FIGURES

TABLES

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 and Climate Change (MOECC) prepared *Technical Rules (2009)*, 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.

In recognition of the extensive water budget work undertaken in the Credit Valley Source Protection Area (CVSPA) prior to the advent of Source Water Protection (SWP), Credit Valley Conservation (CVC) was permitted to forego the requirement of undertaking conceptual and Tier 1 water budgets (*Technical Rule 24*) for the Assessment Report. Due to moderate drinking water quantity stress identified in this early water budget work CVSPA was required to undertake a Tier 2 Water Budget. Based on the outcome of the Tier 2 Water Budget work, Tier 3 Water Budget studies were required for subwatersheds 19, 10 and 11.

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.

Natural water occurrence and availability were estimated via three-dimensional numeric computer modelling. A key objective of the modelling was to develop a quantified understanding of the hydrological and hydrogeological fluxes (i.e., movement of water over and under the land) through the SPA.

Numeric modelling aimed to develop a detailed quantification of the hydrological cycle. To accomplish this, the following components of the cycle have been simulated (modelled):

- Precipitation: rainfall, snowfall, etc.
- Surface fluxes: once precipitation hits the ground, how much of it flows over the surface, where it goes, and how it moves.

- Evapotranspiration: how much precipitation is returned to the atmosphere through evaporation from water surfaces (ponds, lakes, rivers, etc.), or through transpiration from vegetative surfaces.
- Recharge: what proportion of precipitation enters the ground from the land surface, and from subsurface flow from neighbouring watersheds and subwatersheds (where applicable).
- Groundwater fluxes: once in the ground, how does water move, and where does it go.

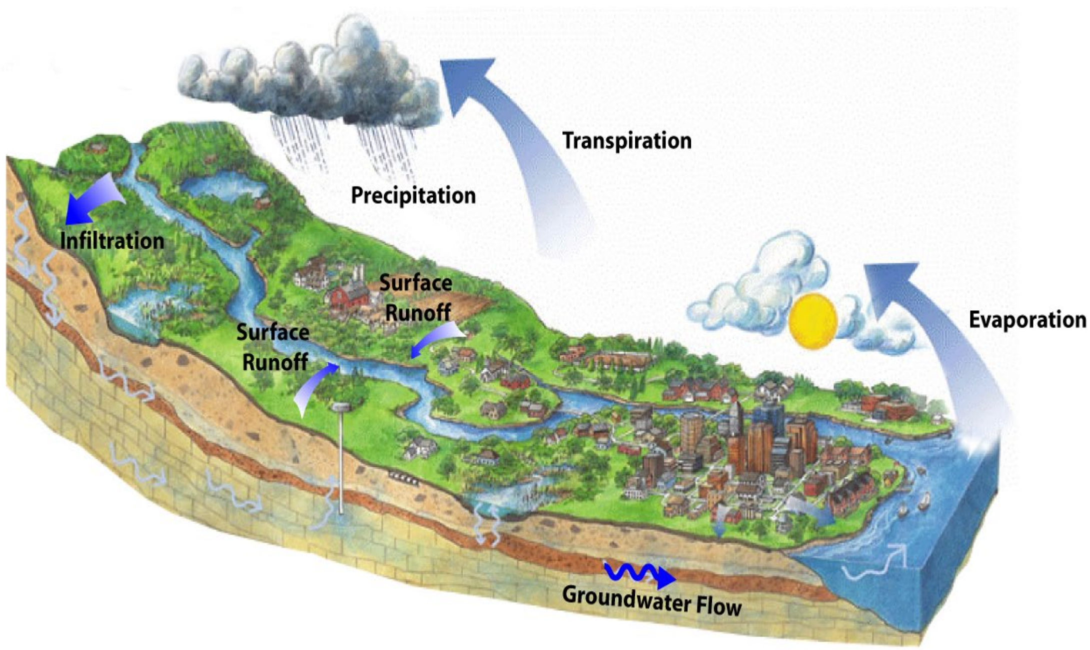


Figure 3.1: Key Components of the Water Budget

A review of the various processes influencing and directly impacting the water budget of the CVSPA is provided below. An attempt has also been made to interpret and describe current data trends relating to the key components.

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

3.2 PHYSICAL GEOGRAPHY

The landform and vegetative cover of CVSPA have been described in **Chapter 2.2**. A water budget study analyzes how the physical attributes of the land can influence and impact the occurrence and movement of surface water and groundwater.

3.2.1 Topography

Much of the irregular bedrock topography is attributed to *fluvial* erosion whereby paleodrainage was focussed along the bedrock for extensive periods of time, leading to the erosion of river valleys in the bedrock. These buried bedrock valleys are significant as they host municipal supply *aquifer*s in both Halton Region and Peel Region.

There are five major buried bedrock valleys in the watershed, three of which lie above the Niagara Escarpment:

- Orangeville—beneath the Credit River trending south easterly towards the Niagara Escarpment;
- Belfountain—beneath the West Credit River valley running to Erin and westward towards the Grand River watershed; and
- Limehouse/Acton—westerly extension of this re-entrant valley beneath the Black Creek subwatershed into and beyond Acton.

Below the escarpment lies a more complex system of buried bedrock valleys. The major bedrock valleys are as follows:

- Limehouse/Acton is an easterly extension of this re-entrant valley beneath the Black Creek subwatershed through Georgetown area and eventually extending to Lake Ontario;
- Forks of the Credit River to Cheltenham, running northeast of the present-day Credit River valley;
- The Caledon East Channel, running beneath subwatershed 13 eastward into the Humber River watershed; and
- From Cheltenham to Port Credit, beneath the present-day Credit River.

Many of these valleys are infilled with coarse-grained material, and some are known to transmit large volumes of water for municipal supply, including the valley that lies beneath Georgetown.

3.2.2 Physiography

Eight major and two minor physiographic regions have been described by Chapman and Putnam, 1984. The major physiographic regions are shown in **Figure 3.2,** and include:

- Lake Iroquois Plain;
- South Slope;
- Peel Lake Plain;
- Niagara Escarpment;
- Oak Ridges Moraine;
- Horseshoe Moraines (Galt, Paris, and Singhampton);
- Guelph Drumlin Moraine; and
- Hillsburgh Sandhills (Orangeville Moraine).

Glaciolacustrine: Sediments deposited in a lake associated with glacial ice

Lake Iroquois Plain

The Lake Iroquois plain slopes gently towards Lake Ontario and is covered with a thin veneer *of glaciolacustrine* sand and silty sand. Some sand and gravel beach terraces are also present along the abandoned shoreline.

South Slope

Characterized by low-lying ground moraine with irregular knolls and hills, the South Slope is divided into two areas below the Niagara Escarpment—a northern portion covering the base of the escarpment, and a southern portion that includes part of the Trafalgar Moraine between the Peel Plain and the Lake Iroquois Plain. In an area west of the Credit River, the Trafalgar Moraine provides some subtle topographic relief to the otherwise relatively flat topography.

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

Peel Plain

Characterized by flat to undulating area of clay soils deposited when glacial meltwater ponded on top of the low permeability Halton *Till* plain, the Peel Plain is underlain by silts and clays and fine-grained till.

Niagara Escarpment

This is the most distinctive physiographic feature in the CVSPA. It trends from north to south and separates the Horseshoe Moraine to the west from the South Slope and Peel Plain to the east.

The escarpment is a major topographic break in the bedrock and formed as a result of differential erosion of softer underlying shale and harder dolostone. The ground surface topography west of (above) the escarpment is rugged and hilly, while topography east of (below) the escarpment is gently sloping.

Oak Ridges Moraine

This region is characterized by a hilly topography with relief varying by as much as 50 m locally. It occupies a small portion of the watershed and represents the western extremity of an extensive interlobate moraine existing across the top of the Greater Toronto Area, eastwards towards the Trent River. In the Credit River watershed, the Oak Ridges Moraine is characterized by hummocky hills of fine-grained sand.

Horseshoe Moraines

This is a broad belt of moraines above the Niagara Escarpment that extends in a north-south direction. The Horseshoe Moraines run from Acton to Orangeville, primarily just west of the escarpment. They are composed mostly of sand to silt tills of the Galt, Paris, and Singhampton Moraines.

The Paris Moraine is a moderate relief till ridge that is underlain by a rise in the bedrock topography. The Paris Moraine acts as a local water divide in the northern portions of the watershed.

Guelph Drumlin Field

This is an area of low rolling drumlins located between the Singhampton Moraine and the Orangeville Moraine. It is characterized by a series of streamlined drumlins separated from one another by interconnected meltwater channels.

Hillsburgh Sandhills

The most northwesterly portion of the watershed is a physiographic region known as the Hillsburgh Sandhills. The area is composed mainly of the coarse-grained Orangeville Moraine, an area of higher relief with thick deposits of glacial outwash overlying bedrock.

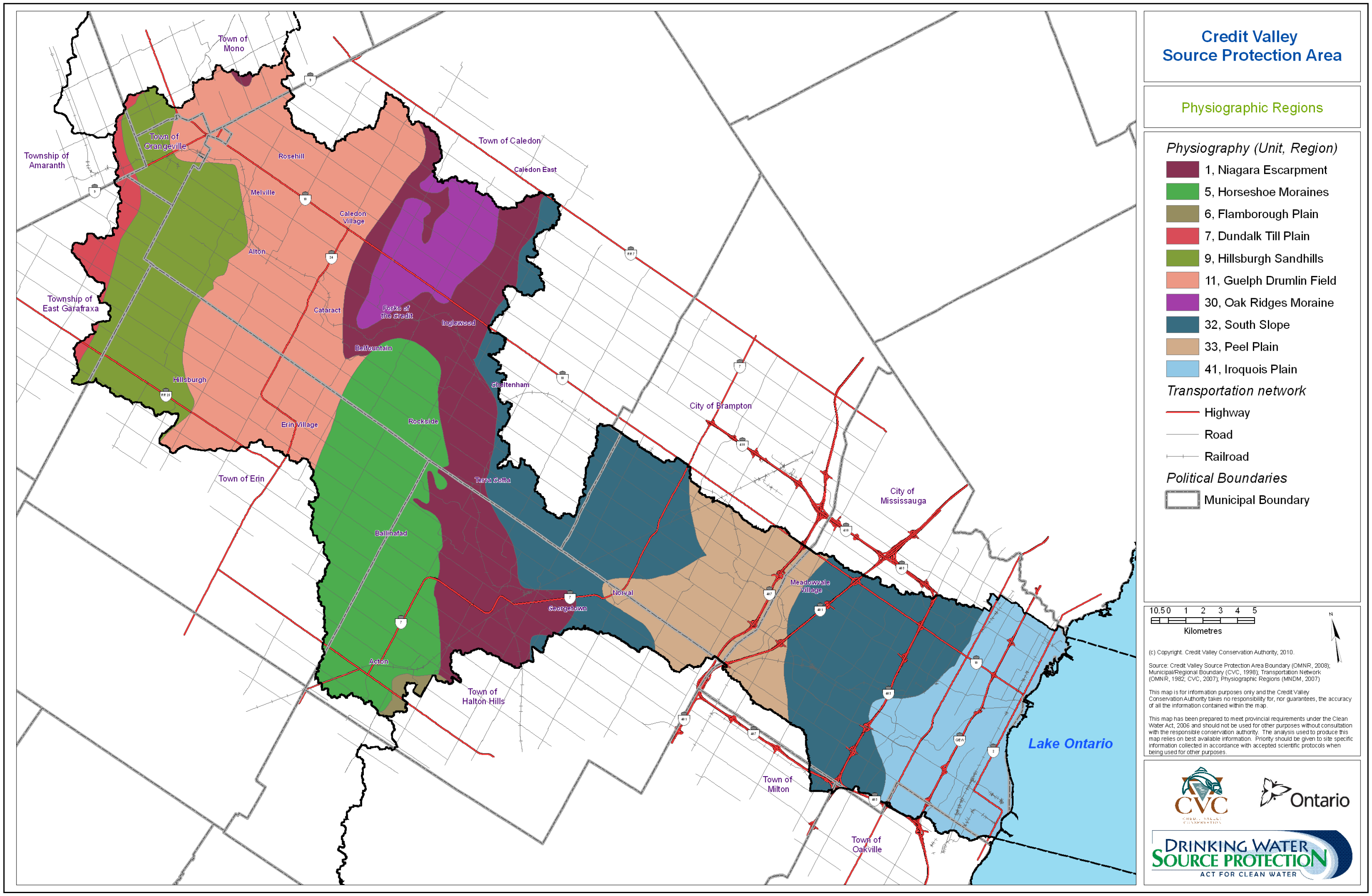


Figure 3.2: Physiographic Regions

3.3 GEOLOGY

3.3.1 Stratigraphic Framework

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

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

The geology of the CVSPA is built upon a foundation of Precambrian–aged bedrock material (granites and gneisses) and overlain by a thick overburden sequence of *Paleozoic*-aged sedimentary rocks (dolostones, limestones, and shales). These are, in turn, overlain by unconsolidated overburden sediments, as shown conceptually in (**Figure 3.3**). Geological mapping has been developed through extensive work done by the Ontario Geologic Survey (OGS, 2003).

The Niagara Escarpment is the most significant geological feature in the watershed and was formed through differential erosion of the bedrock units by marine intrusion and *fluvial* erosion prior to glaciation. It creates a topographic break bisecting the watershed in a north-south direction.

Much of the recent geologic investigations in the CVSPA and in watersheds to the east have focussed on the development of the Oak Ridges Moraine, characterizing buried valleys, and "tunnel channels" that represent important water supply aquifers in many areas.

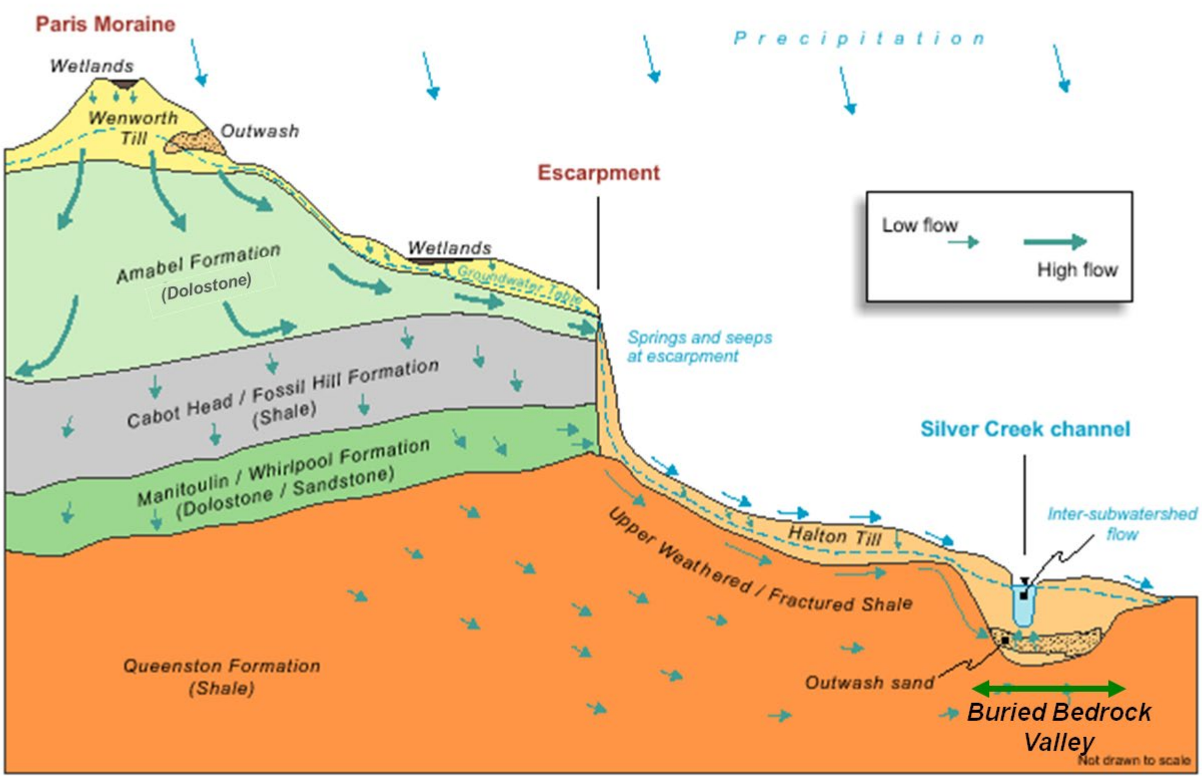


Figure 3.3: Conceptual Geological Surfaces in the CVSPA (cross-section running north-west by south-east)

3.3.2 Bedrock Geology

Bedrock consists of Paleozoic sedimentary material composed of limestone, dolostone, sandstone, and shale sequences overlying a Precambrian basement. The bedrock units exhibit a regional dip to the southwest, and outcrops in the Niagara Escarpment and along river valleys where overburden has been eroded away.

The Georgian Bay and Queenston Formations **(Figure 3.4)** are the oldest bedrock units within the watershed. They form the bedrock surface east of the escarpment and underlie younger bedrock formations above the escarpment. The Georgian Bay Formation consists of blue-grey shale with interbeds of siltstone, sandstone, and limestone, and has an approximate thickness of 165 m.

The Queenston Formation conformably overlies the Georgian Bay Formation and consists of unfossilifereous, thinly to thickly bedded red shale. The Queenston Formation shale has a maximum thickness east of the escarpment of up to 135 to 150 m and thins in a northerly direction.

West of (above) the Niagara Escarpment, Queenston Formation shale is unconformably overlain by the Whirlpool and Manitoulin formations, which are in turn overlain by the Cabot Head, Reynales-Fossil Hill, Amabel, and Guelph formations.

The Whirlpool Formation is a thinly to massively bedded, grey to reddish sandstone, which is up to 5 m thick. It outcrops at the base of the escarpment above the Queenston Formation.

The Manitoulin Formation is a grey, medium-bedded dolostone with shaley interbeds, with a maximum thickness of 5 m. The Cabot Head Formation consists of approximately 15 m of greenish-grey and red silty shale. The Reynales-Fossil Hill Formation consists of approximately 2–3 m of argillaceous dolostone.

The Amabel Formation forms the cap rock for the Niagara Escarpment and is described as a grey to blue-grey medium, crystalline, massively bedded dolomite. The Amabel is up to 40 m thick in the upper reaches of the watershed and contains significant secondary porosity from solution cavities and fracturing. The Guelph Formation is present in the western portion of the watershed and is described as a light brown, porous, fine to medium crystalline dolostone. The combined thickness of the Guelph and Amabel formations ranges from 45 to 120 m.

Fracturing is present in all bedrock units but is most pervasive in the upper few metres of bedrock and in areas close to the escarpment face. The increased fracture frequency results from erosion and weathering of the bedrock surface.

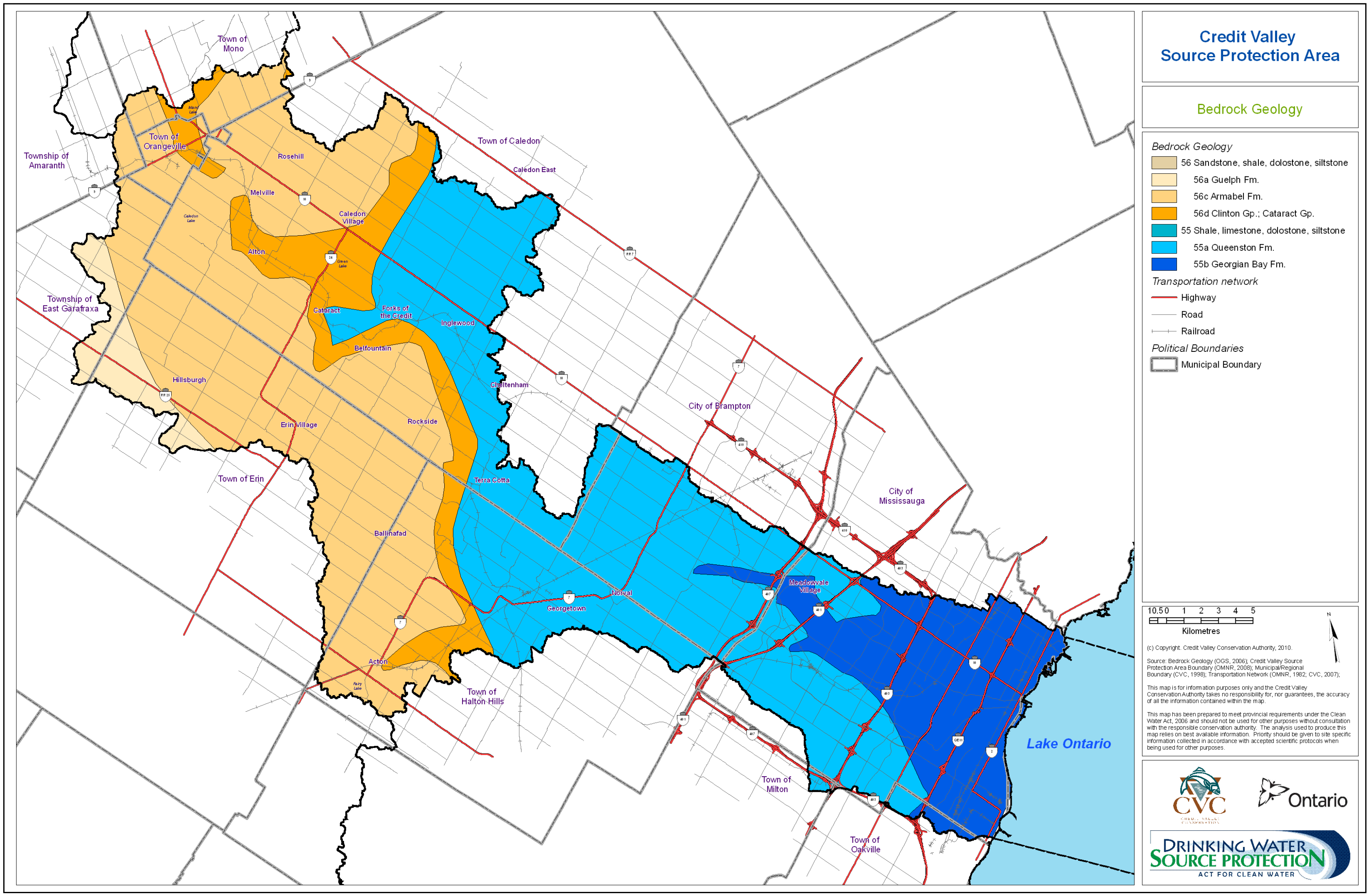


Figure 3.4: Bedrock Geology

3.3.3 Quaternary Sediments

A summary of the major Quaternary deposits within the CVSPA is given below. **Appendix C 1** provides additional detail on lithology and stratigraphic relations, while **Figure 3.5** shows the spatial distribution of these units at surface across the CVSPA.

Quaternary aged overburden sediments provide a detailed record of glacial and interglacial events throughout the most recent glaciation (Wisconsinan glaciation).

Quaternary overburden sediments were deposited over an extended period of time and under a wide variety of depositional environments and can be grouped into the following general categories:

- Glacial tills/diamicts (till plains/end or terminal moraine);
- Ice-contact stratified drift (kames, kame-moraines);
- Outwash deposits (meltwater channels, glaciodeltaic deposits);
- Glaciolacustrine deposits; and
- Recent alluvial deposits.

Glacial Tills/Diamicts

Five different glacial till units have been identified. These till packages were deposited as terminal or end moraines, or as till plains (ground moraine). The five tills can be divided into two groups based on matrix grain size and hydrogeologic function. These two groups are coarse-grained tills and fine-grained tills.

Coarse-grained tills (e.g., sandy silt to sand tills), include:

- Northern Till (also known as the Newmarket Till as referenced by the Oak Ridges Moraine Groundwater Program (formerly Conservation Authorities Moraine Coalition–York-Peel-Durham-Toronto (CAMC-YPDT));
- Wentworth Till; and
- Port Stanley Till.

The Northern Till is reported to outcrop in the Township of Mono and Town of Caledon and is described as sandy silt till with numerous coarse-grained lenses of stratified drift. It ranges in thickness from 10 to 30 m and comprises a large portion of the Singhampton Moraine. This till is the most regionally extensive below the escarpment.

West of the escarpment, the Wentworth Till forms a hummocky till plain that extends from Acton in the southwest, to the headwaters of Caledon Creek in the northeast. The Wentworth Till has a sandy to silty-sand matrix, and ranges in thickness from 1 m up to 15 m on the Paris Moraine.

The Port Stanley Till is present throughout much of the Town of Erin and Town of Caledon. It is described as stony sandy-silt till, and it forms part of the Guelph Drumlin field. It ranges in thickness from 1 to 30 m.

Fine-grained tills (e.g., silt to silty clay tills), include:

- Tavistock Till; and
- Halton Till.

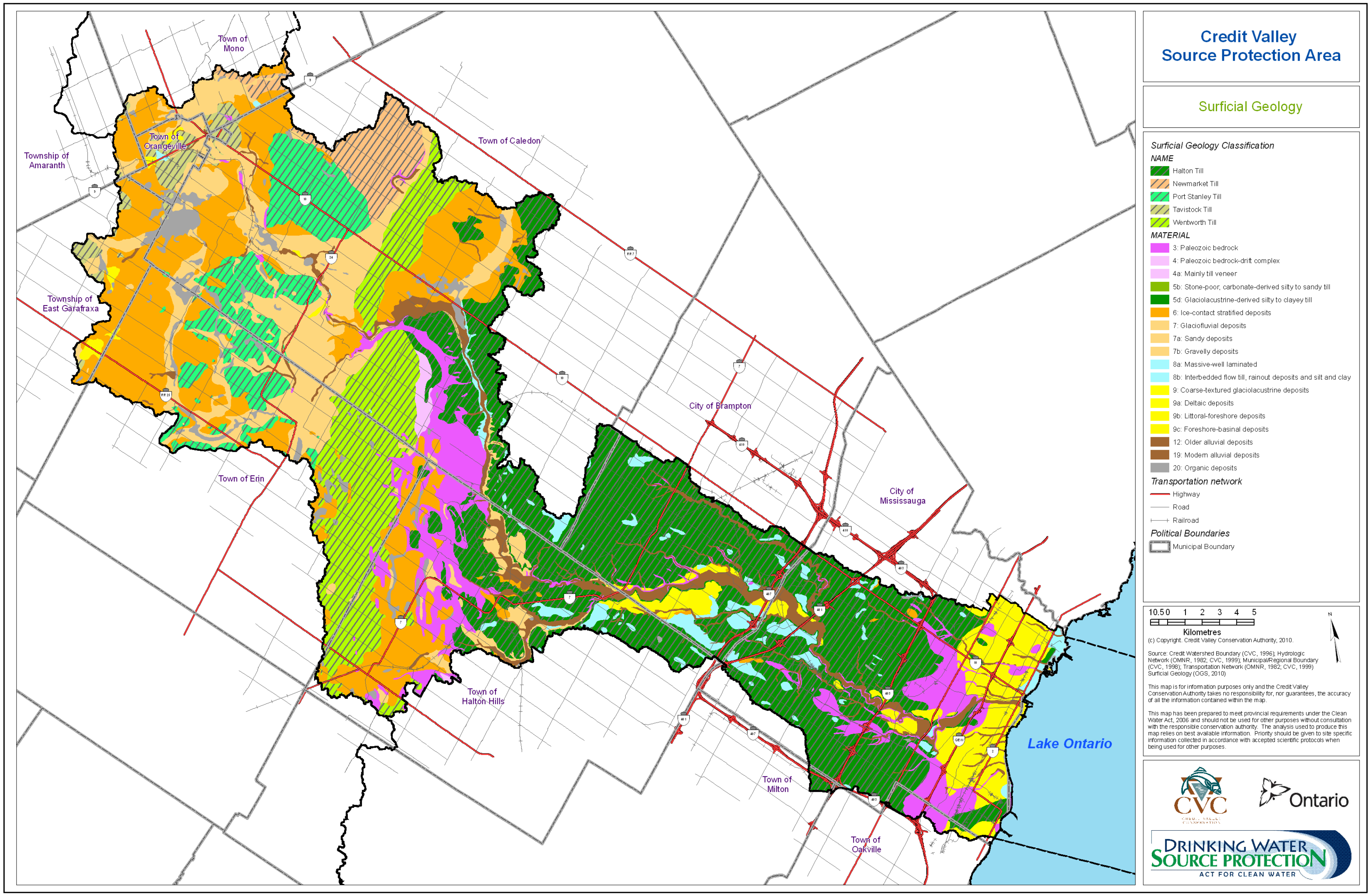


Figure 3.5: Surficial Geology

The Tavistock Till is found in the most northwestern part of the CVSPA, and has a thickness typically less than 12 m. It is described as having a clayey silt matrix, and, where it overlies the Orangeville Moraine, the till contains thin interbeds of sand.

The Halton Till is the most prevalent till in the southern portion of the watershed, east of the Niagara Escarpment. The Halton Till forms a gently rolling till plain from the lower slopes of the escarpment to the former Lake Iroquois shoreline. This distinctively maroon to red clay to clayey silt till overlies Queenston Formation Shale bedrock, and near the Escarpment is commonly interbedded with fine-grained sand lenses. The Halton Till and the Wentworth Till are the youngest tills in the watershed, and they typically overlie coarse-grained materials associated with the Mackinaw Interstade (also known as the Oak Ridges Moraine Equivalent).

Ice-Contact Stratified Drift

Glaciofluvial deposits are deposits laid down by water flowing from, or beneath, a glacier. Within the watershed, glaciofluvial deposits include ice-contact stratified drift, glacial outwash, and meltwater channel deposits.

Ice-contact stratified drift within the watershed is associated with the Orangeville Moraine as well as the Oak Ridges Moraine. These two interlobate moraines are composed of stratified sand, silt, and gravel, and they exhibit a relief of over 50 m above the surrounding till plains.

Outwash Sands and Gravels

Large volumes of sediment-laden meltwater flow from the front of a retreating glacier depositing high-energy coarse-grained sediment termed glacial outwash. Outwash is commonly focussed along channels or topographic lows leading to the formation of outwash or meltwater channels.

Several meltwater channels have been identified and are described, including:

- The Hillsburgh Channel consisting of up to 7 m of sand and gravel that were deposited between Caledon Lakes and Hillsburgh along the eastern limb of Orangeville Moraine;
- The Orangeville to Alton channel, which is filled with 8 to 15 m of gravel and sand;
- The Black Creek and Silver Creek Channel that extends to Georgetown;
- The Caledon Meltwater Channel extending from Caledon through Cataract to Erin; and
- The Caledon East Meltwater Channel, which runs from Albion to Inglewood then reappears at Terra Cotta and extends to Glen Williams.

Glaciolacustrine Deposits

Glaciolacustrine deposits refer to sediments that were laid down in glacially derived lakes. These deposits include the thin veneer of clay, silt, and fine sand deposited east of the escarpment and, to a minor extent, in the Orangeville Moraine area. These deposits are generally thin and fill in the topographic lows on the till plains.

Glaciolacustrine sediments are interpreted to infill the base of the Caledon East Meltwater Channel/buried valleys in the East Credit subwatershed.

Recent Alluvial Deposits

The youngest deposits are the recent sediments that are actively being deposited within stream and river valleys and their floodplains across the CVSPA. These deposits are composed of a mixture of silt, sand, gravel, and clay that has been eroded, transported, and subsequently deposited.

3.3.4 Hydrogeologic Units

Units composed of primarily coarser grained materials (e.g., sands, gravels, and silts) are referred to as aquifers, and units composed of lower permeability units (e.g., clay, till) are referred to as aquitards.

These units are not grouped solely on lithology, as fracturing or weathering may increase the ability of a low permeability unit such as clay or shale to transmit modest amounts of groundwater such that it may be considered a weak aquifer.

Twelve hydrostratigraphic units are identified in terms of their geology and are shown on **Table 3.1**.

Table 3.1: Hydrostratigraphy of the CVSPA

Hydrostratigraphic Unit Name	Zone	Stratigraphic Units Represented
Surficial sediments	Overburden	Meltwater channel deposits; modern alluvium; peat and organic bog material
Upper (younger) Till Aquitard	Overburden	Halton, Wentworth, and Newmarket Tills
Upper (younger) Aquifer	Overburden	Ice-contact drift, Mackinaw interstadial sand and gravel (ORM equivalent sediments)
Intermediate (older) Till Aquitard	Overburden	Port Stanley, Tavistock, and Northern Till (Catfish Creek Till)
Intermediate Aquifer	Overburden	Sand/gravel outwash (Thorncliffe or equivalent)
Basal Aquitard	Overburden	Fine-grained glaciolacustrine valley infill sediments (Sunnybrook Drift or equivalent)
Basal Aquifer	Overburden	Coarse-grained (glacio) fluvial valley infill sediments (Scarborough Sands or equivalent)
Weathered Bedrock	Bedrock Contact zone	Contact zone, upper 3–5 m of weathered bedrock outside valleys
Guelph/Amabel Aquifer	Bedrock	Guelph/Amabel Formations
Cabot Head Aquitard	Bedrock	Cabot Head Formation
Manitoulin/Whirlpool Aquifer	Bedrock	Manitoulin/Whirlpool Formations
Queenston Aquitard	Bedrock	Queenston Formation
Georgian Bay Aquitard	Bedrock	Georgian Bay Formation

The Intermediate Aquifer (Thorncliffe or equivalent), Basal Aquitard (Sunnybrook or equivalent), and Basal Aquifer (Scarborough or equivalent) are collectively referred to, by the Oak Ridges Moraine Groundwater Program (ORMGP), formerly YPDT Groundwater Management Group and the Geological Survey of Canada (GSC), as the “Lower Sediments” (Sharpe and Russell, 2004). These units are observed only in a few very deep boreholes that penetrate the deepest portions of the buried valley.

Aquifer Complexes

Most groundwater abstraction occurs in the middle and upper zones of the CVSPA. Singer and others (2003) developed a summary of the aquifer complexes from which groundwater supplies are derived, as shown in **Table 3.2**.

Table 3.2: Major Aquifer Complexes in the CVSPA (Singer et al., 2003)

Aquifer Complex	CVSPA Zone	Aquifer Material	Description
Orangeville Moraine Aquifer	Upper	Gravel, sand, minor silt	Glaciofluvial gravel, glaciolacustrine sand, and silt
Hillsburgh Channel	Upper	Outwash gravel	Meltwater or tunnel channel; on southern limb of Orangeville Moraine
Alton Channel	Upper	Sand and silty gravel to stratified gravel	Meltwater or tunnel channel; on northeastern limb of Orangeville Moraine
Caledon Meltwater Channel	Upper	Gravel and sand	Meltwater or tunnel channel; traverses the rim of Escarpment from Caledon to Erin; broad valley
Black–Silver Creek Channel	Middle	Sand and gravel	Meltwater or tunnel channel; water supply for Acton and Georgetown
Caledon East Meltwater Channel	Middle	Fine to medium sand	Meltwater or tunnel channel; extends from Albion to Inglewood
Lake Peel Deltaic Aquifer	Lower	Fine sand and silt	Extends from Highway 7 to Churchville; minor aquifer
Contact Zone—Weathered Bedrock	Entire Watershed	Fractured bedrock and overlying coarse material	Upper 3–5 m of fractured bedrock
Guelph-Amabel	Upper/Middle	Dolostone	Paleozoic bedrock

Several of the aquifer complexes are shallow and may be more susceptible to surficial contamination than other aquifers. These shallow aquifers include the meltwater channel deposits (Hillsburgh, Alton, Caledon, and Caledon East Meltwater Channels) as well as the Lake Peel Deltaic Aquifer.

The aquifers within the Black–Silver Creek Channel are the aquifers associated with the buried bedrock valley that runs from Acton to Georgetown. It is interpreted that these aquifers include the Mackinaw interstadial sediments, and potentially some of the “Lower Sediments” aquifers (e.g., Thorncliffe Formation or Scarborough Sands equivalent sediments) outlined in **Table 3.2**.

3.4 SURFACE WATER FLOW SYSTEM

Long-term monitoring of streamflow is recorded at ten Water Survey of Canada (WSC) HYDAT locations in the CVSPA, listed in **Table 3.3**. Seven of these gauges are still in operation, of which three (Cataract, Melville, Silver Creek/Norval) have been in operation for over 30 years. The Cataract gauge has been operating since 1912 and represents one of the oldest stations in southwestern Ontario.

Table 3.3: Stream Gauge Summary—CVSPA

Subwatershed	Station	Location	Status	Gross Drainage area (km^2)	Period of record (Regulation)
18	Cataract	Cataract	Active	205	1912–Present
9	Erindale	Erindale	Discontinued	795	1945–1993
11	Silver Creek/Norval	Norval	Active	127	1960–Present
19	Melville	Orangeville	Active	62.2	1967–Present
20	Boston Mills	Boston Mills	Active	402	1982–Present
17	Shaw's Creek	Above Alton	Discontinued	59.5	1983–1991
15	West Credit/Erin	Above Erin	Active	32.3	1983–Present
10	Black Creek	Below Acton	Active	615	1988–Present
12	Credit River/Norval	Norval	Active	18.9	1987–Present
9	Mississauga Golf Course	Mississauga	Discontinued		1988–2003

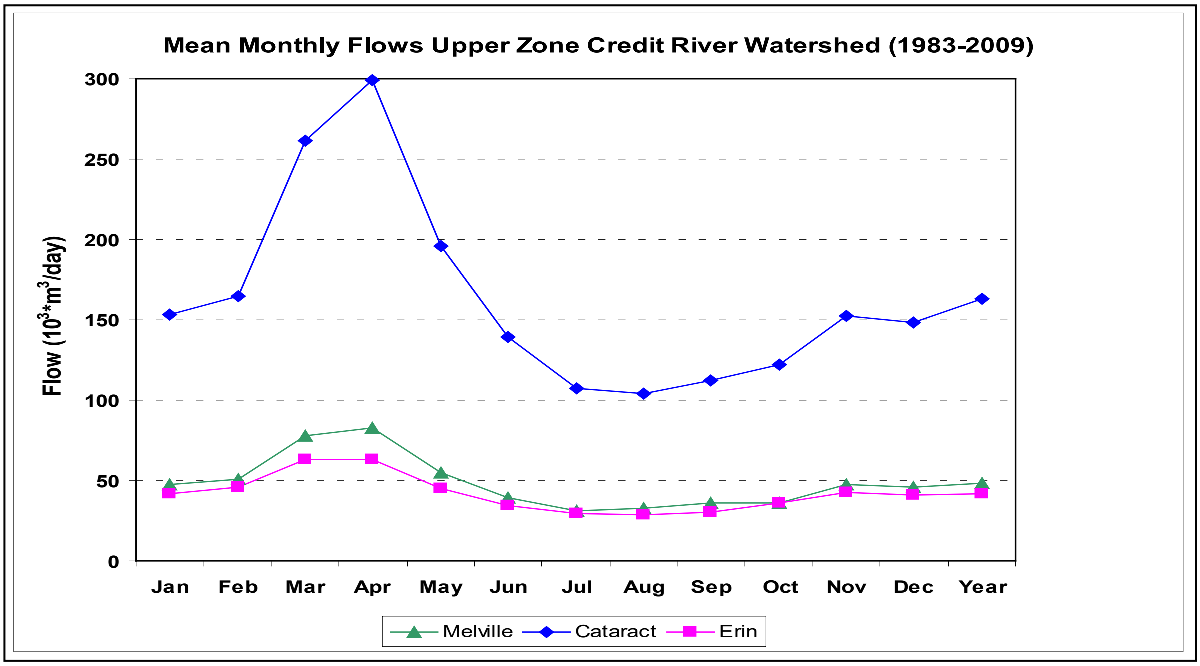
3.4.1 Upper Zone

The upper zone of the CVSPA is composed of till plains, moraines, and glacial spillways. Soils have a high permeability that permit a significant amount of infiltration, which in turn contributes to the regional groundwater system. The rolling topography generally provides well-drained conditions; however, in some areas natural outlets are poor and drainage is primarily through infiltration. In addition, the upper CVSPA and escarpment areas have significantly more vegetative cover than the lower watershed, leading to higher infiltration and snow storage conditions.

The most significant hydrologic feature in the upper CVSPA is the Island Lake Reservoir and control structure, which forms the headwaters of the Credit River and is located east of the Town of Orangeville. The reservoir was created in 1967 with the construction of two dams to augment low flows in the headwaters of the Credit River. The South Dam controls water flow into the Credit River, augmenting and improving the water quality in the upper reaches of the river.

Based on the historical streamflow data in the upper CVSPA, there is a cyclical trend to the mean monthly flow data, with the peak flows occurring between March and April, and the low flows occurring between June and September. This is primarily due to a combination of snowmelt and rainfall, or rainfall on frozen ground conditions. In addition, the mean monthly flow data vary on a monthly basis. Runoff rates in the upper zone are lower than runoff rates in the lower watershed due to higher infiltration rates, snow storage conditions, increasing drainage areas, and changing land uses.

Historically, the mean annual streamflow along the Upper Credit River is distributed as follows: 51.5 metre^3/day at the Melville station, 43.2 x 10^3 metre^3/day at the Erin station, and 155.5 x 10^3 metre^3/day at the Cataract station. **Figure 3.6** shows the time series of annual maximum flows at the Melville, Cataract, and Erin Branch gauges for the period from 1983 to 2009.



(Water Survey of Canada)

Figure 3.6: Mean Monthly Flows, Upper Zone Credit River Watershed CVSPA (1983–2009)

More than 75% of the annual maximum flows in the upper zone occur during the "spring freshet" in the months of February, March, and April, when flood flow results from snowmelt or a combination of rain and snowmelt on frozen ground conditions. In the last 10 years, 40% of the highest flows have occurred in late November, December, and January when early winter thaws and significant rainfalls contribute to high flows. Flood flows in the late summer and early fall periods are typically caused by tropical storm systems when the infiltration capacity for most soils in the area is reduced to 25 to 35% of their mid-summer values. Here, the runoff potential is at its highest without a snowpack.

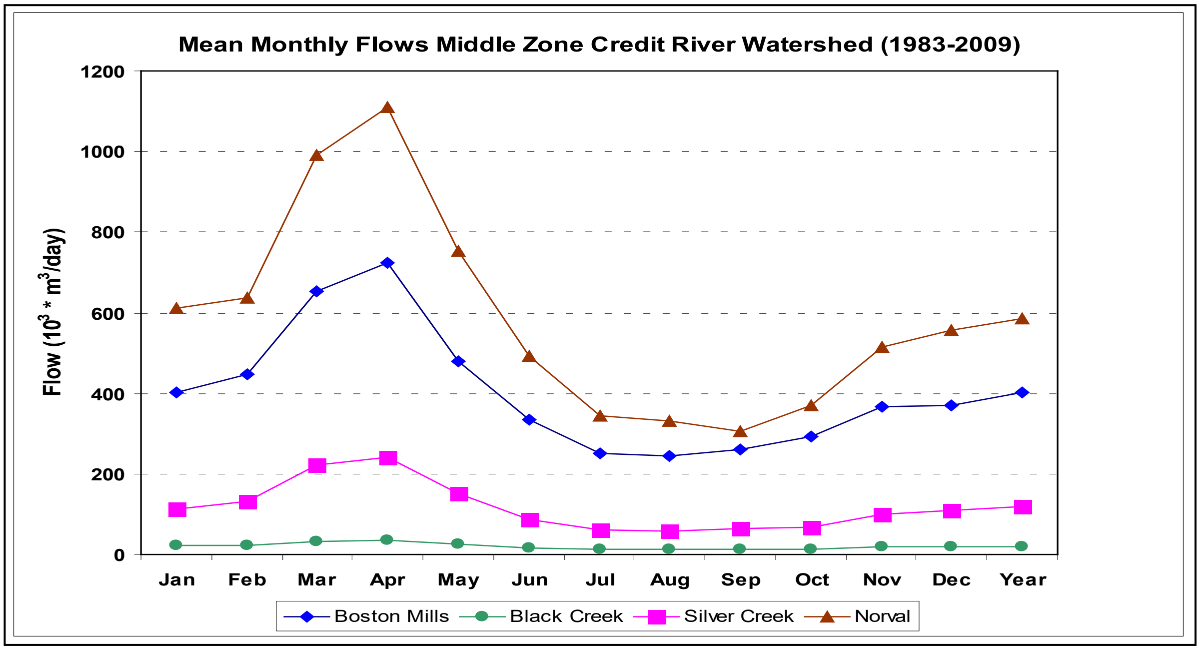
3.4.2 Middle Zone

Steep slopes and significant areas of rock outcrops and shallow soil conditions characterize the Niagara Escarpment. The topography leads to relatively high runoff volumes and velocities; however, the high forest cover tends to act against this influence by slowing runoff and increasing infiltration.

The Boston Mills station is representative of the streamflow conditions along the Niagara Escarpment or middle zone. The Norval station is CVC's southernmost stream gauge and is representative of the streamflow conditions for both the upper and middle watershed.

The Credit River West Branch at Norval station is situated at the mouth of Silver Creek before it outlets to the Credit River, and is representative of the flows from Black and Silver creeks' major tributaries of the Credit River watershed. Approximately a third of the flows at Norval are representative of the flows coming from Silver Creek.

Historically, the mean annual streamflow along the Niagara Escarpment is distributed as follows: 406 x 10^3 $metre^3$/day at the Boston Mills station, 120 x 10^3 $metre^3$/day at the Silver Creek station, 19 x 10^3 $metre^3$/day at the Black Creek below Acton station and 587 x 10^3 $metre^3$/day at the Norval station **(Figure 3.7)**.



(Water Survey of Canada)

Figure 3.7: Mean Monthly Flows Middle Zone Credit River Watershed CVSPA (1983–2009)

More than 75% of the annual maximum flows in Silver Creek occur during the "spring freshet" in the months of February, March, and April, when flood flow result from snowmelt or a combination of rain and snowmelt on frozen ground conditions. In the last ten years, 40% of the highest flows have occurred in December and January, when early winter thaws and significant rainfalls contribute to high flows. Flood flows in the late summer and early fall periods are typically caused by tropical storm systems when the infiltration capacity for most soils in the area is reduced to 25 to 35% of their mid-summer values. Here, the runoff potential is at its highest without a snowpack.

3.4.3 Lower Zone

The lower zone is composed of two primary physiographic regions—Peel Plain and Iroquois Plain. Both have low infiltration characteristics in comparison to the upper watershed. The Iroquois Plain, however, does contain some localized sandy soil conditions. The topography is relatively flat, leading to longer runoff times.

The lower zone includes portions of the City of Brampton and the City of Mississauga and is predominantly made up of urbanized areas with a high level of imperviousness, resulting in higher peak flows. This point was further verified through a site frequency analysis of two streamflow gauges—Norval and Erindale. The Erindale gauge was discontinued in 1993, although it was in operation since 1945 and contains over 45 years of data.

Through a site frequency analysis, the 100-year peak flow rate at Norval was estimated to be 139 metre^3/second in comparison to the Erindale gauge, which was estimated to be 333 metre^3/second, three times the flow at Norval.

Furthermore, as development proceeds upstream along the watershed, streamflow is generated as a result of rainfall-runoff events, as opposed to rainfall-snowmelt events, in which case the maximum runoff will occur during the months of March and April.

3.5 GROUNDWATER FLOW SYSTEMS

The regional groundwater flow system is controlled primarily by topographic relief and the ability of the subsurface geologic materials to transmit water. Precipitation falling in areas with high permeability surficial sediments will infiltrate to the water table and flow within the groundwater system at a greater rate than precipitation falling on soils with low permeability. Groundwater flows both laterally and vertically depending on soil and rock permeability and the presence of boundaries (i.e., streams, lakes) that can either add or remove water from the groundwater system. High permeability geologic units such as sand and gravel are typically dominated by rapid lateral movement of groundwater, while low permeability units such as silt and clay are typically dominated by slow vertical movement of water.

Groundwater moves from areas of high hydraulic head to areas of low hydraulic head, generally following topographic relief, unless impeded by geologic conditions or local changes in relief such as stream valleys that intersect the water table. In areas where rivers or streams intersect the water table, groundwater will discharge into the stream or river and contribute baseflow to the surface water feature.

3.5.1 Groundwater Flow

Shallow Groundwater Flow

The shallow water contours generally follow topographic relief, with the highest water level elevations located in the northwest, and a general declining trend in water level elevations towards the escarpment and Lake Ontario. Notable exceptions include the local topographic lows of the West Credit River and the main branch of the Credit River above the forks of the Credit where shallow groundwater flows towards these surface water features.

The water table declines dramatically (over 100 metre) across the slope of the Niagara Escarpment, following the ground surface topography. Below the escarpment, groundwater flow is generally southeastward towards Lake Ontario, but is strongly influenced by the Credit River (and the underlying buried bedrock valley).

Groundwater discharge (see p. 3-24) occurs along the face of the escarpment and forms the headwaters of several tributaries that feed the main Credit River between Inglewood and Georgetown. Water level elevations decrease to the southeast towards Lake Ontario but are strongly influenced by the buried bedrock valley system beneath the Credit River. The groundwater elevation (water table) in the overburden is shown in **Figure 3.8**.

In several areas, the escarpment is a steep face where the overburden above the escarpment is not hydraulically connected to the overburden units below the escarpment. In these areas, the water level is representative of the shallow bedrock water levels and not the overburden water level elevations.

Deep Groundwater Flow

The deep groundwater level is representative of water levels within deeper overburden or within bedrock, depending on the thickness of overburden. Deep groundwater flow generally mimics bedrock topography and the groundwater flow in the shallow overlying system. Above the escarpment, the highest water levels occur where bedrock elevations are highest—i.e., beneath the crest of both the Orangeville and Paris Moraines—so the corresponding deep groundwater level surface elevations beneath these moraines are also higher than the surrounding areas on the flanks of the moraines. In the northwestern portion of the CVSPA, where the elevation of the bedrock surface is higher than in other areas, water levels in the bedrock reach up to 475 metres above sea level (mASL). The groundwater elevation in the bedrock is shown in **Figure 3.9**.

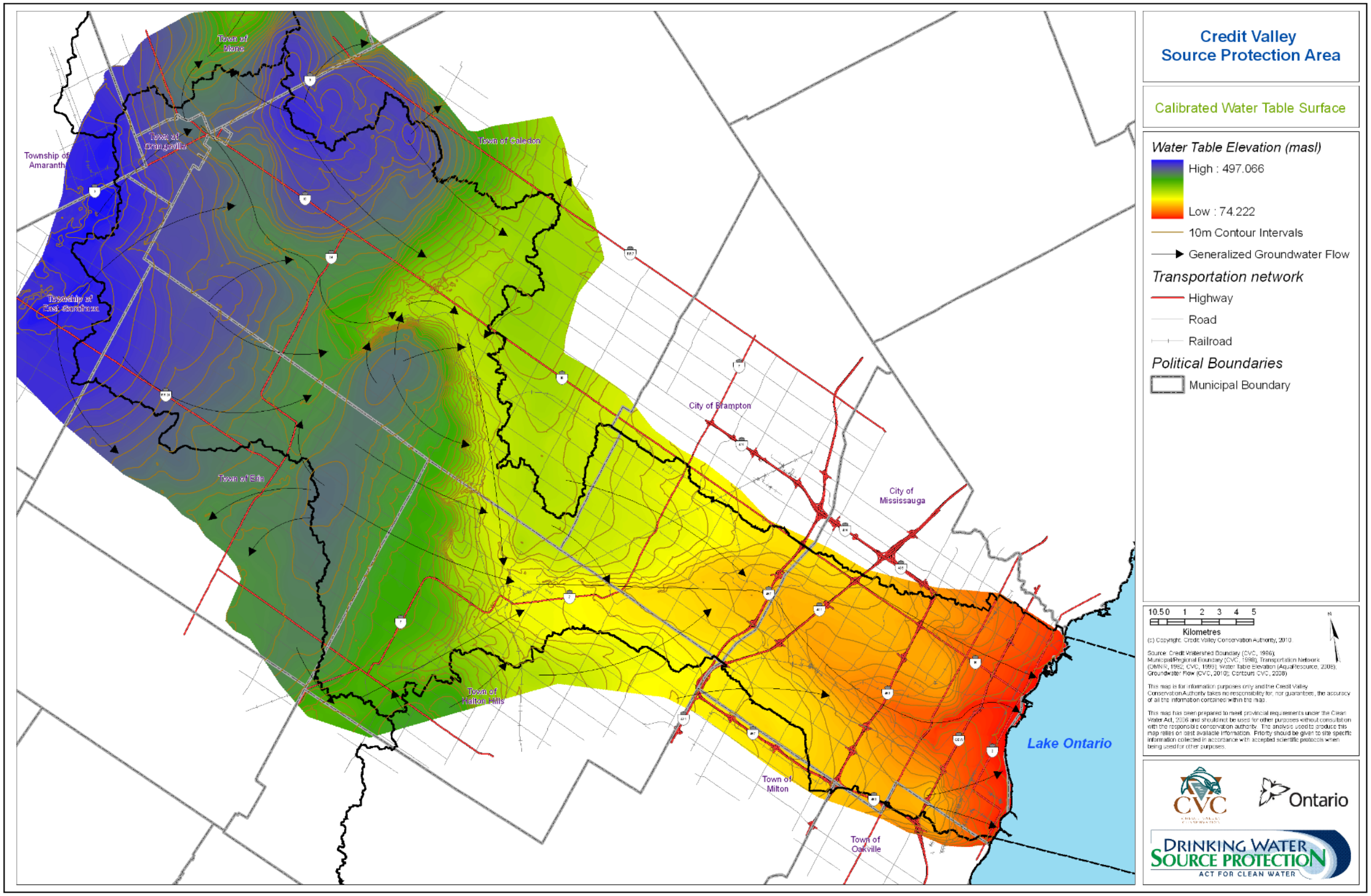


Figure 3.8: Calibrated Water Table Surface

3.5.2 Interaction between Groundwater and Surface Water (Recharge and Discharge)

The interaction of shallow groundwater with surface water drainage features (such as streams and stream channels) is reflected in the water table surface. When surface water drainage features are projected onto the study area, they coincide with the deflection and closer spacing of water table contours.

Wetlands

There are 45 provincially and 31 locally significant wetland complexes in the CVSPA jurisdiction. Most are either swamps or marshes and are described below.

Upper Zone

Wetlands make up a total of 11% of this zone. The majority have been classified as swamps (51 km^2) or marshes (10.2 km^2) though a small proportion (1.02 km^2) of bog habitat has also been identified. This zone includes:

- The Orangeville Wetland Complex is situated within the Orangeville subwatershed (Sub 19). It is primarily marsh (92%) with portions of swamp (8%) and is associated with the Island Lake Reservoir which supports a significant warmwater fishery.
- The Caledon Lake Wetland Complex is within the Shaw's Creek subwatershed (Sub 17). It is swamp dominated (91%) and supports rare flora and vegetation communities. Other significant features include a large kettle lake (0.4 km^2), and a series of smaller lakes and ponds that formed as a result of marl extraction.
- The West Credit Wetland Complex occupies the lowlands of the West Credit subwatershed (Sub 15) and extends from west of the village of Alton, through the villages of Hillsburgh and Erin. It is dominated by eastern white cedar and poplar swamps (87%). These wetlands play an important role in the maintenance of the self-sustaining population of heritage brook trout of the Credit River watershed.
- Eramosa-Blue Springs Wetland Complex is a large wetland complex (1.7 km^2) that is shared between the CVSPA and the GRSPA. It represents one of the best examples of tamarack–cedar swamps with boreal species.

Middle Zone

The Ballinafad Ridge Wetland Complex extends from west of Belfountain to just north of Acton. It forms the headwaters of the Black Creek and Silver Creek subwatersheds (Subs 10 and 11) and contributes groundwater to the West Credit River. It contains all four wetland types: swamp, marsh, fen, and bog.

- Many of the wetlands of the Ballinafad Ridge Wetland Complex have formed between the hummocks of the moraine and others are associated with groundwater discharge at the base of the moraine.
- The Caledon Mountain Wetland Complex supports a wide diversity of vegetation communities, numerous locally rare plants, and the nationally threatened Jefferson salamander. The complex also serves an important hydrologic function, as groundwater discharges into several water courses and swales that flow eastward from the escarpment towards the Credit River.
- Little Credit River Wetland Complex is situated in the East Credit subwatershed (Sub 13) and is comprised of both swamps and marshes.

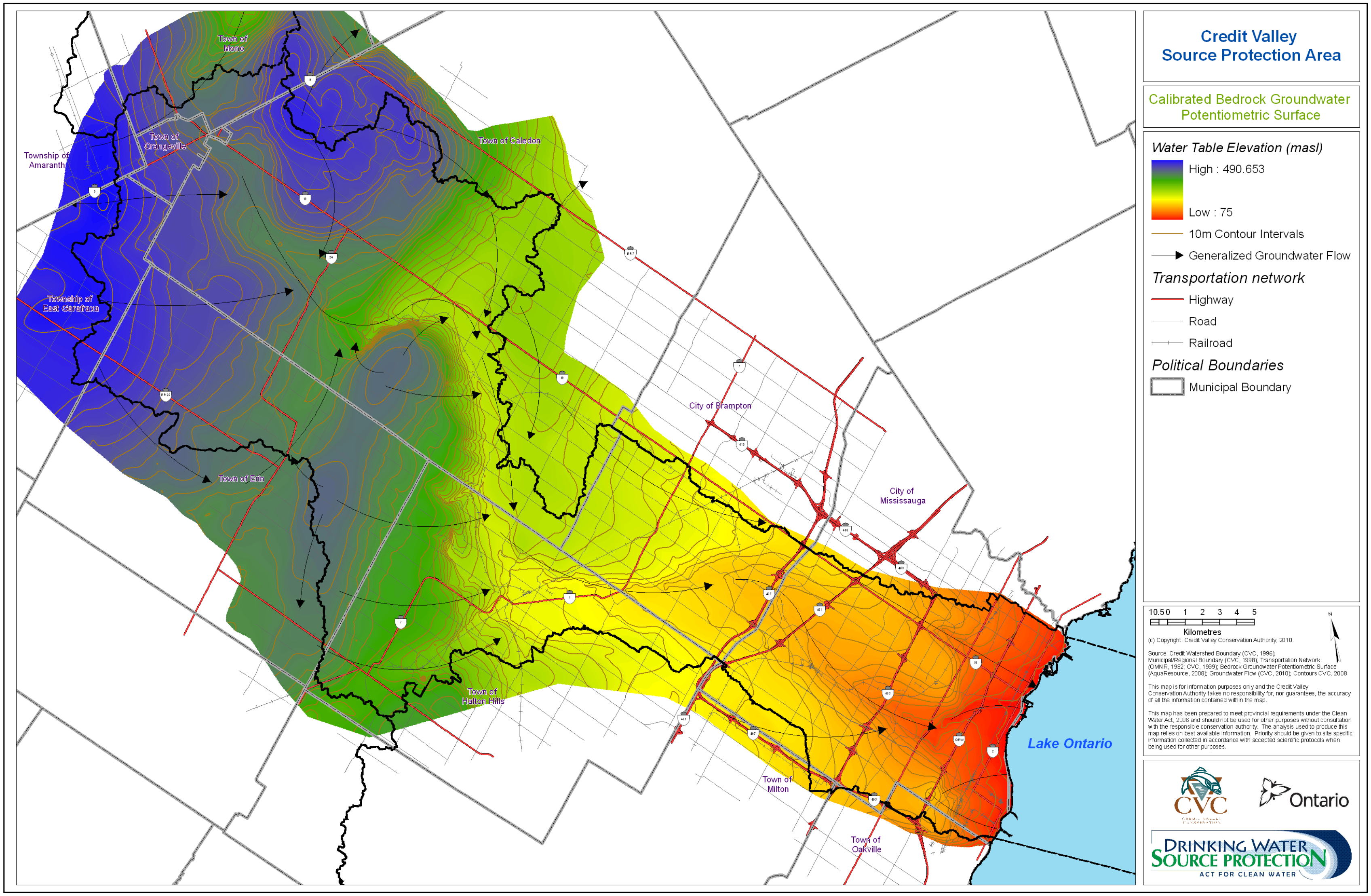


Figure 3.9: Calibrated Bedrock Groundwater Potentiometric Surface

Lower Zone

- The Churchville-Norval Wetland Complex is largely associated with the floodplain of the Credit River and includes a number of old abandoned river channels.
- The complex is comprised of marsh (67%) and swamp (33%), is predominantly riverine and is one of the few remaining wetlands on the Peel Plain.

Groundwater Recharge

The influences of topography, geology, and climate on groundwater recharge are evident when looking at the relative contributions from the different areas of the CVSPA. The greatest amount of recharge occurs in the upper zone, where coarse-grained moraine sediments lie at ground surface. Significant local recharge occurs above the escarpment along the Orangeville, Paris, and Oak Ridges Moraine. Recharge is also considered significant along the meltwater channels, where there is coarse-grained sediment at ground surface that permits the downward flow of water to deeper aquifers. Areas where the bedrock formations (Guelph/Amabel/Manitoulin formations) outcrops at ground surface, or lie beneath a thin layer of overburden, are also considered to be potentially significant recharge areas.

Although there are a few areas in the lower zone of the CVSPA where bedrock outcrops at surface, the fine-grained nature of the shale bedrock reduces the potential for significant groundwater recharge. Below the escarpment there is limited recharge to the overall groundwater system given the lower permeability of the Halton Till and associated glaciolacustrine silts and clays. There is also little topographic relief present to “drive” the groundwater flow system. Groundwater recharge occurring below the escarpment is primarily local and restricted to coarse-grained deposits in the Georgetown and Brampton areas. Groundwater recharge in the CVSPA is shown in **Figure 3.10.**

Groundwater Discharge

A high proportion of flow in the Credit River is represented by groundwater discharge contributions. The influences of topography, geology, and climate on the flows along the length of the Credit River are also evident when looking at the relative contributions from the different parts of the watershed. The mean annual flow and estimated average annual baseflow for nine of the ten HYDAT stations are presented in **Table 3.4**.

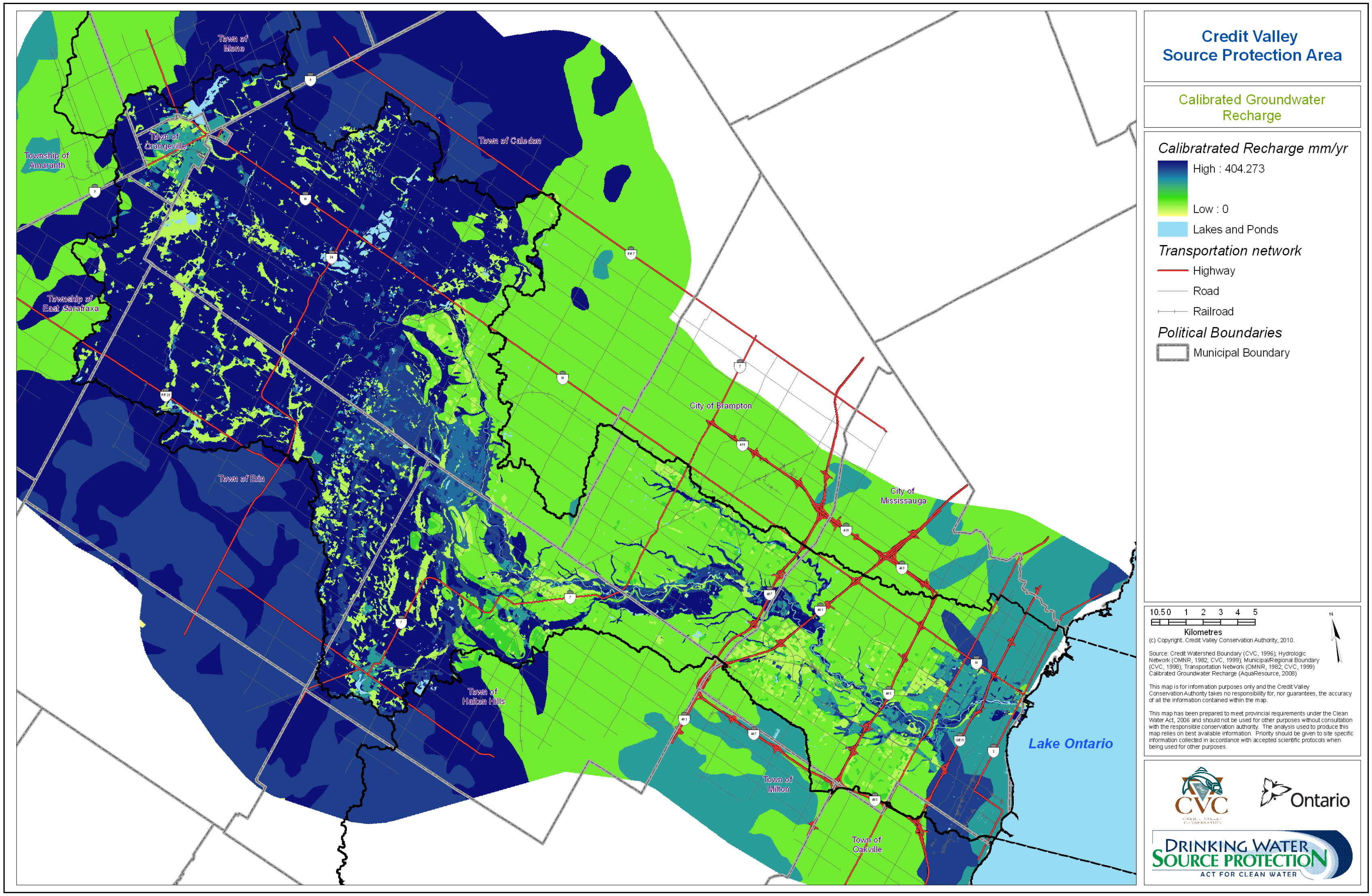


Figure 3.10: Calibrated Groundwater Recharge

Table 3.4: Summary of Mean Annual Flow and Baseflow at WSC Gauges (1990—2000)

Gauge	Description	Watershed Zone	Average Flow (m^3/s)	Average Est. Baseflow (m^3/s)	Baseflow/ Mean Flow
02HB001	Cataract	Upper	1.83	1.36	75%
02HB002	Erindale	Lower	9.59	5.90	62%
02HB008	Silver Creek/Norval	Middle	1.28	0.80	63%
02HB013	Melville	Upper	0.54	0.37	69%
02HB018	Boston Mills	Middle	4.5	3.26	73%
02HB019	Shaws Creek	Upper	0.78	0.55	71%
02HB020	West Credit/Erin	Upper	0.47	0.33	71%
02HB024	Black Creek	Middle	0.24	0.16	67%
02HB025	Credit River/Norval	Middle	6.61	4.66	71%
02HB029	Credit R. at Streetsville	Lower	Gauges were installed in fall of 2005. Rating curves are currently being developed.		
02HB030	Cooksville Creek, Mississauga	Lower			
02HB031	West Credit River in Hillsburgh	Upper			

The table demonstrates the relative importance of groundwater discharge to streamflow in the upper areas of the CVSPA as compared to the lower areas. At the Cataract gauge (02HB002), 76% of the mean annual flow is attributed to baseflow, while downstream at Erindale (02HB002) only 62% of the mean annual flow is attributed to baseflow. These trends are expected given our understanding of elevated recharge rates in the upper compared to the lower areas of the CVSPA.

The Credit River and its tributaries are ecologically important as self-sustaining coldwater fisheries. Groundwater discharges to the river and provides a significant portion of streamflow, particularly in the upper and middle portions of the watershed. Discharge areas are commonly observed just west of the escarpment, along the flanks of moraines (e.g., Orangeville Moraine and Paris Moraine). Significant discharge areas are also associated with the Niagara Escarpment, where wetland complexes are observed to reside along the main Credit and West Credit rivers. Below the escarpment, south of Georgetown, the data suggests that baseflow is largely derived from water that discharged to the river in the upper zone. Groundwater discharge in the CVSPA is shown in **Figure 3.11.**

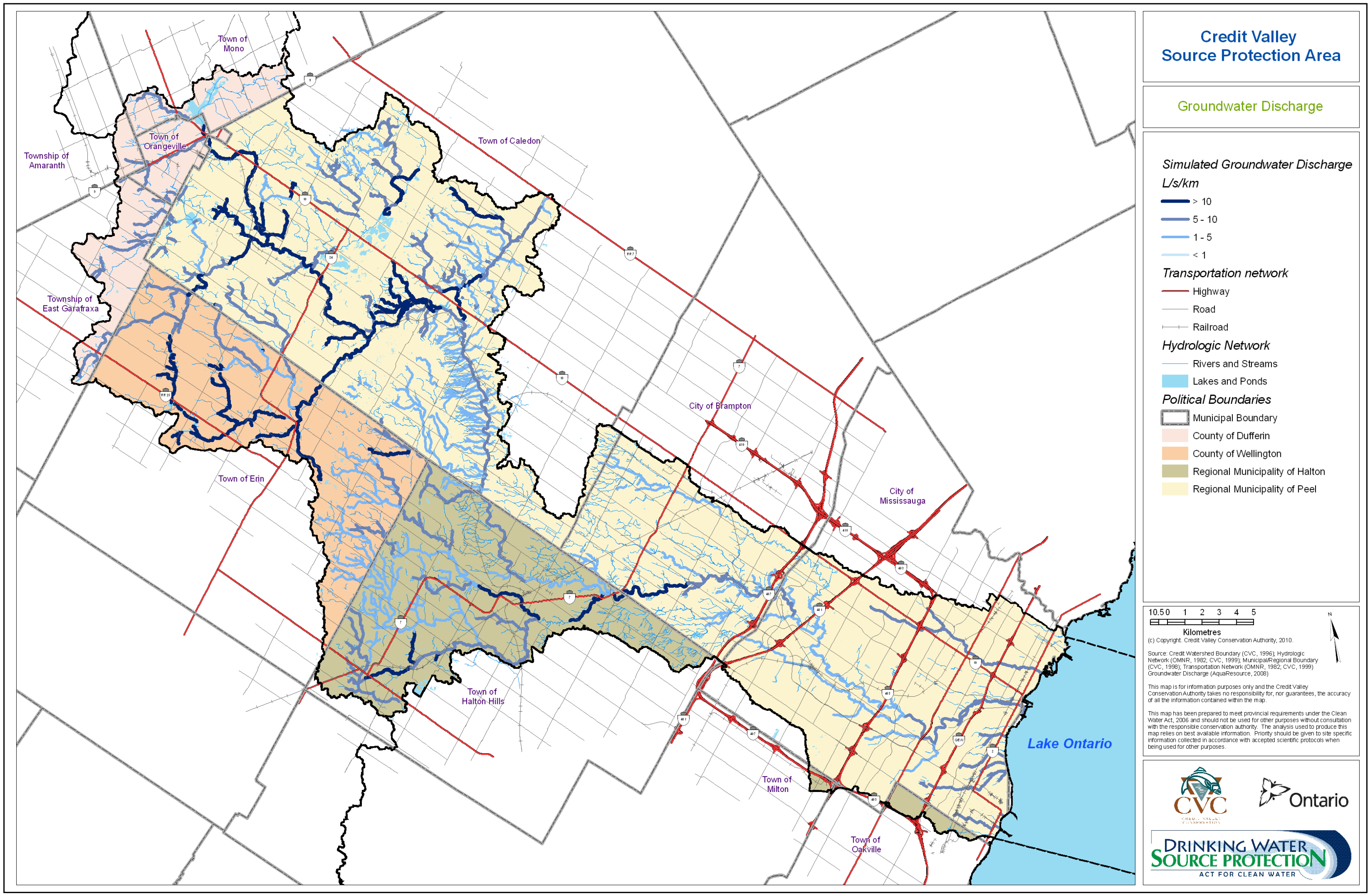


Figure 3.11: Groundwater Discharge (CVSPA)

3.6 CLIMATE

3.6.1 Historical Monitoring

The climate of Southern Ontario is characterized as having warm summers, mild winters, a long growing season, and usually reliable precipitation. Long-term monitoring of meteorological quantities has occurred within and surrounding the CVSPA for more than 100 years. Historical data are primarily available from Environment Canada's Meteorological Services of Canada.

Several climate stations have been used to characterize climate variability across the CVSPA:

- The Toronto Lester B. Pearson International Airport weather station is representative of the climatic conditions for areas located in the lower watershed region. This station contains close to 40 years of data. Long-term data collected from this station were used to support model calibration and scenarios in the Tier 2 Water Budget Study.
- The Orangeville MOECC station is representative of the climatic conditions in the Upper Watershed. The station contains over 40 years of continuous daily data. Long-term data collected from this station were used to support model calibration and scenarios in the Tier 2 study.
- The Guelph Turf Grass Institute (GTI) is representative of climatic conditions in the vicinity of Subwatersheds 10 and 11 in the western portion of the CVSPA. This region is characterized by having higher precipitation on the western side of the Niagara Escarpment. Long-term data collected from this station were used to support model calibration and scenarios in the Tier 2 study.
- The Shand Dam station is representative of the climatic conditions for the upper watershed. The Shand Dam is located northwest of the watershed and contains over 38 years of recorded data.
- The Georgetown Water Pollution Control Plant is representative of the climatic conditions in the middle watershed region, and it contains over 40 years of climate data.
- The Region of Peel operates a climate station at the Caledon Landfill to measure rainfall, snowfall, temperature, and solar radiation. These data have not been taken through a quality control process similar to that followed for Meteorological Services of Canada stations and, therefore, were not used to support the CVC's water budget efforts.

3.6.2 Climate and Meteorological Characteristics

The mean annual precipitation in the CVSPA is 850 mm, of which 15% appears as snowfall (or 125 centimetres in depth). The greatest precipitation amounts occur in the northern part of the watershed south of Erin, due in part to influence of the Niagara Escarpment on "lake effect" storms originating over Lake Ontario. Lake effect precipitation originating from Lake Huron and Georgian Bay are also possible, but they influence totals in the northern part of the watershed (CVC, 2003).

The mean annual evapotranspiration in the CVSPA is about 540 millimetres. This has been verified from water balance analyses using observed streamflow data. The area has an annual frost-free period of 148 days, with a growing period of about 202 days. The mean annual air temperature is 6.0°C; the mean daily temperature in January is about -6.4 °C and 20.3 °C in July (CVC, 2003).

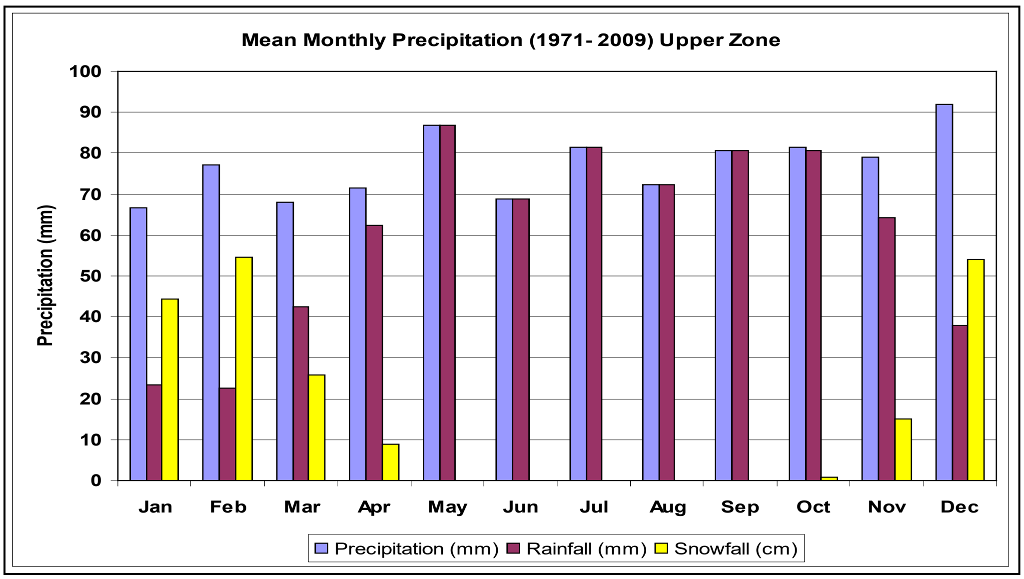
Total precipitation and air temperature vary on a monthly and seasonal basis. Total precipitation and air temperature also vary between the upper, middle, and lower portions of the SPA. Variances in climatic conditions can be attributed to the shape and size of the watershed as well as the existence of the Niagara Escarpment.

The following sections provide detailed descriptions of the climatic conditions in these areas.

Upper Zone

The mean annual precipitation for the upper zone is about 892 mm, 18% of which appears as snowfall (or 160 cm in depth). These totals are distributed in a fairly even pattern in a north-south direction. However, the greatest precipitation totals occur in the Orangeville area, due in part to some "orographic" influence of the Niagara Escarpment on "lake effect" rain storms originating over Lake Ontario.

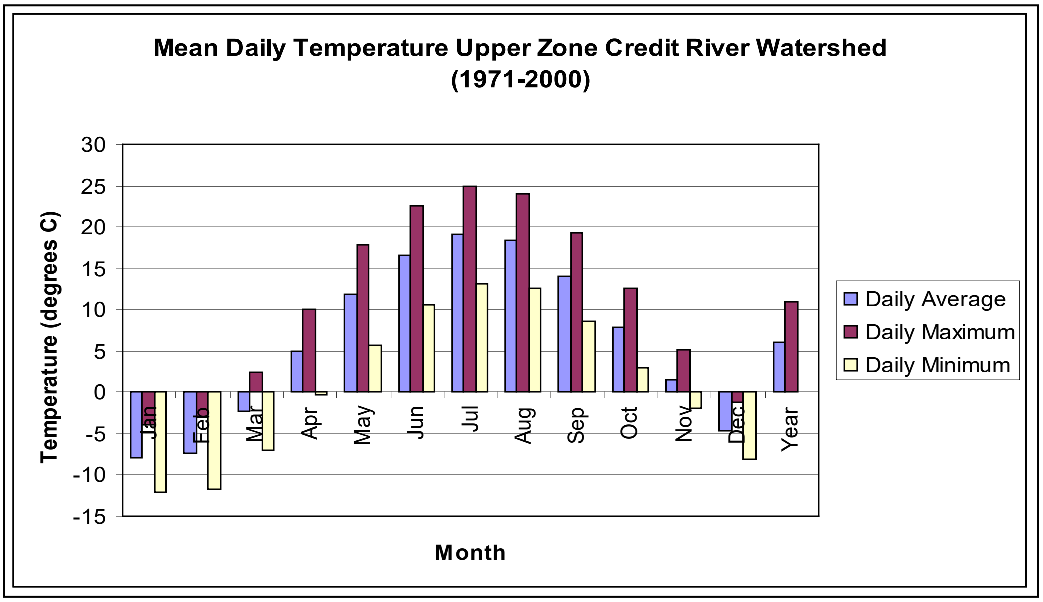
The total precipitation is distributed such that August, September, and November are the wettest months, and January and February are the driest months **(Figure 3.12)**. Frozen ground conditions are persistent between mid-November and late March, yielding high runoff potential for all soil types.



(Meteorological Services Canada)

Figure 3.12: Mean Monthly Precipitation (1971-2009) Upper Zone of the CVSPA

The mean annual evapotranspiration is about 530 millimetres. However, water balance analyses using observed streamflow data show that the mean annual evapotranspiration to be about 650 millimetres (Singer *et al*., 1994). This value is higher than that of the surrounding area, which suggests that a significant amount of water must be available in ponds, swamps, and marshes or held in soil-water storage. The area has an annual frost-free period of 135 days, with a 195-day growing season. The mean annual temperature for the area is about 6.0°C, with a lowest mean daily temperature of -8.0°C in January, and highest of 19.1°C in July (**Figure 3.13**).



(Meteorological Services Canada)

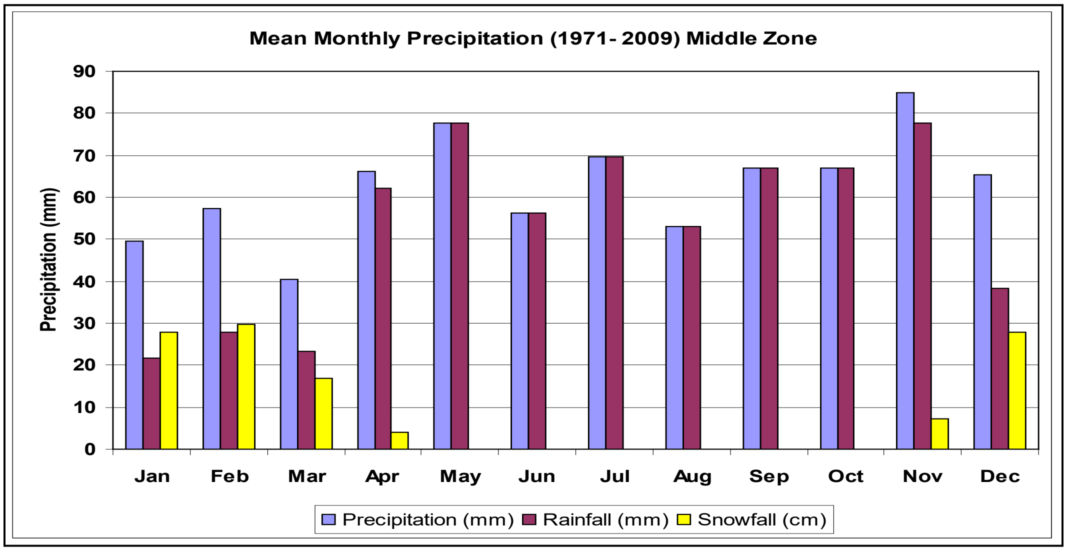
Figure 3.13: Mean Daily Temperature Upper Zone Credit River Watershed CVSPA (1971–2009)

Middle Zone

The mean annual precipitation along the middle zone is about 885 mm, of which 16% appears as snowfall (or 141.5 cm in depth). These totals are distributed in a fairly even pattern in a northwest to southeast direction. The greatest precipitation amounts occur in the northern part of the zone south of Erin, due in part to some “orographic” influence of the Niagara Escarpment on “lake effect” storms originating over Lake Ontario.

Total precipitation is distributed such that August, September, and November are the wettest months, and January and February are the driest months (**Figure 3.14**). The lowest total precipitation (59 mm) occurs in February, whereas the highest precipitation amount occurs in August (85 mm).

On average, there are 82 days with measurable rainfall annually, and another 32 days with snowfall. Frozen ground conditions are persistent between mid-November and late March, yielding high runoff potential for all soil types.

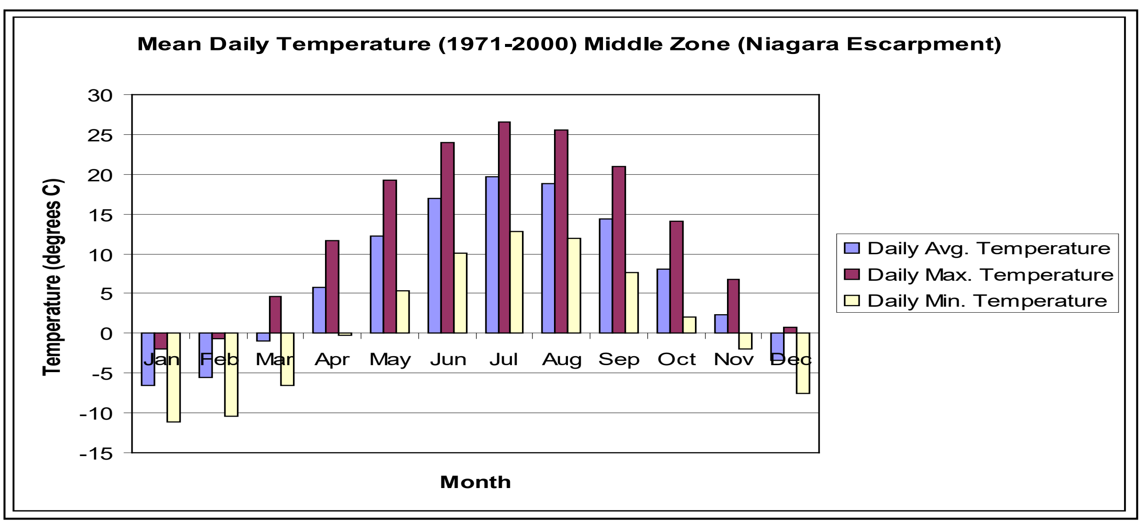


(Meteorological Services Canada)

Figure 3.14: Mean Monthly Precipitation (1971-2009) Middle Zone of the CVSPA

The mean annual evapotranspiration is about 540 mm, as deduced from isohyetal maps for southern Ontario, which has been verified from water balance analyses using observed streamflow data by Singer *et al*. (1994). In some places along the middle zone, this value could be higher because of significant amounts of water available in ponds, swamps, and marshes, or held in soil-water storage.

The mean annual air temperature is 6.8°C. The lowest mean daily temperature is in January at about –6.6°C, and the highest is 19.7°C in July (**Figure 3.15**).



(Meteorological Services Canada)

Figure 3.15: Mean Daily Temperature (1971-2000) Middle Zone (Niagara Escarpment)

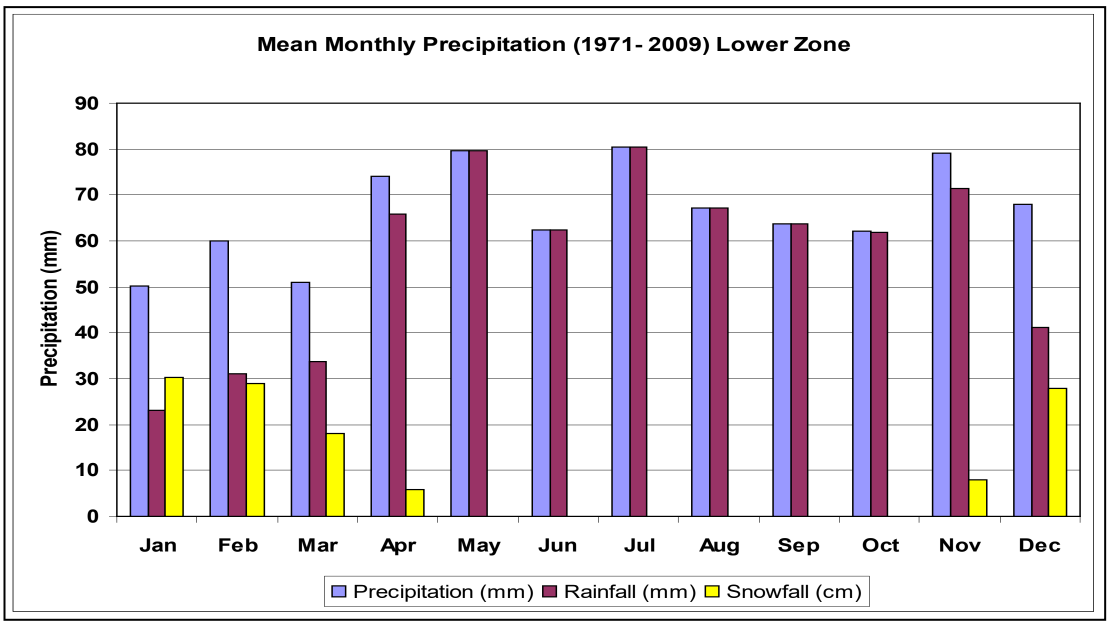
Although the precipitation is generally evenly distributed throughout the years, during the summer period there is a net deficit in the amount of precipitation that falls and is lost through evapotranspiration. The potential evapotranspiration amounts (e.g., lake evaporation) are higher than the total precipitation input for May through August.

Lower Zone

The mean annual precipitation along the lower watershed is about 793 mm, of which 15% appears as snowfall (or 115 cm in depth). These totals are distributed in a fairly even pattern in a northwest to southeast direction.

The greatest precipitation amounts occur in the northern part of the lower zone due in part to some "orographic" influence of the Niagara Escarpment on "lake effect" storms originating over Lake Ontario.

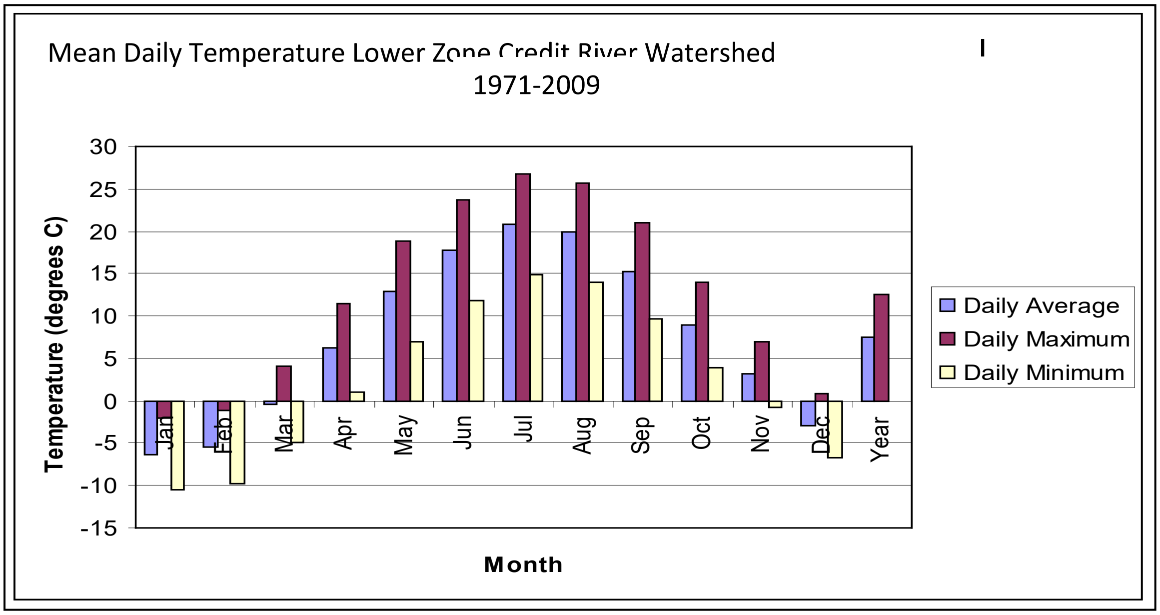
Total precipitation is distributed such that June, July, August, and September are the wettest months, and January and February are the driest months **(Figure 3.16)**. The lowest total precipitation (42.6 mm) occurs in February, whereas the highest precipitation amount occurs in August (80 mm). Frozen ground conditions are persistent between mid-November and late March, yielding high runoff potential for all soil types.



(Meteorological Services Canada)

Figure 3.16: Mean Monthly Precipitation (1971-2009) Lower Zone

The mean annual evapotranspiration is about 540 mm, as deduced from isohyetal maps for southern Ontario, which has been verified from water balance analyses using observed streamflow data by Singer et al. (1994). The area has an annual frost-free period of 148 days, with a growing period of about 202 days. The mean annual air temperature is 7.5°C; the lowest mean daily temperature is in January at about – 10.5°C, and the highest is 20.8°C in July **(Figure 3.17)**.



(Meteorological Services Canada)

Figure 3.17: Mean Daily Temperature Lower Zone Credit River Watershed (1971-2009)

Although the precipitation is generally evenly distributed throughout the years, during the summer period there is a net deficit in the amount of precipitation that falls and is lost through evapotranspiration. The potential evapotranspiration amounts (e.g., lake evaporation) are higher than the total precipitation input for May through August.

3.6.3 Historical 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% (Chiotti and Lavender, 2008), and the number of days with precipitation (rain or snow) has increased significantly (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).

Climatic trends in the CVSPA were reviewed as part of climate change study undertaken for the CVC (*Phase 1 Climate Change Model for the Credit River Watershed: Background Review and Characterization, Draft Report, May 2009*).

Datasets from key climatic stations were statistically analyzed to assess the data quality and to understand past climatic trends. Summaries of the observed trends in mean annual temperature, annual total precipitation, and monthly snowfall analysis are presented in the report referenced above.

The study inferred that annual and monthly temperatures have been relatively constant over the period of records. It also inferred that there are no statistically significant trends in the time series of monthly precipitation for the climate stations analyzed. The study concluded that snowfall as an indicator of climate change may be a poor parameter due to its wide variability in measurement and overall poor data quality.

3.6.4 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 time during 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. 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. 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 South Slope is topographically higher and farther from the lake, and hence the influence of the lake is diminished. The two zones are largely distinguished by differing temperature patterns.

In 2008, the Ministry of Natural Resources and Forestry (MNRF), in association with Environment Canada and CVC, undertook a review of available meteorological and hydrological data, and attempted to develop methodologies for assessing future climate change. This joint effort culminated in a report entitled *Guide for Assessment of Hydrologic Effects of Climate Change in Ontario, EbnFlo Environmental, AquaResource Inc., December 2009.*

The objective of the study was to establish a standard procedure for conducting climate change assessments of hydrologic systems in Ontario and, thus, facilitate the mainstreaming of climate change assessment. It also attempted to establish a standard procedure for conducting assessments of the effects of climate change on water resources in Ontario to inform management and adaptation decision making.

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 (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 precipitations (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).

Climate Change Scenario

The Water Management Strategy process and Hydrological Simulation Program—Fortran (HSP-F) based surface water flow and water quality model (Bicknell *et al.*) was set up and calibrated at the SPA level. Several scenarios representing future conditions were devised to test the sensitivity of the CVSPA to further urbanization and various water management strategies. In addition, two climate change scenarios were developed and used as input for simulations. The scenario runs were selected to represent the largest projected changes in air temperature and precipitation and, thus, bracketed the larger group of Global Climate Model—Greenhouse Gas (GCM-GHG) emission scenario combinations. The scenarios represented warm and drier conditions (Canadian CGCM2) and warmer and wetter conditions (UK HadCM3) in annual average terms.

The change field method employed average monthly GCM-based change fields for four variables (i.e., precipitation, air temperature, solar radiation, and wind speed). Changes were applied to a time series of historical meteorological data, adjusting individual observations by the monthly change field values.

Downscaling was not conducted, and this method does not account for changes in extreme events. Simulation results indicated that the warmer future climates would result in much less snowpack accumulation and greatly reduced spring freshets. In both scenarios, the annual hydrograph with climate change displayed much higher fall and winter streamflow. Summer results differed in that the drier CGCM case resulted in lower summer flow rates, and the wetter Hadley case resulted in a small increase in summer flows. Potential evapotranspiration was significantly higher in both climate change cases due to warmer air. Actual evapotranspiration was elevated in the warmer wetter case and similar in the warmer drier case. Water quality was greatly impacted with both future climates as bare winter soils in these cases resulted in elevated erosion.

3.7 INTEGRATED TIER 2 WATER BUDGET

In recognition of the extensive water budget work undertaken in the CVSPA prior to the advent of source water protection, Credit Valley Conservation (CVC) was permitted to forego the requirement of undertaking conceptual and Tier 1 water budgets (*Technical Rule 24*) for the Assessment Report. Due to moderate drinking water quantity stress identified in this early water budget work CVSPA was required to undertake a Tier 2 water budget.

Conceptual model: Visual representation of the groundwater flow system.

Numerical model: Numerical representation of conceptual model; may involve simplifications or assumptions when representing conceptual model.

The Tier 2 water budget analysis built upon previous modelling efforts undertaken in the CVSPA since 1998 and aimed to improve the understanding of the hydrological cycle and of the dynamics of competing demands at the subwatershed scale of analysis.

The analysis utilized three-dimensional numeric modelling to simulate/model the components of the hydrological cycle in order to quantify the surface water and groundwater fluxes (i.e., movement of water over and under the land) throughout the CVSPA.

The groundwater flow modelling involved the creation of a conceptual geological model of the watershed, then the development of a *numerical model* using applicable computer software. The *conceptual model* was built using GIS software and OGS-based physical data/geological surfaces. It was subsequently converted into a detailed three-dimensional numeric model. A detailed description of the process can be found in **Appendix C1.**

The modelling approach integrated hydrological (surface water) components and hydrogeological (groundwater) components. Each model was subject to a calibration and validation process to ensure that it simulates the natural processes as accurately as possible. The overall flow modelling process is shown in **Figure 3.18**, and summarized in the discussion below.

The numeric modelling and stress assessment are documented in the report *Integrated Water Budget Report—Tier 2, Credit Valley Source Protection Area (*AquaResource Inc*., 2009)*. This document was extensively peer-reviewed by a panel of municipal and provincial representatives, private consultants, and the CVC prior to acceptance by the CTC Source Protection Committee (SPC). Additionally, both models have been subject to independent peer review prior to their use in source protection water budget modelling exercises.

The *Tier 2 Water Budget Report* which is available online at www.ctcswp.ca contains the technical data and information upon which the summary below has been based.

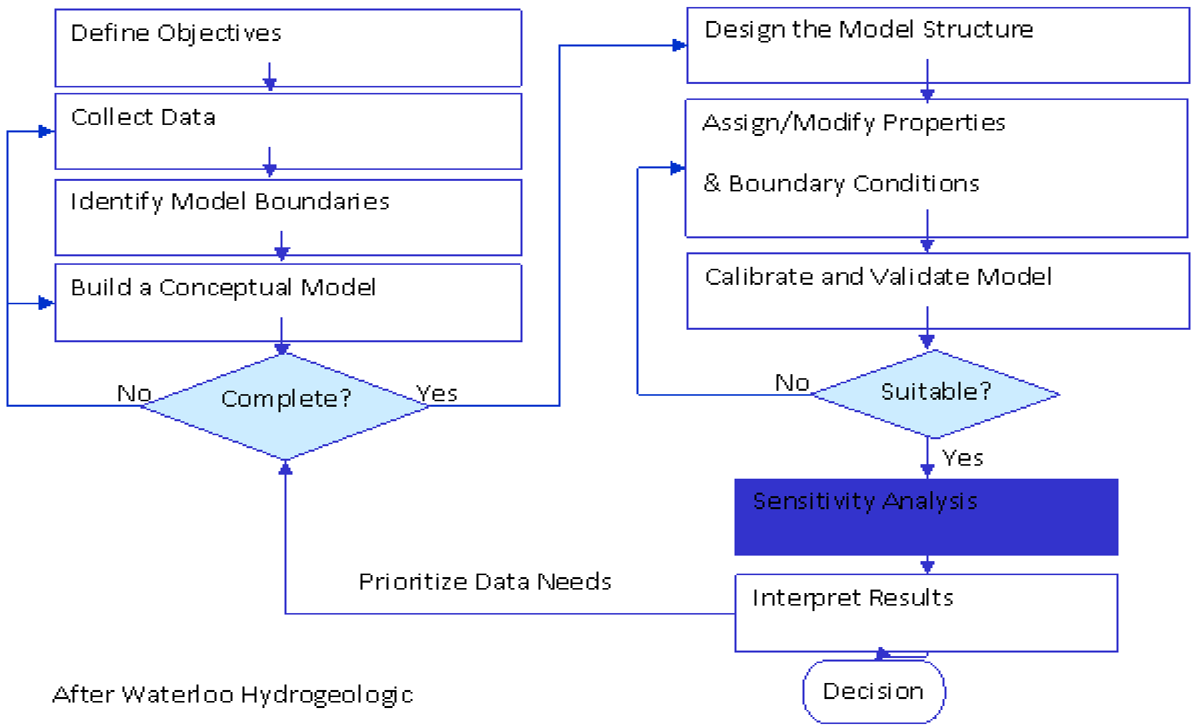


Figure 3.18: Numerical Model Development

3.7.1 Numeric Modelling

The modelling analysis was an integrated approach, using the following software:

Hydrological Simulation Program—Fortran (HSP-F) (v.12) (Bicknell et al., 2001) software: evaluation of surface flow based on precipitation, geology, soils, slopes, land use, demands, etc.

FEFLOW (Finite Element Flow) software: evaluation of subsurface flows and fluxes based on surface recharge (from HSP-F output), geology, boundaries, demands, hydrogeology, hydraulic conductivities, etc.

The outputs of the HSP-F were introduced into the groundwater model as recharge within the integrative process. FEFLOW, in turn, was used to simulate steady-state groundwater conditions throughout the CVSPA. The area modelled (model domain) is shown in **Figure C2**, **Appendix C1.**

The water budget components have been calculated over the time period 1961 to 2004 and are based on the limitations and assumptions of the long-term climate dataset used.

The water budget assumes a *steady-state condition*, where any changes that occurred in storage over the assessment time period are perceived to be negligible. Therefore, the water budget assumed that the water inputs were equal to the water outputs.

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

The development and calibration of the numeric flow models relied on numerous datasets, ranging from rainfall, surface water and groundwater data, to physical land parameters (physical geology, soil conditions, land morphology, etc.). Regional and local datasets were provided through provincial and municipal partners (CVC, Provincial Groundwater Monitoring Network (PGMN), MOECC, MNRF, ORMGP, etc.), and have been updated at regular intervals.

Justification of both models, a summary of the considerations, data inputs, and processes that were involved in the development of the three-dimensional numeric model is provided in **Appendix C1.**

Calibration and Validation

Both models were calibrated and validated to ensure that their outputs estimated natural processes as accurately as possible (**Figure 3.18**).

Calibration is the process by which model input parameters and boundary conditions are systematically adjusted within an expected range until the differences between model output and field observations are within selected criteria (i.e., acceptable margin of error) for performance. The desired calibration targets are presented in **Figure 3.19**. The calibration process is iterative, and critical in refining the uncertainty with respect to the input parameters for both surface and groundwater models. Further description on the calibration and validation of both models is provided in **Appendix C1** and in *Integrated Water Budget Report—Tier 2, Credit Valley Source Protection Area (*AquaResource Inc*., 2009)*.

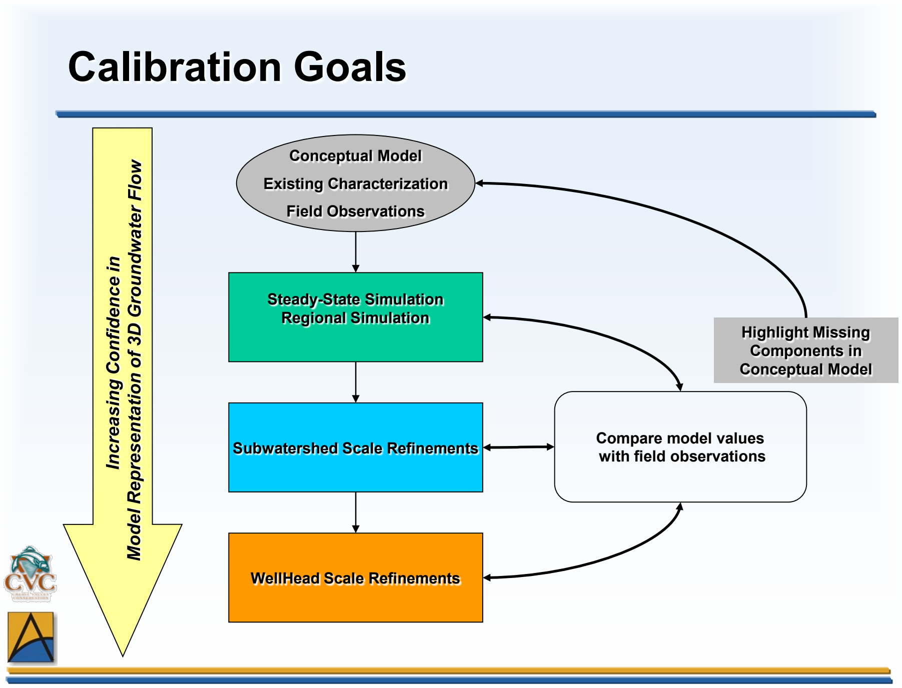


Figure 3.19: Calibration Targets

Validation is the complementary process by which the calibrated model output is compared to a different set of field observations. Validation is an independent test of the model's capability to represent the important processes occurring in the natural system.

Major Inferences

Simulated groundwater levels are generally consistent with observed values. The simulated water levels appear to be consistent with those reported at municipal pumping wells. Simulated groundwater discharge rates are also consistent with those estimated using baseflow recession techniques and spot flow measurements.

The upper zone of the CVSPA is conceptualized and simulated as having relatively high recharge rates, a distribution of overburden and bedrock aquifers, and significant groundwater discharge to wetlands and coldwater streams.

The middle zone is conceptualized and simulated to consist of outcropping Niagara Escarpment bedrock layers, and abundant groundwater discharge to seeps, streams, and buried bedrock valleys transmitting large volumes of groundwater.

The lower zone is conceptualized and simulated to consist of low permeability Halton Till and Queenston Formation shale bedrock, relatively low groundwater recharge, and few high-yield production aquifers outside the buried bedrock valley aquifer complexes.

Urbanization greatly increases the range of instream flow rates, particularly the lower watershed. The upper 75% of the watershed displays characteristics of a rural stream in terms of streamflow. The model reflects urban impacts through detailed runoff routing.

The Credit River displays a trend of hydrologically degraded conditions towards the mouth through the urbanized portion of the system. This is apparent in terms of relatively lower baseflow and greater peakiness in the urbanized subwatersheds. Upstream sites display the stabilizing influence of Water Pollution Control Plant discharges, especially in Subwatersheds 10, 11, and 19, as well as greater rates of groundwater recharge and storm runoff attenuation.

Model simulations are considered accurate at a regional or subwatershed scale. However, local scale hydrogeologic conditions are not anticipated to be well represented by the regional-scale model.

Surface Water and Groundwater Fluxes

Table C1.9 in **Appendix C1** summarizes precipitation, runoff, evapotranspiration, and groundwater recharge for each subwatershed and watershed zone as related to the HSP-F model. For groundwater, the table summarizes recharge, discharge to surface water features, large, permitted water takings, inter-catchment flow, and inter-watershed flow.

At the watershed scale, the estimated average recharge rate is 203 mm/year, and the average runoff rate is 213 mm/year. The average estimated evapotranspiration rate is 432 mm/year.

Based on the integrative modelling analysis, the calibrated water table surface and bedrock potentiometric surfaces within the CVSPA are shown earlier in **Figure 3.8** and **Figure 3.9**, respectively. Groundwater recharge and discharge areas are shown earlier in **Figure 3.10** and **Figure 3.11**, respectively.

As expected, the data show higher runoff rates in the lower zone of the CVSPA where finer grained soils and high urbanization dominate the landscape, and higher recharge rates in the upper subwatersheds where coarse-grained soils dominate.

Urbanization impacts, such as increased runoff and reduced evapotranspiration, are noted in the lower watershed, and this trend is most significant in Subwatershed 1, where the estimated evapotranspiration rate is 318 mm/year and the average annual runoff and recharge are 415 mm/year and 45 mm/year, respectively.

Groundwater divides tend to generally follow the Credit River watershed’s surface water divides; however, this is not the case along the outer boundaries of the CVSPA or on the interior subwatershed boundaries.

Uncertainty

The Tier 2 water budget reflects the best scientific effort available at the time of completion. Its findings describe prevailing conditions within the CVSPA and present stress assessments premised upon a varied range of input data spanning a defined snapshot of time. However, the following must be appreciated:

- Variation in meteorologic conditions, land use activities, and water taking permitting should be carefully monitored, as this can alter the dynamics of the watershed, and the nature and distribution of the observed stresses. This, in turn, can impact the accuracy of results and inferences presented in this Assessment Report.
- Modelling was applied at the subwatershed scale, so it is also essential to appreciate that results of the stress assessments do not pertain to smaller or site-specific scales. Where additional information has been deemed necessary, a Tier 3 level of study is recommended.

Overview of the main points pertaining to the uncertainty assessment undertaken for both surface water and groundwater models is presented below, while greater detail is provided in the foundation report (AquaResource Inc., 2009).

Surface Water Flow Model

- Accurate streamflow calibration is limited by a lack of representative monitoring for rainfall and streamflow in many regions of the CVSPA, especially in urban subwatersheds and near the mouth of the Credit River.
- A significant source of uncertainty relates to the water balance for low permeability soils (i.e., Halton Till) in the lower watershed. The modelled recharge values in this area cannot be tested against observed streamflow.
- Data gaps include accurate Water Pollution Control Plant and other urban runoff volumes (i.e., dry weather storm sewer flows).
- The compound influence of all possible errors in model setup and calibration renders the model less valuable in terms of its reliability in simulating absolute values for streamflow at any time and at any location. However, the model's simulation confidence is sufficiently high in relative evaluations to make the model most useful in this form of assessment.

Groundwater Flow Model

- The model simulations are considered accurate at a regional or subwatershed scale, and the confidence in the model predictions decreases as the scale of assessment increases. Uncertainties in the conceptual model and calibration reduce the reliability of the model when simulating groundwater levels and discharge at a local scale in the CVSPA.
- The simulations were carried out using average annual recharge estimates, and the steady-state results will not represent seasonal and annual hydrogeologic variability.

3.7.2 Stress Assessment

As directed by the *Technical Rules* subwatershed stress assessments were undertaken to evaluate the potential impacts of competing demands on surface water and groundwater sources, and to rationalize stress levels in relation to municipal water supplies (i.e., to assess the sustainability of municipal supplies in relation to natural availability).

The elements of the stress assessment are as follows:

- Potential Groundwater Stress. The potential groundwater stress is determined by estimating the percent water demand as a function of the estimated consumptive water demand under existing and future conditions (future population growth), as well as the water supply and water reserve for groundwater.
- Potential Surface Water Stress. The potential surface water stress is determined by estimating the percent water demand as a function of the estimated existing consumptive water demand as well as the water supply and water reserve for surface water. Future surface water stress was not evaluated as there are no inland surface water municipal intakes within the CVSPA.
- Drought Scenario—Groundwater. The purpose of the drought scenario is to estimate the potential impacts of a severe two-year drought on the municipal drinking water wells. This assessment is completed by removing recharge from the groundwater model for a two-year simulation period and examining the resulting drawdown at the municipal wells under these conditions.

3.7.3 Methodology

The potential for stress is estimated by assessing the natural water availability against competing demands created by municipal and non-municipal requirements.

The stress assessment was undertaken at the subwatershed level throughout the watershed and attempts to describe the sustainability of existing and projected future demands with respect to natural system's capacity to generate the resource. This study entailed evaluations of:

- Natural water availability—supply and reserves;
- Water demand—municipal and non-municipal (domestic, agricultural, industrial, etc.); and
- Natural water supply was estimated via numeric modelling, whilst the reserves are set as a percentage in the *Technical Rules* and are dependent on whether the source is surface water or groundwater-based.

Water demand within the CVSPA was assessed through consultation with the MOECC's Permit to Take Water (PTTW) database, through communication with member municipalities, and via field visits/verification with permit holders. Demand was thoroughly assessed in respect to consumption relating to usage and seasonal factors.

The stress results are assessed by using the threshold criteria and equations prescribed by the *Technical Rules* and reproduced in **Appendix C1.**

Data Sources

Demand assessment was undertaken by incorporating data from a variety of sources, including PTTW, member municipalities, CVC/MOECC water use surveys (2006), and Statistics Canada data. Extensive efforts were made to account for both surface water and groundwater takings.

The MOECC's PTTW Program has been in place since the early 1960s and requires that any person taking more than 50,000 L/day, on any given day in a year, is required to hold an active PTTW. Exceptions are granted for domestic water use, livestock watering, and water taken for firefighting purposes. Information such as geographic location of the source, maximum permitted volumes, and the general and specific purposes of the water takings are stored within the PTTW database.

Several categories of water taking are examined in this assessment. These are as follows:

- Municipal, groundwater—wells servicing CVSPA municipalities.
- Non-municipal, groundwater—unserviced (rural) domestic, pits and quarries, aggregate washing, golf course irrigation, schools, aquaculture, bottled water, and snowmaking.
- Non-municipal, surface water—golf course irrigation, plant nurseries, agriculture irrigation, wildlife conservation/wetlands/recreational, snowmaking, and construction requirements.

The locations of permitted (municipal and non-municipal) takings are shown in **Appendix C1, Figure C-3**. The demand associated with each category of water taking is also tabulated there. The tables reflect permit data for 2007, with the exception of Subwatershed 16, which was updated to 2008, based on a directive from the CTC SPC.

The *Technical Rules* require that future demands be assessed to meet population growth projections, and that this analysis be based upon population growth estimates from Official Plans, where available, other documentation, and from direct communication with municipalities. This is discussed in **Chapter 3.6.4**. Results of the existing and future demand assessments are presented in **Section 3.7.5**.

The *Technical Rules* also require that groundwater drought scenarios be studied, to determine whether drawdown during the drought period could result in the inability to pump sufficient quantities of water to meet demand. This is discussed in **Section 3.7.7**.

Consumptive Usage

A critical component of demand assessment is the estimation of *consumptive demand*. This refers to the volume of water that has been taken out of storage (surface water or groundwater), but not returned to the water source. If the water is never returned to the source, then usage is 100% consumptive. If all the water is returned to the source the consumptive demand is 0%.

Consumptive use factors are assigned to the various demand usages in order to estimate the amount of water not being returned to a given surface water or groundwater source.

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

Consumptive usage was estimated by referencing:

- Municipal pumping rates;
- MOECC PTTW records—adjusted to account for estimated monthly and annual consumption; and
- Estimation of rural residential consumptive water use.

The information was refined using the literature by liaising with the MOECC, with individual permit holders, and by field-validation.

The estimation of consumption has been accounted for in the application of so-called consumptive factors. A description of consumptive use and the consumptive factors for the various categories of taking have been incorporated in the demand tables shown in **Appendix C1**. A summary of considerations used for the derivation of the consumptive factors is provided there, while the details are presented in the foundation report.

It is recognized that there also are a number of non-consumptive water users:

- Sewage treatment plants—water for waste assimilation (**Chapter 2**, **Table 2.7**); and
- Ecological flow requirements—natural heritage sustenance.

These needs do not remove water from its source, but they do rely on having healthy and sustainable streamflows. It is possible to estimate the amount of streamflow needed along a particular reach of a stream to sustain ecological requirements. However, there are no clearly defined criteria for assessing ecological flow requirement at a larger scale, such as within a watershed or subwatershed. This is to be addressed through the Tier 3 level of water budget study.

3.7.4 Assessment of Water Quantity Demand - EXISTING

The assessment compares the natural availability (fluxes estimated by modelling) with estimated consumptive water demands to examine issues of sustainability in relation to municipalities' ability to meet existing and future water demands.

The stress assessment may only be as reliable as the demand analysis permits. This being so, the demand inputs were subject to intense quality control, review, verification (MOECC/CVC survey), and, where possible, field checking before being deemed reliable and reflective of the situation on the ground. Estimating water demand is critical in the development of a water budget framework. An estimate of the extent and variability of water use throughout the CVSPA was required to identify areas under the highest degree of hydrologic stress and to guide efforts to refine the water budget tools in those areas. As the CVSPA continues to experience both economic and population growth, there will be increased demands on the watershed's water resources to supply sufficient water to residential, commercial, and industrial consumers.

Consumptive Demand—Surface Water

There are 25 permitted surface water takings (see **Appendix C1** — **Table C-14**) in the CVSPA. These are all non-municipal, with abstraction being variable. The estimated average and maximum monthly consumptive surface water demand per subwatershed is shown in **Table 3.5**.

Table 3.5: Consumptive Surface Water Demand in the CVSPA

No.	Name	Surface Water Demand (m^3/d)	
		Average	Maximum Monthly
1	Loyalist Creek	ND	ND
2	Carolyn Creek	ND	ND
3	Sawmill Creek	ND	ND
4	Mullett Creek	ND	ND
5	Fletcher's Creek	893	1,532
6	Levi Creek	500	948
7	Huttonville Creek	ND	ND
8a	Springbrook Tributary	ND	ND
8b	Churchville Tributary	ND	ND
9	Norval to Port Credit	4,997	11,901
10	Black Creek	288	575
11	Silver Creek	0	0
12	Credit River—Cheltenham to Glen Williams	1,221	1,832
13	East Credit River	454	454
14	Credit River—Glen Williams to Norval	197	394
15	West Credit River	ND	ND
16	Caledon Creek	ND	ND
17	Shaw's Creek	ND	ND
18	Credit River—Melville to Forks of the Credit	2,523	6,546
19	Orangeville	139	416
20	Credit River— Forks of the Credit to Cheltenham	ND	ND
21	Lake Ontario Shoreline	ND	ND
22	Lake Ontario Shoreline	ND	ND
	Total	**11,212**	**24,599**

Note: ND—No Demand Identified

The consumptive surface water demand is due largely to golf course (70%) and agricultural irrigation along the main branch of the Credit River. There is a significant seasonal fluctuation associated with those water takings. Other takings relate to snowmaking and wildlife conservation.

On an average annual basis, 11,212 m^3/day of water is estimated to be consumed from surface water sources, translating to approximately 2% of the Credit River's mean annual flow. The maximum monthly consumptive demand is estimated to be 24,599 m^3/day, or more than double the average annual rate.

Consumptive Demand—Groundwater

Apart from the municipal withdrawals, by the towns of Orangeville, Mono, and Erin, and the regional municipalities of Peel and Halton, consumptive groundwater demand is exercised through 39 permitted non-municipal water takings, and by unserviced (no permit required) residences (see **Appendix C1**—**Table C-13** and **Table C-15**). **Table 3.6** shows consumptive groundwater demand at the subwatershed level. Average municipal and peak municipal consumptive demand remain the same (hence the information has not been reproduced in the "Peak Consumptive Demand" column), while peak non-municipal consumptive demand also includes rural demand.

Table 3.6: Existing Groundwater Demand

No.	Name	Average Consumptive Demand (m3/d) Annual				Peak Consumptive Demand (m3/d)-Monthly	
		Municipal Demand	Permitted Non-Municipal	Rural Domestic Demand	Total	Permitted Non Municipal[1]	Total
1	Loyalist Creek	ND	ND	1	1	1	1
2	Carolyn Creek	ND	ND	ND	ND	ND	ND
3	Sawmill Creek	ND	ND	2	2	2	2
4	Mullett Creek	ND	ND	14	14	14	14
5	Fletcher's Creek	ND	334	17	351	590	590
6	Levi Creek	ND	161	48	209	402	402
7	Huttonville Creek	ND	72	30	102	138	138
8a	Springbrook Tributary	ND	ND	18	18	18	18
8b	Churchville Tributary	ND	ND	7	7	7	7
9	Norval to Port Credit	ND	ND	101	101	101	101
10	Black Creek	7,177	1,655	225	9,057	2,207	9,384
11	Silver Creek	6,504	ND	151	6,655	151	6,655
12	Credit River—Cheltenham to Glen Williams	ND	ND	124	124	124	124
13	East Credit River	ND	515	87	602	1,324	1,324
14	Glen Williams to Norval	ND	13	42	55	55	55
15	West Credit River	1,814	4,534	255	6,603	6,130	7,944
16	Caledon Creek	724	2,135	69	2,928	4,834	5,558
17	Shaw's Creek	2,501	993	94	3,588	2,368	4,869
18	Credit River—Melville to Forks of the Credit	650	697	64	1,411	1,586	2,236
19	Orangeville	7,020	ND	95	7,115	95	7,115
20	Credit River—Forks of the Credit to Cheltenham	567	ND	105	672	105	672
21	Lake Ontario Shoreline	ND	ND	ND	ND	ND	ND
22	Lake Ontario Shoreline	ND	ND	ND	ND	ND	ND
	Total	**26,957**	**11,109**	**1,549**	**39,615**	**20,251**	**47,208**

Note: ND—No Demand Identified; [1] Includes Permitted and Rural Water Demand

On an average annual basis, 39,600 m^3/day of water are estimated to be removed from groundwater aquifers in the CVSPA. Abstractions are variable, with the greatest average annual consumptive usage taking place in areas of high municipal takings such as Subwatershed 10 (Black Creek), Subwatershed 19 (Orangeville), and Subwatershed 11 (Silver Creek). Average annual consumptive use in subwatersheds 15 and 16 is also relatively high due to a number of aggregate uses.

Maximum monthly water demand is approximately 19% higher than average annual water demand. Many of the non-municipal water users operate on a seasonal basis, and, as a result, their consumptive use is much higher in the summer than in the winter months. The water usage presented above has been reorganized in **Table 3.7** to reflect the average consumptive groundwater demand exercised by the various water use sectors in the CVSPA.

Table 3.7: Estimated Consumptive Groundwater Demand by Sector

Purpose	Average Annual Consumptive Groundwater Use	
	m^3/d	% of Total
Municipal	26,957	69%
Aggregate	7,780	20%
Rural Domestic	1,549	4%
Other (short term permits, dewatering)	1,752	4%
Golf Course	941	2%
Agriculture	411	1%
Bottled Water	225	1%
Total	**39,615**	**100%**

Municipal water use is therefore concluded to account for about 70% of the consumptive groundwater demand in the CVSPA, vis-à-vis representing 26% of takings inferred through the PTTW database review (**Chapter 2, Table 2.9**). Specifically, the municipal groundwater taking represents 26% of all overall groundwater taking, but when the consumptive nature of the taking is estimated with respect to the source from which the water is taken (and not returned) the municipal proportion of 'consumptive' water use is 70%. Non-municipal usage accounts for the balance of the consumptive groundwater demand.

3.7.5 Assessment of Water Quantity Demand - FUTURE

It is noted that this estimate of population growth is not based entirely on land use planning information and is presented primarily to assess the hydrologeologic sensitivity of the watershed to increased water demands.

The future water demand estimate is based on the following assumptions:

- Without the ability to predict non-municipal and non-domestic water demand within a subwatershed, it is not feasible to evaluate it as part of a future water demand assessment.
- Region of Peel provided official (dated 2007) population growth estimates; 2031 population growth is estimated across the region. The figures show that nearly all of the Region of Peel's growth is anticipated within the lower zone, and, as a result, this growth will be satisfied by the region's Lake Ontario surface water supply.
- Town of Erin estimated 2031 population at 14,850. For this study, the population growth is assumed to be distributed evenly across the township. As a result, most of this growth will take place within Subwatershed 15 (West Credit River).
- For this analysis, a 35% increase in municipal groundwater demand was predicted.
- Town of Mono does not have a growth plan. For this analysis, a 35% increase in groundwater demand was projected from the population estimate of 2007 by Town of Mono, which differs from 2006 Census Canada population estimates reported in **Chapter 2, Table 2.11**.
- Town of Orangeville does not have a 2031 growth plan. For this analysis, a 35% increase in groundwater demand was projected from the population estimate of 2007 by Town of Mono, which differs from the 2006 Census Canada population estimates reported in **Chapter 2, Table 2.11**.

The estimated future water demands to 2031 have been computed for each subwatershed as shown in **Table 3.8**. Please note that only future municipal and domestic drinking water estimates have been evaluated, and were derived as follows:

- Existing Water Demand. The future water demand projections start with an estimate of the existing water demand, represented by the sum of municipal and rural domestic water estimates. This demand is based on 2007 estimated population figures, and not the 2006 Census Canada population reported in **Chapter 2.5**.
- Region of Peel. The future water demand is calculated based on an estimated future water use of 335 L/day per person in the middle and upper zones and the population increases outlined in their growth plans. It is assumed that the increased water demands for the region in the lower zone will be met by the Lake Ontario surface water supply.
- Town of Erin. The future water demand is calculated based on an estimated future water use of 335 L/day per person in the middle and upper zones and the population increase estimates provided by the town.
- Town of Halton Hills. The existing estimated water demand in subwatersheds 10, 11, 12, and 14 is assumed to increase by 35%.
- Orangeville/Mono/Dufferin. The existing estimated water demand in subwatersheds 17 and 19 is assumed to increase by 35%.

Based on the analyses, the average future groundwater demand is projected to increase by 30,009 m^3/day. This is based on a series of assumptions for the purpose of evaluating the potential hydrogeologic sensitivity to this growth.

Table 3.8: Future Water Demand (Estimated to 2031)

No.	Name	Average Demand (m^3/d)			Peak Demand (m^3/d)	
		Municipal and Rural Demand	Non-Municipal	Total	Non-Municipal	Total
1	Loyalist Creek	1		1		1
2	Carolyn Creek	0		0		0
3	Sawmill Creek	2		2		2
4	Mullett Creek	14		14		14
5	Fletcher's Creek	17	334	351	573	590
6	Levi Creek	48	161	209	354	402
7	Huttonville Creek	30	72	102	108	138
8a	Springbrook Tributary	18		18		18
8b	Churchville Tributary	7		7		7
9	Norval to Port Credit	101		101		101
21	Lake Ontario Shoreline	0		0		0
22	Lake Ontario Shoreline	0		0		0
	Lower Watershed	**238**	**567**	**805**	**1,034**	**1,272**
10	Black Creek	10,148	1,655	11,803	1,982	12,130
11	Silver Creek	9,152		9,152		9,152
12	Credit R.—Cheltenham to Glen Williams	309		309		309
13	East Credit River	101	515	616	1,237	1,338
14	Credit R.—Glen Williams to Norval	62	13	75	13	75
20	Credit R.—Forks of the Credit to Cheltenham	672		672		672
	Middle Watershed	**20,444**	**2,183**	**22,627**	**3,232**	**23,676**
15	West Credit River	2,916	4,534	7,450	5,875	8,791
16	Caledon Creek	1,333	2,136	3,469	5,898	6,179
17	Shaw's Creek	3,802	993	4,796	2,274	6,077
18	Credit R.—Melville to Forks of the Credit	691	697	1,388	1,522	2,213
19	Orangeville	9,585		9,585		9,585
	Upper Watershed	**18,327**	**8,360**	**26,687**	**15,569**	**33,896**
	Total	**39,009**	**11,110**	**50,120**	**19,836**	**58,845**

3.7.6 Stress Assessment Results

Given reporting timelines, the stress assessments do not reflect post 2007 permit information. This is, with the exception of Subwatershed 16 (Caledon Creek), which was further evaluated to December 2008, as directed by the CTC SPC.

Surface Water

The surface water potential stress classification for each subwatershed was computed using criteria from the *Technical Rules* and is set out in **Appendix C1.** Computation involved the calculation of monthly percent water demand, which is shown in **Appendix C1.** The maximum percent water demand for all months was used to categorize the quantity potential for stress into one of three levels: significant, moderate, or low. The results of the analysis are summarized in **Table 3.9** and illustrated in **Figure 3.20**.

Table 3.9: Subwatershed Surface Water Potential Stress Classification

ID	Subwatershed	Municipal Supply	Maximum Monthly % Water Demand	Maximum Monthly Water Demand (m³/d)	Supply (m³/d)	Reserve (m³/d)	Potential Stress Classification
1	Loyalist Creek	None	ND	ND	2,740	1,090	Low
2	Carolyn Creek	None	ND	ND	1,580	722	Low
3	Sawmill Creek	None	ND	ND	5,000	2,200	Low
4	Mullett Creek	None	ND	ND	8,450	3,460	Low
5	Fletcher's Creek	None	25% (Oct)	1,532	13,700	7,520	Moderate
6	Levi Creek	None	15% (Sept)	948	12,700	6,210	Low
7	Huttonville Creek	None	ND	ND	3,600	1,980	Low
8a	Springbrook Tributary	None	ND	ND	1,480	759	Low
8b	Churchville Tributary	None	ND	ND	2,470	1,190	Low
9	Norval to Port Credit	None	6% (Sept)	11,901	406,000	211,000	Low
10	Black Creek	None	5% (Sept)	575	26,600	14,600	Low
11	Silver Creek	None	ND	ND	67,600	51,800	Low
12	Credit River— Cheltenham to Glen Williams	None	2% (Oct)	1,832	267,000	143,000	Low
13	East Credit River	None	3% (Sept)	454	28,200	11,900	Low
14	Credit River—Glen Williams to Norval	None	ND	ND	316,000	177,000	Low
15	West Credit River	None	ND	ND	64,700	26,000	Low
16	Caledon Creek	None	ND	ND	17,400	6,580	Low
17	Shaw's Creek	None	ND	ND	29,300	11,300	Low
18	Credit River— Melville to Forks of the Credit	None	16% (Sept)	6,546	89,400	49,100	Low
19	Orangeville	None	5% (Sept)	416	32,200	15,600	Low
20	Credit River—Forks Credit to Cheltenham	None	ND	ND	215,000	108,000	Low
21	Lake Ontario Tributaries	None	ND	ND	ND	ND	Low
22	Lake Ontario Tributaries	None	ND	ND	ND	ND	Low

Notes: ND—No Consumptive Surface Water Demand Estimated for Subwatershed

Subwatershed 5 (Fletcher's Creek) has been assigned a moderate potential hydrologic stress level. As there are no municipal surface water systems within the subwatershed, no further study is required. All other subwatersheds have been assigned low potential hydrologic stress levels.

Surface water stress assessments were not undertaken for future and drought scenarios as there are no municipal water systems based on the Credit River.

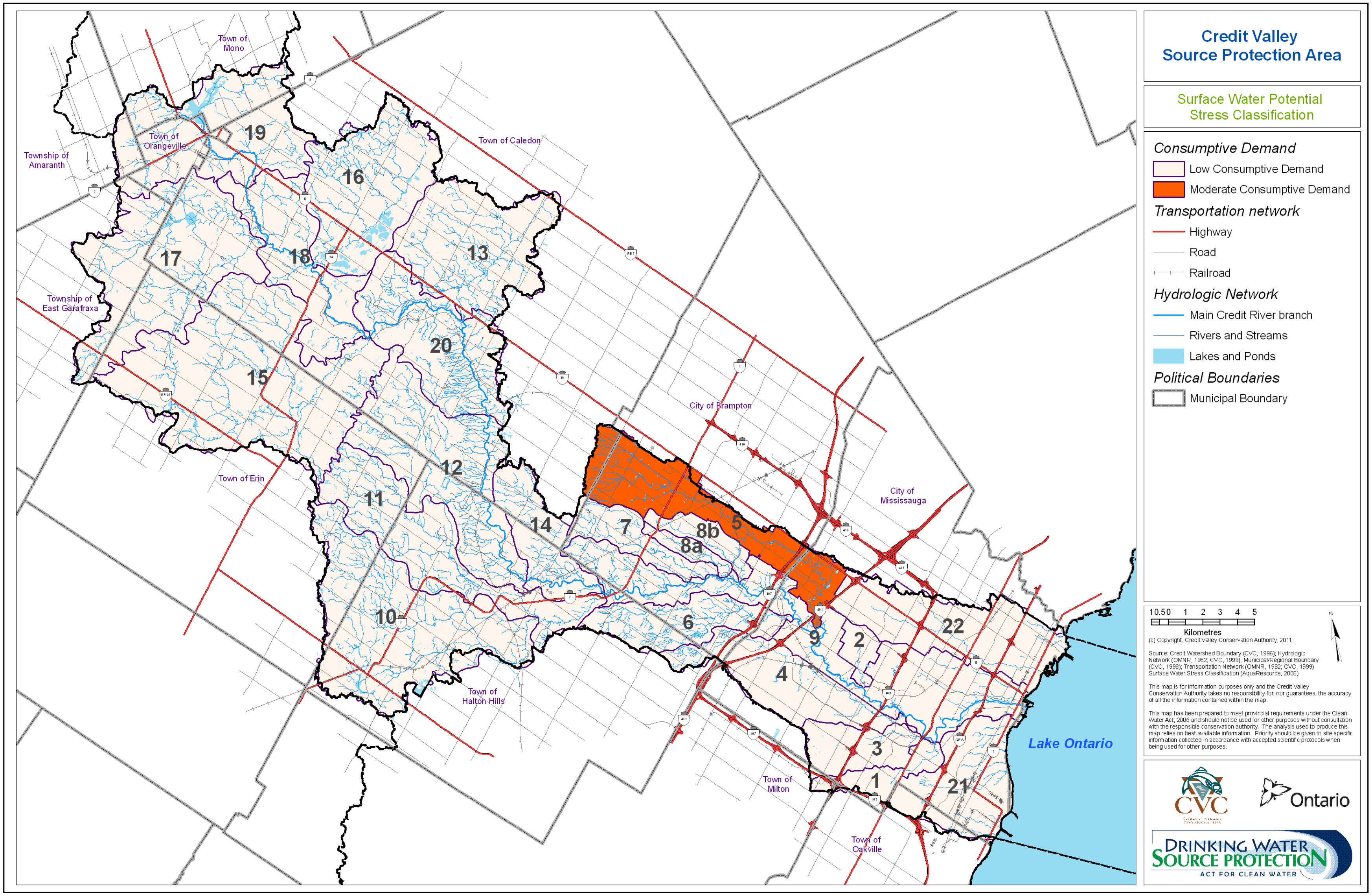


Figure 3-20: Surface Water Potential Stress Classification

Groundwater

The groundwater potential stress classification for each subwatershed was undertaken using criteria from the *Technical Rules* as set out in **Appendix C1**. Groundwater supply is defined as the amount of recharge within a subwatershed in addition to the rate of groundwater flowing into each subwatershed expressed as a flow rate of cubic meters per day (m^3/day). As described in the *Technical Rules,* the stress assessment included only the groundwater that flows into a subwatershed as part of the supply term. The stress assessment was evaluated for the average annual demand conditions and for the monthly maximum demand conditions. The stress level is categorized again into three levels (significant, moderate, or low). The *Technical Rules* require that assessments be undertaken to compare the existing and estimated future water demand against the estimated groundwater availability.

Existing Scenario

The Tier 2 Stress Assessment uses average annual groundwater supply and reserve for monthly stress calculations, and therefore, monthly values are not provided. Monthly values are then equivalent to average annual values expressed as a rate (m^3/day). For the existing scenario, the results are summarized in **Table 3.10**, and illustrated in **Figure 3.21**. Additional clarification is provided in **Appendix C1**.

Groundwater supply was calculated using estimated groundwater recharge **(Table 3.10)** and groundwater flow calculated as the sum of all positive flows into each subwatershed. Groundwater reserve was calculated as 10% of the total groundwater discharge to streams and wetlands in each subwatershed. Percent average annual water demand was then calculated using the average annual existing water demand shown in **Table 3.6**. Similarly, percent peak monthly water demand was calculated using the maximum monthly water demand on **Table 3.6**.

Three subwatersheds are classified as being under potential stress with respect to groundwater. These are subwatersheds 19 (Orangeville), 10 (Black Creek), and 11 (Silver Creek). All communities within these subwatersheds receive drinking supplies through groundwater-based municipal systems.

The Town of Orangeville is located within Subwatershed 19, as are portions of the Town of Mono and Township of Amaranth. The estimated water demand-to-availability ratio for the subwatershed has been estimated at 14%, based on the annual percent water demand calculation. Given the threshold stress criterion (10% per *Technical Rules*), a moderate level of stress was assigned to the subwatershed.

Subwatersheds 10 and 11 contain the communities of Acton and Georgetown in the Town of Halton Hills. The estimated water demand-to-availability ratios in subwatersheds 10 and 11 are 18% and 20%, respectively, based on the annual percent water demand calculation. Given the threshold, a moderate level of stress was also assigned to both subwatersheds. In respect of this, the *Technical Rules* require that they each be subject to a refined quantity risk assessment of a Tier 3 level Water Budget Study.

Though classified as such, it should be noted that the subwatershed is not necessarily experiencing hydrologic or ecologic stress. The classification merely indicates that the demand-to-availability percentage is greater than the defining threshold for moderate stress, and that additional information is required to understand the cumulative impacts of water withdrawals.

Table 3.10: Subwatershed Groundwater Potential Stress Classification (Existing Water Demand)

Name	Area (km^2)	Supply Calculation (m^3/d)			Groundwater Reserve Calculation (m^3/d)			Average Annual Conditions			Peak Monthly Conditions		
		Average Annual Recharge	GW Inflow	Total Supply	Average Annual Discharge	GW Reserve (10% Avg Annual Disch.)	Supply minus Reserve	Average Water Demand (m^3/d)	% Water Demand	Stress	Water Demand (m^3/d)	% Water Demand	Stress
1.Loyalist Creek	9.8	1,200	350	1,550	-800	80	1,470	1	0%	Low	1	0%	Low
2.Carolyn Creek	5.6	500	200	700	-100	10	690	0	0%	Low	0	0%	Low
3.Sawmill Creek	16.5	2,300	200	2,500	-1,500	150	2,350	2	0%	Low	2	0%	Low
4.Mullett Creek	32.9	4,700	900	5,600	-3,700	370	5,230	14	0%	Low	14	0%	Low
5.Fletcher's Creek	42.5	5,000	500	5,500	-4,300	430	5,070	351	7%	Low	590	12%	Low
6.Levi Creek	24.7	5,700	2,950	8,650	-2,050	205	8,445	209	2%	Low	402	5%	Low
7.Huttonville Creek	15.1	2,200	300	2,500	-1,400	140	2,360	102	4%	Low	138	6%	Low
8a. Springbrook Tributary	4.8	800	250	1,050	-550	55	995	18	2%	Low	18	2%	Low
8b. Churchville Tributary	8.4	1,000	0	1,000	-400	40	960	7	1%	Low	7	1%	Low
9.Norval to Port Credit	72.8	23,300	11,700	35,000	-33,400	3,340	31,660	101	0%	Low	101	0%	Low
21.Lake Ontario Tributaries	33.0	17,050	0	17,050	-7,300	730	16,320	0	0%	Low	0	0%	Low
22.Lake Ontario Tributaries	44.2	11,900	450	12,350	-2,400	240	12,110	0	0%	Low	0	0%	Low
Lower Watershed	**310.5**	**75,650**	**17,800**	**93,450**	**-57,900**	**5,790**	**87,660**	**805**	**1%**		**1,272**		
10.Black Creek	79.3	50,300	3,450	53,750	-36,500	3,650	50,100	9,057	18%	Moderate	9,384	19%	Low
11.Silver Creek	48.8	26,800	8,550	35,350	-25,750	2,575	32,775	6,655	20%	Moderate	6,655	20%	Low
12.Credit River - Cheltenham to Glen Williams	62.1	33,700	4,000	37,700	-35,300	3,530	34,170	124	0%	Low	124	0%	Low
13.East Credit River	50.6	35,100	4,350	39,450	-38,550	3,855	35,595	602	2%	Low	1,324	4%	Low
14.Credit River - Glen Williams to Norval	23.1	3,400	200	3,600	-3,200	320	3,280	55	2%	Low	55	2%	Low
20. Forks of the Credit to Cheltenham	46.0	22,600	14,550	37,150	-36,600	3,660	33,490	672	2%	Low	672	2%	Low
Middle Watershed	**310.0**	**171,900**	**35,100**	**207,000**	**-175,900**	**17,590**	**189,410**	**17,165**	**9%**		**18,214**		

Name	Area (km^2)	Supply Calculation (m^3/d)			Groundwater Reserve Calculation (m^3/d)			Average Annual Conditions			Peak Monthly Conditions		
		Average Annual Recharge	GW Inflow	Total Supply	Average Annual Discharge	GW Reserve (10% Avg Annual Disch.)	Supply minus Reserve	Average Water Demand (m^3/d)	% Water Demand	Stress	Water Demand (m^3/d)	% Water Demand	Stress
15.West Credit River	105.6	92,100	9,000	101,100	-86,400	8,640	92,460	6,603	7%	Low	7,944	9%	Low
16.Caledon Creek	52.0	44,000	100	44,100	-22,100	2,210	41,890	2,928	7%	Low	5,558	13%	Low
17.Shaw's Creek	72.0	58,500	4,050	62,550	-49,350	4,935	57,615	3,588	6%	Low	4,869	8%	Low
18.Credit River - Melville to Forks of the Credit	39.2	36,800	22,350	59,150	-49,050	4,905	54,245	1,411	3%	Low	2,236	4%	Low
19.Orangeville	59.8	47,700	6,350	54,050	-29,200	2,920	51,130	7,115	14%	Moderate	7,115	14%	Low
Upper Watershed	**328.6**	**279,100**	**41,850**	**320,950**	**-236,100**	**23,610**	**297,340**	**21,645**	**7%**		**27,722**	**9%**	
Total	**949.0**	**526,650**	**94,750**	**621,400**	**-469,900**	**46,990**	**574,410**	**39,615**	**7%**		**47,208**	**8%**	

Figure 3-21: Groundwater Potential Stress Classification (CVSPA) — Existing Demand

Future Scenario

The estimated parameters relating to water supply and reserve were not modified from those used for existing demands. **Table 3.11** shows the results of the groundwater stress classification based on future demands. **Table 3.11** indicates that subwatershed 15, 16 and 17 all attain a percent water demand of 8%. These subwatersheds are already using conservative water demand estimates and are not in high-growth areas where demand is expected to increase substantially.

The only planned system currently is the Pullen Well in Amaranth. This system is included in the Tier 3 water budget analysis. Estimated future conditions do not reclassify any "low" stress subwatersheds as being "moderate". Therefore, future conditions do not launch any further requirement for Tier 3 analysis. This being so, a future conditions map would appear identical to the existing stress classification map **(Figure 3.21)**.

3.7.7 Groundwater Drought Scenarios

Groundwater drought scenarios were undertaken in two parts (Part A and Part B Scenarios) to determine whether drawdown during the drought period could result in the inability to pump sufficient quantities of water to meet demand. For groundwater supplies, the *Technical Rules* require that these scenarios be evaluated using a transient application of the groundwater flow model. The *Technical Rules* specify that a Part A Scenario be conducted initially. If this analysis shows that there could be an impact at a municipal well, then the Part B Scenario is required. If no impact can be demonstrated, then the latter scenario can be omitted.

The Part A drought scenario represents a situation where groundwater recharge is eliminated for a recommended time period of two years. At the end of the period, drawdown at municipal wells is compared to the elevation of the well screens to assess whether a municipality's water supply sources could be affected by this scenario.

The Part B drought scenario involves estimated monthly recharge rates over a ten-year drought period. Similar to Part A, the maximum drawdown observed during the modelled drought scenario is compared to the elevation of the well screens at the municipality's supply wells to evaluate potential impacts on source supplies during the drought period.

Drought Scenarios—Methodology

Part A Scenario was completed using the calibrated FEFLOW model. The initial conditions (e.g., starting heads) were set equal to the calibrated groundwater heads, and the groundwater recharge was set equal to zero. Groundwater storage parameters were applied to the model as follows: specific yield values applied were equal to 0.2 and specific storage equal to 2.0×10^{-4}/s.

Drought Scenarios—Results

The outputs of the Part A drought scenario are tabulated in **Table C-23**, **Appendix C1**. The table shows the model predicted drawdown at each municipal well at the water table and the upper bedrock contact zone.

Drawdown in the contact zone for almost all of the municipal wells was predicted to be less than approximately 2.5 m under the Part A drought scenario. Information available at the time of report preparation suggests that the available drawdown at all municipal wells within the watershed is greater than this amount, and, as a result, it appears that the municipal wells will be able to meet their water supply requirements in extreme drought conditions. As such, a Part B analysis is not required.

Table 3.11: Subwatershed Groundwater Potential Stress Classification (Future Water Demand)

Name	Area (km^2)	Supply Calculation (m^3/d)			Groundwater Reserve Calculation (m^3/d)			Average Annual Conditions			Peak Monthly Conditions		
		Average Annual Recharge	GW Inflow	Total Supply	Average Annual Discharge	GW Reserve	Supply - Reserve	Average Water Demand (m^3/d)	% Water Demand	Stress	Water Demand (m^3/d)	% Water Demand	Stress
1.Loyalist Creek	9.8	1,200	350	1,550	-800	80	1,470	1	0%	Low	1	0%	Low
2.Carolyn Creek	5.6	500	200	700	-100	10	690	0	0%	Low	0	0%	Low
3.Sawmill Creek	16.5	2,300	200	2,500	-1,500	150	2,350	2	0%	Low	2	0%	Low
4.Mullett Creek	32.9	4,700	900	5,600	-3,700	370	5,230	14	0%	Low	14	0%	Low
5.Fletcher's Creek	42.5	5,000	500	5,500	-4,300	430	5,070	351	7%	Low	590	12%	Low
6.Levi Creek	24.7	5,700	2,950	8,650	-2,050	205	8,445	209	2%	Low	402	5%	Low
7.Huttonville Creek	15.1	2,200	300	2,500	-1,400	140	2,360	102	4%	Low	138	6%	Low
8a. Springbrook Tributary	4.8	800	250	1,050	-550	55	995	18	2%	Low	18	2%	Low
8b. Churchville Tributary	8.4	1,000	0	1,000	-400	40	960	7	1%	Low	7	1%	Low
9.Norval to Port Credit	72.8	23,300	11,700	35,000	-33,400	3,340	31,660	101	0%	Low	101	0%	Low
21.Lake Ontario Tributaries	33.0	17,050	0	17,050	-7,300	730	16,320	0	0%	Low	0	0%	Low
22.Lake Ontario Tributaries	44.2	11,900	450	12,350	-2,400	240	12,110	0	0%	Low	0	0%	Low
Lower Watershed	**310.5**	**75,650**	**17,800**	**93,450**	**-57,900**	**5,790**	**87,660**	**805**	**1%**		**1,272**	**1%**	

Name	Area (km^2)	Supply Calculation (m^3/d)			Groundwater Reserve Calculation (m^3/d)			Average Annual Conditions			Peak Monthly Conditions		
		Average Annual Recharge	GW Inflow	Total Supply	Average Annual Discharge	GW Reserve	Supply - Reserve	Average Water Demand (m^3/d)	% Water Demand	Stress	Water Demand (m^3/d)	% Water Demand	Stress
10.Black Creek	79.3	50,300	3,450	53,750	-36,500	3,650	50,100	11,803	24%	Moderate	12,130	24%	Low
11.Silver Creek	48.8	26,800	8,550	35,350	-25,750	2,575	32,775	9,152	28%	Sig.	9,152	28%	Moderate
12.Credit River - Cheltenham to Glen Williams	62.1	33,700	4,000	37,700	-35,300	3,530	34,170	309	1%	Low	309	1%	Low
13.East Credit River	50.6	35,100	4,350	39,450	-38,550	3,855	35,595	616	2%	Low	1,338	4%	Low
14.Credit River - Glen Williams to Norval	23.1	3,400	200	3,600	-3,200	320	3,280	75	2%	Low	75	2%	Low
20.Credit River - Forks of the Credit to Cheltenham	46.0	22,600	14,550	37,150	-36,600	3,660	33,490	672	2%	Low	672	2%	Low
Middle Watershed	**310**	**171,900**	**35,100**	**207,000**	**-175,900**	**17,590**	**189,410**	**22,627**	**12%**		**23,676**	**12%**	
15.West Credit River	105.6	92,100	9,000	101,100	-86,400	8,640	92,460	7,450	8%	Low	8,791	10%	Low
16.Caledon Creek	52.0	44,000	100	44,100	-22,100	2,210	41,890	3,468	8%	Low	7,231	17%	Low
17.Shaw's Creek	72.0	58,500	4,050	62,550	-49,350	4,935	57,615	4,796	8%	Low	6,077	11%	Low
18.Credit River - Melville to Forks of the Credit	39.2	36,800	22,350	59,150	-49,050	4,905	54,245	1,388	3%	Low	2,213	4%	Low
19.Orangeville	59.8	47,700	6,350	54,050	-29,200	2,920	51,130	9,585	19%	Moderate	9,585	19%	Low
Upper Watershed	**328.6**	**279,100**	**41,850**	**320,950**	**-236,100**	**23,610**	**297,340**	**26,686**	**9%**		**33,896**	**11%**	
Total	**949**	**526,650**	**94,750**	**621,400**	**-469,900**	**46,990**	**574,410**	**50,119**	**9%**		**58,845**	**10%**	

It is noted that the FEFLOW model has not been calibrated to transient groundwater conditions, or to local wellfield conditions in all wells. Therefore, the results of the drought scenario should only be considered as rough estimates of the potential impacts under low recharge conditions.

Drought scenarios have not been completed for the future conditions in the stressed subwatersheds. This is because these larger municipal systems in the subwatersheds 10, 11 and 19 (Acton, Georgetown and Orangeville) have already been identified as having moderate groundwater stress levels and therefore are not required to undertake the drought assessment.

3.7.8 Uncertainty Assessment

Water Demand

The PTTW database utilized for this assessment was obtained by the CVC from the MOECC. It may not contain the most up-to-date information as it may not contain changes to permits made in recent years. Furthermore, permitted water use rates must be adjusted to account for seasonal variability, consumption, and redundancy. During this study, the database was updated as best as possible to accommodate the above issues.

With respect to uncertainty in undertaking the stress assessment, the following must be recognized:

- When specifying the amount of water required for their specific use, permit holders will often request a volume of water that exceeds their requirements. This may be done to ensure compliance in dry years, or to secure sufficient water for possible future expansion of the operation. As such, water demand estimates have been conservatively estimated.
- The database does not maintain a record of seasonal water use. Actual water use for irrigation (agricultural, golf course, etc.) would be much higher during a dry summer than a wet summer. Similarly, water takings for a snowmaking operation such as a ski hill will also fluctuate depending on the climatic conditions.
- Multiple wells or sources may be included on a particular permit, and the permitted rate refers to the total for all sources associated with that permit. As an example, two nearby municipal wells may operate under one permit, but the permit for those wells specifies that they cannot operate simultaneously. In this case, each well source could pump at the maximum permitted rate, but not at the same time. To estimate total demand, the total permitted rate should be divided amongst the active source locations.
- The spatial location of water taking sources is not always accurate.
- The PTTW database is not current with respect to the MOECC's actual permitting activities (recent permit numbers may not be included within the database).
- The source of water may be characterized in the PTTW database by either "S" for surface water, "G" for groundwater, or "B" where both groundwater and surface water are used. There are no standardized fields that indicate whether a specific source is taking water from surface water or groundwater.
- Historic municipal water wells, which can be significant, are often "grandfathered" and do not require a permit. As such, that demand will not be reflected in the PTTW database.

Subwatershed Stress Results

Subwatersheds 10 and 11—Black Creek and Silver Creek

The vast majority of the water takings in both subwatersheds are municipal, and, as such, the estimated groundwater demand is relatively certain. The assessments also show that these takings are highly consumptive, in the order of above 5000 m^3/day.

The results of the assessment also appear to be consistent with historical observations and experiences relating to hydrogeological stresses, particularly in the Georgetown area.

There are uncertainties associated with the climate dataset used in the development of the overall water budget parameters, but, given the relatively high water demand, the assigned stress classifications are unlikely to change within the bounds of uncertainty of the parameters.

Given the reliability of the demand information, of the hydrological input data, and of the modelling process, there is a high level of confidence that results of the assessment are reflective of the observations and experiences relating to hydrological stress within the subwatersheds.

Subwatershed 19—Orangeville

The Town of Orangeville is the only permitted water user in Subwatershed 19, and, as such, the estimated groundwater demand is relatively certain. The town maintains the water system for the neighbouring Town of Mono, which also has the majority of its supply wells in the subwatershed.

Historical records show that municipal groundwater takings have been known to impact local surface water features (Monora and Mill Creeks, tributaries of the Credit River) within the subwatershed.

Given the reliability of the demand information, of the hydrological input data, and of the modelling process, there is a high level of confidence that results of the assessment are reflective of the observations and experiences relating to hydrological stress within the subwatershed.

Drought Scenarios

The *Technical Rules* specify that the drought scenarios must be undertaken for both the current and future (Table 1, Scenarios D and E) periods. However, municipal pump rates could not be procured for the future scenario (Scenario E), and, as such, drought scenarios were not undertaken for that period. This represents a data gap in the assessment that should be addressed in any updates to the study.

3.7.9 Limitations of Study

This study has been prepared to meet provincial requirements under the *Clean Water Act* (*2006*) and if it is proposed that this analysis be used for another purpose, it would be advisable to first consult with CVC.

The water budget process follows a tiered process to screen the areas to identify where there is potential water quantity stress. The process is designed so that each successive tier in the analysis (up to and including Tier 3) becomes more complex, requiring increasingly 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 more recent 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.

3.8 TIER 3 WATER BUDGET

3.8.1 Overview

The overall objective of the Tier 3 Water Budget Study 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 that show moderate or significant water quantity stress and if the groundwater or surface water are the source for municipal drinking water supplies. Based on the results of the Tier 2 Water Budget studies (**Section 3.7.5**), moderate groundwater quantity stresses were identified in Subwatershed 19 in the headwaters area of the CVSPA, and in subwatersheds 10 and 11 in the middle zone of the CVSPA. The Town of Orangeville's supply wells are all located in Subwatershed 19, as are a portion of those servicing the Town of Mono, and a designated supply well for the Township of Amaranth. The municipal wells servicing Acton and Georgetown are located in Subwatersheds 10 and 11, respectively. The following section describes the findings of the Tier 3 Water Budget analyses for municipal wells located in these subwatersheds.

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

3.8.2 Tier 3 Methodology

The two major components of the Tier 3 Water Budget Study 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 Tier 2 Water Budget, 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 in the surface flow system, and in 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 occurs within the *Local Areas*. Local Areas 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.

The Tier 3 Water Budget was developed through key refinements in the numerical surface water and groundwater models used for the analyses. These include 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, compared to the regional-scale representation created for the Tier 2 water budget assessment.

The Local Area Risk Assessment involves evaluation of risk scenarios within the Local Areas. The risk scenarios were developed to represent existing, committed and planned pumping rates as well as existing and planned land uses. The scenarios were used to estimate the response of groundwater and surface water flow patterns and water levels, to variations in pump rates and reduction in recharge rates due to increased imperviousness from changes in land use. These analyses assess the future sustainability of the municipal water source as population grows and land use changes.

The risk assessment scenarios also consider the requirements of other water uses, particularly those that must be maintained by provincial or federal law such as wastewater assimilation flows, the ecological flow requirements of coldwater fish habitats and wetlands, and for recreational use. These other water uses were not explicitly represented in the groundwater model as they do not remove or supply water from the groundwater flow system, but they are water uses that require flow provided by the groundwater and surface water systems. These other water uses were considered as part of the Local Area Risk Assessment.

The risk scenarios used the calibrated surface water and groundwater flow models to estimate changes in water levels in the municipal supply aquifer, and to estimate the impacts to groundwater discharge and base flow to streams under average climate conditions.

Where the scenarios identify the potential that a well will not be able to supply their allocated or planned rates, the Local Area is assigned a ‘moderate’ or ‘significant’ water quantity risk level. Once the risk level is assigned to the Local Area, all 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 identified as drinking water threats.

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 reductions in recharge are classified as significant 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.

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 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,

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.

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.

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 in December 2013:

- **Existing Demand** – amount 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 greater than the current lawful PTTW taking is considered part of the planned quantity 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 of Water** – 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 of Water** – (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 3.23**. 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.

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 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. 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.

3.8.3 Numeric Modelling for Municipal Wells in Town of Orangeville and in parts of Town of Mono and Township of Amaranth

The Tier 3 Water Budget modelling approach integrates surface water (hydrological) and groundwater (hydrogeological) components of the flow system. The numerical modelling was done using the Hydrological Simulation Program-Fortran (HSP-F model) for simulating surface water flow, and the Modular Flow (MODFLOW model) for simulating groundwater flow. The model covered the entire upper subwatershed area of the CVSPA, to extend to the natural boundaries of the groundwater flow system. In the west, the model was extended beyond the Credit River and Grand River watershed divide since previous modeling work had suggested that the groundwater divide was located west of the surface water divide. The modelled area is shown in **Figure 3.22**.

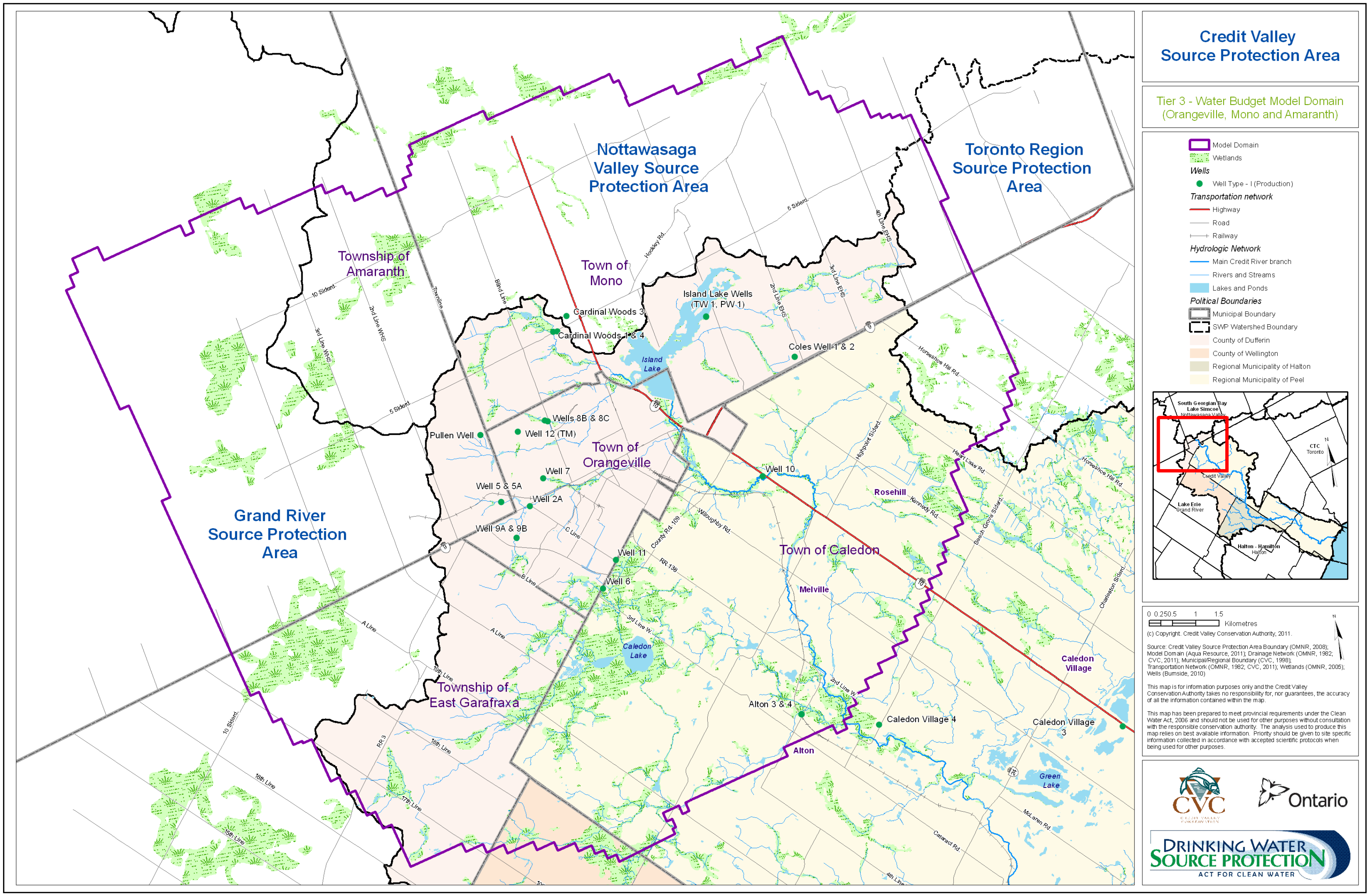


Figure 3.22: Tier 3 – Water Budget Model Domain (Orangeville, Mono and Amaranth)

Both models were calibrated to represent typical flow conditions under average (steady-state), variable (transient) climate conditions, and flow conditions as well as validated to ensure that the natural processes were simulated as accurately as possible. The representation of a wide variety of climate conditions is necessary in order to predict the ability for the municipalities' water sources to reliably meet water demand under this range of climate conditions.

Model Refinements

The Tier 3 Water Budget models improve upon those developed for the Tier 2 assessment in terms of the model simulation, and the representation of the movement of groundwater between and across subwatershed boundaries.

Improvements in the HSP-F model were mainly attributed to refinements in the model characterization and refined calibration, while those in the MODFLOW model were based on enhanced representation of the geology and hydrogeology, particularly in the areas immediately surrounding municipal wells. To enable this, the grid cells in the model were reduced so that the subsurface details could be made more accurate and more reflective of actual conditions.

Details on the refinement of both models are provided in Appendix A of the Tier 3 foundation document (AquaResource Inc., 2011). Summary information pertaining to models' calibration and validation is also presented in **Appendix C2** of this Assessment Report.

Modelling Approach

The use of a linked model scheme is favoured where the surface water model can accurately provide simulations of the short- and long-term hydrologic processes, including the simulation of dynamic streamflow response and groundwater recharge, while the groundwater model can more accurately determine the subsurface movement of groundwater at time scales that are more relevant for these processes.

The modelling approach is summarized below:

- Surface Water Model - HSP-F (Bicknell *et al*., 2001) was designed to simulate water budget components in a spatially detailed and temporally dynamic manner. The model simulated hourly continuous streamflow and was used to model the impact of changing climate and land use on the surface water flows, and on groundwater recharge rates.
- The model was calibrated to the Melville streamflow gauge at the downstream limit of Subwatershed 19, for the period 1997 to 2000. Following the calibration to the Melville gauge, the model was validated to stream flow data collected at the Melville gauge between 2005 to mid-2007. Model scenarios were completed to simulate groundwater recharge over a period extending from 1960 to 2006.
- Groundwater Flow Model - MODFLOW model was built to represent the interaction between the groundwater system and the surface water system, and as such, was calibrated to hydraulic head measurements, as well as surface water data (spot baseflow observations, streamflow gauge data at Melville). The model was also calibrated transiently to a three-well pumping test that took place over a 44-day period. This pumping test was simulated to ensure that linkages between deep and shallow groundwater systems and the surface water system were properly understood and represented in the model. The model was also verified to long-term aquifer response under past climatic conditions and monthly varying average pumping rates.

The calibration of the model focused on replicating the hydraulic heads in the aquifer at each municipal well under average annual groundwater pumping conditions.

Although the HSP-F model simulated hourly continuous streamflow, and the MODFLOW model simulated average annual groundwater discharge and baseflow conditions, each of the models estimates important aspects of the same surface water flow system. As such, they were both calibrated to the same streamflow data.

Output from the surface water model was used as the initial input (recharge) into the groundwater flow model. This coupling was used to examine the impact of future land development on water levels in aquifers, and reductions in discharge to streams and surface water features. The combined results of the two water budget models produce an improved understanding of the hydrologic and hydrogeologic flow systems.

3.8.4 Characterization of Water Demand for Municipal Wells in Town of Orangeville and in parts of Town of Mono and Township of Amaranth

To characterize water demand in the study area, the following data was 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 Definition - the safe water level at each well or intake was estimated or calculated. The safe water level corresponds to the minimum groundwater or surface water elevation that can be sustained while pumping at the intake.
- Maximum Yield or Sustainable Yield Estimate - these estimates may be less than the permitted rates and were therefore considered when defining the allocated rate for each well. They are important for planned wells or intakes where permits are not yet in place; and
- Operational procedure and maintenance information.

3.8.5 Results of Characterization for Municipal Wells in Town of Orangeville and in parts of Town of Mono and Township of Amaranth

The Tier 3 Water Budget and Local Area Risk Assessment are documented in the report *Orangeville, Mono and Amaranth Tier Three Water Budget and Local Area Risk Assessment, Final Report* (AquaResource Inc., 2011). This report was extensively peer-reviewed by a panel of municipal and provincial representatives, private consultants, and the CVC prior to acceptance by the CTC SPC. It is the foundation document, upon which this section has been based. It should be noted that the terminology used in the foundation report to describe existing, committed and planned demand and the allocated and planned quantities of water are not consistent with current terminology described in **Section 3.8.3** due to recent changes by the Province in Interim Guidance (December 2013). This primarily effects the discussion of baseflow impacts in **Section 3.8.7**; however, the technical analysis and final findings of the report are not affected.

Geographic Setting

The Tier 3 study area (**Figure 3.22)** lies within the headwaters of four major rivers - the Credit River (CVSPA, CTC Source Protection Region); the Humber River (Toronto and Region Source Protection Area, CTC Source Protection Region); the Nottawasaga River (Nottawasaga Valley Source Protection Area, South Georgian Bay Lake Simcoe Source Protection Region); and the Grand River (Grand River Source Protection Area, Lake Erie Source Protection Region). The Nottawasaga River flows northwest into Georgian Bay which is part of Lake Huron. The Grand River flows southwest into Lake Erie. The Credit and Humber rivers flow southeast to Lake Ontario.

The study area includes the Town of Orangeville and portions of the Town of Mono, Town of Caledon, and Townships of East Garafraxa and Amaranth. Except for the Town of Caledon, which is part of the Region of Peel, the other municipalities are part of the County of Dufferin.

In the northern portion of the CVSPA (Subwatershed 19), the Upper Monora Creek, Middle Monora Creek, and Lower Monora Creek all drain into Island Lake Reservoir from the west. There are also two unnamed tributaries that drain directly into the Island Lake Reservoir from the east.

Outflow from Island Lake Reservoir at the South Dam marks the start of the Credit River. Mill Creek joins the Credit River downstream of the South Dam, and the river continues to flow in a southward direction. At the southern end of the subwatershed near Melville, three additional unnamed tributaries located within the Town of Caledon empty into the Credit River. The downstream limit of Subwatershed 19 is the Melville Dam.

Water Flow into and out of Subwatershed 19

The combined results of the two water budget models produce an improved understanding (conceptualization) of the hydrologic and hydrogeologic flow systems. The following sections quantify and outline the water budget components within Subwatershed 19 (headwaters) of the CVSPA. Each of the components was calculated assuming no net change in stored water occurs over the time period 1961 to 2006 and were based on the limitations and assumptions of the long-term climate dataset. **Table 3.12** summarizes the estimated overall water budget fluxes for Subwatershed 19, while additional detail on the modelling results is presented in **Appendix C2**. The table summarizes watershed inflows including precipitation, wastewater influent, and groundwater flow. Outflows include evapotranspiration, streamflow (Credit River), groundwater pumping, and groundwater flow.

Table 3.12: Overall Water Balance Table (Subwatershed 19)

	Flow (m^3/d)	Flow (mm/yr)	Percent of Precipitation
Inflows			
Total Precipitation	148,500	891	100%
Groundwater Flow In			
Flow from GRCA into Sub 19	5,000	30	3%
Flow from Subs 17 and 18 into Sub 19	4,000	24	3%
Flow from NVCA into Sub 19	1,900	11	1%
Flow from TRCA into Sub 19	200	1	0%
Total Inflow	**159,600**	**958**	**108%**
Outflows			
Evapotranspiration	93,200	560	63%
Streamflow (Melville)	58,000	348	39%
Groundwater Flow Out			
Flow from Sub 19 into NVCA	8,400	50	6%
Total Outflow	**159,600**	**958**	**108%**

Average annual precipitation in Subwatershed 19 is 891 millimetres per year (mm/yr.) as measured at the MOECC Orangeville climate station. This translates to a rate of 148,500 cubic metres per day (m^3/d) over the subwatershed. Groundwater modelling results indicate that a fairly significant amount of groundwater flows into Subwatershed 19 across the subwatershed boundaries. Approximately 5,000 m^3/d of groundwater flows into the subwatershed from the Grand River watershed, and an additional 4,000 m^3/d flows into the subwatershed from subwatersheds 18 and 17 to the south. As shown in **Table 3.12**, groundwater inflow into Subwatershed 19 is approximately 11,100 m^3/d, representing approximately 7% of the total recharge.

Outflows from Subwatershed 19 include evapotranspiration, streamflow, groundwater pumping, and groundwater flow. Average annual evapotranspiration is approximately 560 mm/year. Average annual streamflow, as measured at Water Survey of Canada Melville Gauge is 58,000 m^3/d. Approximately 8,400 m^3/d of groundwater flows to the north out of Subwatershed 19 into the Nottawasaga River watershed along the eastern boundary of the subwatershed. This flow to the north is driven by the steep hydraulic gradient into the valley north of the Island Lake Reservoir.

Table 3.13 shows the water balance for groundwater within Subwatershed 19. The water budget models predict an average annual groundwater recharge rate of 237 mm/yr., or 39,500 m^3/d into Subwatershed 19.

Table 3.13: Water Balance, Groundwater (Subwatershed 19)

	Flow (m^3/d)	Flow (mm/yr)	Percent of Precipitation
Inflows			
Groundwater Recharge	39,500	237	100%
Flow from Sub 17 into Sub 19	4,000	24	10%
Flow from NVCA into Sub 19	1,900	30	5%
Flow from TRCA into Sub 19	200	1	1%
Flow from GRCA into CVC	5,000	30	13%
Total Groundwater Inflow	**50,600**	**304**	**128%**
Outflows			
Surface Water Discharge	34,800	208	88%
Permitted Wells	7,400	44	19%
Flow out of Sub 19 into NVCA	8,400	50	21%
Total Groundwater Outflow	**50,600**	**304**	**128%**

Groundwater outflows include discharge to surface water (streams and wetlands), groundwater wells, and groundwater flow out of the watershed. Total groundwater discharge to surface water is approximately 34,800 m^3/d or 208 mm/yr. Groundwater pumping is 7,400 m^3/d, or approximately 19% of the total recharge into the subwatershed. Groundwater flow into the Nottawasaga River watershed from Subwatershed 19 is 8,400 m^3/d or 21% of the total recharge in Subwatershed 19.

These values are comparable to those estimated using the regional (Tier 2) model. The differences in water budget parameters between the two rounds of analyses are attributed to the conceptual and numerical model updates made in the HSP-F and groundwater model, and the local-scale calibration. The Tier 3 water balance estimates are therefore considered more accurate and reliable than those calculated in the Tier 2 assessment.

Calculated Water Demand - Municipal

Municipal demand was identified as the most consumptive usage of groundwater in the CVSPA (see **Chapter 2**, **Table 2.9**). The three municipalities in the Tier 3 Study Area - Orangeville, Mono and Amaranth, each have groundwater sourced municipal water supplies. A discussion on the efforts taken to assess consumptive demand, and descriptions of each system is provided in **Appendix C2**.

The demand characterization is shown conceptually in **Figure 3.23**, while demand data for each municipal well is shown on **Table 3.14**. The existing pumping conditions for Orangeville and Mono were based on the 2008 average annual pumping rates **(Table 3.14)**, since the 2009 annual averages were not available in advance of the study. The Pullen Well (Amaranth) is not currently pumping, and as such was not simulated in the groundwater flow model in the Existing Conditions scenario. The pumped water level elevation in each municipal well (Orangeville and Mono) for 2008 was determined by examining water level hydrographs for each municipal well during periods when it was pumped.

The allocated and planned quantities of water for the pumping wells in each municipality are also shown on **Table 3.14.** These rates represent the existing plus committed demand for Orangeville's and Mono's wells, and the planned demand for the Pullen Well in Amaranth. The committed demands were forecast using the municipal growth plans based on the approved Official Plan population projections at the time of the study and through extensive discussion with municipal officials. The planned demand for the Pullen Well represents projected quantities required to service a residential estate subdivision and are based on rulings from the Ontario Municipal Board hearing which approved the development. A description of the factors informing the derivation of future demand for each municipality is provided in **Appendix C2**.

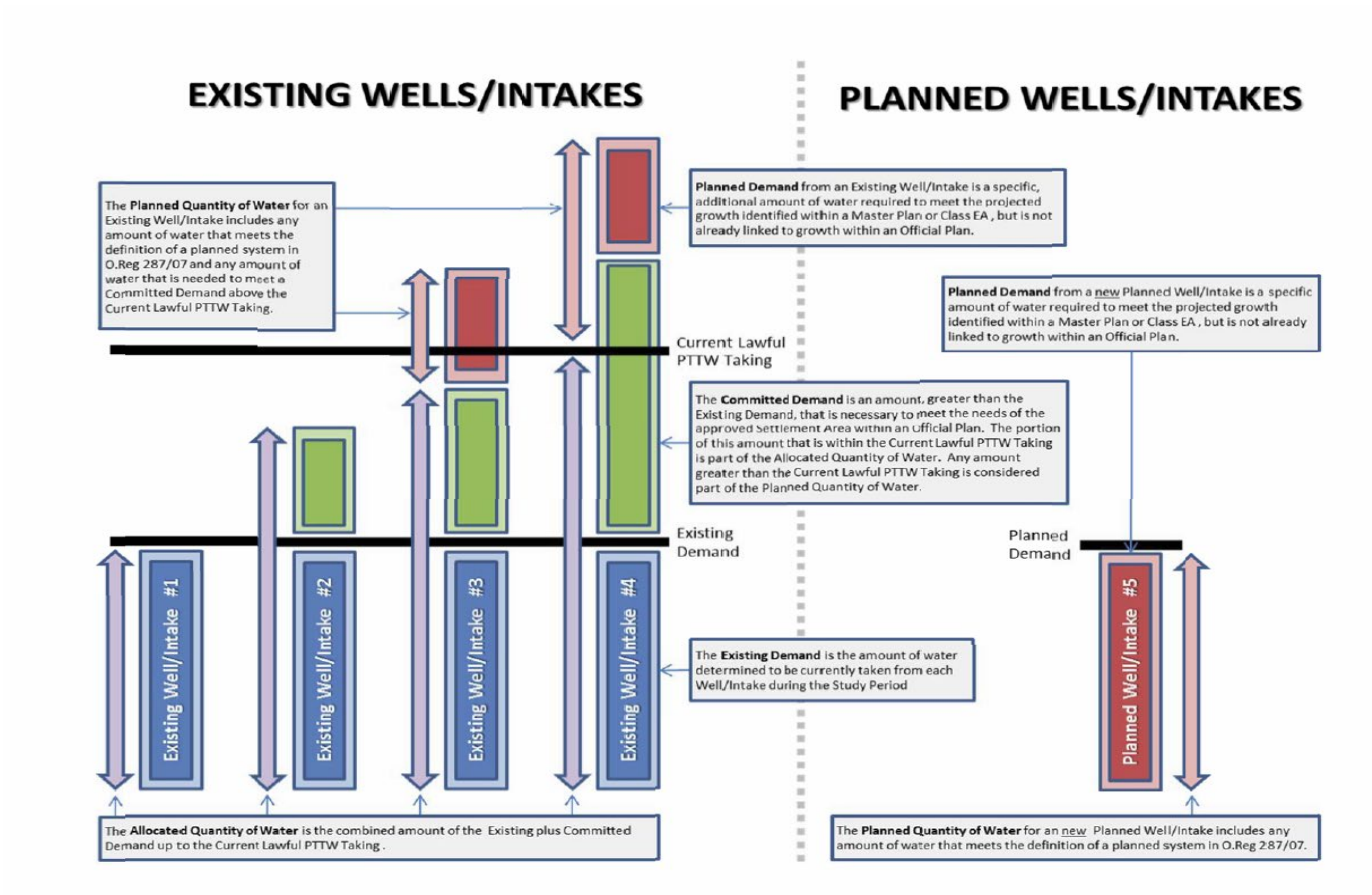


Figure 3.23: Characterization of Existing and Planned Systems

Table 3.14: Municipal Water Demand

Town	Municipal Well	Aquifer	Pumping Rates (m^3/day)		
			Maximum Permitted	**Annual Average Demand (2008)**	**Existing Plus Committed Plus Planned Demand[a]**
Orangeville	Well 2A	Bedrock	1,309	286	400
	Well 5/ 5A	Overburden	6,000	3,359	3,500
	Well 6	Bedrock	3,600	1,358	1,600
	Well 7	Bedrock	1,309	755	1,235
	Well 8B, 8C	Bedrock	655[1]	478	550
	Well 9A/ 9B	Bedrock	878	559	560
	Well 10	Overburden	1,452	121	1,235
	Well 11	Bedrock	1,309	939	1,235
	Well 12	Bedrock	1,309	781	1,240
		Total	**17,333**	**8,636**	**11,555**
Mono	Cardinal Woods 3[2]	Bedrock	1,571	240	392
	Cardinal Woods 1[2]	Bedrock	817	8	8
	Cardinal Woods 4[2]	Bedrock	753	0	0
	Coles Wells 1/ 2[3]	Overburden	655	82	116
	Island Lake PW1[4]	Overburden	1,958	5	347
	Island Lake TW1[4]	Overburden	820	118	
		Total	**6,582**	**453**	**863**
Am.	Amaranth Pullen Well	Bedrock	737[5]	0	220[6]
		Total	**24,652**	**9,089**	**12,637**

Notes:

[a] Orangeville existing plus committed estimate of 11,555 m^3/d is the total estimated taking divided by a peaking factor of 1.5; Mono existing plus committed estimate of 863 m^3/d was based on land use developments specified in the Official Plan, and the Pullen Well planned demand estimate is taken from estimated demands to service a residential estate subdivision.

[1] Wells 8B and 8C have a maximum combined permitted taking of 655 m^3/d

[2] Total permitted of 1571 m^3/d from either Cardinal Woods Well 3, ***or*** Cardinal Woods Wells 1 and 4. (Cardinal Woods Well 3 is the primary well, and Wells 1 and 4 act as backup wells)

[3] Each well permitted for 570 m^3/d but combined taking of 655 m^3/d

[4] 72 hour combined daily average of 2,614 m^3/d

[5] Permit has expired; previous permitted rate was 737 m^3/d

[6] Planned rate based on average day demand required to meet the needs of a residential estate subdivision

Safe Additional Drawdown

Safe additional drawdown is defined as the additional depth that the water level within a pumping well could safely fall while maintaining that well's allocated and planned pumping rates. To establish the safe additional drawdown for each municipal pumping well within the study area, the following components were evaluated or calculated for each municipal well:

- Safe water level elevations - the lowest elevation within a municipal pumping well that an operator can take the water level to without causing physical damage or reduced output from the well. This elevation may be related to the well screen elevation, pump intake elevation or other operational limitations;
- Existing (2008) water level elevations in the pumping wells - the elevation of the observed average annual pumped water level within each municipal well;
- Estimated non-linear well losses at each well - drawdown within the well in response to well inefficiencies (e.g., entrance losses, turbulent flow around pump fittings) created during groundwater extraction; and
- Convergent head losses at each well - MODFLOW does not specifically simulate the water level at the location of a well located within a grid cell. Additional water level drawdown is referred to as convergent head loss and can be quantified to properly predict the pumped water level in a well.

Further discussion and details on the computation of these components are provided in **Appendix C2**.

The safe water level elevation for each well in Orangeville was provided by the town's Public Works staff and is based on the elevation at the top of the well screen, the elevation of the pump intake and other pump settings, which included a measure of safety to account for seasonal water level fluctuations and other well losses that may not be accounted for in the groundwater flow model.

The safe water level elevations for the Town of Mono's wells and the Pullen Well were based solely on the pump intake elevations as operational considerations were not available.

The safe water level elevations and the safe additional drawdown at each municipal well in the study area are listed in **Table C-41** of **Appendix C2**. With the inclusion of non-linear well losses, and convergent head losses, the safe additional aquifer drawdown at each well has been derived from the safe additional drawdown. This data is shown in **Table C-42**, **Appendix C2**.

Calculated Water Demand – Non-Municipal

Water Users with Permits to Take Water

There are a number of large permitted non-municipal water takers in the study area, mainly for agricultural, commercial and industrial usage. There are 13 such permits. **Appendix C2** provides the details on these permits.

Water Users Not Required to Obtain Permits to Take Water

Non-permitted water use represents water takings for domestic water or other use where the taking is less than 50,000 litres per day (L/d) or for any amount of taking for livestock watering. Several wells exist within the provincial water well database within the Town of Orangeville. These wells may pre-date the provision of municipal water and therefore may no longer be in use, or that may be used occasionally for lawn watering or similar uses. Consumptive water use from domestic wells in the areas of Subwatershed 19 without municipal water service was estimated to be 95 m^3/d (AquaResource Inc., 2009). This water use represents approximately 1% of the estimated municipal water use within Subwatershed 19 and less than 1% of the total permitted water use within the subwatershed. As such, these water uses were not simulated in the groundwater flow model or in the Subwatershed 19 water budget calculations.

Other Water Uses

Aquatic Habitat and Provincially Significant Wetlands

Groundwater discharge requirements for coldwater aquatic habitat are poorly understood, and the impacts of a reduction in groundwater discharge into the aquatic habitat cannot be definitively predicted. Consequently, the province introduced the use of thresholds to evaluate the impacts of reductions in groundwater discharge into coldwater streams.

In Ontario, there has been increasing recognition of the water needs of aquatic ecosystems in legislation and policy. In general, this reflects a growing awareness of the importance of identifying the water needs of aquatic ecosystems for watershed planning and better linking of design criteria for specific watershed management measures to the ecological responses of receiving waters. As such, several projects aimed at developing approaches to support the implementation of ecological flow assessments, have been undertaken in recent times.

One such study, a Pilot Project, was undertaken as part of the Tier 3 work, to estimate ecosystem water needs in the Orangeville area. The objective was to identify specific targets that could be used to evaluate the degree of impact that future water supply scenarios may have on ecological water uses. The study focused on the Lower Monora Creek, a coldwater stream located in Orangeville, in close proximity to several municipal pumping wells. The study concluded that while the modelling methods and available data provided some approximate targets, the hydrologic modelling lacked adequate spatial resolution, and the groundwater flow model lacked adequate temporal resolution to define specific ecological flow targets. Furthermore, the estimation of specific ecological flow requirements requires a detailed study of aquatic and terrestrial fish and plant species to begin to understand the ability of the species to withstand changes in a hydrologic regime.

Based on these conclusions, the province elected to prescribe specific baseflow reduction thresholds to be used when assigning a risk level associated with predicted impacts to coldwater fish community streams in response to increased municipal pumping. These thresholds are discussed later on in this Assessment Report.

Figure 3.24 shows the coldwater fisheries and wetlands within the study area. Coldwater fisheries are observed in the Lower Monora Creek, Upper Monora Creek, and a few of the Island Lake tributaries, and Caledon tributaries. The upper portion of Mill Creek (near Well 5/5A) is also managed as a coldwater stream; however, the portion of Mill Creek towards the Credit River is a mixed coolwater stream. The Credit River downstream of the Island Lake Reservoir is classified as a mixed coolwater community, and a warmwater community south of Highway 10 (south crossing) to the Melville Dam.

The *Technical Rules* also identify provincially significant wetlands as other water uses that cannot be significantly impacted by municipal pumping. The wetland systems within Subwatershed 19 include swamps, marshes, fens, and bogs. Evaluated wetlands are classified under a standard methodology taking into account the wetlands biological, hydrological, and socio-economic features and functions. Based on this system, wetlands can be identified as Provincially Significant Wetlands, and these are protected under the wetland component of the Provincial Policy Statement. Two Provincially Significant Wetland Complexes are located in the Headwaters Subwatershed: Speersville and Orangeville. The Orangeville Wetland Complex is approximately 340 hectares in area and is primarily marsh with lesser areas of swampland. The complex includes wetlands that surround the Island Lake Reservoir, the Credit River, North Branch of Lower Monora Creek, Middle Monora Creek, the eastern portion of Upper Monora Creek, and the riverine wetlands south of Island Lake that support coldwater fish communities. The Speersville Wetland Complex includes those wetlands located in the far southeastern portions of the subwatershed, within the Town of Caledon. CVC notes that the classification of the designation of provincial significance of wetlands within the subwatershed was completed over 30 years ago, and information on the communities may no longer be valid due to changing hydrologic schemes, especially within the urban areas.

South of Subwatershed 19, in Subwatershed 17 lays the Caledon Lake Wetland Complex. It is a 547 hectare Provincially Significant Wetland Complex that is dominated by swampy vegetation (87.1%). The wetland complex supports flora and vegetation communities rare to other areas of the Credit River watershed. Caledon Lake, a large kettle lake (38 hectare), and a series of smaller lakes and ponds that formed as a result of previous marl extraction, also lie within the wetland complex.

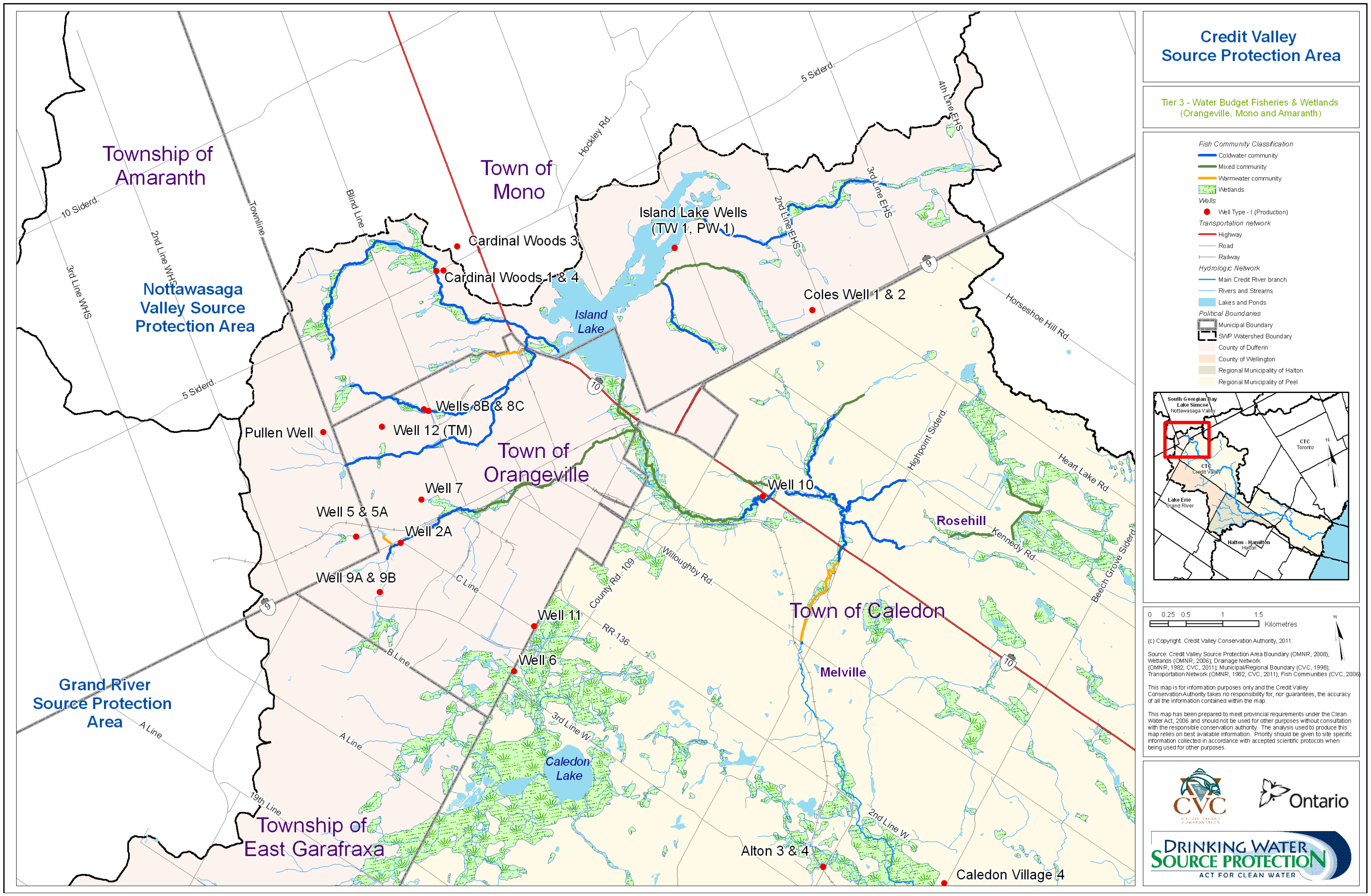


Figure 3.24: Tier 3-Water Budget Coldwater Fisheries and Wetlands (Orangeville, Mono and Amaranth)

Wastewater Assimilation

Orangeville's Water Pollution Control Plant discharges into the Credit River, downstream of the Island Lake Reservoir. Flow in the Credit River is regulated by the outflow from the Island Lake Reservoir through an MOECC PTTW issued to CVC. The minimum mean monthly outflow rates from Island Lake, which must be maintained at various times of the year in order to provide consistent downstream flow to assist with the assimilation of effluent from the Orangeville Water Pollution Control Plant, are specified in the PTTW. The flow targets (quantities of water) vary on a seasonal basis, but the average is 0.16 m^3/s (9,600 L/min) for the period January through May, and 0.18 m^3/s (10,800 L/min) for the period June through December for the 2011 calendar year.

Municipal groundwater wells located upgradient of the Credit River have the potential to reduce the baseflow to the Credit River and its tributaries and reduce the assimilative capacity of the river. As such, the impact of municipal groundwater pumping on the Credit River and its ability to assimilate waste from the Water Pollution Control Plant was a consideration in this assessment.

Recreation

The Island Lake Reservoir forms the backbone of the CVC's Island Lake Conservation Area, which provides year-round recreation. The reservoir is 182 hectares in area and is surrounded by wetland, forest and meadow that are maintained by CVC as a conservation area. It is used in the summer for fishing, boating, canoeing, and windsurfing, and in the winter for ice skating, ice-fishing, cross-country skiing and snowshoeing.

Land Use Change and Increased Imperviousness

Since changes in land use could potentially alter groundwater recharge, the *Technical Rules* also require that the Tier 3 modelling scenarios evaluate the impact existing land use and future land development on groundwater recharge.

The following steps were undertaken to identify potential changes in land use:

- Creation of a map of existing land use (**Figure 3.25**);
- Creation of a map of future land use using the Official Plan;
- Identify areas of land use change by comparing future land use against existing land use. **Figure 3.25** shows the areas where land use may change according to the Official Plans as compared to current land use. This figure was created by digitally overlaying the existing and future land use maps (**Appendix C2**) using a Geographic Information System;
- Estimate the future change in imperviousness for each of the areas of land use change. This required making of assumptions relating to the imperviousness of land use categories and the reduction in recharge. This work was done in consultation with the towns of Orangeville and Mono, and Township of Amaranth; and
- Creation of a map of future reduction in recharge for areas of planned land use change. The most significant land use changes that may potentially occur are located on the western reaches of the Town of Orangeville and in the nearby townships of Amaranth and East Garafraxa. This area is illustrated on **Figure 3.25** and is a sensitive area as the recharge area for many of the Town of Orangeville and Township of Amaranth (Pullen Well) wells.

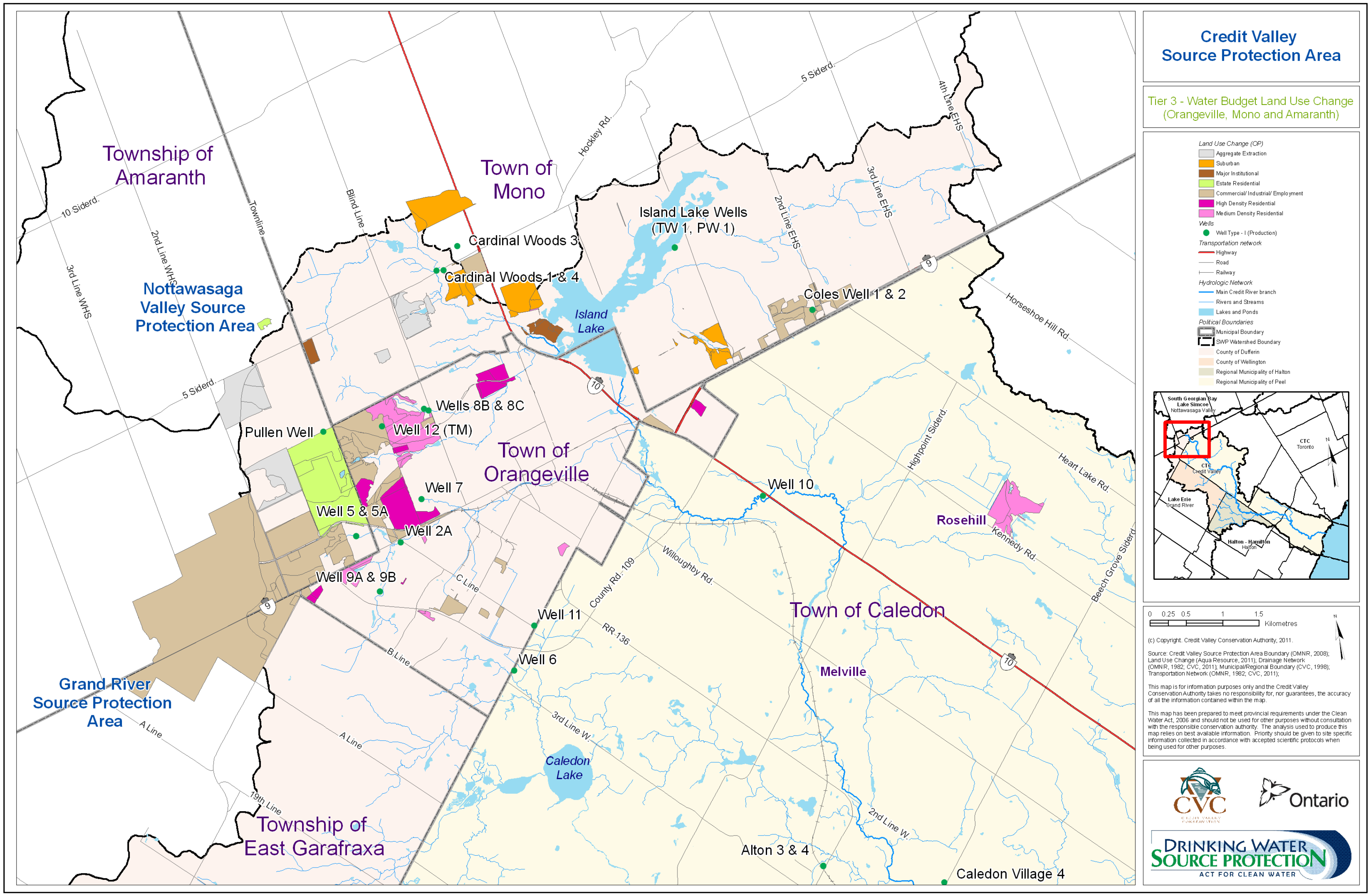


Figure 3.25: Tier 3- Water Budget Land Use Change (Orangeville, Mono and Amaranth)

Additional detail on the development of the existing and future land use maps is presented in **Appendix C2.**

Per the *Technical Rules*, the potential impact of best management practices such as stormwater management measures and low impact development techniques, were not considered when estimating imperviousness changes for future land use. Consideration of how to lessen or avoid the impact of land use change on reducing recharge is part of the source protection planning phase.

The Tier 3 model represents land use changes by reducing groundwater recharge proportionally to amount of impervious area. **Table 3.15** summarizes the percentage of impervious surfaces used to calculate the recharge reduction for different land use types. These values were obtained in consultation with municipal staff and the CVC. The recharge rates assigned for these areas were calculated by multiplying the impervious value by the recharge rate estimated for undeveloped conditions.

Table 3.15: Imperviousness Estimates Applied for Future Land Use Areas Local Area Risk Assessment

Future Land Use	Imperviousness / Recharge Reduction
Commercial	70%
Institutional	70%
Industrial (excluding aggregate extraction)	70%
Industrial (aggregate extraction)	0%
Special Suburban	70%
Estate Residential	0%
Residential (high and moderate density)	50%

3.8.6 Delineation of Water Quantity Vulnerable Areas for Municipal Wells in Town of Orangeville and in parts of Town of Mono and Township of Amaranth

Local Areas are the areas to which water quantity risk is assigned and within which vulnerable areas 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 groundwater model was used to delineate Vulnerable Areas WHPA-Q1 and WHPA-Q2 and the Local Area within which risk scenarios are evaluated.

The vulnerable areas delineated to protect the quantity of water required by a municipality to meet current or future water needs are called WHPA-Q1 and WHPA-Q2 under the *Technical Rules*. They are delineated for all municipal water supply wells that extract water from a subwatershed assigned a groundwater stress level of significant or moderate in the Tier 2 Water Budget Assessment.

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.

The WHPA-Q1 is delineated as the combined area that is the *cone of influence* of the well, and the whole of the cones of influence of all other wells that intersect that area. The extent of the cone of influence is determined by selecting an appropriate drawdown threshold, which considers several factors. These factors include the seasonal change in aquifer water levels (often in the range of 0.5 metre – 1.0 metre over the year) and available field observations of how pumping the municipal well or wells causes a reduction in the aquifer water level (drawdown) near the well.

The WHPA-Q1 was delineated by examining the change in predicted water level within the Amabel formation which is the major aquifer used by these municipal wells, based on two model scenarios.

- Steady-state model simulating existing land use, and no municipal pumping. This scenario establishes water levels that would exist without pumping.
- Steady-state model simulating existing land use, and existing plus committed plus planned municipal pumping rates.

The model predicted water levels in the Amabel Formation for each scenario which were then subtracted from one another, and the resulting predicted water levels were mapped. Seasonal water level fluctuations varied from 1 to 1.5 metres per year in this area. Based on this, a drawdown contour interval of 1 metre was selected to delineate the WHPA-Q1 areas for Mono, Orangeville, and Amaranth, as shown in **Figure 3.26**. Five WHPA-Q1 areas lie within the Orangeville, Mono and Amaranth area, and are labelled as WHPA-Q1-A to WHPA-Q1-E. Additional detail on the WHPA-Q1 delineation is presented in **Appendix C2**.

The WHPA-Q2 is defined as the WHPA-Q1 area, plus any area where a future reduction in recharge may have a measurable impact on the cone of influence of the municipal wells. Areas where future reduction in recharge may occur were calculated (**Table 3.15**). These areas are shown in **Figure 3.27**. Five WHPA-Q2 areas were delineated and are designated WHPA-Q2-A to WHPA-Q2-E. Additional information on the WHPA-Q2 delineation is presented in **Appendix C2**.

Delineation of Vulnerable Areas-Local Areas

The Local Areas delineated for Orangeville, Mono and Amaranth are shown on **Figure 3.28**. The Local Area is determined by combining the following areas:

- The cone of influence of the municipal supply wells (**Figure 3.25**); and
- The areas where a reduction in recharge would have a measurable impact on the cone of influence of the well(s) (WHPA-Q2) (**Figure 3.27**).

The WHPA-Q2-A1 and WHPA-Q2-A2 and areas lie in close proximity to one another. Municipal wells in each area extract water from the same bedrock source. Since they are so closely integrated, the Local Area A (**Figure 3.28**) was drawn to encompass both areas to ensure that water quantity threats within this area could be managed together.

Local Area A crosses the boundaries of three source protection areas located in three separate source protection regions. In addition to the municipalities under study, parts of the Town of Caledon (Region of Peel) and Township of East Garafraxa are also located within this Local Area. The consumptive uses or recharge reduction taking place within each Local Area could pose potential water quantity threats to municipal supplies in that Local Area (**Chapter 5.3.1**). Each SPC is required to develop policies to address any significant water quantity threats identified within their respective source protection area(s).

The Region of Peel (Caledon) and Township of East Garafraxa do not have a municipal water supply located in Local Area A. The Region of Peel does have municipal supply wells located in the Town of Caledon outside of Local Area A but within the CVSPA. There are no water quantity threats identified with these supplies. Water quality threats for these wells are further discussed in **Chapters 4.8** and **5.5.6**. The Township of East Garafraxa does not have any municipal wells in the CVSPA. For information on the Township of East Garafraxa municipal water supplies located in the Grand River Source Protection Area, the reader should contact the Lake Erie Source Protection Region.

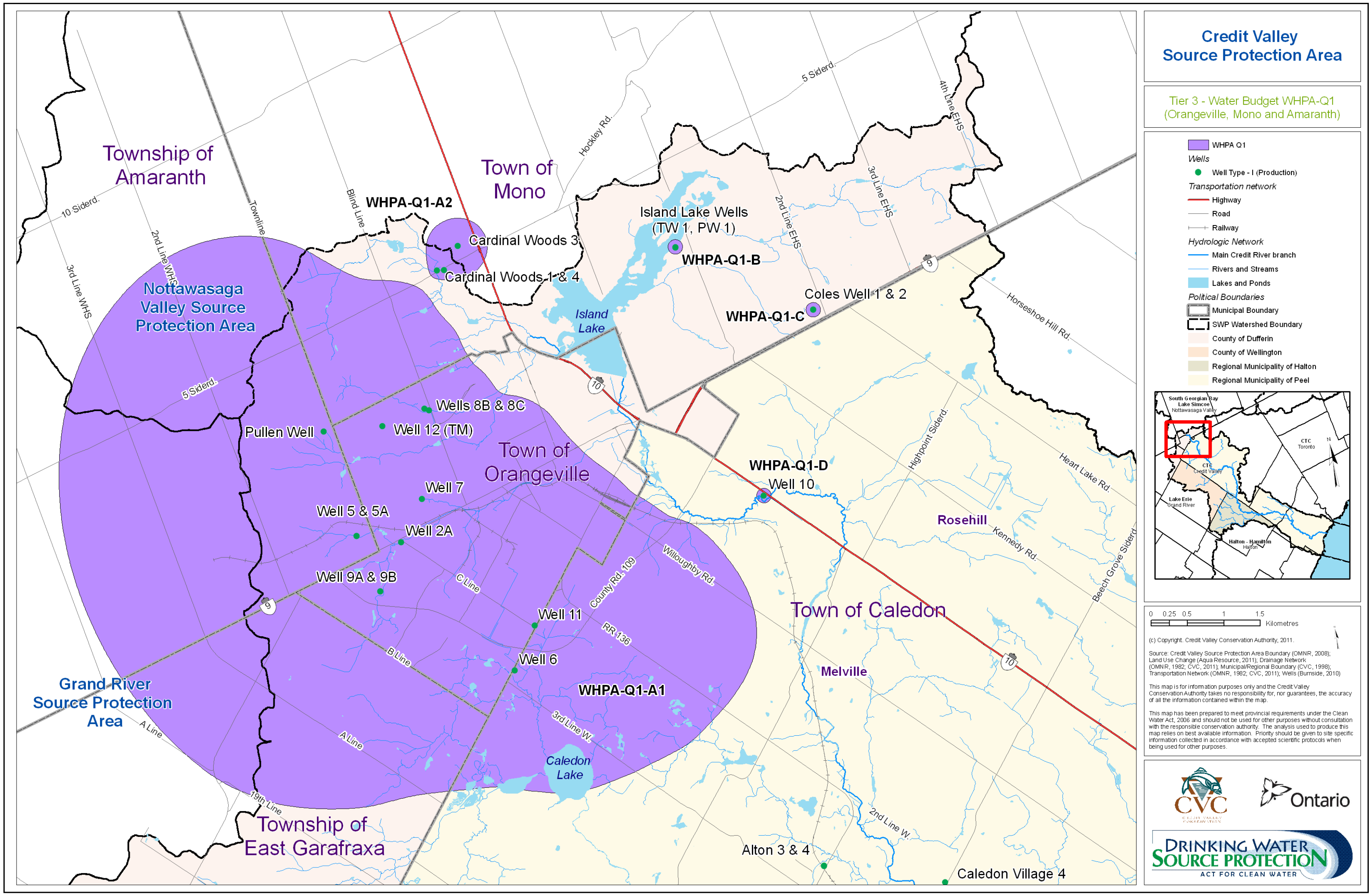


Figure 3.26: Tier 3 - Water Budget WHPA-Q1 (Orangeville, Mono and Amaranth)

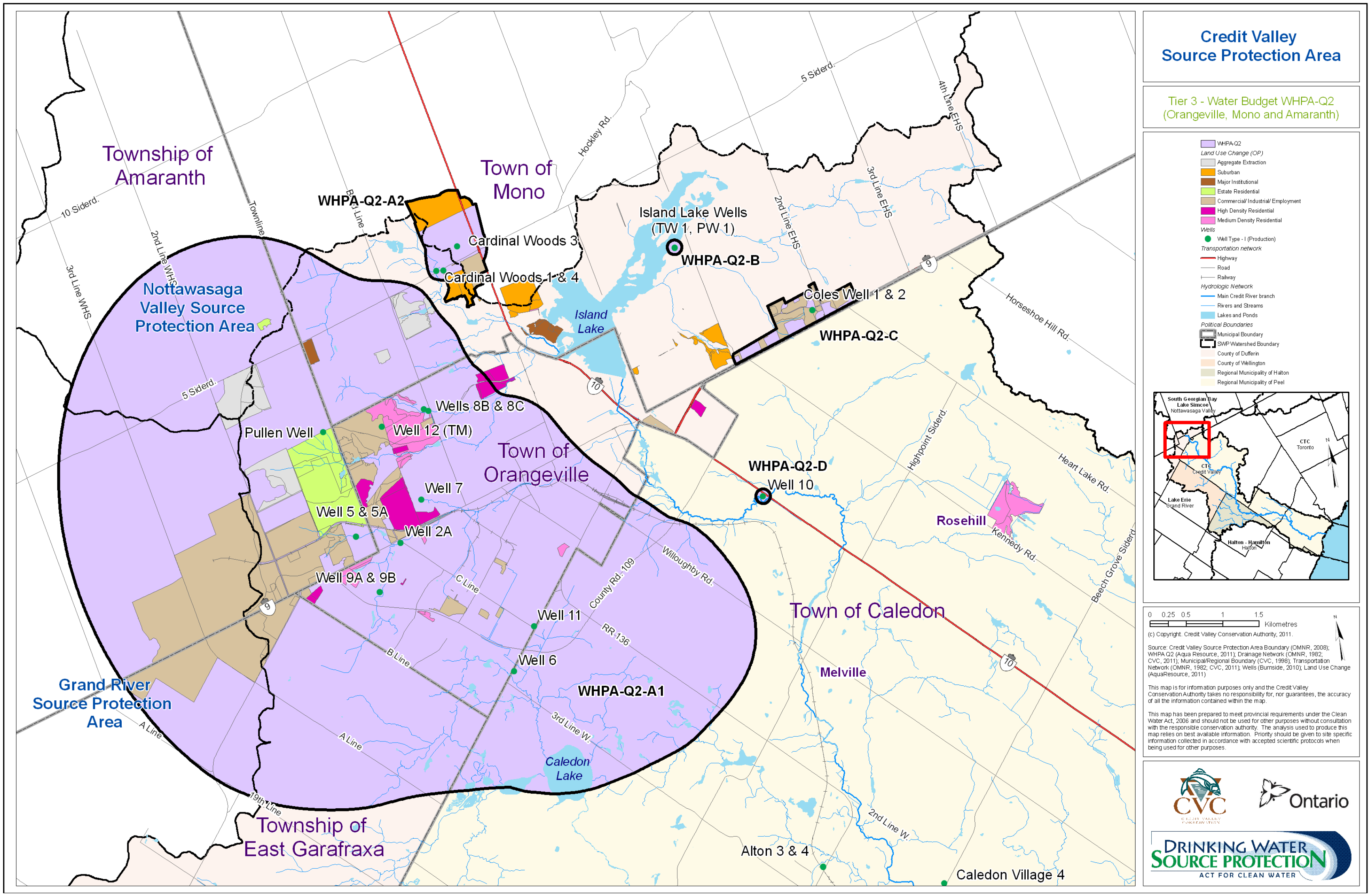


Figure 3.27: Tier 3 -Water Budget WHPA Q-2 (Orangeville, Mono and Amaranth)

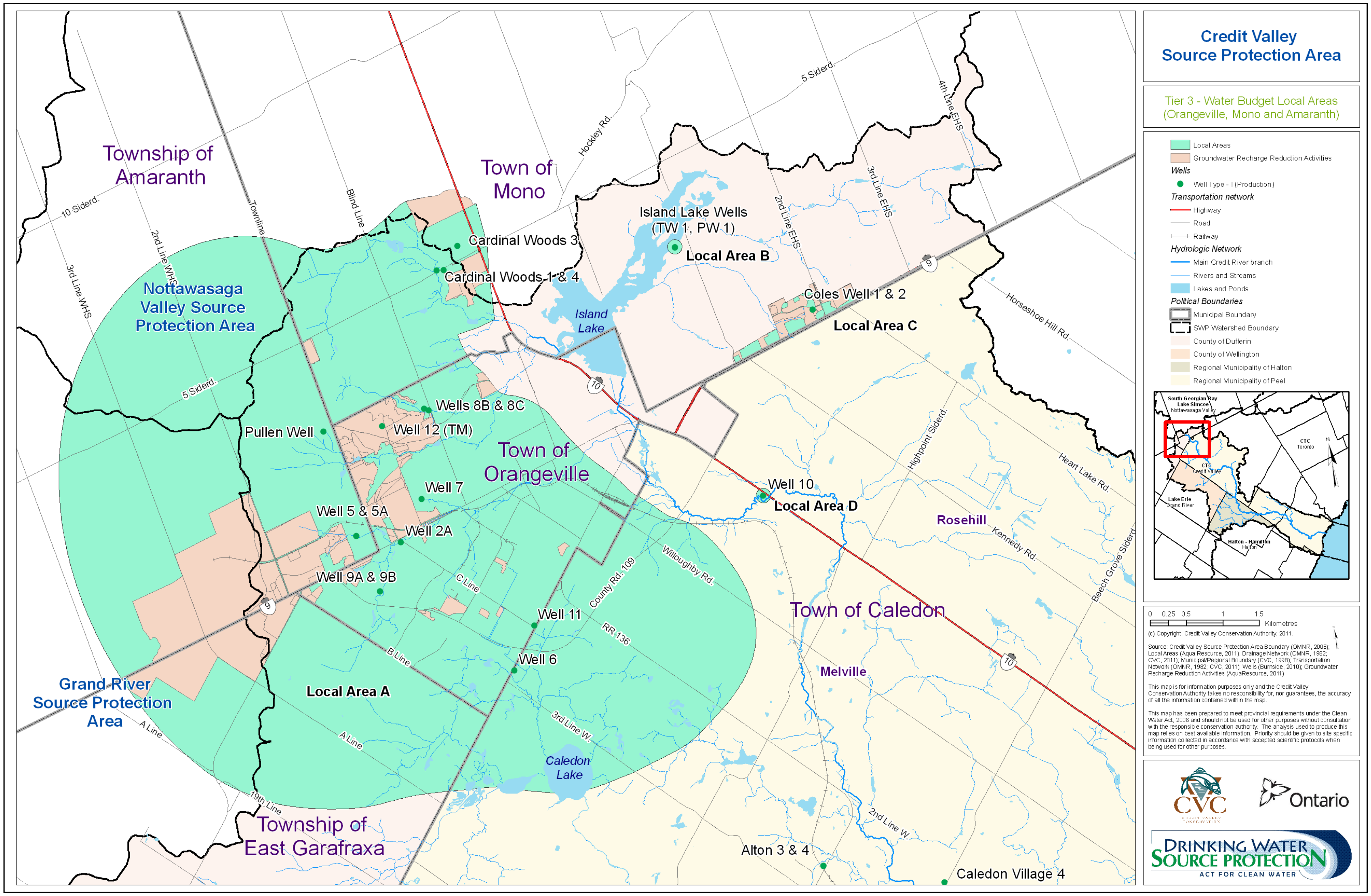


Figure 3.28: Tier 3 - Water Budget Local Areas (Orangeville, Mono and Amaranth)

3.8.7 Risk Assessment Scenarios for Municipal Wells in Town of Orangeville and in parts of Town of Mono and Township of Amaranth

For the Risk Assessment, the groundwater model was used to examine whether existing and planned municipal wells are able to sustain their allocated and planned quantities of water, and to help predict the resultant impacts to other water uses. This model was also used to assess the potential response of aquifers to long-term drought conditions.

The *Technical Rules* require that four major risk scenarios be evaluated. These scenarios are described in **Table 3.16**.

Scenarios C and D correspond to existing pumping rates and existing land cover under average climate (C), and drought conditions (D). Scenarios G and H correspond to future land cover and allocated pumping rates for existing wells and planned pumping rates for new wells under average climate (G), and drought conditions (H).

The scenarios were assessed as follows:

- Scenarios C and G represent average climate conditions and were simulated using steady-state conditions;
- Scenarios D and H represent drought conditions and were simulated using a transient model representing two drought periods between 1960 and 2006; and
- Multiple versions of scenarios G and H were required to evaluate the impact of allocated pumping rates as separate from impacts of land cover on groundwater recharge; and the cumulative impact of both.

Table 3.16: Summary of Risk Assessment Scenarios (MOE, 2009)

Scenario	Time Period	Data Restrictions
C	The period for which climate and stream flow data are available for the Local Area	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the study year.
D	Ten-year drought period	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the study year.
G	The period for which climate and stream flow data are available for the Local Area	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the year in which the planned system or an existing system with a committed demand is operating at its allocated or planned quantity.
H	Ten-year drought period	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the year in which the planned system or an existing system with a committed demand is operating at its allocated or planned quantity.

Table 3.17 summarizes the Local Area Risk Scenarios developed for each municipal well in Orangeville, Mono and Amaranth. The scenarios were designed to meet the criteria shown in **Table 3.16**. More detail on each scenario is given in **Appendix C2**, and a review of the sensitivity analyses of the scenarios to various input parameters is provided in **Appendix C2**.

Table 3.17: Risk Assessment Model Scenarios

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 (2008)	Existing	Existing	Steady-state, Average Annual Recharge	
D	10 year drought period	Existing	Existing	Transient (1960-2006); Monthly recharge rates	
G(1)	Period for which climate and stream flow data are available for the Local Area	Official Plan	Allocated	Groundwater Recharge Reduction and Increase in Demand	Steady-state, Average Annual Recharge
G(2)		Existing	Allocated	Groundwater Discharge Reduction from Increase in Demand	
G(3)		Official Plan	Existing	Groundwater Recharge Reduction from Land Cover	
G(4)		Existing	Allocated	Per (G)2; Impacts on other users	
G(5)		Existing	Planned	Per (G)2; Impacts on other users	
H(1)	10 year drought period	Official Plan	Allocated	Groundwater Recharge Reduction and Increase in Demand	Transient (1960-2006); Monthly recharge rates
H(2)	10 year drought period	Existing	Allocated	Groundwater Discharge Reduction from Increase in Demand	
H(3)	10 year drought period	Official Plan	Existing	Groundwater Discharge Reduction from Increase in Demand	

3.8.8 Model-Predicted Scenario Results

Drawdown

The predicted maximum drawdown at each well, under each model scenario was assessed by comparing the drawdown at the end of the model run to the estimated safe additional drawdown at each municipal well. The predicted maximum drawdown at each well is calculated relative to the existing conditions (Scenario C) simulated heads and is shown in **Table 3.18.**

For the steady state models (Scenarios G (1), G (2) and G (3)), the difference between the water levels at the well in Scenario C and those at the end of each model scenario were recorded as the model scenario drawdown **(Table 3.18)**.

For the transient scenarios, the lowest simulated water level elevation in the aquifer at each municipal pumping well was compared to the water level in the existing conditions scenario (Scenario C) and this value was also recorded on **Table 3.18**. The model simulated drawdown was then compared to the field-based safe additional drawdown to identify municipal wells where there is a potential that the wells will be unable to pump their allocated or planned quantities of water. The table identifies the wells and scenarios where these conditions may occur. Well 6 drawdown is close to or greater than the safe additional drawdown following the 1960's drought periods for both scenarios H (1) and H (2).

Table 3.18: Risk Assessment Drawdown Results - Orangeville

WHPA-Q1 Area	Well Name	Safe Additional Aquifer Drawdown (2008)	MODFLOW Groundwater Model Scenario Drawdown (m)						
			Average Climate			Drought			
			G(1)	G(2)	G(3)	D	H(1)	H(2)	H(3)
			Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction	Existing Recharge, Demand	Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction
A1	Well 2A	4.7	3.1	2.2	0.8	1.2	4.3	3.3	2.0
	Well 5/ 5A	3.2	3.7	0.6	2.5	1.3	5.3[1]	2.0	4.0
	Well 6	2.9	2.6	2.2	0.3	1.5	4.1[2]	3.7	1.8
	Well 7	8.7	4.8	3.9	0.7	1.2	6.0	5.0	1.9
	Well 8B	7.4	1.9	1.3	0.5	0.9	2.9	2.2	1.4
	Well 8C	7.5	2.0	1.4	0.5	0.9	3.0	2.3	1.4
	Well 9A/ 9B	4.8	3.0	0.4	2.3	1.4	4.6	1.9	3.8
	Well 11	6.6	3.1	2.7	0.3	1.6	4.7	4.3	1.9
	Well 12	10.0	5.3	4.0	1.1	1.1	6.1	4.5	2.2
	Pullen Well	29.9	3.5	2.6	0.8	1.2	4.8	2.3	2.0
A2	Cardinal Woods 1	4.8	0.7	0.4	0.3	0.8	1.5	1.1	1.1
	Cardinal Woods 3	2.4	2.4	2.0	0.3	0.8	3.1[3]	2.8	1.0
B	Island Lake Wells	22.0	0.3	0.3	0.0	0.4	0.8	0.7	0.4
C	Coles 1, 2	34.7	0.6	0.1	0.3	1.7	2.2	1.8	2.0
D	Well 10	33.7	1.4	1.4	0.0	0.2	1.6	1.6	0.2
(blue shading)	Pumped drawdown close to, or greater than, the safe additional available drawdown								

[1] Safe additional drawdown level predicted to be exceeded 76% of the time (35 years in the 46-year simulation).
[2] Safe additional drawdown level predicted to be exceeded 32% of the time (19.1 years in the 46-year simulation).
[3] Safe additional drawdown level predicted to be exceeded 7.2% of the time (3.3 years in the 46-year simulation).

Average Climatic Conditions

For average climatic conditions, (Scenarios G (1), G (2) and G (3)), the model predicted drawdown in the aquifers at each municipal well, with the exception for Orangeville Well 5/5A, as lower than the estimated safe available drawdown.

The results suggest that all municipal wells are capable of supplying their allocated rates (Scenario G (2)) under average conditions. Under a reduction in recharge, all municipal wells with the exception of Well 5/5A would be capable of supplying their allocated rates (Scenario G (1)). The results suggest that the long-term sustainability of Well 5/5A is mainly influenced by potential reductions in recharge with approximately 68% of the additional drawdown attributed to reductions in recharge under average climatic conditions.

Drought Conditions

For drought periods with the current water taking characteristics (existing recharge and existing pumping rates (Scenario D), the model predicted the wells are able to sustain these withdrawals. The drawdown in the aquifers at each municipal well is predicted to be less than the estimated safe additional drawdown available at each of the wells.

The results also showed that the majority of the municipal wells are capable of supplying their allocated rates in their PTTW (includes existing pumping rates and committed pumping rates to meet population increase in the Official Plan as of mid-2010) during drought conditions if there is no change in land use to reduce recharge. However, Orangeville Well 6 and Mono Cardinal Woods Well 3 are the exceptions - the model predicts that estimated safe additional drawdown would be exceeded by approximately 27% in Well 6, and by approximately 17% in Cardinal Woods Well 3.

Under the reduction in recharge scenario (H (3)), all municipal wells with the exception of Well 5/5A would be capable of supplying their existing pumping rates. The results suggest that the long-term sustainability of Well 5/5A is mainly influenced by potential reductions in recharge. This indicates that the reductions in groundwater recharge would have a significant impact on its ability to meet the existing demands, not including any population growth.

When the cumulative impacts of drought conditions, increased municipal pumping rates to meet population projections and reductions in recharge due to future land cover (Scenario H (1)) are considered, the model predicted the following:

- Orangeville Wells 5/5A – drawdown exceeds the safe additional drawdown for more than 75% of the simulation period.
- Orangeville Well 6 – drawdown exceeds the safe additional drawdown for more than 30% of the simulation period.
- Orangeville Wells 9A/9B – drawdown is almost equal to the safe additional drawdown during the simulation period.
- Mono Cardinal Woods Well 3 – drawdown exceeds the safe additional drawdown for more than 50% of the simulation period.

Baseflow Reduction

It should be noted that the terminology used in the foundation report to describe existing, committed, and planned demand and the allocated and planned quantities of water are not consistent with current terminology described in **Section 3.8.3** due to recent changes by the Province to Interim Guidance (December 2013). This primarily effects the discussion of baseflow impacts in this section, however, the technical analysis and final findings of the report are not affected.

The groundwater model simulated groundwater discharge to the environment by examining the reduction in simulated baseflow to rivers, streams, and wetlands of interest. **Figure 3.29** shows the areas within the model where baseflow impact was assessed. Baseflow evaluation was undertaken by examining average annualized simulated baseflows to these natural systems.

The *Technical Rules* require that baseflow impact be assessed under conditions of increased municipal pumping under average climate conditions when evaluating risks to the Local Area. Baseflow impacts were assessed for existing and planned systems using their allocated quantities of water and average climate conditions – the G (2) scenarios shown in **Table 3.18**. Impacts to other water uses are not evaluated for drought scenarios (D and H).

The groundwater model simulated groundwater discharge to the environment by examining the reduction in simulated baseflow to rivers, streams, and wetlands. **Figure 3.29** shows the locations where baseflow impact was assessed.

Baseflow impacts were modelled for Scenarios G (1), G (2) and G (3) by predicting the reduction in baseflow relative to that simulated for the existing conditions (Scenario C). The groundwater model's estimate of average annual groundwater discharge into each stream reach is contained in **Table 3.19** and shown in **Figure 3.30**.

The previous thresholds used within the *Technical Rules (March 2011*), prior to the Interim Direction (*December 2013*), to establish the Local Area Risk Level were as follows:

- Baseflow reductions of between 10% and 20% result in a water quantity risk level classification of 'moderate' for the Local Area,
- Baseflow reductions greater than 20% result in a water quantity risk level of 'significant' for the Local Area.

While three different scenarios were modelled, only Scenario G (2) is considered when evaluating the risk level of the Local Areas, based on impacts to other water uses, for source protection planning purposes. The *Clean Water Act* only has the legislative authority to evaluate impacts to other water uses associated with increased groundwater pumping (e.g., Scenarios G (2)).

The model predicts that an increase in municipal pumping rates would cause a reduction in the water table greater than 1 metre in the area surrounding Orangeville Wells 7 and 11, with lesser reductions in the surrounding areas. Reductions of up to 0.5 metre are estimated beneath some of the wetlands associated with the Caledon Lake Provincially Significant Wetland Complex. This reduction in the water table reduces the discharge of groundwater (called baseflow) into the nearby streams and wetlands. Under Scenario G (2) baseflow is predicted to be reduced as follows:

- In Upper and Lower Mill Creeks by 27% and 22%, respectively (significant water quantity risk level classification under the March 2011 *Technical Rules* that would change to moderate water quantity risk level under the December 2013 Interim Direction); and

- In Upper and Lower Monora Creeks by 10 and 20% (moderate water quantity risk level classification under both the March 2011 *Technical Rules* and December 2013 Interim Direction).

The model results also show that there are reductions in baseflow under the other scenarios as shown in **Table 3.19** and **Figure 3.30**. The greatest impacts to baseflow occur in Scenario G (1) (reductions in recharge due to land use changes and increases in municipal pumping to meet planned rates). In Scenario G (1) baseflow in Upper and Lower Mill Creek is predicted to fall by 91% and 73%, respectively. Baseflow in Monora Creek is also predicted to be reduced by more than 20% in the G (1) scenario. When the results of the G (3) scenario are considered, the impacts of proposed land use development which would reduce recharge is predicted to lower baseflow by more than 20% to Upper and Lower reaches of Mill Creek and parts of Monora Creek. These results indicate that current baseflow may be very sensitive to future proposed land use changes for these areas.

While **Table 3.19** summarizes baseflow impacts for Scenarios G (1), G (2) and G (3), under the *Technical Rules*, the Tier 3 Assessment only considers reduction in baseflow resulting from increased pumping from municipal wells (Scenarios G (2) when determining the risk level assigned to the Local Areas.

Table 3.19: Impacts to Groundwater Discharge - Scenario G

Stream / Reach	Scenario C – Existing Conditions GW Discharge (L/s)	Scenario G(1) (Increased Demand and Recharge Reduction)		Scenario G(2) (Increased Demand) *Note only this scenario used to determine risk level*		Scenario G(3) (Recharge Reduction)	
		GW Discharge (L/s)	Percent Reduction (%)	GW Discharge (L/s)	Percent Reduction (%)	GW Discharge (L/s)	Percent Reductio n (%)
North Arm of Lower Monora	20.5	12.8	37.6	17.4	15.1	15.8	22.9
South Arm of Lower Monora	5.3	4.0	24.5	4.4	17.0	4.9	7.5
Total Lower Monora	30.9	22.0	28.8	27.3	11.7	26.1	15.5
Upper Monora	38.1	30.4	20.2	34.2	10.2	34.9	8.4
Upper Mill	11.3	1.0	91.2	8.3	26.5	2.8	75.2
Lower Mill	14.8	4.0	73.0	11.5	22.3	6.2	58.1
Island Lake Tributaries	19.7	17.2	12.7	18.2	7.6	17.3	12.2
Caledon Tributaries	16.9	15.7	7.1	16.6	1.8	16.2	4.1
Caledon Lake Wetlands	11.3	9.0	20.4	10.2	9.7	10.2	9.7
Credit River	397.9	381.2	4.2	383.1	3.7	396.4	0.4

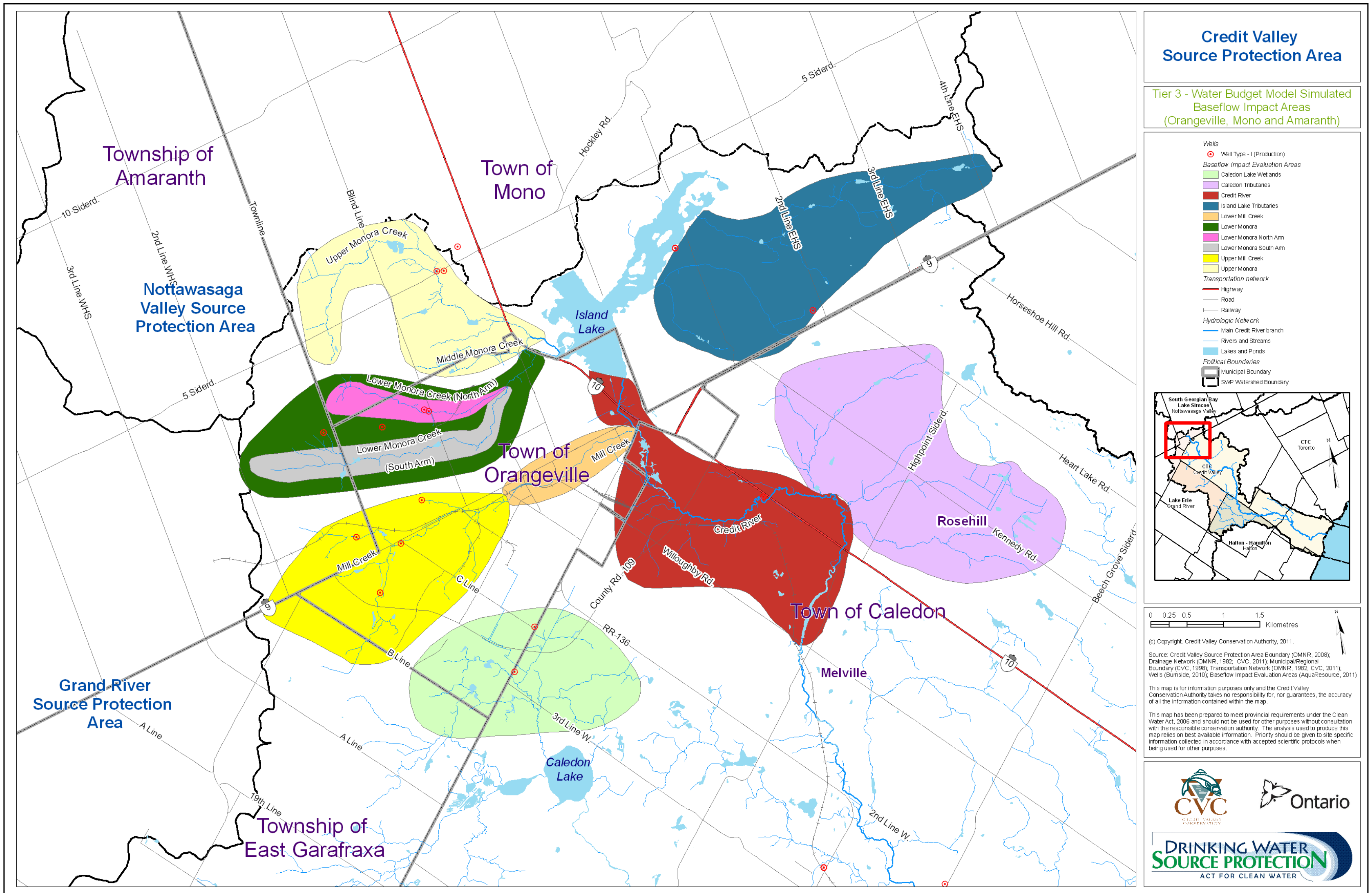


Figure 3.29: Tier 3 - Water Budget Model Simulated Baseflow Impact Areas (Orangeville, Mono and Amaranth)

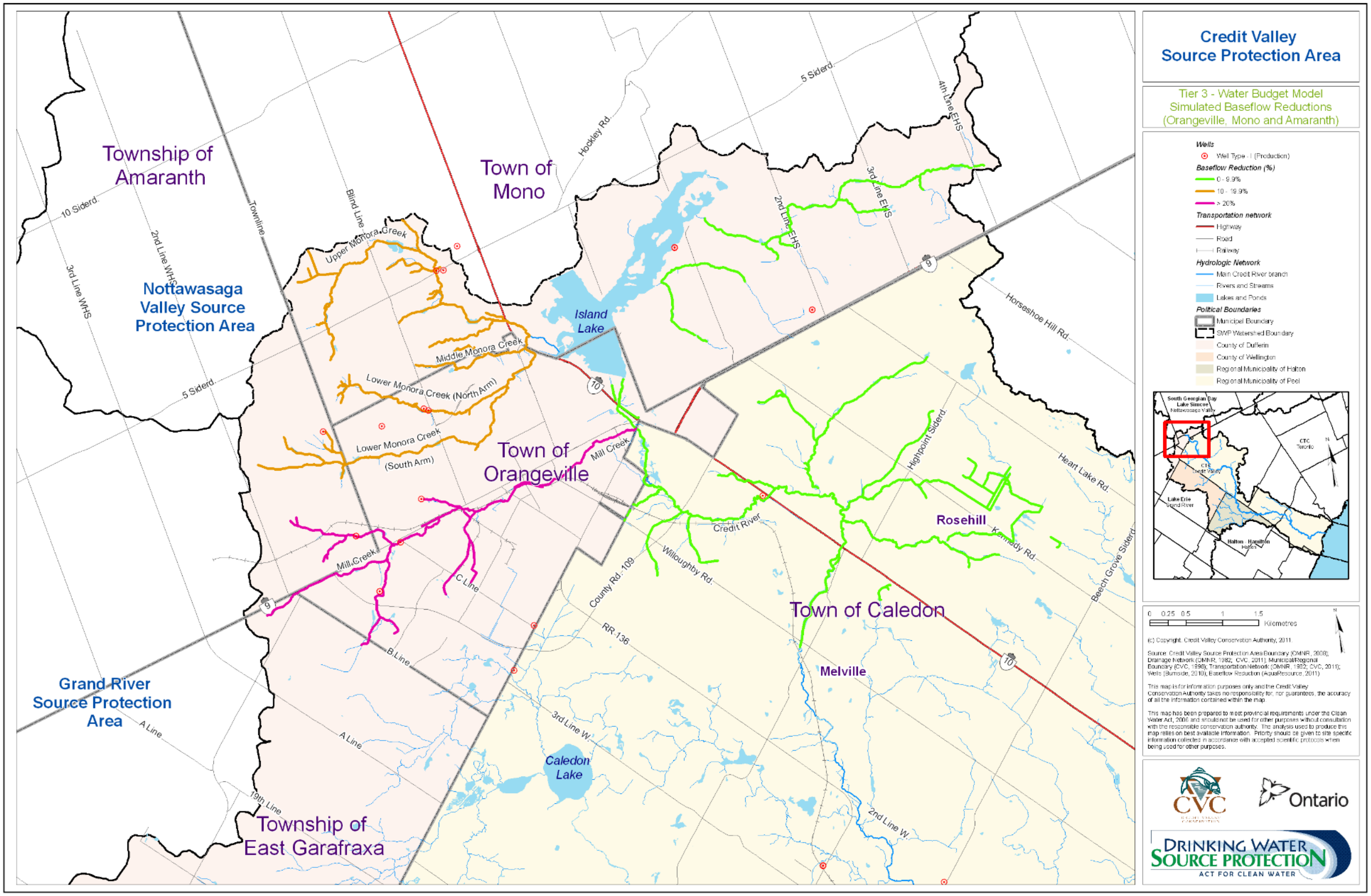


Figure 3.30: Tier 3 - Water Budget Model Simulated Baseflow Reductions (Scenario G(2))(Orangeville, Mono and Amaranth)

3.8.9 Summary of Local Area Risk Assessment Results for Municipal Wells in the Town of Orangeville and parts of the Town of Mono and Township of Amaranth

A summary of the results of the Local Area risk scenarios is presented in **Table 3.20**. The table provides a comprehensive overview of the assumptions informing the scenarios including the quantity of water demand, the land cover modelled in each scenario and the scenario results.

The results of the scenarios suggest that the tolerance of the Orangeville, Mono and Amaranth systems is high, as they are able to meet their existing water demands (Scenario C).

The *Technical Rules*, and Technical Bulletin: Part IX Local Area Risk Level (April 2010), list a series of circumstances, where if present in any of the Risk Assessment scenarios, then the Local Area must be assigned a “significant risk” level. In this Tier 3 Water Budget and Risk Assessment Study, the following scenarios were found to apply:

- The existing or planned system wells are not able to meet their allocated quantity of water or planned quantity of water because the drawdown at a municipal well exceeds the Safe Available Drawdown.
- The municipal demands result in measurable and unacceptable impacts to other water uses in Scenario G (2). For coldwater streams, an unacceptable impact is defined by a circumstance where baseflow is reduced by 20% of the existing monthly baseflow (MOE and MNR, 2010).

These scenarios, and specific wells for which these circumstances apply, are summarized in **Table 3.21.**

Based on the results of the risk scenarios, the Local Area A was assigned a significant risk level due to the following circumstances:

- The allocated quantity of water for Orangeville Well 5/5A would not be met in Scenario G (1) (**Table 3.18**). Most of the drawdown impact in this scenario is due to recharge reduction;
- The allocated quantity of water for Orangeville Wells 5/5a, Well 6, Wells 9A/9B and Cardinal Woods Well 3 is not met in Drought Scenario H (1) (**Table 3.18**). Drawdown at Wells 5/5a and Well 9 is impacted primarily due to recharge reductions. Well 6 and Cardinal Woods Well 3 are influenced more by planned pumping rates;
- The allocated quantity of water for Orangeville Well 6 and Cardinal Woods Well 3 is not met in Drought Scenario H (2) (**Table 3.18**) since an increased pumping regime creates a water level reduction that exceeds the safe additional drawdown;
- The allocated quantity of water for Orangeville Well 5/5A is not met in Drought Scenario H (3) (**Table 3.18**) since an increased pumping regime creates a water level reduction that exceeds the safe additional drawdown; and
- Groundwater discharge to Mill Creek, a designated coldwater stream, is reduced by more than 20% in Scenario G (2) (Average Climate, Allocated Pumping, **Table 3.19**).

The sensitivity analysis (**Appendix C2**) indicates that the above conclusions would still be made after considering the range of variability in model input parameters.

The Local Area A was also assigned a moderate risk with respect to baseflow reductions to Monora Creek in Scenario G (2) (Average Climate, Allocated Pumping, **Table 3.19**).

The Local Areas B, C, and D would be assigned a low risk level as these Local Areas were not assigned a risk level of significant or moderate (MOE, 2010). All three of these well systems are predicted to be able to meet their allocated quantity of water without impacting other uses.

Table 3.20: Results of Risk Assessment Scenarios in Local Areas of Orangeville, Mono and Amaranth

Risk Assessment Model Scenarios					Results – Risk Level			
Scenario	**Time Period**	**Land Cover**	**Quantity of Water**	**Other Permitted Water Demand**	**Local Area A**	**Local Area B**	**Local Area C**	**Local Area D**
C (base)	Period for which climate and stream flow data are available for the Local Area	Existing	Existing Demand	Existing Demand	Low	Low	Low	Low
D (base with drought)	10 year drought period	Existing	Existing Demand	Existing Demand	Low	Low	Low	Low
G(1) (Impact on municipal wells)	Period for which climate and stream flow data are available for the Local Area	Official Plan	Allocated	Anticipated Demand	Significant	Low	Low	Low
G(2) (Impact on municipal wells & other water uses)	Period for which climate and stream flow data are available for the Local Area	Existing	Allocated	Existing Demand	Significant (only in relation to other water uses)	Low	Low	Low
G(3) (Impact on municipal wells)	Period for which climate and stream flow data are available for the Local Area	Official Plan	Existing Demand	Anticipated Demand	Low	Low	Low	Low
H(1) (Impact on municipal wells)	10 year drought period	Official Plan	Allocated	Anticipated Demand	Significant	Low	Low	Low
H(2) (Impact on municipal wells)	10 year drought period	Existing	Allocated	Existing Demand	Significant	Low	Low	Low
H(3) (Impact on municipal wells)	10 year drought period	Official Plan	Existing Demand	Anticipated Demand	Significant	Low	Low	Low

Table 3.21: Risk Assessment- Significant Risk Level Circumstances

Scenario	Circumstances	Results
Existing or Planned System with future land use and average annual climate (G) or 10-yr drought (H)	The quantity of water that can be taken from groundwater in the Local Area would not be sufficient to meet the allocated quantity of water or planned quantity of water for those wells	Well 5/5A Well 6 Well 9A/B Cardinal Woods 3 (Drought)
Existing or Planned System – average annual climate (G)	The quantity of water that can be taken from groundwater in the Local Area would be sufficient to meet the allocated quantity of water for those wells and one or more of the following circumstances exists: i. the reduction in existing groundwater levels and/or flows results in unacceptable impacts to existing regulated water levels and/or flows or permits. ii. the reduction in existing groundwater discharge into a coldwater watercourse by a threshold calculated as greater than 20 percent as compared to the existing estimated monthly streamflow Qp80 (the flow that is exceeded 80 percent of the time) or the average monthly baseflow of the watercourse or another threshold that has already been defined as a condition in an existing permit. iii. the reduction in existing groundwater levels and/or flows results in unacceptable impacts to provincially significant wetlands (MOE, 2009).	Mill Creek

The towns of Orangeville and Mono have never historically had problems meeting required pumping rates, even during periods of higher water demand prior to the implementation of water conservation measures. The risk level categories do not indicate a problem associated with current municipal wells and their current pumping rates. However, they reflect a need to manage the drinking water resources in the Local Areas to protect against future problems.

Furthermore, the results indicate a need to manage the drinking water as a regional resource shared by the towns of Orangeville and Mono, and the Township of Amaranth.

3.8.10 Uncertainty Assessment

The uncertainty analysis examined the range of potential hydraulic conductivity and recharge distributions that would produce calibrated models. The predictions made by models with acceptable ranges of parameters produced consistent model results. The assigned risk levels to the Local Areas are therefore considered appropriate. Consequently, the uncertainty associated with the risk levels applied to the Local Areas is low.

3.8.11 Numeric Modelling for Municipal Wells in Halton Hills

The Tier 3 Water Budget and Local Area Risk Assessment are documented in the report *Risk Assessment Report*, *Halton Hills Tier Three Water Budget and Local Area Risk Assessment, Final Report (AquaResource Inc., 2014)*. This report was extensively peer-reviewed by a panel of municipal and provincial representatives, private consultants, and the CVC prior to acceptance by the CTC SPC. It is the foundation document, upon which this section has been based.

Study Area

The study area, presented in **Figure 3.31** is approximately 745 km^2 in area, encompassing part of the Town of Halton Hills, inclusive of the municipalities of Acton and Georgetown in the Region of Halton. Boundaries of the study area also overlap portions of the:

- Town of Milton (Region of Halton);
- Township of Guelph/Eramosa, and the Town of Erin (County of Wellington); and
- Town of Caledon, City of Brampton, and the City of Mississauga (Region of Peel).

The Credit River and Sixteen Mile Creek watersheds are the two major drainage areas of the study area. Sixteen Mile Creek lies in the south, and the main branch of the Credit River lies in the eastern part of the study area. Silver Creek, a major tributary of the Credit River, and Black Creek, a tributary of Silver Creek, occur in the western half of the domain. The Black Creek and Silver Creek subwatersheds (known as subwatershed 10 and 11, respectively) located in the CVSPA, are the areas of focus for the Tier 3 study. Fairy Lake in Acton forms the headwaters of Black Creek.

Additional drainage areas in the domain include parts of three other source protection areas. A small section of Etobicoke Creek watershed which is within the Toronto and Region Source Protection Area (CTC SPR) is intersected along the eastern boundary. Part of the Grand River watershed, which is located along the western boundary is in the study area. This is in the Grand River Source Protection Area in the Lake Erie Source Protection Region. To the south, the study area extends into the Halton Source Protection Area in the Halton-Hamilton Source Protection Region. Each SPC is required to develop policies to address any significant water quantity threats identified within their respective source protection area(s).

Only the Region of Halton has municipal water supplies located within the study area. The municipal supply systems for Acton and Georgetown are located in subwatershed 10 and 11. These systems are shown on **Figure 3.31** and include the Fourth Line, Davidson, and Prospect Park wellfields of Acton; and the Lindsay Court, Princess Anne and Cedarvale wellfields of Georgetown. The lands surrounding these wellfields are dominated by agricultural and urban activities (CVC *et al.*, 2002; CVC *et al.*, 2011), with other land uses such as aggregate extraction and natural heritage features, e.g., wetlands and/or forest communities.

Numerical Models

The Tier 3 Water Budget represents an improved estimate of the quantification of the hydrologic cycle in the localized scale of the study area. The modelling approach integrates surface water (hydrological) and groundwater (hydrogeological) components of the flow system. The numerical modelling was done using the software program MIKE SHE for simulating surface water flow, and the finite element groundwater modelling code FEFLOW for simulating groundwater flow. The modelled domain is shown in **Figure 3.31** and described in **Appendix C3**.

One component of the Tier 3 assessment is an improved estimate of the water budget components included in the hydrologic cycle within the study area. The surface water and groundwater flow models were used to estimate average annual values for the various components of the hydrologic cycle. While the MIKE SHE model and FEFLOW model were separate and independent models, the modelling was linked through the groundwater recharge and common representation of the subsurface structure and properties and representation of groundwater interflow components (flow between subwatersheds). The combined results of the two water budget models produce an improved conceptualization of the hydrologic and hydrogeologic flow systems compared with the previously completed Tier 2 water budget analysis. This new understanding has also resulted in significant changes to the delineation of WHPAs used for assessing water quality threats compared to those described in the previous version of this Assessment Report approved by the MOECC in January 2012. See **Chapter 4.7** for further discussion and maps.

Detailed description of the models, their calibration and validation methodologies are provided in the foundation document, while key details have been reproduced in **Appendix C3**.

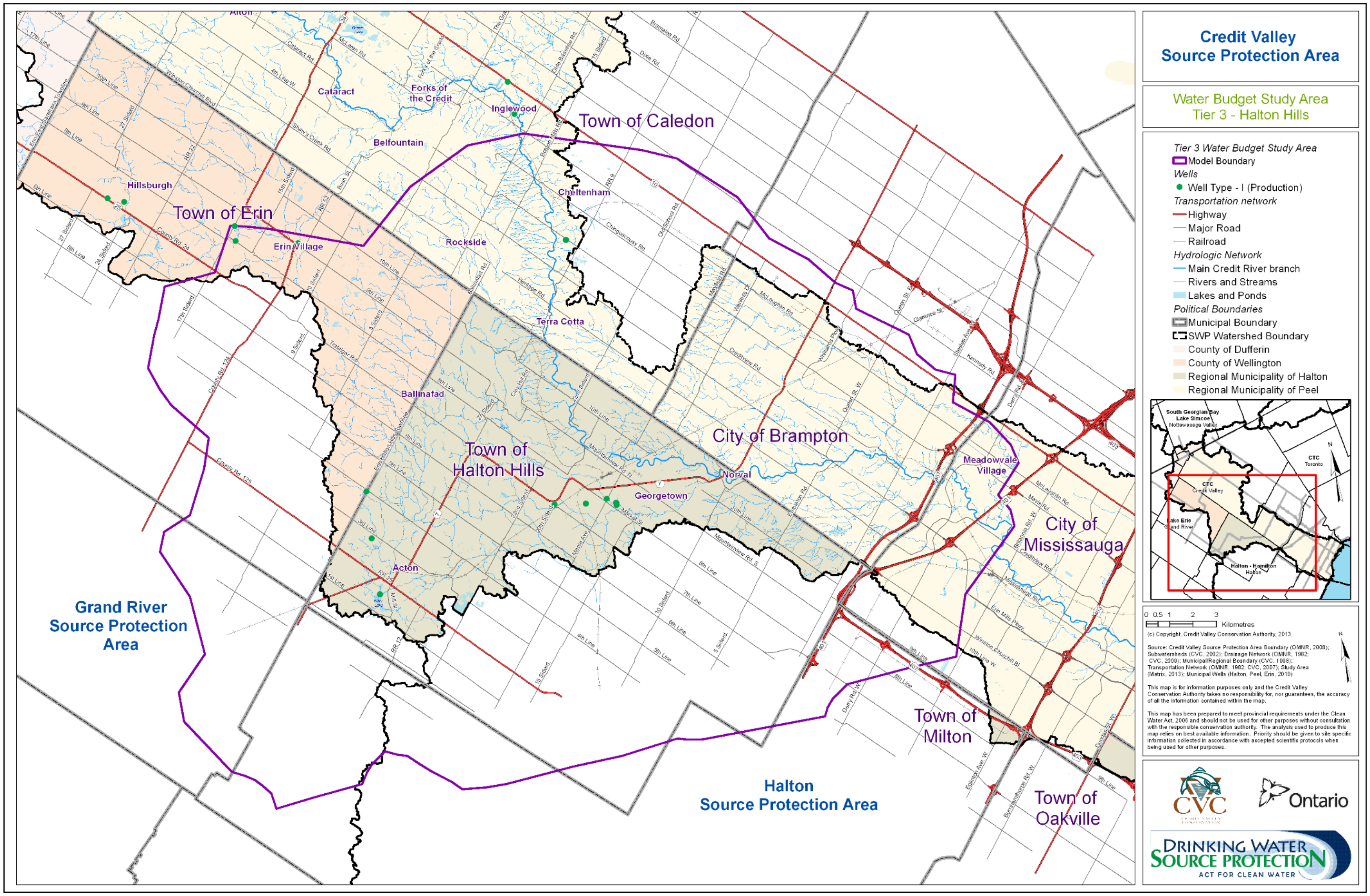


Figure 3.31: Water Budget Study Area – Tier 3 Halton Hills

Modelling Approach

The use of a linked model scheme is favoured where the surface water model can accurately provide simulations of the short- and long-term hydrologic processes, including the simulation of dynamic streamflow response and groundwater recharge, while the groundwater model can more accurately determine the subsurface movement of groundwater at time scales that are more relevant for these processes.

The modelling approach developed for the Tier 3 assessment builds upon previous work completed for the Cedarvale wellfield where a surface water model was built and calibrated to regional stream flows and used to estimate groundwater recharge conditions within a groundwater flow model (EarthFx Inc., 2009).

Although the MIKE SHE model simulated hourly continuous streamflow, and the FEFLOW model simulated average annual groundwater discharge and baseflow conditions, each of the models estimates important aspects of the same surface water flow system. As such, the two models were calibrated to the same streamflow and high-quality water level and data.

Output from the surface water model was used as the initial input (recharge) into the groundwater flow model. This coupling was used to examine the impact of future land development on water levels in aquifers, and reductions in discharge to streams and surface water features. The combined results of the two water budget models produce an improved understanding of the hydrologic and hydrogeologic flow systems.

Model Refinements

The Tier 3 Water Budget model improves upon previous assessments in terms of the model simulation, and the representation of groundwater movement between and across subwatershed boundaries. The advanced scope of work allowed for additional borehole development and seismic surveying of the study area. This work produced new data, allowing for a refinement of the conceptual understanding of the subsurface environment, and for a much-improved simulation of the groundwater flow system in the area.

Data from additional drilling/monitor installation and spot streamflow measurements were utilized to further characterize the hydrostratigraphy and interactions between groundwater and surface water features at key areas that potentially contribute flow to the Acton and Georgetown municipal wells.

The refinements were incorporated as follows:

- Updated hydrostratigraphy using borehole data derived from the field program;
- Refined representation of vertical flow gradients from newly collected observation data, and model layer structure, which is important for simulating groundwater-surface water interactions;
- Refined steady-state calibration with additional high quality hydraulic head data and spot streamflow observations;
- Refined model representation of groundwater-surface water interactions by incorporating additional spot streamflow locations and sampling periods;
- Refined model calibration and confidence in the model results by incorporating a transient model calibration to large scale pumping tests or events;

- Refined groundwater recharge distribution, that was developed using a physically based model that couples surface water and groundwater processes (MIKE SHE) and which was calibrated to streamflow measurements; and
- A coupled groundwater and surface water flow models calibrated to common data sets that include hydraulic head data and stream flow data.

Details on these refinements are provided in the foundation document and in **Appendix C3**. Summary information pertaining to models' calibration and validation is also presented in **Appendix C3.**

3.8.12 Characterization of Water Demand for Municipal Wells in Acton and Georgetown

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

- Permit Details - where possible, original copies of PTTW were 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 Definition - the safe water level at each well or intake was estimated or calculated. The safe water level corresponds to the minimum groundwater or surface water elevation that can be sustained while pumping at the intake;
- Maximum Yield or Sustainable Yield Estimate - these estimates may be less than the permitted rates and were therefore considered when defining the allocated quantity of water for each well. They are important for planned wells or intakes where permits are not yet in place; and
- Site visits if warranted to better estimate consumptive water use.

The *Technical Rules* require that the existing, committed, and planned water demands 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 in December 2013:

- **Existing Demand** – amount of water determined to be currently taken from each well or intake. For this study, existing demand has been based on the 2005 to 2011 average annual pumping rates. 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 greater than the current lawful PTTW taking is considered part of the planned quantity 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 of Water** - 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 of Water** - (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.

3.8.13 Results of Characterization for Municipal Wells in Acton and Georgetown

A summary of the major findings of the Tier 3 water budget modelling study is provided below. Supporting details are provided in **Appendix C3**.

Groundwater and Surface Water Interaction

The thermal regime of a river or stream can provide a general indication of the groundwater and surface water interaction. Groundwater discharge is important for moderating stream temperature and maintaining water levels during low-flow periods. In addition, areas of groundwater upwelling are critical for fish spawning.

Coldwater fisheries communities, considered a strong indicator of groundwater discharge, have been mapped throughout the study area along reaches of Black Creek; Silver Creek; Huttonville Creek; Eramosa River; Blue Springs Creek; the main Credit River from Forks of the Credit to Cheltenham, Cheltenham to Glen Williams, Glen Williams to Norval, and Norval to Port Credit; and within headwater areas of Sixteen Mile Creek in the Upper West Branch, Middle Branch and Middle East Branch (CVC *et al.*, 2011; Credit River Anglers Association (CRAA), 2006; Gartner Lee Limited (GLL), 2003; MNR and CVC, 2002). Groundwater discharge is also thought to occur along the upper reaches of Beeney Creek, which is managed as coldwater fish habitat, and along Hospital Tributary (GLL, 2009).

A critical aspect of the modelling effort was the determination of stream losses to the groundwater system in areas immediately surrounding the municipal wellfields. Spot streamflow measurements collected within subwatershed 10 and 11 provide insight into losing and gaining conditions within those watercourses.

Beeney Creek and Hospital Tributary are significant to the hydrogeological regime of the study area because of their possible connections to the municipal supply aquifer for the Lindsay Court and Princess Anne wellfields. The data suggests that Beeney Creek is a losing reach (i.e., a section of stream/creek bed where surface water recharges the subsurface through the stream bed thereby reducing baseflow) just north of 22nd Sideroad where it crosses the buried bedrock feature that hosts the municipal aquifer. Surface water loss may also occur along Black Creek where it crosses the buried bedrock valley feature. Numerical modelling of these features suggests these areas of surface water loss are locally significant source areas for the municipal wells.

Groundwater Recharge Distribution

Estimated recharge rates ranged from a low of 0 mm/yr. along some streams and at saturated wetlands, to a maximum in excess of 350 mm/yr. associated with hummocky topography along the crest of the Paris and Acton moraines and areas of flat topography with bedrock outcrop or coarse-grained outwash deposits, e.g., just above the crest of the escarpment. As the surface water and groundwater flow models were both calibrated to average baseflow, the estimated overall average recharge rate across the model is considered reliable. **Appendices C3** outlines how the MIKE SHE model was used to estimate spatially and temporally variable groundwater recharge for the Tier 3 groundwater flow model.

Water Flow into and out of Subwatersheds 10 and 11

The water budget components within Black Creek and Silver Creek subwatersheds (Subwatersheds 10 and 11) are described below. Each component was calculated assuming no net change in stored water occurs over the time period 2005 to 2009 and was based on the limitations and assumptions of the long-term climate dataset. **Table 3.22** summarizes the estimated cross boundary flow between Subwatersheds 10 and 11. Cross-boundary groundwater flow into Subwatershed 10 is significant along the southeast and west boundaries. These flows are interpreted to be the natural flow directions in the west hydraulic gradients and are enhanced by Acton municipal pumping. Cross-boundary groundwater flow out of Subwatershed 10 is interpreted to be enhanced due to pumping within Georgetown. Cross-boundary flows into Subwatershed 11 are significant along the Subwatershed 10 and southeast boundaries. Groundwater flows out of Subwatershed 11 in the northeast to the main Credit River subwatershed as flow converges on the Niagara Escarpment.

Table 3.22: Summary of Cross Boundary Water Flow between Subwatersheds 10 and 11

Subwatershed 10 Boundary	Cross Boundary Flow (m^3/d)
From West boundary into Subwatershed 10	+3,000
Subwatershed 10 to Southwest boundary	-4,000
From Southwest boundary into Subwatershed 10	+4,700
Subwatershed 10 into Subwatershed 11	-14,400
Net Cross Boundary Groundwater Flow	**-10,700**
Subwatershed 11 Boundary	**Cross Boundary Flow (m^3/d)**
Subwatershed 11 to Northwest boundary	-1,100
Subwatershed 10 into Subwatershed 11	+14,400
From Southeast boundary into Subwatershed 11	+3,500
Subwatershed 11 into Northeast Boundary	-3,500
Net Cross Boundary Groundwater Flow	**+13,300**

Table 3.23 summarizes the estimated overall water budget fluxes for subwatersheds 10 and 11. The average annual precipitation in both Subwatershed 10 and Subwatershed 11 is 850 mm/year. Groundwater modelling results indicate that 3% of the total inflow into Subwatershed 10 is from groundwater flow from adjacent subwatersheds. The groundwater inflow from adjacent subwatersheds to Subwatershed 11 is 14% of the total inflow and 11% of the cross-boundary inflow comes from Subwatershed 10. Cross-boundary flow is interpreted to occur under the non-pumping conditions but is enhanced by municipal pumping.

Table 3.23: Overall Water Balance for Black Creek and Silver Creek Subwatersheds

Subwatershed 10			
Inflows	**Flow (m³/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Precipitation	186,400	850	97%
Net Groundwater Flow in			
From west boundary into Subwatershed 10	3,000	10	1%
From Southeast boundary into Subwatershed 10	4,700	20	2%
Total Inflow	**194,100**	**880**	**100%**
Outflows	**Flow (m³/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Evapotranspiration	-126,700	-580	-66%
Streamflow	-40,700	-180	-20%
Pumping	-8,300	-40	-5%
Net Groundwater Flow out			
Subwatershed 10 to southwest boundary	-4,000	-20	-2%
Subwatershed 10 into Subwatershed 11	-14,400	-60	-7%
Total Outflow	**-194,100**	**-880**	-100%

Subwatershed 11			
Inflows	**Flow (m³/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Precipitation	110,700	850	86%
Net Groundwater Flow in			
From west boundary into Subwatershed 10	14,400	110	11%
From southeast boundary into Subwatershed 10	3,500	30	3%
Total Inflow	**128,600**	**990**	**100%**
Outflows	**Flow (m³/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Evapotranspiration	-74,900	-570	-58%
Streamflow	-38,900	-300	-30%
Pumping	-10,200	-80	-8%
Net Groundwater Flow out			
Subwatershed 10 to southwest boundary	-1,100	-10	-1%
Subwatershed 10 into Subwatershed 11	-3,500	-30	-3%
Total Outflow	**-128,600**	**-990**	-100%

Average annual evapotranspiration is computed at approximately 580 mm/year in Subwatershed 10 and 570 mm/year in Subwatershed 11. Average annual streamflow is 180 mm/year from all streams across the Subwatershed 10 and 300 mm/year across Subwatershed 11.

Table 3.24 summarizes the water balance for groundwater within the subwatersheds. The water budget models predict an average annual groundwater recharge rate of 376 mm/year (55,100 m³/d) into the subwatershed.

Table 3.24: Groundwater Balance for Black Creek and Silver Creek Subwatersheds

Subwatershed 10			
Inflows	**Flow (m^3/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Groundwater Recharge	50,500	230	80%
Cross Boundary Flows	13,000	60	20%
Total Groundwater Inflow	**63,500**	**290**	**100%**
Outflows	**Flow (m^3/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Groundwater discharge	-31,500	-140	-50%
Permitted Wells	-8,300	-40	-13%
Cross Boundary Flows	-23,700	-110	-37%
Total Outflow	**-63,500**	**-290**	**-100%**

Subwatershed 11			
Inflows	**Flow (m^3/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Groundwater Recharge	26,400	200	55%
Cross Boundary Flows	21,100	160	45%
Total Groundwater Inflow	**47,500**	**360**	**100%**
Outflows	**Flow (m^3/d)**	**Flow (mm/yr)**	**Percent of Total Inflow**
Groundwater discharge	-29,500	-220	-61%
Permitted Wells	-10,200	-80	-22%
Cross Boundary Flows	-7,800	-60	-17%
Total Outflow	**-47,500**	**-360**	**-100%**

The total groundwater discharge to surface water in Subwatershed 10 is approximately 31,500 m^3/d or 140 mm/year and is 29,500 m^3/d or 220 mm/year in Subwatershed 11. Subwatershed 10 groundwater pumping is 8,300 m^3/d, or approximately 13% of the total groundwater inflow (recharge plus cross-boundary flows). Subwatershed 11 groundwater pumping is 10,200 m^3/d, or approximately 22% of the total groundwater inflow into the subwatershed. These values are within 10% of those estimated using the Tier 2 (watershed-scale) FEFLOW model; however, discharge to streams is better represented within the Tier 3 model based on the calibration to continuous gauges and additional spot streamflow measurements.

Calculated Water Demand – Municipal

Municipal demand was identified as the largest consumptive use of groundwater in the CVSPA **(Chapter 2**, **Table 2.9)**. Acton and Georgetown, the two municipalities in the study area, each have groundwater sourced municipal water supplies.

Through the Sustainable Halton planning process, a water demand assessment was done by AECOM (2011) to quantify future water supply needs in Halton Hills and identify the potential servicing options required to meet those needs. The assessment was based on population growth targets to 2031, which assume a 75% increase over 2011 population levels and a 27% increase over 2011 employment levels, with most of the growth occurring in Georgetown due to expansion of the urban envelope. Modest growth is projected for Acton where it is associated with infill within the existing urban envelope.

Population and employment projections were based on Halton Region's 2011 best planning estimates for their preferred growth option. Population projections were used to develop estimates of future residential water demand, and employment projections were used to develop estimates for future industrial, commercial, and institutional uses. Details on the development of the water demand projections are summarized in **Appendix C3**.

The results of the water demand assessment showed that there was insufficient capacity in the Acton and Georgetown municipal supply systems to meet the average day demands for the 2031 planning horizon. Therefore, the full permitted capacity of all existing wells is required to meet the projected demand; however, a deficit will still exist. Additional strategies to meet demand with groundwater supply include the installation of backup wells at Lindsay Court and Princess Anne 6, and the installation of a new production well north of Acton, and the twinning of Fourth Line Well A. In addition, Halton Region is planning on integrating water takings from Lake Ontario to meet much of the demand associated with planned growth in Georgetown.

Planned demand includes only those demands that have been approved through the Master Planning or EA process (*Technical Rules* amendments, December 2013). Since none of the proposed wells or intakes has gone through the EA process, planned demand was not assessed for this Tier 3 Water Budget Study. However, projections from the Sustainable Halton process were used to obtain a best assessment of committed demand at all existing and active municipal supply wells. Projected pumping rates for existing wells from the Sustainable Halton process are the same as the Maximum Annual Average Daily Taking at each wellfield currently approved in the Acton and Georgetown PTTW, with the exception that the pumping rate for the Cedarvale Wellfield has contingent approval pending the results of an ongoing monitoring program. Per the Interim Guidance, the allocated quantity of water is considered as the combined amount of the existing plus any committed demand up to the current lawful PTTW.

The demand characterization is shown conceptually in **Figure 3.23**, while demand data for each municipal well is shown on **Table 3.25.** The existing pumping conditions for Acton and Georgetown were based on the 2005 to 2011 average annual pumping rates. The pumped water level elevation in each municipal well was determined by examining water level hydrographs for each municipal well during periods when it was pumped.

The allocated quantity of water for the pumping wells represent the future pumping demand, and were forecast using the municipal growth plans based on the approved Official Plan population projections at the time of the study and through extensive discussion with municipal officials. A description of the factors informing the derivation of future demand for each municipality is provided in **Appendix C3**.

Table 3.25: Municipal Water Demand – Acton and Georgetown

	Permitted (m^3/d)				Allocated Quantity of Water (m^3/d)		
	Maximum Daily Taking at Well [1]	Maximum Annual Average Daily Taking at Wellfield[1]	Maximum Daily Taking at Wellfield[1]	Municipal Drinking Water Licence WTP Capacity[2]	Existing Demand[3]	Existing plus Committed Demand[4]	Comments
Fourth Line A	1,309	1,309	1,309	n/a	805	1,309	
Davidson Well 1	1,250	2,500	2,500	n/a	1,080	2,500	Two wells represented by one boundary node in model
Davidson Well 2	1,250			n/a			
Prospect Pk Well 1	2,273	1,517*	1,517*	2,270	1,477	1,517*	Two wells represented by one boundary node in model
Prospect Pk Well 2	2,273						
Total Acton	**8,355**	**5,326**	**5,326**	**n/a**	**3,362**	**5,326**	
Lindsay Court 9	6,545	6,545		n/a	4,979	6,545	
Princess Anne 5	4,582	6,800	13,021	n/a	2,579	3,400	Max ann avg daily taking divided equally based on historical & planned extraction
Princess Anne 6	13,091			n/a	2,589	3,400	
Cedarvale 1a	2,618	5,790	14,404	12,960	1,064	1,447.5	Max ann avg daily taking divided equally based on historical & planned extraction
Cedarvale 3a	3,931				1,551	1,447.5	
Cedarvale 4	7,855				1,087	1,447.5	
Cedarvale 4a	5,891				1,302	1,447.5	
Total Georgetown	**44,513**	**19,135**	**34,040**	**n/a**	**15,449**	**19,135**	

Notes: Abbreviations: n/a- not applicable, WTP – Water Treatment Plant.

1. *Values from PTTW No. 7801-825PBJ for the Georgetown Municipal Water Supply, and PTTW No. 6281-7WFQB3 for the Acton Municipal Water Supply*
2. *Refers to limits under Municipal Drinking Water License for Prospect Park and Georgetown Water Treatment Plants. The Allocated Quantity of Water must not exceed this limit. Applies only to allocated rates at the Prospect Park and Cedarvale wellfields*
3. *Average Annual daily taking for 2005 to 2011*
4. *Representative of maximum annual average daily taking at wellfield per PTTWs.*

* *Blended rate given maximum daily taking of 2273 m3/d for June 1 to September 30; and 1137 m3/d for October 1 to May 30 of each calendar year*

Safe Additional Drawdown

Safe additional drawdown is defined as the additional depth that the water level within a pumping well could fall while maintaining that well's allocated pumping rate. To establish the safe additional drawdown for each municipal pumping well within the study area, the following components were evaluated or calculated for each municipal well:

- Safe water level elevations - the lowest elevation within a municipal pumping well that an operator can take the water level to without causing physical damage or reduced output from the well. This elevation may be related to the well screen elevation, pump intake elevation or other operational limitations;
- Existing water level elevations in the pumping wells - The elevation of the observed average annual pumped water level within each municipal well for the 2005 to 2011 time period during periods of normal operation;
- Estimated non-linear well losses at each well - drawdown within the well in response to well inefficiencies (e.g., entrance losses, turbulent flow around pump fittings) created during groundwater extraction; and
- Convergent head losses at each well - FEFLOW does not specifically simulate the water level at the location of a well located within a grid cell. Additional water level drawdown is referred to as convergent head loss and can be quantified to properly predict the pumped water level in a well.

Further discussion on the computation of these components is provided in **Appendix C3**.

The safe water level elevation for each well was provided by Halton Region staff and is based on the elevation at the top of the well screen, the elevation of the pump intake and other pump settings, which included a measure of safety to account for seasonal water level fluctuations and other well losses that may not be accounted for in the groundwater flow model.

The safe water level elevations and the safe additional drawdown at each municipal well in the study area are listed in **Appendix C3**. With the inclusion of non-linear well losses, and convergent head losses, the safe additional aquifer drawdown at each well has been derived from the safe additional drawdown. This data is shown in **Appendix C3**.

Calculated Water Demand – Non-Municipal

Water Users with Permits to Take Water

Non-municipal groundwater users in the study area with water takings in excess of 50,000 L/day (500 m^3/day) are listed in **Appendix C3.** These water users are referred to as large, non-municipal, water takers, and represent agricultural, commercial, and industrial uses. Non-municipal PTTW holders were identified from the 2006 MOE PTTW database and cross-referenced with results of the Tier 2 water budget assessment.

The takings associated with the Acton Quarry (PTTW 02-P-3087) were represented in the model using actual estimates of the groundwater portion of the dewatering based on site monitoring data (AquaResource Inc., 2014).

PTTW 7530-8FP6GZ is the only large, non-municipal, water taker within the study area. The water taking occurs at an institutional complex where groundwater is extracted for the purpose of cooling building and equipment. The water taking is considered to be a net non-consumptive user of groundwater, since the extracted groundwater is returned to the supply aquifer through injection wells after it is cycled through the cooling system. Since PTTW 7530-8FP6GZ is not a consumptive user of groundwater, it was not represented in the developed numerical modelling tools as a groundwater taking.

Water Users Not Required to Obtain Permits to Take Water

Several wells that are located in serviced areas pre-date the supply of serviced water to the area. Although these well may no longer be used for potable supply, they may still be used for lawn watering or similar uses. Domestic water takers were not simulated in the groundwater flow model as their individual takings are relatively insignificant compared to municipal pumping. Consumptive water use from the unserviced domestic wells in subwatersheds 10 and 11 was estimated at 981 m^3/day (AquaResource Inc., 2009). This represents approximately 5% of the average annual water taking at municipal supply wells within Acton and Georgetown between 2005 and 2011, or less than 3% of the maximum permitted municipal water taking volume. As such, these water uses were not simulated in the groundwater flow model or considered in the water budget calculations.

Other Water Uses

Aquatic Habitat and Provincially Significant Wetlands

Groundwater discharge requirements for coldwater aquatic habitat are poorly understood, and the impacts of a reduction in groundwater discharge into the aquatic habitat cannot be definitively predicted. Consequently, the Province introduced the use of thresholds to evaluate the impacts of reductions in groundwater discharge into coldwater streams.

In Ontario, there has been increasing recognition of the water needs of aquatic ecosystems in legislation and policy. In general, this reflects a growing awareness of the importance of identifying the water needs of aquatic ecosystems for watershed planning and better linking of design criteria for specific watershed management measures to the ecological responses of receiving waters. As such, several efforts aimed at developing approaches to support the implementation of ecological flow assessments, have been undertaken in recent times.

Currently though, the Province has elected to prescribe specific baseflow reduction thresholds to be used when assigning a risk level associated with predicted impacts to coldwater fish community streams in response to increased municipal pumping. These thresholds are discussed later on in this Assessment Report.

Figure 3.32 shows the coldwater fisheries and wetlands within the study area. Coldwater fisheries communities have been mapped along reaches of Black Creek; Silver Creek; Huttonville Creek; Eramosa River; Blue Springs Creek; the main Credit River from Forks of the Credit to Cheltenham, Cheltenham to Glen Williams, Glen Williams to Norval, and Norval to Port Credit; and within headwater areas of Sixteen Mile Creek in the Upper West Branch, Middle Branch and Middle East Branch (CVC *et al.*, 2011; Credit River Anglers Association (CRAA), 2006; Gartner Lee Limited (GLL), 2003; MNR and CVC, 2002). Groundwater discharge is also thought to occur along the upper reaches of Beeney Creek, which is managed as coldwater fish habitat, and along Hospital Tributary (GLL, 2009).

The *Technical Rules* also identify provincially significant wetlands as an "other water use" to be assessed. The wetland systems within Subwatershed 19 include swamps, marshes, fens, and bogs **(Figure 3.32)**.

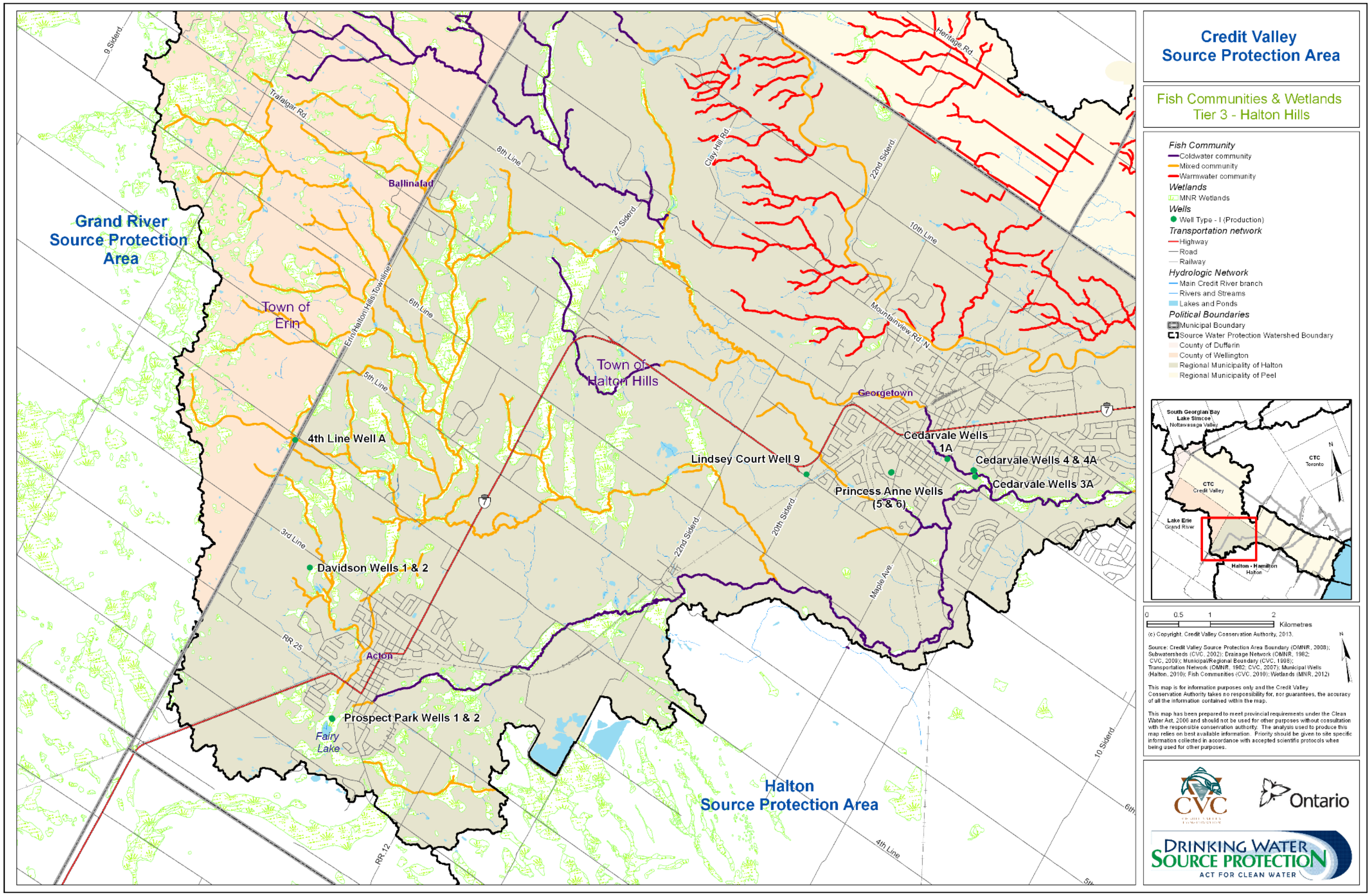


Figure 3.32: Fish Communities and Wetlands - Tier 3 Halton Hills

Evaluated wetlands are classified under a standard methodology taking into account the wetlands biological, hydrological, and socio-economic features and functions. Based on this system, wetlands can be identified as Provincially Significant Wetlands and these are protected under the wetland component of the Provincial Policy Statement. Provincially Significant Wetlands in the study area include the Ballinafad Ridge Wetland Complex, Acton-Silver Creek Wetland Complex, Crewson's Corner Swamp, Eramosa River-Blue Springs Creek Wetland Complex, Black Creek at Acton Wetland Complex, Halton Escarpment Wetland Complex, Hungry Hollow Wetland Complex, and Guelph Junction Woods. Surface water features and wetland complexes local to the municipal well systems within the study area are illustrated on (**Figure 3.32**).

Wastewater Assimilation

The Acton and Georgetown Wastewater Treatment Plants (WWTPs) discharge into Black Creek and Silver Creek, respectively. The Acton WWTP discharges to the creek upstream of Fourth Line, and the Georgetown WWTP discharges east of Ninth Line upstream of the confluence of Silver Creek with the main Credit River (**Figure 3.32**). Environmental Compliance Approvals for the plants specify the minimum streamflow rates required for wastewater assimilation under existing conditions. Future plant operation is based on Class EA approved expansion designs, which assume minimum 7Q20 stream flows (lowest 7-day average flow based on a 20-yr return period) at Black Creek of 1,400 m^3/d for the Acton WWTP, and 8,000 m^3/d for the Georgetown WWTP, to allow for adequate assimilation of discharge wastewater.

The Acton and Georgetown municipal wells have the potential to reduce the baseflow to the Black Creek and Silver Creek and/or their tributaries, which would effectively reduce the assimilative capacity of Black and Silver Creeks. As such, the impact of municipal groundwater pumping on Black and Silver Creeks and their ability to assimilate waste from the WWTPs was a consideration in this Tier 3 assessment.

Recreation

Groundwater discharge to local rivers, creeks, streams, and lakes can also maintain water levels during low flow periods. Where local water ways are used for activities such as fishing, boating, or swimming, groundwater inputs support the recreational use of the water way. Within the study area, recreational use of groundwater occurs on both private and public lands. Public recreational users of groundwater include Fairy Lake in Acton and three conservation areas run by the CVC (Silver Creek Conservation Area along Silver Creek near Ballinafad, Limehouse Conservation Area along Black Creek near Limehouse, and Terra Cotta Conservation Area in the headwaters area of the Credit River north of Georgetown). Private recreational use may also be common along Credit River, Eramosa River, Blue Springs Creek and Sixteen Mile Creek, where these water ways run through privately held land tracts.

Fairy Lake is used year-round as a recreational area for fishing, swimming, and canoeing. It is located within Prospect Park, a 14-acre green space area just south of Hwy 7 and Regional Road 25. The lake contributes to the overall character of the green space area, which is used for picnicking, bird watching, cycling and other sporting activities. Flow within the lake is regulated at Fairy Lake dam by the Halton Region, and lake levels must be kept a minimum stage of 345 mASL to allow continued recreational use (pers. comm. T. Renic, Halton Region). In addition, the three conservation areas in the study area are frequented year-round for a range of recreational activities. The Credit River, Eramosa River, Blue Springs Creek and Sixteen Mile Creek support significant recreational fishing activity during the spring, summer and fall months.

Land Use Change and Increased Imperviousness

Since changes in land use could potentially alter groundwater recharge, the *Technical Rules* also require that the Tier 3 modelling scenarios evaluate the impact existing land use and future land development have on groundwater recharge.

The following steps were undertaken to identify potential changes in land use. They are fully discussed in **Appendix C3**:

- Creation of a map of existing land use (**Appendix C3**) - existing land use within the study area is representative of the 2005-to-2009-time frame. The data set shown is the Southern Ontario Land Resource Information System (SOLRIS), Version 1.2, as distributed by the MNRF, Science and Information Branch (2008). The existing urban land use is divided into Employment Areas (industrial/commercial land uses), Urban Areas (industrial /commercial/mixed use and residential land uses) and the Natural Heritage System (Green Belt Policy Area and other Natural Heritage Features, e.g., wetlands, woodlands, watercourses.
- Creation of a map of future land use using the Official Plan - Halton Region adopted the Regional Official Plan (ROP) in 2006, "to give clear direction as to how physical development should take place in Halton to meet the current and future needs of its people." (Regional Municipality of Halton, 2006). To accommodate the Ontario provincial planning regulations under the *Places to Grow Plan*, *Greenbelt Protection Plan*, and *Provincial Policy Statement*, Halton Region initiated the Sustainable Halton process. The Sustainable Halton process involved the creation of a growth management plan, as well as a basic and comprehensive review of the ROP. AECOM (2011) completed a water demand assessment as part of the Sustainable Halton process, which was summarized earlier. In 2009, the region adopted Amendment No. 38 to the Regional Official Plan, or ROPA 38, based on the results of the Sustainable Halton process and review of the ROP (Regional Municipality of Halton, 2009).
- Identify areas of land use change by comparing future land use against existing land use.

Figure 3.33 shows the areas where land use may change according to the Official Plans as compared to current land use. This figure was created by digitally overlaying the existing and future land use maps (**Appendix C3**) using a Geographic Information System. These areas were identified by comparing existing conditions and future (ROPA 38) land use patterns.

The Tier 3 model represents land use changes by reducing groundwater recharge proportionally to amount of impervious area.

Table 3.26 summarizes the imperviousness values applied to the land use areas that, according to the Official Plans, will be modified in the future. These values were obtained by comparing each soil class used within the recharge estimation for both urban and nonurban settings within the Halton Region portion of the study area. The recharge rates for these areas were calculated by multiplying the impervious value by the recharge rate estimated for undeveloped conditions.

Per the *Technical Rules*, the potential impact of best management practices such as stormwater management measures and low impact development techniques, were *not* considered when estimating imperviousness changes for future land use. Consideration of how to lessen or avoid the impact of land use change on reducing recharge is part of the source protection planning phase.

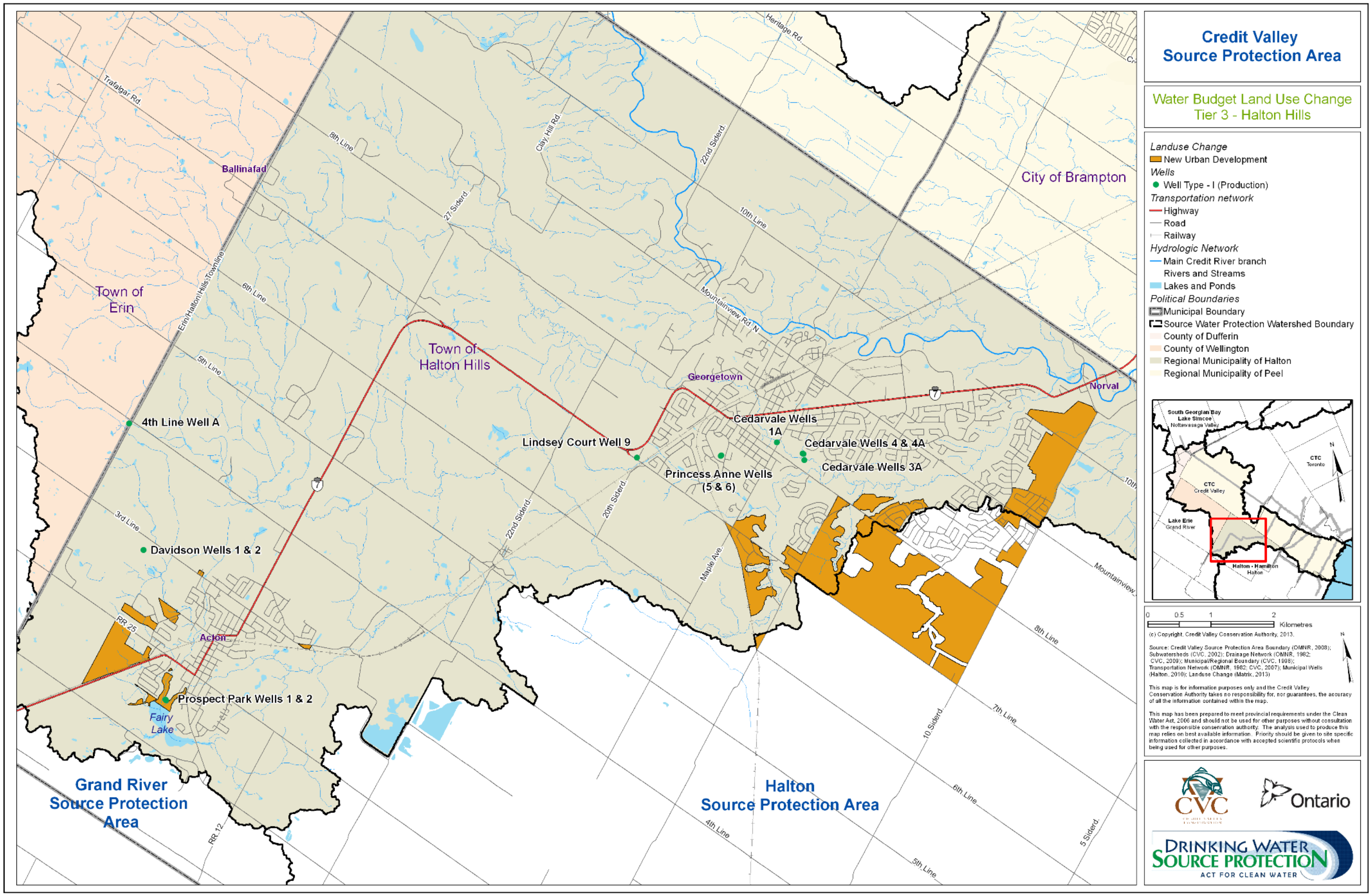


Figure 3.33: Water Budget Land Use Change - Tier 3 Halton Hills

Table 3.26: Imperviousness Estimates Applied for Future Land Use Areas

Soil Type	Sample Average Recharge (mm/yr.)		Imperviousness (Recharge Reduction)
	Urban	Non-Urban	
Halton Till	36	74	49% (51%)
Wentworth Till	133	218	61% (39%)
Clay	8	16	55% (45%)
Sand	288	375	77% (23%)
Bedrock	245	376	65% (35%)
Gravel	284	323	88% (12%)

The most significant areas of change are south of Georgetown just to the northeast of Milton, along Steeles Road between 6th Line and Winston Churchill Boulevard; and along Highway 401 between 6th Line and 8th Line south to Derry Road. Specific future urban land uses are not identified in ROPA 38. To represent land use changes (imperviousness changes) assumptions about likely land uses were made based on the surrounding current land uses or developments underway.

3.8.14 Delineation of Water Quantity Vulnerable Areas for Municipal Wells in Acton and Georgetown

The Tier 3 Water Budget groundwater model was used to delineate vulnerable areas WHPA-Q1, WHPA-Q2, and the Local Areas within which risk scenarios are evaluated. Local Areas are areas to which water quantity risk is assigned and are the vulnerable areas within which policies may apply to protect the quantity of water required by a municipality to meet their current or future water needs.

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.

The vulnerable areas delineated to protect the quantity of water required by a municipality to meet current or future water needs are called WHPA-Q1 and WHPA-Q2 under the *Technical Rules*. They are delineated for all municipal water supply wells that extract water from a subwatershed assigned a groundwater stress level of significant or moderate in the Tier 2 Water Budget Assessment.

The WHPA-Q1 is delineated as the combined area that is the *cone of influence* of the well, and the whole of the cones of influence of all other wells that intersect that area and any surface water drainage area upgradient of the area that contributes a significant proportion of surface water directly to the wells. The extent of the cone of influence is determined by selecting an appropriate drawdown threshold, which considers several factors. These factors include the observed seasonal aquifer water levels fluctuations (often in the range of 0.5 metre – 1.0 metre over the year) and available field observations pumping induced drawdown around the municipal wells.

The WHPA-Q1 was delineated by examining the change in predicted water level within the production aquifer between two model scenarios.

- Steady-state model simulating existing land use, and no municipal pumping. This scenario establishes water levels that would exist without pumping.
- Steady-state model simulating existing land use, and existing plus committed plus planned municipal pumping rates.

The model predicted water levels in the production aquifer for each scenario which were then subtracted from one another, and the resulting predicted water levels were mapped. The average seasonal water level fluctuation within wells monitoring heads in the production aquifer is about 1.0 m, and therefore, the 1.0 m drawdown contour interval was selected for use in delineating the WHPA-Q1 areas for Acton and Georgetown. With respect to Georgetown's municipal wells, additional consideration was given to the neighbouring surface catchment area, which has been shown to contribute recharge to the Georgetown municipal aquifer.

Groundwater modelling studies show that the lower reach of Beeney Creek, west of Georgetown, loses on average, approximately 4,130 m^3/day, through leakage from the base of the stream bed to the underlying aquifer (see **Appendix C 3**). This aquifer is part of the Acton-Georgetown buried bedrock valley aquifer east of Limehouse and is intersected by Lindsay Court and Princess Anne wellfields. The observed average leakage represents 27% of the existing pumping demand from the Georgetown wellfields. A measurable reduction in streamflow in Beeney Creek could arguably reduce leakage to the municipal aquifer and impact well production. The Beeney Creek catchment area is illustrated in **Figure 3.34.**

Model scenario analysis and calibration indicates that leakage from Beeney Creek provides an important recharge function for the buried bedrock valley aquifer. Stream flow and recharge reduction activities in the catchment area of Beeney Creek could impact the ability of the wells to meet demand. Therefore, the Beeney Creek catchment area is included as part of the WHPA-Q1 for Georgetown.

Three WHPA-Q1 areas have been delineated within the Acton and Georgetown areas, and are labelled as WHPA-Q1 A, B and C, as shown in **Figure 3.35**. WHPA-Q1-A lies northwest of Acton and is associated with Fourth Line Well A and Davidson Well. WHPA-Q1-B is associated with Prospect Park Well and represents the 100 m buffer area around the well. WHPA-Q1-C is the largest area delineated and is associated with the Georgetown wells (Lindsay Court, Princess Anne and Cedarvale) and the area west and north of the urban areas. No other large consumptive water users beyond the municipal wells were identified within the cones of influence. Additional detail on the WHPA-Q1 delineation is presented in **Appendix C3**.

The WHPA-Q2 is defined as the WHPA-Q1 area, plus any area where a future reduction in recharge may have a measurable impact on the area. Proposed land development areas that had the potential to reduce the available drawdown in a municipal well were simulated in the groundwater model. These are primarily south and west of Georgetown and a small area in the western portion of the Acton boundary. The reduction in hydraulic head due to the development of residential lands was predicted to be between 2 cm and 9 cm for the Georgetown municipal wells, and between 0 cm and 2 cm for the Acton municipal wells. The seasonal variation in water levels of approximately 1 m would mask this change. Further, the reduction in hydraulic head is much smaller than the available drawdown at all wells (> 4.5 m). Therefore, the reduction in recharge outside of the WHPA-Q1 is not considered to have a measurable impact on the wells. As such, land use changes that lie outside the WHPA-Q1 areas were not included in the final WHPA-Q2 delineation and all WHPA-Q2's are assumed to be equivalent to the WHPA-Q1 extents.

Three WHPA-Q2 areas for Acton and Georgetown were delineated and are designated as WHPA-Q2-A to WHPA-Q2-C as shown in **Figure 3.36**. Additional information on the WHPA-Q2 delineation is presented in **Appendix C3**.

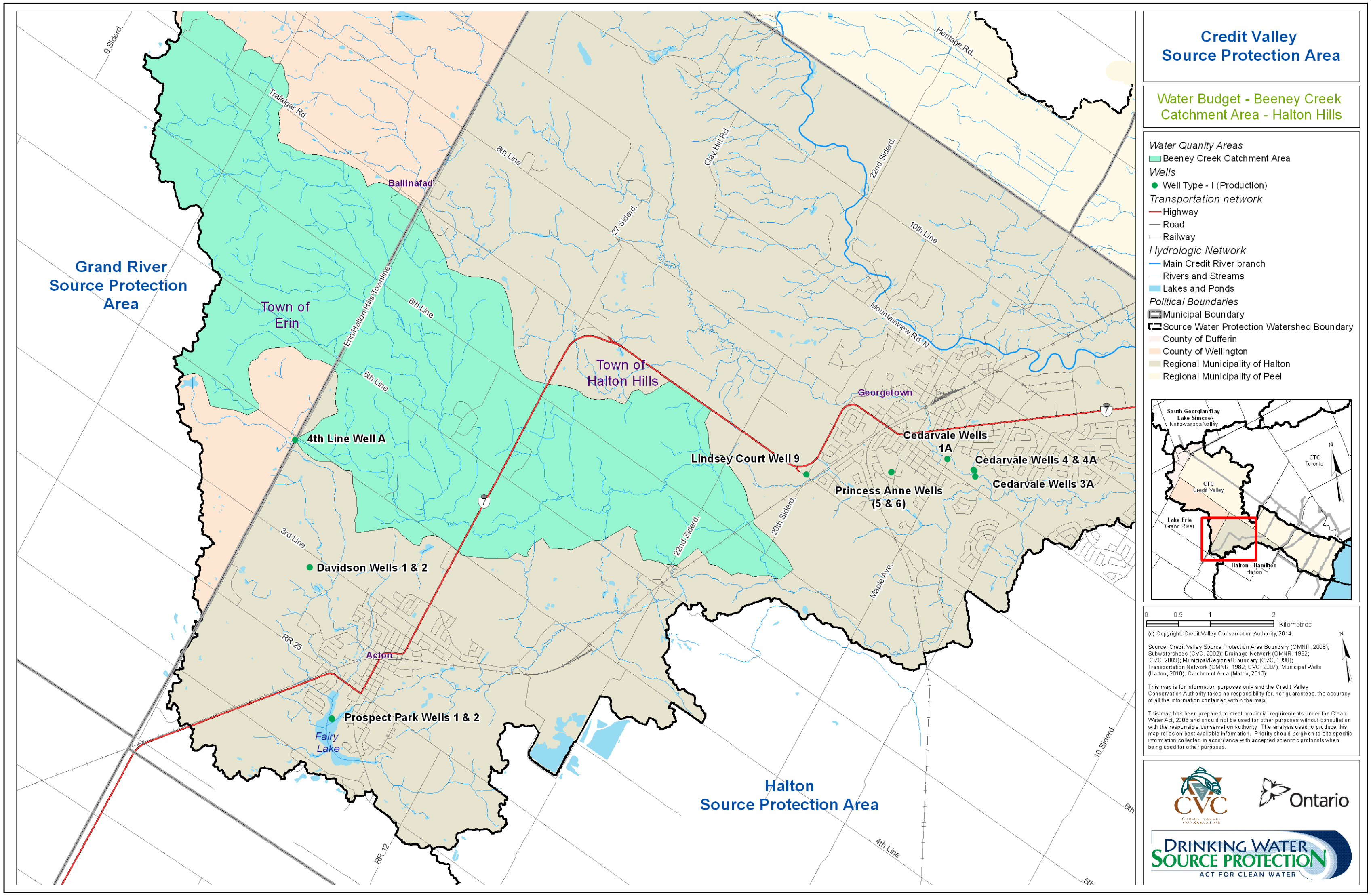


Figure 3.34: Water Budget - Beeney Creek Catchment Area – Halton Hills

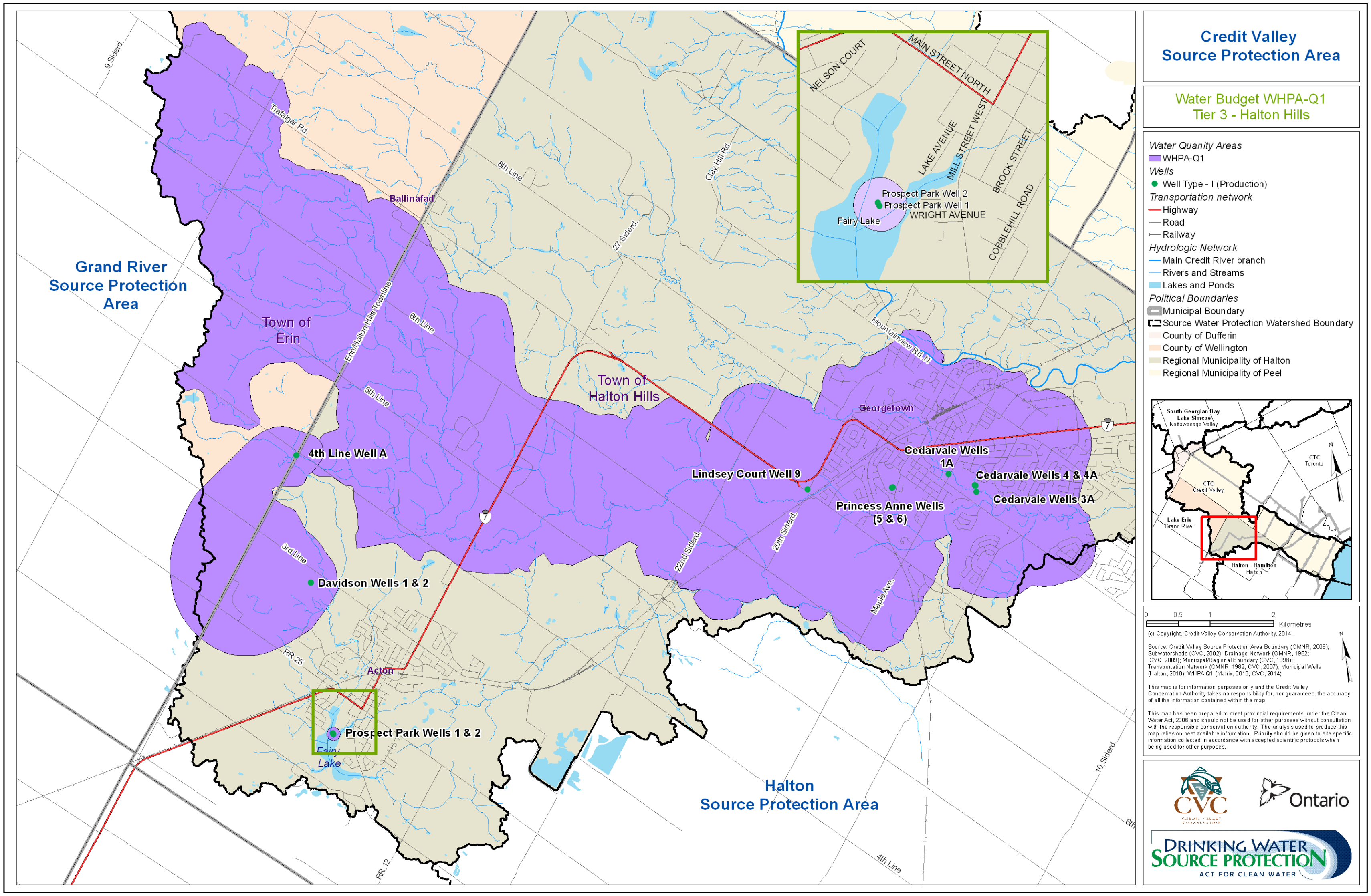


Figure 3.35: Water Budget WHPA-Q1 - Tier 3 - Halton Hills

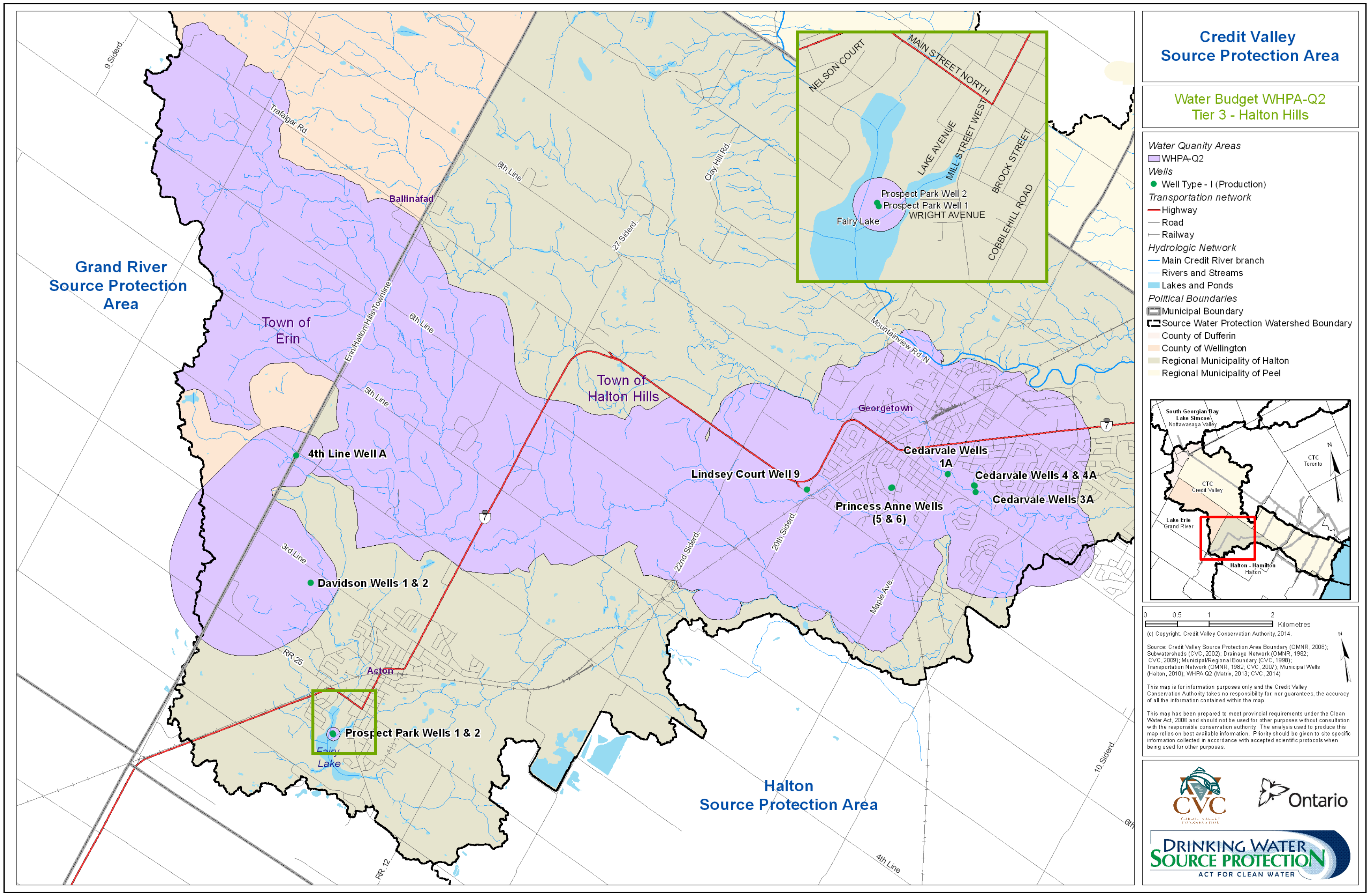


Figure 3.36: Water Budget WHPA-Q2 - Tier 3 - Halton Hills

Delineation of Groundwater based Vulnerable Areas-Local Areas

The Local Areas delineated for Acton and Georgetown are shown on **Figure 3.37**. The Local Area is determined by combining the following areas:

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

WHPA-Q1 and WHPA-Q2 areas for all municipal wells are coincident reflecting low potential for measureable impact on water levels at the municipal wells under proposed changes in land use outside the WHPA-Q1. The Beeney Creek catchment area has been included as part of the WHPA-Q1 in the Local Area for Georgetown, as a measure aimed at protecting recharge from Beeney Creek to the municipal aquifer supplying the Lindsay Court and Princess Anne wellfields.

Three Local Areas have been delineated – A, B and C. Local Area A is the area surrounding the Davidson and Fourth Line wellfields, while Local Area B occurs around the Prospect Park wellfield. Both of these Local Areas are around wells serving Acton. Local Area C is the area associated with the Georgetown wellfield and includes the catchment area for Beeney Creek per the discussion above.

Local Area A includes part of two source protection areas, mostly in the CVSPA in the CTC SPR and a small part in the Grand River SPA in the Lake Erie SPR. Local Area C also includes parts of two source protection areas, again primarily in the CVSPA and a small part in the Halton SPA in the Halton-Hamilton SPR. Local Areas A and C extend beyond the Region of Halton (Town of Halton Hills) into the County of Wellington (Town of Erin) **(Figure 3.37).** The consumptive uses or recharge reduction taking place within either municipality in each Local Area could pose potential water quantity threats to Halton's municipal supplies in that Local Area (**Chapter 5.3.2**). Furthermore, each SPC is required to develop policies to address any significant water quantity threats identified within their respective source protection area.

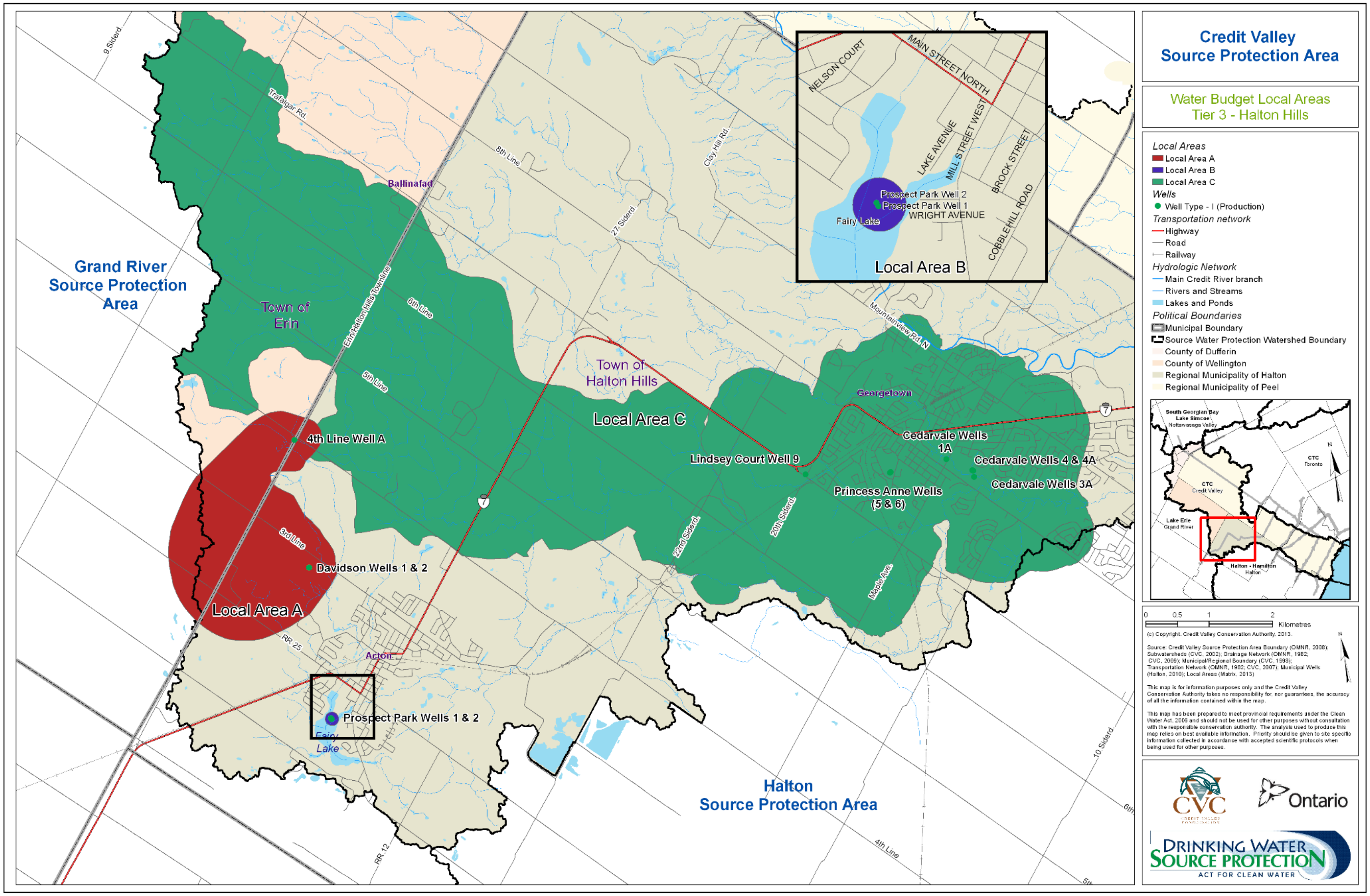


Figure 3.37: Water Budget Local Areas Tier 3 – Halton Hills

3.8.15 Risk Assessment Scenarios for Municipal Wells in Acton and Georgetown

For the risk assessment, the groundwater model was used to examine whether existing and planned municipal wells are able to sustain their pumping rates under existing and planned conditions, and to help predict the resultant impacts to other water uses. This model was also used to assess the potential response of aquifers to long-term drought conditions.

The *Technical Rules* require that four major risk scenarios be evaluated. These scenarios are described in **Table 3.27**.

Scenarios C and D correspond to existing pumping rates and existing land cover under average climate, and drought conditions, respectively. Scenarios G and H correspond to future land cover and allocated or planned pumping rates for existing or planned wells under average climate, and drought conditions, respectively.

The scenarios were assessed as follows:

- Scenarios C and G represent average climate conditions and were simulated using steady-state conditions;
- Scenarios D and H represent drought conditions and were simulated using a transient model representing two drought periods between 1960 and 2006; and
- Multiple versions of scenarios G and H were required to evaluate the impact of allocated pumping rates separately from impacts of land use change on groundwater recharge, and the cumulative impact of both.

Table 3.27: Summary of Risk Assessment Scenarios (MOE, 2009)

Scenario	Time Period	Data Restrictions
C	The period for which climate and stream flow data are available for the Local Area	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the study period (2005-2011).
D	Ten-year drought period	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the study period (2005-2011).
G	The period for which climate and stream flow data are available for the Local Area	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the period in which the planned system or an existing system with a committed demand is operating at its allocated or planned quantity.
H	Ten-year drought period	Data related to average monthly pumping rates for water takings and land cover reflect conditions during the period in which the planned system or an existing system with a committed demand is operating at its allocated or planned quantity.

Table 3.28 summarizes the Local Area risk scenarios developed for each municipal well in Acton and Georgetown. The scenarios were designed to meet the criteria shown in **Table 3.27**. Additional detail on each scenario is presented in **Appendix C3.**

Table 3.28: Risk Assessment Model Scenarios

<table>
<tr><th rowspan="2">Scenario</th><th rowspan="2">Time Period</th><th colspan="4">Model Scenario Details</th></tr>
<tr><th>Land Cover</th><th>Municipal Pumping</th><th colspan="2">Model Simulation</th></tr>
<tr><td>C</td><td>Period for which climate and stream flow data are available for the Local Area (2008)</td><td>Existing</td><td>Existing</td><td colspan="2">Steady-state, Average Annual Recharge</td></tr>
<tr><td>D</td><td>10 year drought period</td><td>Existing</td><td>Existing</td><td colspan="2">Transient (1960-2006); Monthly recharge rates</td></tr>
<tr><td>G(1)</td><td rowspan="5">Period for which climate and stream flow data are available for the Local Area</td><td>Official Plan</td><td>Allocated</td><td>Groundwater Recharge Reduction and Increase in Demand</td><td rowspan="5">Steady-state, Average Annual Recharge</td></tr>
<tr><td>G(2)</td><td>Existing</td><td>Allocated</td><td>Groundwater Discharge Reduction from Increase in Demand</td></tr>
<tr><td>G(3)</td><td>Official Plan</td><td>Existing</td><td>Groundwater Recharge Reduction from Land Cover</td></tr>
<tr><td>G(4)</td><td>Existing</td><td>Allocated</td><td>Per G(2); Impacts on other users</td></tr>
<tr><td>G(5)</td><td>Existing</td><td>Planned</td><td>Per G(2); Impacts on other users</td></tr>
<tr><td>H(1)</td><td>10 year drought period</td><td>Official Plan</td><td>Allocated</td><td>Groundwater Recharge Reduction and Increase in Demand</td><td rowspan="3">Transient (1960-2006); Monthly recharge rates</td></tr>
<tr><td>H(2)</td><td>10 year drought period</td><td>Existing</td><td>Allocated</td><td>Groundwater Discharge Reduction from Increase in Demand</td></tr>
<tr><td>H(3)</td><td>10 year drought period</td><td>Official Plan</td><td>Existing</td><td>Groundwater Discharge Reduction from Increase in Demand</td></tr>
</table>

3.8.16 Model-Predicted Scenario Results

Drawdown

The predicted maximum drawdown at each well, under each model scenario was assessed by comparing the drawdown at the end of the model run to the estimated safe additional drawdown at each municipal well. The predicted maximum drawdown at each well is calculated relative to the existing conditions (Scenario C) simulated heads and is shown in **Table 3.29.**

For the steady-state models (Scenarios G (1), G (2) and G (3)), the difference between the water levels at the well in Scenario C and those at the end of each model scenario were recorded as the model scenario drawdown **(Table 3.29)**.

For the transient scenarios, the lowest simulated water level elevation in the aquifer at each municipal pumping well was compared to the water level in the existing conditions scenario (Scenario C) and this value was also recorded on **Table 3.29**. The model simulated drawdown was then compared to the field-based safe additional drawdown to identify municipal wells where there is a potential that the wells will be unable to pump their allocated rates. The table identifies the wells and scenarios where these conditions may occur.

Table 3.29: Risk Assessment Drawdown Result – Acton and Georgetown

Well Name	Safe Additional Aquifer Drawdown (2005-2011)		Model Scenario Drawdown (m)						
			Average Climate			Drought			
		C	G(1)	G(2)	G(3)	D	H(1)	H(2)	H(3)
		2005-2011 Average Pumping Rates	Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction	Existing Recharge, Demand	Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction
Fourth Line Well A	5.6	0.4	4.8	4.8	0.0	2.5	7.9	7.9	2.5
Davidson	8.2	-0.9	2.8	2.8	0.1	2.8	5.8	5.8	2.8
Prospect Park	14.0	0.7	0.1	0.1	0.0	1.4	1.5	1.5	1.4
Lindsay Court Well 9	10.1	-1.5	3.8	3.6	0.1	3.8	8.6	8.5	4.0
Princess Anne Well 5	14.7	0.3	5.2	4.9	0.2	3.0	9.0	8.8	3.3
Princess Anne Well 6	13.0	1.2	5.1	4.9	0.2	2.9	8.9	8.7	3.2
Cedarvale Well 1A	11.8	3.5	3.5	3.3	0.3	2.4	6.5	6.2	2.7
Cedarvale Well 3A	10.1	-0.1	2.0	1.7	0.3	1.8	3.9	3.7	2.1
Cedarvale Well 4	8.8	2.4	2.4	2.1	0.3	1.9	4.5	4.3	2.1
Cedarvale Well 4A	4.5	-3.5	2.3	2.0	0.3	1.7	4.2	4.0	2.0
	Pumped drawdown greater than safe additional drawdown								

Note: The model scenario drawdown at each well for Scenarios G, D and H is calculated relative to simulated Scenario C (2005-2011 average conditions) and corrected for the 2005-2009 calibrated model head residual and well losses as appropriate.

Average Climatic Conditions

For average climatic conditions, (Scenarios G (1), G (2) and G (3)), the model predicted drawdown in the aquifers at each municipal well is lower than the estimated safe available drawdown.

The results suggest that all municipal wells are capable of supplying their allocated rates (Scenario G (2)) under average conditions. Under a reduction in recharge, all municipal wells would be capable of supplying their allocated rates (Scenario G (1)).

Drought Conditions

For drought periods with the current water taking characteristics (existing recharge and current pumping rates (Scenario D), the model predicted the wells are able to sustain these withdrawals. The drawdown in the aquifers at each municipal well is predicted to be less than the estimated safe additional drawdown available at each of the wells.

The Scenario H (2) results also showed that most municipal wells are capable of supplying their allocated rates (existing plus committed pumping rates to meet population increase in the Official Plan) within their PTTW during drought conditions. Fourth Line Well A, however, is the exception - the model predicts that estimated safe additional drawdown would be exceeded by approximately 41%.

Under the reduction in recharge (Scenario H (3)), the model predicts that all municipal wells would be capable of supplying their current pumping rates.

When the cumulative impacts of drought conditions, increased municipal pumping rates to meet population projections and reductions in recharge due to future land cover (Scenario H (1)) are considered, the model predicted that all municipal wells, with the exception of Fourth Line would be capable of supplying their current pumping rates.

Baseflow Reduction

The groundwater model simulated groundwater discharge to the environment by examining the reduction in simulated baseflow to rivers, streams, and wetlands of interest. The simulated impact on baseflow for rivers, streams and wetlands of interest within the study area was assessed for Scenarios G(1), G(3) and G(4) by comparing the simulated groundwater discharge or stream leakage under each of the model scenarios to the groundwater discharge or stream leakage simulated under 2005-2011 average pumping conditions (Scenario C). **Figure 3.38** shows the areas within the model where baseflow impact was assessed.

The *Technical Rules* require that baseflow impact be assessed under conditions of increased municipal pumping under average climate conditions when evaluating risks to the Local Area. The groundwater model's estimate of average annual net groundwater discharge or stream leakage into each reach is contained in **Table 3.29**. Baseflow impacts were assessed only for existing systems with committed demand (existing plus committed demand at or below the current PTTW rate) and average climate – the G scenarios. Impacts to other water uses are *not* evaluated for drought scenarios (D and H).

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 identified within the Tier 3 assessment. Within the Halton Hills Tier 3 assessment there was no planned quantity identified by the municipality (only an allocated quantity). Therefore, although the modelled impact of reducing baseflow in some streams was above the significant risk level threshold for cold-water streams of 20%, the highest level of risk that can be assigned, based on these impacts, is moderate. Likewise, if the significant threshold for baseflow reduction in warm water streams, or for lowering the water level below a provincially significant wetland is exceeded due to modelling the effects of pumping the allocated quantity, the resultant risk level is assigned as moderate. Should a new planned quantity of water be identified within the Local Area, then it will be necessary to reassess the water quantity risk level as it might be deemed to be significant.

The groundwater model simulated groundwater discharge to the environment by examining the reduction in simulated baseflow to rivers, streams, and wetlands. **Figure 3.38** shows the locations where baseflow impact was assessed.

Baseflow impacts are modelled for Scenarios G (1), G (3), G (4) by predicting the reduction in baseflow relative to that simulated for the existing conditions (Scenario C). Since planned demand was not evaluated in this study, applicable results were produced only for the Scenario G (1), G (3), and G (4). The groundwater model's estimate of average annual groundwater discharge into each stream reach is presented in **Table 3.30** and shown in **Figure 3.38**.

Table 3.30: Impacts to Groundwater Discharge - Scenario G

Stream / Reach	Scenario C 2005-2011	Scenario G(1) (Increased Demand and Recharge Reduction)		Scenario G(4) (Increased Demand)		Scenario G(3) (Recharge Reduction)	
	GW Discharge/ Stream Leakage (m^3/d)	GW Discharge/ Stream Leakage (m^3/d)	Percent Reduction (%)	GW Discharge/ Stream Leakage (m^3/d)	Percent Reduction (%)	GW Discharge/ Stream Leakage (m^3/d)	Percent Reduction (%)
Silver Creek	-31,900	-29,800	7	-30,500	4	-31,100	3
Lower Black Creek	-5,000	-4,600	8	-4,800	4	-4,900	2
Upper Black Creek	-25,600	-23,400	9	-23,900	**7**	-25,100	2
Lower Beeney Creek	6,300	7,800	24	**7,700**	**22**[1]	6,400	2
Upper Beeney Creek	-10,700	-10,300	4	-10,300	4	-10,700	0
Hospital Tributary	-600	-100	83	**-300**	**50**[1]	-400	33

[1] moderate risk level

Note: Convention: negative represents net discharge of water from aquifer to the stream reach. Positive represents net leakage from the stream reach to the aquifer. Reductions and discharge (less negative) or increases in leakage (more positive) indicate a potential impact to stream and are collectively referred to as impacts to groundwater discharge. Scenario G (4) bold values used for assessing impacts. Other scenarios used to provide indication of contribution to impacts from land use and combined effects.

The modelling shows that an increase in municipal pumping to the allocated rates is predicted to cause the largest water table reduction (greater than 2 m) in the area surrounding the Georgetown wells (Lindsay Court well 9, Princess Anne well 5 & 6, and Cedarvale well 1A). Lesser water table reductions are predicted in the surrounding areas. Since the seasonal water level fluctuation in the production aquifer and shallow systems is approximately +/-1 m, predicted water reduction will only be measurable in the areas near the pumping wells. Impacts on the water table elevation outside of these areas are not likely to be measurable as the predicted change in the water table elevation is less than the seasonal variation. Nonetheless, groundwater discharge to the wetlands in Georgetown may be reduced based on the model simulations.

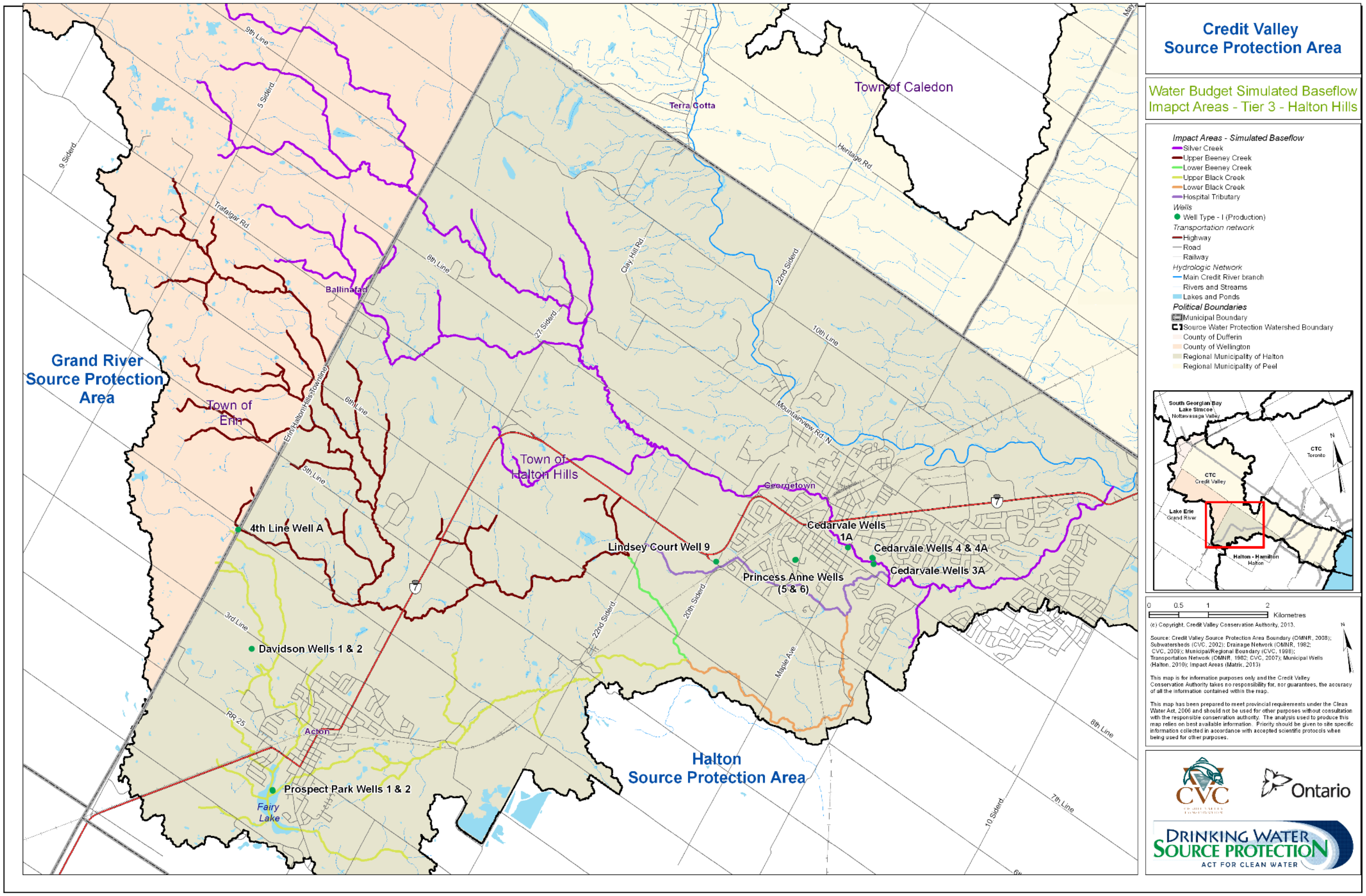


Figure 3.38: Water Budget Simulated Baseflow Impact Areas – Tier 3 – Halton Hills

The scenario modelling yielded a maximum wetland water table reduction of 4 m along Hospital Tributary near the Georgetown wells. The discharge function to the wetlands along Hospital Tributary is likely to be impacted and the tributary lies within Local Area C. Given that the risk scenario modelling showed no negative impacts on any of the municipal wells in the Local Area, and that the water table reduction modelled was based on allocated, not a planned, water demand, the Local Area C was assigned a moderate risk level in keeping with the amended *Interim Direction* (December 2013) made under the CWA 2006.

Note that this is not the same test as required under the *Ontario Water Resources Act* (OWRA) by the Director in determining whether or not to issue or amend a PTTW. Under the OWRA, all uses of water including protection of the natural functions of the ecosystem must be taken into account when issuing, amending or renewing a PTTW. Further impacts that are observed during the duration of a PTTW may result in amendments to the allowed quantities of water that can be taken under an existing PTTW, for example during low water periods or where unacceptable impacts or interference are occurring.

The average wetland water table reduction is 0.06 m and water table fluctuations are less than 1 m outside of Hospital Tributary, therefore there is a low-risk assignment to Local Areas A and B for impacts on the wetlands as an "other water use".

While three different scenarios were modelled for Acton and Georgetown, only Scenario G (4) is considered when evaluating the risk level placed on the Local Areas related to baseflow reductions for source protection planning purposes. This is due to the fact that baseflow reductions arising from land use development are independent from increased groundwater pumping, and only those impacts associated with groundwater pumping (e.g., Scenarios G (4)) should be used to evaluate water quantity risk level. Since a planned demand was not identified in this study, applicable results were produced only for the Scenario G (4).

Thresholds (*Technical Rules*) used to establish the Local Area risk level were as follows:

- Baseflow reductions equal to or greater than 10% result in a water quantity risk level classification of moderate for the Local Area,

The model results for the G (4) scenario are illustrated in **Figure 3.39**. The potential baseflow reductions associated with this scenario are predicted to be 10% or less, except for Lower Beeney Creek and Hospital Tributary, which show reductions of 22% and 50%, respectively. Since the risk scenario modelling showed no negative impacts on any of the municipal wells in the Local Area, and since the baseflow reductions were realized using the existing plus committed water demand (allocated rate), the Local Area C was assigned a moderate risk level consistent with the Interim Guidance (December 2013). See discussion above.

The model results also show that there are reductions in baseflow under the other scenarios as shown in **Table 3.30.** The potential baseflow reductions associated with only recharge reductions are minor (less than 2%) except for Hospital Tributary (33%) in Scenario G (3). Modelling the recharge reduction from future land uses did not consider implementation of any low impact development or best management practices designed to minimize the impact. Fixed percent impervious surface estimates were used based on the proposed land use. While these scenarios are conservative, they indicate whether baseflow is sensitive to increased pumping, or to recharge reduction from land use development, or to both. In this case, the groundwater discharge is most sensitive to a combination of the two, due to the fact that increased pumping will increase the extent of the 3D drawdown cone, to encompass areas where new development is proposed which will reduce recharge (i.e., WHPA-Q2).

3.8.17 Summary of Local Area Risk Assessment Results

A summary of the results of the Local Area risk scenarios is presented in **Table 3.31**. The table provides a comprehensive overview of the assumptions informing the scenarios, including the quantity of water demand, the land cover modelled in each scenario, as well as the scenario results.

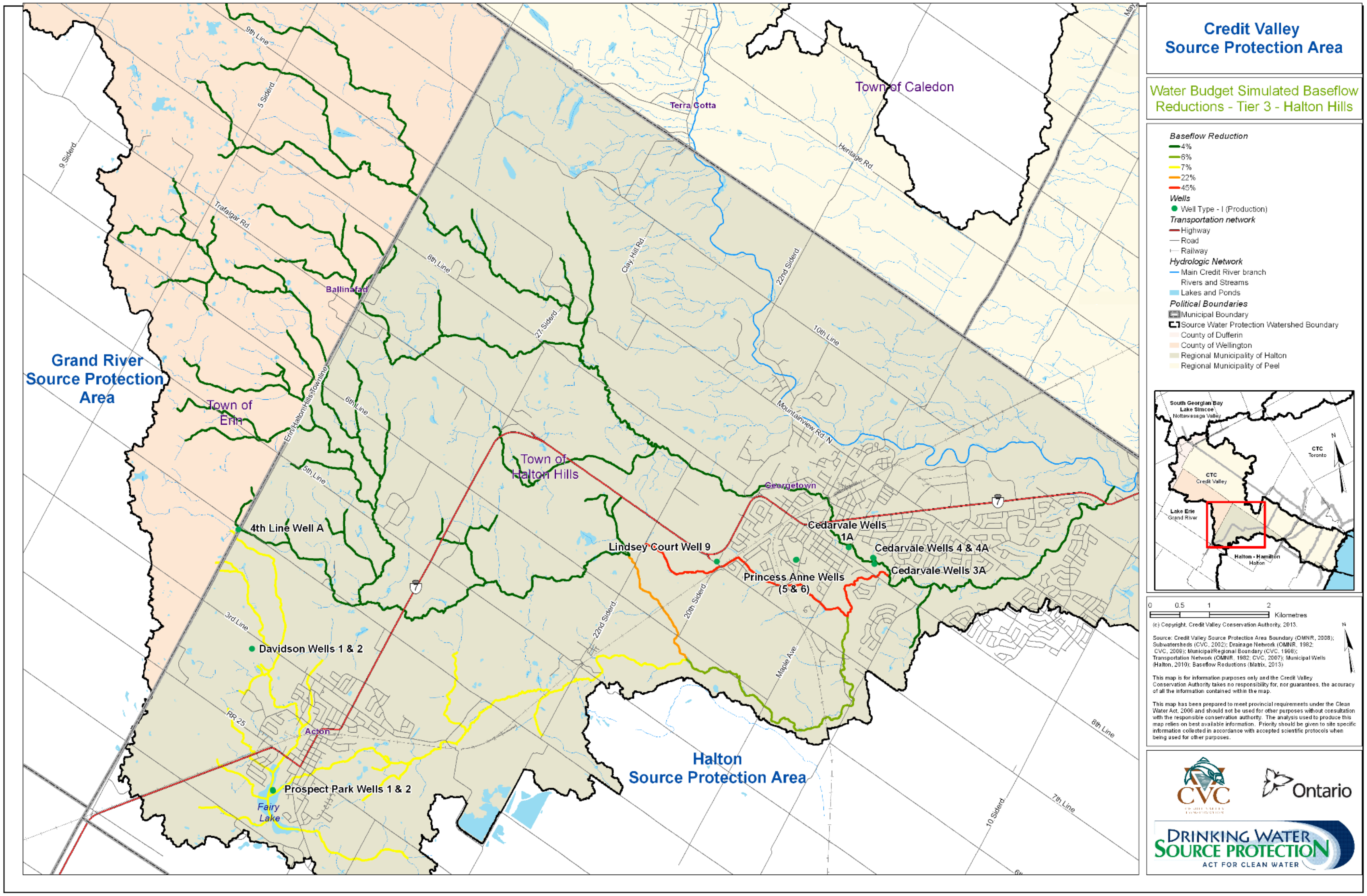


Figure 3.39: Water Budget Simulated Baseflow Reductions Tier 3 – Halton Hills (Scenario (G) 4)

Table 3.31: Results of Risk Assessment Scenarios in Local Areas of Acton and Georgetown

Risk Assessment Model Scenarios					Results – Risk Level		
Scenario	**Time Period**	**Land Cover**	**Quantity of Water**	**Other Permitted Water Demand**	**Local Area A**	**Local Area B**	**Local Area C**
C (base)	Period for which climate and stream flow data are available for the Local Area	Existing	Existing Demand	Existing Demand	Low	Low	Low
D (base with drought)	10 year drought period	Existing	Existing Demand	Existing Demand	Low	Low	Low
G(1) (Impact on municipal wells)	Period for which climate and stream flow data are available for the Local Area	Official Plan	Allocated	Anticipated Demand	Low	Low	Low
G(2) (Impact on municipal wells)		Existing	Allocated	Existing Demand	Low	Low	Low
G(3) (Impact on municipal wells)		Official Plan	Existing Demand	Anticipated Demand	Low	Low	Low
G(4) (Impact on other uses)		Existing	Allocated	Existing Demand	Low	Low	Moderate
G(5) (Impact on other uses)		Existing	Planned	Existing Demand	-	-	-
H(1) (Impact on municipal wells)	10 year drought period	Official Plan	Allocated	Anticipated Demand	Significant	Low	Low
H(2) (Impact on municipal wells)		Existing	Allocated	Existing Demand	Significant	Low	Low
H(3) (Impact on municipal wells)		Official Plan	Existing Demand	Anticipated Demand	Low	Low	Low

The results of the scenarios suggest that the tolerance of the Acton and Georgetown systems is high, as they are able to meet their existing water demands (Scenario C).

The *Technical Rules*, and Technical Bulletin: Part IX Local Area Risk Level (April 2010), list a series of circumstances, where if present in any of the risk assessment scenarios, then the Local Area must be assigned a significant risk level. In this Tier 3 Water Budget and Risk Assessment Study, the following circumstance was found to apply:

- The existing or planned system wells are not able to meet their existing or future demands because the drawdown at a municipal well exceeds the safe available drawdown.

This scenario, and specific well for which this circumstance applies, are summarized in **Table 3.32**.

Table 3.32: Risk Assessment- Significant Risk Level Circumstances

Scenario	Circumstances	Results
Planned or Existing plus Committed System with future land use and average annual climate (G) or 10-yr drought (H)	The quantity of water that can be taken from groundwater in the Local Area would not be sufficient to meet the allocated quantity of water for those wells	Fourth Line A Well

The Local Area A was assigned a significant risk level based on the following:

- The allocated quantity of water for Fourth Line Well A is not met in Scenarios H (1) and H (2) (Drought). Drawdown is impacted primarily due to increased pumping rates.

Local Areas B was classified as having low risk level.

The Local Area C was assigned a moderate risk level based on the following:

- Groundwater discharge to Hospital Tributary, a designated coldwater stream, is reduced by more than 10% in Scenario G (4) (Average Climate, Allocated Pumping);

- Groundwater discharge to Lower Beeney Creek, a designated coldwater stream, is reduced by more than 10% in Scenario G (4) (Average Climate, Allocated Pumping); and

- Groundwater levels are lowered by a measurable and unacceptable amount beneath provincially significant wetlands on Hospital Tributary (Average Climate, Allocated Pumping).

Results of the scenarios suggest the tolerance of the Halton Region system is high, as the drinking water systems are able to meet their existing water demands.

3.8.18 Uncertainty Assessment

The uncertainty analysis examined the range of potential hydraulic conductivity and recharge distributions that would produce calibrated models (see **Appendix C3** for details). The predictions made by the alternative models with acceptable ranges of parameters resulted in increased drawdown and identified the potential for drawdown exceeding the safe additional drawdown for two wells in Cedarvale wellfield (Local Area C) in one scenario. However, this scenario is considered less likely than the base case scenario which shows sufficient available drawdown at these wells. The assigned risk levels to the Local Area are therefore considered appropriate. Consequently, the uncertainty associated with the risk levels applied to the Local Areas is Low.

3.9 SUMMARY

The climatic and meteorological review of the CVSPA provides key trends and statistics and is based on almost forty years of temperature and evapotranspiration data. Although on-going studies using more recent data do show the review to be robust and relevant, updated analyses, using the most current data has been made available through the Tier 3 studies being undertaken in the CVSPA.

Water budget analyses are required to determine the sustainability of drinking water supplies. The *CWA* is primarily concerned with “stress” (higher ratio of demand to supply) as it relates to municipal drinking water supplies. Water budget analyses are nonetheless required to assess water quantity sustainability for all sources within the jurisdiction. These analyses for CVSPA are done on a subwatershed basis where demand is reviewed against supply to determine where potential stress exists. The water budget analysis assessed potential water quantity stress in both surface water (not including Lake Ontario) and groundwater.

Groundwater sources in CVSPA are used for drinking water supplies for both municipal and private wells, and to support ecosystem functions. Surface water in Beeney Creek has been shown to be an important source of recharge to the aquifer in the vicinity of some municipal wells in Georgetown (Region of Halton). The surface water in streams in the study area is also important for supporting the ecosystem, and for irrigation and other non-drinking water purposes (wastewater assimilation and recreation).

Fletcher’s Creek Subwatershed (15) was found to have moderate surface water stress levels, while the Orangeville, Black Creek, and Silver Creek subwatersheds (19, 10, and 11) were inferred to have moderate groundwater stress levels. All other subwatersheds in the CVSPA have low stress levels for both groundwater and surface water.

Since Fletcher’s Creek is not utilized for municipal supplies, no additional action is required by the *CWA*, but additional investigation and management is recommended through the Conservation Authority Watershed Protection programs.

The Tier 3 Water Budget Study for Orangeville, Mono and Amaranth, delineated four water quantity vulnerable areas, called WHPA-Q1/2’s – A, B, C, and D. Based on risk assessments carried out in each of their Local Areas, a significant risk level was assigned to Local Area A, while a low risk level was assigned to the others.

The Tier 3 Water Budget Study for Acton and Georgetown delineated three groundwater quantity vulnerable areas, called WHPA-Q1/2’s – A, B, and C. Based on risk assessments carried out in each of their Local Areas, a significant risk level was assigned to Local Area A, and a moderate risk level was assigned to Local Area C, while a low risk level was assigned to Local Area B.

The municipalities of Orangeville, Mono, and the Region of Halton's wells in Acton and Georgetown have never historically had problems meeting required pumping rates. The risk level categories do not indicate a problem associated with current municipal wells and their current pumping rates; rather, they reflect a need to manage the drinking water resources in the Local Areas to protect against future problems. **Chapter 5** describes further the drinking water threats related to water quantity.