GROUNDWATER QUANTITY AND QUALITY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

3.0 GROUNDWATER QUANTITY AND QUALITY

Groundwater resources play an important role in the Etobicoke and Mimico Creeks watershed ecosystem. Groundwater usage in these watersheds includes private potable drinking supplies, as well as agricultural, recreational and industrial uses. In addition, many plants and aquatic organisms depend on groundwater or groundwater discharge for survival. During drought conditions, when surface water flows are minimal, groundwater contributions to baseflow are even more important to the aquatic ecosystem. Groundwater also affects surface water quality. Cool groundwater discharge moderates stream temperatures, important for aquatic habitats in the warm summer months, and the quality is high because of natural filtration processes.

Land use activities influence both the quantity and quality of groundwater. Land clearing reduces infiltration by reducing the impediments to overland flow and increases soil compaction due to stripping activities that involve the use of heavy machinery. These activities increase surface runoff and reduce groundwater discharge. Aggregate extraction and grading affects groundwater flow rates and directions. Activities such as excessive application of fertilizers and de-icing salts, improper storage of manure, and spills of hazardous materials can lead to excessive levels of various contaminants in groundwater. Contaminated groundwater affects surface water quality at discharge locations, which can have negative implications on the health of both humans and aquatic organisms that utilize these resources.

This **Groundwater Quantity and Quality Section** addresses a knowledge gap identified in the previous Etobicoke and Mimico Creeks watersheds strategy and report card documents, by drawing upon newly available groundwater-related information. This section introduces a set of objectives, indicators and targets for groundwater quantity and quality management in these watersheds. The discussion builds on the geologic framework presented in the **Study Area and Physical Setting Section,** by interpreting the overall hydrogeologic setting, including areas of recharge and discharge, water levels, water budget, and ground-surface interactions, particularly in relation to several wetland complexes. The section presents key groundwater management recommendations in the context of existing and future land uses. **Box 1** contains a set of definitions for technical terms used in this section.

Box 1: Groundwater Terms

Groundwater - Water that occurs below the earth's surface. It originates as precipitation, runoff, and snowmelt, which infiltrates vertically downward into the ground via gravity to the water table.
Water table - The zone where the pore spaces are fully saturated
Aquifer - A sufficiently permeable zone in the soil or rock (between soil particles, as well as small voids, fractures, fissures and joints in bedrock)
Aquitard - A zone of low permeability materials
Hydrostratigraphic Unit - Collectively, aquifer and aquitard layers are known as hydrostratigraphic units. As is the case with geologic units, all hydrostratigraphic units may not occur everywhere throughout the watershed.
Aquifer complex - designates a unit where the majority of the sediments have moderate to high permeability although the sediments may vary both vertically and laterally.
"or equivalent" - denotes a hydrostratigraphic unit that is at the same topographic level as another unit, with similar physical characteristics, but with a different geologic origin. An example of this would be the Mackinaw Interstadial deposits, which are considered a hydrostratigraphic equivalent of the Oak Ridges Aquifer deposits.

3.1 WATERSHED OBJECTIVES, INDICATORS AND TARGETS

The Etobicoke and Mimico Watersheds Coalition was not able to recommend a set of watershed objectives and targets for groundwater management as part of *Greening Our Watersheds: Revitalization Strategies for Etobicoke and Mimico Creeks* (TRCA, 2002) or *Turning over a new leaf: The Etobicoke and Mimico Creeks Watersheds Report Card* (TRCA, 2006), due to a previous deficiency in understanding of the groundwater system. Based on the findings of this Technical Update, TRCA staff recommends the following watershed objectives and targets for groundwater as shown in **Table 3-1**.

Table 3-1: Watershed Objectives, Indicators and Targets

Groundwater Quantity **Objective:** **Current groundwater recharge and aquifer water levels are maintained throughout the watersheds and restored within the Brampton Esker, to the maximum extent possible.**	
Indicator	**Targets**
Recharge	• Maintain existing annual average watershed recharge rates of 0.72 m^3/s (103 mm/year) for Etobicoke Creek and 0.22 m^3/s (94 mm/year) for Mimico Creek (as reported in Technical Update, TRCA, 2010). Site specific recharge rates as per **Figure 3-19**.
Groundwater Level	• Maintain 2009 groundwater levels (as per 2009 Provincial Groundwater Monitoring Network (PGMN) data, reported in Technical Update, TRCA, 2010)

Groundwater Quality **Objective:** **Groundwater meets Ontario Drinking Water Standards**	
Indicator	**Targets**
Groundwater Quality-Conventional Pollutants	• All aquifers should meet the Ontario Drinking Water Standards for all health-related parameters.

3.2 OBJECTIVES OF TECHNICAL UPDATE

The subject of groundwater was mostly limited to a discussion on permeability of soils and typical infiltration rates in the *State of the Watershed Report: Etobicoke and Mimico Creek Watersheds (TRCA, 1998)*. The report suggested a lack of information on major groundwater aquifers, bedrock and overburden aquifers, and a deficiency in monitoring of baseflow to establish an understanding of ground-surface water interactions and trends. Also, water use information was not available to assess the number of users and volume of water used.

Now, data are available from a broad network of monitoring partnerships that have evolved over the past decade. In 2001, TRCA developed a Regional Watershed Monitoring Program, including a groundwater monitoring component, with the objective of furthering a network approach between agencies collecting watershed environmental data and enhancing data integrity and shareability through the establishment of relational databases. In 2000 TRCA developed a Low Flow Program to monitor baseflow levels and water use information to allow for a better understanding of the interconnections between groundwater and surface water systems. Finally, since the development of the York-Peel-Durham-Toronto – Conservation Authority Moraine Coalition (YPDT-CAMC) in 2002, the TRCA has had access to an extensive geologic and hydrogeologic database, including modelling tools.

Drawing upon this new information, the principle objectives of the groundwater system component of this Technical Update are as follows:

- Provide an interpretation of the geology and hydrogeology of the Etobicoke and Mimico Creeks watersheds;
- Assess the areas of significant groundwater recharge and discharge within both watersheds;
- Prepare a water budget for both watersheds;
- Interpret the hydrogeological conditions of the Heart Lake Wetland Complex; and
- Present management considerations to achieve the groundwater objectives listed.

3.3 DATA SOURCES AND METHODS

3.3.1 Data Sources

The following data and background reports were used in developing the Technical Update:

- *Geology and Groundwater Resources, Toronto and Region Conservation Authority Watersheds - DRAFT version 1.* Gerber, R. and Holysh, S., 2005.
- *Groundwater Modelling of the Oak Ridges Moraine Area*. York-Peel-Durham-Toronto - Conservation Authority Moraine Coalition (YPDT-CAMC) Technical Report #01-06. Kassenaar, J.D.C. and Wexler, E.J., 2006.
- View log modelled GRD output files dated June 9, 2006 and April 8, 2008. EarthFx, 2006 and 2008.
- *Brampton Esker Hydrology Study - Report and Technical Data Catalogue.* Morrison Beatty Limited *et al.*, February 1983.
- *Heart Lake Road Realignment, Class Environmental Assessment Study*, *Environmental Study Report - DRAFT.* McCormick Rankin Corporation, 2004.
- *Esker Lake South Secondary Plan, Background Study*. Glen Schnaar & Associates, January 1994.
- *Esker Lake North, Water Quality Evaluation*. Niblett Environmental Associates Inc., November 1995.
- *Esker Lake North Secondary Plan, Background Study & Development Concept*. Kentridge Johnson Limited, March 1996 and revision dated October 1996.
- Esker Lake North Secondary Plan, Conceptual Stormwater Management Plan, Armbro Inc., City of Brampton. RAND Engineering Corporation, May 1996.
- Hydrogeologic Evaluation North Esker Lake Complex Brampton, Ontario. Terraprobe Limited, 2006. File No. 1-06-1243. Prepared for Ranburne Holdings.
- Provincial Groundwater Monitoring Network (PGMN). Automated water level measurements and chemical water quality analyses, from monitoring wells W366 and W021 (Heart Lake Conservation Area). Years of data used were November 2003 - July 2009 and June 2001 - March 2009 respectively
- *Source Water Protection, Conceptual Understanding of the Watersheds, Toronto and*

Region Conservation Authority. Puopolo, J. and Usher, S., 2006.
- *Geotechnical Investigation, Realignment of Heart Lake Road at Bovaird Drive (Highway 7), Brampton, Ontario.* Thurber Engineering Limited, 2006.
- *Stormwater Management Implementation Report, Ranburne Holdings Limited, Draft Plan of Subdivision 21T-98006B*. RAND Engineering Corporation, March 2001.
- *Stormwater Management Implementation Report, Lakelands South, Draft Plan of Subdivision 21T-02011B, TACCPAR South Developments Inc*. RAND Engineering Corporation, April 2004.
- *Stormwater Management Report, Lakeland North Subdivision (21T-95040B).* Schaeffers Consulting Engineers, May 2003.
- *Draft Tier 1 Water Budget Report (PRMS).* Toronto and Region Conservation Authority, 2009.
- Category 3 Permit To Take Water Application, Hydrogeologic Assessment, Turnberry Golf Club, Brampton. Stantec Consulting Engineers. 2008. Prepared for Eagles Nest Golf Club Inc.
- File Number 4431-7JXLN9 Permit To Take Water, Surface Water. Ontario Ministry of the Environment (MOE). November 2008.
- File Number. 1-03-0114. Hydrogeologic Evaluation, City of Brampton, Condition 13, TACCPAR North Subdivision, Brampton, Ontario. Terraprobe Limited. May, 2003. Prepared for Taccpar North Developments Inc.

3.3.2 Methods

A review of previous geological interpretations was undertaken, with a focus on the Brampton Esker. Three key cross-sections, which highlight the regional geology and hydrogeology, were generated using Viewlog® software developed by EarthFx Inc. The most recent York-Peel-Durham-Toronto - Conservation Authority Moraine Coalition (YPDT-CAMC) issued database of 2006, along with geological surfaces prepared for Toronto and Region Conservation Authority (TRCA) technical work program under the *Clean Water Act, 2006* were used for this work. The Viewlog® software allows complete control and analysis of well log data, three-dimensional (3-D) geologic modelling, interpretation and visualization.

TRCA staff extracted the water budget parameters for the study area from the TRCA-wide water budget model prepared as part of the *Tier 1/Tier 2 Water Budget, TRCA Watersheds* (Draft - TRCA. Details of the development of water budget are shown in the **Water Budget Section 3.4.5).**

Groundwater level monitoring is an important ongoing activity from which the data can be used to assess seasonal groundwater fluctuation in both shallow and deep aquifers as well as long term trends. Under the Provincial Groundwater Monitoring Network (PGMN) program, TRCA operates two groundwater monitoring wells within the study area, both of which are located in the Heart Lake Conservation Area. State-of- the-art data loggers and pressure transducers record hourly groundwater levels in these wells. The transducer measures the total pressure head while the data loggers store the information along with the date and time. Data from each logger is either downloaded through a telemetric system or during a site visit by TRCA field technicians. The assessment of the water level data is detailed in the **Groundwater Levels Section 3.5.3.**

In addition to water level monitoring, TRCA previously completed a two month long program for measuring infiltration rates for various soil types using a Guelph Permeameter in the Upper Etobicoke Creek headwater area bounded by Old School Road to the north, Heart Lake Road to the east, Mayfield Road to the south and Chinguacousy Road to the west. Seepage meters and mini-piezometers were used to measure groundwater discharge rates at specific locations of interest. The field program confirmed the low permeability rates of the native surficial soil. The study also concluded that most of the upper reaches of Etobicoke Creek exhibited groundwater contribution (as seeps) to segments of the watercourse (TRCA, 2005). As the groundwater discharge measurements were taken at each subject location only once during the limited monitoring program, assessment of seasonal discharge variation and permanence of such contributions could not be undertaken.

3.4 EXISTING CONDITIONS AND INTERPRETATION

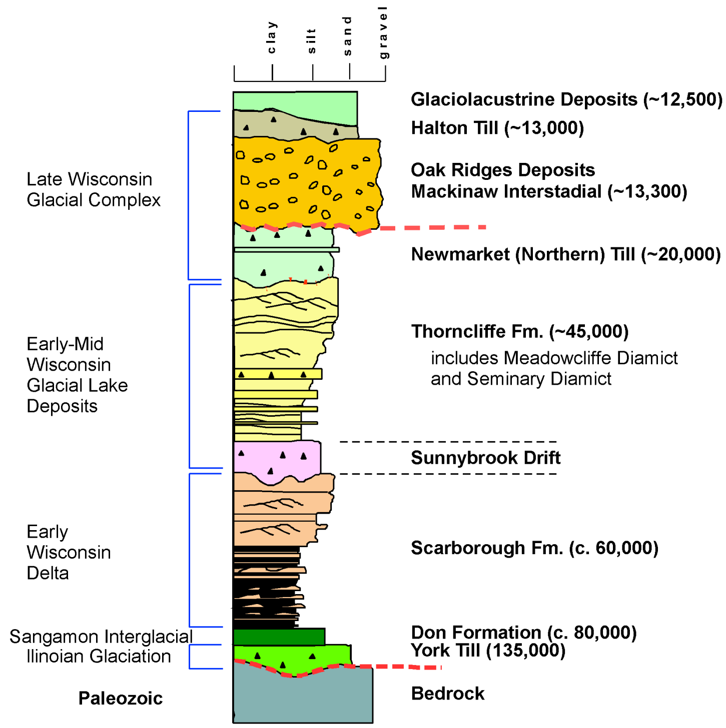
3.4.1 Hydrogeologic Units

This section builds on the geologic framework presented in **Section 2.0** and describes the groundwater flow paths through the various hydrogeologic layers. It is important to note that the "aquifers" are not homogeneous and may locally contain higher or lower amounts of fine grained sediments, such as silt and clay. The hydrogeology of the study area is dominated by aquitards, with the Oak Ridges Aquifer north of Mayfield Road, a buried east-west trending bedrock valley along Steeles Avenue, and the Brampton Esker in north Brampton.

The eight hydrostratigraphic units which are considered to influence groundwater flow within the Etobicoke and Mimico Creeks watersheds are listed below and illustrated in **Figure 3-1.**

Layer 1: Surficial Aquifer (recent deposits and weathered Halton Till),
Layer 2: Halton Aquitard,
Layer 3: Oak Ridges Aquifer (or equivalent) Complex / Mackinaw Interstadial (ORAC),
Layer 4: Newmarket Aquitard,
Layer 5: Thorncliffe Aquifer Complex (TAC),
Layer 6: Sunnybrook Aquitard,
Layer 7: Scarborough Aquifer Complex (SAC),
Layer 8: Weathered Bedrock

Figure 3-1: Hydrostratigraphic Layers



Characteristics of the hydrostratigraphic units that influence the flow of groundwater in these watersheds include:

- Configuration of the bedrock valleys and their degree of connection with other aquifers;
- Thickness and lateral extent of the aquitards which separate the shallow and deeper groundwater systems; and
- Thickness, lateral extent, and nature of the sediments in the aquifer complexes.

Figure 3-2 shows the locations where three cross-sections were constructed from the hydrogeologic model. These cross-sections illustrate the hydrostratigraphic layers present along Mimico Creek, Etobicoke Creek, and within the Heart Lake Wetland Complex, as shown in **Figure 3-3, Figure 3-4**, and **Figure 3-5,** respectively. Three principal regional aquifer systems exist across the study area. The succession of aquifers from the deepest to shallowest are: the Scarborough Aquifer Complex (SAC), the Thorncliffe Aquifer Complex (TAC), and the Oak Ridges Aquifer (or equivalent) Complex (ORAC). Separating each aquifer are aquitard layers, including the Halton Aquitard, which overlies the ORAC; the Newmarket Aquitard that separates the ORAC from the Thorncliffe Aquifers, and the Sunnybrook Aquitard that separates the Thorncliffe and Scarborough Aquifers.

Figure 3-2: Etobicoke and Mimico Creeks Watersheds Cross-Section Locations

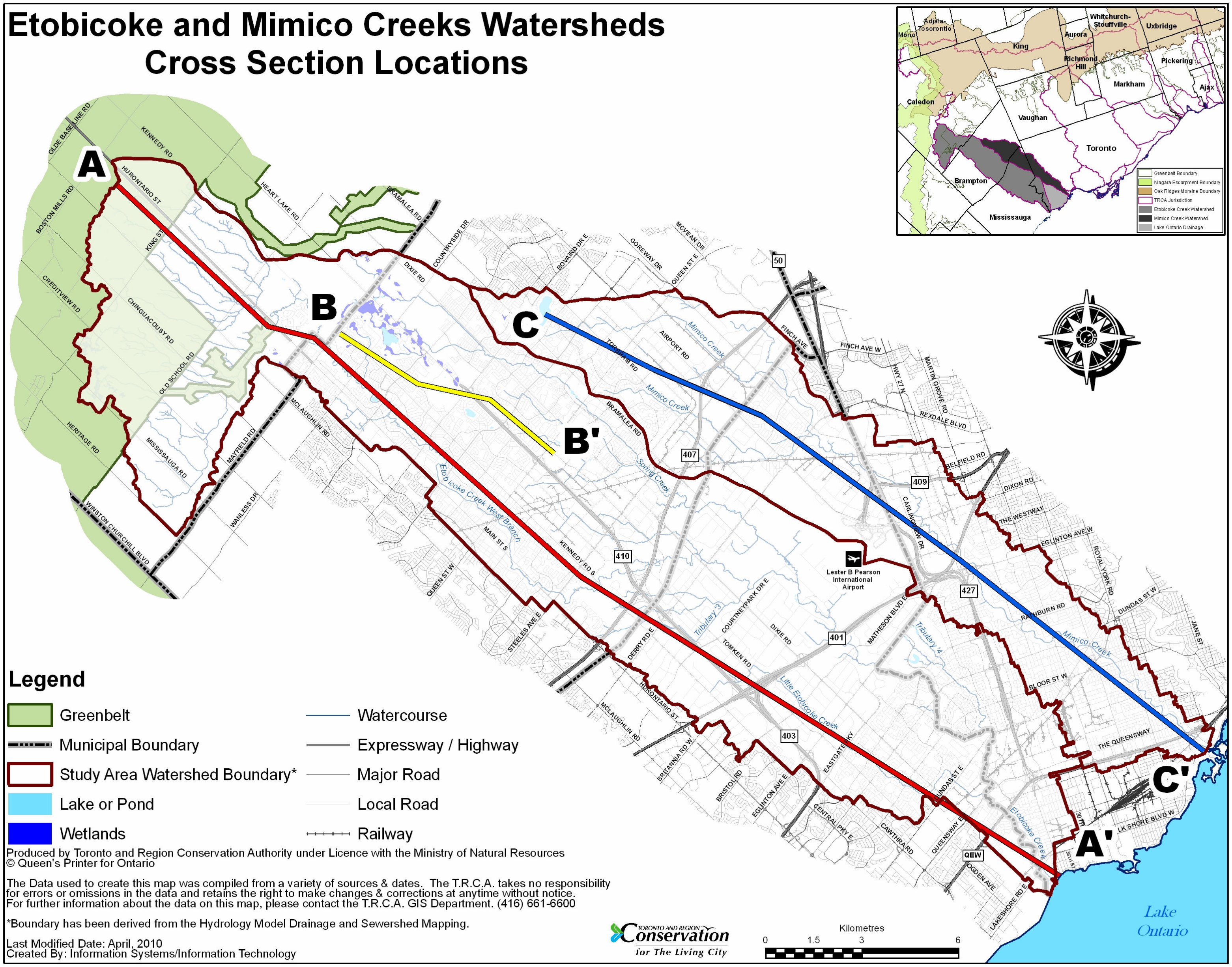


Figure 3-3: Cross-Section along Mimico Creek

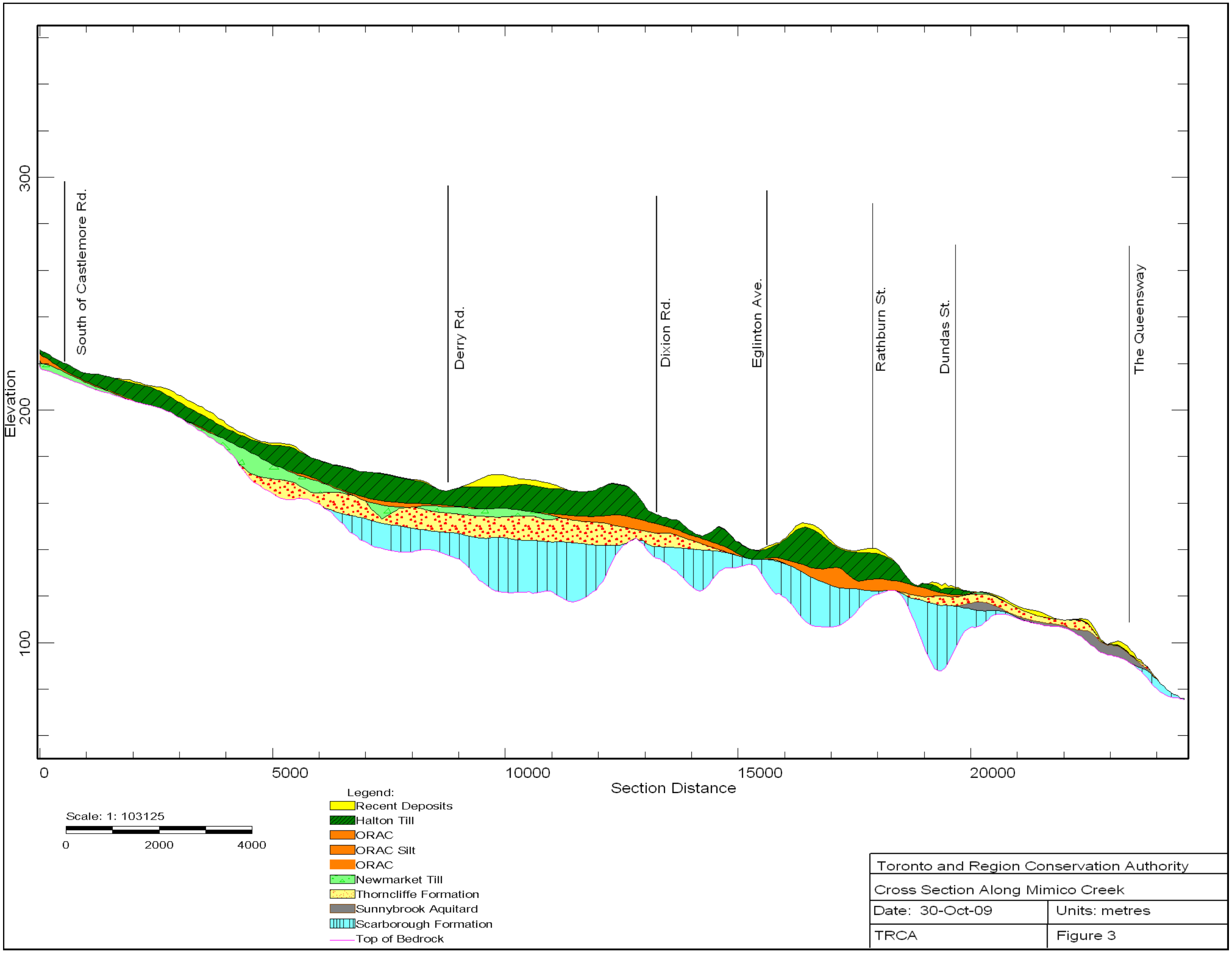


Figure 3-4: Cross-Section along Etobicoke Creek

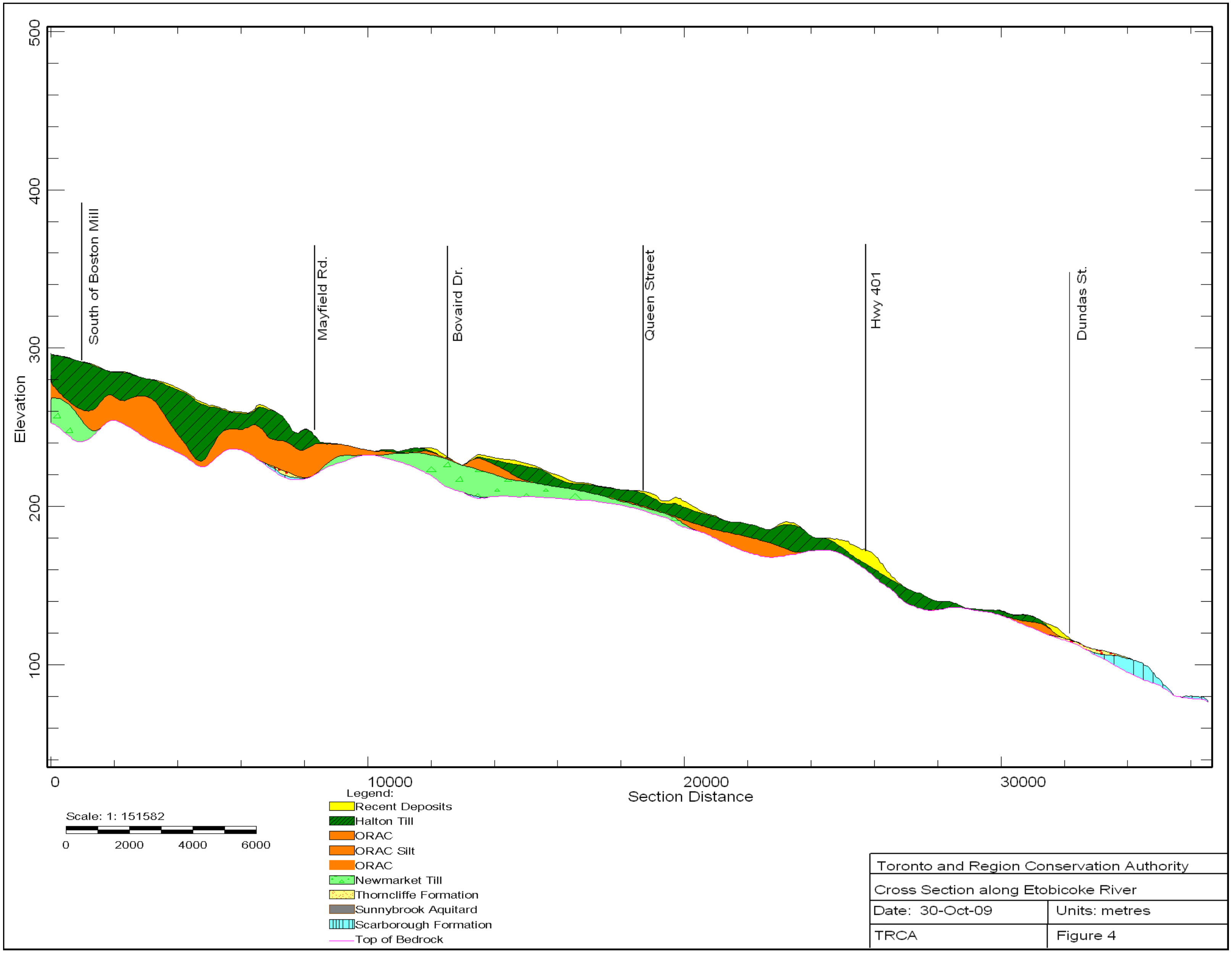
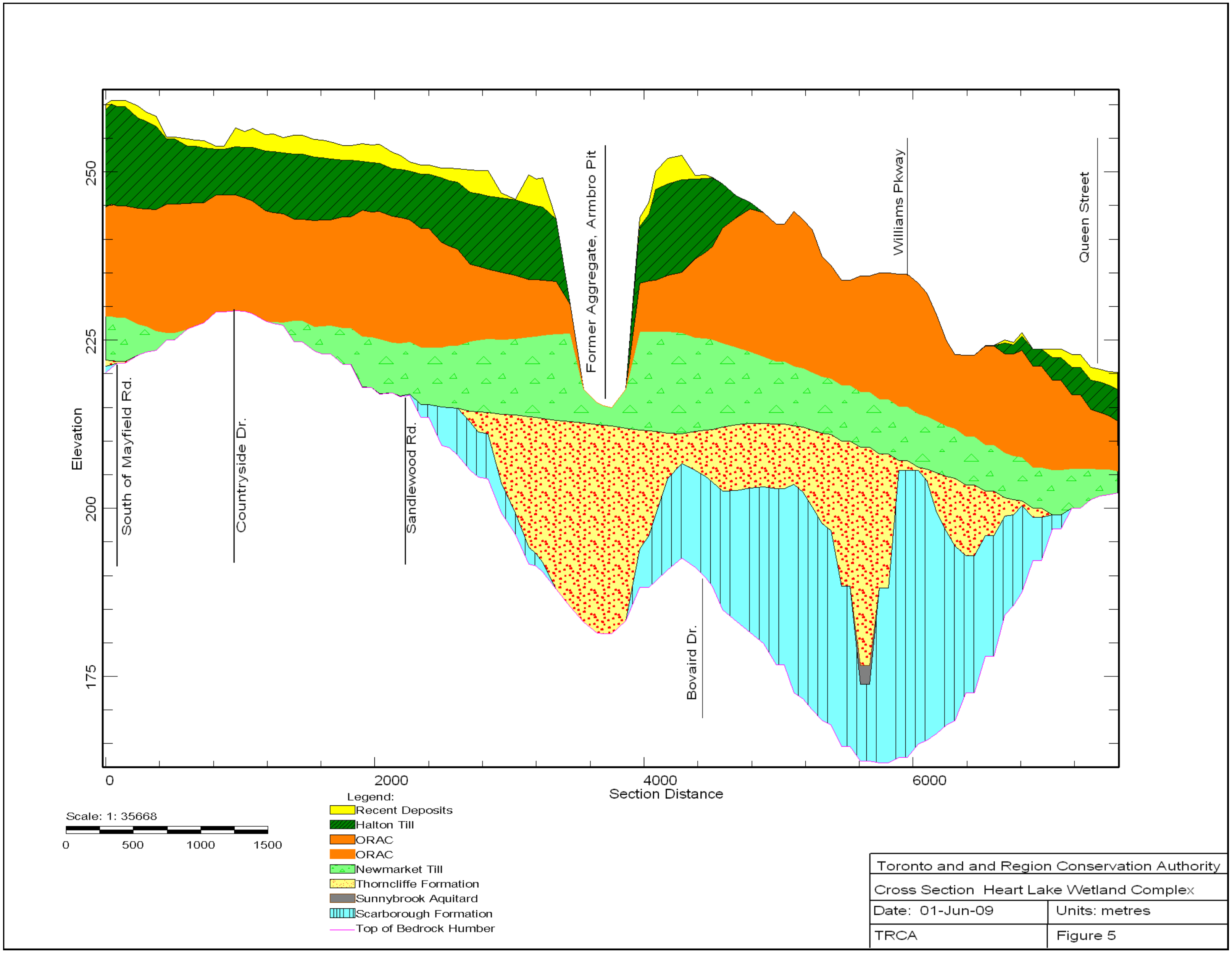


Figure 3-5: Cross-Section within Heart Lake Wetland Complex



Variances in aquifer thicknesses are interpreted across the Etobicoke and Mimico Creeks watersheds as follows:

- The Oak Ridges Aquifer (or equivalent) Complex is thickest (approaching 30 metres) north of Mayfield Road;
- The Brampton Esker (in places, up to about 25 metres thick) is a localized, linear feature along Highway 410 between Mayfield Road and Queen Street that has been grouped with the Oak Ridges Aquifer (or equivalent) Complex as an equivalent hydrostratigraphic unit (see **Figure 3-6**);
- The Thorncliffe Aquifer, within the Etobicoke Creek watershed is located in the Bovaird Drive / Highway 410 area in Brampton and to a greater extent (up to about 10 metres thick) in the extreme northwest corner of the watershed (see **Figure 3-7**);
- The Thorncliffe Aquifer is greatest within Mimico Creek watershed (in the vicinity of 10 metres) south of Highway 401 and east of Highway 427;
- The Scarborough Aquifer is thickest (up to about 30 metres) in the central portion of both the Etobicoke and Mimico Creeks watersheds (see **Figure 3-8**).

3.4.2 Groundwater Recharge

Groundwater recharge is less than 100mm/ year across most of the study area; because the surficial soils are dominated by silt and sandy silt till (for more details refer to **Section 2.0**, **Figure 2-3**). The exception is the Brampton Esker, with estimated recharge of close to 380 mm/ year (in its current form).

3.4.3 Groundwater Levels

Groundwater levels fluctuate naturally depending on seasonal patterns of precipitation and evapotranspiration. Creation of impervious surfaces (e.g. pavement, building roofs, etc.) reduces infiltration, especially when land use changes occur from mainly rural agricultural to urban settings. The degree of change is dependent on the percentage increase in impervious cover, and the mitigation techniques used to counter the reduced infiltration. The lowering of groundwater levels changes the hydraulic gradients which, in turn, reduce the volume of groundwater discharge.

Groundwater level elevations are highest in the headwater areas of both watersheds, for each of the three main aquifer systems, as shown on **Figure 3-9, Figure 3-10,** and **Figure 3-11**. Consequently, groundwater flows primarily from the headwater areas in the northwest toward Lake Ontario.

Figure 3-6: Oak Ridges Aquifer (or equivalent) Thickness (m)

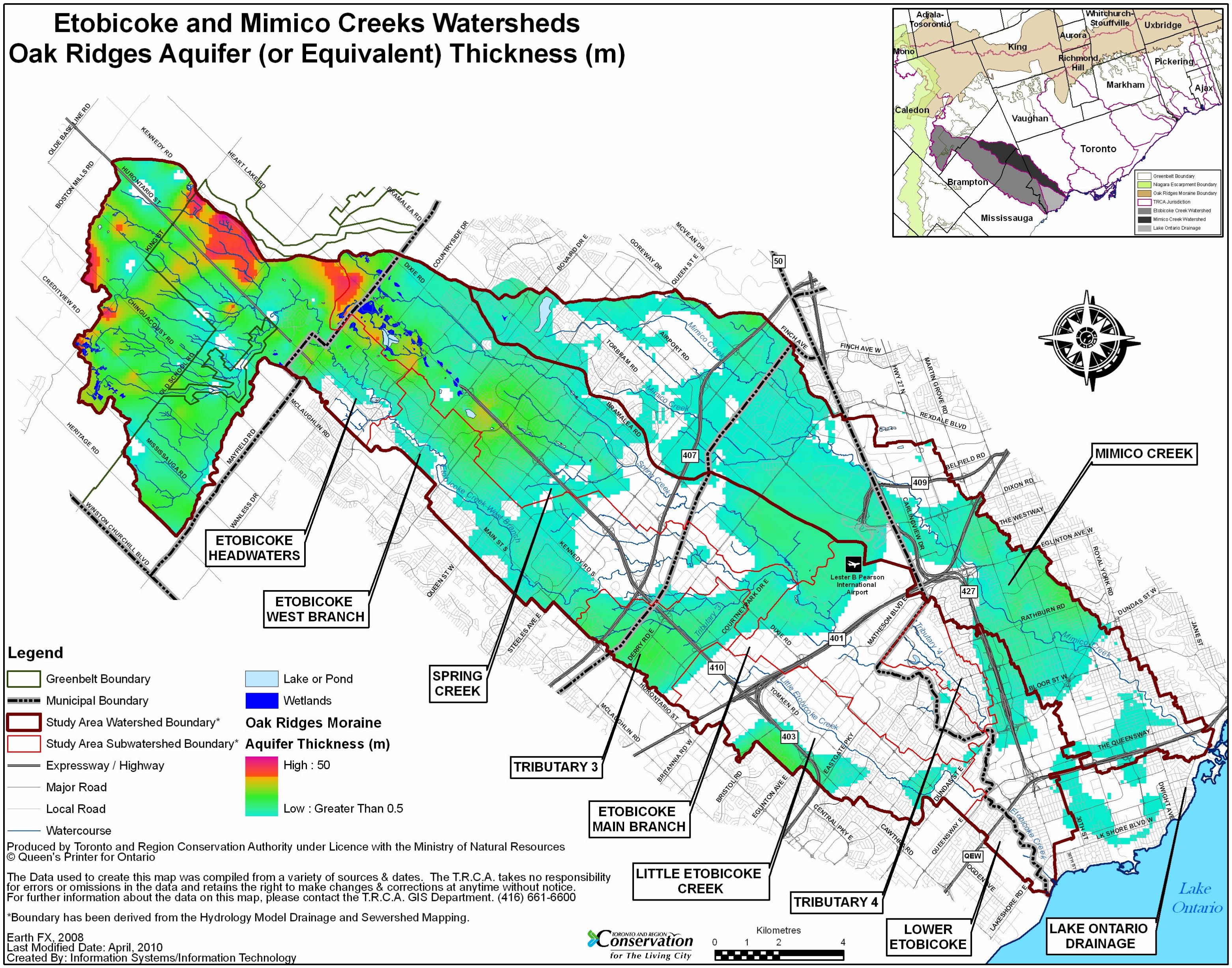


Figure 3-7: Thorncliffe Aquifer Thickness (m)

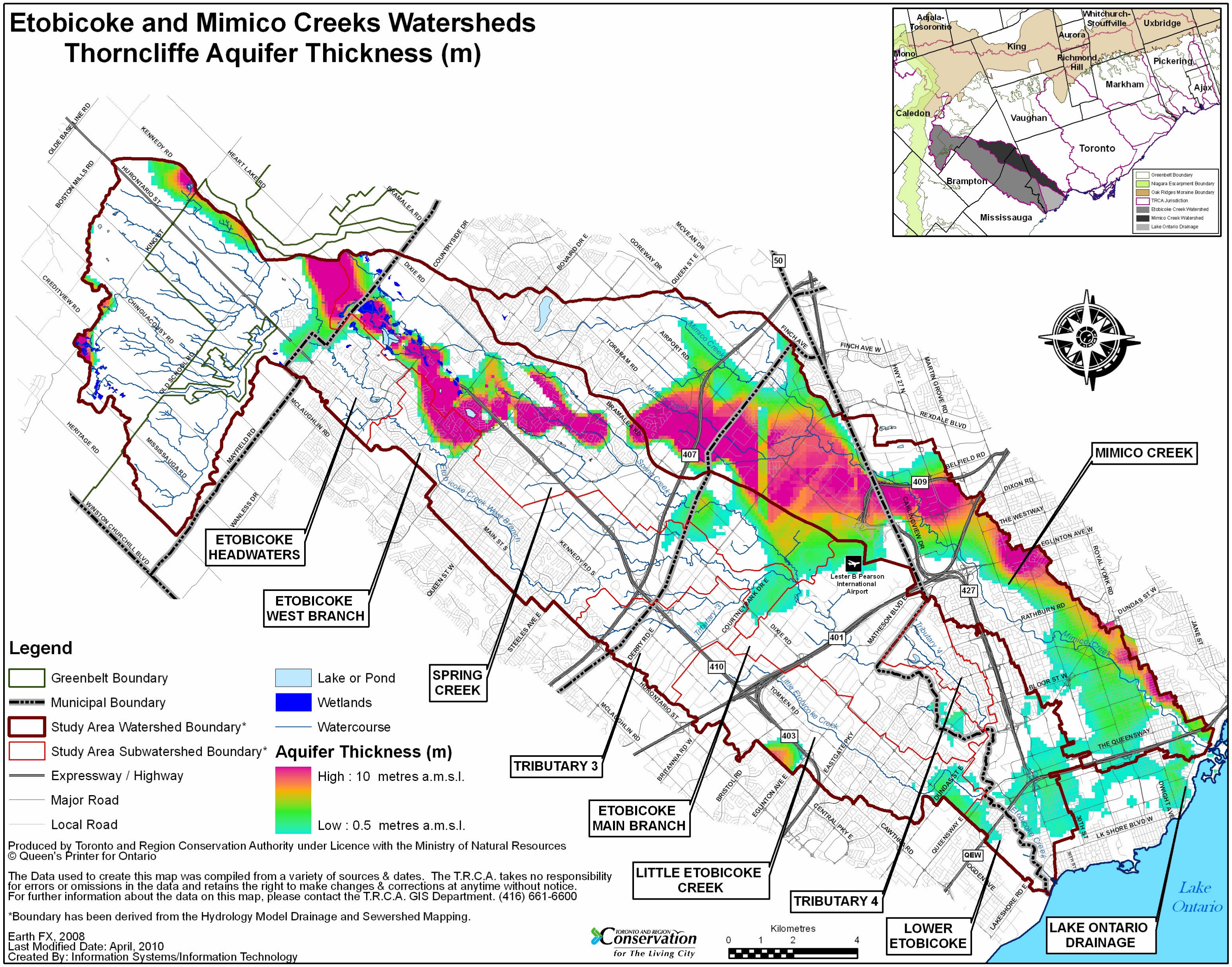


Figure 3-8: Scarborough Aquifer Thickness (m)

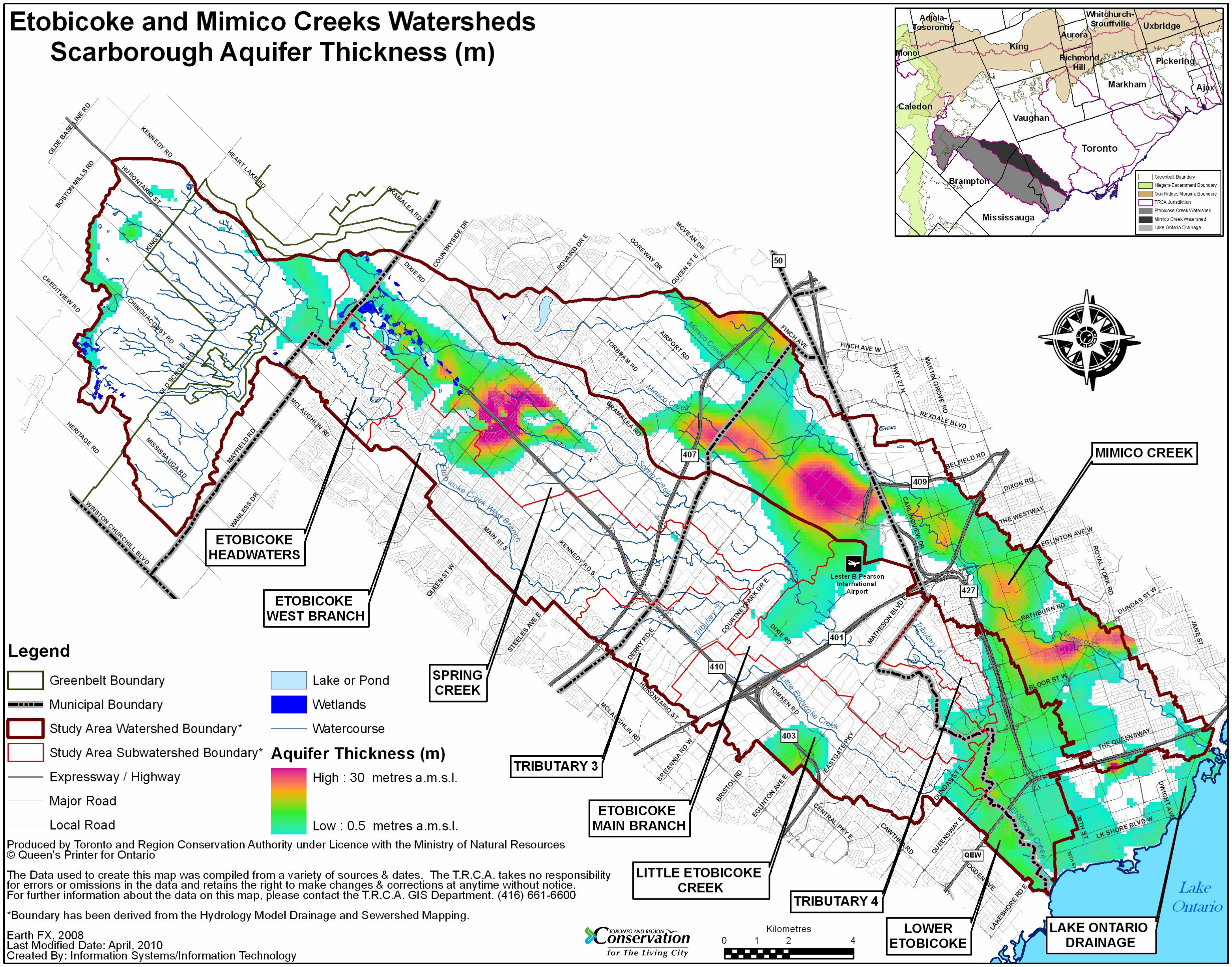


Figure 3-9: Groundwater Levels – Oak Ridges Aquifer (or equivalent)

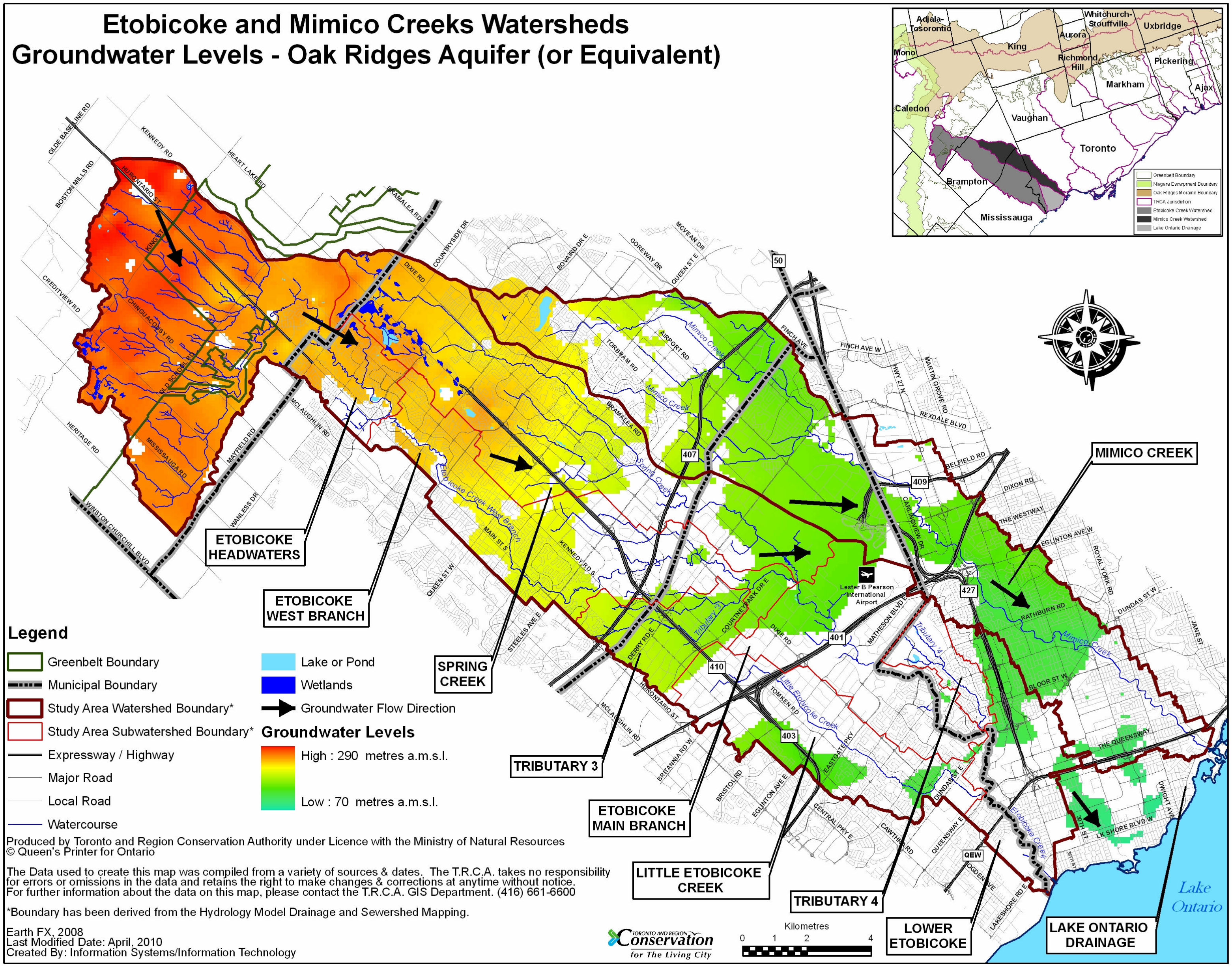


Figure 3-10: Groundwater Levels – Thorncliffe Aquifer Complex

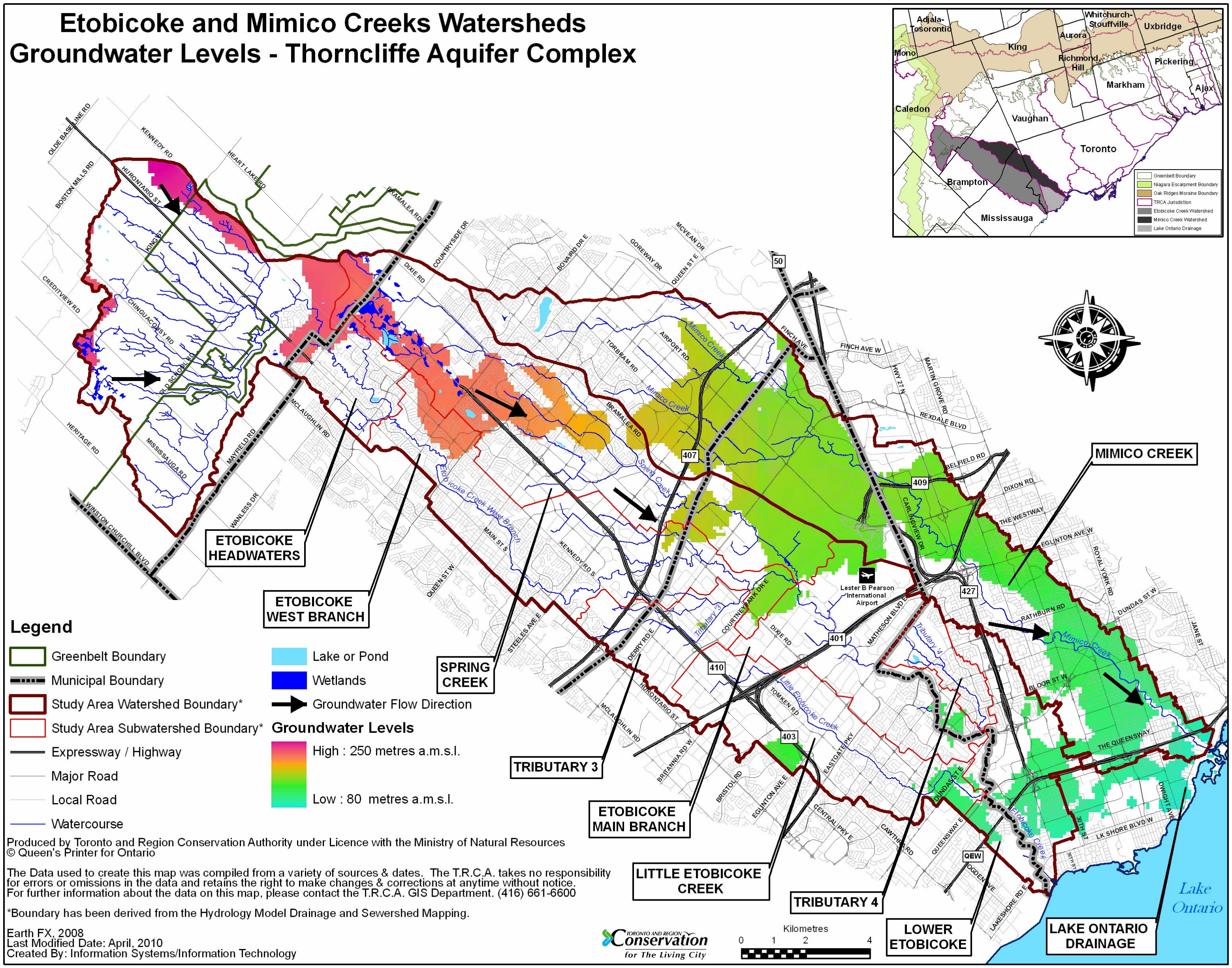
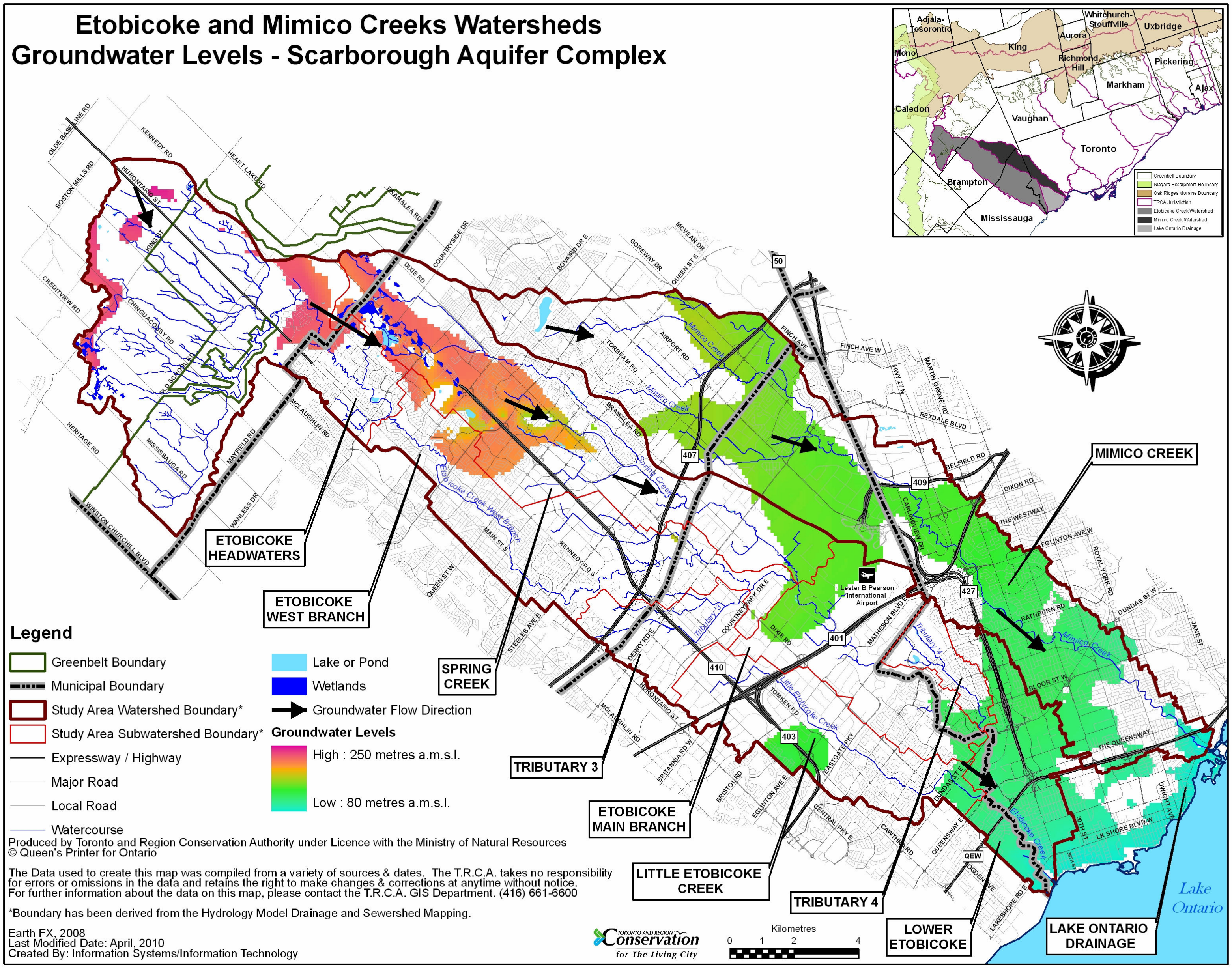


Figure 3-11: Groundwater Levels – Scarborough Aquifer Complex



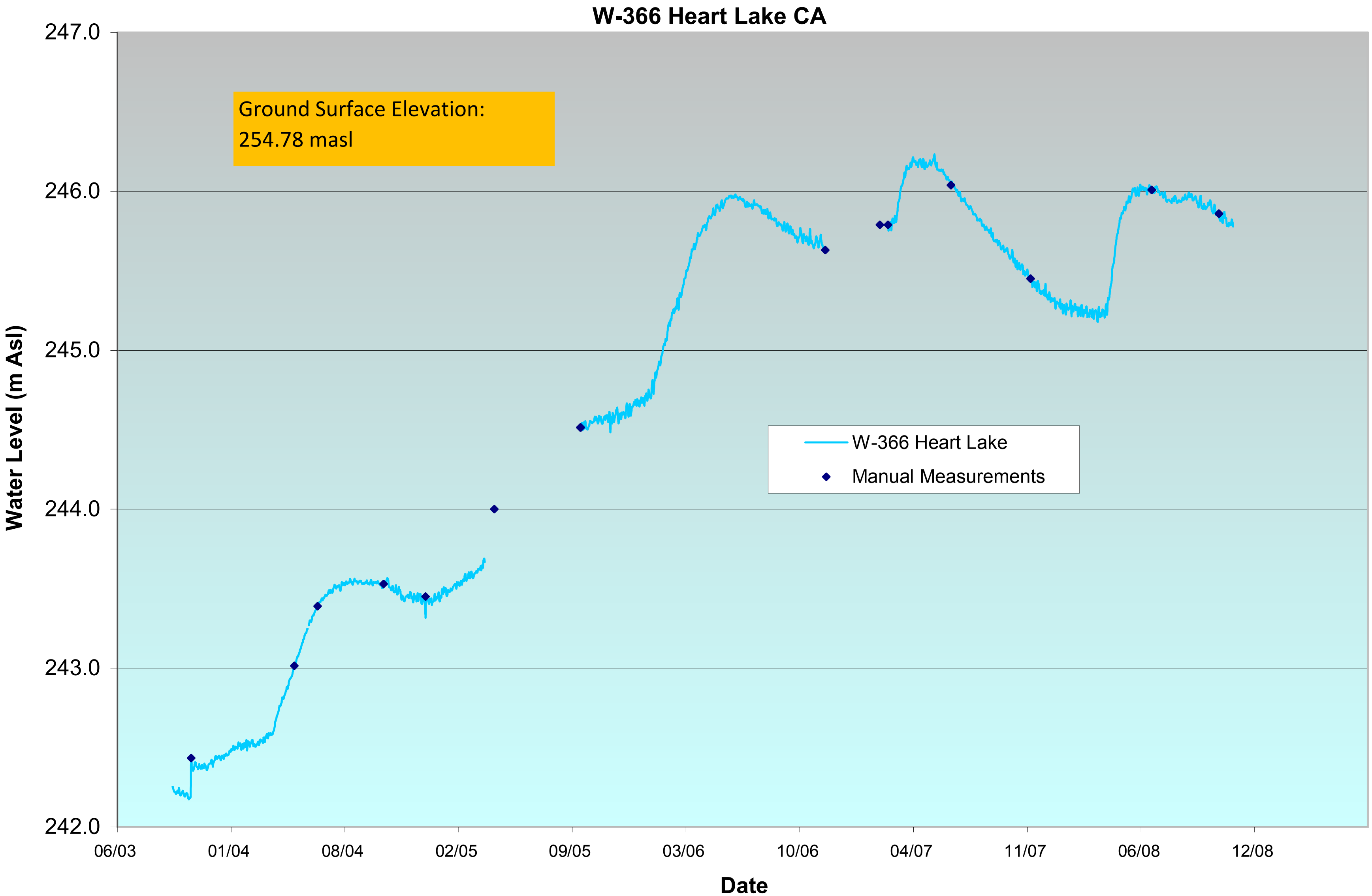
The water level data from the two Provincial Groundwater Monitoring Network (PGMN) wells situated within the Heart Lake Conservation Area are summarized below. Groundwater hydrographs for Wells W-366 (see **Figure 3-12**) and W-021 (see **Figure 3-13**) indicate rising water levels of about 4.0 and 3.4 meters respectively. The original water table in this area was between 5 and 15 m below grade.

The two PGMN monitoring wells are approximately 2.2 kilometers and 2.7 kilometers respectively from the former Armbro - Bovaird gravel pit (located north of Bovaird Drive and west of Heart Lake Road). As groundwater levels recover within the former gravel pit, it is expected that baseflow in the West Branch of the Etobicoke Creek watercourse will increase. Further information is provided in the **Baseflow and Water Use Section**.

This gravel pit was in operation from about 1955 to 1990 (Morrison *et al.,* 1983, Schnaar, 1994). Once the sand and gravel were removed from above the water table, further extraction below the water table was achieved by dewatering below the depth of excavation. Historical studies suggest that aggregate extraction did not reach the water table until about 1957 (Morrison Beatty *et al.,* 1983). It was after this time that pit operators undertook aquifer dewatering. Also, between 1964 and 1972, the Town of Brampton (now the City of Brampton)pumped water from the Brampton Esker for its municipal water supply, which reduced the dewatering requirements of the aggregate operations (ibid). Once pit dewatering for aggregate extraction was discontinued in 1990 (Schnaar, 1994), groundwater levels within the remaining esker granular materials began to recover. Evidence of later recovery has been documented in TRCA's groundwater monitoring wells in the Heart Lake Conservation Area as mentioned earlier.

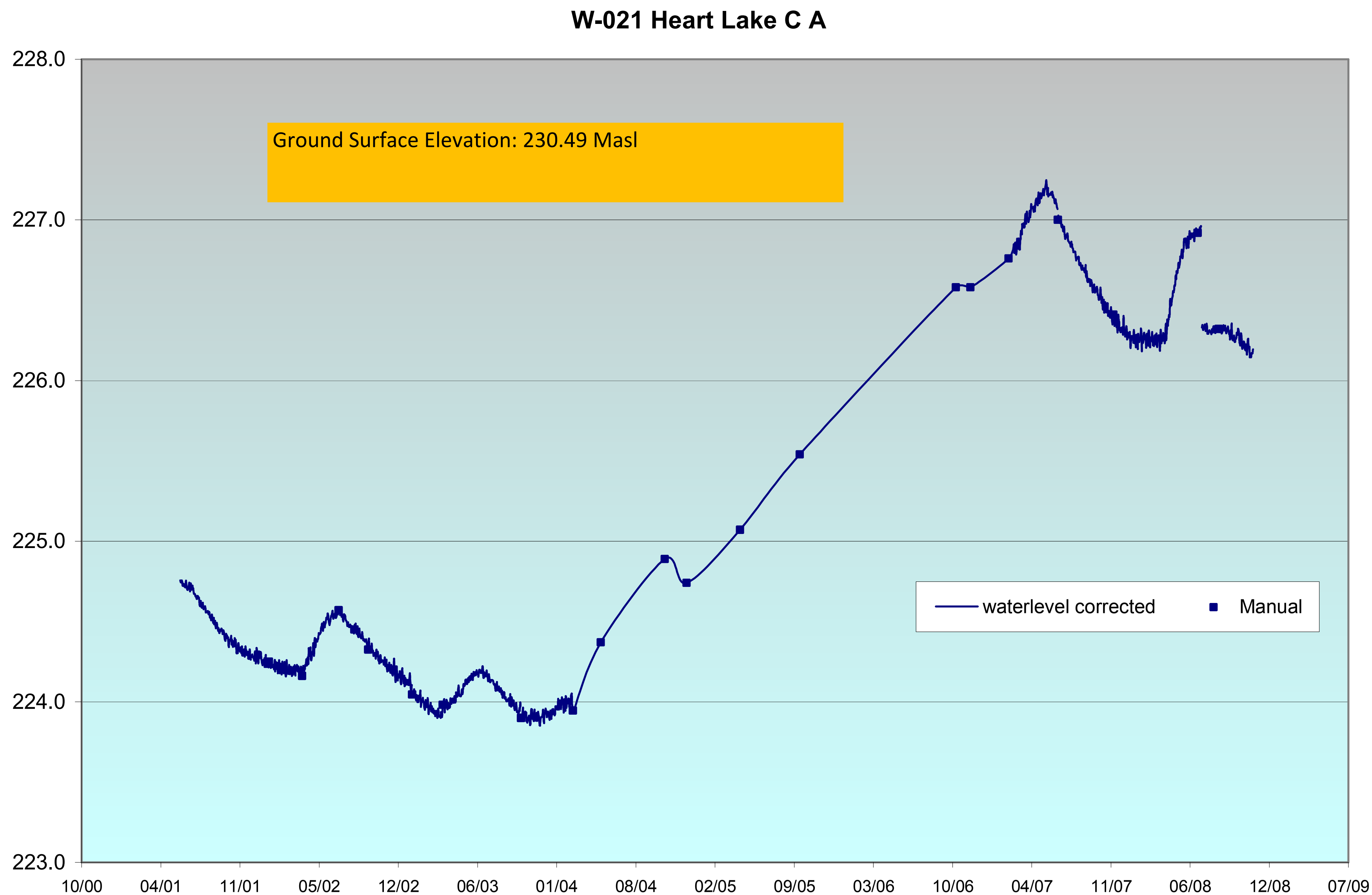
Three geologic cross-sections from the Morrison report, reproduced as **Figure 3-14** and **Figure 3-15**, depict the type of overburden deposits, their interpreted correlation (geologic contacts) along each section, the water table location and interpreted groundwater flow directions. The natural groundwater flow in the esker is from the northwest to southeast, but was locally altered by the dewatering for the aggregate operations and groundwater use by the City of Brampton. Once the aggregate operations and the dewatering ceased, pit rehabilitation efforts were undertaken. Backfill materials consisted of silt till material removed from urban building construction sites in the region.

Figure 3-12: Groundwater hydrographs for Well W-366 [1]



[1] Well W-366 is located on the south shore of Heart Lake.

Figure 3-13: Groundwater hydrographs for Well W-021 [2]



[2] Well W-021 is located southwest of Heart Lake Road at Country Side Drive

Figure 3-14: Geologic Cross-Sections from the Morrison Report (North, West-East)

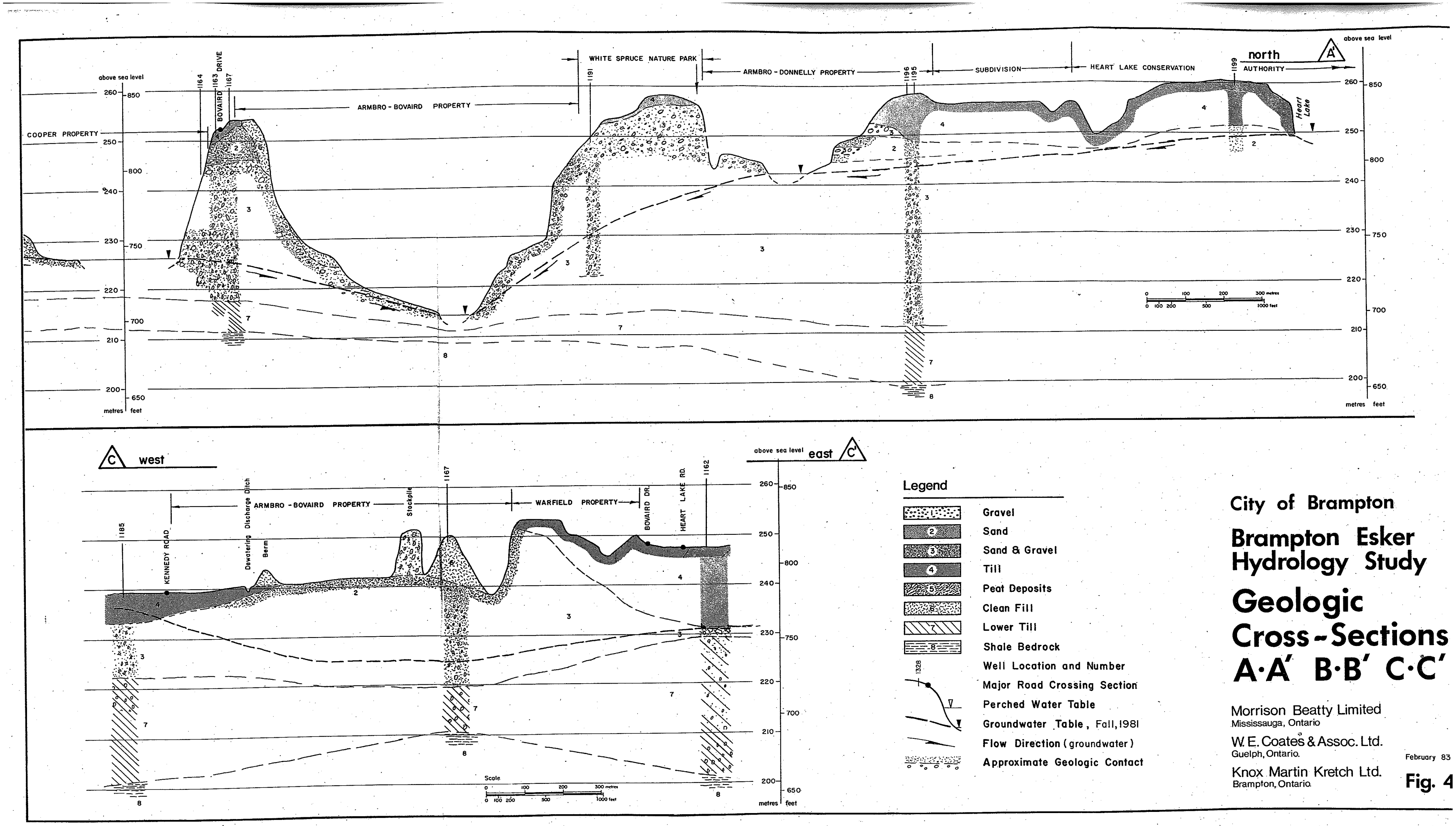
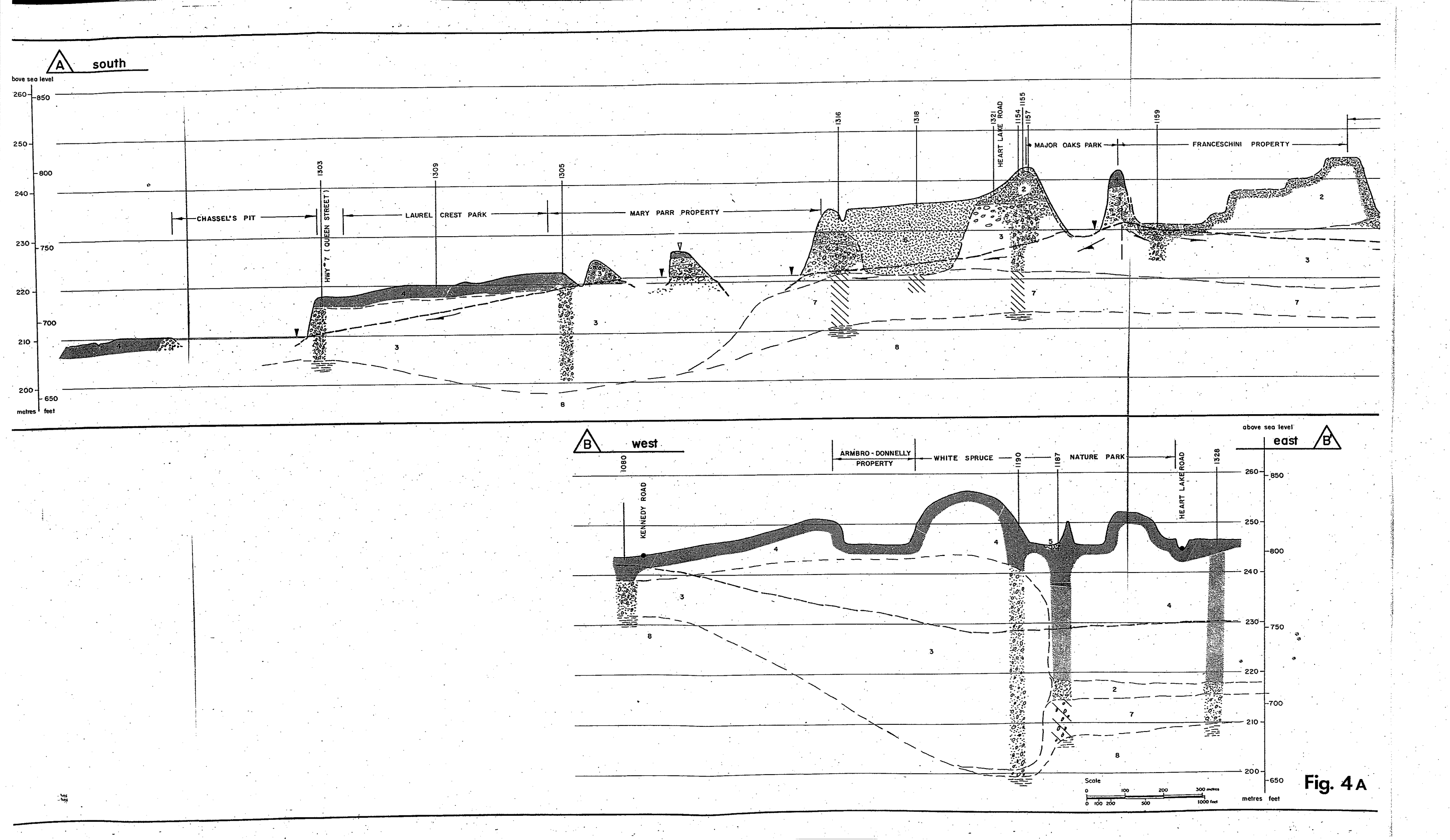


Figure 3-15: Geologic Cross-Sections from the Morrison Report (South, West-East)

[redacted]



3.4.4 Groundwater Modelling

Groundwater and surface water models can be used to estimate water budget components, depict groundwater flow, and estimate groundwater fluxes. The outputs can also be used to predict contaminant transport and estimate groundwater levels in areas where monitoring data are not available. This is particularly important within the study area, since only two monitoring points currently exist. It must be recognized however, that all models are simplifications of reality, and that there is always uncertainty associated with the mapping of geologic units below ground surface.

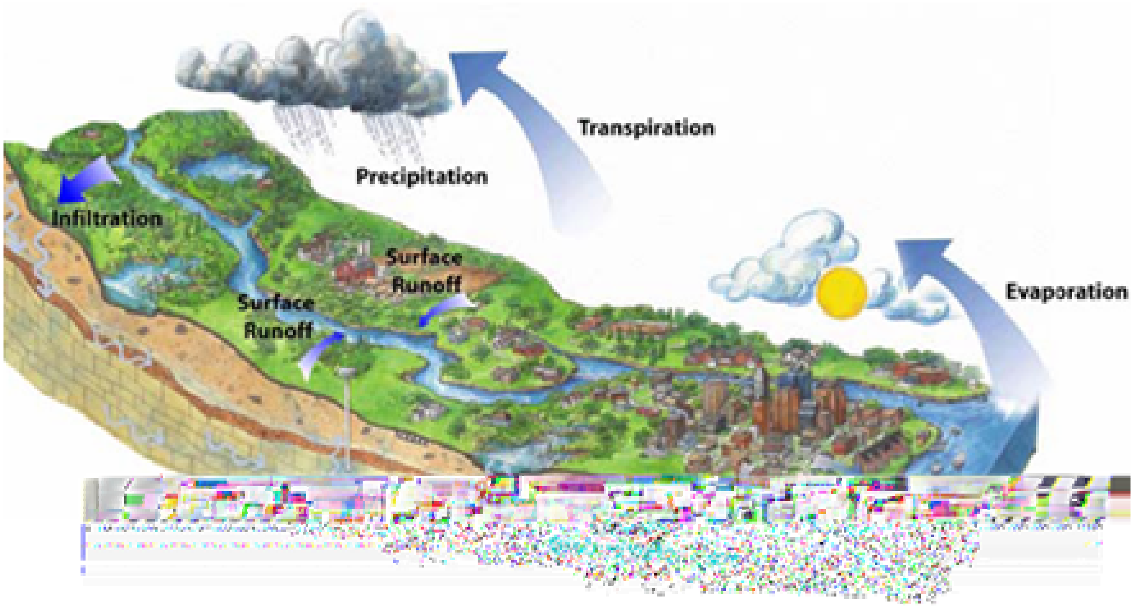
The YPDT-CAMC has developed a calibrated groundwater model for TRCA watersheds using the United States Geological Survey (USGS) program code referred to as MODFLOW (three-dimensional MODular FLOW System). TRCA has linked this groundwater model with a continuous surface water model (PRMS: Precipitation - Runoff Management System, also developed by the USGS). The PRMS model uses climate, topography, and land cover data to evaluate the impacts of various combinations on stream flow. The PRMS model allows for evaluation in changes to water balance relationships and groundwater recharge.

The groundwater model simulates the groundwater system across a geographic area spanning from Mississauga eastward to Pickering, and from Lake Simcoe southward to Lake Ontario. The model predicts water levels in each of the eight hydrostratigraphic layers, directions and rates of groundwater flow and groundwater discharge areas and rates (Kassenaar and Wexler, 2006). Field measurements of such parameters as recharge and discharge rates, water levels in wells and boreholes, and stream flow have been used to validate the input parameters of the groundwater flow model. **Section 3.4.5** describes in detail the technical findings as produced by this model run for Etobicoke and Mimico Creeks watersheds data parameters.

3.4.5 Water Budget

A water budget describes in a quantitative manner the major components of the hydrologic cycle within a watershed and then provides a measure of the balance that exists in the system. The process is cyclical and referred to as the hydrologic cycle, shown in **Figure 3-16.** Inputs are precipitation, groundwater or surface water inflows; which must equal the outputs of evapotranspiration, water supply removals (or abstractions), surface or groundwater outflows, as well as any changes in storage within the area of interest (MOE, 2007).

Figure 3-16: Hydrologic Cycle



The quantitative equation of the water budget is as follows:

Inputs = Outputs + Change in Storage, or

$$P + SW_{IN} + GW_{IN} + ANTH_{IN} = ET + SW_{OUT} + GW_{OUT} + ANTH_{OUT} + \Delta S$$

Where:
- P = precipitation
- SW_{IN} = surface water flow into the watershed
- GW_{IN} = lateral groundwater flow into the watershed
- $ANTH_{IN}$ = anthropogenic or human inputs such as waste discharges
- ET = evapotranspiration
- SW_{OUT} = surface water flow out (includes runoff)
- GW_{OUT} = groundwater flow out (to Lake Ontario)
- $ANTH_{OUT}$ = discharge to wells (i.e., drinking water supplies)
- ΔS = change in storage (surface water, soil moisture, groundwater)

The net loss to the local hydrologic system is the difference between precipitation and stream flow, due to the combined effect of evaporation and plant transpiration (referred to as evapotranspiration). The difference between total precipitation and evapotranspiration is generally referred to as water surplus. The water surplus may be partitioned between the water that infiltrates into the ground (groundwater recharge), and that which enters local streams as surface run-off. Since the groundwater recharge usually re-enters the watercourses as groundwater discharge, baseflow separation techniques assist in achieving this partitioning (Veissman *et al*.,1989).

The overall water balance for Etobicoke Creek watershed is presented in **Figure 3-17** and **Figure 3-18** represents Mimico Creek watershed. Some of the key findings are summarized within the components of precipitation, evapotranspiration, runoff, groundwater recharge, storage, groundwater flow, groundwater discharge, water use, overall water balance, groundwater/surface water interactions.

Figure 3-17: Etobicoke Creek Water Balance

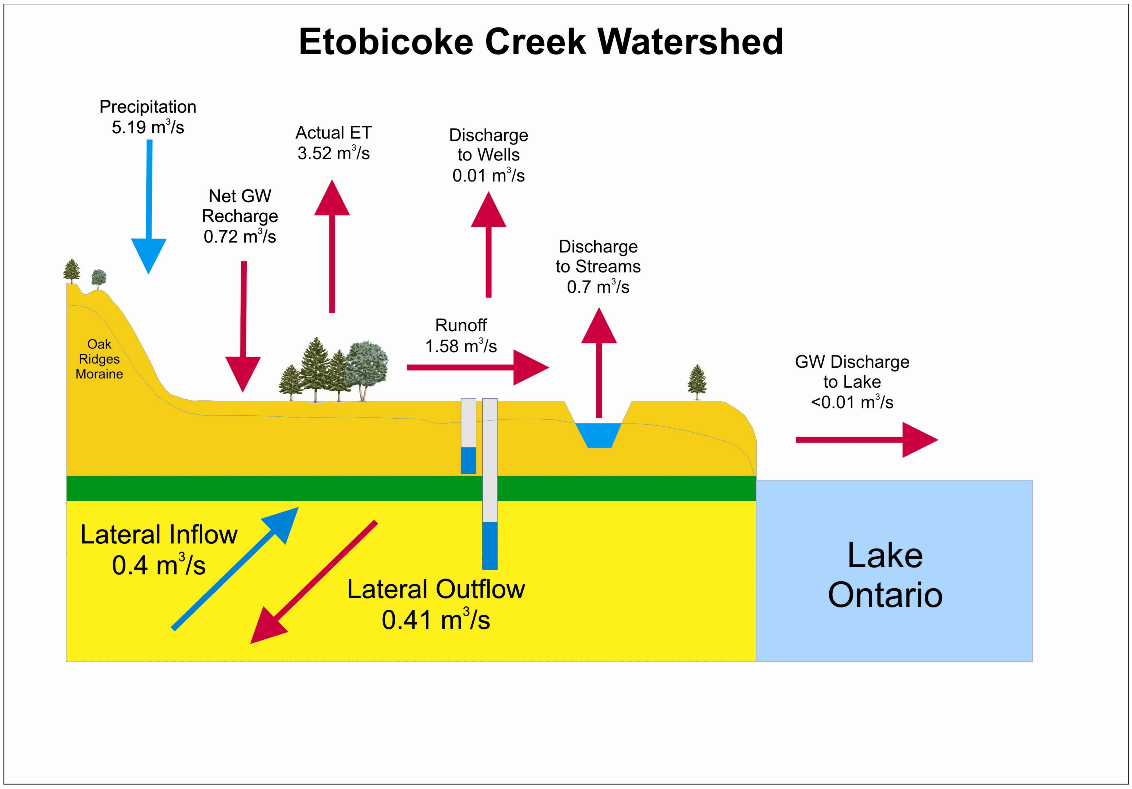
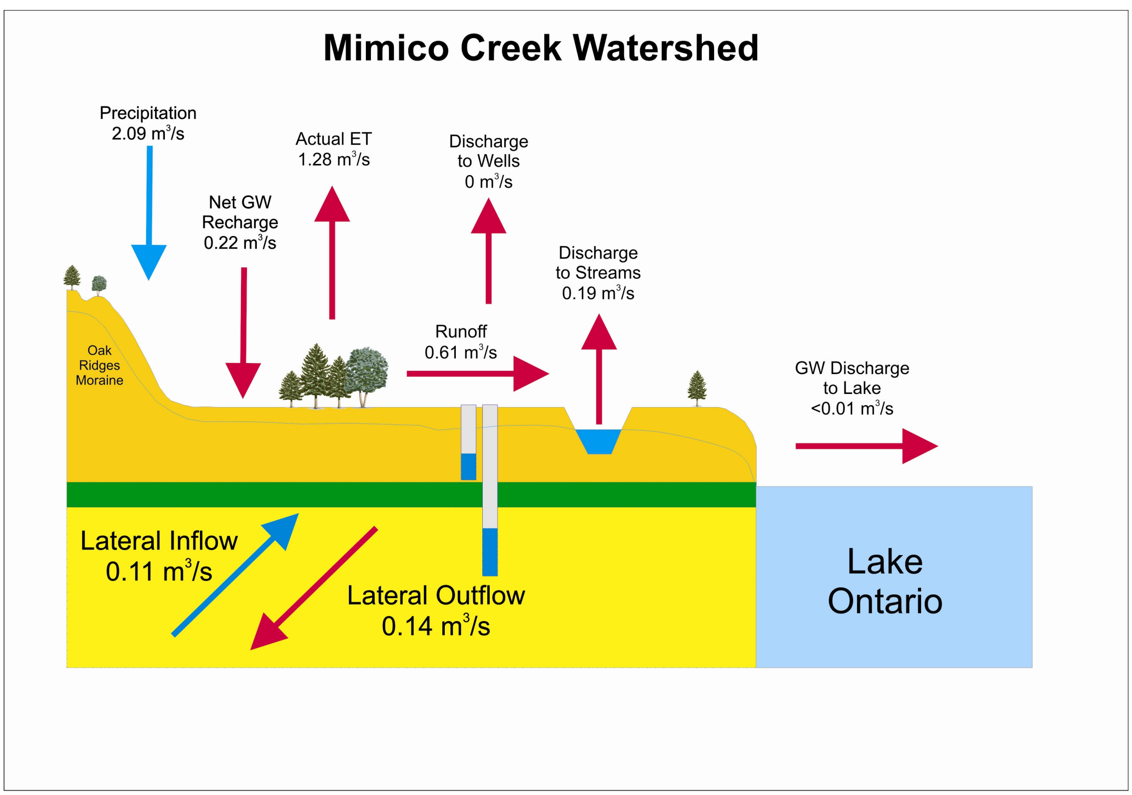


Figure 3-18: Mimico Creek Water Balance



Precipitation

Precipitation is the single input variable for the water budget calculations, and is partitioned into the various other components. A long history of precipitation records is available for the Toronto area. The data from these records indicate that precipitation varies across the watershed both spatially and temporally with local variations created by such factors as topography, prevailing winds and proximity to Lake Ontario. Average annual precipitation measured at 48 stations within the regional groundwater model (Core Model) area, which includes the TRCA watersheds, York Region, and parts of Peel and Durham Regions, ranged from 734 to 946 millimetres for the period of 1980 to 2002. There are nineteen climate stations within the Etobicoke and Mimico Creeks watersheds, and the average annual total precipitation ranges from 760 to 850 millimetres (Gerber and Holysh, 2005).

Evapotranspiration

Evapotranspiration is the combination of water lost, both due to evaporation from land surface and transpiration from plants.

Evaporation can be measured using calibrated evaporation pans, but such data are limited across the GTA. Plant transpiration rates are highly variable and not easily measured.

Due to the difficulties in obtaining the physical parameter measurements, evapotranspiration is usually calculated using empirical formulae based on calibrations in many watersheds (Thornthwaite and Mather, 1957) or estimated based on numerical modelling techniques. The mean annual potential evapotranspiration for the period 1971 to 2000 ranges from 575 mm/year along the moraine to 600 mm/year along the shore of Lake Ontario in the GTA. The mean annual evapotranspiration for the Great Lakes region including the Etobicoke and Mimico Creeks Watersheds is calculated to be 512 mm/year, based on output from the PRMS-based surface water model (TRCA Draft Tier 1 Water Budget, April 2009).

Runoff

Based on the PRMS model results, the water surplus ranges from 318 mm to 358 mm/year. The average water surplus for Etobicoke and Mimico Creeks watersheds is 342 mm/ year and 340 mm/ year respectively. In a simplistic and practical sense, the stream flow hydrograph based on daily average flows can be separated into two components - runoff and groundwater discharge. Interflow (unsaturated zone flow) is not explicitly estimated in this analysis but assumed to be included in either recharge or run-off. Average runoff for the Etobicoke and Mimico Creeks watersheds equates to 240 and 248 mm/year [1.58 and 0.61 m^3 /year] respectively.

Groundwater Recharge

Recharge or infiltration to the groundwater system occurs by the migration of precipitation through the surficial geology. The amount of recharge or infiltration at a specific site depends on the amount of precipitation evaporated back into the atmosphere, the amount of water transpired from natural vegetation to the air, site topography, type of vegetation and surficial soil type. Surficial geology influences recharge rates. Areas of hummocky topography exhibit higher recharge rates since soil run-off collects in depressions where it can then infiltrate through the surficial geology. Reduction in recharge within urban settings occurs due to paved driveways/roads or impermeable rooftop surfaces.

Vegetative cover also affects infiltration because plants intercept precipitation and surface run-off, reducing the surface sheet flow velocity, thus allowing water more time to infiltrate. Root structures increase the permeability of the surface soils by creating secondary porosity. This porosity also provides short-term groundwater storage. The total amount of water retention varies with vegetation type.

The surficial geology of the study area is dominated by low permeability glacial tills, and the estimated average annual recharge rates for the Etobicoke Creek and Mimico Creeks watersheds are 103 mm/year and 94 mm/year, respectively. The highest annual groundwater recharge in the Etobicoke Creek watershed is estimated to be about 380 mm/year within the Heart Lake Wetland Complex in the north part of Brampton (see **Figure 3-19**). The Mimico Creek watershed has two small areas estimated to have annual groundwater recharge rates of up to about 340 mm/year. The first patch is located south of the Torbram and Castlemore Road intersection, with the second in the Dundas Street East and Islington Avenue area. The increased rates of recharge in the two patches are associated with infiltration into remnants of Lake Iroquois Shoreline sand deposits.

Storage

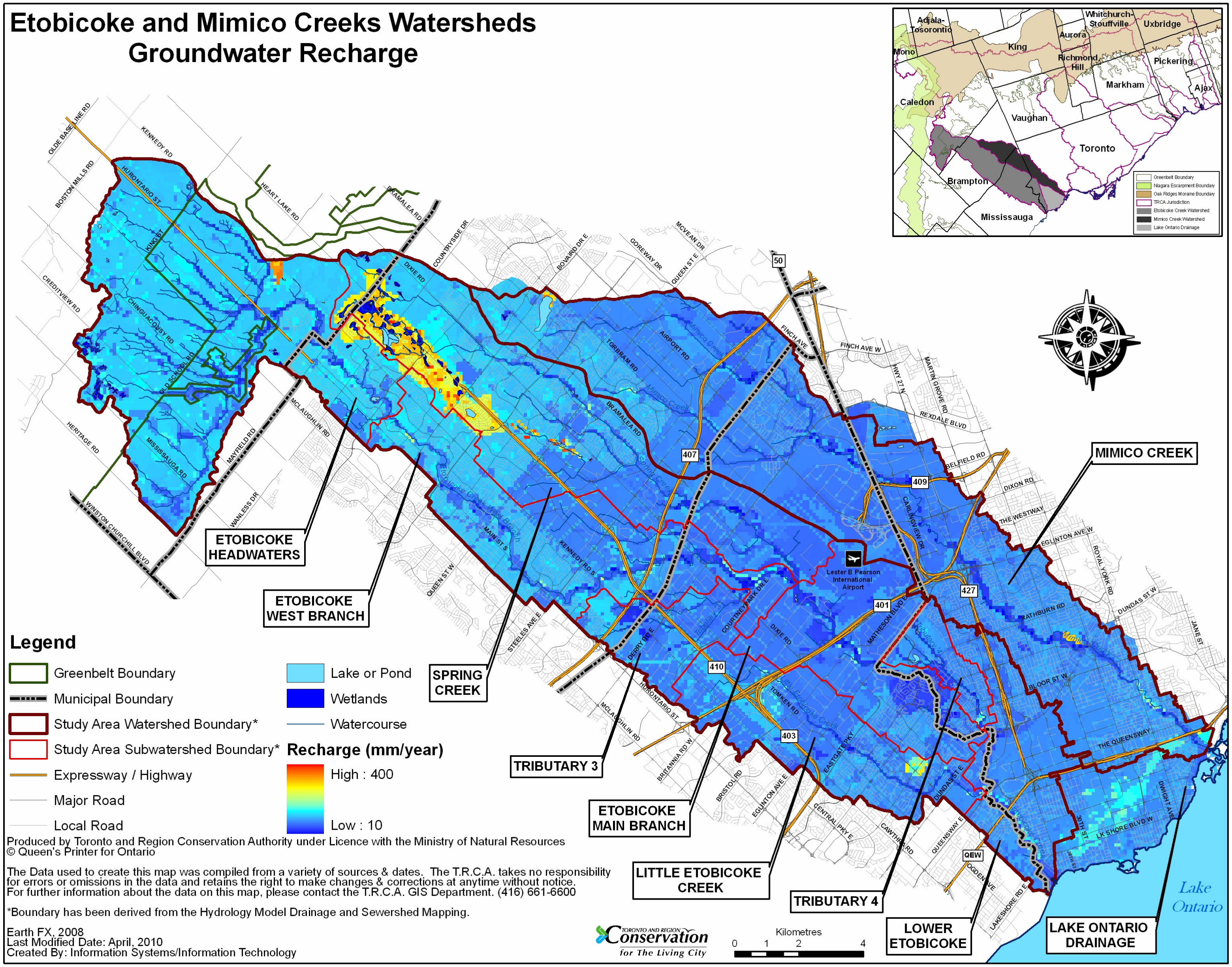
Storage represents the volume of groundwater contained in the pore spaces of unconsolidated material or fractures within bedrock aquifers. Although water levels vary seasonally, over the long term, the change in storage is assumed to be zero for water budgeting purposes.

Groundwater Flow

Groundwater flow direction for both watersheds is initially influenced by flows derived from the Oak Ridges Moraine and the Niagara Escarpment, north and west of the watershed boundaries, (see **Figure 3-9**, **Figure 3-10** and **Figure 3-11)**. Local flow occurs eastward off of the Niagara Escarpment; and local flow deflections occur near streams and associated valleys.

In the headwaters of Etobicoke Creek, lateral groundwater inflow initially follows a south-easterly direction with a shift to the east-southeast in the vicinity of Mayfield Road / Countryside Drive within the Oak Ridges Aquifer (or equivalent). In the lower portion of this watershed, groundwater flow in the Oak Ridges Aquifer (or equivalent) follows to the southeast, with final discharge to Lake Ontario. Within the Thorncliffe and Scarborough Aquifers, groundwater flow occurs in a general southerly direction with a deflection to the southeast in the Mayfield Road / Countryside Drive area. Where the aquifer thickness becomes negligible (or non-existent), groundwater discharge occurs to local streams. Groundwater flow in the lower third (approximately below Hwy. 407) of the watersheds occurs south-easterly and discharges into Lake Ontario.

Figure 3-19: Groundwater Recharge



As previously detailed, aggregate extraction has occurred historically from the Brampton Esker. When groundwater was pumped from the gravel pits to allow deeper sand and gravel production to advance, the resultant depressions within the groundwater level surface created local radial flow toward the pits. The lateral and vertical extent of the water level depressions varied according to the rate and duration of the pit dewatering. Subsequent to cessation of pumping activities, local recovery of groundwater levels commenced evident by rising water level measurements.

Between June 2001 and July 2009, water levels at both PGMN monitoring wells have risen between 3 to 4 m. Continued groundwater monitoring at these PGMN wells should be undertaken to confirm the current trend. As the former Armbro - Bovaird gravel pit was about a minimum 2.2 kilometres south of the PGMN wells, the water level recovery in the pit area would be greater. As groundwater levels have risen and exhibited smaller fluctuations, groundwater flow directions in remnants of the Brampton Esker have and will continue to re-adjust to the changing conditions.

In the northern portion of the Mimico Creek watershed, groundwater flow in the Oak Ridges Aquifer (or equivalent), Thorncliffe and Scarborough aquifers occurs in an easterly and east-southeasterly direction. A gradual shift in flow occurs to the southeast in the lower third portion (approximately below Hwy. 407) of the watershed, with final groundwater discharge into Lake Ontario.

<u>Groundwater Discharge</u>

Groundwater that flows into surface water is considered groundwater discharge. Stream flow data from long term continuous stream flow gauges are used to estimate groundwater discharge through the use of hydrograph separation techniques. This process involves removing the surface runoff volume from the total stream flow. Alternatively, baseflow can be estimated through manual surface water flow measurements made more than 72 hours after a rainfall event. These techniques are discussed further in the **Base Flow and Water Use Section.**

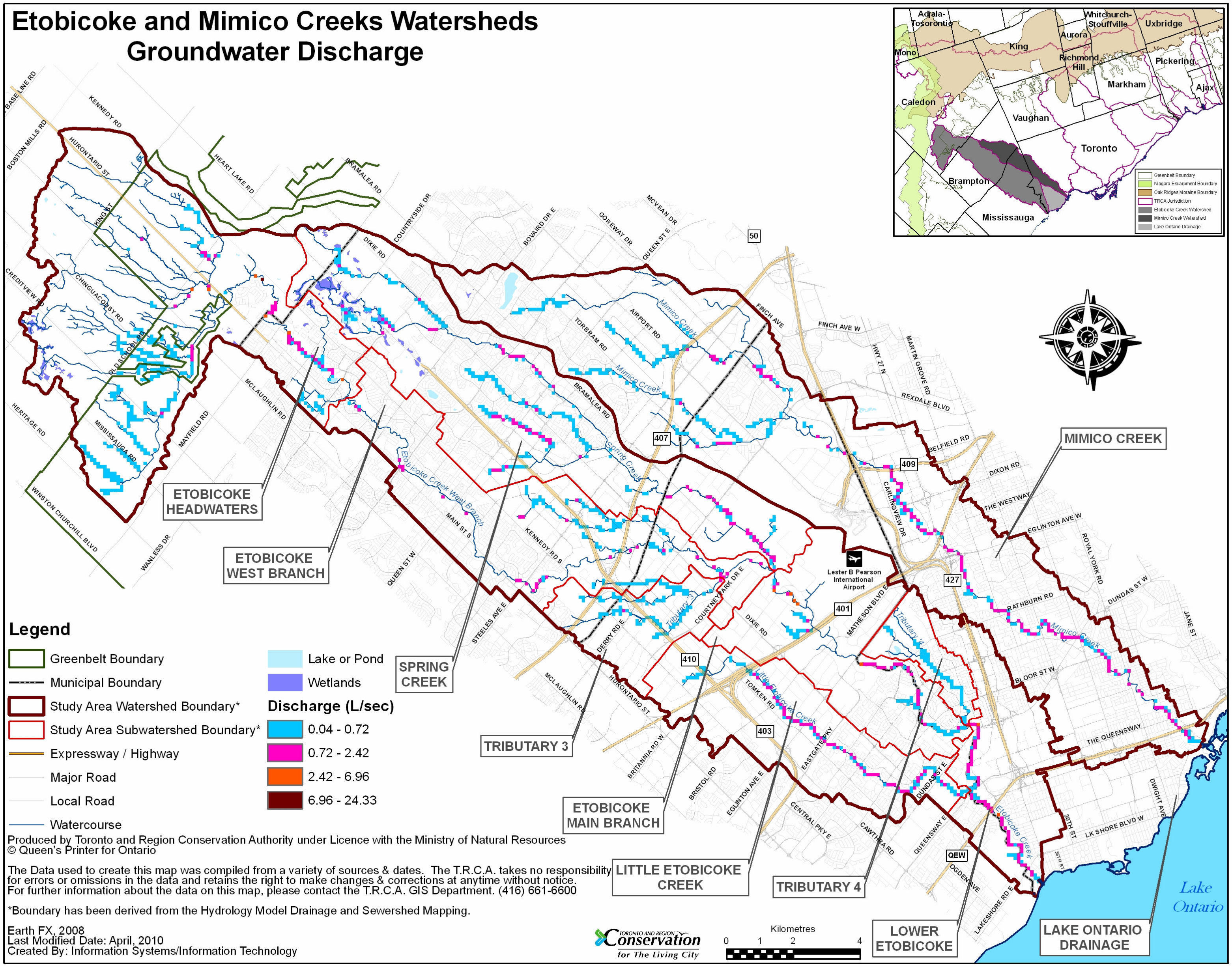
Figure 3-20 depicts modelled groundwater discharge within the study area. The highest discharge area is predicted in the Main Etobicoke Creek branch, south of Bovaird Drive near Steeles Avenue. This coincides with the area where the Oak Ridges Aquifer (or equivalent) outcrops beneath the watercourse.

Other areas of elevated groundwater discharge in the Mimico Creek watershed include the reach from about Eglinton Avenue south to Dundas Street (Thorncliffe Aquifer) and the Bloor Street area (Scarborough Aquifer).

<u>Water Use</u>

Groundwater use is concentrated in the upper reaches of the Etobicoke Creek watershed primarily for livestock / agricultural purposes (28 sites), commercial groundwater takings (2 sites) and groundwater remediation (1 site), as noted from the TRCA water taking survey. Further details of survey results are contained in the **Baseflow and Water Use Section.** There are no municipal water takings for potable drinking water within the Etobicoke Creek watershed, although the capture zone for the Cheltenham wells extends into the Etobicoke Creek headwaters. There are no reported groundwater takings within the Mimico Creek watershed because the watershed is fully urbanized with a lake-based water supply.

Figure 3-20: Groundwater Discharge



<u>Overall Water Balance</u>
As previously mentioned, **Figure 3-17** and **Figure 3-18** depict the overall water balance of the Etobicoke and Mimico Creeks watersheds respectively. Total recharge for the Etobicoke Creek watershed is estimated to be 0.67 m^3/s, while total groundwater water use is estimated to be 0.003 m^3/s. For the Mimico Creek watershed, the total recharge is 0.20 m^3/s, with no groundwater use (TRCA, 2010). The groundwater use for both watersheds represents less than 1% of the total recharge. The *Technical Rules: Assessment Report* issued by the MOE in December 2008 under the *Clean Water Act, 2006* indicates that groundwater withdrawals less than 10% of the total recharge represent a low level of stress on the groundwater system. Accordingly, groundwater use in the study area is not currently an issue of concern.

<u>Groundwater / Surface Water Interaction</u>
During the exploratory test drilling for the PGMN well at the southern edge of Heart Lake; at least 8 m of unsaturated sand was encountered below estimated lake level (approximate elevation 250.4 m). Soil samples below approximate elevation 241 m identified wet / saturated conditions during the continued drilling operations and well completion activities (D. Ford, pers. comm.). While groundwater levels in the PGMN well suggest that Heart Lake is not currently groundwater fed, the lake remains part of the groundwater system due to leakage of surface water through finer grained / organic deposits that form the lake bottom.

As mentioned previously, the Brampton Esker constitutes the most significant hydrogeologic feature in the Etobicoke Creek watershed (see **Figure 3-21**). However, aggregate extraction and follow-up pit rehabilitation (i.e., backfilling with low permeability silt and clay) have modified the esker's original hydrogeologic function. Previously, water recharged into the aquifer north of Bovaird Drive, and flowed underground to the southern limit of the esker where it discharged into tributaries of Etobicoke Creek south of Queen Street. Now, a series of man-made ponds (Esker Lake South, Major Oaks Park Pond, Parr Lake North, Parr Lake South, and Norton Park Pond) exist along the length of the Esker. These features are linked by a series of underground pipes and watercourse segments. The end result is that the groundwater discharge occurs along this drainage network that extends from Sandalwood Parkway to Queen Street. An appreciable flow of water from the inlet structure to Major Oaks Park Pond was noted (although yet to be quantified) originating from the upstream Esker Lake South. Due to the lack of precipitation for the week prior to the March 4, 2009 site visit, this flow represents groundwater discharge into Esker Lake South in addition to pumping from Esker Lake North (also known as North Esker Lake).

<u>Wetland Complexes</u>
The Heart Lake Wetland Complex north of Bovaird Drive, as shown in **Figure 3-22** is associated with peat deposits overlying the till deposits on the esker flanks. Prior to the aggregate extraction process, similar wetlands likely existed south of Bovaird Drive to south of Queen Street. Groundwater levels within the aggregate pits were much lower than in the wetland complex, indicating that the wetlands are not hydraulically connected to the esker and that the wetland complex is primarily dependent on surface water inputs. In addition, the underlying glacial till and organic wetland sediments reduce the amount of infiltration to the more granular esker deposits.

Another important physical feature within the study area is the Cheltenham Wetland Complex. This complex is located west of Creditview Road between King Street and Old School Road. Based on the regional water table elevations from the YPDT-CAMC database and the geologic surfaces, groundwater levels occur from about 5 to 10 m below grade within the Halton Till. Therefore, given that the wetlands directly overlie the Halton Till with below-grade water table water levels, this complex is primarily dependent on surface water rather than resulting from groundwater discharge.

Figure 3-21: Extent of Brampton Esker

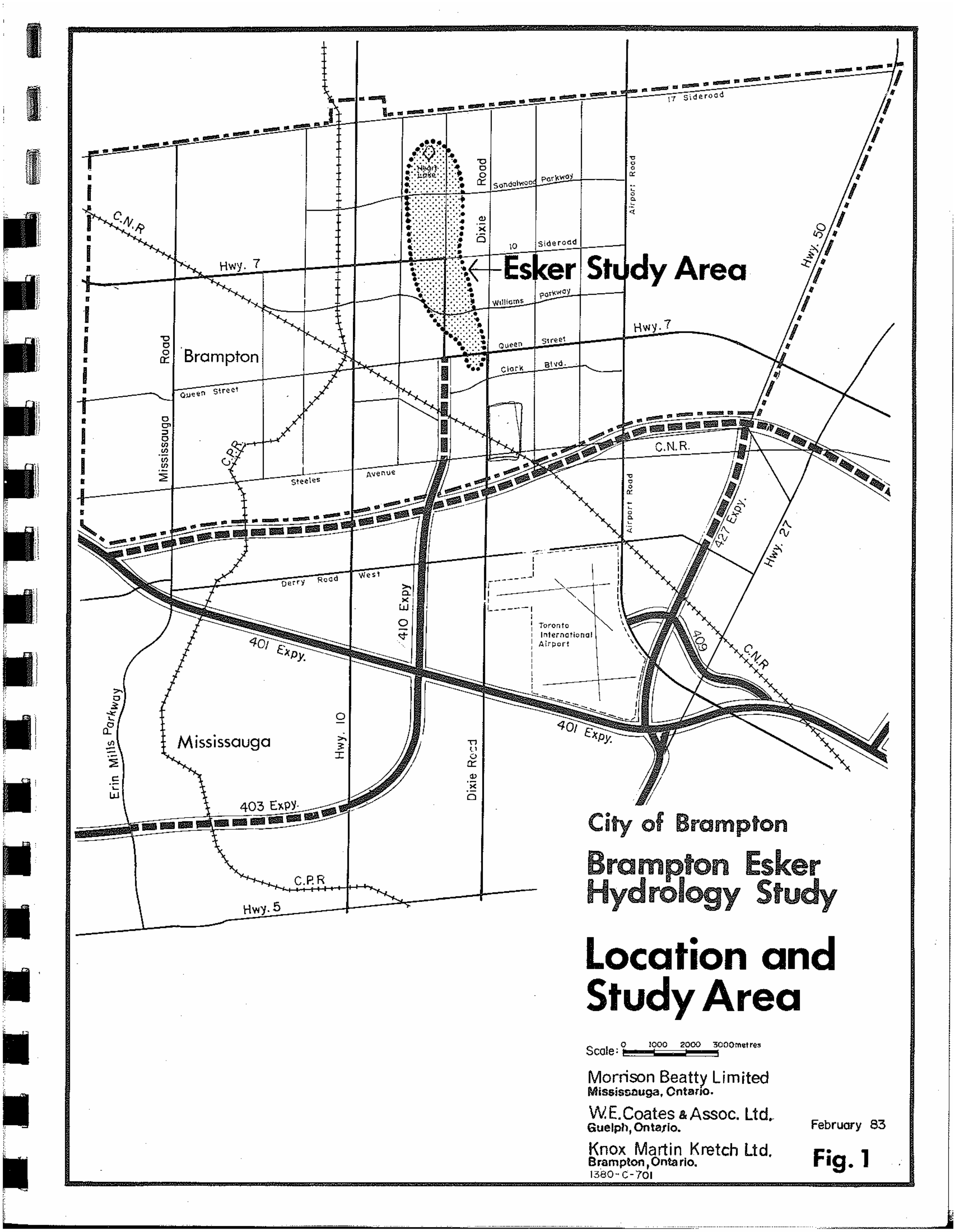
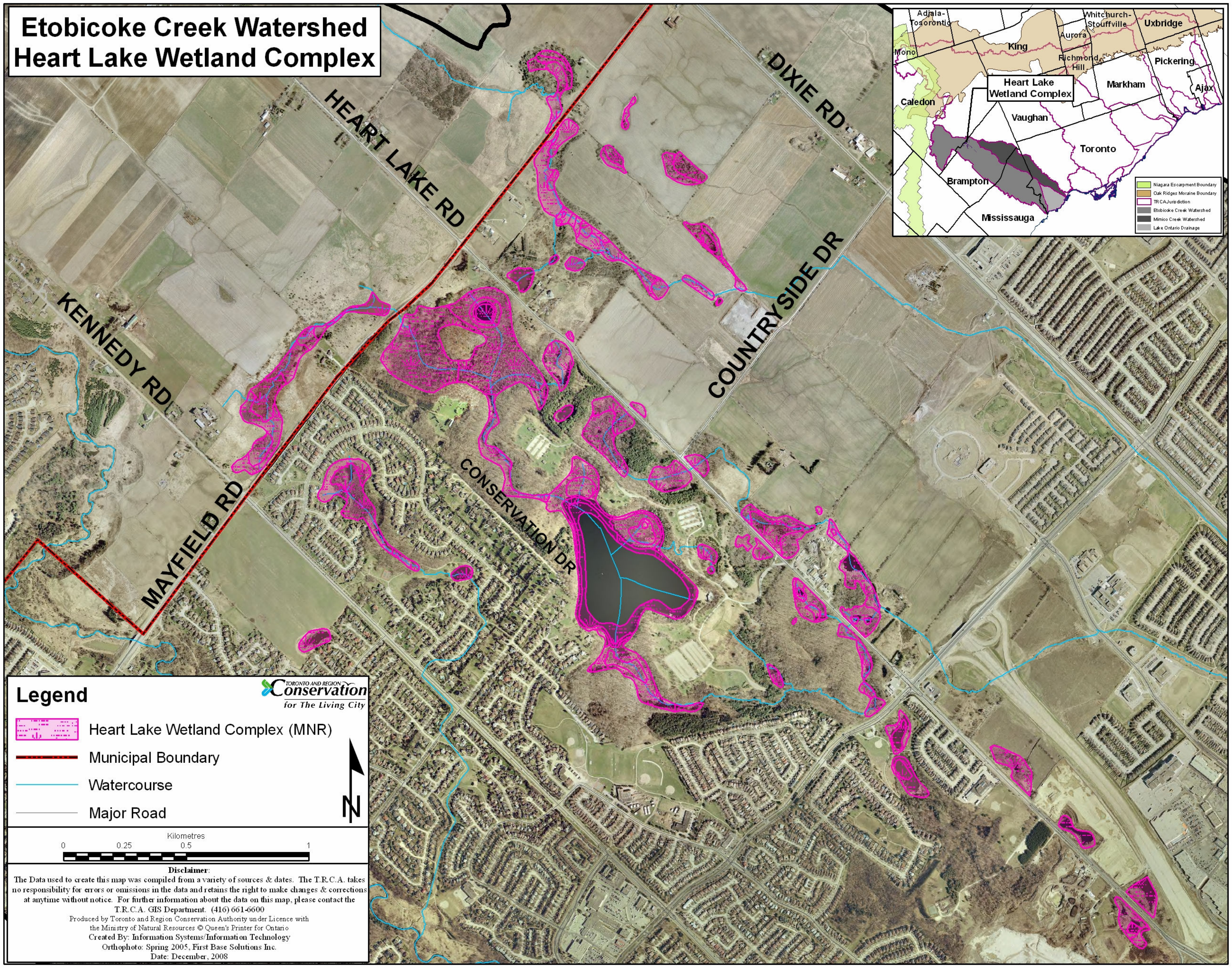


Figure 3-22: Heart Lake Wetland Complex



3.4.6 Groundwater Quality

Groundwater quality is often better than surface water quality because of the slow movement of groundwater, combined with the natural filtration and reaction processes that occur as it moves through the subsurface. However, deterioration of groundwater quality can result from the introduction of contaminants into the subsurface from accidental spills (such as gasoline, diesel, solvents likely from a point source) or from intentional application (such as herbicides/ pesticides, fertilizers, and road salt). Contaminants such as road de-icing salts move readily through the groundwater system with little or no attenuation. Short groundwater flow paths between contaminant sources (e.g., a landfill) and local discharge areas may provide insufficient natural attenuation. Also, some aquifers exhibit naturally elevated chloride and iron concentrations due to the mineral composition of the soil or rock. The degree of groundwater chemical deterioration is related in part to the concentration and volume of the contaminant material, the type of surficial soil material, the absorption capacity of the soil to retard the specific contaminant(s), potential for microbiological degradation of the contaminant and depth to the top of the aquifer.

Remediation of contaminated groundwater remains very difficult, expensive and time consuming because of the slower, unconstrained movement of water in the subsurface. These complications mean that a total aquifer clean-up may not be even achievable.

Limited groundwater chemical quality data is available for the major aquifers within the study area. The chemical quality of groundwater extracted from the Oak Ridges Aquifer (or equivalent) during the operation of the Heart Lake Municipal Water Wells (1964 to 1972; Morrison *et al.*, 1983) is understood to have generally met the then applicable potable water standards (Ontario Drinking Water Objectives, 1964 and 1968). Limited information is available as to any treatment undertaken for chemical parameters during the municipal well operation.

The two PGMN wells within the study area enable the collection and analysis of groundwater contained in the Oak Ridges Moraine Aquifer (or equivalent) Complex. Both wells (W021 and W366) are situated within the Heart Lake Conservation Area. Selected parameter results from November 2003 and January 2005 along with the Ontario Drinking Water Standards (ODWS) are listed in **Table 3-2.**

Table 3-2: Groundwater Quality Parameters

Parameter	Concentration		
	Range (mg/L)	Average (mg/L)	ODWS (mg/L)
Hardness	246 to 803	503	80 to 100
Total Dissolved Solids	239 to 1175	678	500
Nitrate	0.01 to 0.09	0.05	10
Sodium	11.9 to 27.7	18.1	200
Iron	0.002 to 7.9	1.5	0.3

The parameter values described above are all typical of chemical water quality within shallow aquifers in Southern Ontario and characterize the water as a calcium / magnesium carbonate type, sourced from a glacially derived sedimentary aquifer. Given that there are no monitoring wells in the deeper Thorncliffe and Scarborough Aquifers within the Etobicoke and Mimico Creeks watersheds, no chemical water quality information is available for those aquifers.

3.5 MANAGEMENT RECOMMENDATIONS

This section outlines potential groundwater considerations in terms of aggregate pit rehabilitation, maintenance of groundwater recharge, management of groundwater levels and improving groundwater quality.

3.5.1 Development within former Brampton Esker Aggregate Pits

The following interpretation of the groundwater conditions in this section of the report is made with reference to existing information contained within various TRCA planning and development files for projects within the Brampton Esker. Only portions of the chronology of site-specific development activities on the Esker lands were available at the time this document was prepared.

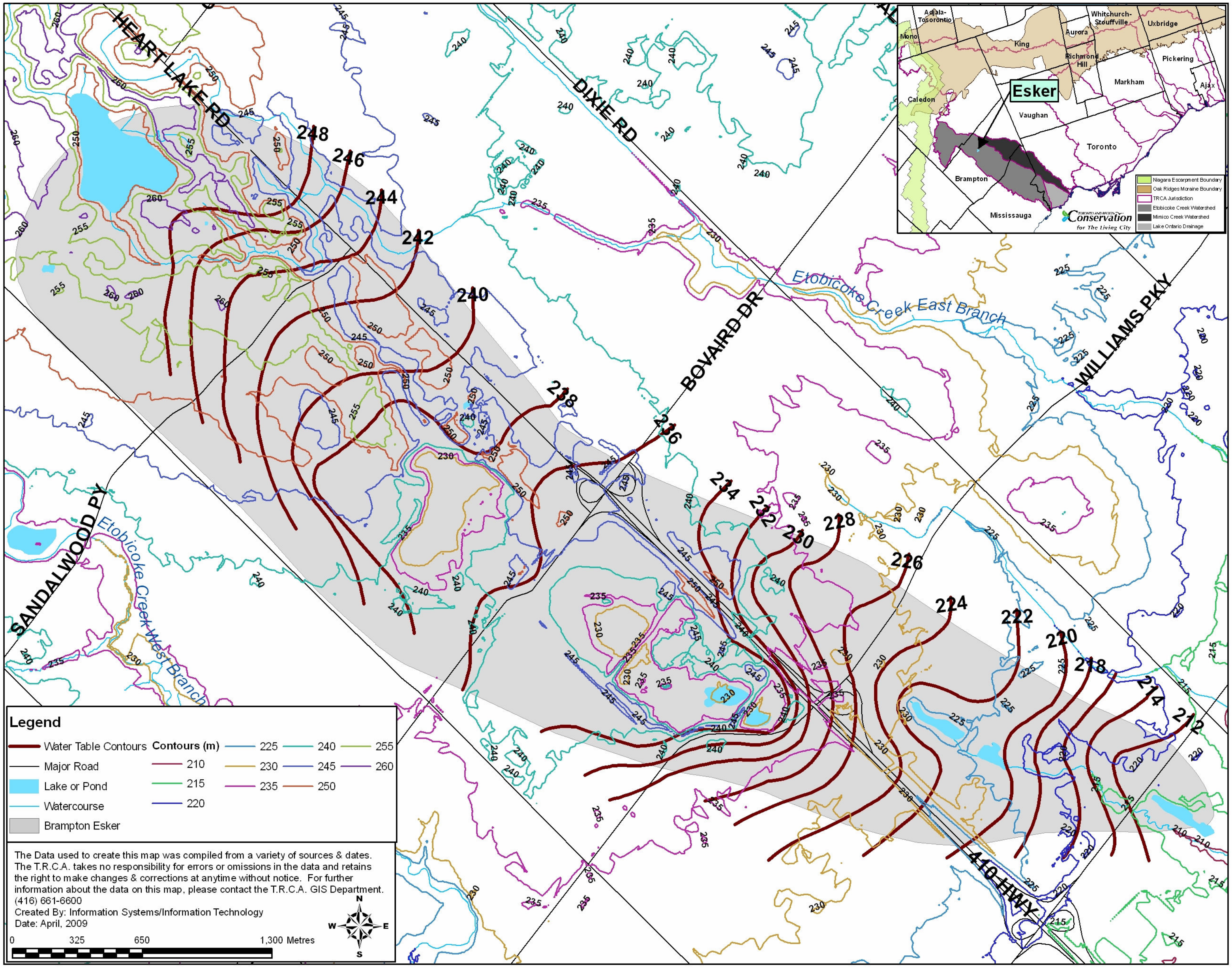
The most important management consideration in the Etobicoke Creek watershed arises from increased ground and surface water levels in the areas within the limits of the former Brampton Esker (see **Figure 3-21**). Post aggregate extraction remediation plans considered various development options or scenarios incorporating such features as Esker Lake North, Esker Lake South, Major Oaks Park pond, Parr Lake North and Parr Lake South. Ultimately a series of suburban developments were constructed, which necessitated partial backfilling of the pits as part of the rehabilitation plans.

One example of the extent and degree of backfilling activity is located immediately north of Bovaird Drive and west of the new Heart Lake Road, the area referred to as Esker Lake North. Aerial photographs taken between 1999 and 2007 (see **Appendix 3-A**) display the reduced pond size by significant infilling with low permeability material (i.e. compacted glacial till). As mentioned previously, groundwater levels at the two PGMN wells adjacent to Heart Lake have risen about 3-4 metres, however, this has to be confirmed based on long term monitoring data. This rise is a result of cessation of aquifer dewatering for pit operation combined with lowered aquifer volume from the backfilling. The groundwater levels are now controlled by dewatering by the golf course, currently under construction.

The rising groundwater levels could result in higher water levels in Heart Lake, since the downward hydraulic gradient between the lake and groundwater system is declining. If this occurs, permanent flow may begin from the outlet at the southwest corner of the lake. Any plans for walking trails or boardwalks within the Conservation Area should take into account the possibility of high surface water levels and permanent surface water outflow.

The Brampton Esker Hydrology Study report predicted higher groundwater levels following closure of the gravel pits. **Figure 3-23** shows the predicted water table contours superimposed over the most recent TRCA topographic mapping in the Brampton Esker (2002). The projected water level in the vicinity of Esker Lake North was to be almost 8 meters higher than the current pond level elevation of 230 m. A below-grade pumping station has been installed at the southern end of Esker Lake North (RAND Engineering, 2001) as part of the Ranburne Holdings Stormwater Management Plan. The pumping station was designed to serve two functions: a) irrigation to the Turnberry Golf Course and b) control the pond water level to elevation 232.5 m. A Permit to Take Water (PTTW) was issued by the Ministry of the Environment in November 2008 that authorized the proposed takings.

Figure 3-23: Esker Drainage Network



Water from Esker Lake South is conveyed to Major Oaks Park and then into a piped system beneath Highway 410, south of Williams Parkway and into Parr Lake North. The 450 mm diameter outlet pipe from Major Oaks Park was installed by the City of Brampton in 1991 with direct connection to Parr Lake North (Schaeffers, 2003). The outlet pipe from the Major Oaks Park pond represents a potential constraint in the drainage system. A pipe blockage or flow increase from stormwater events could result in flooding within the Park and adjacent neighbourhoods.

Baseflow measurements should be undertaken, particularly at the inlets to each lake / pond within the esker system as increases in groundwater discharge volumes may reduce the capacity of existing storm sewers to convey storm flow events.

In summary, the key recommendations include:

- Within the northern Brampton Esker, continue groundwater level monitoring at the PGMN wells;
- Investigate the extent of backfilling of the current pond base in Esker Lake North and the degree of hydraulic connection to the permeable underlying esker sand;
- Install groundwater monitoring wells into the lower Brampton Esker sands around Esker Lake North;
- Obtain pumping rates at golf course pumping station to assess the stability of local groundwater levels;
- In proposed development areas bordering Esker Lake North, project consultants should consider the higher groundwater levels when designing foundation and installation for buildings and other infrastructure;
- Assess the hydraulic capacity of the 450 mm diameter outlet pipe from Major Oaks Park pond into Parr Lake North;
- Undertake base flow measurements at the inlets to each lake / pond within the esker system as part of a conveyance capacity evaluation;
- Conduct baseflow monitoring in the Etobicoke Creek tributaries within 3 km of Esker Lake South to confirm whether an increase in groundwater discharge to water courses is occurring;
- Partner with the City of Brampton in developing action plans around Esker Lake North and the outlet from Major Oaks Park pond. Action plans should address long term risk management, habitat enhancement opportunities, monitoring needs and other aquatic issues, as required.

3.5.2 Groundwater Recharge

Management considerations in terms of groundwater recharge should be considered in relation to new and existing urban development. In any new proposed development that converts previously natural surfaces (i.e. grass field/ cropland) to impervious surfaces (i.e. roads/ parking lots/ roofs) outside the limits of the Brampton Esker various infiltration measures should be encouraged. Measures such as the use of infiltration trenches, pervious pavement for driveways and parking lots or soak-away pits, where feasible and practical, that allow effective infiltration of clean roof runoff, should be considered. Such measures would assist in mitigating the reduction of infiltration to the soils from the increased area of impervious surfaces. Where feasible and practical, infiltration of clean roof runoff through a 'third pipe" solution (a perforated pipe in granular bedding immediately above a roadway storm sewer pipe) should be recommended.

For properties undergoing renovation or redevelopment south of the Lake Iroquois shoreline, where significant thickness of beach sands occur, consideration should be given to incorporating soak-away pits or infiltration trenches to enhance recharge. The feasibility and effectiveness of these systems will depend on site specific conditions.

Land use change can have a significant impact on groundwater recharge and quality as well. Areas having higher recharge rates require special protection, such as hummocky topography areas. Key recommendations include:

- In the areas outside the limits of the Brampton Esker, maintain existing pre-development infiltration rates through innovative lot level and conveyance stormwater management controls;
- Encourage the development of less intensive urban land use in significant recharge areas;
- Discourage placement of fill materials with lower hydraulic conductivity than native soils (i.e., gravel pit rehabilitation with imported low permeability fill);
- Minimize impervious surfaces associated with new urban developments;
- Direct roof downspouts to front and back lawns in all new developments; and
- Encourage construction with permeable materials.

3.5.3 Groundwater Levels

There should be consideration given to placing monitoring wells within the Thorncliffe and Scarborough Aquifers to provide water level data for those aquifers. Currently, two monitoring wells remain operational within the Oak Ridges Aquifer (or equivalent) in the Etobicoke Creek watershed. Consultation with the Ministry of the Environment (MOE) regarding possible access to available digital water level data from either golf courses or industrial facilities (as part of their Permit to Take Water conditions) remains another possible information source in filling data gaps. Groundwater level monitoring of the three major aquifer systems within the watershed at three different locations is recommended. With the existing two PGMN monitoring wells, the addition of another two wells is recommended.

In summary the key groundwater management recommendations include:

- Maintain baseline piezometric surfaces/groundwater levels;
- Continue and expand the present groundwater monitoring program;
- Establish additional monitoring wells to obtain more accurate information of existing conditions and trends (at least one monitoring well in each aquifer system). The two observation wells are recommended for monitoring of the intermediate and deeper aquifer systems.
- Establish more accurate information of shallow ground water aquifer system, which are similarly lacking in monitoring data
- Every effort should be made to maintain the existing recharge rates outside of the Brampton Esker;
- Future proposed development plans within the Etobicoke Creek headwaters (i.e. north of Mayfield Road) should further assess groundwater discharge for seasonal variation and permanence.

3.5.4 Groundwater Quality

There was no evidence of groundwater quality issues based on the limited information available. However, previously drilled open boreholes from geotechnical studies, improperly sealed boreholes, improperly decommissioned former private drilled / dug water wells and service trenches provide pathways through which seepage of surface contaminants can percolate to the major aquifer. Should such works extend into the aquifer, contaminant migration occurs directly into this zone. In areas where the overlying till cap has been removed and exposes the underlying aquifer, contaminants would also directly impact the chemical water quality. Such a situation arises where pit rehabilitation measures of former aggregate extraction operations have not incorporated a re-establishment of a protective cap.

Groundwater quality impairment in the urban setting originates, most often from winter road de-icing activities. The use of Best Management Practices, as developed by the Ministry of Transport Ontario and the Ministry of Environment, should be encouraged by the municipalities and their contractors.

As there is no available chemical water quality information from the deeper Thorncliffe and Scarborough Aquifers within the Etobicoke and Mimico Creeks watersheds due to lack of sampling points, monitoring wells should be installed into those aquifers should sustainable funding becomes available.

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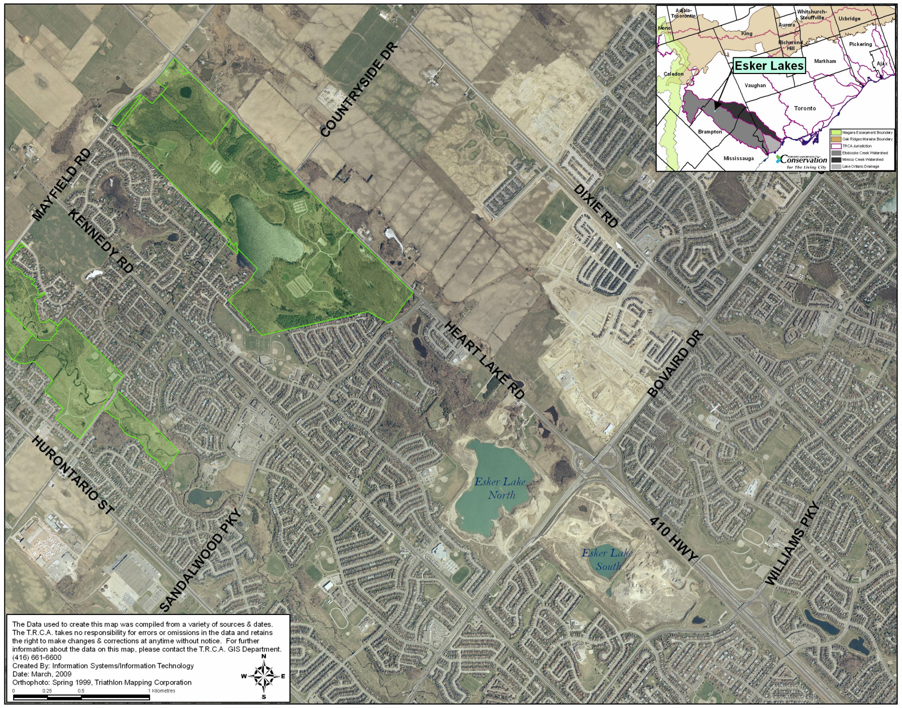
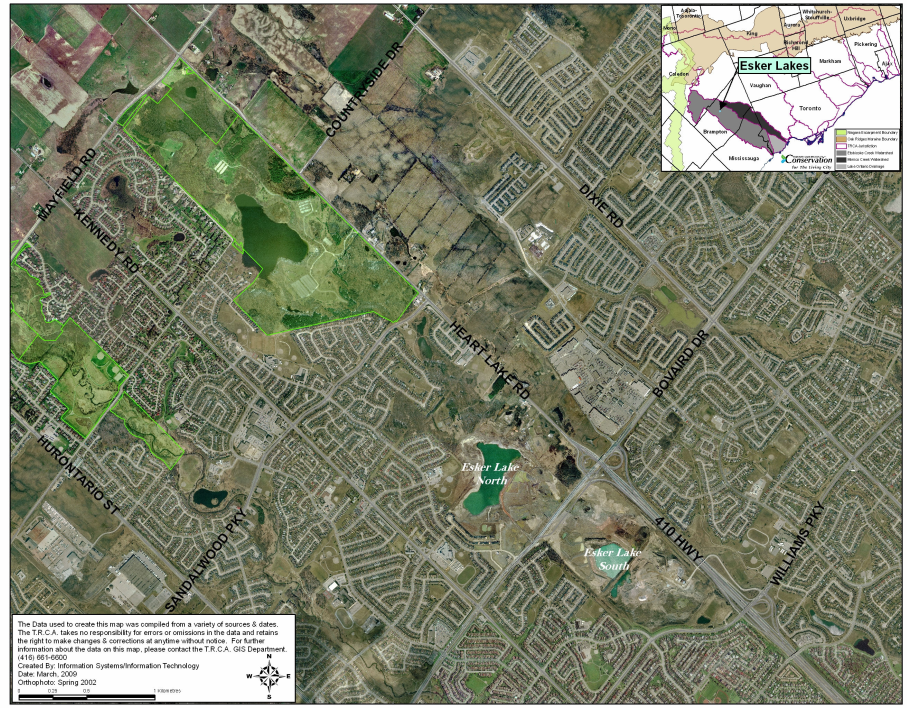
3.7 APPENDIX 3-A: AERIAL PHOTOGRAPHS OF ESKER LAKE NORTH TAKEN BETWEEN 1999 AND 2007

Aerial photographs of Esker Lake North 1999



Aerial photographs of Esker Lake North 2002



Aerial photographs of Esker Lake North 2005

Aerial photographs of Esker Lake North 2007