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3.0 WATER BUDGET AND STRESS ASSESSMENT

Developing a source protection plan requires organizing and understanding data about water flow through the watershed. This can be accomplished by preparing a water budget. Water budgets show each part of a watershed's hydrologic system, and uses data to describe the pathways that water takes through that watershed. A water budget looks at how much water enters a watershed, how much water is stored in it, and how much water leaves it (through both natural and human processes). This information helps determine how much water is available for human use while ensuring enough is left for natural processes. The watershed must have enough water to maintain streams, rivers, and lakes, and to support aquatic life and wetlands.

The Ministry of the Environment, Conservation and Parks (MECP) prepared *Technical Rules*, which outline the steps required to:

- Estimate the quantity of water flowing through a watershed;
- Describe the significant processes that affect flow;
- Characterize the general movement of water; and
- Assess the sustainability of drinking water supplies.

The *Technical Rules* which guide the completion of the tiered water budgets are designed as a screening mechanism for gaining a progressive understanding of the characteristics of a watershed, the dynamics of surface water and groundwater interaction, and the impacts of water takings on municipal water supplies within the watershed.

The higher the tier, the more complex the science involved and the narrower the geographic focus. Moving from one tier to another helps those involved in source protection planning to understand where sources of water are located and how much water is being used in order to focus attention where it is most needed. The level of investigation required in the tiered approach depends on the severity of local water quantity issues.

While the water budget analysis primarily targets municipal drinking water sources, the knowledge gained and tools developed through the process are applicable to other areas of water resource and watershed management.

The framework includes up to four levels of analysis depending of the level of stress determined at each consecutive level. These tiers include:

- Conceptual Water Budget;
- Tier 1 Water Budget;
- Tier 2 Water Budget; and
- Tier 3 Water Budget.

This work was initiated following technical guidance distributed by the Province (Guidance Module 7) and was later modified to meet the requirements outlined in the *Technical Rules (2009).* In accordance with the *Technical Rules*, this water budget analysis does not include demand from Lake Ontario water. Water budgeting analyses are not required for the Great Lakes sources of drinking water. All levels of water budget analyses (as with all of the technical studies contained in this Assessment Report*)* were peer-reviewed by technical consultants, as well as provincial and municipal staff.

All comments and suggestions were considered in the final documentation, and sign-offs from the peer reviewers were obtained. A separate and more detailed peer review process was required by the Province as part of the water budget and Significant Groundwater Recharge Area analyses. This process and all associated documentation were provided to the Province as part of the approval process.

The conceptual level is the most general analysis (lowest tier). A conceptual water budget provides a basic understanding of the key components of the water budget while the higher tier analyses refine the knowledge base regarding the competing demands vis-à-vis water availability. The higher the tier, the more complex the analysis becomes and the narrower the geographic focus. All source protection areas must complete a conceptual water budget and Tier 1 water budget analysis (excluding analysis of the Great Lakes), but Tier 2 analysis is required only on watersheds identified with potential stress where there are municipal drinking water systems. The Tier 3 analysis is only conducted where the Tier 2 study confirms moderate or significant potential stress.

Water is withdrawn across the TRSPA for a number of uses including:

- Municipal supply;
- Communal supply;
- Private domestic supply;
- Agricultural use;
- Industrial use;
- Golf course irrigation; and
- Groundwater pressure control.

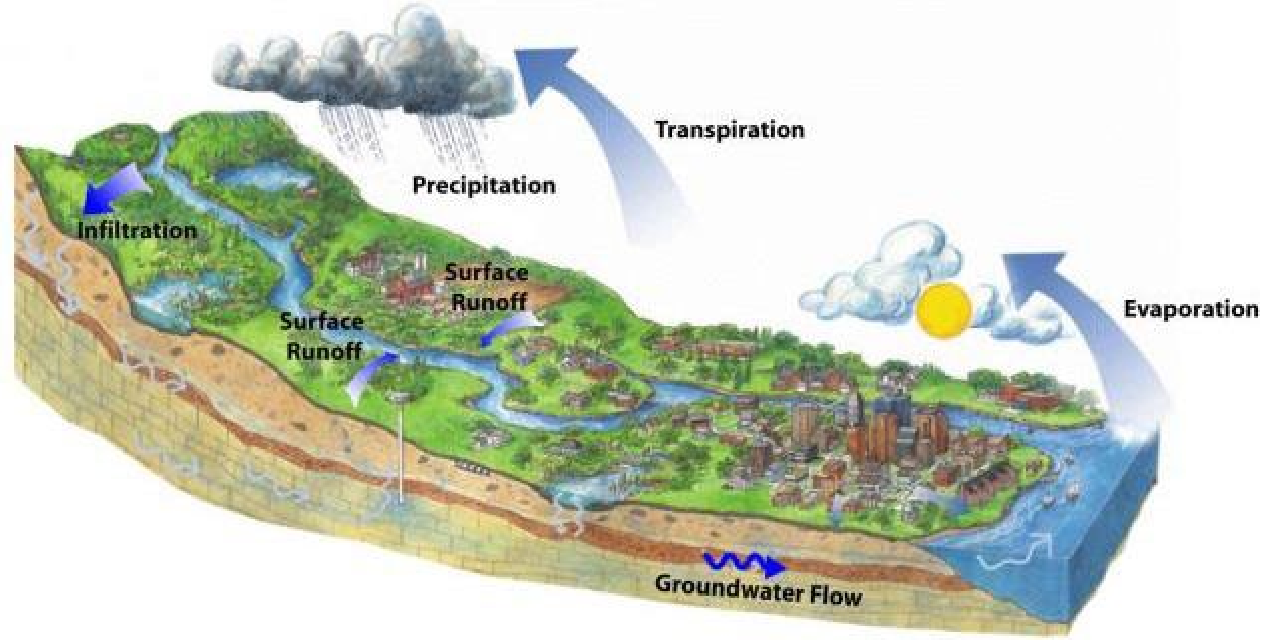
In the TRSPA most of the municipal water supply is drawn from Lake Ontario. Groundwater is also used extensively, particularly across the northern portion of the watershed. In addition, golf courses and agricultural operations withdraw water from surface water sources, primarily for crop or turf irrigation. Industrial water use is very limited, except in unserviced areas. As explained in **Section 2.3.4**, groundwater pressure control is mainly temporary in nature and predominantly for construction purposes (except for permanent dewatering in Richmond Hill and Markham).

Major sectors of water withdrawals in the TRSPA watersheds are golf course irrigation and municipal water supplies, which withdraw significantly more than other high-use sectors, at approximately 4 million to 6 million m^3/year. Aquaculture, industrial, and agricultural takings are also of significance, all together withdrawing a little more than 1 million m^3/year.

A full list of active ground and surface water users was included as an appendix in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010).

3.1 CONCEPTUAL WATER BUDGET

Generally, the basic concepts of the hydrologic cycle, or the water budget, are familiar and understood by watershed stakeholders. The most commonly understood components are precipitation, evaporation, and streamflow within a given watershed, as shown in **Figure 3.1**. In scientific circles these have been further subdivided to account for plant transpiration, groundwater recharge, and groundwater flow. The measurements of precipitation and streamflow are comparatively straightforward, and data for these two parameters have been recorded for many decades by Environment Canada as well as, more recently, by Toronto and Region Conservation Authority (TRCA) staff.



Graphic courtesy of Conservation Ontario

Figure 3-1: Water Budget Components

Streamflow volume is usually about one-third of the total precipitation for a given watershed. The difference between these two components is mostly the result of net water loss to the local system through evaporation and transpiration, collectively known as evapotranspiration. This value is challenging to measure directly, but can be calculated using empirical formulae based on data from many watersheds (e.g., Thornthwaite and Mather, 1957).

The difference between the total precipitation and the evapotranspiration is generally referred to as the surplus. It is partitioned between the majority that enters local streams as surface runoff and the relatively small volume of water that infiltrates into the ground (usually averaging less than 10% of precipitation). Since most of the groundwater recharge re-enters the watercourses as groundwater discharge (estimated 95% for TRSPA watersheds), this partitioning can be estimated by baseflow separation techniques (Viessman *et al.,* 1989). The methodologies used to define these parameters across the TRSPA jurisdiction are detailed in **Appendix C1** and **Appendix C2**, and are summarized in the following sections. The *Conceptual Water Budget Report* was prepared by Gartner Lee (now AECOM) in 2007 (Gartner Lee Limited, 2007), while the *Tier 1 Water Budget Report* was prepared by TRCA, with numerical modelling prepared by Earthfx Inc. (TRCA, 2010). The geologic and hydrogeologic surfaces were generated by Earthfx in May, 2007 as part of the Tier 1 Water Budget. The results are based on an 8-year modelling period that encompassed wet, dry and average years (TRCA, 2010).

The water budget process is cyclic, with the evapotranspiration losses in a particular watershed entering the atmosphere and subsequently forming the precipitation in another watershed. The earlier guidance document on water budgets for Source Water Protection (MOE, 2007a) identifies the components of a water budget that are considered in this study, and is quoted here:

A water budget for a given area consists of inputs, outputs, and changes in storage. The inputs are precipitation, groundwater or surface water inflows, and *anthropogenic* inputs such as waste effluent. The inputs must equal the outputs, which are evapotranspiration, water supply removals or abstractions, surface or groundwater outflows, as well as any changes in storage within the area of interest. This can be expressed as follows:

Anthropogenic: Human-created, as opposed to natural.

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 in*
GW_{in} = *groundwater flow in*
$ANTH_{in}$ = *anthropogenic or human inputs such as waste discharges*
ET = *evaporation and transpiration*
SW_{out} = *surface water flow out*
GW_{out} = *groundwater flow out*
$ANTH_{out}$ = *anthropogenic or human removals or abstractions*
ΔS = *change in storage (surface water, soil moisture, groundwater)*

Reference can be made to Singer, 1981; and Walton, 1970 for further details

3.1.1 Precipitation (Q_P)

Figure 3.2 presents a map of measured total annual precipitation (Q_P) in mm/yr based on values from Environment Canada weather stations. The modelled net annual precipitation calculated from the surface water flow model (PRMS - Precipitation-Runoff Modelling System) is provided in **Figure 3.3**. Net precipitation accounts for interception losses. Therefore, forested areas receive less net precipitation than the agricultural areas, and much less than urban areas. However, other losses (i.e., to depression storage) offset the higher net precipitation in the urban areas (TRCA, 2010).

3.1.2 Evapotranspiration (Q_E)

Figure 3.4 shows a map of annual average evapotranspiration (Q_E) in mm/yr simulated using PRMS. This parameter includes losses from depression storage on impervious areas. This map reflects a combination of factors such as land cover, soil type and climate. Lower rates occur on the Oak Ridges Moraine because of the well-drained soils and on urban areas because of the lack of vegetative cover. Average evapotranspiration rates over the TRCA watersheds are about 550 mm/year (TRCA, 2010).

3.1.3 Runoff (Q_{RO})

Figure 3.5 presents annual average runoff in mm/yr (Q_{RO}) for the TRCA watersheds, simulated using PRMS. As expected, Q_{RO} is highest in the urbanized areas (150-300 mm/yr), especially along roads and in the areas designated as commercial and industrial, with low permeability soils. Runoff rates are low over the Oak Ridges Moraine (< 50 mm/yr), while moderate to high rates of runoff occur on the South Slope (200-250 mm/yr). The lower runoff values (50-100 mm/yr) in Toronto, near Lake Ontario, are associated with the pervious Iroquois sand deposits (TRCA, 2010).

3.1.4 Recharge ($_{QR}$)

Figure 3.6 presents the annual average recharge (Q_R) in mm/year simulated using PRMS. As with Q_E, the distribution of Q_R is a function of topography, soils, land-use, land cover and climate. The values vary over a wide range. Generally, in areas overlain by Halton and Newmarket tills, the values are in the order of 100 to 150 mm/year. The major recharge areas occur along the Oak Ridges Moraine where recharge rates for surficial sand and gravel deposits can exceed 300 mm/yr. The hummocky terrain present over much of the Oak Ridges Moraine prevents the formation of stream channels, and accordingly, any precipitation that is not lost to evapotranspiration will infiltrate or form local runoff that collects between hummocks, and subsequently infiltrates in these permeable deposits.

Much of the south flank of the Oak Ridges Moraine is covered with till, or till with a *lacustrine* veneer of fine sand, silt and clay. Recharge rates for these deposits are less than half of those on the Oak Ridges Moraine. Recharge through the surficial till is enhanced where the topography is hummocky along the ORM, but is greatly reduced along the Oak Ridges Moraine south flank (e.g., Richmond Hill and Stouffville) where the Oak Ridges Aquifer Complex is confined by the overlying till. In these areas vertical hydraulic gradients are upwards between the Oak Ridges Aquifer Complex and the water table, with minor local recharge occurring to sand bodies contained within the till.

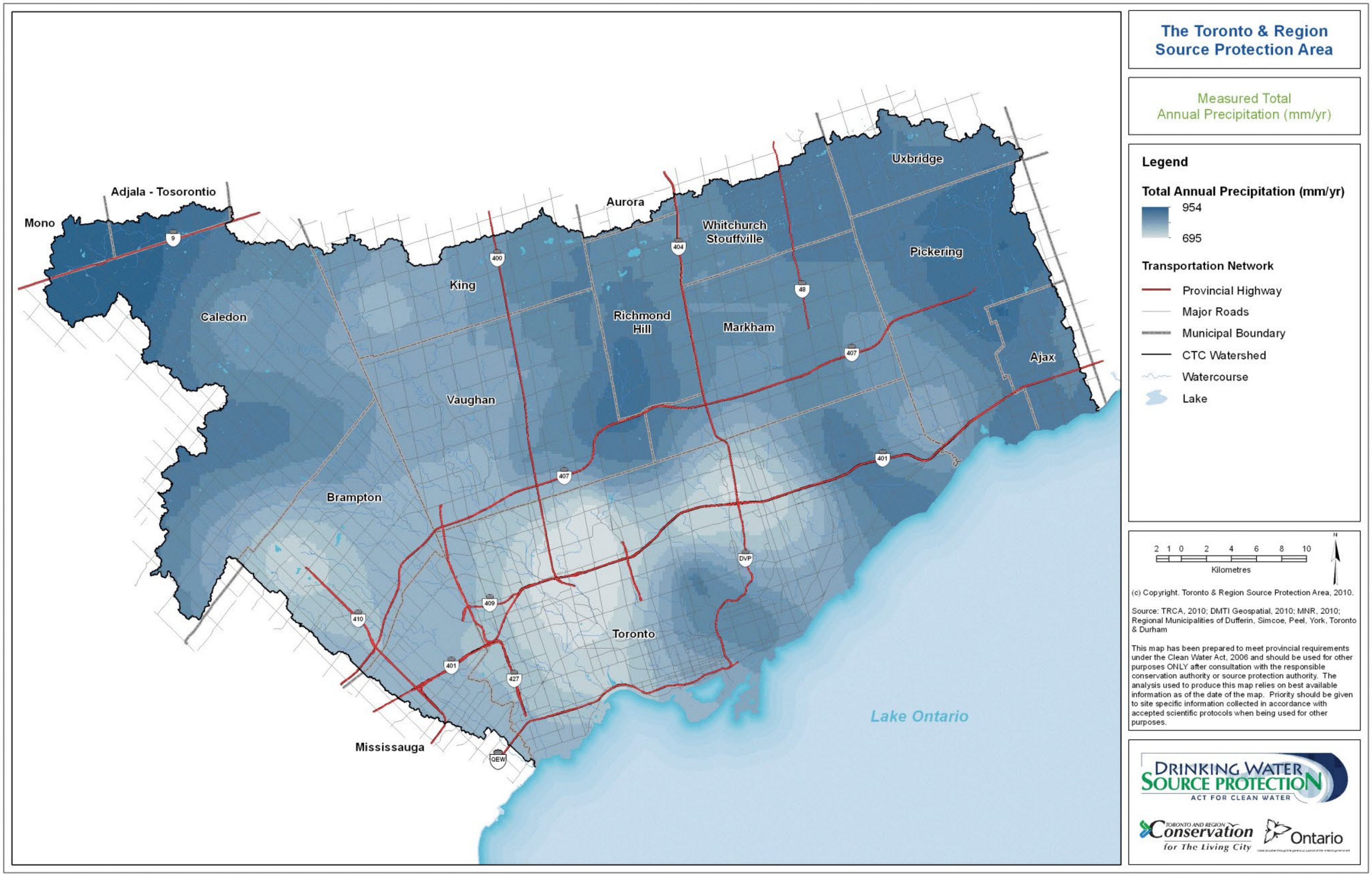
Lacustrine: in geology, a sedimentary environment of a lake.

The matrix material for the surficial Halton Till deposits also becomes more fine-grained (silt and clay) to the west, which lowers the recharge rates compared to the eastern part of the TRCA area. Where the Halton Till is not present to the south, the Newmarket Till also restricts infiltration and causes lower recharge rates. Recharge rates through these till soils, in the areas that are not controlled by hummocky terrain, are 30 to 100 mm/yr.

The southern part of the TRCA watersheds contains different Glacial Lake Iroquois deposits, exhibiting varying recharge rates. The Lake Iroquois beach bluff deposits of sand and gravel will have the highest unit recharge rates for this area, except where upward vertical gradients occur along the toe of the topographic slope. Near shore recharge rates generally range between 150 to 200 mm/yr, but decrease to 50 mm/yr where surficial clay deposits are thicker. The other Lake Iroquois sediments range progressively from lacustrine sands, to silty fine sands, to silt and clay with increasing distance from the shoreline bluff.

3.1.5 Groundwater Discharge (Q_{GD})

Figure 3.7 shows the net discharge from groundwater (Q_{GD}) in litres per second per hectare over the study area, using the groundwater flow model (MODFLOW - three dimensional MODular groundwater FLOW modelling system). The major zone of groundwater discharge to streams occurs along the southern flank of the Oak Ridges Moraine, where the Oak Ridges Aquifer Complex discharges to surface. Another major zone of groundwater discharge to streams occurs south of the Lake Iroquois shoreline where there are strong upward gradients from the Thorncliffe and Scarborough aquifers, and where the confining till units are either thin or absent.



Source: TRCA, 2010; DMTI Geospatial, 2010; MNR, 2010; Regional Municipalities of Dufferin, Simcoe, Peel, York, Toronto & Durham

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Figure 3-2: Measured Total Annual Precipitation (mm/yr)

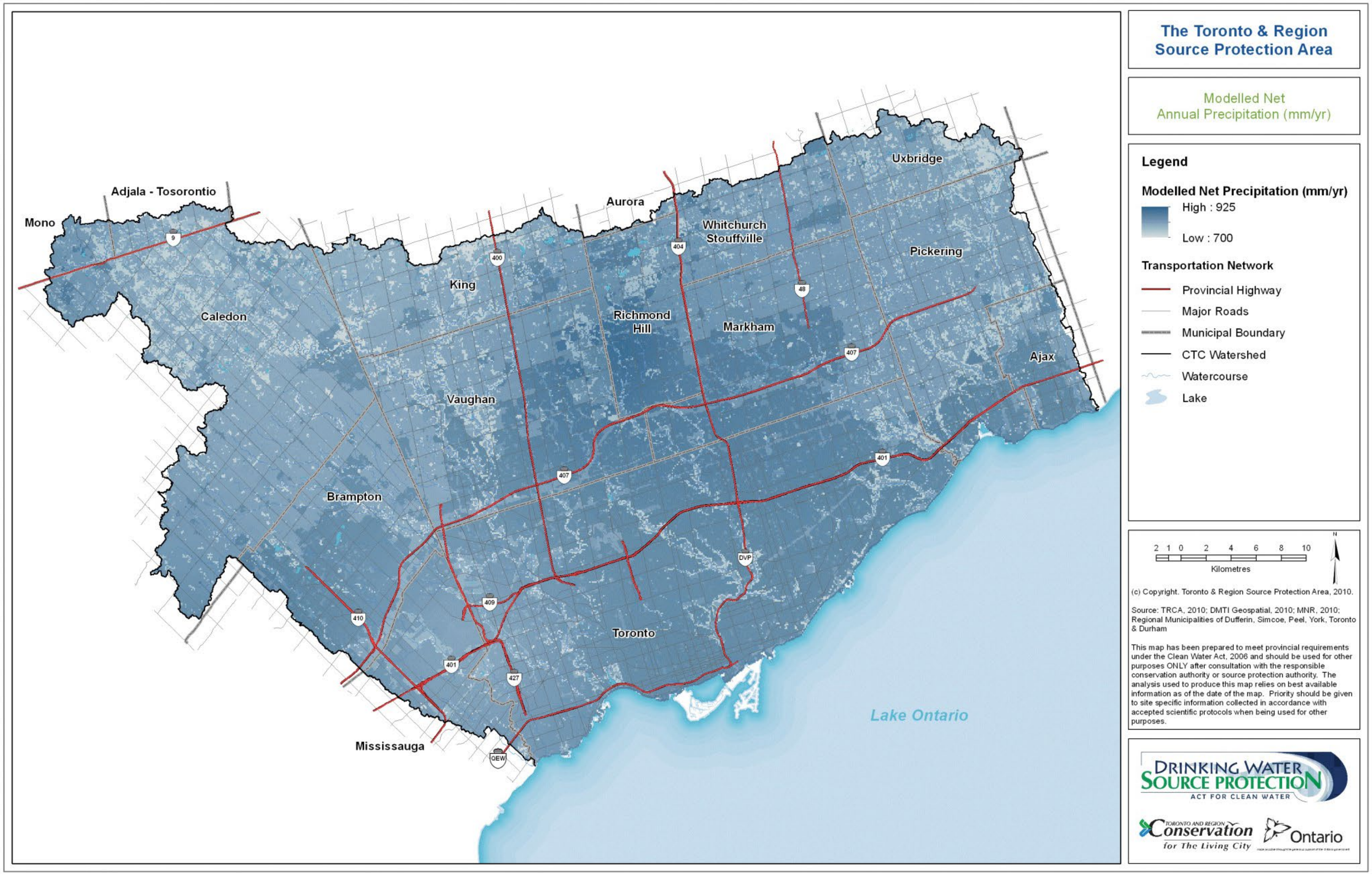

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Figure 3-3: Modelled Net Annual Precipitation (mm/yr)

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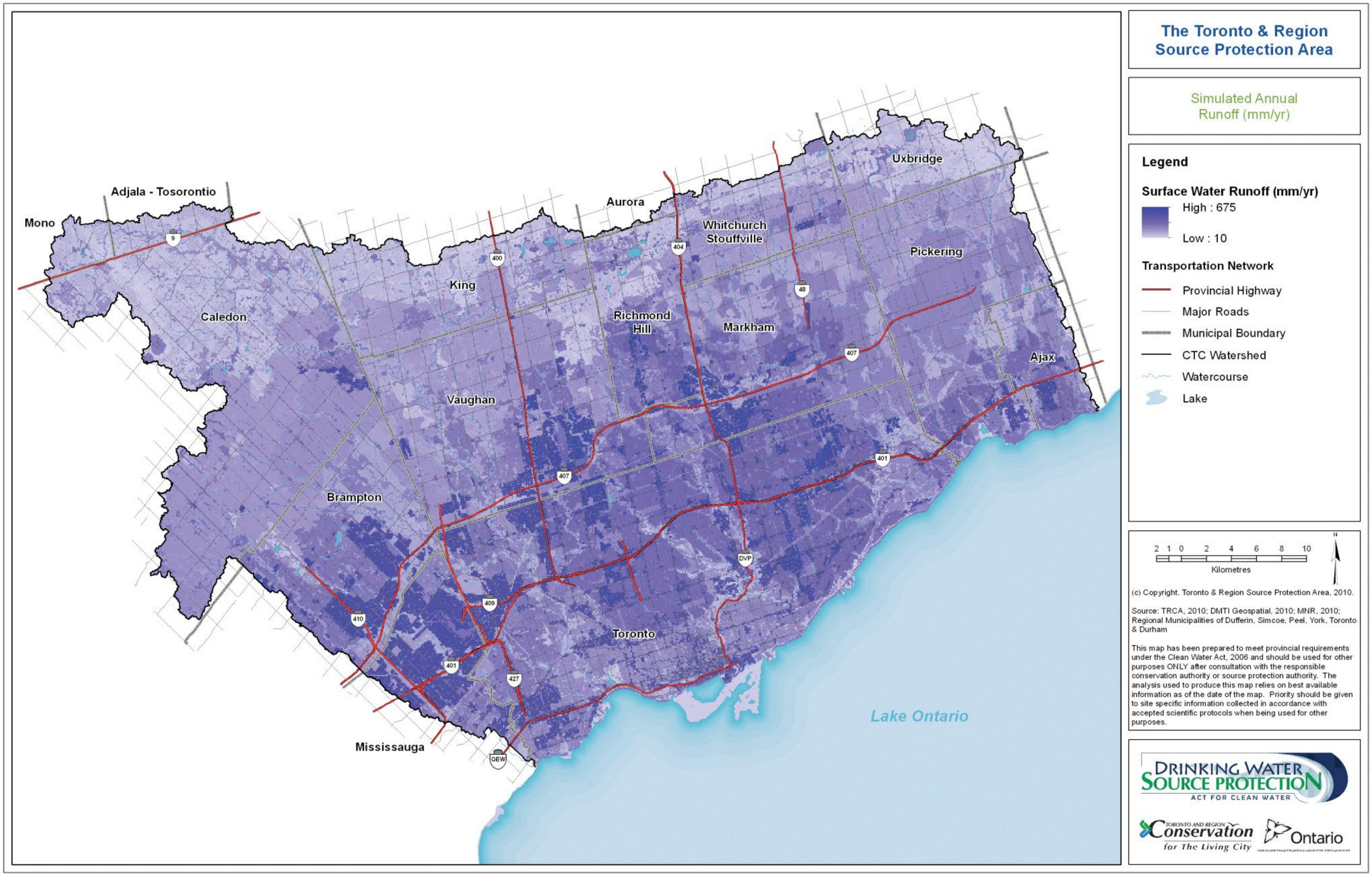
Figure 3-4: Simulated Annual Evapotranspiration (mm/yr)



The Toronto & Region Source Protection Area

Simulated Annual Runoff (mm/yr)

Source: TRCA, 2010; DMTI Geospatial, 2010; MNR, 2010; Regional Municipalities of Dufferin, Simcoe, Peel, York, Toronto & Durham

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Figure 3-5: Simulated Annual Runoff (mm/yr)

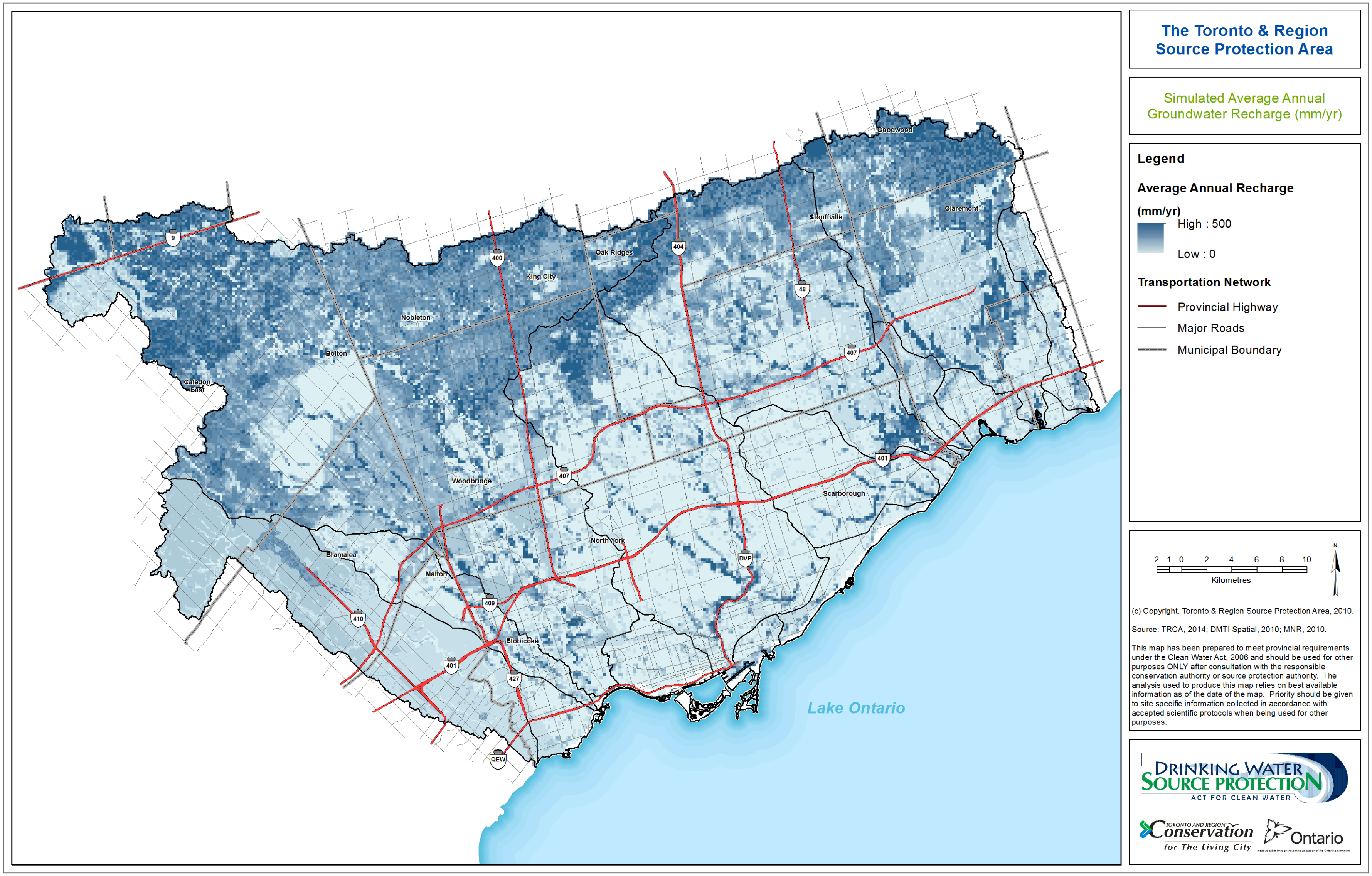

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Figure 3-6: Simulated Average Annual Groundwater Recharge (mm/yr)

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Figure 3-7: Simulated Average Annual Groundwater Discharge

3.2 PHYSICAL GEOGRAPHY

3.2.1 Topography

Land surface topography in the TRSPA jurisdiction varies from a minimum elevation of 75 metres above sea level (mASL) at Lake Ontario to a maximum of about 475 mASL on the crest of the Niagara Escarpment south of Mono (see **Figure 3.8**). Although the principal slope direction is from north of the crest of the Oak Ridges Moraine southwards toward Lake Ontario, slopes to the east are prevalent off the Niagara Escarpment in the Upper Humber and Etobicoke Creek headwaters. In addition, hummocky terrain (hilly, uneven landscape) dominates the Oak Ridges Moraine (see **Figure 3.9**) and creates areas with closed surface water drainage. This results in scattered small ponds and wetlands and typically higher than average groundwater recharge.

3.2.2 Physiography

The TRSPA jurisdiction includes five physiographic regions, as defined by Chapman and Putnam (1984) and shown in **Figure 3.10:**

- The Horseshoe Moraine and Guelph Drumlin Field along the western TRSPA boundary;
- Oak Ridges Moraine in the north;
- The South Slope through the core of TRSPA's jurisdiction;
- The Peel Plain (also known as the Peel Ponds) in the middle reaches of the Humber River watershed and the headwaters of the Mimico Creek watershed; and
- The Lake Iroquois Plain in the south along the Lake Ontario shoreline.

The Horseshoe Moraine and Guelph Drumlin Field are situated on top of the Niagara Escarpment, in the extreme northwest corner of TRSPA's jurisdiction. These areas are characterized by hummocky topography, similar to that of the Oak Ridges Moraine.

The Oak Ridges Moraine stands out as one of the most distinctive physiographic units of Southern Ontario (Chapman and Putnam, 1984). The surface is hilly, with a knob and basin (hummocky) relief that probably formed as the margin of the Lake Wisconsinan ice melted back from atop the Niagara Escarpment (Barnett *et al.,* 1998). It passes east-west through the centre of York Region, roughly midway between Lake Simcoe and Lake Ontario. The ridge formed by the Oak Ridges Moraine reaches a maximum elevation of about 400 mASL and extends eastward from the Niagara Escarpment to the Trent River, a distance of over 160 km.

The majority of the hills are composed of sandy or gravelly materials; however some of the highest points are formed of till that protrudes above or caps the sand. The overall structure of the moraine can be divided into four major "wedges" where the north–south extent of the moraine widens. These wedges are located, from west to east, in the vicinities of Albion Hills, Uxbridge, and Pontypool, and east of Rice Lake.

Due to its predominantly sandy surface soils and hummocky topography, the moraine serves as the primary recharge area to underlying aquifers. The moraine forms a surface water and groundwater divide (although the groundwater and surface water divides are not always coincident) between water flowing south to Lake Ontario, and water flowing north to Lake Simcoe and the Kawartha Lakes. While few streams are located on the moraine itself, springs along the flanks of the moraine provide groundwater discharge to streams that drain the till plains to the north and south. These springs are recharged on the Oak Ridges Moraine.

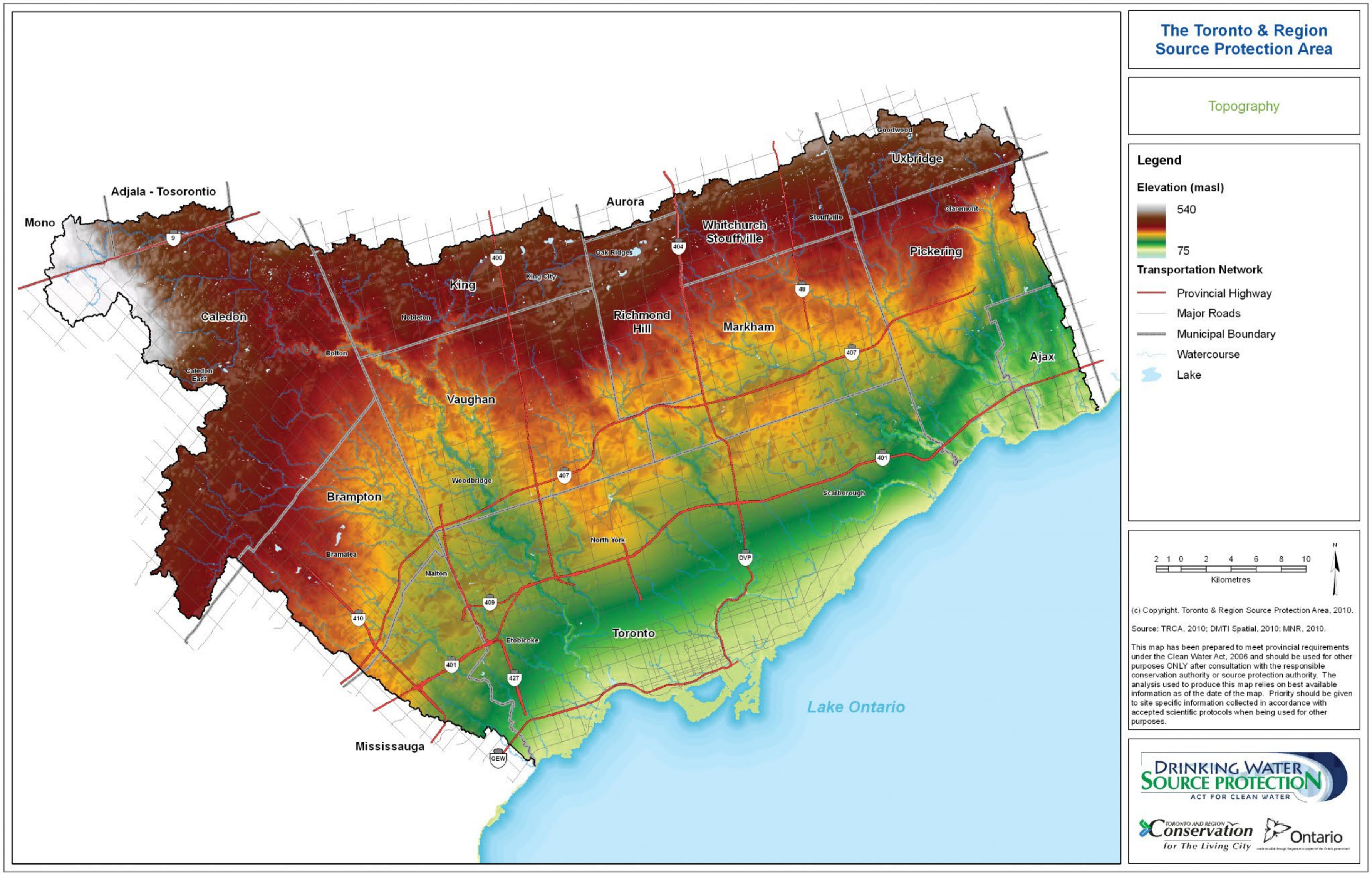

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Figure 3-8: Topography

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Figure 3-9: Hummocky Topography

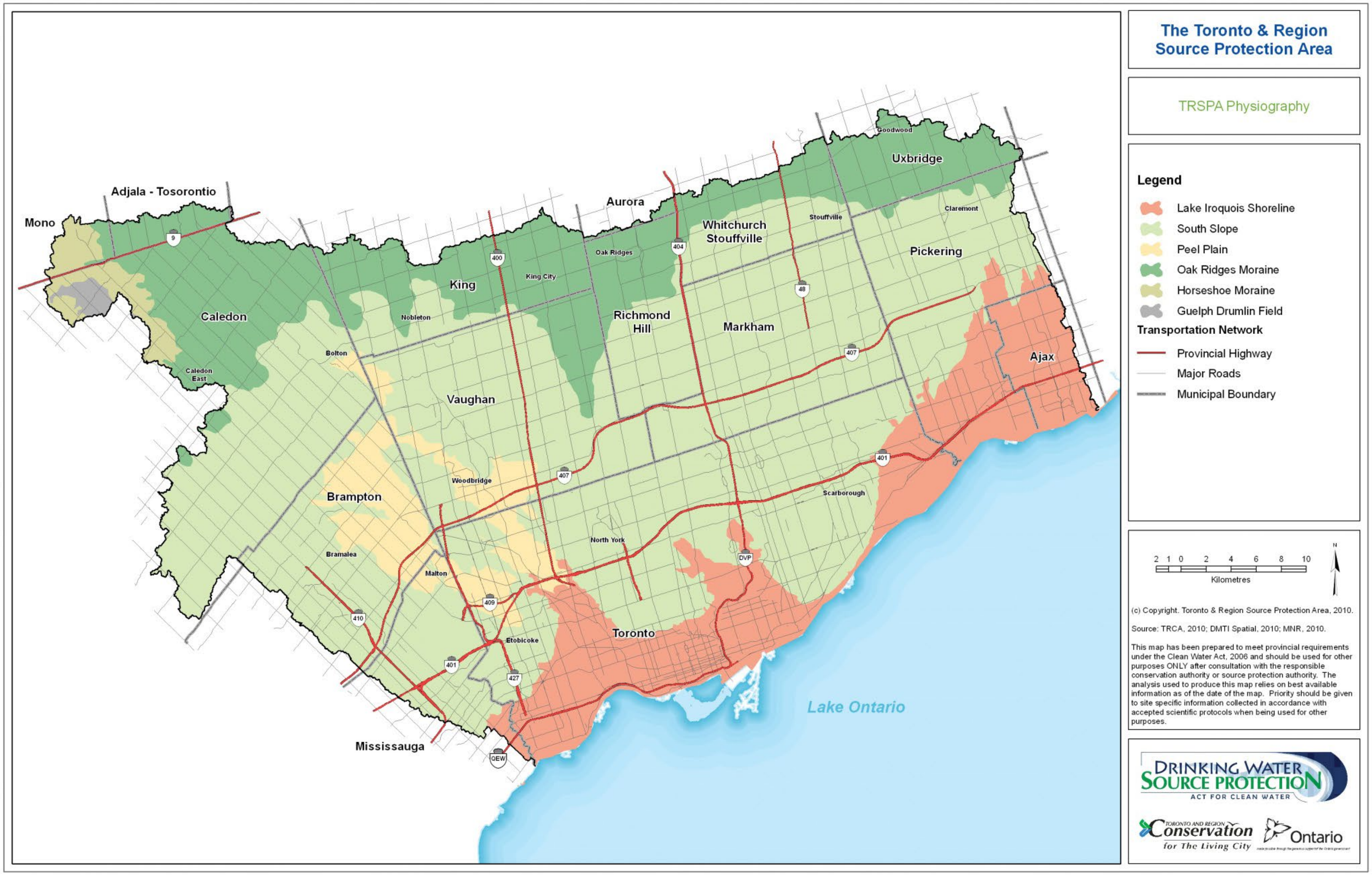

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Figure 3-10: TRSPA Physiography

The area south of the Oak Ridges Moraine has been divided into three physiographic regions: the South Slope, the Peel Plain, and the Iroquois Lake Plain (Chapman and Putnam, 1984). The South Slope is smooth, faintly *drumlinized* clay till plain containing the deeply incised stream valleys of the Credit, Humber, Don, and Rouge rivers. Elevations range from about 280 mASL where the South Slope intersects the Oak Ridges Moraine to about 80 mASL near the Lake Ontario shoreline.

The Peel Plain lies within the centre of the South Slope area and is a faintly undulating to flat till plain with a lake clay veneer. The Peel Plain is also deeply incised by the stream valleys. Finally, the Iroquois Lake Plain represents the near-shore area of glacial Lake Iroquois. Wave action on this predecessor to Lake Ontario cut down and smoothed the Halton and older tills and deposited beach sand and lake-bottom silts and clays within 5 km of the present shoreline.

Drumlinized: A landscape that is characterized by scattered elongated, low hills that are believed to have been formed under the glacial ice.

Laurentian Valley: An ancient river system that extended from what is now Georgian Bay to Lake Ontario. It created a valley estimated to be up to 4 km wide and 300 m deep.

Paleozoic: Geologic Era dating from about 250 to 650 million years before present.

Pleistocene: Geologic Epoch dating from about 10,000 to 2.6 million years before present.

3.2.3 Surficial Soils

A soils map is provided in **Figure 3.11**. This map was generated based on regional soil mapping by the Federal Department of Agriculture (Ontario Soil Survey, 1953, 1955, 1956, 1962, and 1964). The soils within TRSPA's jurisdiction are dominated by clay, clay loam, and loam (low permeability soils) derived from the Halton and Newmarket Tills and the Peel Plain clay deposits. Sandy loam soils (higher permeability soils) are present in the following areas:

- Upper reaches of the Humber River watershed north of Caledon East;
- Headwaters of the Humber, Don, and Rouge river watersheds between Maple, King City, and Richmond Hill;
- Headwaters of Duffins Creek in Uxbridge; and
- Middle reaches of Duffins Creek north of Ajax.

For a detailed assessment of the soils of each watershed, the reader is referred to the watershed plans prepared by TRCA staff (e.g., TRCA, 2007b, 2008), and *TRCA Tier 1 Water Budget Report* (TRCA, 2010).

3.3 GEOLOGY

3.3.1 Stratigraphic Framework

Fluvial: processes associated with rivers and the deposits and landforms they create.

To understand the geologic setting, the stratigraphic framework must be established. The stratigraphic framework is a conceptual description of the individual geologic units, and the sedimentological processes (deposition and erosional) that affected the units. The stratigraphic framework for the study area has been very well established in previous work (Karrow 1967; Dreimanis and Karrow, 1972; Sharpe *et al*., 2002; and Kassennaar and Wexler, 2006). The geology of the area can be characterized as consisting of sedimentary bedrock units overlain by unconsolidated overburden materials that have been deposited and modified by glacial, *fluvial* and lacustrine processes (Kassenaar and Wexler, 2006). The stratigraphic framework for the study area is outlined below and consists of (from oldest to youngest):

1. Canadian Shield
2. Paleozoic Bedrock (458 to 350 million years ago)
    i. Simcoe Group Limestone
    ii. Georgian Bay Shale
    iii. Queenston Shale
    iv. Cataract and Clinton Group Sandstones and Shales
    v. Lockport Dolostone
3. Regional Unconformity “The Big Gap” (350 million to 135,000 years ago)
4. Pleistocene Overburden (135,000 to 20,000 years ago)
    vi. York Till (or equivalent)
    vii. Don Formation (or equivalent)
    viii. Scarborough Formation (or equivalent)
    ix. Sunnybrook Drift (or equivalent)
    x. Thorncliffe Formation (or equivalent)
    xi. Newmarket Till (also referred to as the Northern Till)
5. Regional Unconformity (channel infill deposits) (After approx. 20,000 years ago)
    xii. Oak Ridges Moraine/Mackinaw Interstadial Deposits (Approx. 13,300 years ago)
    xiii. Halton/Kettleby Till (or equivalents, including Wentworth Till)
6. Glaciolacustrine Deposits (sand, silt and clay) (Approx. 12,500 years ago)

Details regarding the major bedrock and overburden units present in the TRSPA are provided in the following sections.

3.3.2 Bedrock Geology

A map of the bedrock geology based on data from the Ontario Geological Survey (OGS) is provided in **Figure 3.12**. Bedrock within the study area primarily comprises shale of the Upper Ordovician Georgian Bay and Queenston Formations. However, sandstone, shale, and dolostone of the Clinton and Cataract Groups and dolostone of the Lockport-Amabel Formations occur along the western boundary of the study area (Johnson *et al*., 1992). In addition, a small "finger" of the Middle Ordovician limestones of the Lindsay Formation extends into the north-central portion of the TRSPA (Armstrong and Dodge, 2007). (These rocks are between 458 and 438 million years old and were deposited in an ancient sea known as the Lapetus Ocean).

Prior to *Pleistocene* glaciation, the *Paleozoic* bedrock surface was deeply eroded by an ancient mid-continent river system (Eyles, 2002; Eyles *et al*., 1993). This surface forms the boundary that separates bedrock from the overburden sediments. The general location of valleys on this surface have been mapped previously on a regional basis (e.g., Eyles *et al*., 1993) and for various map sheets within or near the study area by the Ontario Geological Survey (Holden *et al*., 1993a; Holden *et al*., 1993b; Holden *et al*., 1993c; Holden *et al*., 1993d; Karrow, 1970; Karrow, 1992; Rogers *et al*., 1961; Sharpe and Clue, 1978; White, 1975). The best documented of these buried valleys, the *Laurentian Channel*, extends from Georgian Bay to Lake Ontario (Spencer, 1881) and is buried by sediment up to 200 m thick. Beneath the Oak Ridges Moraine, the geometry of the bedrock surface is poorly defined, as few wells intersect bedrock. In the Bolton area, valleys eroded into the Niagara Escarpment form tributary valleys to the main Laurentian Channel. These bedrock valleys may contain productive aquifers. It is also important to remember that processes associated with successive glacial and interglacial periods that have occurred throughout the Quaternary Period that began approximately 1.8 million years ago probably altered this bedrock valley system.

Diamicton: A till-like material that may or may not have been deposited by glacial ice.

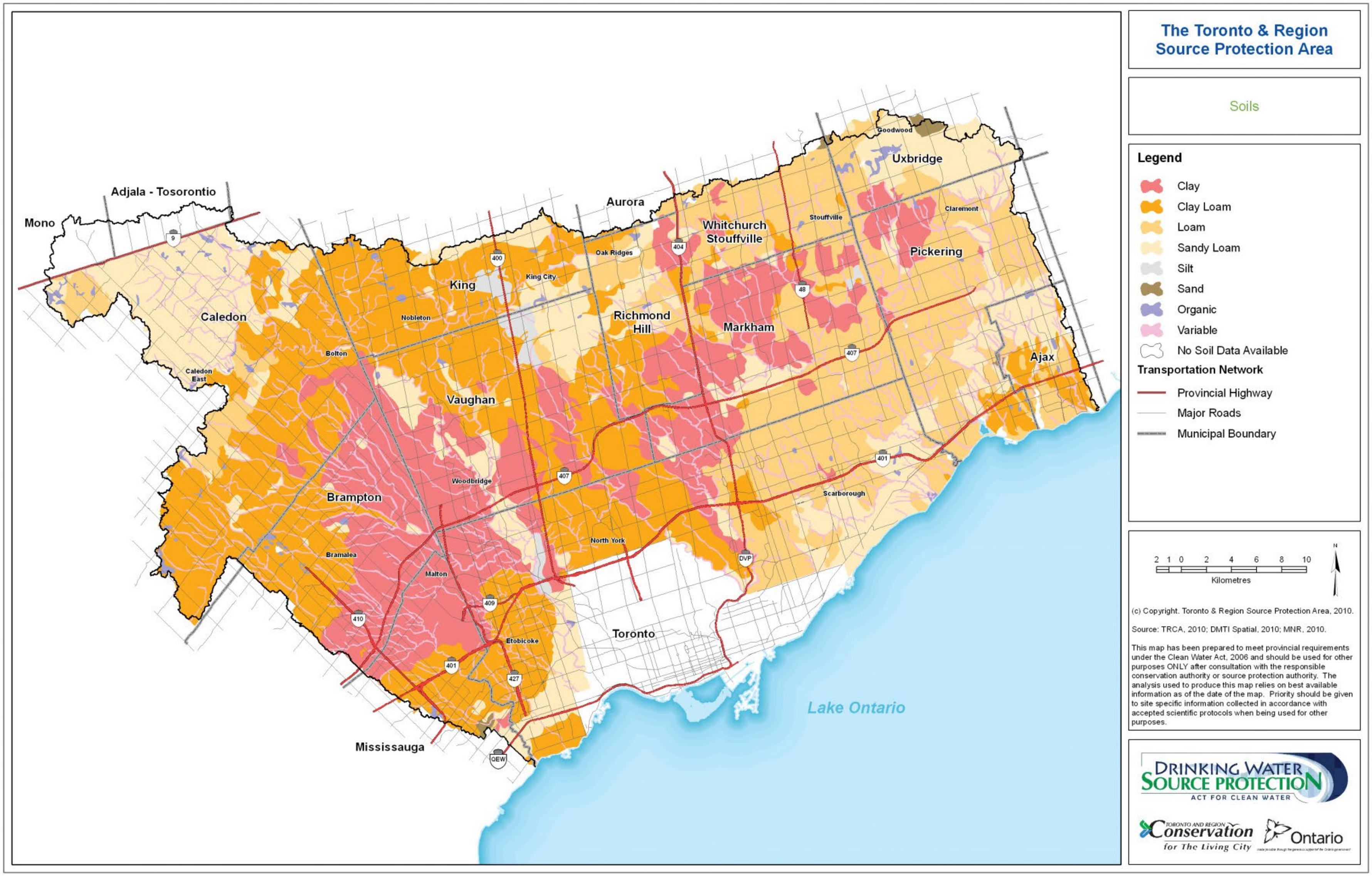
Glaciolacustrine: Sediments deposited in a lake associated with glacial ice.

Stratigraphy: The soil and rock layers within a study area and the layering process that created them.

Till: A term applied to a mixture of different grain sizes ranging from clay to boulders deposited directly by glacial ice.

An updated bedrock surface has been produced (Kassenaar and Wexler, 2006) that builds on the existing bedrock topography mapping mentioned above. This interpretation considers the bedrock surface as a fluvial river drainage system with associated tributaries that may have been altered by glacial/interglacial processes (see **Figure 3.13**).

The axis of this valley has been traced through all of the known bedrock low points as well as beneath deep overburden wells that did not intercept the bedrock surface. The major channel extends from High Park at Lake Ontario northwards through the west-central part of the study area near Maple and Nobleton. Major tributary valleys are interpreted to have drained to the main channel from the west through Bolton and Kleinburg. Tributary valleys from the east are believed to exist along the Holland Marsh area from Lake Simcoe, east of Bradford, and from Mount Albert through Aurora, King City, and Richmond Hill. Two main outlets are interpreted along the Lake Ontario shoreline near Humber Bay, and east of the Toronto Islands following the original Don River channel prior to human re-routing through the Toronto harbour area.



Source: TRCA, 2010; DMTI Spatial, 2010; MNR, 2010.

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Figure 3-11: Soils (Ontario Soil Survey: 1953, 1955, 1956, 1962, and 1964)

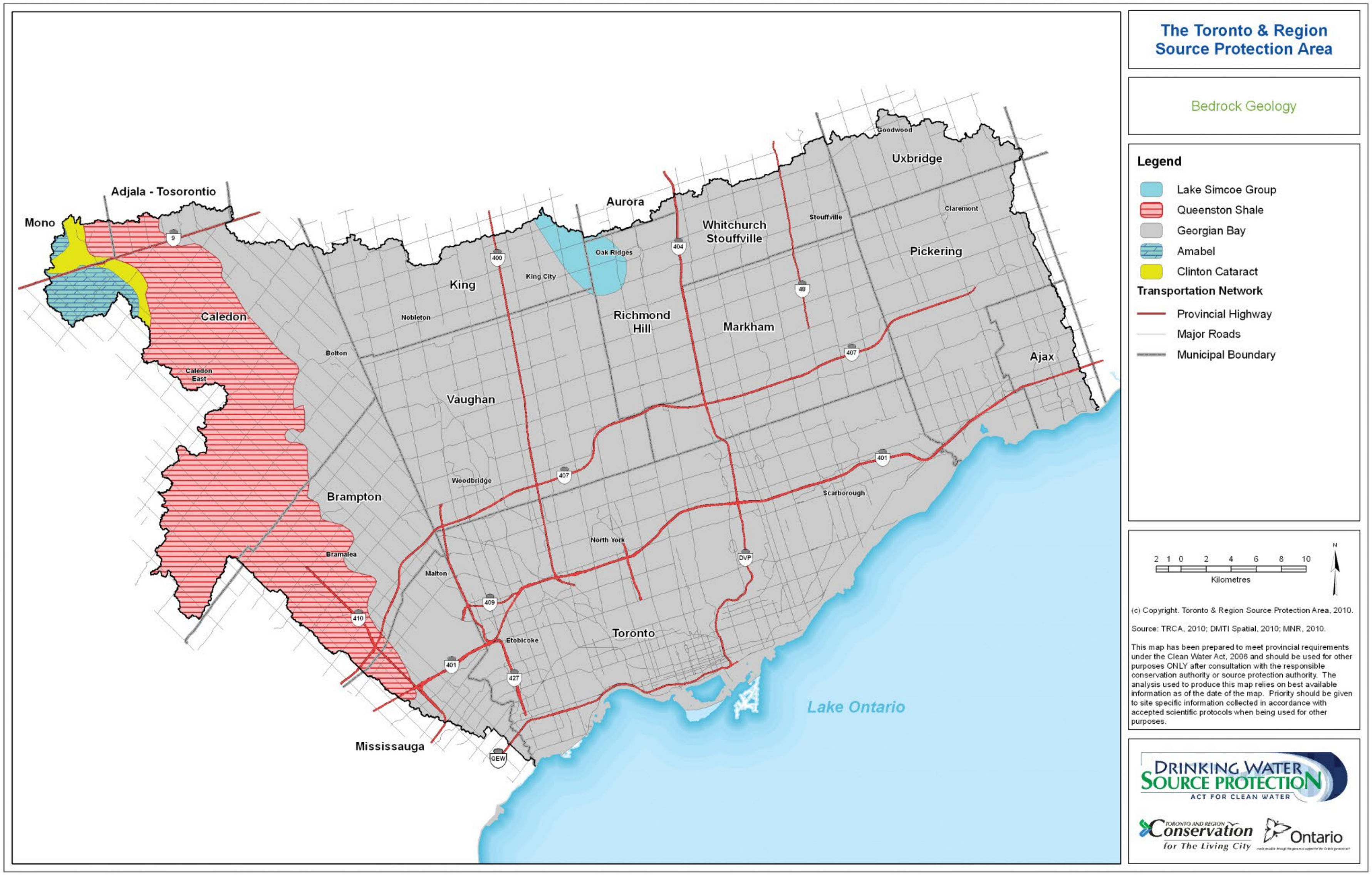

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Figure 3-12: Bedrock Geology (after Johnson et al., 1992)

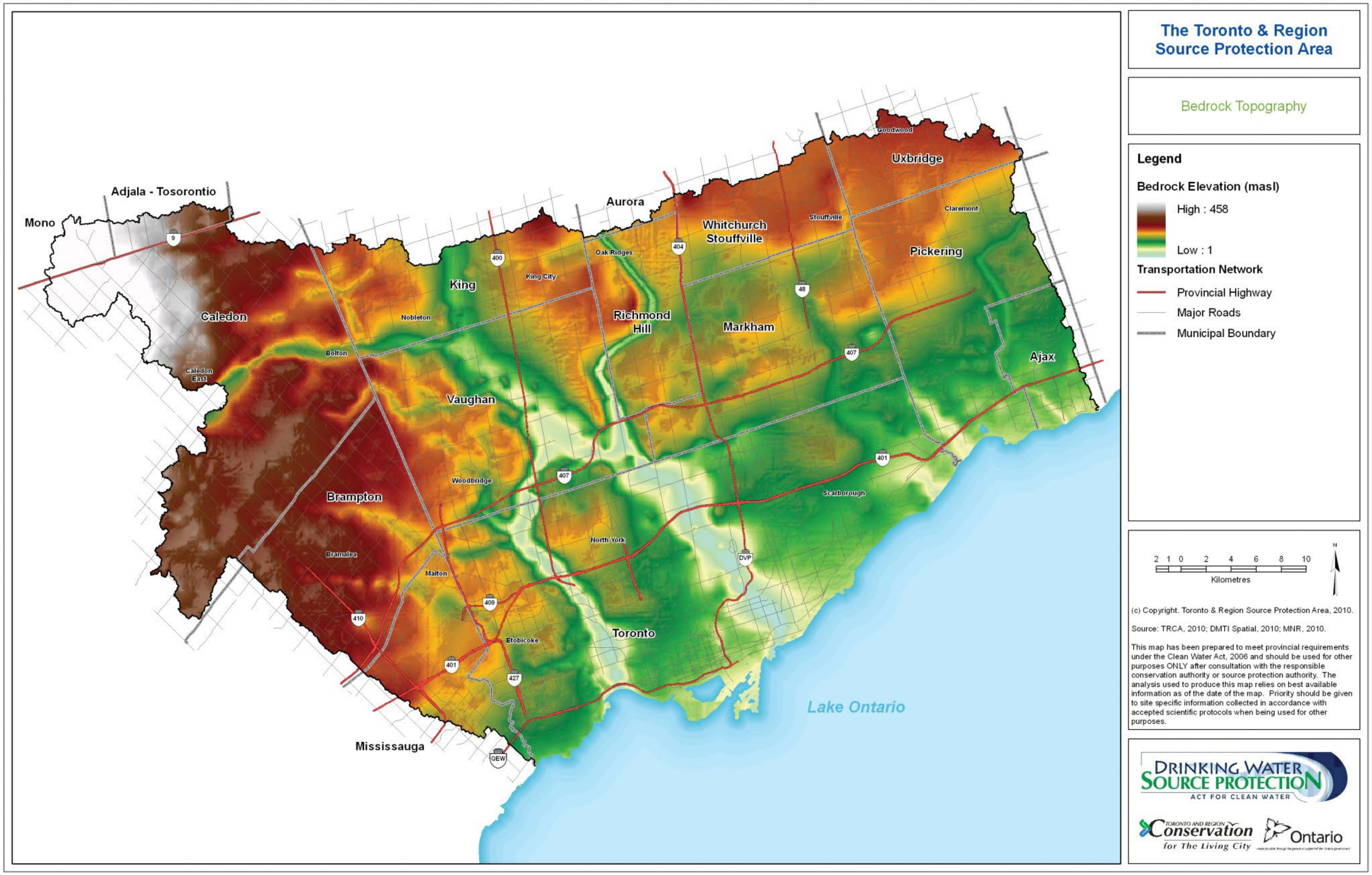

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Figure 3-13: Bedrock Topography

3.3.3 Overburden

The overburden geology of the study area consists of a succession of sediments that overlie the bedrock surface discussed previously. This succession is up to 200 m thick, as shown in **Figure 3.14**, and represents deposition over the last 135,000 years. A simplified surficial geology map for the study area is shown in **Figure 3.15**, and a schematic of the general *stratigraphy* of TRSPA's jurisdiction is shown in **Figure 3.16.** The aquifer and aquitard units are also presented on a typical north-south cross-section through the Humber River watershed (see **Figure 3.17**).

The surficial landforms and geologic deposits in this area were formed by a succession of glacial periods (when the climate was cooler than today) and interglacial periods (when the climate was similar to that of today (Eyles, 1997). One of the dominant landforms is the height of land known as the Oak Ridges Moraine, discussed above. This ridge of extensive sand and gravel was deposited approximately 12,000 years ago, and marks the boundary between two glacial ice lobes; one from the north known as the Simcoe lobe, and one from the south out of the Lake Ontario basin. Along the south slope of the moraine, the surficial deposits consist of *till*. These low permeability deposits are locally covered by a thin veneer (<5 m thick) of silt and clay (Glacial Lake Peel deposits) deposited in lakes and ponds formed from glacial melt water from the retreating glaciers.

A second prominent landform is an escarpment known as the Lake Iroquois shoreline discussed above. This lake existed approximately 10,000 years ago when water levels were approximately 60 m higher than the present lake level. Surficial geologic deposits south of the Lake Iroquois shoreline consist of near-shore beach sands and gravels, and deeper water silts and clays. Pleistocene glacial and non-glacial sediments are exposed to the south of the study area along the Lake Ontario bluffs and in the Don Valley brickyard (e.g., Eyles and Clark, 1988; Karrow, 1967; Brookfield *et al*., 1982) and underlie the Oak Ridges Moraine (Duckworth, 1979; Sado *et al*., 1984; Eyles *et al*., 1985). This complex stratigraphy generally consists of till, glaciolacustrine sand, silt, clay and diamicton. Further details regarding the geologic history of TRSPA's jurisdiction are provided in the *Conceptual Water Budget Report* (Gartner Lee, 2007*), TRCA Tier 1 Water Budget Report* (TRCA, 2010), and in Kassenaar and Wexler, 2006.

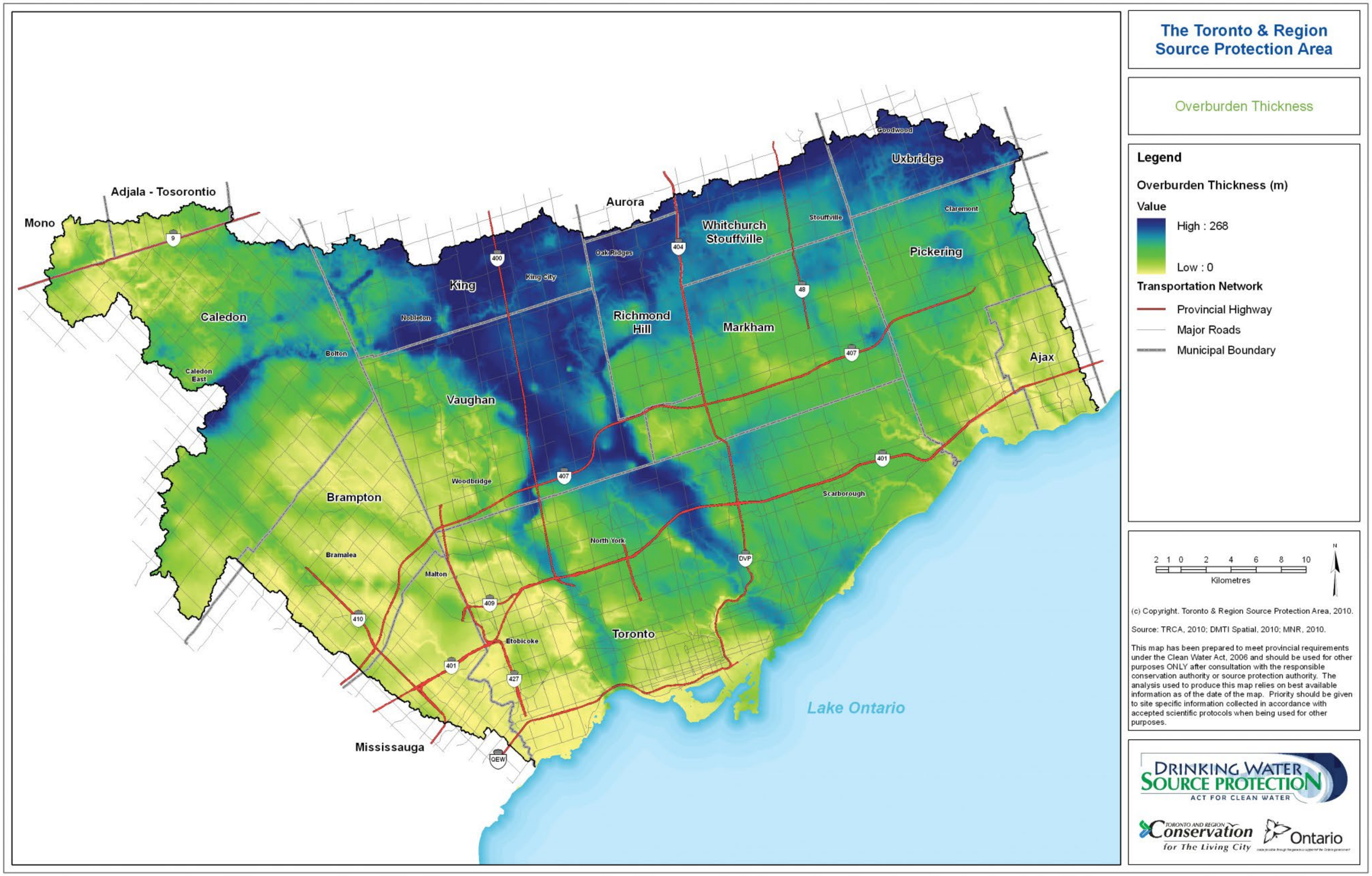

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Figure 3-14: Overburden Thickness (m)

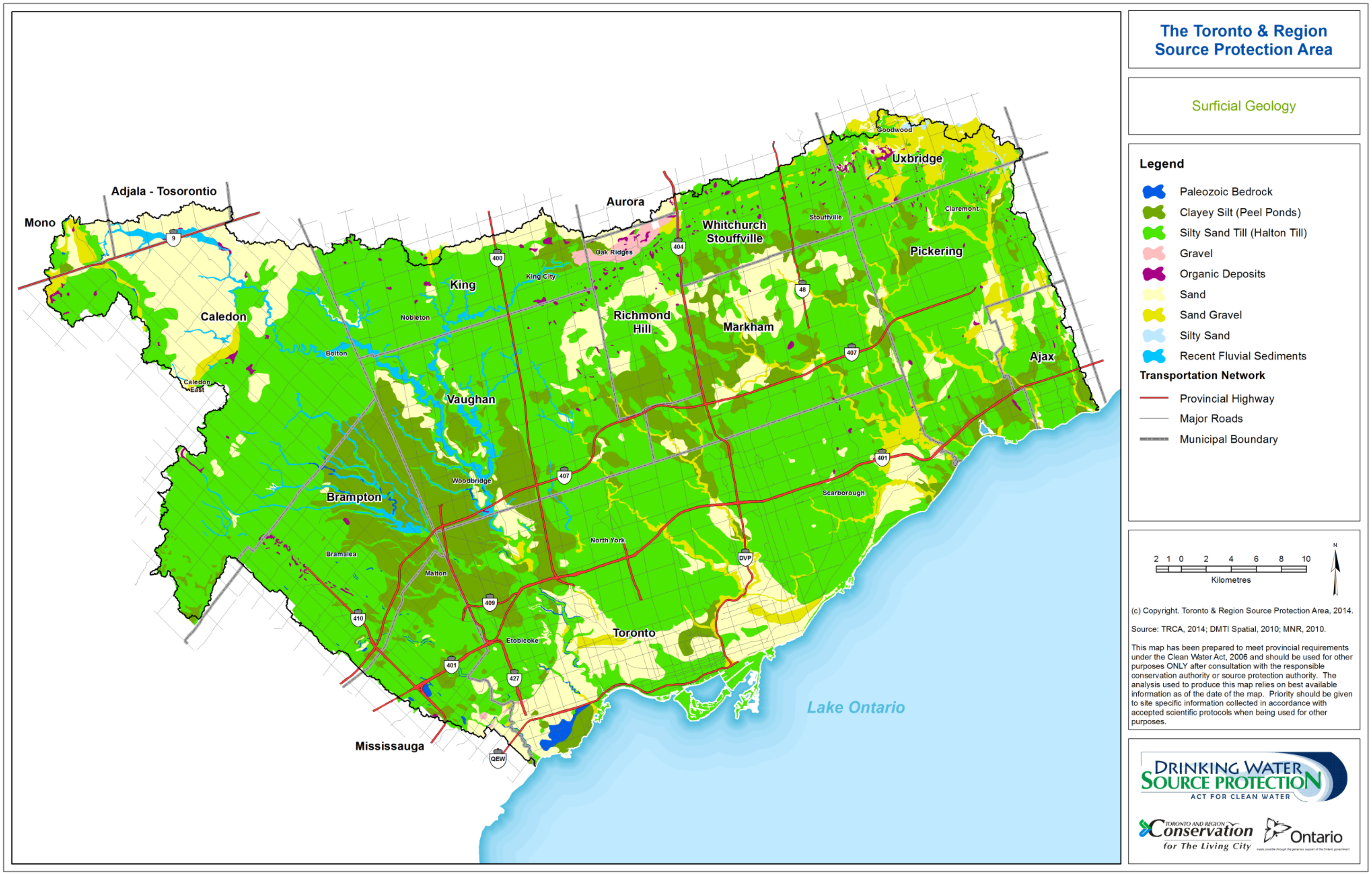

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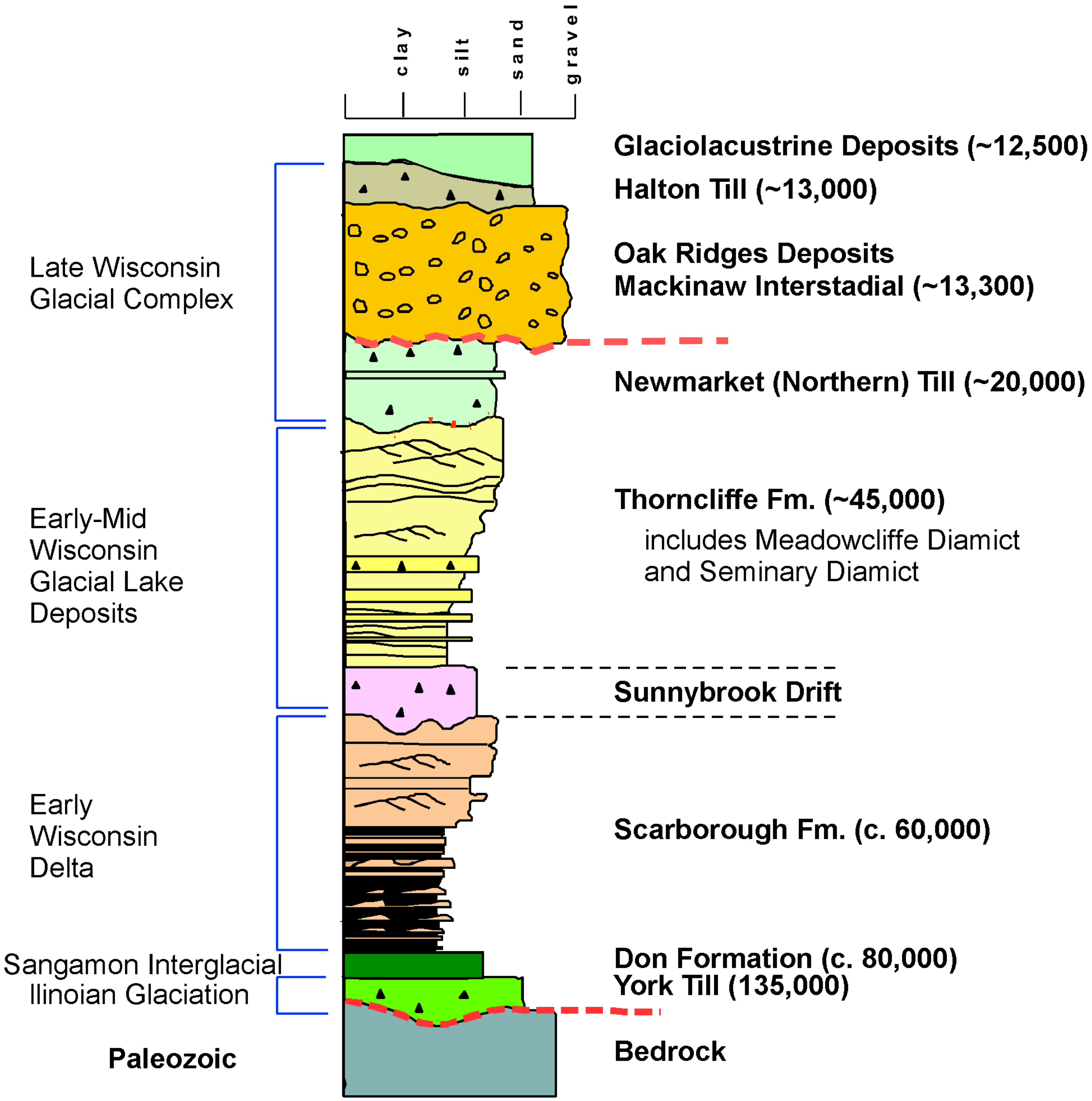
Figure 3-15: Surficial Geology (after Barnett et al., 1991)



Note:

Figure modified from Eyles, 2002.

Figure 3-16: General Stratigraphy of TRSPA's Jurisdiction

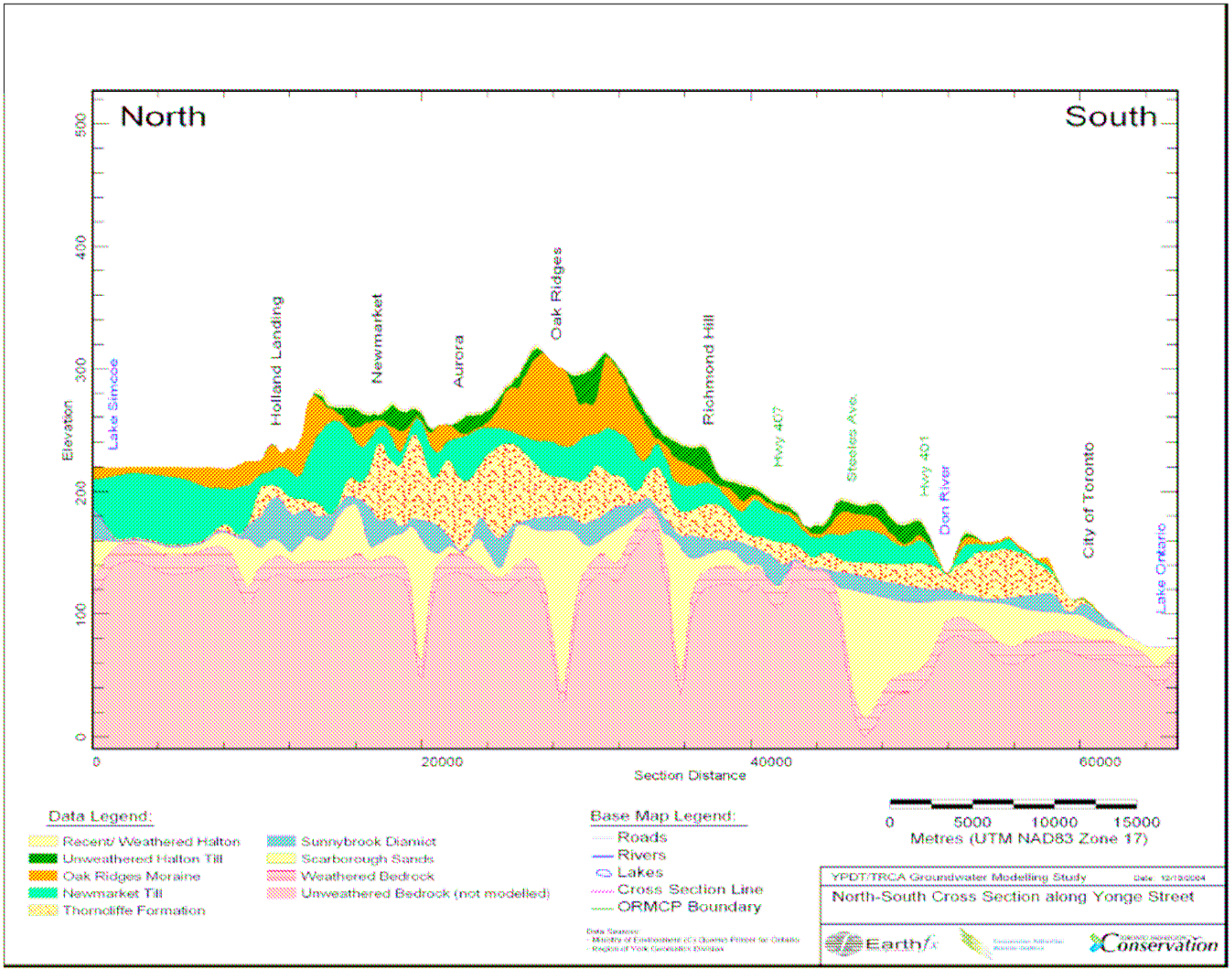


Figure 3-17: Typical North-South Cross-Section

3.4 SURFACE WATER FLOW SYSTEM

As mentioned in **Chapter 1**, the TRSPA jurisdiction includes nine major watersheds, namely the Etobicoke Creek, Mimico Creek, Humber River, Don River, Highland Creek, Rouge River, Petticoat Creek, Duffins Creek, and Carruthers Creek. There are many complex hydrologic factors involved in determining the amount of flow present in each of the watersheds including soil types (with varying abilities to both hold and transfer water), topography, land use, and climate (see **Table 3.1** and **Table 3.2**).

Although surface water quantity varies through the year, there is a general tendency for annual peak flows to occur in the spring, coinciding with spring melts, and the lowest flows in the summer, when precipitation is at a minimum and evapotranspiration is at its highest. Flooding is a natural, common occurrence in all the TRSPA watersheds, and the presence of wide floodplain areas extending beyond the banks of watercourses is common. Native aquatic species have evolved to take advantage of natural fluctuations in surface water flow, adapting to historic variations in rainfall/runoff characteristics. Fish spawning, rearing, and migration typically occur in the spring or fall, which coincides with higher baseflows and runoff volumes. Wetlands and small streams help reduce the frequency of threatening events by stabilizing water levels, absorbing flow when it is abundant and replenishing water during periods of drought.

All TRSPA watersheds have been affected by urbanization, which has had significant impact on the natural hydrologic cycle. Cleared and paved lands within TRSPA watersheds have resulted in a loss of infiltration, which in turn generates increased flows that have caused significant erosion and loss of aquatic habitat in many areas. Highly urbanized watersheds such as Highland Creek and Mimico Creek have been further impacted by past engineering practices that sought to convey the increased runoff as quickly as possible to streams via storm sewers and concrete channels. This practice has resulted in many wetlands and small streams being enclosed or buried. Urbanization has also resulted in floodplain encroachments, which have reduced the natural storage capacity. Seasonal variations in streamflow caused by vegetative cover and infiltration are no longer as prominent as they were in the past and the more urbanized watersheds exhibit a much more rapid hydrologic response, which poses a greater flood hazard.

Monitoring of both stream level (or flow) and precipitation is achieved partly through the Regional Water Monitoring Network (RWMN), which currently has 63 active stream gauges, as well as 101 active precipitation gauges. The stream gauges are currently operated through the RWMN with Environment Canada–Water Survey Branch (see **Table 3.2**). Environment Canada's stream gauge records are subject to a lag time between collection and publication for QA/QC purposes. The period of record shown for these stations reflects the available published data. TRCA also operates a jurisdictional baseflow monitoring program, which provides spot flow measurements during baseflow conditions. Added to the TRCA precipitation network are the federal climate stations, owned and operated by Environment Canada. These stations (e.g., Pearson International Airport, #6158733; Toronto, #6158350) have significant historic records, dating as far back as the early 1900s.

Figure 3.18 shows the location of stream gauge stations in the study area, and **Table 3.2** shows the average annual flows for these subwatersheds.

Table 3-1: TRSPA Stream Hydrologic Characteristics

Watershed	Drainage Area (km^2)	Channel Length (km)	Stream Density (m/km^2)	Average Slope (%)	Mean Annual Flow (m^3/s)	Trend in Average Annual Flow
Etobicoke	212	241	1138	3.3	2.3	Increasing
Mimico	77	58	748	3.4	0.8	Increasing
Humber	911	1,137	1248	6.0	6.8	Stable
Don	358	371	1037	5.2	4.0	Increasing
Highland	102	118	1162	4.1	1.1	Increasing
Rouge	333	429	1289	4.4	2.9*	Increasing
Petticoat	27	32	1178	3.8	0.5	Not determinable
Frenchman's Bay	27	27	987	4.0	> 0.3*	Not determinable
Duffins	287	331	1156	6.1	2.6	Stable
Carruthers	38	48	1269	3.9	0.4	Not determinable

** Catchment only partially gauged*

Table 3-2: Surface Water Flow at Specific Stream Gauges

Station Number	Watershed	Station Name	Period of Record	Annual Average Flow (m^3/s)
Water Survey of Canada Stations (Environment Canada)				
02hc005	Don	Don River at York Mills	1945 - 2006	1.00
02hc024	Don	Don River at Todmorden	1962 - 2006	4.5
02hc019	Duffins	Duffins Creek above Pickering	1960 - 2006	1.30
02hc038	Duffins	West Duffins Creek above Green River	1974 - 2006	0.62
02hc049	Duffins	Duffins Creek at Ajax	1989 - 2006	2.84
02hc017	Etobicoke	Etobicoke Creek at Brampton	1957 - 2009	0.64
02hc030	Etobicoke	Etobicoke Creek below QEW	1966 - 2006	2.53
02hc013	Highland	Highland Creek near West Hill	1956 - 2006	1.42
02hc003	Humber	Humber River at Weston	1945 - 2006	6.87
02hc009	Humber	East Humber River near Pine Grove	1953 - 2006	1.39
02hc023	Humber	Cold Creek near Bolton	1962 - 2006	0.49
02hc025	Humber	Humber River at Elder Mills	1962 - 2003	2.63
02hc027	Humber	Black Creek near Weston	1966 - 2006	0.90
02hc031	Humber	West Humber River at Highway 7	1965 - 2006	1.25
02hc032	Humber	East Humber River at King Creek	1965 - 2006	0.61
02hc047	Humber	Humber River near Palgrave	1981 - 2006	1.53
02hc051	Humber	Centreville Creek near Albion	2002 - 2006	0.38
02hc057	Humber	Humber River near Ballycroy	2005 - 2006	0.52
02hc033	Mimico	Mimico Creek at Islington	1965 – 2006	0.88
02hc022	Rouge	Rouge River near Markham	1961 - 2006	1.54
02hc028	Rouge	Little Rouge Creek near Locust Hill	1963 - 2006	0.96
02hc053	Rouge	Little Rouge River near Dickson's Hill	2002 - 2006	0.73
02hc012	Humber	Humber near Cedar Hills	1957 – 1981	0.05

RWMN Surface Water Flow Stations				
32	Carruthers	Carruthers at Bayly Street	2007 - 2009	0.38
107	Don	Don River at Knightswood	2007 – 2009	0.80
45	Don	Taylor Creek	2004 – 2009	0.30
92	Don	Wilket Creek	2007 – 2009	1.58
95	Don	West Don River at Dufferin & Steeles	2005 – 2009	0.76
29	Duffins	Brougham Creek at 5th Concession	1997 – 2009	0.18
30	Duffins	Urfe Creek at Rossland Road	1997 – 2009	0.24
53	Duffins	Mitchell Creek–Claremont CA	2001 – 2009	0.29
54	Duffins	East Duffins Creek–Claremont CA	2001 – 2009	1.53
84	Duffins	Ganetsekiagon Creek	2003 - 2008	0.12
97	Duffins	West Duffins at Highway 7	2005 – 2008	1.06
28	Duffins	Reesor Creek at 8th Concession	1974 - 2009	0.61
90	Etobicoke	Spring Creek	2003 – 2009	0.50
91	Etobicoke	Etobicoke Creek at Derry and Dixie	2003 – 2009	1.08
51	Frenchman's Bay	Pine Creek at Radom	2007 – 2009	0.22
52	Frenchman's Bay	Krosno Creek at Sandy Beach Road	2000 – 2008	0.04
46	Highland	Highland Creek–Malvern Branch	2003 – 2009	1.27
41	Humber	Humber at Goreway Road	2004 – 2009	0.58
71	Humber	Plunkett Creek	2004 – 2009	0.52
57	Mimico	Mimico Creek–Wildwood Park	2003 – 2009	0.83
55	Petticoat	Petticoat Creek Conservation Area	2001 – 2009	0.33
36	Rouge	Burndenet Creek at Kennedy & Austin Drive	2001 – 2005	0.10

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Source: TRCA, 2010; DMTI Geospatial, 2010; MNR, 2010; Regional Municipalities of Dufferin, Simcoe, Peel, York, Toronto & Durham

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Figure 3-18: Surface Water Monitoring Locations

3.4.1 Surface Water Modelling

Peak Flows

Hydrologic models using Hydrologic Modelling (HYMO) software have been developed for all nine TRSPA watersheds to simulate runoff from single design storm events (i.e., 2 to 100 year return and *Regulatory Storm*). Results from these models have served as input to develop a river hydraulic model (HEC-RAS: Hydrologic Engineering Centers River Analysis System) to calculate flood lines, which in turn have been used to produce floodplain maps. The hydrology and floodplain mapping program is ongoing, and is updated by watershed every five to seven years, using the most current land use data available.

Regulatory Storm: The largest observed storm on record for a given region, or the 100 year return storm, whichever is greater.

Total Flow and Baseflow

There are a number of water budget investigations that have been conducted within the TRSPA that involved the estimation of groundwater recharge. The model codes utilized were:

- Hydrological Simulation Program–Fortran Models (HSP-F) developed by the United States Geologic Survey (USGS)(Bicknell *et al.,* 1996);
- Water Balance Analysis System (WABAS) developed by Clarifica Inc.; and
- Precipitation-Runoff Modelling System (PRMS), developed by the USGS (Leavesely *et al.,* 1987).

These models enabled assessments to be made regarding the effect of land use change on the hydrologic cycle and also allowed estimates to be derived for groundwater recharge on a spatial basis for both existing and future land use conditions. This approach also facilitated the identification and evaluation of alternative mitigation techniques needed to maintain existing groundwater recharge levels following land use changes. To date, TRCA staff has completed water budget assessments for the Don, Rouge, Humber, Etobicoke, and Mimico watersheds using HSP-F, the Duffins and Petticoat watersheds using WABAS, and the Humber and Rouge watersheds using PRMS for the surface water component and MODFLOW for the groundwater component.

In addition to the work done by TRCA and its consultants, the City of Toronto developed hydrological and water quality models for all local area watersheds to predict stormwater runoff and water quality in local streams and the Toronto waterfront as a part of the *Toronto Wet Weather Flow Management Master Plan (TWWFMMP)*. The principal analytical tool used was the HSP-F model. This numerical model is capable of simulating hydrologic processes, pollutant generation, and transport processes both within catchments and along watercourse networks. The model for the individual watersheds was calibrated to streamflow, surface water quality, and sewer discharge data, and then applied to assess the potential benefits of implementing stormwater management practices across the City of Toronto (Totten Sims Hubicki, 2003; XCG Consultants Limited, 2003a; Marshall Macklin Monaghan Limited, 2003; Aquafor Beech Limited, 2003).

All of the surface water models were developed with inputs of:

- Daily precipitation;
- Average or maximum daily temperature;
- Pan evaporation;
- Daily streamflow measurements;
- Physical basin parameters including imperviousness and interception; and
- Vegetation and soil characteristics.

The outputs from the models included time series of:

- Runoff;
- Infiltration;
- Evaporation; and
- Storage conditions within each water reservoir (pervious and impervious interception, surficial soil, and snowpack).

Water Budget Analysis

For the water budget analysis under the *Clean Water Act, 2006* (*CWA)*, the PRMS model output was selected to represent total flow volumes and rates for the surface water flow system. While utilizing continuous stream gauging data was explored, due to the combination of record length and gauge locations, only 11 of the 52 catchments could be assessed using gauge data. The PRMS model, loosely coupled with MODFLOW, has the ability to fully distribute both groundwater discharge and runoff, and provided the best calibration and validation throughout the entire TRSPA. Model parameters (median daily groundwater discharge and median daily runoff) were summed by catchment, and flows were then accumulated through the watershed catchments to represent cumulative median monthly streamflow. Channel and reservoir routing was not part of this process. Details on the modelling work are included in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010).

This method allowed for the surface water stress assessment to be based on modelled median monthly flow (Qp_{50}) for supply estimates, and the modelled 10th percentile flow (Qp_{90}) for the reserve estimates. The difference between the two is the resulting “available supply”, which was then compared to the monthly demand estimates (TRCA, 2010).

3.4.2 Surface Water Trends

A linear regression analysis was completed at seven gauging stations across the TRSPA jurisdiction to determine the linear trends in baseflow volumes between the early 1960s and 2001 (**Figure 3.19** to **Figure 3.25**). Daily streamflow records were separated into the baseflow and runoff components through a baseflow separation method. The technique used to separate baseflow and runoff was derived from a combination of methods for baseflow separation (Pilgrim and Cordery, 1993; Viessman *et al*, 1989; Clarifica Inc., 2002). This technique can be referred to as a ‘floating average’ of minimum stream flow over a period of time.

Hydrological data for each TRCA stream gauge was obtained from the Water Survey of Canada and the daily flow is extracted for a given time period. The data are organized into a continuous time series for January to December and the minimum flow for a 6-day period is extracted by calculating the minimum flow 2-days before and 3-days after the measurement to generate a 6-day minimum. If the average of the 6-day minimum values is less than the measured flow, the average minimum was considered the baseflow. If the average of the 6-day minimum values was greater than the measured flow, the measured flow for that day was considered the baseflow. The same technique in calculating the 6-day minimum values was used to calculate the average baseflow. The average baseflow value was subtracted from the measured flow to estimate runoff. From this, a hydrograph is produced depicting the measured flow, baseflow, and runoff for any given gauging station and time period.

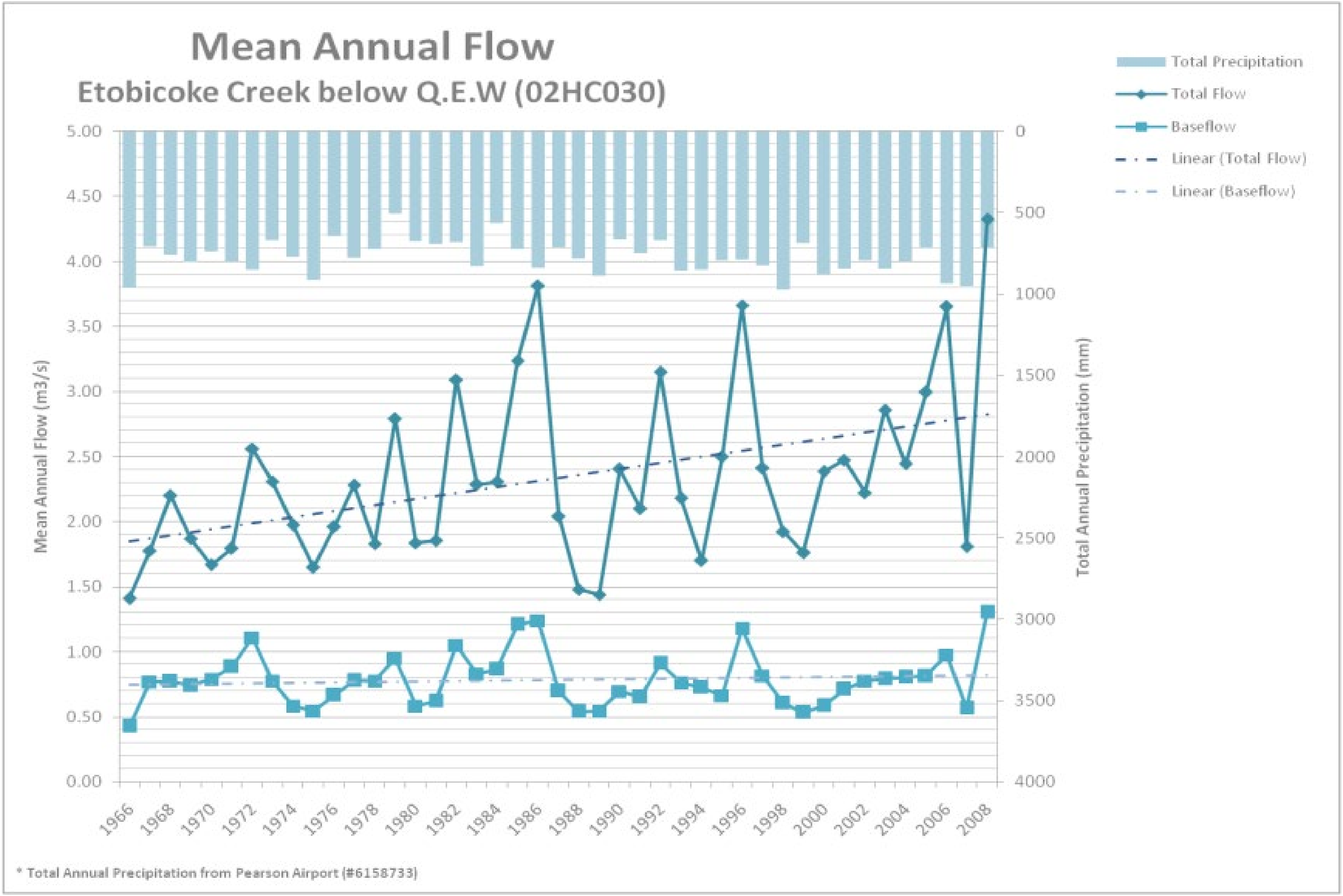


Figure 3-19: Mean Annual Flow, Baseflow, and Precipitation Trends – Etobicoke Creek

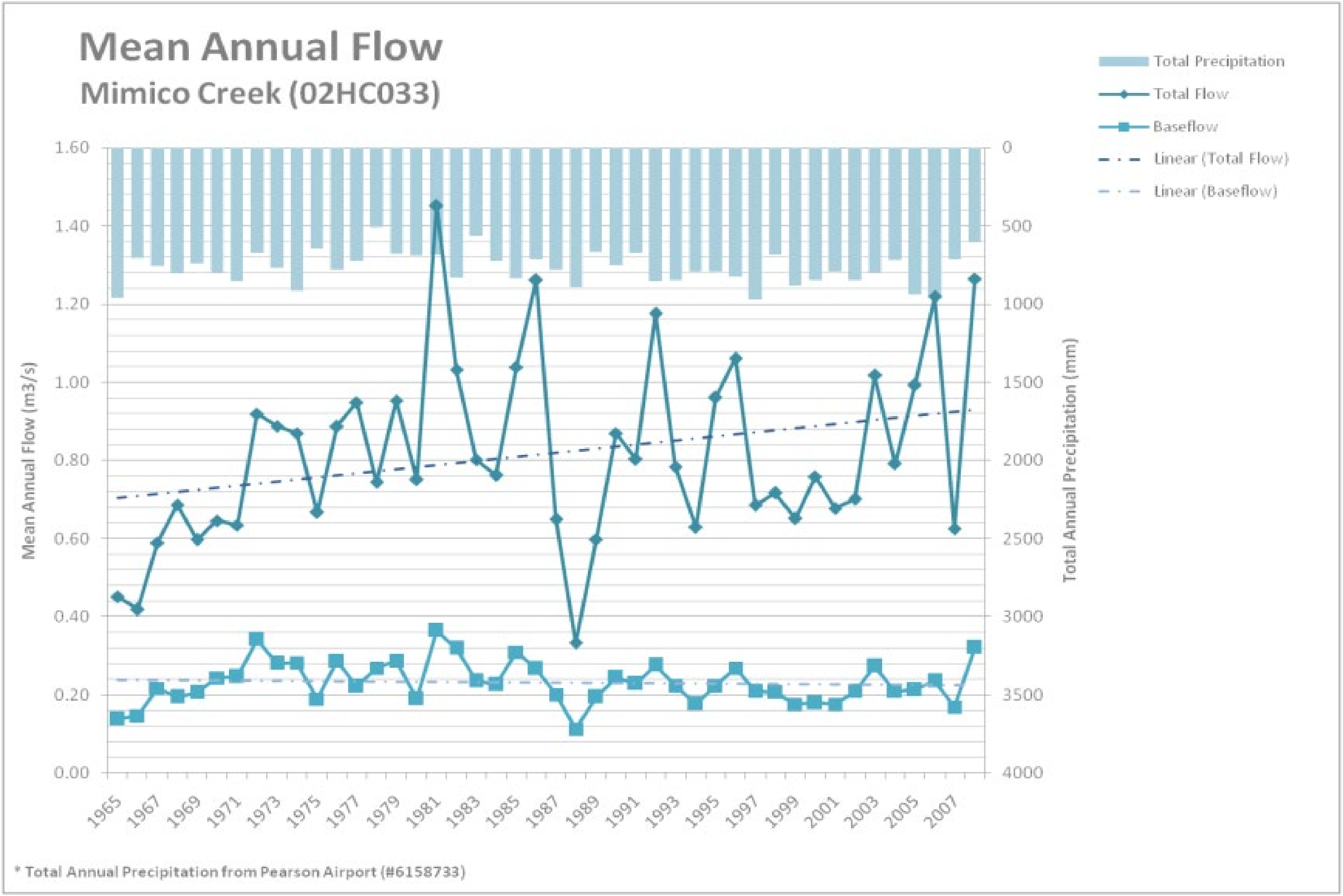
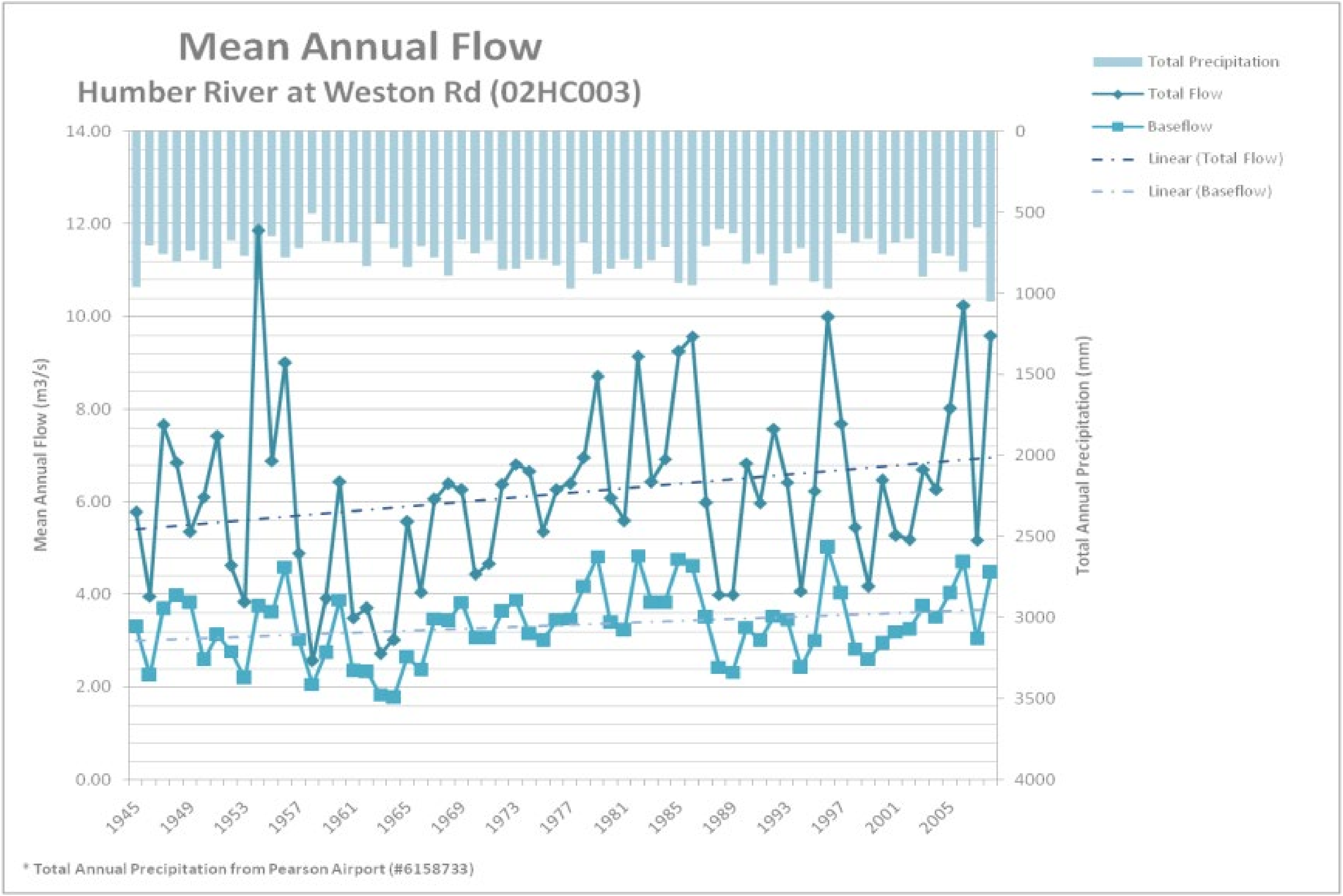


Figure 3-20: Mean Annual Flow, Baseflow, and Precipitation Trends – Mimico Creek



* Total Annual Precipitation from Pearson Airport (#6158733)

Figure 3-21: Mean Annual Flow, Baseflow, and Precipitation Trends – Humber River

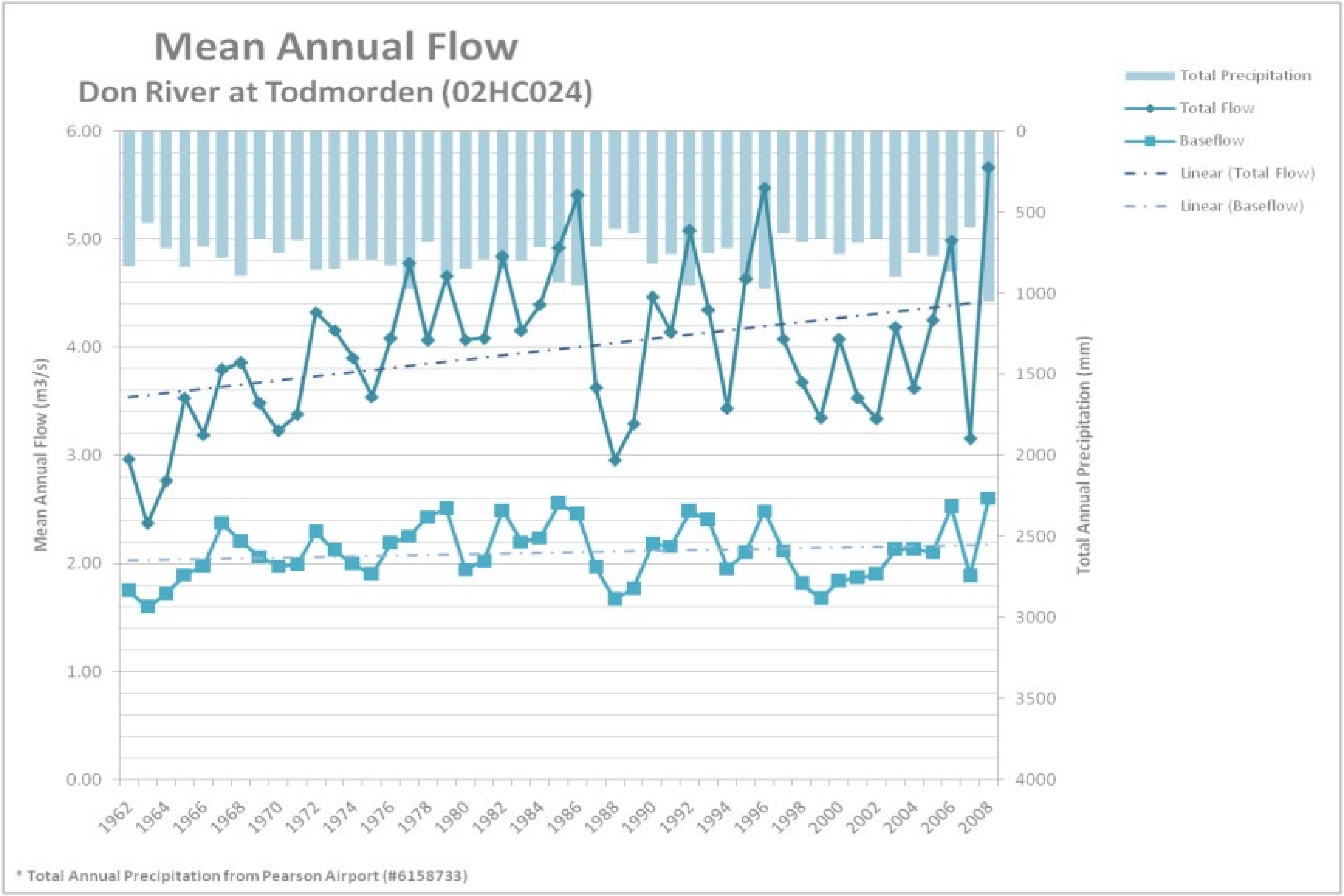
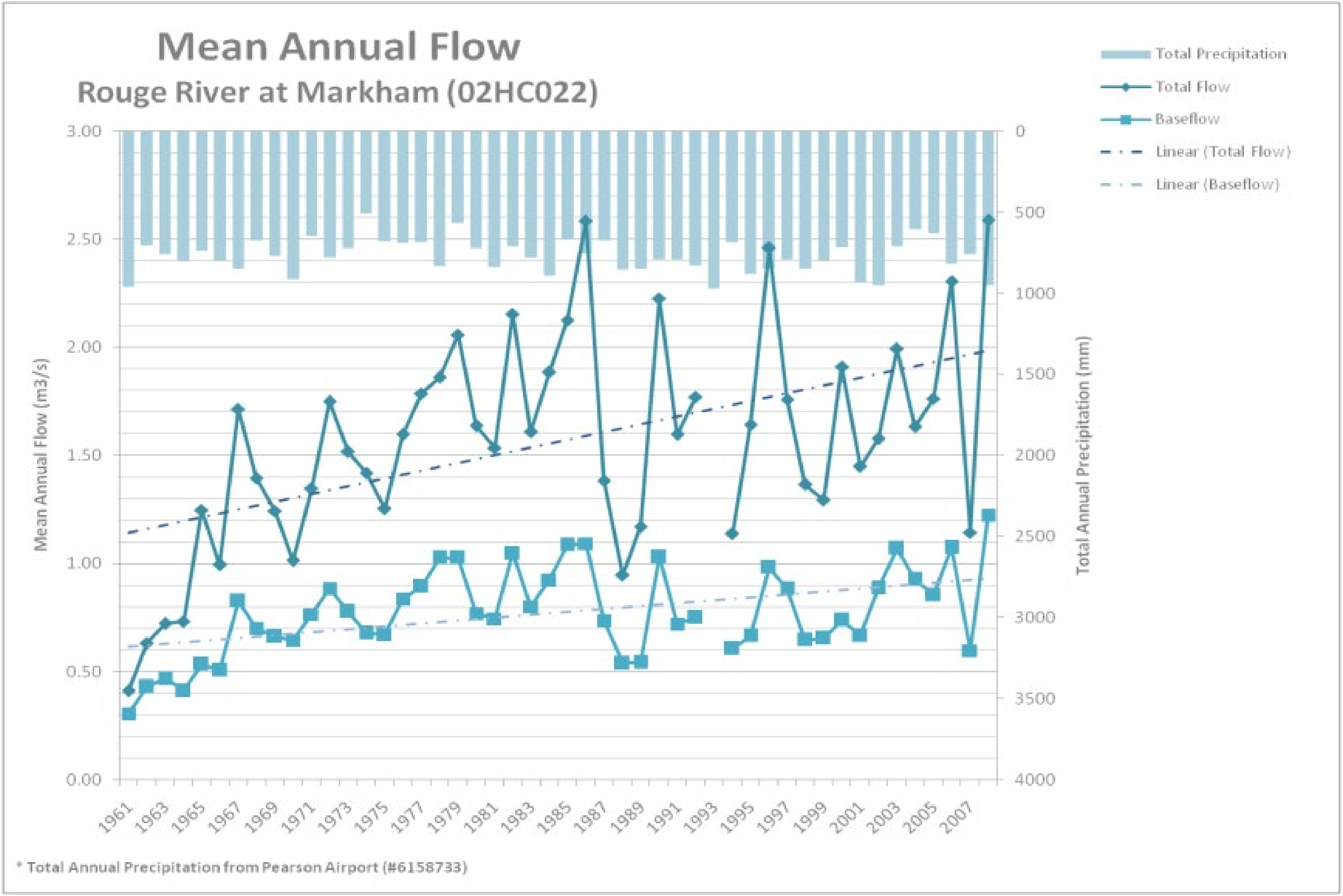


Figure 3-22: Mean Annual Flow, Baseflow, and Precipitation Trends – Don River



* Total Annual Precipitation from Pearson Airport (#6158733)

Figure 3-23: Mean Annual Flow, Baseflow, and Precipitation Trends – Rouge River

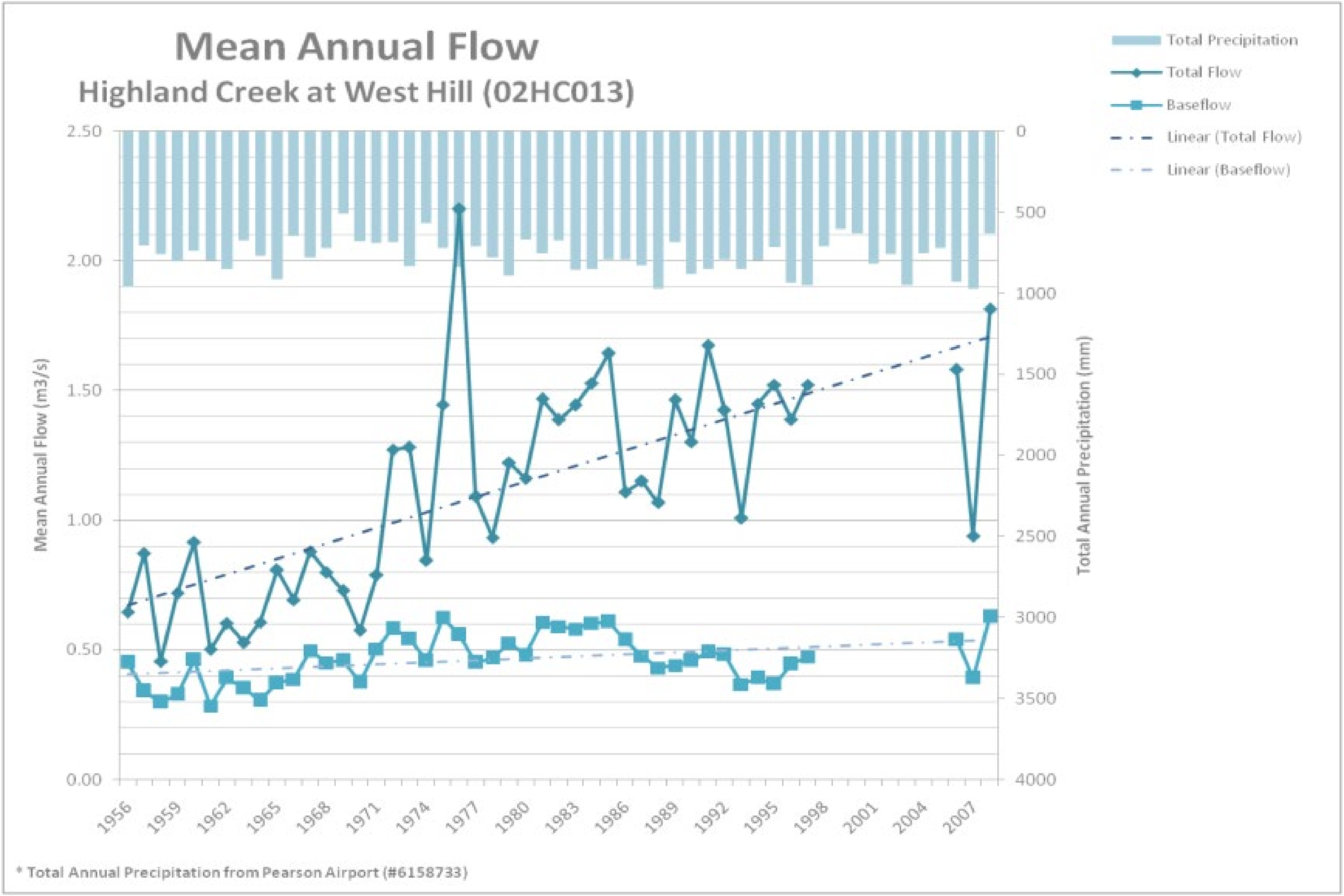


Figure 3-24: Mean Annual Flow, Baseflow, and Precipitation Trends – Highland Creek

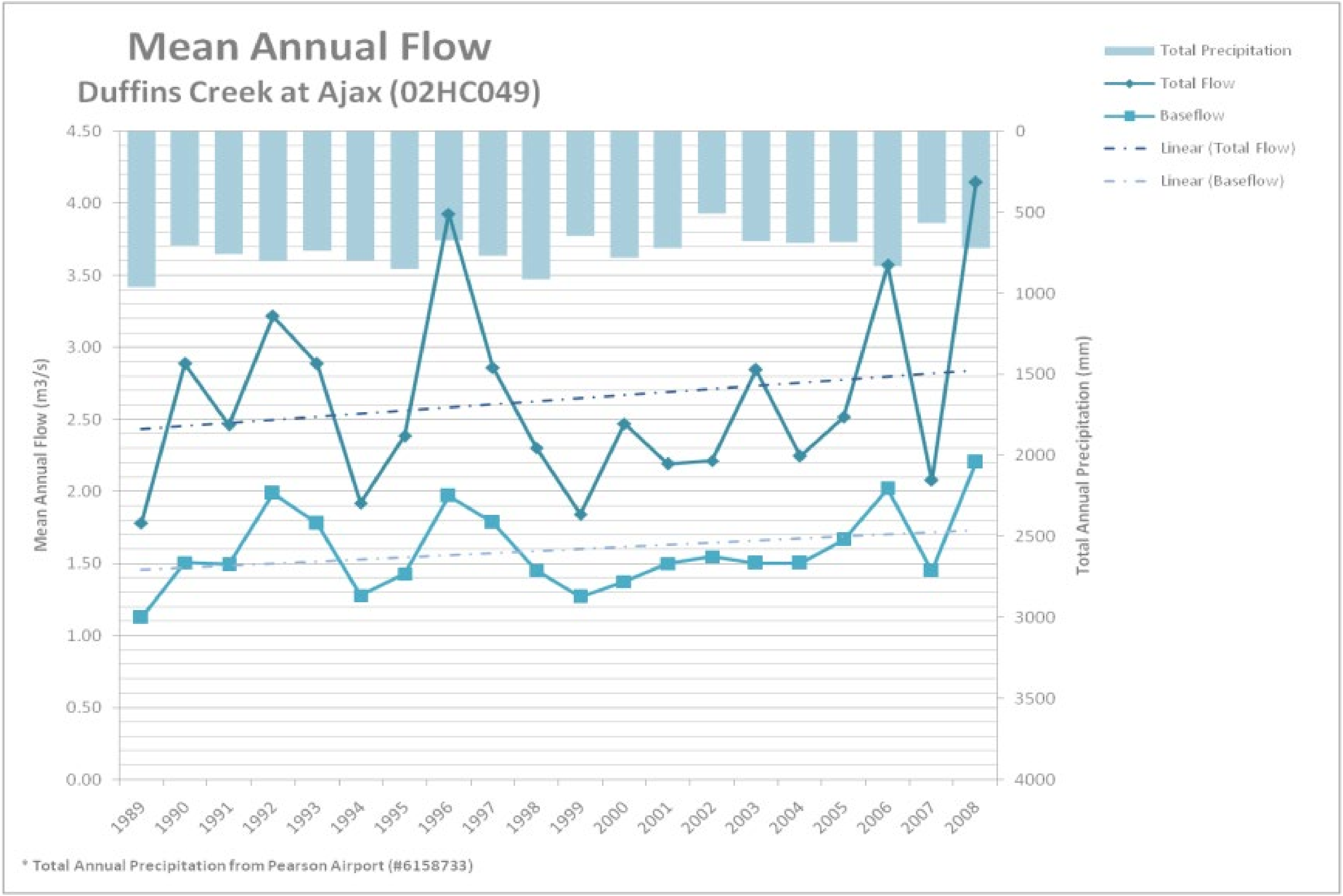


Figure 3-25: Mean Annual Flow, Baseflow, and Precipitation Trends – Duffins Creek

At all but two gauging stations, a positive or upward trend was observed. These upward trends vary depending on the watershed, ranging from 2% in the Don and Etobicoke watersheds and up to 45% in the Rouge. These overall increases to baseflow volumes are contrary to the common thought that increased impervious cover leads to reduced baseflow. The trends observed in dry weather flow may be due more to “false” baseflow from anthropogenic influences, such as water distribution systems and stormwater management features, as opposed to natural groundwater discharge. However, the smallest overall change is observed in the Duffins Creek watershed, which is the least urbanized watershed included in the study. Because of the high variability of the gauged baseflows over this approximately 40-year period, the level of confidence with utilizing a linear trend is low. Further data analysis will attempt to distinguish whether this is an ongoing linear trend, or if these increases are predominant within a specific time period between the early 1960s and 2001.

Based on the same linear regression, mean annual flows are increasing in all TRSPA watersheds, predominantly due to increases in impervious cover. These increases range from 0.5% per year in the Mimico Creek watershed, up to 2.38% per year in the Humber River watershed. Historically, stormwater management facilities were only designed to detain and attenuate peak flows. Today, innovative stormwater management practices are encouraged, which utilize infiltration and evaporation (or a combination of the two) to return runoff into the natural hydrologic cycle, both to control peak flows and reduce the total annual flow to more natural levels.

3.4.3 Surface Water Control Structures

As managers of flood control for the GTA and surrounding area, the TRCA currently operates four regulatory structures within its watersheds. These structures are detailed in **Table 3.3** and are shown on **Figure 3.26**.

Table 3-3: Flood Control and Regulatory Structures in TRSPA Watersheds

Regulatory Structure	Watershed	Permit Number
G. Ross Lord Dam	Don	00-P-3084
Claireville Dam	Humber	00-P-3086
Milne Dam	Rouge	00-P-3083
Stouffville Dam	Duffins	00-P-3085

Claireville and G. Ross Lord dams are major flood control structures with active operating schedules. The remaining dams are not operated on a regular basis, and provide for flood control and storage. Ownership of dams for reservoir storage is not limited to the TRCA as there are several private dams known to exist in TRCA watersheds. These private dams are highly varied in the type of dam and storage capacity. Through the TRCA’s Fish Barrier Identification Project many of these dams have been identified and mapped. The function of these private dams, from an operational standpoint, is currently unknown.

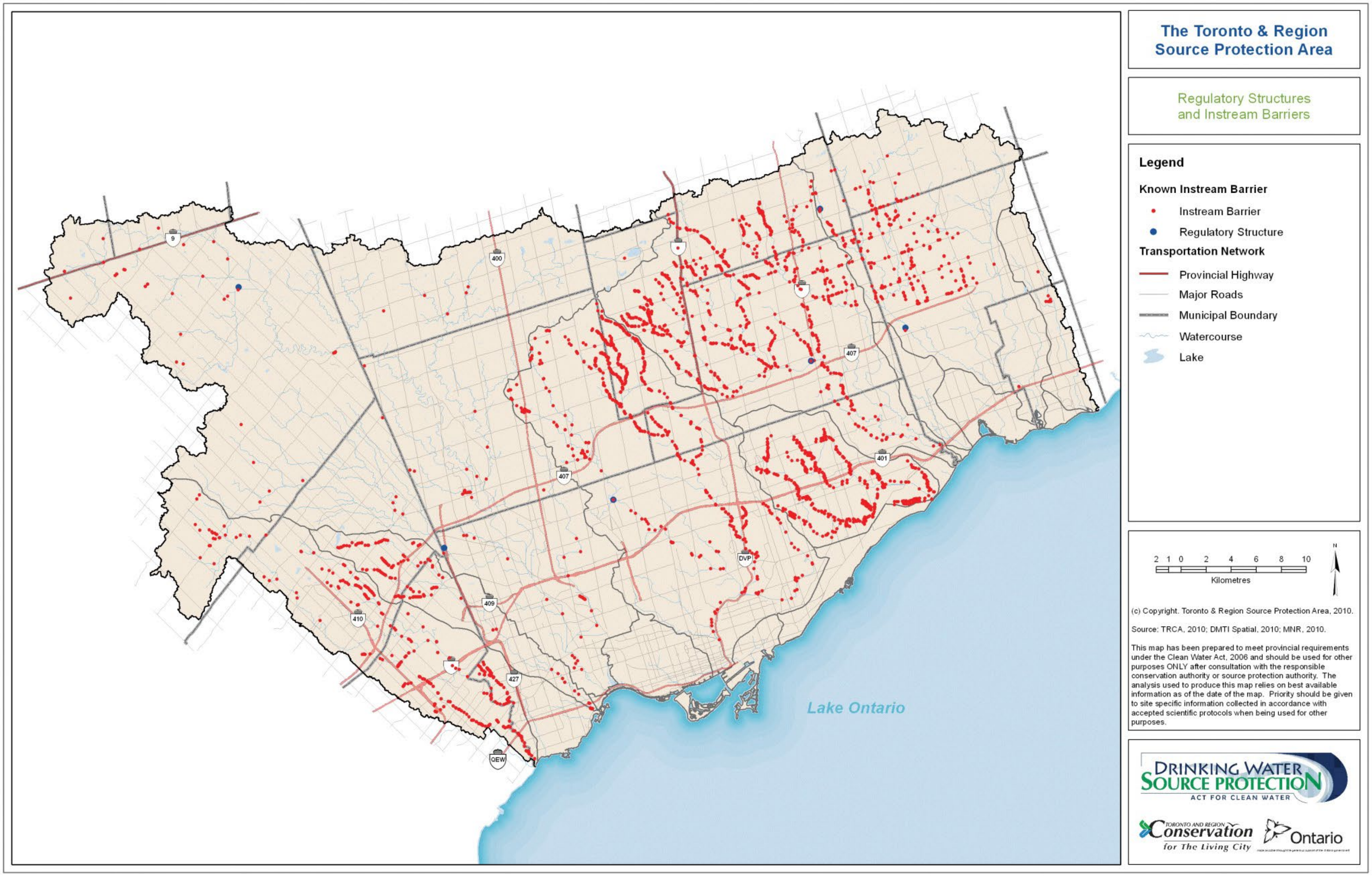


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Figure 3-26: Regulatory Structures and Instream Barriers

3.4.4 Interactions between Groundwater and Surface Water

Baseflow indices were used to designate areas of significance with regards to surface and groundwater interactions. The Baseflow Index (BFI – ratio of baseflow to total flow) for all long-term Water Survey Canada Gauges is shown in **Table 3.4**. Areas with the highest connectivity between the ground and surface water systems generally occur in the northern portion of the watersheds, where the river networks consist primarily of first- and second-order streams. The northern areas of the TRSPA watersheds on the Oak Ridges Moraine are also where much of the baseflow originates for the TRSPA watercourses, as discussed in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010).

Gauging records are limited in the headwater reaches. However, the Humber River does have a number of gauges in the upper portions of the watershed. BFI values derived from these gauges showed relatively high values, ranging from 0.58 to 0.72. These values are among the highest of the gauges included in the analysis. The Duffins Creek watershed also showed high ratios of baseflow to total flow (0.57 to 0.65). However, these gauges were generally located further south than those in the Humber watershed. From the BFI values, areas where there are significant interactions between the ground and surface water systems are most evident in the Humber and Duffins watersheds. These specific areas/reaches are summarized in **Table 3.4**.

Table 3-4: Specific Surface Water Areas with High Groundwater Influences

Humber Watershed		Duffins Watershed	
Watershed Area	**BFI**	**Watershed Area**	**BFI**
Main Humber River—upstream of Palgrave, including Centreville Creek.	0.72	East Duffins Creek—above Pickering	0.65
Main Humber River—upstream of Rutherford Rd., draining Centreville and Cold Creeks	0.67	Main Duffins Creek—below confluence of East and West Duffins	0.64
Main Humber River—Cold Creek Subwatershed	0.66	West Duffins Creek—excluding Reesor Creek	0.64

Areas that were found to have the lowest BFI values were also found to be disconnected from the Oak Ridges Moraine, and/or are typically in an urban setting. These include:

- Mimico Creek at the mouth;
- West Humber River;
- Etobicoke Creek south of Brampton; and
- Black Creek in the Humber watershed.

All of the above-noted areas had a BFI value of less than 0.40, which translates to more than 60% of the total annual flow being derived from surface runoff.

3.4.5 Land Cover

The statistics on land use, drainage area, and riparian cover for seven of the watersheds in the Toronto region are presented in **Table 3.5**. In descending order of urbanization, the watersheds in the TRSPA are: Highland Creek, Mimico Creek, Don River, Etobicoke Creek, Humber River, Rouge River, and Duffins Creek.

Table 3-5: Land Use and Riparian Vegetation by Watershed

Watershed	Size (km^2)	Landuse (%)					
		Agriculture	Built-Up Impervious	Built-Up Pervious	Natural Cover	Water	Riparian Veg. (%)
Etobicoke	211	24	57	13	6	0	17
Mimico	77	5	81	12	3	0	23
Humber	909	40	25	16	18	1	43
Don	357	5	72	15	8	0	35
Highland	102	0	83	13	6	0	32
Rouge	332	38	28	21	13	0	49
Petticoat	26	46	19	19	15	0	n/a
Frenchman's Bay	27	4	63	22	11	0	n/a
Duffins	281	44	10	22	23	0	51
Carruthers	38	42	26	18	13	0	n/a
Waterfront	121	0	83	12	4	1	n/a
TRSPA	**2481**	**29**	**40**	**17**	**14**	**0**	**n/a**

n/a = not available

Source: SOLRIS land use mapping, 2000-2002

Land use in the TRSPA watersheds was previously presented in **Section 2.5**. In general, urban land use in the watersheds extends north from Lake Ontario to a migrating urban fringe, beyond which the landscape is predominantly rural, and interspersed with small towns and cities. As shown previously in **Section 2.5**, the most urbanized watersheds have the largest density of storm sewer outfalls. As stormwater flows across hard surfaces, it picks up oil, grease, animal waste, pesticides, and other toxic pollutants that are transported through storm sewers to local rivers and the waterfront.

Combined sewers, which convey sanitary sewage and stormwater in the same pipe, are located in the older areas of the City of Toronto in the lower reaches of the Humber and Don River watersheds. Combined sewer low flows are treated in water pollution control plants. During wet weather, when the volume of flow in the combined sewer pipe exceeds its capacity, excess flow (combined sewer overflow) is diverted to the nearest watercourse. Since these discharges include sanitary sewage from residential and industrial areas, the concentration of contaminants such as bacteria, metals, nutrients, and unconventional pollutants (e.g., industrial organics) is often higher than observed in untreated stormwater runoff (Maunder *et al*., 1995).

3.5 GROUNDWATER FLOW SYSTEMS

Overall, the Oak Ridges Moraine topography controls the regional groundwater levels, and results show that the central moraine flow divide penetrates through all the *aquifer* layers (although data are sparse for the Scarborough Formation in the Oak Ridges Moraine area). In some watersheds (e.g., Humber, Rouge, and Duffins), the groundwater divide is north of the crest of the moraine because of groundwater mounding underneath the permeable sands and gravels north of the drainage divide. The mounds are less pronounced in the deeper units due to head loss through the confining units.

Aquifer: An underground layer of water-bearing sediments (e.g., sand, gravel) or permeable rock from which groundwater can be usefully extracted via a water well.

Potentials in the shallowest (Oak Ridges) aquifer are strongly influenced by the presence of streams and watershed divides. The watershed boundaries and influence of streams are also broadly visible in the lower aquifer systems, for example the influence of the Humber River is particularly pronounced.

Some correlation between the channels and the regions of lower water level gradient is apparent. High downward head differences exist away from the tunnel channel area, and smaller downward gradients or upward gradients exist within these zones. The channel zones allow more exchange of groundwater between aquifers than in areas where the Newmarket Till is present and the occurrences of silt sequences limit the rate of flow.

The bedrock valley system does not exhibit a large influence on the water level patterns, although there is some effect seen in the deep Scarborough Aquifer. This influence may not be readily discernible given the limited number of wells in the valleys and the complexity of the flow system. However, a groundwater divide does exist within the Scarborough Formation, but it varies from the surface water divide, and is typically located more northerly.

Results from the groundwater flow model (Kassenaar and Wexler, 2006) for the TRSPA indicate the following:

- Groundwater flow patterns are strongly influenced by streams;
- Model results were extremely sensitive to the permeability of the Newmarket Till that controlled aquifer heads both above and below the till layer; and
- Tunnel channels facilitate the exchange of water between the Lower Sediments and the Oak Ridges Aquifer Complex.

3.5.1 Aquifer Units

The geological surfaces for this Assessment Report were those developed for TRCA's Tier 1 Water Budget analysis as of May, 2007. The interpreted groundwater levels were calculated in April, 2008. The three main overburden aquifer units, from shallowest to deepest, are:

- Oak Ridges Aquifer Complex;
- Thorncliffe Aquifer Complex; and
- Scarborough Aquifer.

In addition, a bedrock aquifer unit is present in the Amabel dolostone in the northwest corner of the TRSPA jurisdiction. This aquifer is no longer used for municipal water supplies in the TRSPA area, but does provide potable water for residents on private drinking water systems.

Oak Ridges Aquifer Complex (or Equivalent)

The Oak Ridges Aquifer Complex is an extensive, stratified, sediment complex that generally corresponds to the Oak Ridges Moraine, but extends beyond the boundary of the moraine.

The extent and thickness of the Oak Ridges Aquifer Complex is shown in **Figure 3.27.** Sand layers below the surficial tills, along the south side of the Oak Ridges Moraine, thought to be deposited during a warm period known as the Mackinaw Interstadial, are also included in this aquifer unit. These sediments are considered hydrogeologically “equivalent” to the Oak Ridges sediments, since they are similar materials deposited in the same stratigraphic position. The Oak Ridges Aquifer Complex sediments are up to 100 m thick along the core of the moraine, but in areas further from the Oak Ridges Moraine, the sands of the Mackinaw Interstadial are scattered and generally less than 10 m thick. As can be observed from **Figure 3.28**, groundwater flow in the Oak Ridges Moraine Aquifer is generally in a southerly direction; however many of the headwaters of the stream systems receive baseflow from these deposits.

Aquitard: A layer of geological material that prevents or inhibits the transmission of water in a confined aquifer.

Thorncliffe Aquifer

The Thorncliffe Aquifer corresponds to sand and silty sand deposited in low areas on the underlying deposits. Further to the south, the formation comprises mostly silt, sand, pebbly silt, and clay deposited by glacial meltwaters entering a deep, ice-dammed lake that existed before Lake Ontario. These sediments were deposited approximately 45,000 years ago (Barnett, 1992).

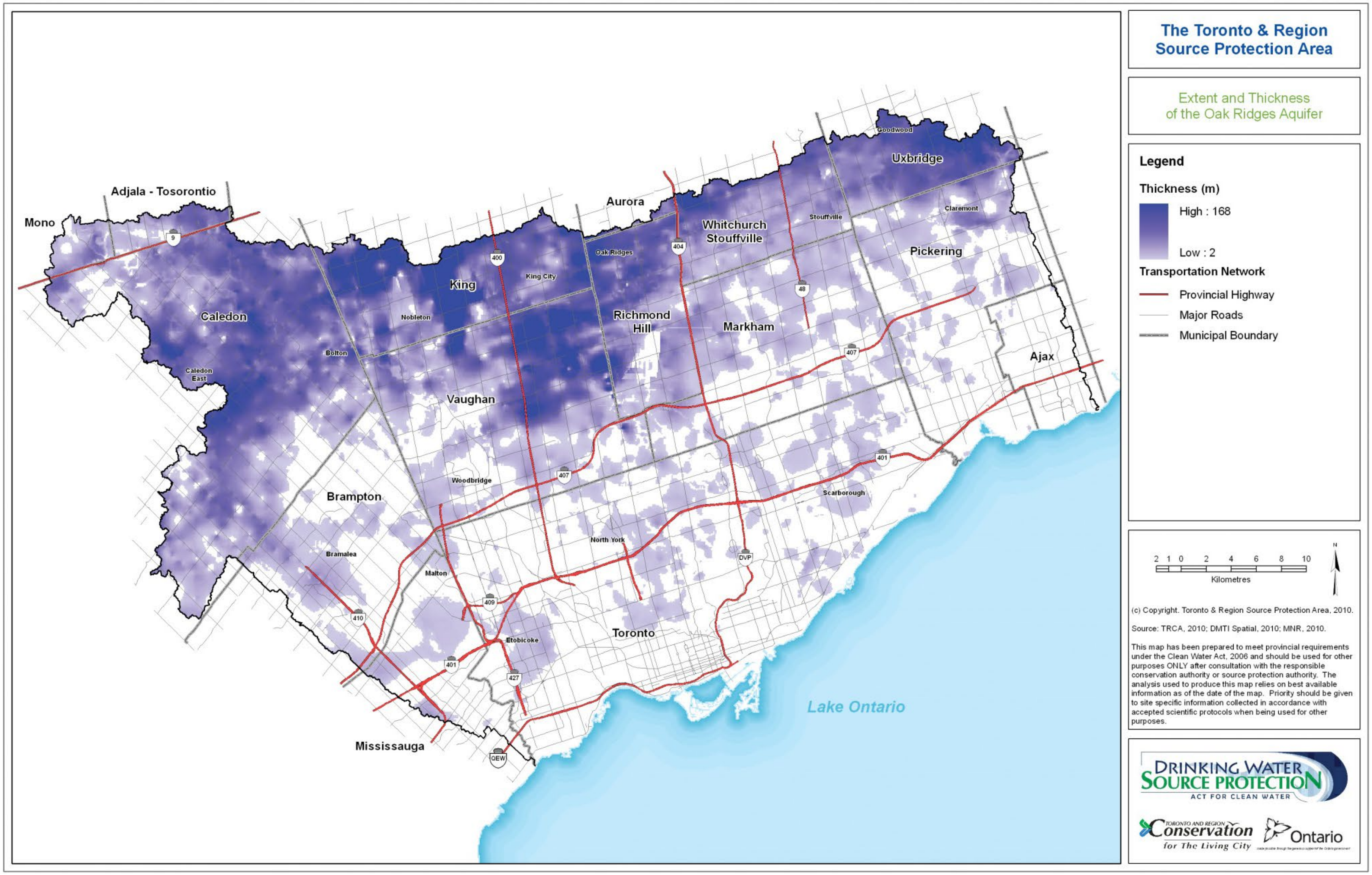
Geotechnical investigations have encountered considerable variation in grain size and thickness of sands within the Thorncliffe Aquifer. This is interpreted to represent coarser material being deposited closer to the sediment source, while the fine-grained sand and silty sand deposits represent deposition further from the source. The permeability of this aquifer changes abruptly both laterally and vertically. Therefore it is an aquifer in some places and an *aquitard* in others.

The highest point of this aquifer occurs along and to the north of the Oak Ridges Moraine, a reflection of the ground surface elevation. As shown in **Figure 3.29,** this unit reaches its maximum thickness (up to 50 m) beneath the Oak Ridges Moraine, where the top of the aquifer is 150 m below ground surface. Of note, the Humber and Don River valleys appear to intersect the Thorncliffe Aquifer.

Groundwater levels in the Thorncliffe Aquifer are provided in **Figure 3.30***,* which indicates the groundwater elevations in metres relative to sea level. The direction of groundwater movement is perpendicular to the colour boundaries shown on the figure. Groundwater flow is generally south towards Lake Ontario, with local deviation towards the major river systems.

Deep Overburden Aquifer (Scarborough Aquifer)

The Scarborough Aquifer marks the beginning of the Wisconsinan glaciation, which started approximately 70,000 to 80,000 years ago. These sediments are interpreted as being deposited by large rivers draining from an ice sheet (Karrow, 1967; Eyles, 1997). The lower silts and clays are up to 60 m thick at the Scarborough Bluffs along Lake Ontario and are believed to be in transitional contact with the muds of the underlying Don Formation (Eyles, 1997). The upper sands are channelized in some locations, possibly as a result of fluvial erosion due to fluctuating lake levels (Gerber, 2004; draft).



The Toronto & Region Source Protection Area

Extent and Thickness of the Oak Ridges Aquifer

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Source: TRCA, 2010; DMTI Spatial, 2010; MNR, 2010.

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Figure 3-27: Extent and Thickness of the Oak Ridges Aquifer Complex (or equivalent, m)

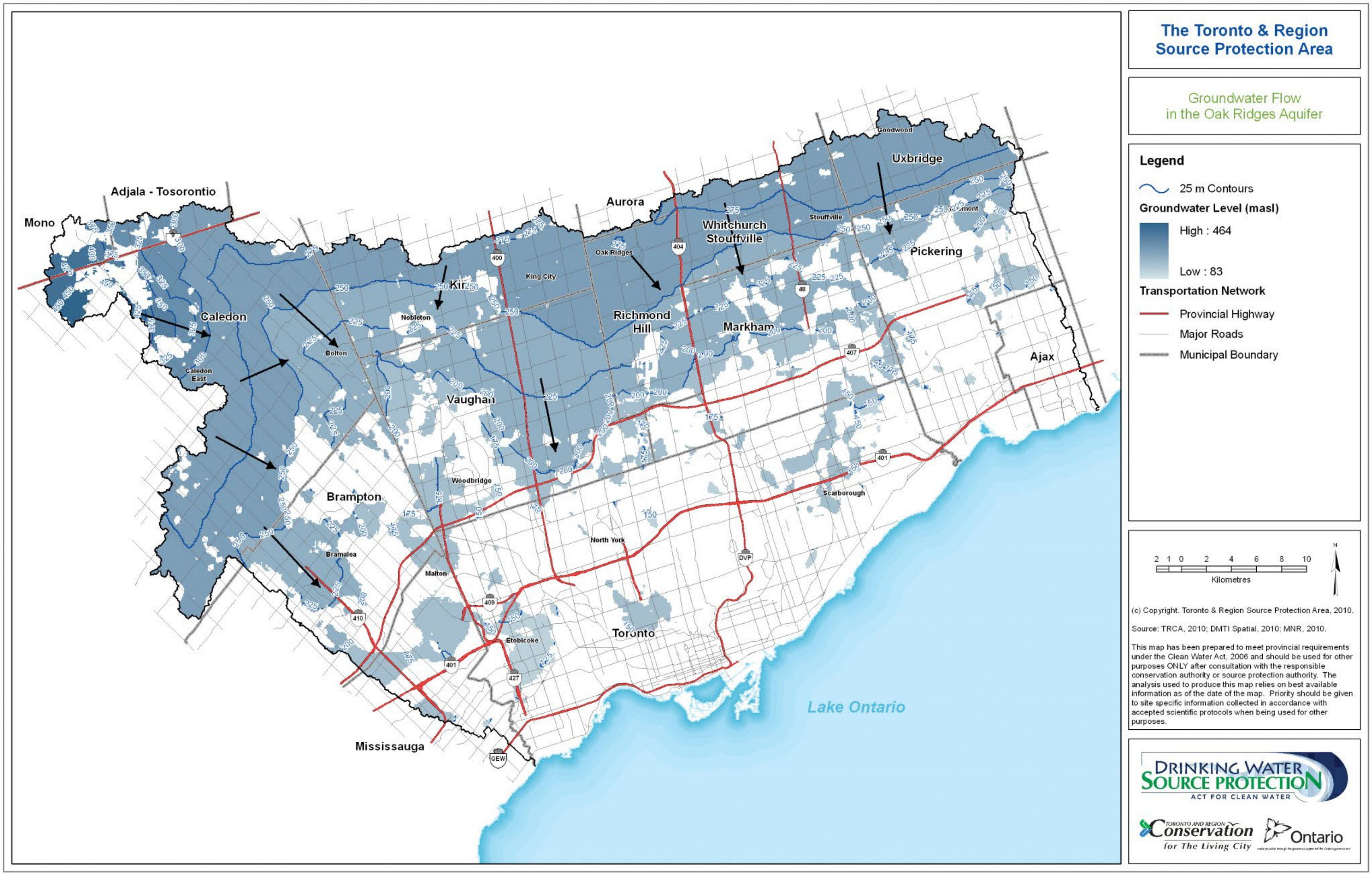

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Figure 3-28: Groundwater Flow in the Oak Ridges Aquifer Complex (or equivalent)

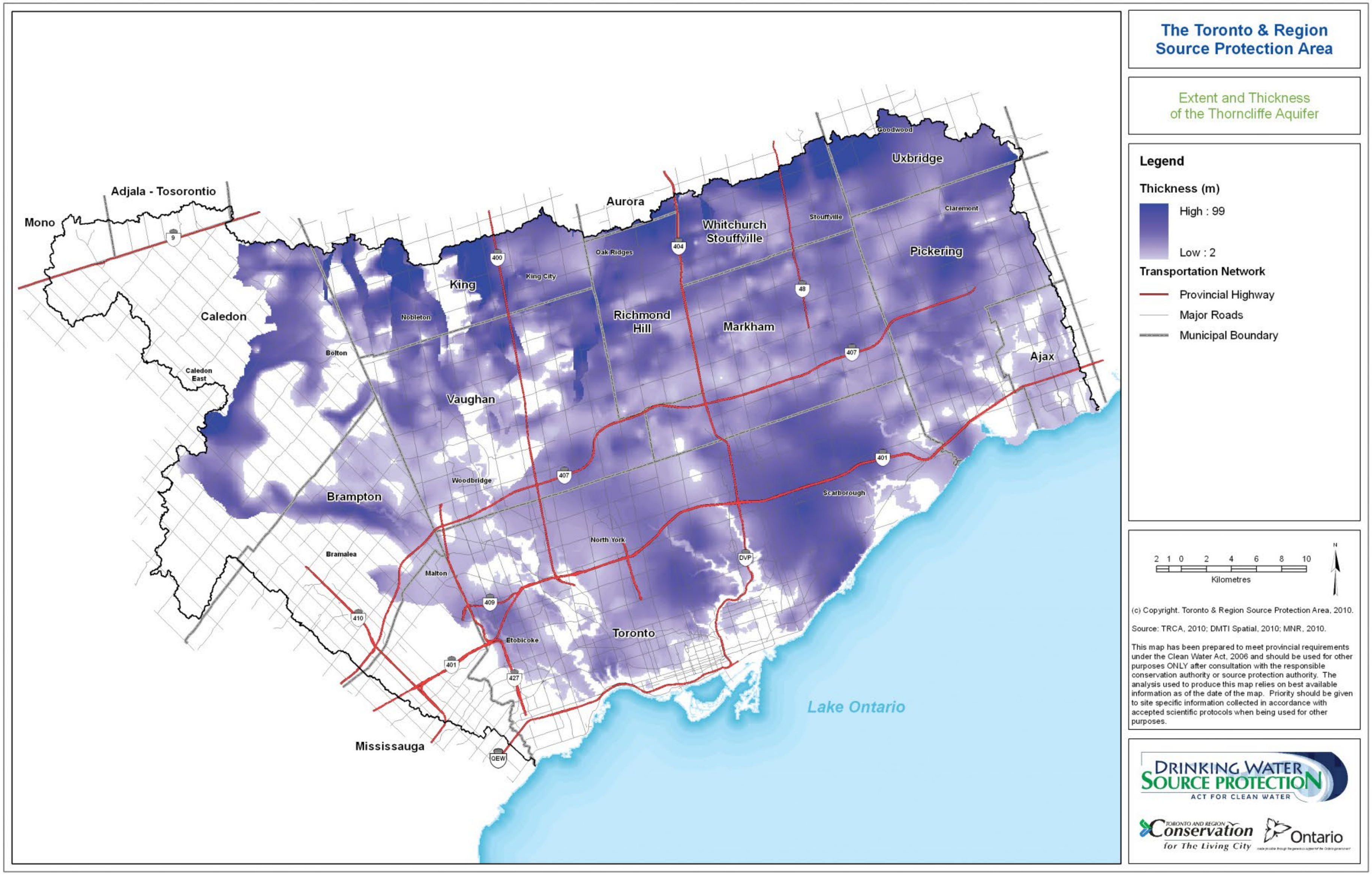

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Figure 3-29: Extent and Thickness of the Thorncliffe Aquifer (m)

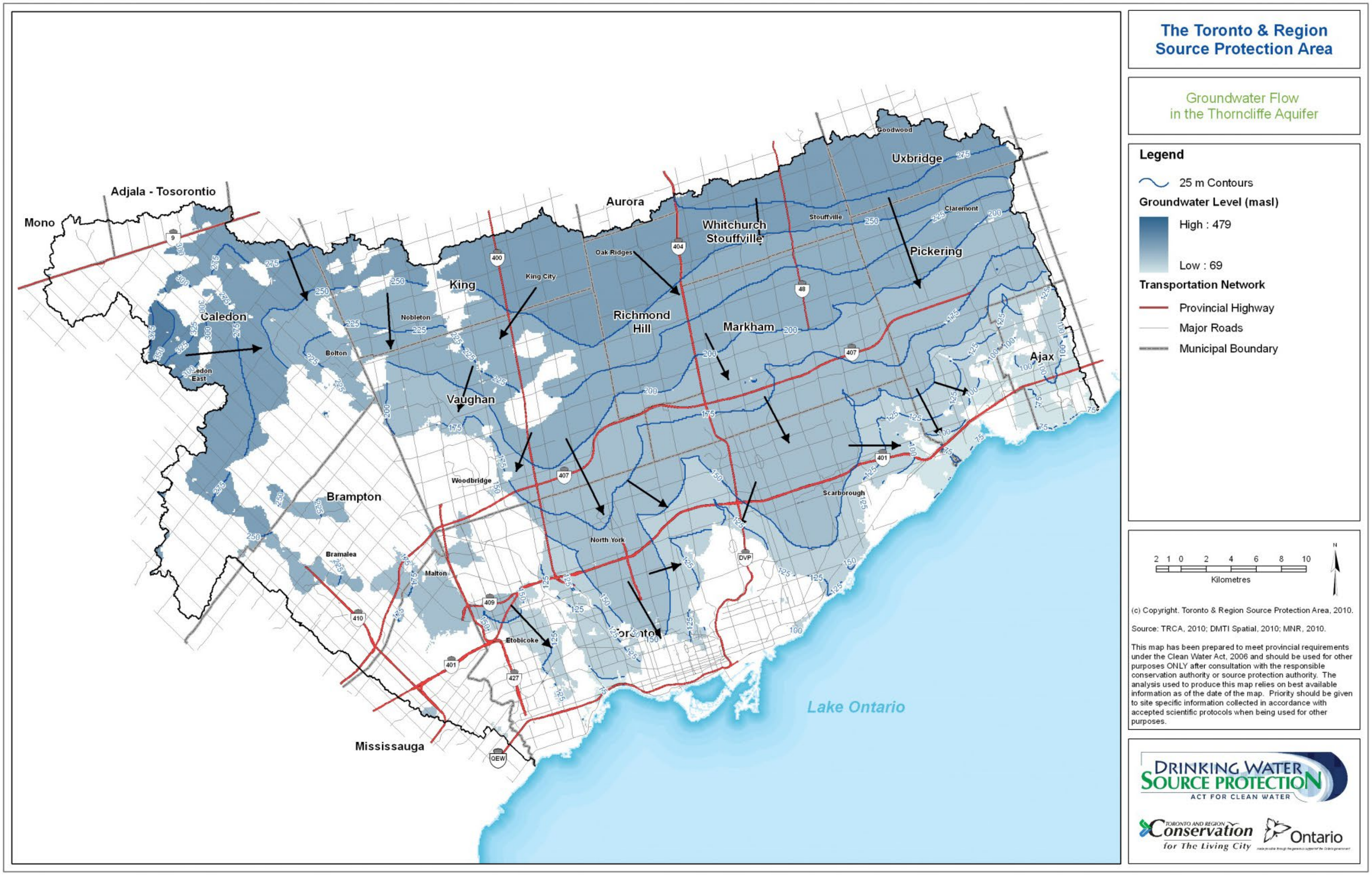

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Figure 3-30: Groundwater Flow in the Thorncliffe Aquifer

The Scarborough sediments are believed to extend from the Lake Ontario shore northward towards Lake Simcoe, over an area of about 200 km^2 (Fligg and Rodrigues, 1983; Eyles *et al*., 1985; Pugin *et al*., 1996; Sharpe *et al*., 1996). Although this formation is present throughout much of the TRSPA, it is only found in appreciable thickness in the bedrock valleys, as shown in **Figure 3.31**. To the northeast, the unit is pinched out by the higher bedrock. However, for the creation of the groundwater flow model it was extended into this area to represent lower aquifer materials that may or may not actually be Scarborough sediments, but share similar hydraulic characteristics.

Groundwater flow patterns in the Scarbourgh Aquifer, as shown in **Figure 3.32,** are similar to those in the Thorncliffe Aquifer, except the local influences of the watercourses are not evident until closer to Lake Ontario (i.e., generally south of Highway 401).

Bedrock Aquifer

Along the western TRSPA boundary are sandstones and dolostones of Silurian age (417 to 443 million years old). These include the Clinton and Cataract groups, and the Lockport–Amabel Formations. These units, particularly the Lockport–Amabel Formation in the Mono Mills area, represent the only bedrock aquifers within the TRSPA. Bedrock outcrops are exposed along the Niagara Escarpment and at the bottom of deep river valleys near the mouths of rivers such as the Humber, the Rouge, and Duffins Creek.

The structure of deeper Precambrian and Paleozoic rock layers has a broad control on groundwater resources and flow patterns in the area. It is thought that a major northeast trending structure in the underlying Canadian Shield may control the orientation of the bedrock valleys that occur in the northern Oak Ridges Moraine area (Scheidegger, 1980).

Flow directions in the bedrock aquifer in the TRSPA area are not well understood, given that only one provincial groundwater monitoring well (W-328) is installed in this aquifer. However, it is expected that the flow follows the bedrock topography.

3.5.2 Groundwater Monitoring

TRCA staff maintains a network of 22 monitoring wells that are part of the PGMN, as shown in **Figure 3.33.** The geographic coverage of TRCA's groundwater monitoring program is reasonable, but there is a general scarcity of deep wells, particularly under the Oak Ridges Moraine. Therefore, TRCA has obtained water level data for additional wells, monitored others, and is considering adding further wells to the network to ensure that the three main aquifers are adequately monitored. To date, TRCA has secured data from four York Region monitoring wells and one well monitored by the Central Region Office of the MOECC. Together, these 27 wells provide the best available data to assess ambient groundwater levels across TRSPA's watersheds. Information of the monitoring periods and aquifer units for all 27 wells are provided in **Table 3.6**.

Most of these wells do not indicate any significant long term trends, either up or down. However, rising trends are apparent in eight wells in the Etobicoke Creek, Humber River, and Rouge River watersheds. Most of the rising trends are associated with the cessation of dewatering activities (i.e., former aggregate pits in the Etobicoke Creek watershed, and dewatering for deep infrastructure installation in the Rouge River watershed), but the cause of rising groundwater levels in some of the Humber River watershed wells is unknown.

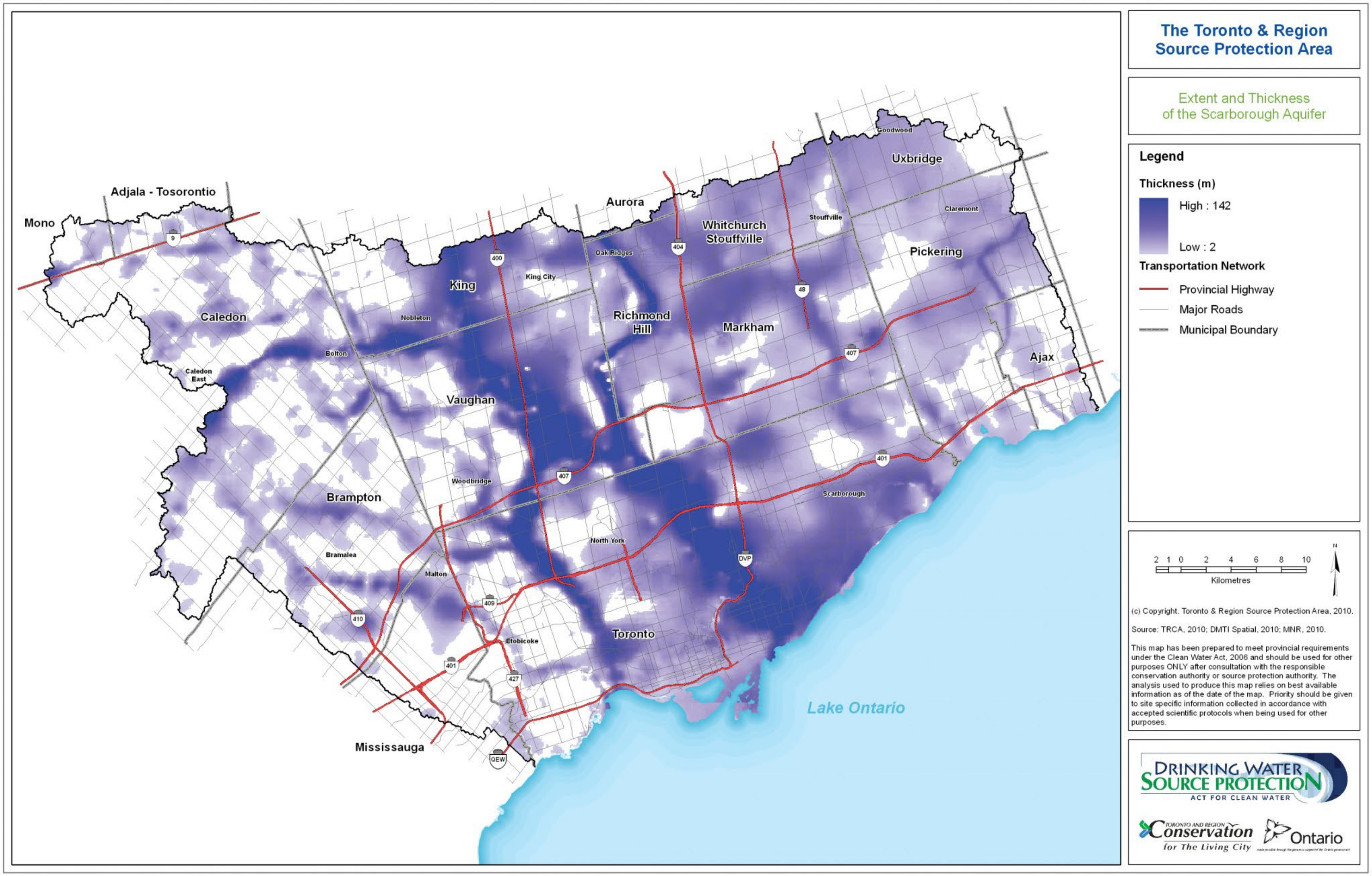

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Figure 3-31: Extent and Thickness of Scarborough Aquifer (m)

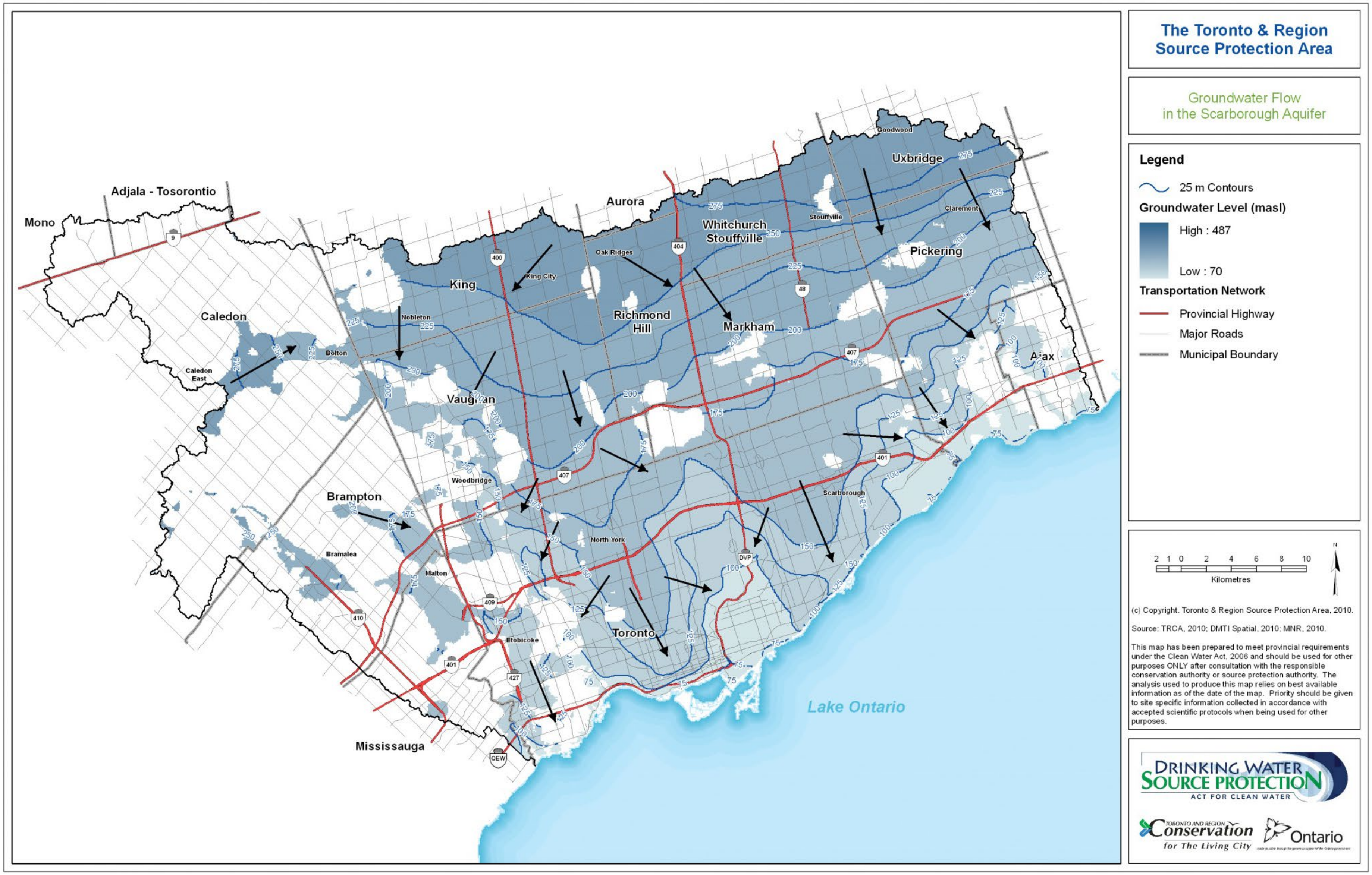

Figure 3-32: Groundwater Flow in the Scarborough Aquifer

Source: TRCA, 2010; DMTI Geospatial, 2010; MNR, 2010; Regional Municipalities of Dufferin, Simcoe, Peel, York, Toronto & Durham

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Figure 3-33: Groundwater Monitoring Wells Used in the Analysis

Table 3-6: Groundwater Monitoring Well Information

Watershed	Sub-watershed	Well Name	Aquifer	Trend	Comments
Etobicoke	ET04	W021-1	Oak Ridges	Rising	Rising trend 1 m/yr
		W366-1	Oak Ridges	Rising	Rising trend 1 m/yr
Humber	HU01	W325-1	Scarborough	None	No significant change
	HU03	W367-1	Oak Ridges	None	No significant change
	HU06	W075-1	Thorncliffe	None	No significant change
	HU08	W060-1	Thorncliffe	None	No significant change
		W061-1	Scarborough	Rising	Slight (0.1 m/yr)
	HU10	W327-3	Thorncliffe	None	No significant change
		W327-4	Scarborough	Rising	Slight (0.2 m/yr)
	HU11	W329-1	Oak Ridges	Rising	Slight (0.3 m/yr)
	HU11	W330-1	Thorncliffe	None	No significant change
	HU12	W328-1	Bedrock	None	No significant change
Don	DO04	W017-2	Scarborough	None	None
Rouge	RO02	Stouffville 700	Oak Ridges	None	No significant change
	RO03	MW-09	Thorncliffe	Rising	Rising trend 1 m/yr since January 2001(aquifer recovery after dewatering project)
		MW-02	Scarborough	Rising	Slight rising 0.5 m/yr since 2001
	RO04	W382-1	Oak Ridges	None	No significant change
	RO05	W059-1	Oak Ridges	Rising	Slight (0.1 m/yr)
	RO06	MW-26	Scarborough	None	No significant change
	RO07	W006-1	Oak Ridges	None	No significant change
Duffins	DU03	W326-2	Water Table	None	No significant change
		W326-3	Thorncliffe	None	None
		W045-1	Scarborough	None	No significant change
	DU04	W012-1	Water Table	None	No significant change
	DU04	W011-1	Thorncliffe	None	No significant change
		W010-1	Scarborough	Declining	Slight (0.1 m/yr)

3.6 CLIMATE

3.6.1 Climate: Historical and Projections

Climate change is affecting average and extreme climate conditions in Ontario, and will continue to do so. Recent droughts, floods, heat waves, and warmer winters have had various effects in Ontario, including water shortages, forest fires, lower water levels in the Great Lakes, declines in agricultural production, power outages, and outbreaks of water-borne diseases (Natural Resource Canada*, 2007*). The *CWA* requires a discussion of climate change, as it could impact estimates of water supply in the water budget analysis.

The Great Lakes have a large influence on the region's climate. They cause higher autumn and winter precipitation (including very heavy snowfalls), and mitigate extreme hot and cold temperatures.

Ontario experiences a variety of extreme weather events and associated natural disasters. Major storms hit Ontario at least once or twice per year, with high winds, rain, freezing rain, or snow. In spring, rapid snowmelt or ice jamming can lead to flooding, especially in northern communities. Tornados can be experienced in southern Ontario, which has the highest frequency of tornadoes in Canada, in the spring and summer months. Remnants of hurricanes also occasionally produce high winds and excessive rainfalls. In recent years, Ontario has experienced some exceptionally severe weather events, including the 1998 ice storm.

3.6.2 Climate Trends

During the last half of the twentieth century (1948–2006), the annual average temperature in Ontario increased between 0–1.4°C, with larger increases observed in the spring (Chiotti and Lavender, 2008).

Since 1999, annual precipitation in southern Canada has increased by about 5–35% (Zhang *et al*., 2000), and the number of days with precipitation (rain or snow) has increased significantly (Bruce *et al*., 2000; Chiotti and Lavender, 2008).

Autumn snowfalls have been increasing in the area, but snowfalls have declined in spring and winter. Snowfall trends in the south subregion are not statistically significant, although there is evidence of an increase in snow (Chiotti and Lavender, 2008).

3.6.3 Climate Projections

The climate of Ontario is primarily influenced by maritime polar and modified continental air masses from the north and west, and by maritime tropical air from the south. The province is relatively shielded from Atlantic air masses (and storms) by the Appalachian mountain system. For about 30% of the winter, continental arctic air from the north brings very cold and dry weather. During summer, the maritime tropical air from the south brings hot and humid conditions for about 14% of the time (Phillips, 1990). Southern Ontario has a humid continental climate with warm summers, mild winters, and a long growing season of 180 to 220 days. Local changes in the climate of southern Ontario are influenced by geographic factors such as latitude, relief, altitude, proximity to the Great Lakes, and position relative to prevailing winds.

Projections for changes in temperature and precipitation were estimated from several Global Circulation Models (GCM) using seven different greenhouse gas emission scenarios. The results range from conservative to aggressive assumptions regarding future emission rates. They indicate an increase in annual temperature and most models also predict an increase in annual precipitation levels within the next 20–50 years. The range of results increases over time and indicates that maximum warming will occur in winter. Also, changes in extreme warm temperatures are expected to be greater than changes in the annual mean temperature (Chiotti and Lavender, 2008). The number of days exceeding 30°C in the south subregion is projected to more than double by 2050 and severe heat days could triple in some cities by 2080 (Chiotti and Lavender, 2008).

Projections of precipitation vary more significantly than those of temperature. However, some of the projections indicate a slight decrease (<2.5%) in annual precipitation for most of the province in the next 50 years. Analysts predict summer and fall decreases of up to 10% by 2050. Warmer temperatures and longer growing seasons will impact net moisture availability, resulting in increased evaporation and evapotranspiration rates. Winter projections show increases in precipitation, increasing from south to north and ranging from 10% to more than 40%.

Changes in extreme daily precipitation are expected to be greater than the changes projected in the annual mean precipitation (Chiotti and Lavender, 2008). This means that rain or snowfall events will become both more intense and more frequent (Chiotti and Lavender, 2008). Lake-effect snow will likely increase over the short to medium term, as lake temperatures rise and winter air temperatures remain cool enough to produce snow. By the end of the twenty-first century, however, snowfall may be replaced by heavy lake-effect rainfall events (Chiotti and Lavender, 2008).

Unseasonal temperatures, more frequent periods of lower than average precipitation, and peak storms resulting in flooding events have been observed and documented in the last decade. Impacts such as lower water levels in wells and flooding have been recorded. It is expected that these types of climatic events will continue to affect the study area. Management strategies that include climate change adaptation components will become increasingly important. Additional discussions regarding potential climate change impacts and threats to drinking water sustainability are presented in **Chapter 5 (Drinking Water Threats Assessment)**.

Within the TRSPA geographic factors produce two main zones of relatively mean daily temperatures for the year, which are useful for broad regional comparisons. The Lake Ontario shore zone closely follows the north shore of Lake Ontario in a relatively narrow band and is under the moderating influence of the lake. The mean annual temperature for the Lake Ontario shore zone, within the TRSPA, is approximately 8°C. The South Slope is topographically higher and farther from the lake, and hence the influence of the lake is diminished. Given its distance from the lake, the South Slope zone has a cooler mean daily temperature of about 7°C (Sanderson, 2004). The differences between the two regions are subtle, but distinct, and are summarized in **Table 3.7**. The northwestern edges of the watershed lie within two other zones - the Simcoe and Kawartha Lakes, and the Huron Slope - but these two zones represent less than 10% of the total area.

Table 3-7: Lake Ontario Shore and South Slope Climatic Zones Characteristics

Item	Lake Ontario Shore	South Slope
Altitude (mASL)	91.5	213.4
Mean Annual Temperature (°C)	8.0	7.2
Daily Range of Temperature January (°C)	8.9	8.3
Daily Range of Temperature June (°C)	11.1	12.8
Extreme Low Temperature (°C)	-34.4	-39.4
Extreme High Temperature (°C)	40.0	40.6
Mean Annual Precipitation (mm)	825	850
Mean Annual Snowfall (mm)	1,651	1,778
Mean Annual Actual Evapotranspiration (mm)	533	559

Item	Lake Ontario Shore	South Slope
Mean Annual Moisture Deficiency (mm)	76	51
Mean Annual Water Surplus (mm)	330	301

Note:

**Values from Sanderson, Marie, 2004. Weather and Climate in Southern Ontario. Department of Geography Publications No. 58, University of Waterloo*

Climate varies on both a short-term (seasonal) and long-term basis, which makes the selected time period for data analysis very important for calculating the water budget. The average annual precipitation for a 160-year period from a climate station in the City of Toronto is shown in **Figure 3.8**. During this period the annual precipitation varied from approximately 600 mm to 1,200 mm per year (mm/yr), with an average value of 800 mm. In the 1930's, there was a decade of below average precipitation, by some 100 mm. In the 1970s and 1980s there were above average values in the order of 80 mm.. For water budget modelling, existing and future climatic conditions should be simulated using appropriate datasets. For both existing and future conditions, average and drought conditions will be simulated for the water quantity risk assessment.

TRCA staff has considered the potential effects from two General Circulation Climate Models - Coupled Global Climate Change Model (CGCM), and the Hadley Model (now refered to as the Unified Model)(TRCA, 2009a) - that are used to predict climate changes and indicate two very different scenarios for southern Ontario (Piggott *et al.,* 2001). Although both models predict increases in temperature, one indicates a 19% *decrease* in recharge, flow, and discharge, whereas the other predicts a 3% *increase*. The warmer temperatures predicted by both models will lead to reduced snow accumulation, resulting in increased monthly baseflows during the winter, and decreased flows during the spring. The hot, dry conditions that characterize the area remain a possibility under climate change, but hot and slightly wetter conditions are also a possibility.

3.7 TIER 1 WATER BUDGET

The Tier 1 Water Budget is the second tier of the four possible water budgets (Conceptual Water Budget, Tier 1, Tier 2, and Tier 3). It considers whether a water source can meet water use demands in a subwatershed without being stressed. Analysts use spreadsheets and GIS maps to assess *consumptive demand.* They also calculate how quickly a natural water source replenishes (recharges) itself. This calculation depends on several factors, including land use, topography, and geology. If there is a possibility that a subwatershed could be stressed, a Tier 2 Water Budget is required.

Consumptive Demand: Amount of water taken from a surface water or groundwater system without being returned to that system.

The primary purpose of the Tier 1 analysis is to quantitatively describe the movement of water within the various elements (such as soils, aquifers, streams, and lakes) that make up the hydrologic cycle within each subwatershed. Tier 1 analyses are more detailed than those in the conceptual water budget, providing a spatial analysis of all the water budget components in the jurisdiction, including watersheds where no gauge stations exist.

Based on the PRMS modelling studies of the TRSPA jurisdiction, the primary components of the water budget have been established for each watershed, as summarized below in **Table 3.8**. Further details can be found in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010).

Table 3-8: Summary of Calculated Values for the Water Budget Components

SubWatershed	Area (km^2)	Imper-vious (%)	Precip-itation (mm)	Surface Runoff		Groundwater Infiltration		Evapo-transpiration	
				(mm)	(%)	(mm)	(%)	(mm)	(%)
ET01	34	42	826	237	29	80	10	520	63
ET02	25	47	832	257	31	96	12	488	59
ET03	50	38	857	247	29	122	14	495	58
ET04	103	20	870	221	25	109	13	548	63
Etobicoke Cr. (avg)	**211**	**31**	**855**	**234**	**27**	**106**	**12**	**524**	**61**
MI01	42	41	830	244	29	86	10	510	61
MI02	14	47	847	262	31	96	11	497	59
MI03	23	44	851	238	28	92	11	531	62
Mimico Cr. (avg)	**77**	**43**	**839**	**246**	**29**	**90**	**11**	**514**	**61**
HU01	89	37	851	226	27	107	13	528	62
HU02	61	37	864	272	31	125	14	473	55
HU03	98	14	856	189	22	104	12	572	67
HU04	107	6	859	166	19	99	12	604	70
HU05	92	11	863	170	20	96	11	608	70
HU06	72	6	875	175	20	111	13	597	68
HU07	94	8	877	128	15	215	25	538	61
HU08	31	6	858	114	13	204	24	544	63
HU09	65	5	851	108	13	201	24	548	64
HU10	48	8	850	133	16	176	21	548	64
HU11	47	5	851	105	12	230	27	520	61
HU12	108	5	863	88	10	266	31	513	59
Humber R. (avg)	**909**	**12**	**861**	**158**	**18**	**156**	**18**	**553**	**64**

SubWatershed	Area (km^2)	Imper-vious (%)	Precip-itation (mm)	Surface Runoff		Groundwater Infiltration		Evapo-transpiration	
				(mm)	(%)	(mm)	(%)	(mm)	(%)
DO01	38	33	865	271	31	128	15	473	55
DO02	34	37	872	286	33	126	14	466	53
DO03	54	35	878	285	32	127	14	471	54
DO04	64	31	871	281	32	141	16	452	52
DO05	58	30	889	262	29	127	14	506	57
DO06	63	19	902	226	25	171	19	510	57
DO07	42	31	896	278	31	140	16	482	54
Don River (av)	**357**	**30**	**883**	**268**	**30**	**139**	**16**	**481**	**54**
HI01	9	23	877	219	25	112	13	558	64
HI02	11	23	877	202	23	110	13	576	66
HI03	50	32	879	316	36	135	15	429	49
HI04	36	38	881	321	36	134	15	427	48
Highland Cr. (av)	**102**	**33**	**879**	**305**	**35**	**132**	**15**	**445**	**51**
RO01	4	24	877	229	26	112	13	545	62
RO02	114	4	883	165	19	134	15	591	67
RO03	64	18	883	251	28	126	14	512	58
RO04	45	32	889	275	31	122	14	499	56
RO05	40	13	900	204	23	171	19	530	59
RO06	31	8	891	183	21	128	14	588	66
RO07	41	7	875	149	17	164	19	569	65
Rouge (avg)	**332**	**13**	**885**	**201**	**23**	**138**	**16**	**553**	**62**
Frenchman's Bay	**25**	**27**	**871**	**252**	**29**	**127**	**15**	**498**	**57**
Petticoat Creek	**26**	**9**	**879**	**198**	**23**	**124**	**14**	**564**	**64**
DU01	24	23	876	230	26	128	15	524	60
DU02	53	7	879	196	22	131	15	558	63
DU03	44	5	877	173	20	125	14	588	67
DU04	63	3	876	112	13	197	22	572	65
DU05	60	4	877	129	15	196	22	558	64
DU06	40	7	879	156	18	161	18	568	65
Duffins (avg)	**281**	**6**	**877**	**157**	**18**	**162**	**18**	**564**	**64**
Carruthers Creek	**38**	**20**	**807**	**194**	**24**	**118**	**15**	**501**	**62**

Note:

Iimperviousness is calculated as the "effective" imperviousness, and does not include impervious surfaces that drain to pervious surfaces. Total imperviousness is therefore, higher.

There is substantial variability in water budget measures between watersheds, largely due to the degree of urbanization. For example, the percentage of effective impervious areas in subwatersheds range from 3 to 47%, and runoff rates are from 88 to 321 mm/yr. Surface runoff is 29 to 35% of precipitation for the Mimico, Don, and Highland watersheds where the impervious areas are greater than 30%. For these same urbanized watersheds, the evapotranspiration is only 51 to 61% of precipitation. Conversely, the Humber, Rouge, and Duffins River watersheds, where the impervious areas are less than 15%, exhibit runoff values that are only 18 to 23% of precipitation. Evapotranspiration in these less urbanized watersheds is higher at 62 to 64% of precipitation.

It is noteworthy that the groundwater recharge values are not substantially different between watersheds, ranging between 11 and 18%. Predictably the Humber and Duffins watersheds, with the greatest proportion of areas drawing from the Oak Ridges Moraine, have the highest recharge values at 18% of precipitation. The lowest is Mimico Creek within the low permeability till soils. However, the degree of urbanization does not seem to have a substantial influence. The more urbanized watersheds (Mimico Creek, Don River, and Highland River) have an average groundwater recharge of 14% of the precipitation, while the less urbanized watersheds (Humber, Rouge, and Duffins rivers) average just 17% of precipitation for groundwater recharge.

3.7.1 Stress Assessment

As indicated above, according to the *Technical Rules*, subwatersheds with significant consumptive takings may jeopardize the reliability of the well or intake. A consumptive taking is defined as taking water from a source and not returning it to the same source. As a result, subwatersheds that experience a significant-to-moderate degree of stress, and that contain municipal drinking water systems, will move on to the Tier 2 Water Budget and Stress Assessment for refinement of estimates.

The stress assessment calculations required by the *Technical Rules* were designed to be completed on subwatersheds approximately 20 to 100 km^2 in size. Therefore, TRCA divided the jurisdiction into 52 stress assessment subwatersheds based on hydrologic boundaries from other studies. The smallest subwatershed was 3 km^2 in area (a small subwatershed draining directly into Lake Ontario), while the largest was 110 km^2, and the average size was 48 km^2. The sizes and boundaries of these subwatersheds were accepted by an external peer review committee and the Ministry of Natural Resources and Forestry (MNRF) prior to the commencement of this study. Further details can be found in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010).

3.7.2 Tier 1 Methodology

Water Use

TRCA staff calculated water use for each subwatershed using TRCA's Water Use Assessment (WUA) database, which is based on the provincial Permit to Take Water (PTTW) database maintained by the MOECC. The TRCA validated the MOECC PTTW database between 2003 and 2005 in the field and has been updating this database over the past two years through Environmental Bill of Rights (EBR) registry postings and MOECC application notifications. Field surveys of local water users collected estimates of actual usage rates, which are generally much less than the maximum permitted rates. Verifying and estimating actual consumption is difficult, but recent legislation (O. Reg. 384/04) requires that metered rates be recorded and reported, so over time, the actual demand estimates will improve.

TRCA staff field verified and supplemented the PTTW database, where possible, with information from the surveys to create the WUA. Staff then applied consumptive factors suggested in *Guidance Module 7* to account for water returned to the hydrologic system from such processes as aggregate washing and irrigation, and calculated the percent water demand.

Existing conditions and a future water demand scenario were considered for water use, and both surface water and groundwater reserves were incorporated into the calculations.

Significant Groundwater Recharge Areas

As part of the Tier 1 Water Budget process, TRCA staff identified Significant Groundwater Recharge Areas (SGRAs). The methodology for this work is summarized in **Section 4.2** and detailed in **Appendix D**.

3.7.3 Stress Assessment Screening Results

Stress Thresholds

The stress thresholds developed by MNRF are provided in **Table 3.9**.

Table 3-9: Water Quantity Stress Thresholds

Water Quantity Stress Assignment	Surface Water	Groundwater	
	Maximum Monthly % Water Demand	Average Annual% Water Demand	Monthly Maximum% Water Demand
Significant	> 50%	> 25%	> 50%
Moderate	20-50%	> 10%	> 25%
Low	<20%	0 – 10%	0 – 25%

Limitations

This stress assessment screening was completed using methodologies outlined in the *CWA* and the *Technical Rules*. If it is proposed to use this analysis for another purpose, it would be advisable to first consult with TRCA staff. The water budget analysis follows a tiered process to screen the source protection area to identify where there may be hydrologic stress at the subwatershed scale. Should such stresses be associated with mandated drinking water supplies, the potentially stressed areas are then studied in more detail.

The process is designed such that each successive tier in the analysis (up to and including Tier 3), becomes more complex, requiring increased sophisticated analysis and data. As a result, with each successive tier the certainty in the findings of the analysis is increased. The analysis used to produce this Assessment Report was based on best information available at the time. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other decision-making purposes, such as determining the impact of a site specific water taking.

Stress Assessment Screening - Surface Water

A summary of the surface water stress assessment under existing conditions is displayed in **Table 3.10**, which shows only those subwatersheds in the moderate or significant stress categories. **Table 3.11** shows a more detailed account of calculated surface water stress by subwatershed. The detailed calculations can be found in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010). Note that these calculations are subject to the limitations described above. The results are mapped in **Figure 3.34.** Individual monthly estimates of stress in all subwatersheds and the results are included in **Appendix C2**. Six subwatersheds are in the significant category, while eleven are in the moderate category. A graph showing the monthly supply and demand for the six subwatersheds in the significant category is shown in **Figure 3.35**. Note that the available supplies for these subwatersheds is very low in July and August, meaning that even low water use during these months could lead to a calculation of stress. The remaining 35 subwatersheds were deemed to have low stress from surface water uses.

Five subwatersheds were found to have abstractions calculated to be greater than 100% of available supply; these were calculated as withdrawing anywhere from 119% up to 360% of available supply. There are a number of contributing factors that can create a demand value higher than that of the supply, including timing of water takings, operational details, and on-site storage reservoirs. All of the subwatersheds found to have >100% demand had one or more users with significant on-site storage. An example of the calculations to assess on-site storage as a mitigating factor is provided below:

- Subwatershed: HU04:
  - Stress Level: Significant (129%);
  - One surface water user; and
  - Storage Facility “required” depth to meet deficit.
- Calculation: monthly water deficit/reservoir area:
  - Monthly deficit = Supply – Reserve – Demand = 3,036 m^3;
  - Reservoir area = 22,415 m^2; and
  - Required reservoir depth = 0.14 m.

Similar calculations were performed for the other subwatersheds with the same result that on-site storage is a reasonable explanation for the monthly deficit values. This stored water is typically used during the extreme low flow months in the low flow periods rather than direct withdrawals from streams. This is consistent with information provided to TRCA staff as part of the water use surveys. Additionally, average monthly rates may overestimate actual usage during these low flow periods. In the future, measured data from the MOECC’s Water Taking and Reporting System will allow further refinement of these monthly average values.

While no individual subwatersheds had zero or negative flow rates after accounting for the Qp_{90} reserve, the modelled minimum monthly flow rates (typically August) were as low as 0.0012 m^3/s (**Figure 3.34)**. Of the subwatersheds screened as stressed, one (DU06, located in the north-west area of the Duffins watershed) contains five municipal supply wells for Whitchurch-Stouffville and Uxville. As expected, the higher stresses occur during the mid-summer months, when supply is typically at its annual low. All subwatersheds screened as significant were found to have the highest percentage of stress in August.

Note that as part of the peer review process, TRCA staff was provided with information that confirms that the construction of the intake of the major water user in subwatershed CA01 restricts the water taking to a point where this watershed cannot be stressed by this particular user. Therefore, this subwatershed was removed from the "significantly stressed" category.

Future usage rates were not calculated for surface water as there are no municipal supplies that are included in the surface water assessment. (*Guidance Module 7* indicates that only municipal pumping rates should be increased in the future projections.) Therefore, TRCA staff has assumed the 2031 surface water demands will be equal to existing surface water demands.

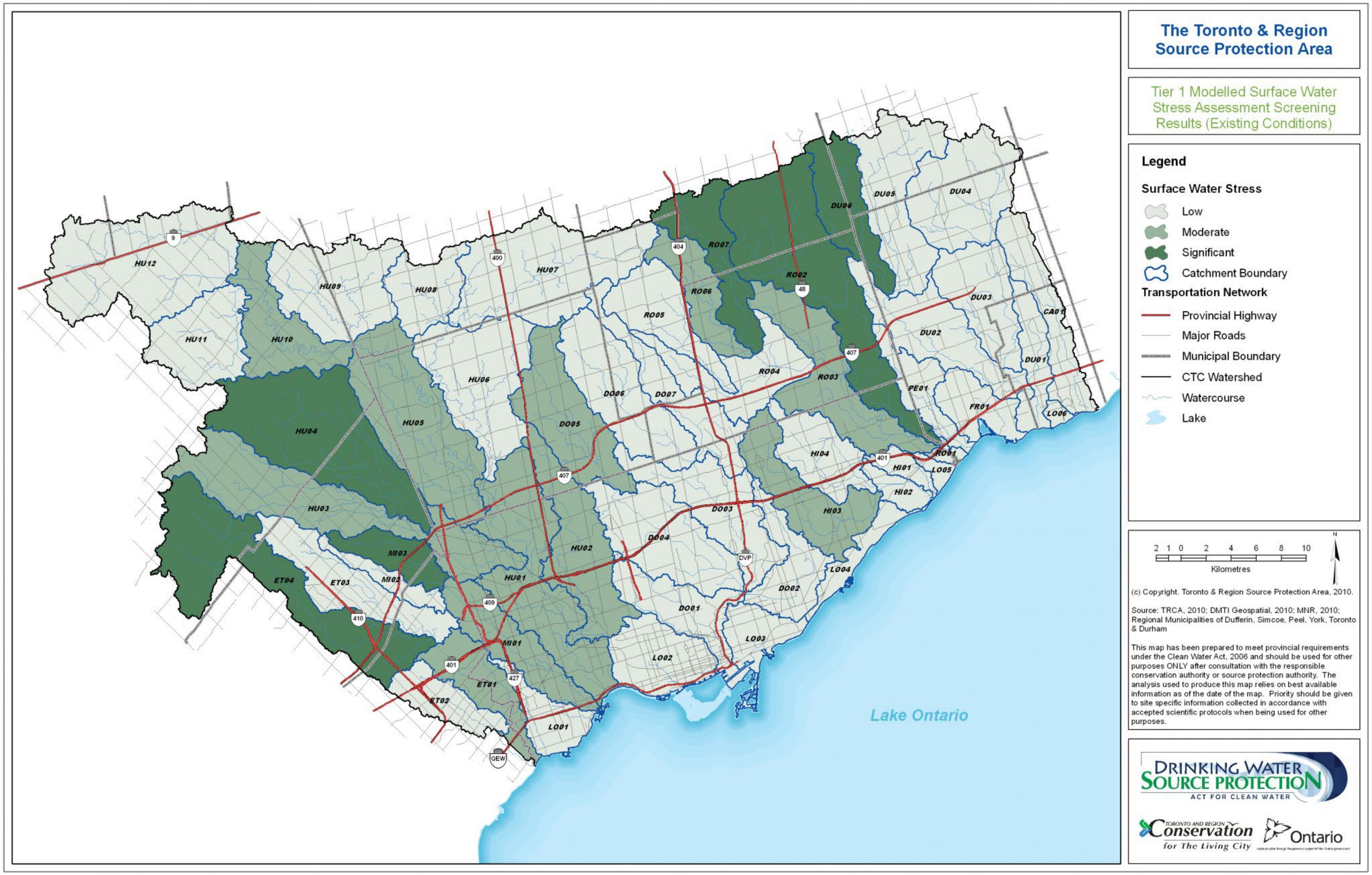
Table 3-10: Surface Water Subwatersheds Screened as Stressed

Watershed	Subwatershed	Maximum Monthly (%)	Stress Assignment	Stressed Months (inclusive)
Etobicoke	ET01	29	**Moderate**	August
	ET04	333	**Significant**	June–September
Mimico	MI01	37	**Moderate**	July–September
	MI03	360	**Significant**	June–September
Humber	HU01	21	**Moderate**	August
	HU02	37	**Moderate**	June–September
	HU03	40	**Moderate**	August
	HU04	129	**Significant**	July–August
	HU05	22	**Moderate**	August
	HU10	23	**Moderate**	August
Don	DO05	32	**Moderate**	July–August
Highland	HI03	44	**Moderate**	July–August
Rouge	RO02	119	**Significant**	July–September
	RO03	21	**Moderate**	August
	RO06	38	**Moderate**	August
	RO07	55	**Significant**	July–August
Duffins	DU06	243	**Significant**	June–September

Table 3-11: Tier 1 Modelled Surface Water Stress Assessment Screening Results

Sub-watershed	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)	Max. Monthly (%)	Stress Assignment
ET01	0	0	0	0	0	5	18	29	16	0	0	0	29	Moderate
ET02	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
ET03	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
ET04	0	0	0	0	0	30	120	333	127	0	0	0	333	Significant
MI01	0	0	0	0	0	9	33	37	31	0	0	0	37	Moderate
MI02	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
MI03	0	0	0	0	0	81	257	360	294	0	0	0	360	Significant
HU01	0	0	0	0	0	1	10	21	3	0	0	0	21	Moderate
HU02	0	0	0	0	0	8	21	37	10	0	0	0	37	Moderate
HU03	0	0	0	0	0	2	8	40	19	0	0	0	40	Moderate
HU04	0	0	0	0	0	0	23	129	0	0	0	0	129	Significant
HU05	0	0	0	0	0	3	9	22	10	0	0	0	22	Moderate
HU06	0	0	0	0	0	5	9	16	7	0	0	0	16	Low
HU07	0	0	0	0	0	0	2	4	0	0	0	0	4	Low
HU08	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
HU09	0	0	0	0	0	0	0	1	0	0	0	0	1	Low
HU10	0	0	0	0	0	3	12	23	8	0	0	0	23	Moderate
HU11	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
HU12	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
DO01	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
DO02	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
DO03	0	0	0	0	0	5	9	10	6	0	0	0	10	Low
DO04	0	0	0	0	0	2	4	7	2	0	0	0	7	Low
DO05	2	3	1	1	2	8	22	32	15	5	1	2	32	Moderate
DO06	0	0	0	0	0	6	6	8	7	0	0	0	8	Low
DO07	1	1	0	0	1	1	3	4	2	1	0	0	4	Low
HI01	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
HI02	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
HI03	0	0	0	0	0	10	25	44	8	0	0	0	44	Moderate
HI04	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
RO01	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
RO02	0	0	0	0	0	10	44	119	24	0	0	0	119	Significant
RO03	0	0	0	0	0	6	15	21	10	0	0	0	21	Moderate
RO04	0	0	0	0	0	0	1	2	0	0	0	0	2	Low
RO05	0	0	0	0	0	5	7	9	6	0	0	0	9	Low
RO06	0	1	0	0	0	1	15	38	3	1	0	0	38	Moderate
RO07	1	1	1	0	1	10	29	55	17	1	1	1	55	Significant
PE01	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
FR01	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
DU01	0	0	0	0	0	1	2	3	2	0	0	0	3	Low
DU02	0	0	0	0	0	3	5	7	4	0	0	0	7	Low
DU03	0	0	0	0	0	3	4	7	4	0	0	0	7	Low
DU04	0	0	0	0	0	4	5	9	5	0	0	0	9	Low
DU05	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
DU06	0	0	0	0	0	30	122	243	54	0	0	0	243	Significant
CA01	0	0	0	0	0	17	71	191	33	0	0	0	191*	Low*
LO01	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
LO02	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
LO03	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
LO04	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
LO05	0	0	0	0	0	0	0	0	0	0	0	0	0	Low
LO06	0	0	0	0	0	0	0	0	0	0	0	0	0	Low

*The one user responsible for 100% of the water use has physical limitations in place that eliminate the potential for hydrologic stress, and for this reason, the subwatershed was assigned a "low" stress level.



(c) Copyright. Toronto & Region Source Protection Area, 2010.

Source: TRCA, 2010; DMTI Geospatial, 2010; MNR, 2010; Regional Municipalities of Dufferin, Simcoe, Peel, York, Toronto & Durham

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

Figure 3-34: Tier 1 Modelled Surface Water Stress Assessment Screening Results (Existing Conditions)

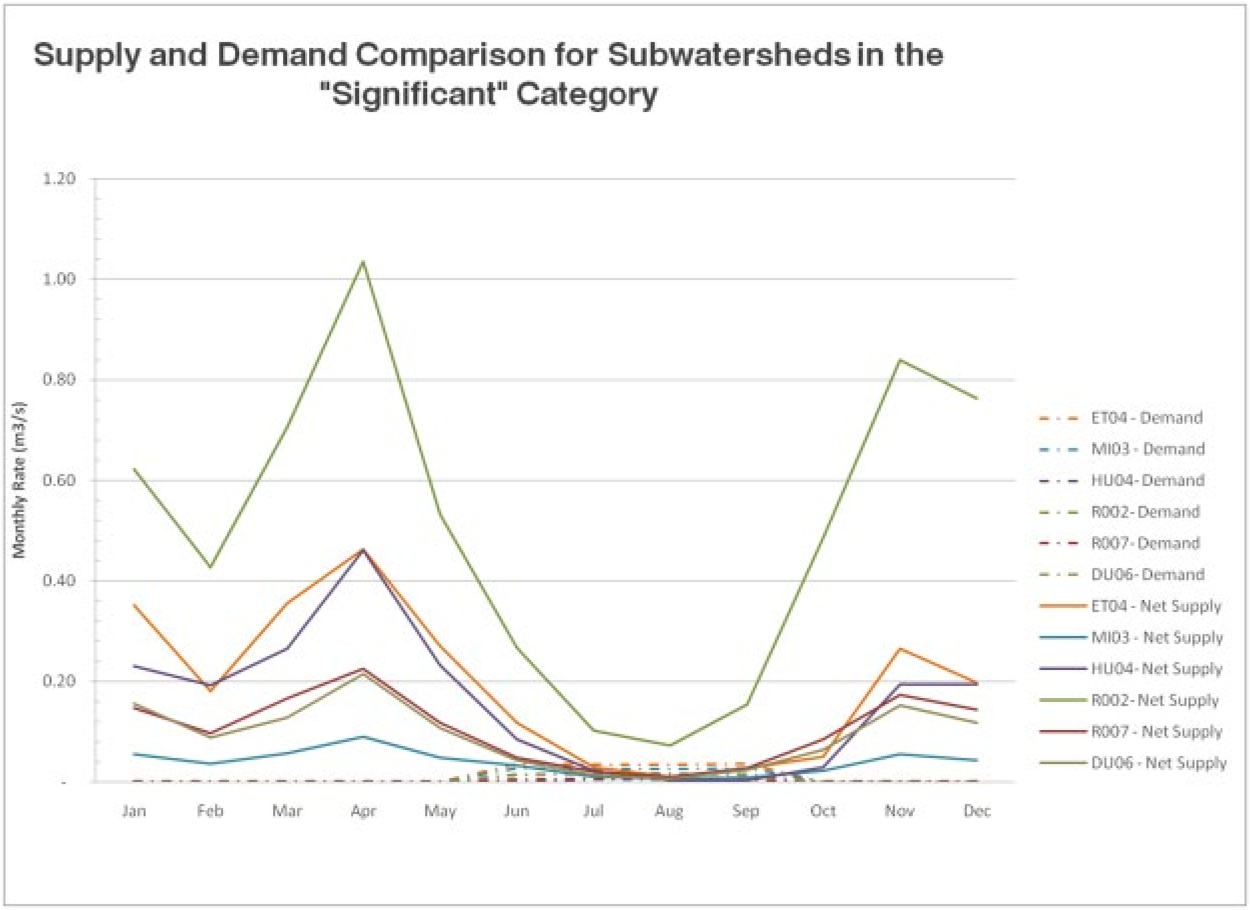


Figure 3-35: Monthly Supply and Demand for Significantly Stressed Subwatersheds

Stress Assessment Screening - Groundwater

The groundwater stress assessment results for the Tier 1 level of analysis are summarized in **Table 3.12,** and shown geographically in **Figure 3.36**. The details of the analysis can be found in the *TRCA Tier 1 Water Budget Report* (TRCA, 2010) and all of the key tables are provided in **Appendix C2**. Note that calculations are subject to the limitations described above and that the results in terms of low, moderate, and significant stress were the same under both existing and future conditions.

The Whitchurch–Stouffville area water supply is located in two subwatersheds that are calculated to have moderate stress (Rouge 02 - Little Rouge Creek, and Duffins 06 – Stouffville and Reesor Creeks). Therefore, a Tier 2 Water Budget was considered for these two subwatersheds, as described below. No further work is warranted under the *CWA* for the DO06, LO01, LO02, or LO03 subwatersheds because they do not contain a groundwater-based municipal drinking water supply.

Table 3-12: Groundwater Subwatersheds Screened as Stressed (Tier 1)

Watershed	Sub-watershed	Stress Level			Municipal Water Supply	Tier 3 Study
		Annual	Monthly	Final		
Don	DO06	**Moderate**	Low	**Moderate**	No	No
Rouge	RO02	**Moderate**	Low	**Moderate**	**Yes**	**Yes**
Duffins	DU06	**Moderate**	Low	**Moderate**	**Yes**	**Yes**
Lake Ontario	LO01	**Significant**	**Significant**	**Significant**	No	No
	LO02	**Moderate**	Low	**Moderate**	No	No
	LO03	**Moderate**	Low	**Moderate**	No	No

Note:

All other subwatershed stress calculation results are "low".

3.8 TIER 2 WATER BUDGET

TRCA staff reviewed the Tier 1 Water Budget stress calculations with the external peer review team, specifically for the Rouge (RO02), and Duffins (DU06) subwatersheds. The findings of this review were as follows:

- The Tier 1 methodology used a complex, continuous surface water model linked to a complex, three-dimensional groundwater flow model;
- Groundwater flows have been estimated into and out of the two subwatersheds calculated to have moderate stress and contain municipal water supply wells;
- Groundwater recharge values have been refined to reflect the output of the surface water model;
- Water use estimates have been refined based on input from municipalities and local water users; and
- For the two subwatersheds that were advanced to Tier 2 there is no requirement to undertake the drought scenario because a moderate stress level was already assigned under Technical Rule 35(2) (a) prior to the requirement of the drought scenario in Technical Rule 35(2) (f).

Based on the above analysis, a Tier 3 level of assessment is required for the municipal water systems located in the RO02 and DU06 subwatersheds because the level of assessment conducted at Tier 1 met the intent of a Tier 2 level of assessment in the *Technical Rules*, and there are two municipal drinking water systems in the watersheds calculated to be stressed. The subsequent Tier 3 analysis was carried out by consultants under the direction of staff from the Region of York, in partnership with the CTC and South Lake Simcoe Georgian Bay source protection regions, and the Regional Municipality of Durham with technical direction on source water protection requirements from the MNRF and MOECC. The approach and findings from this work are summarized in the following section. The complete study approach and findings are provided in the York Tier 3 Water Budget document (Earthfx Inc., 2013).

(c) Copyright. Toronto & Region Source Protection Area, 2010.

Source: TRCA, 2010; DMTI Geospatial, 2010; MNR, 2010; Regional Municipalities of Dufferin, Simcoe, Peel, York, Toronto & Durham

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

Figure 3-36: Modelled Groundwater Stress Assessment Screening Results (Existing Conditions)

3.9 TIER 3 WATER BUDGET PROCESS

3.9.1 Overview

Note that the contents of this section have been excerpted from: *Tier 3 Water Budget and Local Area Risk Assessment for the Region of York Municipal Systems* prepared for the Regional Municipality of York dated November, 2013 (EarthFx Inc., 2013). This foundation report contains additional details regarding the methodology, data, mapping, and risk assessment process and has been extensively peer reviewed by a panel of provincial, municipal, conservation authority, and outside experts.

The overall objective of a Tier 3 Water Budget Assessment is to determine whether a municipality is able to meet its planned water quantity requirements, considering increased municipal water demand, future land development, drought conditions, and other water uses. The Tier 3 Water Budget Assessment is required to:

- Estimate the likelihood that a municipal drinking water source is able to sustain its allocated (existing plus committed and/or planned) pumping rates, while maintaining the requirements of other water uses (e.g. ecological requirements and other water takings); and
- Identify water quantity threats that may influence a municipality's ability to meet their allocated and planned pumping rates.

The *Technical Rules* requires that Tier 3 Water Budget Assessments be completed in subwatersheds where the groundwater and/or surface water are sources for municipal drinking water supplies that show moderate or significant water quantity stress. Based on the results of the TRSPA Tier 2 Water Budget study (see **Section 3.8**), moderate groundwater quantity stresses were identified in the Little Rouge (RO02) and Stouffville/Reesor Creek (DU06) subwatersheds. The Region of York operates supply wells in both subwatersheds, while the Region of Durham operates supply wells in the Stouffville/Reesor Creek subwatershed. The following sections describe the findings of the Tier 3 Water Budget analyses for municipal wells located in both subwatersheds. Note that other municipal wells are present within the study area, but were not the focus of the Tier 3 assessment.

The two prescribed activities which are drinking water quantity threats are defined in the Ontario Regulation 287/07 under the *Clean Water Act, 2006*. These activities are:

- Any consumptive use of water (demand for water); or
- Any activity that reduces recharge to an aquifer.

The information used to assess these water quantity threats includes detailed characterization of current and future municipal and non-municipal consumptive uses (demand), the amount of water available for use in the aquifer or surface water body, as well as potential reduction in recharge from future changes in land use based on the current Official Plan and zoning. The CTC SPC is required to develop policies in the Source Protection Plan to manage or avoid these threats.

3.9.2 Tier 3 Methodology

The two major components of a Tier 3 Water Budget Assessment are:

1. The Tier 3 Water Budget Model - Developed using numerical groundwater and surface water models, which are used to evaluate localized hydrologic or hydrogeologic conditions at a water supply well or surface water intake. The Tier 3 Water Budget represents improvements over the Tier 1 and 2 Water Budgets in terms of the model simulation and representation of groundwater movement between and across subwatershed boundaries. This is made possible by collecting and assessing data that reflects the surface flow system, and the subsurface characterization in the study area, notably in the vicinity of municipal wellheads and surface water intakes.
2. The Local Area Risk Assessment - The evaluation of a series of risk scenarios within the *Local Areas*. Local Areas are the vulnerable areas that are delineated to protect the quantity of water required by a municipality to meet their current or future water needs. The Tier 3 Water Budget Model was used to delineate the Local Area for municipal groundwater wells in the study area.

Local Area: For a surface water system, it is the drainage area that contributes surface water to an intake. For a well, it is the area created by combining the cone of influence of the well; the cones of influence resulting from other water takings where those cones of influence intersect that of the well; and the areas where a reduction in recharge would have a measurable impact on the cone of influence of the well. This includes the upgradient drainage area of a surface water system from the point where it contributes to groundwater. For example where water in a river travels downward into an aquifer, rather than remaining in the river.

Cone of Influence: For one or more wells that draw water from an aquifer, this is the area within the depression created in the water table or potentiometric surface when the wells are pumped at a rate equivalent to their allocated plus planned quantities of water.

Once the Tier 3 models have been calibrated and validated, the Local Areas are delineated and Local Area Risk Assessments are undertaken within these areas. Part IX.1 to Part IX.4 of the *Technical Rules* (MOE, 2009) and the MOECC and MNRF Bulletin (MOE and MNR, 2010) set the requirements and deliverables for the risk assessment process and enumeration of moderate and significant drinking water quantity threats. The primary steps in this process are:

1. Identification of the study area and model domain through the evaluation of the interaction of the cones of influence of municipal wells and other water users, with a threshold set based on natural water level fluctuations in the aquifer(s) involved.
2. Municipal Water Use Assessment – detailed characterization of wells and intakes, specifically existing, committed, and planned demand as well as low water operating constraints.
3. Other Water Use Assessment – identification of other uses that might be influenced by municipal pumping and identify water quantity constraints according to those other uses.
4. Characterization of Future Land Use – comparison of Official Plans with current land use and incorporates assumptions relating to additional imperviousness from future developments.
5. Development and calibration of a Tier 3 Water Budget Model – Numerical surface water and groundwater models created to simulate the movement and extraction of surface water and groundwater in the study area.
6. Refinement of the water budget parameters within the TRSPA portion of the model.

7. Delineation of vulnerable areas for water quantity. These areas are delineated using the Tier 3 Water Budget Model.
8. Evaluation of the risk scenarios within the Local Area to establish the overall risk level for each of the vulnerable areas for water quantity. The risk ranking (low, moderate, or significant) is assigned to each of the vulnerable areas independently based on the results of the scenarios.
9. Enumeration of Drinking Water Quantity Threats and the associated risk level for the threat activity (based on the risk level assigned to the Local Area).
10. Confirmation of Significant Groundwater Recharge Areas from the Tier 1 and 2 studies.

The Tier 3 Water Budget represents improvements to the Tier 1 and Tier 2 water budgets in terms of the model simulation and more accurate estimates of groundwater movement between and across subwatershed boundaries. This is made possible by refinements in the geological conceptualization and subsurface characterization of the study area, particularly in the vicinity of municipal wellheads. The model is used to map the area around each well, or group of wells, and where the water comes from to supply that well(s) – the Local Area.

Wellhead Protection Areas – Quantity (WHPA-Qs) are the vulnerable areas that are considered as most important to protect the quantity of water required by a municipality to meet their current or future water needs. There are two types of WHPA-Qs:

1. The *cone of influence* of the municipal supply wells (WHPA-Q1); and
2. The areas where a reduction in recharge would have a measurable impact on the cone of influence of the well(s) (WHPA-Q2).

The combination of the WHPA-Q1 and the WHPA-Q2 are called a Local Area. The drinking water threats within the Local Area are classified as low, moderate or significant depending on the risk level assigned to the Local Area. If the risk level is significant, then all consumptive water uses and activities which reduce recharge are classified as significant drinking water threats. If the risk level is moderate, current consumptive water uses and recharge reductions are moderate threats, while future activities would be significant threats.

Where the risk scenarios identify the potential that a well will not be able to supply its allocated or planned supply, the Local Area is assigned a ‘moderate’ or ‘significant’ water quantity risk level. Once the risk level is assigned to the Local Area, any activity within the Local Area, that reduces recharge to the aquifer, or that removes water from an aquifer without returning it to the same aquifer (demand) is identified as being a drinking water quantity threat.

Where the risk level assigned to an area is significant, any existing or future threat activity is deemed to be a significant water quantity threat. In an area with a moderate risk level, only a future threat activity is deemed to be a significant water quantity threat. The CTC SPC is required to develop policies in the Source Protection Plan to manage or avoid significant drinking water quantity threats, and may develop policies for moderate or low water quantity threats.

Study Area and Model Domain

The study area model domain for this Tier 3 study considered the surface water and groundwater divides as well as the geographic distribution of municipal water supplies, radii of influence of the wells, and hydrogeologic boundaries (i.e., Lake Simcoe and Lake Ontario). With the large withdrawals from confined aquifers such as the Yonge Street Aquifer combined with the relative proximity of other municipal wells in Simcoe, York, Peel, and Durham regions, a large model domain was required to fully encompass the WHPA-Q1 and Q2 areas. Another consideration was physical extent of the underlying Tier 1 and 2 models. Normally, a Tier 3 model domain is smaller than the previous tiers, but in this case it was larger. In particular, underlying model data were not available east of Uxbridge and northwest of Bradford.

Municipal Water Use Characterization

To characterize water demand in the study area, the following data were collected and assessed for each municipal well:

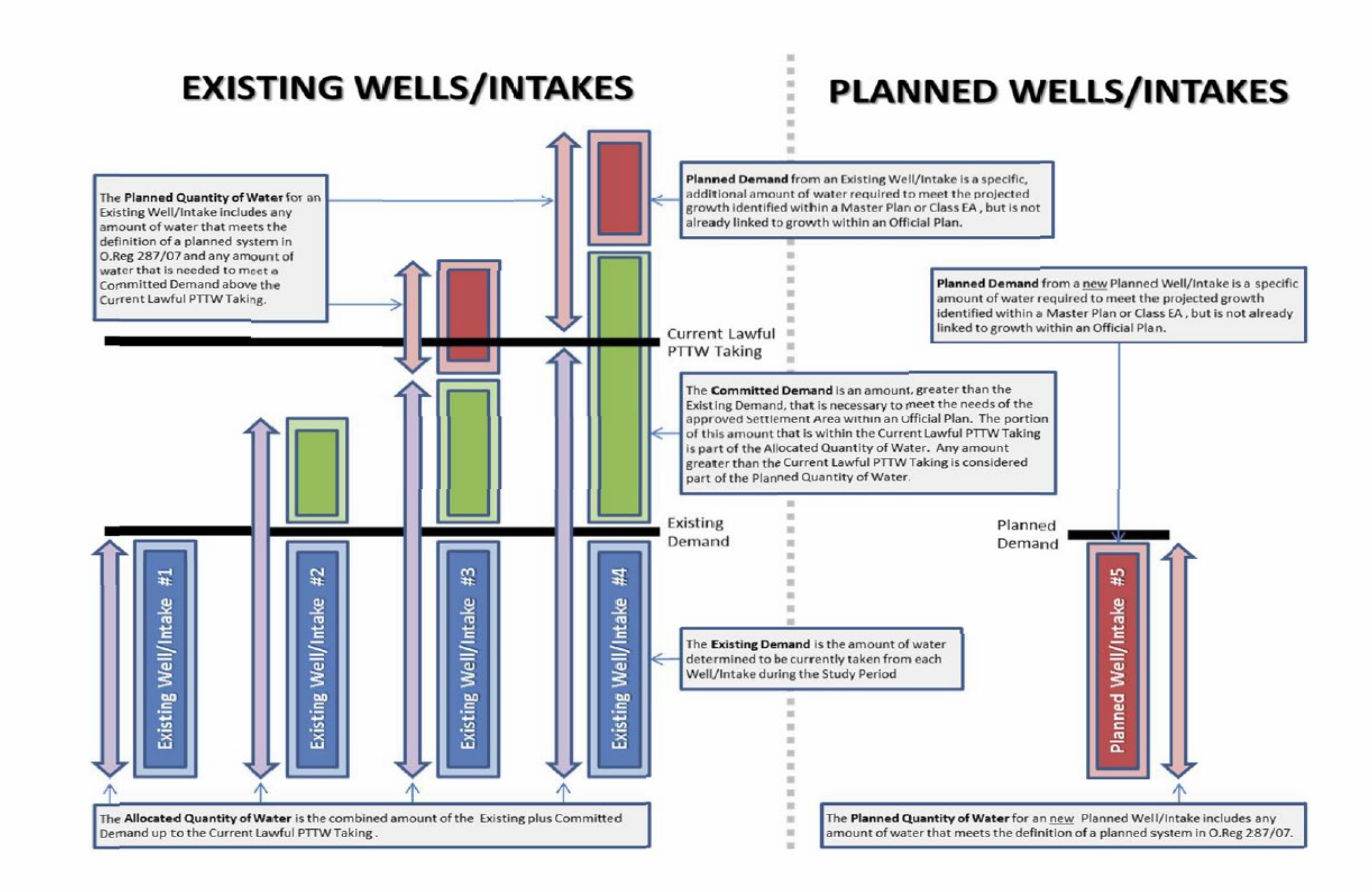
- Permit Details - where possible, original copies of Permits to Take Water was compiled;
- Historical pumping records and water level monitoring data;
- Well completion details - open hole depth, well screen top and bottom depth, position of well screen with respect to the aquifer, casing and screen construction, casing survey data;
- Maintenance records - typical pre- and post-rehabilitation well yields, rehabilitation frequency;
- Safe Water Level at each well or intake was estimated or calculated based on the minimum groundwater or surface water elevation that can be sustained while pumping at the intake;
- Maximum Yield or Sustainable Yield Estimates were estimated for each well (may be less than the permitted rates); and
- Operational procedure and maintenance information.

The *Technical Rules* require that the existing, committed and planned demands associated with the allocated and planned quantities of water be estimated for each existing and planned groundwater well or surface water intake. These terms were first defined through the *CWA, 2006*, and later refined through interim guidance issued by the MOECC in December 2013:

- **Existing Demand** – amout of water determined to be currently taken from each well or intake. For this study, existing demand has been estimated as the average annual pumping during the study year (2008). Maximum monthly and maximum daily demands are also estimated based on historical trends.
- **Committed Demand** – an amount, greater than the existing demand that is necessary to meet the needs of an approved Settlement Area within an Official Plan. The portion of this amount that is within the current lawful PTTW taking is part of the allocated quantity of water. Any amount of usage greater than the current lawful PTTW taking is considered part of the planned uantity of water.
- **Planned Demand** – a specific additional amount of water required to meet the projected growth identified within a Master Plan or Class EA, but is not already linked to growth within an Official Plan.
- **Allocated Quantity** – in respect of an existing surface water intake or an existing well, the existing demand of the intake or well plus any additional quantity of water that would have to be taken by the intake or well to meet its committed demand, up to the maximum quantity of water that can lawfully be taken by the intake or well under the current PTTW.
- **Planned Quantity** – (a) in respect of an existing surface water intake or existing well, any amount of water that meets the definition of a planned system in O.Reg 287/07 and any amount

> of water that is needed to meet a committed demand above the maximum quantity of water that can lawfully be taken by the intake or well under the current PTTW; or(b) in respect of a new planned surface water intake or planned well, any amount of water that meets the definition of a planned system in O.Reg 287/07.

These parameters are shown graphically in **Figure 3.37**. Estimating consumptive water use under existing demand and under allocated demand (existing plus committed plus planned demand) pumping conditions is a key element of the Tier 3 Water Budget Assessment. The term “consumptive” is used to describe the portion of water taken from a surface or groundwater source that is not returned directly to that source. While the focus of the risk assessment is on evaluating the sustainability of the municipal wells in catchments identified as potentially stressed in the Tier 2 assessment, water demand estimates from all surface and groundwater takings across the entire model area has been compiled and simulated in the Tier 3 model. The municipal wells in the study area are shown on **Figure 2.7**, but only municipal wells in the Little Rouge River and Stouffville/Reesor Creek subwatersheds (Whitchurch-Stouffville and Uxville) are subject to the risk assessment for TRSPA.



The **Planned Quantity of Water** for an Existing Well/Intake includes any amount of water that meets the definition of a planned system in O.Reg 287/07 and any amount of water that is needed to meet a Committed Demand above the Current Lawful PTTW Taking.

Planned Demand from an Existing Well/Intake is a specific, additional amount of water required to meet the projected growth identified within a Master Plan or Class EA , but is not already linked to growth within an Official Plan.

Planned Demand from a new Planned Well/Intake is a specific amount of water required to meet the projected growth identified within a Master Plan or Class EA , but is not already linked to growth within an Official Plan.

The **Committed Demand** is an amount, greater than the Existing Demand, that is necessary to meet the needs of the approved Settlement Area within an Official Plan. The portion of this amount that is within the Current Lawful PTTW Taking is part of the Allocated Quantity of Water. Any amount greater than the Current Lawful PTTW Taking is considered part of the Planned Quantity of Water.

The **Existing Demand** is the amount of water determined to be currently taken from each Well/Intake during the Study Period

The **Allocated Quantity of Water** is the combined amount of the Existing plus Committed Demand up to the Current Lawful PTTW Taking.

The **Planned Quantity of Water** for an new Planned Well/Intake includes any amount of water that meets the definition of a planned system in O.Reg 287/07.

Figure 3-37: Characterization of Existing and Planned Systems

A key component of the municipal water use assessment was the identification of the “safe additional drawdown” for the municipal wells. This parameter is defined as the additional depth that the water level within a pumping well could fall and still maintain that well’s allocated pumping rate. The additional drawdown is calculated by considering the amount of drawdown available beyond the drawdown created by the existing conditions and pumping rate (baseline level).

A key aspect of the determination of the “safe additional drawdown” is whether the constraint on the well’s operation is related to either in-well conditions (i.e., related to a pump or well screen elevation) or to in-aquifer conditions (i.e., related to preventing dewatering of a confined aquifer). Another example of an in-well limit might be, for example, a change in casing diameter that prevents the pump from being lowered.

To determine the safe additional drawdowns at each well, the following components were evaluated for each of the municipal wells in the York Tier 3 assessment area:

- **Existing (baseline) pumped water elevations.** The baseline water levels are based on the average annual observed water levels for the period of normal pumping operations during the study period (2010 to 2011). The existing pumped water elevations (either in-well or in-aquifer) are considered to represent long-term average water levels under current pumping conditions.
- **Safe Water Level elevations.** The safe water level is the lowermost elevation within the pumping well (or aquifer) to which water levels can be depressed. This elevation is dependent upon a number of factors (e.g., well screen elevation, pump intake setting, or top of confined aquifer) and is evaluated on a well-by-well basis.
- **Estimated Non-Linear Head Losses and Convergent Head Loss Corrections.** Non-linear head loss refers to drawdown in the pumped well caused by turbulent flow in the well casing, resulting in an increase above the predicted theoretical drawdown. Convergent head loss corrections are applied to account for the difference between the simulated average water level in a model cell and that in the pumping well.

In summary, the “safe additional drawdown”, is selected based on the lesser of:

a) Additional available drawdown in the well, as determined by the difference between the operating level in the well (during the study period) and the top of the well screen. (This is based on the assumption that water levels should not be drawn down into the well screen during operations.)

or

b) Additional available drawdown in the aquifer nearby the well, as determined by the difference between the aquifer water levels (during the study period) and the top of the aquifer. (This is based on the assumption that the confined aquifer should not be dewatered in the vicinity of the well).

If the safe additional drawdown is selected based on in-well conditions, the safe water level threshold is defined by the lower limit of the in-well condition (e.g., the top of casing). If the safe additional drawdown is based on in-aquifer conditions, the safe water level is based on the lower limit of the in-aquifer threshold (e.g., the top of the aquifer).

A well is considered to be at risk if the “Risk Scenario Minimum Simulated Water Level” (i.e., the lowest predicted water level in the well under various Tier 3 assessment scenarios) is below the safe water level.

Identification of Other Water Uses

One of the goals of the Tier 3 assessment process is to develop a better understanding of the effects of the municipal wells on other water uses. Specifically, the analysis must consider whether the allocated municipal water demand can be met while maintaining the requirements of other water uses in the area. These water uses, as defined in the *Clean Water Act*, *2006* include:

- Municipal wells outside of stressed subwatersheds (RO02 and DU06);
- Other water takings including agricultural, commercial and industrial water takings;
- Waste water assimilation;
- Navigation;
- Recreation;
- Aquatic habitat; and
- Provincially significant wetlands.

Municipal wells outside of subwatersheds identified as stressed in the Tier 2 analysis have the potential to be affected by wells inside the stressed subwatersheds. Therefore, these wells were active in the modelling process, but were not subjected to the safe water level threshold evaluation.

Extensive data compilation and analysis of all non-municipal water use (including agricultural, commercial and industrial, and recreational water takings) was included in Section 9 and Appendix E of the Development and Calibration Report (Earthfx, 2013). Recreational water use for golf courses, snowmaking, and recreational fishing from stocked fish ponds were identified along with the other permitted takings. While no specific guidelines are provided for the assessment of risks related to “other takings”, an incremental drawdown threshold of one metre was selected based on the natural fluctuations observed in the study area.

Wastewater assimilation requirements were considered for all sewage treatment plant discharges to watercourses. Each Environmental Compliance Approval within the model domain was reviewed to determine if any low flow minimums were specified.

The model domain was assessed for the presence of navigable waterways that could have minimum water flow requirements.

There are no takings active in the York Tier 3 Model used to represent water demands related to maintaining aquatic habitat. Instead, the *Technical Rules* specify that impacts to aquatic habitat be addressed in terms of “reduction to the flow or level of water that constitutes an unacceptable impact to other water uses”.

The major watersheds, streams, lakes, and wetlands which drain the study area were mapped and classified using the latest MNRF version 2 stream coverage. A total of 4,450 km of mapped streams are found within the study area. Each stream reach was represented in the flow model. Streamflow data for the study area were obtained from the Water Survey of Canada, a division of Meteorological Service of Canada, Environment Canada. There are approximately 75 active and inactive (historical) stream gauges proximal to the study area. The gauges within the TRSPA are shown on **Figure 3.18**. A total of 23 Water Survey of Canada gauges within the study area were selected for use during model calibration based on their period of record, data quality, and catchment size (between 10 and 800 km^2). Daily mean stream discharge data at these stations were employed to calibrate the integrated surface water/groundwater model.

Groundwater exchange between the aquifer systems and each stream reach was computed by the SFR2 module model in the York Tier 3 model. The rate of groundwater discharge to a stream reach is proportional to the difference in head between the aquifer and the water level (stage) in the stream. Unlike the earlier Core Model (Kassenaar and Wexler, 2006), which used a fixed estimate of stream stage based on the DEM, the Tier 3 model stage in the stream is calculated based on the baseflow accumulated (routed) from all upstream tributaries.

Characterization of Future Land Use

The type of land cover has a strong influence on the water balance. Interception and evapotranspiration are directly controlled by vegetation type and cover density, which, affect runoff and infiltration rates. Conversion of natural or agricultural land to urban land use (e.g., residential, commercial, industrial, or institutional) often increases the amount of impervious cover (e.g., roofs and pavement). Urbanization leads to increased evaporation from depression storage and increased overland runoff, which reduces recharge potential. Groundwater recharge is simultaneously increased through reductions to vegetative and pervious cover leading to reductions in evapotranspiration and evaporation from interception and soil zone storage.These competing factors make assessing the net impact to groundwater recharge more difficult to predict.

The Tier 3 analysis characterized projected land use changes following the following steps from the MNRF Water Budget Guide:

1. Existing land use was mapped based on data from the municipalities and TRSPA.
2. Projected land use was mapped based on approved Official Plans.
3. Areas of land use change were identified by comparing projected to existing land use.
4. The projected change in imperviousness for each area of land use change was mapped based on assumptions relating to the imperviousness of each land use category.
5. A map of projected change in imperviousness was generated for areas with projected land use alterations.

The MNRF Water Budget Guide states that potential impacts of stormwater management and low impact development measures are not accounted for when estimating imperviousness changes for future land use. Additionally, future non-municipal water demands due to land use change (e.g., increases in self-supplied domestic use) should not be speculated.

Detailed land use and land cover data for the entire study area were provided by the municipalities, MNRF, and the conservation authorities. This information was used to develop the PRMS recharge model inputs, as described in detail in Chapters 8 and twelve of the Model Development and Calibration Report (see Earthfx, 2013). Official land use plans for York, Peel, and Durham region, and the Town of Bradford West Gwillimbury were compiled. These land use plans include future urban settlement boundaries, but specific future land use within the boundaries is not known at this time. A methodology was developed to reasonably adjust model inputs to represent future conditions.

Model Development and Calibration

The Tier 3 Water Budget includes key enhancements to the Tier 1 and 2 numerical models, including improvements in the simulation of the surface flow system, and in the geological conceptualization of the area - particularly in proximity to municipal wellheads. These updates enabled a more localized representation of the subsurface and its flow systems near the wellheads as compared to the regional-scale representation created for the previous assessments.

The GSFLOW code used for this project is based on the integration of two main “sub-models” used to simulate the surface water and groundwater flow processes. Within each of these submodels additional processes are represented, including snow pack accumulation and snowmelt, unsaturated flow, evapotranspiration, etc. All of these processes are represented in a “distributed” manner, i.e., the study area is subdivided into small representative blocks, or cells, each having unique properties and characteristics.

For the York Tier 3 Water Budget, the processes and unique response of each cell was simulated as well as the interaction between cells and the collective response of all the cells in the model area. The result was a spatially-varied response to the inputs (e.g., precipitation, temperature, and solar radiation) and withdrawals (e.g., well pumping and groundwater discharge to streams).

The GSFLOW sub-models covered the following main processes:

1. Surface water processes including climate, vegetation uptake, land use, soils and flow in streams, wetlands, and riparian areas; and
2. Sub-surface processes, including unsaturated flow and saturated groundwater flow.

The Tier 1 and 2 water budget assessments used separate hydrologic and groundwater flow models that were manually integrated and analyzed. In particular, outputs from the hydrologic model provided the estimate of groundwater recharge to the groundwater model while the groundwater model provided estimates of cross-watershed flows needed to be added to the simulated flows at the catchment outlet. The GSFLOW model used in this study, on the other hand, was a fully-integrated groundwater and surface water model, which modelled the surficial and sub-surficial processes simultaneously, allowing for the responses from each sub-model to interact as they do naturally. This provides for a wide range of modelling improvements and feedback mechanisms that were beyond the capabilities of the loosely-coupled approach. This integrated approach proved particularly necessary in this study because of the significant interactions between the surface water and groundwater processes. For example, wetlands were represented as one-way outflow drains in the Tier 1 and 2 models. This means that wetlands are always assumed to be points of groundwater discharge, even though they can seasonally serve as groundwater recharge points under varying hydrologic conditions. With a fully-integrated approach, no limiting assumptions about wetland function are needed, as water movement into or out of the wetland is simulated based on the actual flow and head-dependant leakage conditions on each day in the simulation period.

The surface water portion of GSFLOW is based on the Precipitation-Runoff Modelling System (PRMS) developed by the USGS (Leavesley *et al*., 1987). PRMS itself is composed of many hydrologic process component models, including:

- A climate sub-model that distributes precipitation types and determines potential evapotranspiration (PET) rates based on temperature and solar radiation data;
- An energy-balance snowmelt model that simulates snowpack dynamics and accounts for snowmelt quantities;
- A vegetation canopy interception model;
- A soil moisture accounting algorithm that computes runoff, storage, actual evapotranspiration (AET), and recharge; and
- An overland flow module that routes runoff downslope until a stream feature or water body is reached.

The GSFLOW version of PRMS also improves on the original PRMS code with the inclusion of a cascading overland flow algorithm that routes surface runoff along flow pathways toward streams and lakes, thus allowing for run-on and re-infiltration; and the ability to communicate with the groundwater model to account for water table feedback mechanisms that may reject potential recharge and add groundwater discharge to the surface water system.

Groundwater processes in GSFLOW are simulated by MODFLOW-NWT (Niswonger, et al., 2011), a well-established groundwater modelling code. MODFLOW-NWT's sub-models include saturated and unsaturated flow processes, lake and wetland water balance and groundwater interaction, and streamflow routing. Lake stage is determined based on stage/area/volume relationships for each water body. The MODFLOW-NWT model is specifically designed to represent complex, fluctuating, shallow water-table conditions that are essential to properly simulating interaction between the surface and subsurface.

Calibration targets for the Tier 3 GSFLOW model included flows recorded at streamflow gauges, and continuous water-level data from PGMN and York Region monitoring wells. Other secondary sources included MOECC Water Well Information System (WWIS) static water levels and wetland mapping. The integrated modelling approach has the benefit that the model must be calibrated to both groundwater and surface water data simultaneously; thus reducing the level of uncertainty typically associated with separate models that make simplifying assumptions regarding the processes not explicitly represented. The integrated calibration also means that artificial or empirical data processing techniques such as baseflow separation are not needed because the model is calibrated to total measured flow at the stream gauges.

To facilitate model construction and evaluation, GSFLOW's sub-models can be run independently during calibration, scenario or sensitivity analysis. For example, the PRMS model was first used to provide an estimate of long-term average recharge. This recharge estimate was then used to develop an initial long-term steady-state groundwater flow model calibration. Once the long-term average sub-models were developed, the final integrated calibration was completed and tested against the more detailed transient water levels and streamflow discharge measurements.

All municipal and non-municipal groundwater takings were represented in the model on a daily basis (rather than monthly) using reported information and consumptive use factors. The surface water model accounted for all surface takings in the study area. The results of model calibration and the insights gained were presented in detail in Earthfx, 2013.

The GSFLOW code can produce maps showing the distribution of model outputs on a daily basis. Outputs include groundwater levels, groundwater discharge to streams, the separate components of overland runoff, potential and actual evapotranspiration, snow pack, soil moisture, etc., for every model cell in the study area.

Water Budget Parameter Refinement

The Tier 3 GSFLOW model produces estimates of model outputs on a daily basis. Outputs include groundwater levels, groundwater discharge to streams, the separate components of overland runoff, potential and actual evapotranspiration, snow pack, soil moisture, etc., for every model cell in the study area.

Maps of each parameter, averaged over the modelling period are provided in the foundation report (Earthfx, 2013). The spatial data were analysed and tabulated by subwatershed for incorporation into this Assessment Report.

Delineation of Vulnerable Areas for Water Quantity

The WHPA-Q1 is defined in the *Technical Rules* for the Assessment Report (MOE, 2009), as:

> "*…the combined area that is the cone of influence of the [municipal] well and the whole of the cones of influence of all other [municipal and non-municipal] wells that intersect that area*".

The cone of influence for a single well can be determined by subtracting the simulated steady-state potentiometric heads in the production aquifer under pumping conditions, from the simulated steady-state potentiometric heads with no pumping. The difference is referred to as the well drawdown. To determine the combined cones of influence needed to define the WHPA-Q1, the simulated steady-state heads in the production aquifer with all wells pumping, were subtracted from the simulated steady-state heads with no wells pumping.

Steady-State Condition: assumes that the amount of water stored in surface water and subsurface reservoirs will vary negligibly over the time scale considered.

As per the *Technical Rules*, the model used to prepare the water budget analyses was used to conduct the simulations needed to delineate WHPA-Q1 and WHPA-Q2 areas. As with Scenarios C and G, the WHPA-Q1 analysis is completed using the steady-state groundwater model and a long-term estimate of average groundwater recharge. It should be noted that under the *steady state condition*s, many of the dynamic surface water processes, such as rainfall/runoff partitioning, cascading overland flow, and groundwater feedback (rejected recharge), are not active and only the baseflow (groundwater discharge) component of the streamflow is routed through the stream network. Groundwater recharge rates used in the steady-state model simulation were determined through a long-term (20-year) simulation with the PRMS sub-model assuming current land use. The model period was from October 1986 to September 2009. The first three years were assumed to be affected by model start up and were not used in the averaging.

The rates of pumping used in the WHPA-Q1 simulations were based on the allocated quantities of water (existing plus committed plus planned municipal demands). In theory, the cone of influence of a well will grow until inflows into the drawdown cone (i.e., recharge, stream leakage, or inflows from natural hydrologic boundaries such as Lake Simcoe) balance the pumping withdrawals. However, because the drawdown decreases exponentially away from the pumping centre, the drawdown at distance may not be measureable and/or may not be distinguishable from natural variation due to precipitation events and other water takings. Accordingly, a drawdown threshold of 1.0 m was selected as the practical limit of the cone of influence for the York Tier 3 WHPA-Q1 delineation. This threshold value was established by a thorough review of seasonal variations in monitoring wells with continuous data. (Earthfx Inc., 2011).

The WHPA-Q2 is defined in the *Technical Rules* for the Assessment Report (MOE, 2009) as the WHPA-Q1 plus *"*any area where a future reduction in recharge would significantly impact that area*"*. This statement has been interpreted in the MNRF Water Budget Guide to mean that the WHPA-Q2 includes the map outline of future land developments, identified in a municipality's Official Plan, that are:

- Outside of or straddle the WHPA-Q1 boundary; and
- Could decrease natural groundwater recharge to a point that it would have a measurable impact on water levels at the municipal pumping wells (MNR, 2011).

For new land developments that straddle the WHPA-Q1 boundary, the WHPA-Q1 would expand to include the outline of the proposed development. For land developments outside the WHPA-Q1, separate WHPA-Q2 areas would be delineated.

The impact of recharge reduction was determined by subtracting the simulated steady-state heads with the adjusted recharge rate for the new land development areas from the simulated steady-state heads using recharge based on current land use. Adjusted groundwater recharge rates were determined through long-term (20-year) simulations with the PRMS sub-model using the percent imperviousness and other changes in vegetative cover properties associated with the new land developments. A drawdown threshold of 1.0 m was selected as the practical limit for the "measurable" impact at nearby municipal wells. It should be noted that this simulation is similar to conditions under Scenario G(1), except that developments within the WHPA-Q1 area were not simulated.

Risk Assessment Scenario Evaluation

The risk assessment requires analysing ten different scenarios to determine potential water quantity stress, as described in **Table 3.13**. These scenarios are based on the requirements outlined in the *Technical Bulletin: Part IX Local Area Risk Level*. They include both existing and future land use, average and drought climate; combined with existing and committed municipal water demand. Note that Scenarios A, B, E, and F relate to surface water systems, and were therefore not considered in in this Tier 3 study (groundwater supply stresses only).

Table 3-13: Risk Assessment Scenarios for the York Tier 3 Water Budget

Scenario	Time Period	Model Scenario Details			
		Land Cover	Municipal Pumping	Model Simulation	
C	Period for which climate and stream flow data are available for the Local Area (1987-2009)	Existing	Existing	Steady-state, Average Annual Recharge	
D	10 year drought period (1956-1966)	Existing	Existing	Transient (1960-2006); Monthly recharge rates	
G(1)	Period for which climate and stream flow data are available for the Local Area (1987-2009)	Projected Demand and Reduction in Recharge	Committed	Groundwater Recharge Reduction and Increase in Demand	Steady-state, Average Annual Recharge
G(2)		Existing	Committed	Groundwater Discharge Reduction from Increase in Demand	
G(3)		Recharge Reduction	Existing	Groundwater Recharge Reduction from Land Cover	
G(4)		Existing	Committed	Per (G)2; Impacts on other users	
G(5)		Existing	Planned	Per (G)2; Impacts on other users	
H(1)	10 year drought period (1956-1966)	Projected Demand and Reduction in Recharge	Committed	Groundwater Recharge Reduction and Increase in Demand	Transient (1960-2006); Monthly recharge rates
H(2)		Existing	Committed	Groundwater Discharge Reduction from Increase in Demand	
H(3)		Recharge Reduction	Existing	Groundwater Discharge Reduction from Increase in Demand	

The risk scenarios relied on the calibrated surface water and groundwater flow models to estimate changes in water levels in the municipal supply aquifers, and to estimate the impacts to groundwater discharge and base flow to streams under average and drought climate conditions. Note that most of the scenarios were evaluated using the steady-state model, but the 10-year drought scenarios (D and H) required transient simulations.

Planned Quanity of Water (existing well or intake): Any amount of water that meets the definition of a planned system in O. Reg. 287/07 and any amount of water that is needed to meet a committed demand above the lawful PTTW Taking.

Committed Demand: An amount greater than the existing demand that is necessary to meet the needs of an approved Settlement Area in an Official Plan.

Cell-by-cell discharge was used to identify stream reaches where there is significant groundwater discharge. The SFR2 module model accumulates the cell-by-cell groundwater discharge and routes it downstream, providing an estimate of baseflow at any point in the network. The accumulated baseflow can, if a downward gradient exists between the stream and the aquifer, leak back into the aquifer. Changes in pumping can lower aquifer levels, induce leakage, and reduce baseflow in the stream. The change in the accumulated baseflow in the stream was selected as the best means to estimate the impact on aquatic habitat.

Where the scenarios identify the potential that a well will not be able to supply their allocated rates, the Local Area is assigned a 'moderate' or 'significant' water quantity risk level. Once the risk level is assigned to the Local Area, activities within the Local Area that reduce recharge to the aquifer, or that removes water from an aquifer without returning it to the same aquifer (consumptive use), are enumerated as drinking water threats.

Part IX.1 to Part IX.4 of the *Technical Rules* and MOECC and MNRF Bulletin (MOE and MNR, 2010) set the requirements and deliverables for the Local Area assessment and risk level. It is important to note that the assignment of a significant risk to a local area, based on the evaluated impacts to "other water uses" using the appropriate scenarios, can only occur when a Planned Quantity of Water has been has been identified within the Tier 3 assessment (MOE, 2013), which is NOT the case in the York Tier 3 Local Area. Impacts to "other water uses" from municipal drinking water use were assessed in the Local Area, as required by the *Clean Water Act, 2006* and the *Technical Rules*, including:

- Groundwater discharge to streams;
- Groundwater discharge to wetlands; and
- Other permitted groundwater takings.

The locations of the warm and cold water streams in the TRSPA were provided on **Figure 2.5** in **Section 2.2.2** of this Assessment Report. The *Technical Rules* provide specific thresholds to be used in evaluating the impact of pumping to meet allocated demand on cold water stream reaches. A reduction by an amount that is greater than either of the following two criteria is assigned a moderate risk level within the York Tier 3 Local Area, since there is no Planned Quantity of Water in the York Tier 3 Local Area:

- 20% of the existing estimated streamflow that is exceeded 80% of the time (Q_{p80}); or
- 20% of the existing estimated average monthly baseflow of the stream.

The first criterion can be used where the Q_{p80} values are estimated from gauged flows. The second criterion is more applicable to ungauged reaches of streams and was selected for use in this study because it is more compatible with the steady-state analyses completed for the risk assessment scenarios discussed.

While no specific thresholds are provided for the evaluation of impacts to warm water streams the impacts on these streams must still be evaluated. A decrease of 50% of the existing estimated monthly average baseflow of the stream was selected as a reasonable threshold for "unacceptable impacts" for the purpose of this study. This assumed that there is some groundwater discharge to warm water streams and that a measureable decrease in that amount could cause an unacceptable impact.

The methodology and thresholds for the evaluation of risks related to provincially significant wetlands were not specified in the *Technical Rules* other than that the municipal takings should not "result in a reduction to the flow or level of water that constitutes an unacceptable impact to other water uses”. An approach that identified wetlands subject to more than a 1 m drawdown in groundwater levels beneath that wetland was selected for two reasons:

1. Model representation: The complexity of wetland function, and model representation of wetlands, suggests that a simplified approach based on the change in the underlying aquifer water levels would be a direct and consistent means of assessment.
2. Understanding of natural seasonal fluctuations: The evaluation of water level fluctuations undertaken for the WHPA-Q1 assessment indicated that a 1 m seasonal fluctuation in groundwater levels is considered normal in the study area. Accordingly, an incremental drawdown threshold of 1 m was selected for wetland risk consideration.

MOECC clarified that these impacts to “other water uses” results in assigning in a moderate risk level to the Local Area as there is no Planned Demand within the Local Area. As such only future (not existing) water quantity threat activities are deemed significant within the Local Area.

Enumeration of Drinking Water Quantity Threats

Two broad categories of water quantity threats are identified in the MOECC *Technical Rules*, which are to be considered in assessing Drinking Water Threats:

1. Consumptive water demand; and
2. Reductions in recharge from land development.

Confirmation of Significant Groundwater Recharge Areas

The *Technical Rules* require that the SGRAs delineated during the Tier 1 and Tier 2 water budget processes (**Section 4.1.3**) must be reviewed based on the results of Tier 3 models. Accordingly, results from the integrated GSFLOW model were used in this analysis. As discussed in the model development report, the GSFLOW model takes into consideration topography, surficial geology, and how land cover (vegetative cover and imperviousness) affects groundwater recharge. The GSFLOW model has the added benefit of taking into consideration groundwater feedback, such as:

- Saturation-excess rejected recharge (i.e., where infiltration rates are limited by soil saturation, including when the water table is seasonally at or near surface, or where soil moisture is elevated due to unsaturated zone process feedback);
- Groundwater discharge feedback (i.e., where groundwater discharge to the soil zone can move downslope, or as overland runoff); and
- Routing of total flow such that leakage from the stream raises water levels in riparian or wetland areas to the point that recharge is prevented.

In summary, groundwater feedback occurs in complex three-dimensional processes, and only a fully integrated model can account for those mechanisms in the recharge estimate.

For this assessment, a separate analysis of SGRAs was made for the TRSPA watersheds, based on *Technical Rule 44(1)* and using the GSFLOW-estimated average recharge across the entire TRSPA jurisdiction (except Etobicoke Creek, which was outside the Tier 3 model domain) for a 30 year period (1983-2013). This use of a single value for all catchments is consistent with the methodology selected by TRSPA for their Tier 1 and Tier 2 studies.

Owing to the cell-based nature of the Tier 3 model and because the parameters that affect recharge are spatially variable, the map of estimated groundwater recharge is also spatially variable and shows relatively small parcels of land that are above the SGRA threshold, as shown on **Figure 4.4** in the next Chapter of this Assessment Report. It is understood that it will likely be difficult to develop workable policies for the management of small, isolated SGRA zones. However, to maintain consistency with the Tier 1 and 2 work, these small areas were maintained in the Tier 3 analysis.

TRCA staff interpreted Rule (45) (delineation of SGRAs) to exclude all parts of the watershed with Lake Ontario sourced drinking water supply during the Tier 1 and 2 analyses. Therefore, these same areas were clipped out of the Tier 3 model results.

3.9.3 Study Area and Model Domain

The York Tier 3 study was exceptional because of its geographical scope. In the early stages of the project, it became clear that the modelled drawdown cones of many different municipal systems intersected. Therefore, the model domain for the York Tier 3 study extended beyond the TRSPA jurisdiction, and includes 12 distinct watersheds from Lake Simcoe to Lake Ontario, as shown on **Figure 3.38**.

The model domain includes the following communities with municipal wells within the TRSPA:

- Caledon East and Palgrave in the Region of Peel;
- Nobleton, Kleinburg, King City, and Whitchurch-Stouffville in the Region of York; and
- Uxville in the Region of Durham.

In addition, the model domain includes the following communities with municipal wells outside of the TRSPA:

- Schomberg, Bradford, Ansorveldt, Holland Landing, Aurora, Newmarket, Ballantrae, and Mt. Albert in the Region of York; and
- Uxbridge in the Region of Durham.

3.9.4 Municipal Water Usage and Requirements

York Region and the Region of Durham operate well-based municipal drinking water systems within the York Tier 3 model domain. The Region of Peel operates wells in the model domain (Caledon East and Palgrave), but the subwatersheds containing these wells were not calculated to be stressed. Therefore, the Peel wells were included in the model, but were not evaluated as part of the stress assessment scenarios, except as “other uses”. The existing and committed extraction rates that were used for the York and Durham wells in the Tier 3 analysis are summarized in **Table 3.14**. Further details of this water use by municipality are provided below.

York Region Municipal Water Use

A long period of record is available for many of the York Region supply wells (see Earthfx, 2013). The records show that groundwater taking generally increased through the 1990’s, stabilized in the early 2000’s, and then declined significantly in 2008 due to an increase in the amount of Lake Ontario sourced water piped into York Region from Toronto and Peel regions. The years 2010 and 2011 were selected for quantifying existing demand as they are most representative of current and future groundwater takings. York Region operates 11 municipal wells in four towns within the TRSPA portion of the York Tier 3 Study Area (one additional well exists in Nobleton, but has not yet been placed in active service). Some of the permits have restrictions on the operations of individual wells along with restrictions on the maximum daily volumes that can be extracted. A summary of the wells and their associated water taking permits are provided in **Table 3.15**. This table also includes notes on the operating conditions listed in the permits.

Source: TRCA, 2014; DMTI Spatial, 2010; MNR, 2010.

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

Figure 3-38: York Tier 3 Water Budget Model Domain

Table 3-14: Simulated Average Municipal Pumping Rates within the TRSPA

Municipal Well	Existing Demand (m^3/d)	Existing plus Committed Demand (m^3/d)	Existing plus Committed plus Planned Demand (m^3/d)	Notes
King City PW3	359.7	359.7	359.7	No change
King City PW4	851.0	851.0	851.0	
Kleinburg PW3	627.8	627.8	627.8	No change
Kleinburg PW4	1,050.4	1,050.4	1,050.4	
Nobleton PW2	487.2	590.0	766.7	Future pumping allocated equally between old and new wells
Nobleton PW3	446.7	590.0	766.7	
Nobleton PW5	0	590.0	766.7	
Stouffville PW1	611.8	611.8	611.8	No change
Stouffville PW2	530.6	530.6	530.6	
Stouffville PW3	973.5	973.5	973.5	
Stouffville PW5	950.1	950.1	950.1	
Stouffville PW6	801.2	801.2	801.2	
Uxville MW1	43.8	115.8	115.8	Future usage increase distributed uniformly to both wells
Uxville MW2	1.6	4.1	4.1	

Table 3-15: Municipal Permit to Take Water Summary within the TRSPA

Municipal Well	MOECC PTTW No.	Permit Issued	Permit Expiry	Maximum Permitted Taking (L/min)	Maximum Permitted Taking (L/d)	Comment
King City PW3	8634-67HR9L	20-Dec-04	31-Jan-15	1,364	1,963,915	There are no conditions placed on this system. In 2011, King City was converted to a Lake Ontario supply. The wells will be retained for back-up purposes, however, and included in the risk scenario modeling.
King City PW4		20-Dec-04	31-Jan-15	1,818	2,618,554	
Kleinburg PW3	2411-789N8E	22-Jan-08	31-Jan-14	3,637	5,237,000	Kleinburg PW3 and 4 are located on the same site and are operated as a single source. Kleinburg will be serviced primarily through surface water in future, although the wells will be retained for back-up sources, and therefore included in the risk scenario modeling.
Kleinburg PW4		22-Jan-08	31-Jan-14			
Nobleton PW2	0747-7SXHU5	26-Jun-09	30-Jun-19	1,364	1,964,000	This permit will be amended; Nobleton PW 4 has been replaced by Nobleton PW 5. The Permit restricts the simultaneous operation of Nobleton PW 2 & 3.
Nobleton PW3		26-Jun-09	30-Jun-19	1,734	2,496,000	
Nobleton PW5	New well not listed in PTTW					
Stouffville PW1	3671-8P9NK5	12-Dec-11	31-Mar-17	2,046	2,946,240	No changes from the previous Permit (Ref. No. 5722-74LPXE). No operational restrictions. Future demand will be serviced from surface water supplies.
Stouffville PW2		12-Dec-11	31-Mar-17	2,046	2,946,240	
Stouffville PW3		12-Dec-11	31-Mar-17	2,046	2,946,240	
Stouffville PW5		12-Dec-11	31-Mar-17	1,590	2,289,600	
Stouffville PW6		12-Dec-11	31-Mar-17	2,160	3,110,400	
Uxville MW1	2835-8MXRAR	27-Oct-11	30-Sep-21	1,318	1,898,000	MW1 is the primary well, with MW2 serving as the backup. The permit governs total pumping from both wells.
Uxville MW2						

The existing water demand for York Region is included in **Table 3.16**. The York Region data provided in this table were obtained from Permits to Take Water, 2010 and 2011 pumping data, and the approved *Water and Wastewater Master Plan* (York Region, 2009), which summarizes future water allocation across York Region based upon approved growth projections through to 2031. Graphs of the water use over time with the measured and safe water levels are provided in **Appendix C3**.

Table 3.17 includes the committed demand for the municipal water systems within the Local Area. The values shown are the difference between the existing demand and the 2016 groundwater taking projections in the approved *Water and Wastewater Master Plan* as per **Table 3.16**. These values reflect anticipated growth that is contained within the York Region Official Plan and plans for the local municipalities. The calculated safe additional drawdown values are presented in **Table 3.18**.

A number of communities in the York Tier 3 study area have no committed demand, including Kleinburg, King City, and Stouffville. Although some future growth is anticipated in Kleinburg, King City and Stouffville through 2016, the additional population will be serviced through surface water supplies piped from Lake Ontario.

The system serving Stouffville is a blended system with mixed surface water and groundwater. The system in King City was converted to Lake Ontario supply in July 2011. The system in Kleinburg is being converted to surface water (Lake Ontario) supply and groundwater will cease to be the primary supply. The wells in King City and Kleinburg will be maintained as back-up supplies in the event of a surface water supply disruption, such as occurred in 2009, where lake-based supply from Peel was interrupted for a period of several months. Reverting to existing groundwater supplies minimized the disruption to local residents as the surface water pipeline was repaired. To similarly avoid interruptions in service to residents from surface water delivery issues in future, groundwater supplies will be retained for back-up wherever lake-based supplies are introduced. Taking from the wells were included in the Tier 3 risk scenarios to be conservative.

Region of Durham Municipal Water Use

Twelve municipal supply systems are operating in Durham Region. Of these, the two municipal wells (MW1 and MW2) that supply potable water to the Uxbridge Industrial Park (Uxville) are within a watershed identified as potentially stressed at the Tier 1/Tier 2 level. The system is classified as a “Small Drinking Water System”. The wells are operated under PTTW 2835-8MXRAR which expires in September 2021 with maximum permitted rate of 1,898 m^3/d.

The Uxbridge Industrial Park consists of 29 serviced lots in Phase 1 and 37 serviced lots in Phase 2 (total 66 lots) spread over 92.1 ha. Existing demand values, presented in **Table 3.16**, reflect average daily extraction from each well for the system for 2010 and 2011 and were equal to 43.8 m^3/d for MW1 and 1.55 m^3/d for MW2, or a total of 45.4 m^3/d. These years were selected to be consistent with the values used for York Region. The data used in the table were obtained from Water Taking Reporting System pumping data and information supplied by Durham Region.

Information used to determine allocated water in **Table 3.17** was provided by Durham Region (pers. comm. B. Golas, April 9, 2013). Pumping is triggered based on water levels in the on-site 1,134 m^3 reservoir. The pumping rates are relatively small and show seasonal variation but no longer-term trend, as shown on the graphs in **Appendix C3**. One short-term spike in pumping was noted in November 2008.

Wells within the Town of Uxbridge, located about 13 km northeast of Uxville, were also represented in the York Tier 3 integrated surface water/groundwater model but are not located in a watershed identified as potentially stressed at the Tier 1/Tier 2 level and are not within the TRSPA jurisdiction.

Table 3-16: Current and Future Municipal Water Use (TRSPA)

Municipal Well	Well Maximum Permitted Extraction (m^3/d)	Water System Maximum Permitted Extraction (m^3/d)	Existing Demand (2010-2011)		2016 and 2031 Master Plan		Water Sources for Demand Increases	Notes
			Well Annual Average (m^3/d)	System Annual Average (m^3/d)	2016 Water System Demand (m^3/d)	2031 Water System Demand (m^3/d)		
King City PW3	1,963.9	4,582.5	359.7	1,210.6	0.0	0.0	Lake Ontario	King City water supply was converted from a groundwater to a Lake Ontario supply in 2011. The wells will be retained for back-up / redundancy purposes only.
King City PW4	2,618.6		851.0					
Kleinburg PW3	5,237.0	6,187.4	627.8	1,680.2	0.0	0.0	Lake Ontario	Kleinburg water supply is being converted from a groundwater to a Lake Ontario supply.
Kleinburg PW4			1,050.4					
Nobleton PW2	1,964.0	6,956.0	487.2	933.9	1,770.0	2,300.0	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Nobleton PW3	2,496.0		446.7					
Nobleton PW5	2,496.0		Not in service					
Stouffville PW1	2,946.2	14,238.7	611.8	3,867.2	3,867.2	3,867.2	Lake Ontario	Stouffville is a blended groundwater and surface water system. Demand increases in Stouffville are to be accommodated using Lake Ontario water. Current groundwater takings are to be maintained in the future.
Stouffville PW2	2,946.2		530.6					
Stouffville PW3	2,946.2		973.5					
Stouffville PW5	2,289.6		950.1					
Stouffville PW6	3,110.4		801.2					
Uxville MW-1	1,898.0	1,898.0	43.8	45.4	1,898.0	1,898.0	Not applicable	Combined pumping from MW-1 and MW-2 cannot exceed 1,898 m^3/d
Uxville MW-2			1.6					

Notes:

Planned average demand for 2031 is based on population, employment data, and water consumption unit rates (252 L/capita/d and 225 L/d for employment use per the 2008 Unit Rates study completed for the master plan). York Region Master Plan average day demand is the PTTW maximum permitted taking divided by the peaking factor. The demand data presented are annual average day values. King City existing demand based on 2010 data - Community was converted to Lake Ontario supply July 2011.

Table 3-17: Municipal Allocated Extraction Rates

Municipal Well	Water Demand Water System Classification	System Max. Permitted Pumping (m^3/d)	Existing Demand (m^3/d)	Committed Demand (m^3/d)	Planned Demand (m^3/d)	Allocated Quantity of Water (m^3/d)	Notes
King City PW3	No Committed and No Planned	4,582.5	1,210.6	0.0	0.0	1,210.6	King City water supply is being converted from a groundwater to a Lake Ontario supply.
King City PW4							
Kleinburg PW3	No Committed and No Planned	6,187.4	1,680.2	0.0	0.0	1,680.2	Kleinburg water supply is being converted from a groundwater to a Lake Ontario supply.
Kleinburg PW4							
Nobleton PW2	Committed and Planned	6,956.0	933.9	836.1	530.0	2,300.0	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Nobleton PW3							
Nobleton PW5							
Stouffville PW1	No Committed and No Planned	14,238.7	3,867.2	0.0	0.0	3,867.2	Stouffville is a blended groundwater and surface water system. Demand increases in Stouffville are to be accommodated using Lake Ontario water. Current groundwater takings are to be maintained in the future.
Stouffville PW2							
Stouffville PW3							
Stouffville PW5							
Stouffville PW6							
Uxville MW-1 *	Committed and No Planned	1,898.0	43.8	74.6	0.0	120.0	Combined pumping from MW-1 and MW-2 cannot exceed 1,898 m^3/d. * Uxville MW-1 is used as the main supply well in this system.
Uxville MW-2			1.6				

Notes:

Values presented are annual daily averages. Existing demand calculated as the average daily demand for 2010 and 2011. Planned average demand for 2031 is based on population, employment data and per capita water consumption unit rates (252 L/capita/d and 225 L/d for employment use per the 2008 Unit Rates study completed for the master plan). King City existing demand based on 2010 data - Community was converted to Lake Ontario supply July 2011.

Table 3-18: Safe Additional Drawdown for Municipal Wells (TRSPA)

Municipal Well	Safe Water Level (mASL)		Existing Water Level (mASL)		Safe Additional Drawdown (m)	
	Lowest Pump Intake	Top of Aquifer	Average In-well Level	Average Aquifer Level	In-well Drawdown	Aquifer Drawdown
Stouffville PW1	184.16	189.34	230.10	229.77	45.94	**40.43**
Stouffville PW2	182.04	186.31	233.00	229.77	50.96	**43.47**
Stouffville PW3	266.74	270.40	279.63	282.12	12.89	**11.73**
Stouffville PW5	301.91	303.43	305.75	306.68	3.84	3.25
Stouffville PW6 [1]	291.26	302.85	299.50	303.11	8.24	0.26
Uxville MW-1 *	293.9	291.7	315.3	320.3	**21.5**	28.6
Uxville MW-2	291.1	307.5	319.9	320.3	22.5	**12.8**

Notes:

Safe additional drawdown for each well emphasized in bold. Corresponds to the more conservative value (smaller safe additional drawdown value) provided by considering the in-well drawdown and the aquifer drawdown.

[1] Stouffville PW#6 in-well safe additional drawdown used because the Lower Oak Ridges Aquifer Complex behaves as an un-/semi-confined aquifer in this area

The Uxville water supply system does not provide water to domestic residents. The system is located within the Oak Ridge Moraine planning area and no further rural residential development is permitted. There is no official plan designation for Uxville development in the future, and population growth estimates for this area are not considered in the Durham Official Plan or in the water use master plan. Therefore, Durham Region does not plan to increase the quantity of water beyond that required to service the industrial park. At most, infilling of the existing industrial park (100% development) would increase demand to approximately 120 m^3/d. As indicated in **Table 3.17**, the committed demand (based on the increase from 45.4 m^3/d to 120 m^3/d) is 74.6 m^3/d and there is no planned demand for this system. The calculated safe additional drawdown values are presented in **Table 3.17**.

Tolerance

The Tier 3 assessment also considers a municipal water system's tolerance to risk. The *Technical Rules* state that "tolerance is evaluated to determine whether an existing system is capable of meeting peak demand". *Technical Rule 100* states:

> *For the purposes of evaluating the groundwater scenarios C and D in Table 4B, a tolerance level shall be assigned to the existing type I, II or III system which the local area relates that is the subject of evaluation in accordance with the following:*
>
> - *A tolerance level of high if the existing system is capable of meeting peak demand during all assessment periods; and*
> - *A tolerance level of low if sub-rule (1) does not apply to the existing system.*

The PTTW for the Yonge Street wellfield allows for increased takings in peak demand periods (up to 67,200 m^3/d on average for May through August and up to 87,656 m^3/d on any given day). However, the yearly average production is still limited to 42,000 m^3/d as simulated in the model for Scenario C.

Scenarios D and H used the actual takings or scaled takings that reflect peak pumping and show that the wells are capable of meeting peak demands even under extreme drought conditions. The tolerance of the York Region wells are generally high because of the ability to reallocate pumping to other nearby wells and/or wellfields that have additional available drawdown. Finally, the ability for York Region to supplement groundwater takings in the Yonge Street wellfields and the Stouffville wellfield with surface water supplies from Lake Ontario provides York Region with a high degree of tolerance under any water taking and drought scenario.

The tolerance of the Uxville system is high, given the low water use (less than 10% of the PTTW) and high well capacity.

3.9.5 Other Water Uses and Requirements

Other Permitted Groundwater Takings

A total of 272 permitted groundwater and combined groundwater/surface water takings are represented in the model, as listed in the Model Development and Calibration Report. Municipal wells located outside of the assessment watersheds (e.g., wells for the towns of Uxbridge, Palgrave, and Caledon East) were also simulated in the model. These municipal wells and the other permitted takings were simulated at their estimated consumptive rate. The effects of future increases in other water takings were not considered in the risk assessment scenario analyses.

Non-permitted water use was also compiled and 286 additional wells in the TRCA watersheds were considered during model development and calibration. Non-permitted use includes wells pumping less than 50 m^3/d mainly for agricultural use and livestock watering. These takings were identified based on field surveys by the TRCA staff. Takings from non-permitted and domestic wells were not represented in the risk assessment scenario analyses because the takings are small and assumed to be non-consumptive (the water is generally returned to the shallow aquifer).

Surface Water Takings

As outlined in the Model Development and Calibration Report (Earthfx 2013b), 432 surface water takings were identified and incorporated into the model (including agricultural, commercial and industrial water takings). The total surface water consumptive use was estimated at 47,120,000 m^3/yr. Agricultural demand represents the largest surface water use at 50% of permitted takings. Golf course takings are significant at 21%. A number of surface water permits (20) for wildlife conservation have been issued by the MOECC. These were assumed to have no consumptive use and were not represented in the model.

Estimates of the available drawdown were made based on the static water level at the time of drilling and the top of well screen (as reported in the WWIS or estimated where the data were not available). Data on available drawdown in the wells under pumping conditions were not available. As noted earlier, proposed revisions to the *Technical Rules* state that if the allocated demand at the municipal wells does not exceed the current permitted amount, then only a moderate risk level can be assigned to the Local Area.

Wastewater Assimilation

Wastewater generated in Kleinburg and Nobleton is collected and treated at individual water pollution control plants (WPCP), then discharged into local watercourses where it eventually flows into Lake Ontario. Wastewater generated in Aurora, King City, Richmond Hill, Vaughan, Markham, and Stouffville is collected at the York-Durham Sewage System which is a large trunk sewer that runs to the Duffins Creek WPCP in Ajax. This wastewater is treated and discharged directly into Lake Ontario. In addition, a small portion of the wastewater generated in Vaughan is treated in Peel Region.

None of the Certificates of Approval for these systems specify a condition relating to the flow rates of receiving watercourses. The issue of assimilative capacity is addressed through specifications of the quality of the effluent discharged, which is closely monitored and reported to the MOECC on a regular basis. Impacts of future pumping on wastewater assimilation were therefore not considered further in the Tier 3 analysis.

Navigation Requirements

No specific water use requirements for navigation have been identified within the TRSPA. Therefore, no impacts are expected.

Recreational Requirements

The Tier 3 analysis included a large number of *artesian* wells and groundwater-fed ponds in the Lemonville area (northwest of Stouffville) with water use purpose classified as "recreational/aesthetic". However, no impacts were identified to these ponds through the Tier 3 analysis.

Artesian: groundwater under sufficient pressure to rise above the top of the aquifer containing it**.**

Aquatic Habitat Requirements

The Oak Ridges Moraine bisects the Local Area, with half of the watercourses arising and flowing north towards Georgian Bay, and the other half arising and flowing south to Lake Ontario. Groundwater discharge creates significant stretches of cold-water habitat in the headwater areas of the TRSPA, as was discussed in **Section 2.2.2** and shown on **Figure 2.5**. Potential impacts to these aquatic habitat requirements were assessed through the various scenarios described in **Section 3.9.2**, and the results are provided in **Section 3.9.10**.

Provincially Significant Wetlands

There are a large number of wetlands and wetland complexes within the study area, most of them located in the hummocky topography of the Oak Ridges Moraine and in the low lying areas in the northeastern portion of the study area near Lake Simcoe. The wetlands within the TRSPA jurisdiction were shown on **Figure 2.4**. Potential impacts to these wetlands are discussed in **Section 3.9.10**.

3.9.6 Future Land Use

For the future condition risk assessment scenarios, the GSFLOW/PRMS cell-based land use input parameters were modified to include locally representative levels of urbanization within the proposed development areas (**Figure 3.39**). Under current conditions 32% of the land use is designated as urbanized in the York Tier 3 model area, and within that area the average percent imperviousness is 65%. For the future land development scenarios, the land use model inputs were modified so that the imperviousness was a minimum of 65% within the future urban settlement boundary areas. The increase in imperviousness was only applied to cells where this resulted in an increase over the existing level. This new input condition was used for all future land development scenarios.

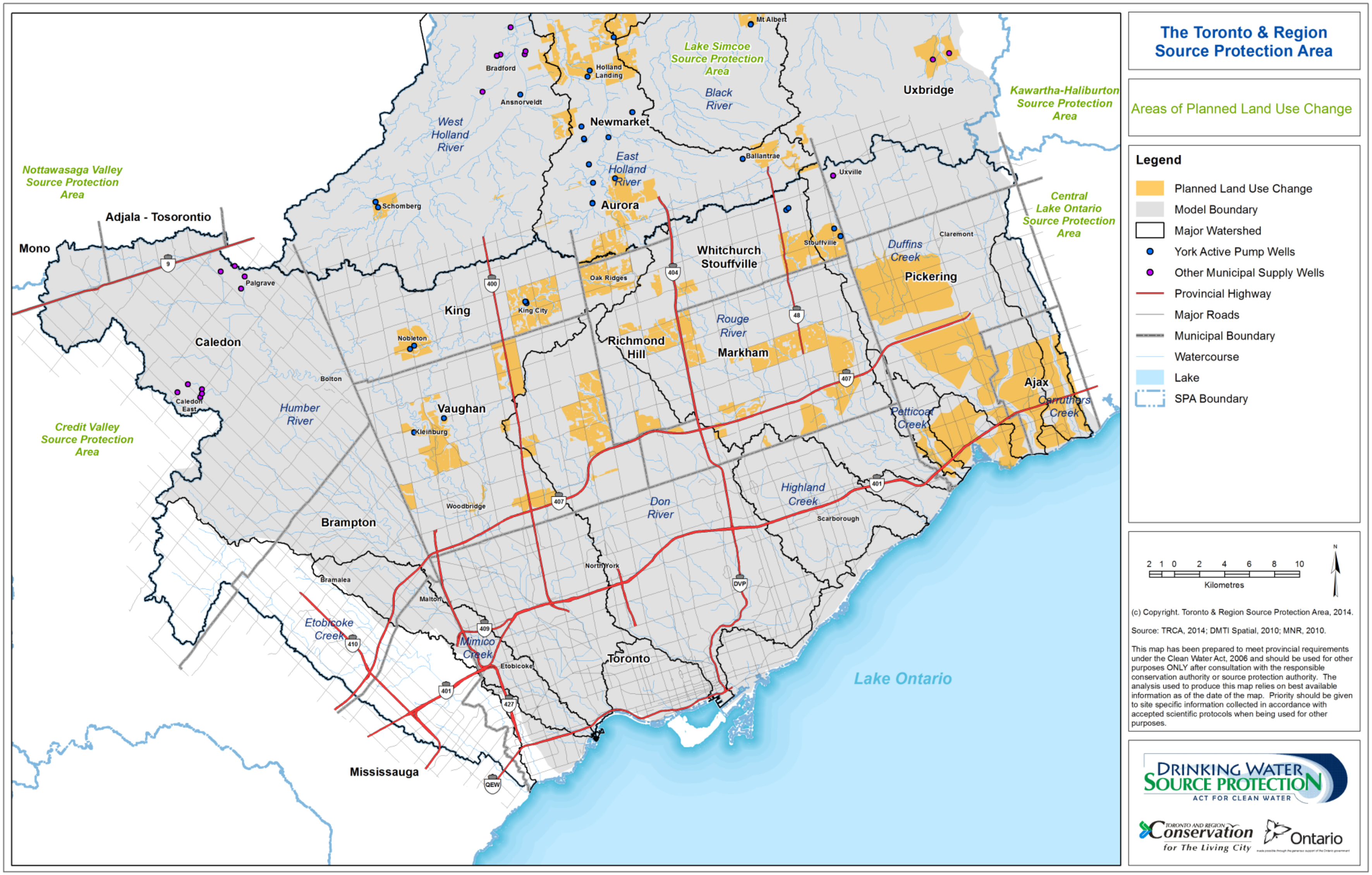


Figure 3-39: Areas of Planned Land Use Change

3.9.7 Model Development and Calibration

The details regarding the model development and calibration process are presented in the foundation report prepared by Earthfx Inc. (Earthfx, 2013). An excerpt of the model development/calibration approach is provided below.

Calibration targets for the Tier 3 GSLOW model included flows recorded at streamflow gauges, and continuous water-level data from PGMN and York Region monitoring wells. Other secondary sources included MOECC WWIS static water levels and wetland mapping. The integrated modelling approach has the benefit that the model must be calibrated to both groundwater and surface water data simultaneously; thus reducing the level of uncertainty typically associated with separate models that make simplifying assumptions regarding the processes not explicitly represented. The integrated calibration also means that artificial or empirical data processing techniques such as baseflow separation are not needed because the model is calibrated to total measured flow at the stream gauges.

To facilitate model construction and evaluation, GSFLOW's sub-models were run independently during calibration, scenario or sensitivity analysis. For example, the PRMS model was first used to provide an estimate of long-term average recharge. This recharge estimate was then used to develop an initial long-term steady-state groundwater flow model calibration. Once the long-term average sub-models were developed, the final integrated calibration was completed and tested against the more detailed transient water levels and streamflow discharge measurements.

All municipal and non-municipal groundwater takings were represented in the model on a daily basis (rather than monthly) using reported information and consumptive use factors. The surface water model accounted for all surface takings in the study area. The results of model calibration and the insights gained were presented in detail in Earthfx 2013b. The replicated the normal seasonal variation of 1 to 2 m in the Oak Ridges Aquifer Complex, Thorncliffe Aquifer, and Scarborough Aquifer.

3.9.8 Water Budget Parameter Refinement

The Tier 3 water budget resulted in updates to the estimates provided in the Tier 1 and 2 water budgets. As noted, traditional definitions of the surface water and groundwater components of the water budget are somewhat limited, because water moves between those systems in complex and highly varied pathways. In addition, some takings, such as takings from ponds and streams, are now specifically simulated in the model and no longer can be classified as either traditional groundwater or surface water takings. **Table 3.19, Table 3.20,** and **Table 3.21** present the groundwater budget derived from the groundwater submodel for the TRSPA subwatersheds within the Local Area. The results are shown spatially on **Figure 3.40** to **Figure 3.43**. These figures were updated in 2018 to reflect output from a 30-year climate normal simulation period using the GSFLOW model (1983-2003).

The integrated nature of this model produces water budget results that require a slightly different interpretation when compared to uncoupled models. While mass is conserved within the model, water can discharge and re-infiltrate multiple times through the model. For example, groundwater can discharge to a stream reach, flow downstream in the channel, and then re-infiltrate into the groundwater system through the streambed, lake-bottom or wetland. Total inflow into the groundwater model cannot therefore be taken as only net recharge plus lateral groundwater inflows because leakage from streams and wetlands must also be considered. As explained above, stream leakage to the groundwater system may be mostly supported by groundwater discharge in upstream areas (especially in the catchment headwaters).

Table 3-19: Groundwater Sub-model Budget (TRSPA)

Inflows and Outflow	Humber		Don		Rouge		Duffins	
	(m^3/d)	(mm/yr)	(m^3/d)	(mm/yr)	(m^3/d)	(mm/yr)	(m^3/d)	(mm/yr)
Inflow								
Recharge in	298,000	120	85,900	89	93,800	102	123,000	159
Lateral inflow	86,500	35	88,300	91	70,200	76	79,200	102
Constant head	2,000	1	20	0	0	0	530	1
Leakage from surface features	1,960	1	800	1	937	1	418	1
Total Inflow	**388,000**	**156**	**175,000**	***181***	**165,000**	***179***	**203,000**	***263***
Outflow								
Lateral outflow	84,800	34	75,300	78	64,300	70	53,500	69
Constant head	4,640	2	781	1	0	0	48	0
Well pumping	9,020	4	6,530	7	4,680	5	7,880	10
Leakage to surface features	290,000	117	92,700	96	96,000	104	141,000	183
Total Outflow	**388,000**	**156**	**175,000**	***182***	**165,000**	***179***	**203,000**	***262***

Note:

Values may be subject to round-off error.

Table 3-20: Groundwater Sub-model Budget by Subwatershed (m^3/day)

Inflows and Outflow* (m^3/d)	**Humber Subwatersheds**					**Don Subwatersheds**			**Rouge Subwatersheds**			**Duffins Subwatersheds**		
	HU05	**HU06**	**HU07**	**HU08**	**HU09**	**DO05**	**DO06**	**DO07**	**RO02**	**RO05**	**RO06**	**DU04**	**DU05**	**DU06**
Inflow														
Recharge in	25,200	27,700	47,100	14,000	23,000	16,200	19,500	10,400	35,100	10,900	8,150	32,100	26,300	16,700
Lateral inflow	38,700	61,700	27,500	14,400	13,100	56,000	50,500	49,700	51,600	27,200	28,600	52,500	39,800	31,600
Constant head	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leakage: surface features	468	106	95	15	40	20	46	26	271	24	20	27	38	42
Total Inflow	**64,300**	**89,500**	**74,700**	**28,400**	**36,100**	**72,200**	**70,000**	**60,100**	**87,000**	**38,100**	**36,800**	**84,600**	**66,200**	**48,300**
Outflow														
Lateral outflow	18,400	39,500	68,900	25,700	22,500	67,000	43,500	50,600	51,100	30,200	31,000	38,400	53,100	37,700
Constant head	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well pumping	2,400	203	1,400	1,150	156	549	4,710	478	3,580	164	159	2,790	1,390	2,900
Leakage: surface features	43,600	49,800	4,320	1,550	13,400	4,680	22,100	8,970	32,300	7,770	5,580	43,400	11,700	8,030
Total Outflow	**64,300**	**89,500**	**74,700**	**28,400**	**36,100**	**72,200**	**70,300**	**60,100**	**87,000**	**38,100**	**36,800**	**84,600**	**66,200**	**48,600**

Note:

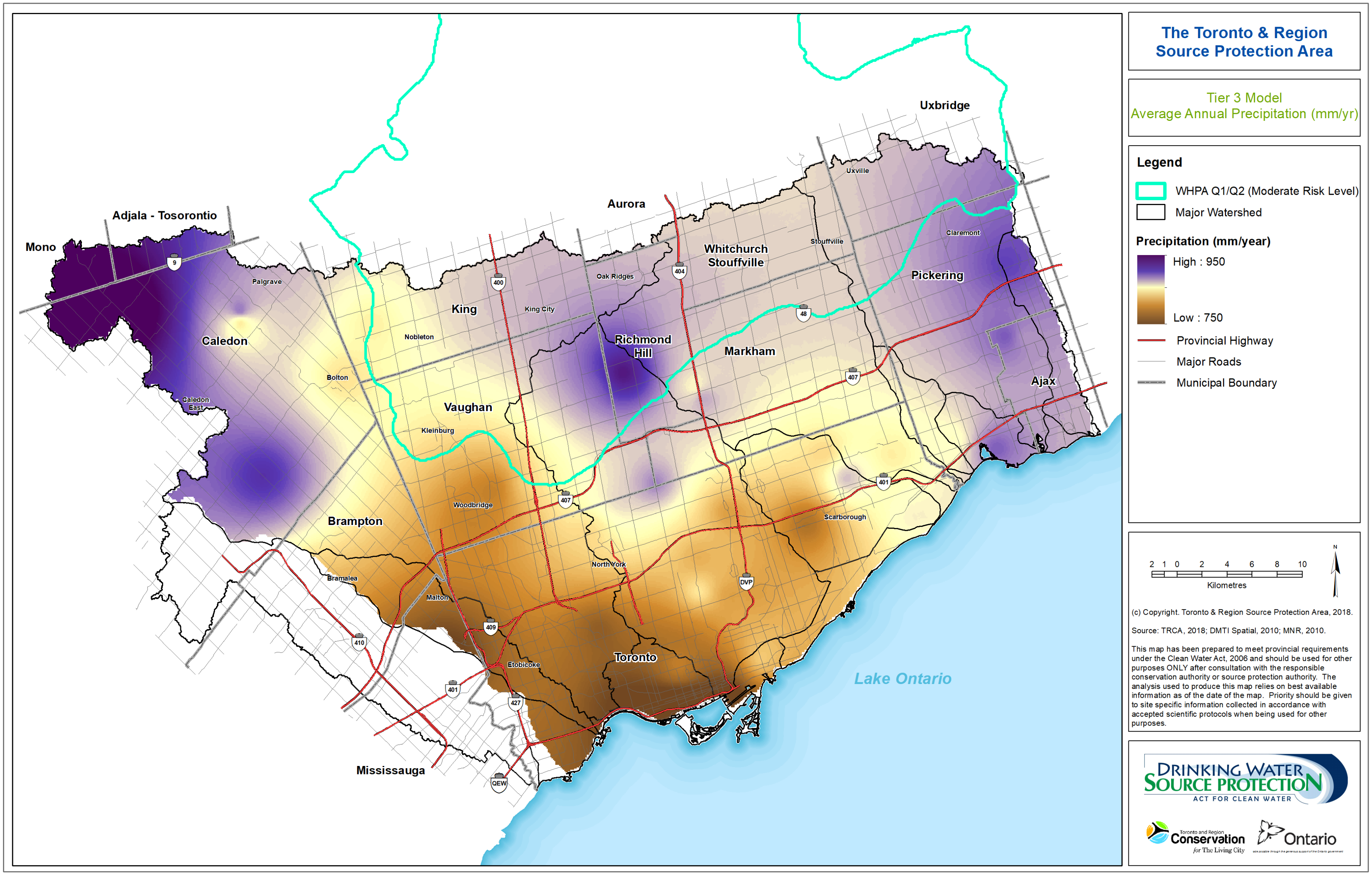
Values may be subject to round-off error.

Table 3-21: Groundwater Sub-model Budget by Subwatershed (mm/yr)

Inflows and Outflow* (m^3/d)	Humber Subwatersheds					Don Subwatersheds			Rouge Subwatersheds			Duffins Subwatersheds		
	HU05	**HU06**	**HU07**	**HU08**	**HU09**	**DO05**	**DO06**	**DO07**	**RO02**	**RO05**	**RO06**	**DU04**	**DU05**	**DU06**
Inflow														
Recharge in	100	141	184	165	130	102	112	91	112	100	97	191	160	155
Lateral inflow	153	315	107	170	74	352	291	436	165	250	341	313	242	292
Constant head	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leakage: surface features	2	1	0	0	0	0	0	0	1	0	0	0	0	0
Total Inflow	**254**	**457**	**291**	**335**	**203**	**454**	**403**	**527**	**278**	**350**	**439**	**504**	**403**	**447**
Outflow														
Lateral outflow	73	202	269	303	127	421	251	444	163	277	370	229	323	349
Constant head	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well pumping	9	1	5	14	1	3	27	4	11	2	2	17	8	27
Leakage: surface features	172	254	17	18	76	29	127	79	103	71	67	259	71	74
Total Outflow	**254**	**457**	**291**	**335**	**203**	**454**	**405**	**527**	**278**	**350**	**439**	**504**	**403**	**450**

Note:

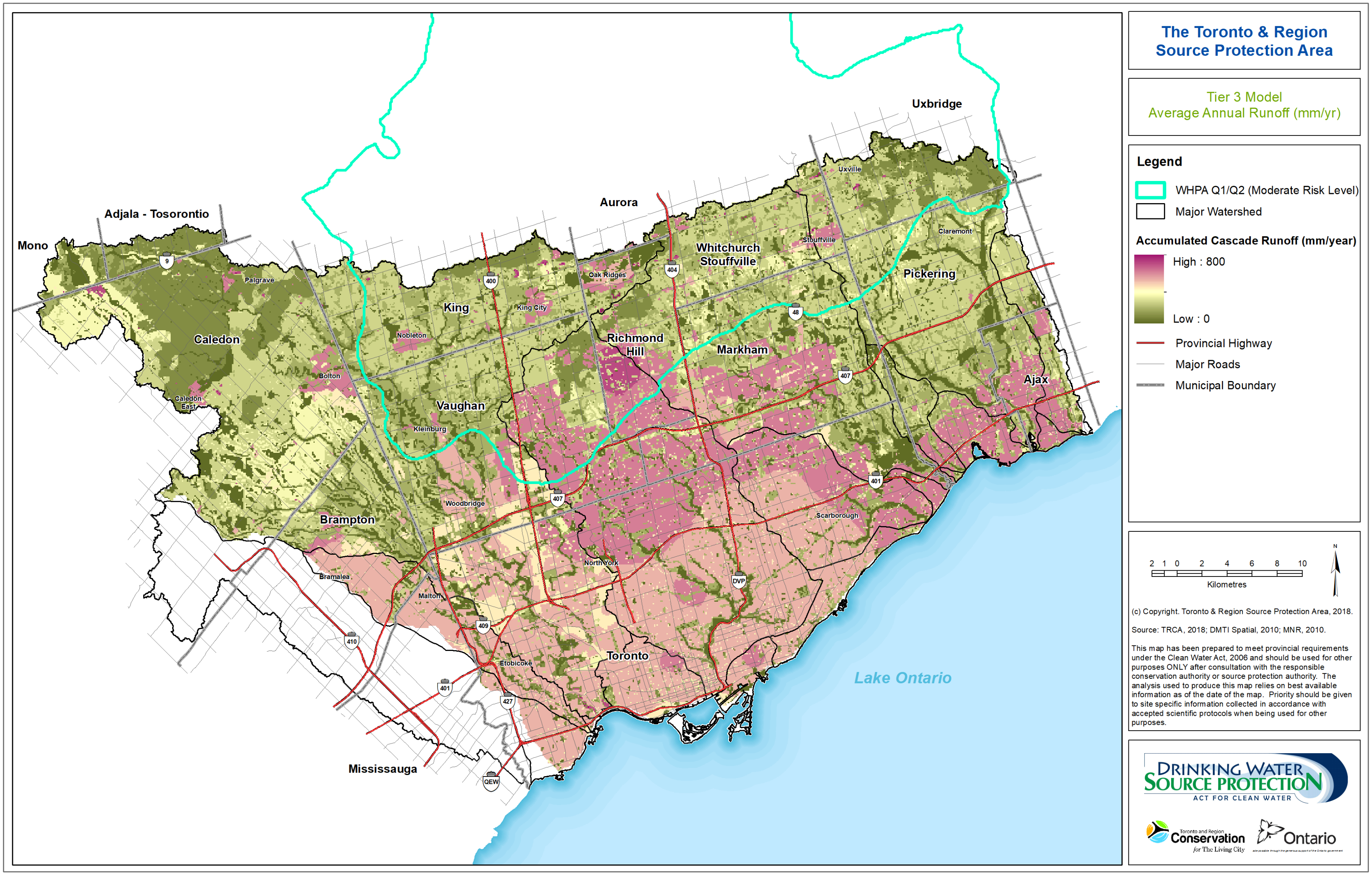
Values may be subject to round-off error.



Source: TRCA, 2018; DMTI Spatial, 2010; MNR, 2010.

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

Figure 3-40: Tier 3 Model - Average Annual Precipitation (mm/yr)



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Source: TRCA, 2018; DMTI Spatial, 2010; MNR, 2010.

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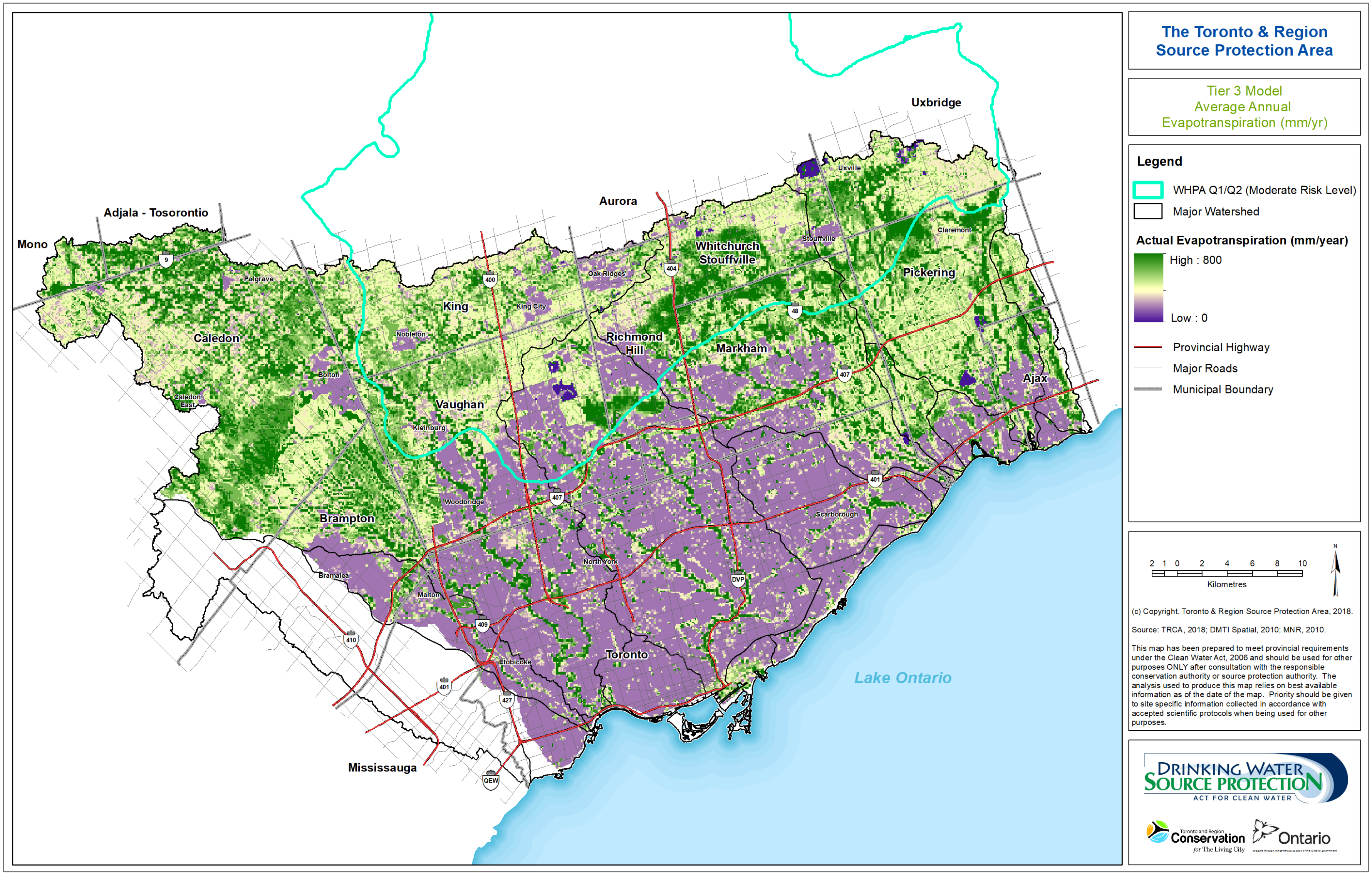
Figure 3-41: Tier 3 Model - Average Annual Runoff (mm/yr)



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Source: TRCA, 2018; DMTI Spatial, 2010; MNR, 2010.

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Figure 3-42: Tier 3 Model - Average Annual Evapotranspiration (mm/yr)

(c) Copyright. Toronto & Region Source Protection Area, 2018.

Source: TRCA, 2018; DMTI Spatial, 2010; MNR, 2010.

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Figure 3-43: Tier 3 Model - Average Annual Recharge (mm/yr)

3.9.9 Delineation of Vulnerable Areas for Water Quantity

The WHPA-Q1 was delineated by determining the change in simulated heads within the production aquifers between the following two model scenarios:

- Steady-state baseline model using existing land use and no municipal or non-municipal pumping to determine “pre-development” conditions; and
- Steady-state model using existing land use and allocated demand rates for municipal pumping and consumptive use rates for all other water uses.

Municipal pumping wells are typically completed in one of the three major aquifers (the Lower Oak Ridges Aquifer Complex, Thorncliffe Aquifer/Tunnel Channel Sediments, and the Scarborurgh Aquifer). In delineating the WHPA-Q1 area, the cones of influence for the municipal wells within each aquifer was calculated and compared. To be conservative, the furthest extent of the cone of influence in each aquifer was considered when delineating the final WHPA-Q1. The cones of influence for each of the aquifers were superimposed to delineate the final WHPA-Q1 area shown on **Figure 3.44**. This WHPA-Q1 area covers approximately a quarter of the model domain, extending from Richmond Hill/Markham in the south to north of Queensville in the north and from Maple in the west to beyond Uxbridge in the east. For clarity, a second map showing the extent of the WHPA-Q1 within the TRSPA is provided as **Figure 3.45**.

As mentioned in **Section 3.9.6**, future land use changes were considered in terms of potential recharge reduction for each municipality in the study area. According to the Official Plans, proposed changes to land use include infilling of both high and low intensity urbanized land. Only those areas with change in land use that straddle or are outside of the WHPA-Q1 boundary were considered in delineating the WHPA-Q2. It should be noted that the cumulative effect of all proposed land use changes were considered in risk assessment Scenarios G(1), G(3), H(1), and (H3).

Inputs to the PRMS sub-model were adjusted to account for increased surface imperviousness and changes in vegetative cover associated with urbanization of rural land. In accordance with the MNRF Water Budget Guide (MNR, 2010), no best management practices to enhance recharge and manage stormwater (e.g., low impact development strategies (LIDS)) were considered in the simulations. A future annual average groundwater recharge rate was determined through a 20-year PRMS simulation and applied to the steady-state groundwater model.

Simulated heads under the WHPA-Q2 simulation were subtracted from simulated heads generated in the WHPA-Q1 simulation. The additional drawdowns in the Lower did not intersect the Stouffville municipal pumping wells (the nearest municipal wells completed in the Lower Oak Ridges Aquifer Complex) and, therefore, future land use change has no “measurable” impact on the municipal wells. Smaller areas of drawdown were obtained in the Thorncliffe Aquifer and Scarborough Aquifer and did not impact any municipal wells.

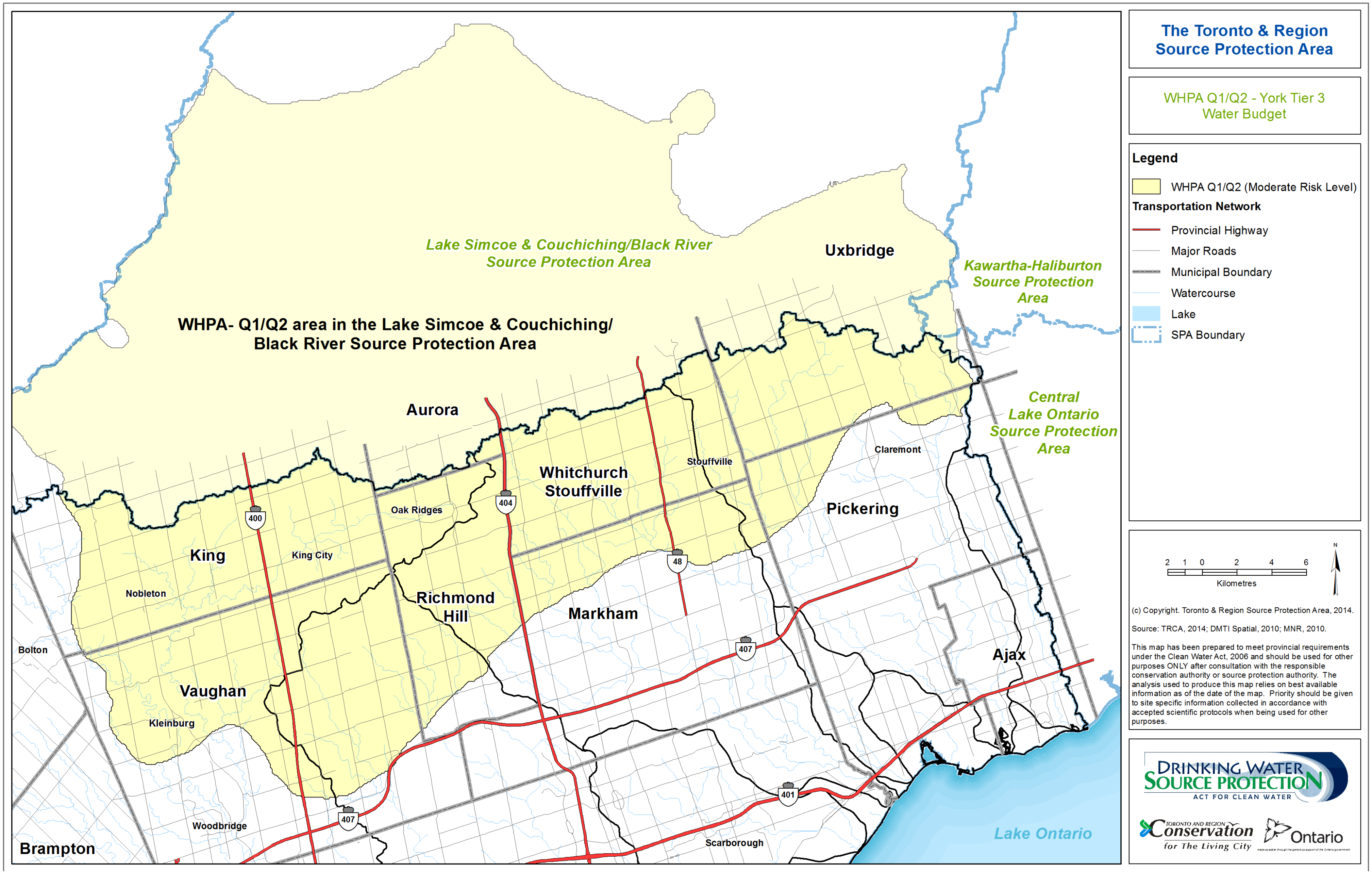


Figure 3-44: WHPA-Q1/ Q2 York Tier 3 Water Budget

Source: TRCA, 2014; DMTI Spatial, 2010; MNR, 2010.

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

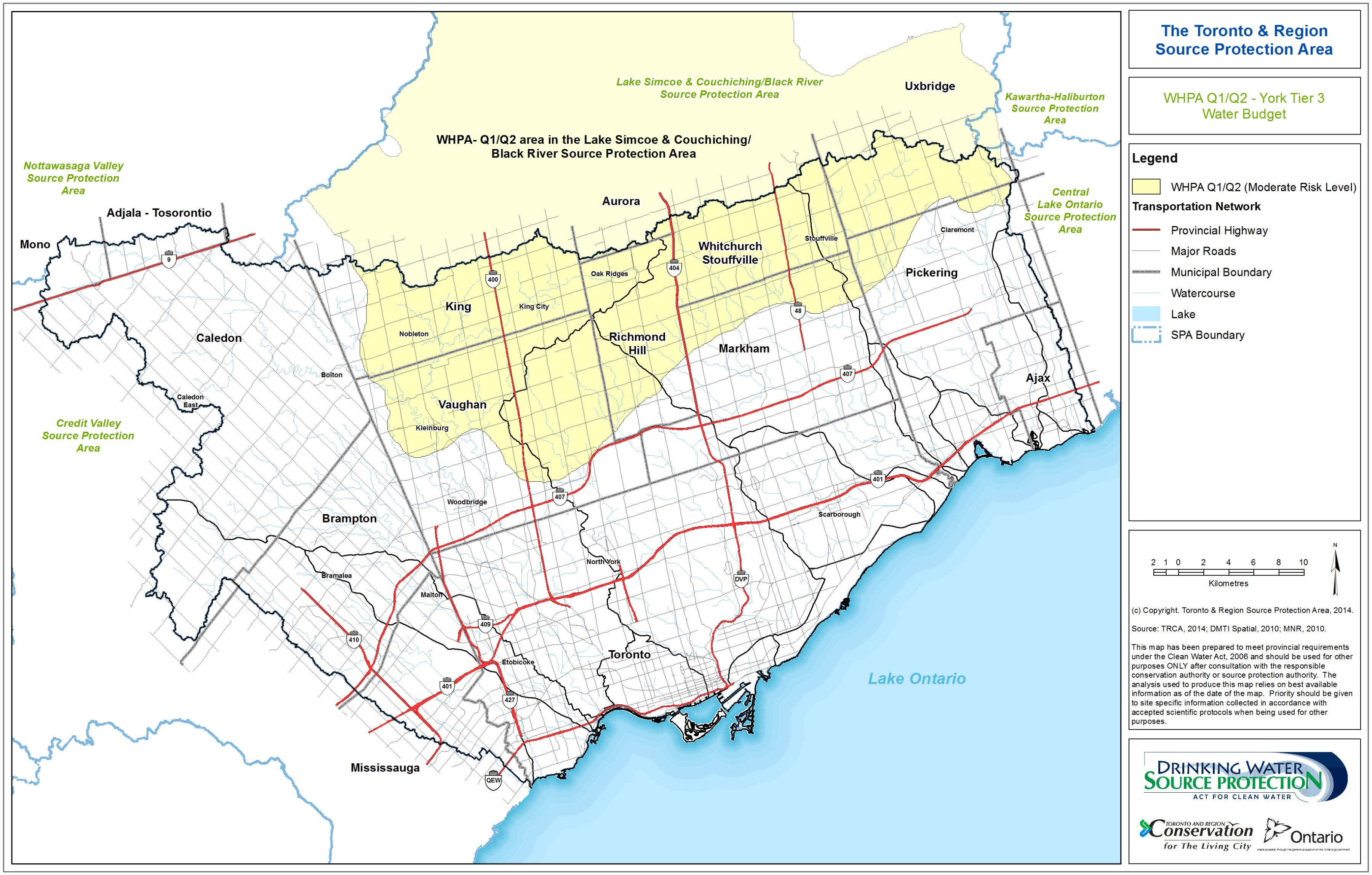


Figure 3-45: WHPA-Q1/Q2 York Tier 3 Water Budget TRSPA Watersheds

The area of predicted drawdown near the Kleinburg municipal water supply wells (south of Nobleton) straddled the WHPA-Q1, but the WHPA-Q1 was not expanded to include this drawdown for two reasons: first, the Kleinburg wells are not in a stressed watershed, and second, the Kleinburg wells were completed in the deeper Thorncliffe Aquifer and Scarborough Aquifer, which did not show a measureable drawdown from the proposed developments in this area.

The results of the WHPA-Q2 assessment confirmed that the proposed future land uses that straddle or are located outside of the WHPA-Q1 area do not produce a significant impact on heads at the municipal pumping wells. The WHPA-Q2 area is therefore coincident with the WHPA-Q1 area **Figure 3.45**.

3.9.10 Risk Assessment Scenario Results

The results of the risk assessment scenarios, tabulated in **Table 3.22** and **Table 3.23** have also been added to the well system characterization graphs included in **Appendix C3**. On each graph, the Risk Scenario Minimum Simulated Water Level is shown as a thick red line. The Safe Water Level threshold is shown in black. The Risk Scenario Minimum Simulated Water Level is above the Safe Water Level for all municipal wells.

York Region has considerable operational flexibility in allocating demand between individual wells and even between nearby wellfields. In addition to multi-well wellfield limits, system-wide permits covering the Yonge Street Aquifer allow pumping to be re-allocated between wellfields. Model test simulations indicated that the shallow wells in Stouffville are relatively more drought sensitive. York Region staff have indicated that pumping at these wells would be shifted to deeper wells under drought conditions. Accordingly, 40% of the daily takings at Stouffville PW5 and PW6 were re-allocated to the deeper wells PW1 and PW2 to reflect operations under drought conditions. It is important to note that, under these Scenario D drought re-allocation rates, the total combined takings for Stouffville reflected the actual 2010-2011 Study Period totals.

The model simulations proceeded as follows:

1. Step 1: The first iteration of the GSFLOW simulation is a steady state run identical to the Scenario C conditions (long term average recharge and water takings). This initializes the water levels in the aquifers.
2. Step 2: After this first iteration, two years of average transient conditions (October 1, 1954 to October 1, 1956) are then simulated to set up antecedent soil and unsaturated zone conditions, groundwater feedback and groundwater/surface water interaction processes in the fully-integrated GSFLOW model. During this two year period all municipal wellfields are pumped at the average daily (2010-2011 Study Period) operational rates.
3. Step 3: On October 1, 1956 (the start of the 10-year drought) the pumping rates in Stouffville are switched to the drought re-allocation rates. All other municipal wells and surface water and groundwater takings continue to be operated at study period rates.
    a. The average water levels in the aquifers in September 1956 (the start of the drought) are used as a reference for drawdown calculations.
    b. The maximum simulated daily drawdown in each well is determined from within 10 year drought period.

Table 3-22: Predicted Drawdowns at the Municipal Wells in the Stressed Watersheds

Well	Aquifer	Safe Additional Drawdown (m)	Additional Drawdown (m)							
			Scenario C	Scenario D	Scenario G(1)	Scenario G(2)	Scenario G(3)	Scenario H(1)	Scenario H(2)	Scenario H(3)
Stouffville PW1	TAC	40.43	6.27	5.66	0.78	0.10	0.70	5.86	5.74	5.79
Stouffville PW2	TAC	43.47	6.06	5.66	0.78	0.10	0.70	5.86	5.74	5.79
Stouffville PW3	Lower ORAC	11.73	6.12	3.65	2.25	0.01	**2.24**	4.54	3.67	4.52
Stouffville PW5	Lower ORAC	3.25	5.59	2.30	0.86	0.14	0.73	2.50	2.41	2.34
Stouffville PW6	Lower ORAC	8.20	5.82	2.30	0.86	0.14	0.72	2.50	2.42	2.35
Uxville-MW1	ORAC	21.50	2.06	4.82	1.62	0.56	**1.07**	6.19	5.91	5.14
Uxville-MW2	ORAC	12.70	1.82	4.63	1.27	0.22	**1.07**	5.38	5.06	4.92

Notes:

Additional drawdowns for Scenario C expressed relative to no-pumping conditions.
Additional drawdowns for Scenario G expressed relative to Scenario C heads.
Highlighted text indicates wells that are significantly affected by changes in land use.

Table 3-23: Predicted Drawdowns at Other Municipal Wells

Well	Aquifer	Additional Drawdown (m)							
		Scenario C	Scenario D	Scenario G(1)	Scenario G(2)	Scenario G(3)	Scenario H(1)	Scenario H(2)	Scenario H(3)
Nobleton PW2	TAC	2.99	4.57	4.06	3.05	0.97	9.34	9.23	4.69
Nobleton PW3	TAC	3.01	4.45	3.93	2.92	0.96	8.96	8.84	4.57
Nobleton PW5	TAC	2.49	4.04	4.85	3.83	0.98	17.85	17.74	4.16
King City PW3	TAC	7.68	6.88	3.02	0.60	**2.30**	7.66	7.27	7.29
King City PW4	TAC	8.15	6.88	3.02	0.60	**2.30**	7.66	7.27	7.29
Kleinburg PW3	SAC	3.06	4.11	0.77	0.11	0.65	4.32	4.22	4.21
Kleinburg PW4	SAC	3.54	4.11	0.77	0.11	0.65	4.32	4.22	4.21
Palgrave PW1	Lower ORAC	1.80	2.14	0.04	0.02	0.02	2.15	2.15	2.14
Palgrave PW2	Lower ORAC	13.4	13.29	0.04	0.03	0.02	13.31	13.31	13.29
Palgrave PW3	Lower ORAC	12.3	6.27	0.00	0.00	0.00	6.27	6.27	6.27
Caledon East PW3	Lower ORAC	40.9	6.95	0.01	0.00	0.00	6.95	6.95	6.95
Caledon East PW4	TAC	1.34	3.56	0.01	0.00	0.01	3.51	3.58	3.54

Notes:

Additional drawdowns for Scenario C expressed relative to no-pumping conditions
Additional drawdowns for Scenario D and H are expressed relative to October 1956 heads.
Additional drawdowns for Scenario G expressed relative to Scenario C heads.
Highlighted text indicates wells that are significantly affected by changes in land use.

The drought simulations, and drought re-allocation rates, reflect the operational flexibility available to York Region. The simulations reflect the changes in operations that could be implemented at the onset of a drought. Additional study and simulations are necessary to determine the triggers (e.g., decrease in precipitation or decline in groundwater levels), and to optimize drought response needed to maintain safe available drawdown.

Scenario C Results: Current Conditions and Climate

This scenario provides the baseline conditions for evaluation of the other scenarios. Best estimates of current water use were applied, and recharge was based on current (2010) land use.

Scenario D Results: Existing Pumping Rates, Current Land Use, and Drought Conditions

Results from the transient drought simulation in Scenario D, in terms of simulated stage, heads, and numerous other water budget components, were produced by the model on a cell-by-cell basis for each day. For presentation purposes, and to facilitate trend analysis and comparisons, these values were also accumulated on a monthly basis to produce monthly average results.

As noted earlier, for transient stress scenario analyses the simulated monthly average aquifer heads and streamflow for September 1956 were taken to represent reference conditions prior to the start of the drought.

The maximum drawdowns under transient drought conditions (Scenario D) were compared to the safe additional drawdown and were found to be less than the safe additional drawdown at all municipal wells. Drawdowns were calculated relative to the average monthly head for September 1956. Values were corrected for convergent head losses and non-linear head losses.

The transient model produces other useful information relevant to the surface water and groundwater system response to drought. Total simulated streamflow includes contributions from overland runoff as well as from groundwater inflow. The maximum change in total streamflow was determined by subtracting the simulated flows for August 1965, the most severe period of the drought, from flows in September 1956. The results showed that the largest relative change in streamflow occurs in the upper (headwater) reaches of most streams with less change in the main stems.

Scenario G Results: Allocated Water Demand, Future Land Use, and Average Climate

Scenario G evaluates the ability for the municipal wells to sustain the allocated water demand pumping rates under average climate conditions. This scenario was simulated using the Tier 3 model in steady-state mode with long-term average annual groundwater recharge rates reflecting long-term average climate conditions.

As per the MNRF Water Budget Guide, Scenario G was subdivided into three scenarios to better isolate the impacts due to increased municipal pumping from impacts due to future changes in land use.

Scenario G(1): Allocated Water Demand and Future Land Use

This simulation evaluates the combined impact of increased municipal pumping rates to meet allocated water demand and reductions in recharge due to future land use change. Scenario G(1) is similar to the WHPA-Q2 scenario discussed previously although all future land development within the study area was simulated in Scenario G(1) rather than just those areas outside the WHPA-Q1.

Inputs to the PRMS submodel were adjusted to account for increased surface imperviousness and changes in vegetative cover in the all future development areas. A new future annual average groundwater recharge rate distribution was determined through 20 years of PRMS simulations.

The simulated drawdowns at the municipal well are less than the safe additional drawdown at all municipal wells. The scenario predicts large areas of drawdown that centre on the municipal wells due to increased pumping. The areas of drawdown extend further south due to projected changes in land use.

Scenario G(2): Allocated Water Demand and Current Land Use

This simulation evaluates only the impact of increased municipal pumping to meet allocated water demand. The average annual groundwater recharge rate represented current land use conditions.

The simulated drawdowns at the municipal wells for Scenario G(2) are smaller than for Scenario G(1) and are less than the safe additional drawdown. As discussed above, the effects of increased pumping to meet allocated demands are centered around the Yonge Street area wells and some of the other municipal wells with significant increases in pumping. Drawdowns are more pronounced in the deeper aquifers, where the majority of the municipal supply wells are screened.

Scenario G(3): Existing Pumping and Future Land Use

This simulation evaluates only the impact of reductions in recharge associated with the future land use change. Existing pumping rates for municipal wells and the average annual groundwater recharge rate for future land use were used in this scenario.

With few exceptions (e.g., Stouffville, King City and Kleinburg), the drawdowns are less than those for Scenario G(2). The additional drawdowns are not centered on the municipal wellfields but occur mainly in the south and southeast parts of the study area, corresponding to locations of projected land use change. The projected changes in future land use have a more direct impact on the shallow groundwater system.

Scenario H Results: Allocated Water Demand, Future Land Use, and Drought Conditions

Results from the Scenario H transient drought simulations include stream stage, aquifer heads, and numerous other water budget components calculated on a cell-by-cell basis for each day. Daily hydrographs and animation results were reviewed during calibration and daily values were used for the risk assessment drawdown analysis. For presentation and trend discussion purposes, the daily values were processed into monthly average results.

The maximum drawdowns under transient drought conditions (Scenario H) were compared to the safe additional drawdown at each of the municipal wells. Drawdowns were calculated relative to the average monthly heads for September 1956 from the Scenario D simulation which served as a reference condition at the start of the drought. As in Scenario G, three different simulations were run to identify the separate and combined contributions of increased pumping to meet allocated demand and projected land use change impacts on the simulated drawdowns.

Scenario H(1): Allocated Water Demand, Future Land Use, and Drought Conditions

This scenario simulates drought conditions and considers both allocated demand and projected land use change. As in Scenario D, maximum decrease in simulated head occurred in August 1965 although local variations in the low-point date were found.

In much of the study area, the drought scenarios can be seen as a superposition of two independent problems: (1) the response to increased pumping and change in recharge and (2) the response to drought. Monthly average heads during August 1965 were taken to represent the most severe drought conditions. The maximum changes were predicted in the Oak Ridges Aquifer Complex and Scarborough Aquifer. The drawdowns are larger than those for Scenario D because of the additional effects of increased pumping and land use change superimposed on the drought response. Areas of high change occur at the wellfields and in areas of proposed land use change as in Scenario G(1), but also at the regional divide in the Oak Ridges Moraine and near inter-stream divides as in Scenario D.

A direct comparison made by subtracting the simulated heads in the Thorncliff Aquifer for Scenario H(1) from those in Scenario D indicates that the difference in response between the two scenarios is due mainly to the increased pumping at the municipal wells. The drawdowns differ from those between Scenario G(1) and Scenario D because the steady-state simulations compare average response and have limited groundwater feedback. Whereas, Scenarios D and H(1) simulate at a more realistic response and account for aquifer storage and non-linear effects such as reduction in leakage to and from streams.

The maximum simulated additional drawdowns for the 10-year drought at the municipal wells are presented in **Table 3.23** and are less than the safe additional drawdown at all municipal wells. This indicates that the wells are capable of sustained pumping to meet allocated water demand under drought conditions and projected land use.

Scenario H(2): **Allocated Water Demand, Existing Land Use, and Drought Conditions**

This scenario simulates the response of the municipal wells under drought climate conditions and considers only increased pumping to meet allocated demand and not projected land use change. The predicted drawdowns are nearly identical to those observed for Scenario H(1), suggesting that the impact of land use change on the overall drought response is relatively minor.

The maximum additional drawdowns at the municipal wells for Scenario H(2) were found to be less than the safe additional drawdown values at all of the municipal wells. The simulated drawdowns at the wells are very close to those for Scenario H(1) confirming that the effect of recharge reductions due to land use change are muted during a drought.

Scenario H(3): Existing Pumping, Future Land Use, and Drought Conditions

This Scenario simulates the response of the municipal wells under drought conditions and considers only projected land use and not increased pumping to meet allocated demand. The small change in heads between Scenario H(3) and Scenario D indicates that the municipal wells are relatively insensitive to land use change under drought conditions.

Results from the Scenario H transient drought simulations include stream stage, aquifer heads, and numerous other water budget components calculated on a cell-by-cell basis for each day. Daily hydrographs and animation results were reviewed during calibration and daily values were used for the risk assessment drawdown analysis. For presentation and trend discussion purposes the daily values were processed into monthly average results.

The maximum drawdowns under transient drought conditions (Scenario H) were compared to the safe additional drawdown at each of the municipal wells. Drawdowns were calculated relative to the average monthly heads for September 1956 from the Scenario D simulation, which served as a reference condition at the start of the drought. As with Scenario G, three different simulations were run to identify the separate and combined contributions of increased pumping to meet allocated demand and projected land use change impacts on the simulated drawdowns.

Risk Assessment Scenario Result Summary

No impacts to aquatic habitats were predicted within the TRSPA. A limited number of individual cold water reaches with moderate to significant decreases in flow were found in the Lake Simcoe Source Protection Area portion of the Local Area, mostly in proximity to the Yonge Street wells as shown on **Figure 3.46.** However, because there is only one Local Area for the entire York Tier 3 study, the risk from these changes also applies to the TRSPA portion of the Local Area. As noted in **Section 3.92**, MOECC has clarified that if the allocated demand does not exceed the current PTTW amount, then a moderate risk level is assigned to the Local Area. Thus only future activities are deemed significant water quantity threats within this Local Area.

(c) Copyright. Toronto & Region Source Protection Area, 2014.

Source: TRCA, 2014; DMTI Spatial, 2010; MNR, 2010.

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

Figure 3-46: Potential Impacts to Other Water Uses (Aquatic Habitats)

Few provincially significant wetlands are located within the area defined by the predicted 1 m drawdown cone. **Figure 3.47** shows one wetland within the TRSPA that could potentially have reduced outflows or water level due to increases in pumping at nearby municipal wells. In addition, two other wetlands were identified within the 1 m drawdown cone north of the TRSPA boundary (Earthfx, 2013). As noted above, if the allocated demand does not exceed the current PTTW amount, then a moderate risk level is assigned to the Local Area even if the identified impact meets the threshold for significant.

3.9.11 Enumeration of Significant Drinking Water Threats

Consumptive Demand

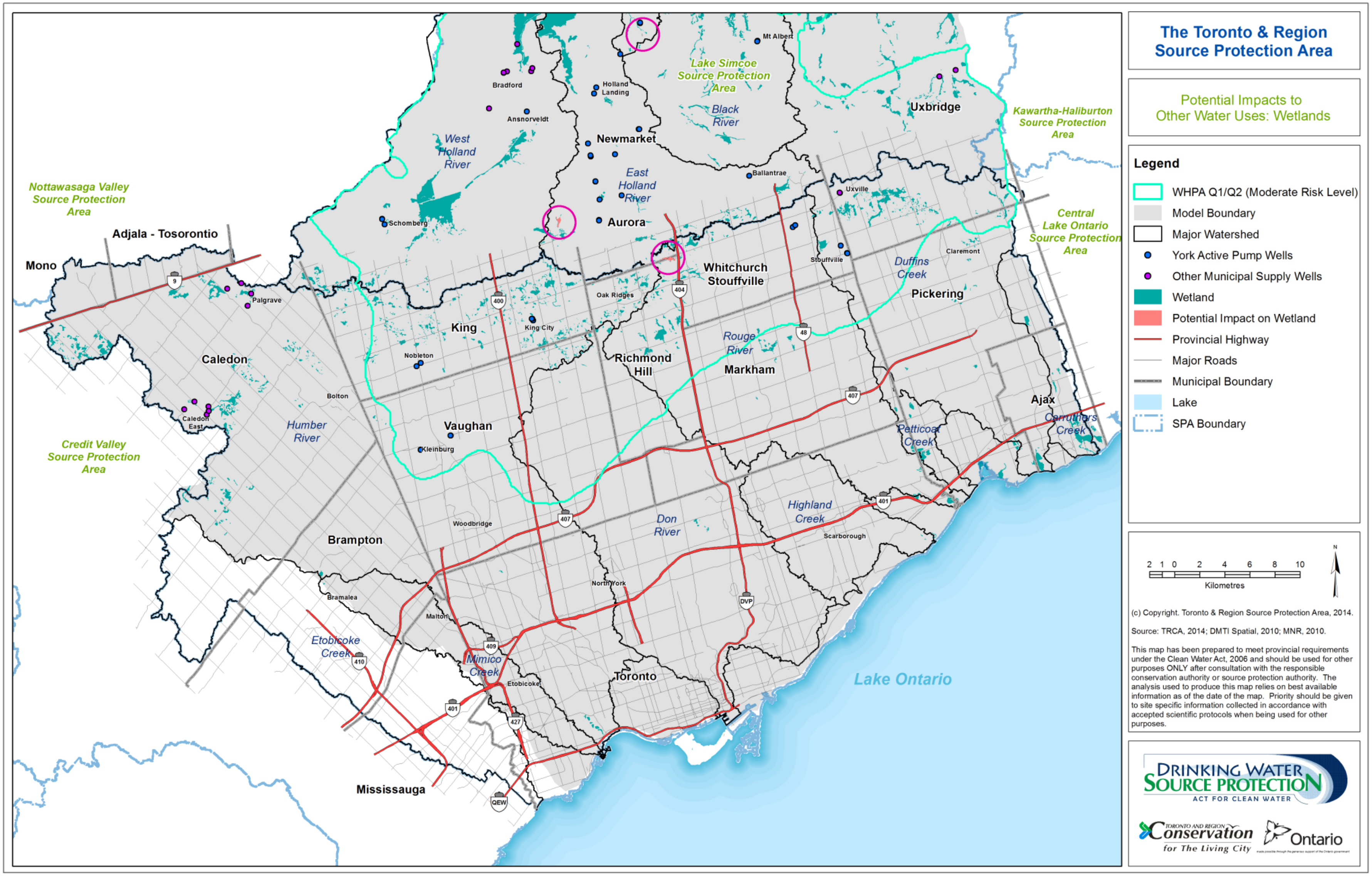
As per the *Technical Rules*, drinking water threats that are located within the Local Area are classified as moderate or significant threats based upon the risk level assigned to the Local Area. Where the risk level assigned is moderate (as in this case), the existing consumptive demands identified within the Local Area are classified as moderate water quantity threats while future consumptive demand activities are identified as significant water quantity threats. Activities prescribed to be drinking water threats include both municipal and non-municipal permitted uses and also includes activities that do not require a PTTW (e.g., domestic wells). These are listed in **Table 3.23.**

The consumptive water threats are summarized in **Table 3.24**. Non-permitted water uses within the study area were based on field surveys by the conservation authorities and presented in the Water Use Compilation Report (Earthfx, 2011) and also in (Earthfx, 2013). Non-permitted uses mainly include agricultural wells pumping less than 50 m^3/d, and are assumed to represent low consumptive use factors. Takings from domestic wells are also considered to be small and generally non-consumptive (the water is generally returned to the aquifer through septic systems), but are listed in the threats table. There is considerable uncertainty in the non-permitted takings.

Recharge Reduction

The *Technical Rules* specify reduction in groundwater recharge as a potential water quantity threat within the Local Area. The Tier 3 Scenarios considered the impact of existing and future land development on groundwater recharge and the resulting impact on water levels in the municipal aquifer at the wells. The analyses of reductions in groundwater recharge within the York Tier 3 Local Area conclude that the vast majority of planned development is slated to occur outside of the areas of significant recharge, and as such the reduction in recharge will not significantly impact the municipal aquifers and a moderate risk level has been assigned. However, future reduction in recharge in areas that have not been assessed to date does have the potential to cause impact and therefore such future recharge reduction is deemed to be a signficiant water quantity threat.

The CTC Source Protection Committee may develop policies that when implemented are intended to prevent the existing moderate drinking water threats in Local Area A from becoming significant and must develop policies that when implemented are intended to prevent future significant threats. Note that the WHPA-Q1 and WHPA-Q2 extend outside the boundary of the TRSPA into into the Central Lake Ontario Source Protection Area (CLOSPA). The policies developed by the CTC Source Protection Committee will also apply within the CLOSPA portion. Since the Local Area also extends into the South Georgian Bay-Lake Simcoe Source Protection Region, their Source Protection Committee has the responsibility for developing policies to apply within their jurisdiction. In addition, there is a small portion that extends into the Kawartha-Haliburton Source Protection Area, part of the Trent Conservation Coalition Source Protection Region. The Trent Conservation Coalition Source Protection Committee is likewise responsible for policies that apply in their jurisdiction.



Source: TRCA, 2014; DMTI Spatial, 2010; MNR, 2010.

This map has been prepared to meet provincial requirements under the Clean Water Act, 2006 and should be used for other purposes ONLY after consultation with the responsible conservation authority or source protection authority. The analysis used to produce this map relies on best available information as of the date of the map. Priority should be given to site specific information collected in accordance with accepted scientific protocols when being used for other purposes.

Figure 3-47: Potential Impacts to Other Water Uses (Wetlands)

Table 3-24: List of Permitted Consumptive Water Uses (TRSPA)

Municipal Wells			
King City PW#3	Kleinburg PW#4	Stouffville PW#1	Stouffville PW#6
King City PW#4	Nobleton PW#2	Stouffville PW#2	Uxville-MW1
Kleinburg PW#2	Nobleton PW#3	Stouffville PW#3	Uxville-MW2
Kleinburg PW#3	Nobleton PW#4	Stouffville PW#5	
Non-Municipal Permitted Wells			
0007-6CFGYE	1774-7KMFKE [Well #4]	6723-7R7MNB [Irrigation pump # 1]	86-P-3014
00-P-3019	2005-6TYPT6 [PW 1 & TW 1 Combined]	6723-7R7MNB [Irrigation pump # 2]	88-P-3071
00-P-3050	2066-6WHLRS [PW1-06]	67-P-176	89-P-3030 [Well 1]
01-P-3015	2165-6FZHZP [Irrigation Pond]	68-P-85	90-P-0010
01-P-3031	2165-6FZHZP [Well 1]	69-P-216	90-P-0010
01-P-3049 [East Well]	2165-6FZHZP [Well 2]	69-P-411	91-P-3086
01-P-3049 [West Well]	2224-7T5PWY [Irrigation Well]	70-P-364	92-P-3048 [Well 2 (Backup)]
01-P-3059	2344-7FNRMT [Pond]	71-P-364	92-P-3048 [Well TW 2/89]
02-P-3001	2344-7FNRMT [Production Well]	71-P-91	92-P-3064
02-P-3004 [Main Farm Well]	2347-7EDRRH [TW 4]	7211-893QM7 [6917267]	92-P-3107 [Pond]
02-P-3004 [New Main Farm Well]	2347-7EDRRH [TW3]	73-P-327	93-P-3051 [Well]
02-P-3004 [North Well]	2627-668HTC [Clubhouse Well]	73-P-494	93-P-3057
02-P-3004 [South Well]	2627-668HTC [Holding Ponds]	75-P-3017	94-P-3029 [Pond]
02-P-3007 [North Well]	2727-7BELN8 [A013021]	77-P-3048	94-P-3069
02-P-3007 [South Well]	2727-7BELN8 [TW 2/89 (WWR5725932]	77-P-3070 [Well A]	94-P-5036 [Well PW-1-89]
02-P-3009 [Well System]	2814-73GGNZ	77-P-3070 [Well B]	94-P-5036 [Well PW-1-90]
02-P-3041	3310-6L7SV6 [PW1, 2, 3 or TW1/90]	77-P-3070 [Well D]	95-P-3010
02-P-3088 [Ponds]	3528-7GDLVK [Clubhouse (WW-11)]	7877-627PUF	95-P-5013 [Pond 1]
02-P-3101 [Pond]	3528-7GDLVK [Irrigation Pond]	7881-72SJMA	95-P-5013 [Well]
0616-6JTMHS [MNRF Well 5]	3528-7GDLVK [Irrigation Well (PW-1)]	80-P-3011	96-P-3001 [Well]
0831-76HM3P [Pond East]	4203-82WKYB [Clubhouse Well]	8186-5ZTPZV [Irrigation Pond]	96-P-3001 [Well]
0831-76HM3P [Pond West]	4203-82WKYB [Condominium Well]	8186-5ZTPZV [PW-1]	96-P-3003
1151-5TLRLH [PW1]	4203-82WKYB [Irrigation Well]	8200-6VBLQE	96-P-3025 [Well 1 (split)]
1314-6VMSZB [South Pond]	4305-7F8P87 [SPWS]	8272-7QUGNH [Well 4]	96-P-3025 [Well 1 (split)]
1314-6VMSZB [North Pond]	4305-7F8P87 [TPWS]	8272-7QUGNH [Well 6]	96-P-3040 [Well 191-3177]
1314-6VMSZB [Central Pond]	4687-77VQZS [PW1]	8272-7QUGNH [Well 9]	97-P-1068 [Dugout Pond]
1348-7TZRF9 [Clubhouse & Irrigation]	4687-77VQZS [PW2]	8288-7BLPLG	97-P-3002

1348-7TZRF9 [TW 2 Irrigation]	4687-77VQZS [PW3]	8327-6Z3TD2 [Pumping Well]	97-P-3002
1417-7TWQQD [East and West Wells]	4754-5WGJS4 [TW1]	83-P-3008	97-P-3002
1417-7TWQQD [Irrigation Well]	5520-6E2NFA [East Irrigation Well]	8422-5XJQR8 [Production Well No. 1]	98-P-3008
1417-7TWQQD [Tannery Creek and]	5520-6E2NFA [House & Shop Well]	8486-7YDQ8G [Irrigation Pond]	98-P-3015
1426-5XJKXN [PW1-98]	5520-6E2NFA [Irrigation Pond]	8486-7YDQ8G [Clubhouse Well]	98-P-3025 [Well]
1426-5XJKXN [PW2-96]	5520-6E2NFA [West Irrigation Well]	8486-7YDQ8G [Pond Network]	99-P-3009
1426-5XJKXN [TW1-96]	63-P-55	85-P-3061	99-P-3021
1426-5XJKXN [TW2-96]	65-P-136	8662-7FFPTD [Pond]	99-P-3071
1741-6M3KDL [Clubhouse Well]	66-P-214	8684-7CDJHK [Pond]	
1774-7KMFKE [New Well]	6723-7R7MNB [Canal Drainage]	8684-7CDJHK [PW 1]	

Table 3-25: Summary of Consumptive Water Quantity Threats

Type	**Source Protection Area**				**Total for Local Area**
	TRSPA	**LSCBRSPA**	**CLOSPA**	**KHSPA**	
Municipal *Count of individual point takings*	15	38	0	0	**53**
Non-Municipal Permitted *Count of individual point takings*	62	81	3	0	**146**
Non-Municipal Non-Permitted *Count of individual point takings*	5,506	9,032	8	6	**14,552**
Total Takings	**5,583**	**9,151**	**11**	**6**	**14,745**

Note:
LSCBRSPA- Lakes Simcoe and Couchiching/Black River Source Protection Area

Uncertainty Assessment

It is estimated that there is low uncertainty in the moderate risk level assignmentto the Local Area for the following reasons:

- The factors contributing to uncertainty indicated a low underlying uncertainty for the risk assignment.
- The moderate risk level is due in part to the potential significant impact on baseflow, provincially significant wetlands , and other permitted water takings. Although there is only limited baseflow discharge measurements in the area and limited data on wetland stage, the areas affected are relatively distant from the municipal wells and impacts are likely to be less significant than those simulated under steady-state conditions.
- Another important factor to consider is that the 2010-2011 municipal water takings represent a reduced taking compared to historic conditions. For example, total pumping was closer to maximum permitted takings in the 2007 to 2009 period. Thus, Scenarios G and H represent a return to historic conditions.

There is low uncertainty in the assignment of high tolerance to the Local Area. The high tolerance is due to the metres of additional drawdown in most wells, the integrated nature of the York municipal supply system, and the fact that a water supply pipeline from Lake Ontario is also available to meet municipal needs.

3.9.12 Tier 3 Significant Groundwater Recharge Areas

As discussed above, the Tier 3 model produced different estimates of the various water budget parameters as compared to the Tier 1 and 2 model. The differences are shown and discussed in **Section 4.1.3**.

3.10 WATER BUDGET SUMMARY

TRCA staff and consultants have developed Conceptual, Tier 1, Tier 2, and Tier 3 water budget models within the TRSPA. The water budget presented in the Tier 3 assessment provides an update to the estimates in the simplified Tier 1 and 2 assessments. The new analysis indicates that traditional definitions of the surface water and groundwater components of the water budget are limited because of the highly interconnected nature of the systems. Some takings, groundwater-fed ponds and golf course ponds (supported by a well), cannot be classified as either groundwater or surface water takings because they begin as an integrated capture of surface and groundwater, and often contribute to aquifer recharge downstream through stream leakage.

The numerical modelling indicates that cross-watershed groundwater flows are significant; suggesting that water management policies must include the broader areas surrounding the stressed watersheds.

Water demand in the study area is varied, complex and there is considerable uncertainty in many of the permitted and non-permitted uses. Continued efforts to quantify and monitor actual water use is essential.

The Tier 3 integrated GSFLOW model represents a significant improvement over previous Tier 1 and Tier 2 modelling efforts in the study area. The Model Development and Calibration Report (Earthfx, 2013) covers all aspects of data compilation, conceptualization, model construction and calibration of the fully integrated SW/GW model used in this risk assessment. Significant improvements include:

- Construction of a comprehensive and updated SQLServer database;
- Extensive “data mining” to compile relevant information from numerous field investigations and measurements completed since the development of the Core Model;
- Significant improvements to the subsurface conceptual model including the sub-division of both the Newmarket Till and Oak Ridges Aquifer Complex units;
- Representation of groundwater interaction and surface water routing throughout the entire 4,450 km York Region stream network;
- Improved representation of wetlands, lakes and the interaction between the shallow water table and soil zone infiltration processes;
- Full simulation of cascading overland runoff and interflow, including the effects of urbanization and focused recharge in the hummocky topography of the Oak Ridges Moraine;
- Extensive compilation, assessment and model representation of all daily surface water and groundwater takings in the study area; and
- Full transient calibration to both groundwater levels and total measured streamflow, spanning a period of average (2006), drought (2007) and wet year conditions (2008).

Of particular note is the extensive work to understand water use in the study area. Much time was devoted to cross-referencing permits, water takings and other water use information so as to best estimate and represent the water takings in the area. Municipal groundwater use dominates, but agricultural and golf course water takings are significant. Despite these efforts, additional measured actual takings are needed as the consumptive use estimates are still subject to many assumptions. Accurate estimates of water demand are essential to the overall water budget.

The Tier 3 GSFLOW model represents a truly integrated assessment of the surface water and groundwater processes in the study area. The individual forcing functions of long-term climate (dry year/wet year), seasonal variation (particularly snowmelt response) and change in water demand on both a seasonal and longer-term basis are very complex and cannot be assessed independently. The GSFLOW model response indicates that each of the forcing functions, both individually and, in many areas, in a combined manner, produce significant local and regional scale changes in water levels, streamflows and the overall water budget.

The risk assessment indicates that the York Tier 3 Local Area is classified at a moderate risk because increases in pumping to meet allocated demand are predicted to create a greater than 1 m incremental drawdown in other permitted wells and under provincially significant wetlands.

The Tolerance of the Local Area is classified as high. The uncertainty in the risk classification is low and the uncertainty in tolerance assignment is also low.

No model is, of course, perfect, and the following improvements could be implemented:

1. The model boundaries could be expanded to incorporate all of the TRSPA watersheds and eliminate internal inconsistencies in SGRA delineation.
2. Long term fully integrated GSFLOW simulations could be undertaken as an improvement over the estimates from the uncoupled steady state simulations. Steady-state uncoupled analysis is limited.
3. Additional refinements to the representation of urbanization, including sewer lines, could be added.
4. A move towards an ecologically driven groundwater recharge assessment is suggested. The use of NEXRAD radar data has proven to be a better estimate of precipitation in other Tier 3 and Lake Simcoe Region Conservation Authority studies, allowing a better calibration to peak flows.
5. Every effort should be made to eliminate the use of general consumptive use factors. Major takings, including irrigation, should be quantified and fully simulated.
6. Other long term water level and pumping tests, such as the 16th Avenue Sewer Construction program, could be assessed as a verification of the model.
7. The water quality WHPA assessment should be updated to reflect the improved understanding of the local geology and interconnected groundwater/surface water system.
8. The drought simulations, and drought re-allocation rates, reflect the operational flexibility available to York Region. The simulations reflect the changes in operations that could be implemented at the onset of a drought. Additional study and simulations are necessary to determine the triggers (e.g., decrease in precipitation or decline in groundwater levels), and to optimize drought response needed to maintain safe available drawdown.