hydrogeological field investigation. It may be possible to confirm the presence of groundwater discharge to the lake that was predicted by other indicators (e.g., habitat type). Remote sensing may be an option.

- Groundwater quality does not appear to be negatively affected by urbanization based on the available groundwater quality data from the Cooksville and Sheridan subwatershed studies. There may be unidentified impacts at a more local scale, and these may be identifiable through a review of environmental assessment reports. If there are localized groundwater quality impacts, what is the significance to the natural environment?

4 REFERENCES

AquaResource Inc., 2009. *Integrated Water Budget Report – Tier 2 Credit River Source Protection Area*

Credit Valley Conservation et. al., 2010. *Sheridan Creek Characterization Report*

Credit Valley Conservation et. al., 2010. *Cooksville Creek Characterization Report*

Davies, S. and Holysh, S., 2007. *Groundwater Resources of the Credit River, Ontario Geological Survey Groundwater Resources Study 6*

Karrow, P.F., 1991. *Quaternary Geology of the Brampton area. Ontario Geological Survey, Open File Report 5819*.

Karrow, P.F., 1967. *Pleistocene Geology of the Scarborough Area. Ontario Ministry of Natural Resources, Toronto*, Report 46, 108 p

S. Singer et al., 1994. *Groundwater Resources of the Credit River Watershed*
YPDT-CAMC Groundwater Study (http://www.ypdt-camc.ca/Home/tabid/171/Default.aspx)