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Chapter 3: Water Budget and Water Quantity Risk Assessment Chapter

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Disclaimer: This chapter has not been significantly edited or changed as a result of updated Technical Rules as the water budgets were completed based on the 2008 Technical Rules and have not been redone since. Therefore, this chapter reflects the 2008 Technical Rules and the names of provincial Ministries at that time.

3 Water Budget and Water Quantity Stress Assessment Summary

A component of the assessment report and ultimately the Source Protection plans will be specific to water quantity management. The goals of this assessment are to identify watershed communities where the sustainability of water supplies is questionable and to highlight key factors that may limit the sustainability, such that appropriate risk management activities can be completed.

1. A water budget is an understanding and accounting of the movement of water and the uses of water over time, on, through, and below the surface of the earth. The water budget analysis in this chapter addresses all of the following questions:
2. Where is the water (i.e. where are the various watershed hydrologic elements (e.g. soils, aquifers, streams, lakes, located?))
3. How does the water move between these elements? (i.e. what are the pathways through which the water travels?);
4. What and where are the stresses on the water? (i.e. where are the water takings?); and
5. What are the trends? (I.e. are levels declining, increasing, or remaining constant over time?).

The water budgets within this Chapter were prepared as per the Clean Water Act, 2006, Ontario Regulation 287/07 – General and the Technical Rules: Assessment Report November, 2009 and have been developed to accommodate all of the following considerations:

- The amount of water within the various reservoirs of the hydrologic cycle, including precipitation, evapotranspiration, runoff, groundwater inflow and outflow, surface water inflow and outflow, change in storage, water withdrawals and water returns.
- A description of groundwater and surface water flow pathways, and temporal, seasonal and annual changes in water quantities within each reservoir.
- Identification of areas of key hydrologic processes and the availability of potential water sources.
- Support for predicted changes in the hydrologic cycle due to trends in climate, land use and additional takings.

Building on a conceptual understanding of the study area, the water quantity assessment is based on a three tiered approach, with each step being more detailed and providing more certainty than the previous one. These steps include:

1. Conceptual Water Budget
2. Tier One Water Budget and Water Quantity Stress Assessment
3. Tier Two Water Budget and Water Quantity Stress Assessment
4. Tier Three Water Quantity Risk Assessment

This tiered process ensures watershed communities complete the degree of assessment consistent with local water quantity issues. The Conceptual and Tier One evaluations are required for the entire Source Protection Region, and in areas where the availability of water far outweighs the demand, this simplified approach (Tier One) is sufficient for decision-making and further efforts are not required. Whereas, Tier Two and Tier Three assessments provide a more thorough understanding of the hydrologic system for managing resources but are only required for those subwatersheds where stress is identified in the previous evaluation (e.g. Tier One assessment) and where there is a municipal drinking water supply system within that subwatershed. These detailed assessments are focused on better quantifying the availability of water for water supply (in relation to other permitted and ecological requirements) and the consumptive demand. Assessment scenarios are designed to assess the sustainability of supplies under current, future and drought conditions. How the subwatersheds and municipalities are moving through the tiered process are summarized on Table 3.0-1.

The framework for the Water Budget and Water Quantity Risk Assessment process is illustrated on Figure 3.0-1. The process involves four stages of evaluation, each one successively advancing the degree of technical complexity. This framework requires a basic level of understanding to effectively address issues and prepare Source Protection Plans. Therefore, a Conceptual Water Budget and Tier One (simple water budget analysis) was completed for the entire Lake Simcoe watershed.

Those subwatersheds that were identified as exceeding the prescribed threshold for potential stress and contain municipal drinking water systems advanced to a more complex Tier Two water budget analysis. The goal of the Tier Two assessment is to confirm or negate the stress assignment completed in the Tier One using a more detailed approach that includes complex numerical modeling for groundwater systems and a detailed time-continuous modeling for surface water systems. The role of the Tier Two assessment is to refine the estimation of water budget components to facilitate a more reliable stress assessment and allow subwatersheds with marginal stress levels to avoid the detailed local assessment in Tier Three. Tier Two assessments have been completed for the following subwatersheds:

1. Barrie Creeks
2. Lovers Creek
3. Hewitts Creek
4. East Holland River
5. West Holland River
6. Maskinonge River
7. Uxbridge River
8. Beaver River

The Tier Three Water Budget and Water Quantity Risk Assessments are being carried out for municipal groundwater systems that are located within subwatersheds that have been assigned a Tier Two moderate or significant potential level of stress. Water quantity risk refers to the likelihood that threats to water quantity may render an existing or planned drinking water source impaired, unusable or unsustainable. The objective of the Tier Three assessment is to evaluate the risk that a community may not be able to meet its existing or future water demand from a water source (e.g., stream, lake, or aquifer). Several subwatersheds in the Lake Simcoe watershed have been identified for further evaluation and are currently undergoing Tier Three Water Budget and Water Quantity Risk Assessments. These subwatersheds include:

1. Barrie Creeks
2. East Holland River
3. West Holland River
4. Maskinonge River
5. Beaver River

The MNR funding agreement to complete the water budget requirement of the Clean Water Act requires each of the water budget studies discussed in this chapter to undergo a peer review process by a team of qualified professionals. The objectives of the peer review process is to ensure consistency with the expectations of the Technical Rules, to ensure appropriate methodologies are utilized and that the technical assumptions are necessary and reasonable and to ensure the products are scientifically defensible. The roles and objectives of the peer review team are discussed further in Section 3.10.

Table 3.0-1: Subwatershed and Municipal Summary of the Water Budget and Water Quantity Risk Assessment Process.

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System (Yes / No)	Conceptual / Tier 1	Tier 2	Tier 3
Barrie Creeks	City of Barrie	City of Barrie	Yes (GW and SW)	√	√	√
Hewitts Creek	Simcoe County	Town of Innisfil	Yes (GW and SW)	√	-	-
Lovers Creek	Simcoe County	Town of Innisfil	Yes (GW and SW)	√	-	-
Innisfil Creeks	Simcoe County	Town of Innisfil	Yes (GW and SW)	√	-	-
Oro Creeks North	Simcoe County	Township of Oro-Medonte	Yes (GW)	√	-	-
Oro Creeks South	Simcoe County	Township of Oro-Medonte	Yes (GW)	√	-	-
Hawkestone Creek	Simcoe County	Township of Oro-Medonte	Yes (GW)	√	-	-
Ramara Creeks	Simcoe County	Township of Ramara	Yes (GW)	√	-	-
West Holland	Simcoe County	Town of Bradford-West Gwilliumbury	Yes (GW and SW)	√	√	√
West Holland	York Region	Township of King	Yes (GW)	√	√	√
East Holland	York Region	Town of East Gwilliumbury	Yes (GW)	√	√	√
East Holland	York Region	Town of Aurora	Yes (GW)	√	√	√
East Holland	York Region	Town of Newmarket	Yes (GW)	√	√	√
East Holland	York Region	Town of Whitchurch-Stouffville	Yes (GW)	√	√	√
Maskinonge River	York Region	Town of East Gwilliumbury	Yes (GW)	√	√	√
Black River	York Region	Town of East Gwilliumbury	Yes (GW)	√	-	-
Whites Creek	Simcoe County; York Region	Townships of Ramara/Brock	No	√	-	-
Georgina Creeks	York Region	Township of Georgina	Yes (SW)	√	-	-
Beaver River	Kawartha Lakes	Kawartha Lakes	Yes (GW)	√	√	√
Beaver River	Durham Region	Township of Brock	Yes (GW)	√	√	-
Uxbridge Brook	Durham Region	Township of Uxbridge	Yes (GW)	√	√	-
Pefferlaw Brook	Durham Region; York Region	Townships of Uxbridge/Georgina/Brock	No	√	-	-
Talbot River	Simcoe County; Durham Region	Townships of Ramara/Broc and City of Kawartha Lakes	No	√	-	-

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*Note: All subwatersheds are required to undergo a Conceptual and Tier 2 analysis. Subwatersheds that are not moving beyond the Tier 1 analysis do not have a municipal groundwater system, and/or were found not to stressed.

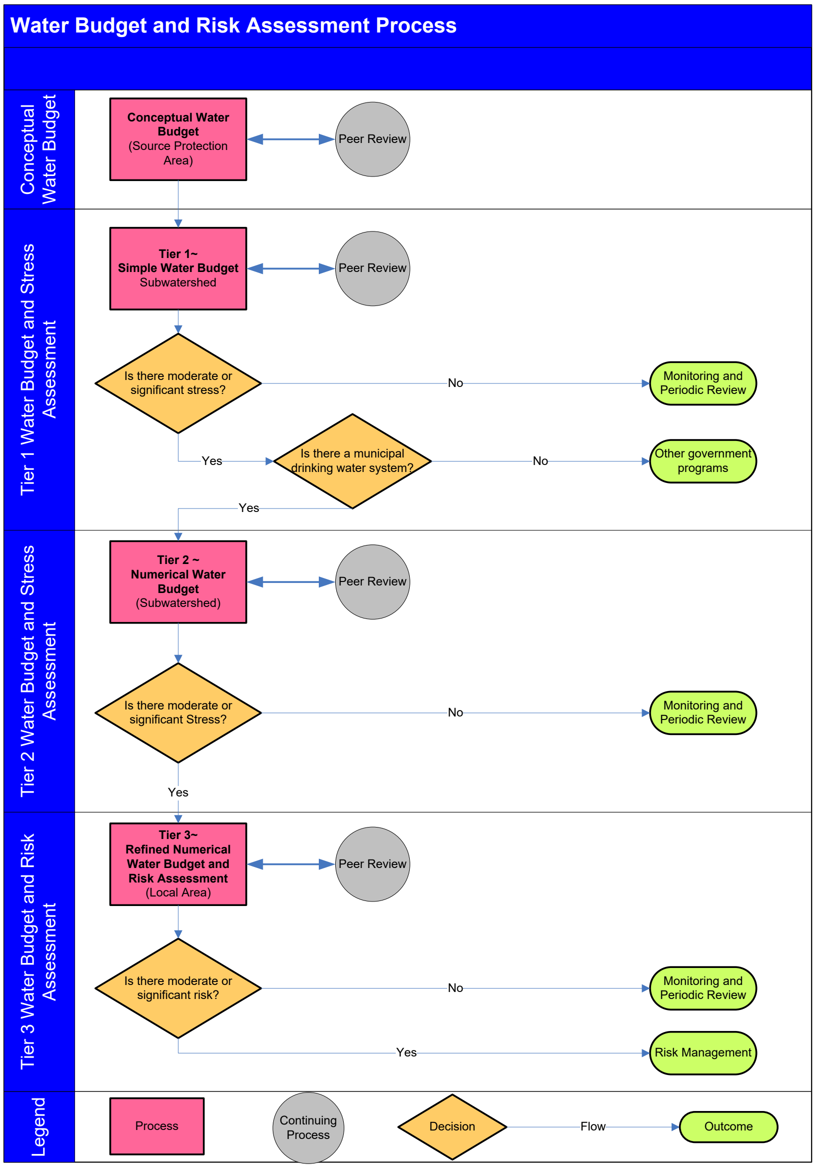

Figure 3.0-1: Water Budget and Risk Assessment Process.

3.1 Conceptual Water Budget

The Conceptual Water Budget is the initial step in the water quantity and risk assessment process. It provides an overview of how the flow system functions and quantifies the amount of water moving within the various components of the hydrologic cycle. These components include:

- Precipitation, evaporation and transpiration;
- Infiltration (water moves from the ground surface vertically downward into the soil);
- Recharge (water that infiltrates into the ground and becomes part of the groundwater flow system);
- Runoff.

In addition to estimating the above inputs and outputs within the watershed, the Conceptual Water Budget must include an understanding of the hydrologic regime and therefore describe:

- Physiography and geology;
- Surface water and groundwater features;
- Land cover;
- Human-made structures (dams, channel diversion, ect); and
- Water takings.

The following subsections discuss the elements of the Conceptual Water Budget. The Conceptual Water Budget prepared for the South Georgian Bay-Lake Simcoe Source Protection Region was used as the guiding document for this section of the assessment report.

Geology and Physiography

This section of the report provides an overview of the physiographic regions and discusses the bedrock and Quaternary geology present within the Lake Simcoe watershed. An understanding of the relationships that make up the physical setting is paramount, as these relationships are the building blocks used to create a digital three-dimensional (3D) geologic and/or hydrostratigraphic frame work models within the Tier Two and Tier Three studies. It is anticipated that these 3D models will be used as tools in the Permit to Take Water Process (PTTW), a variety of planning and land-use applications, groundwater exploration programs, and more importantly, to ensure that sufficient quantities of potable water exist for future use.

Physiography

Physiography is the study of the physical structure of the surface of the land. The study of physiography is important from a drinking water perspective as the knowledge gained from knowing the land composition aids hydrogeologists in understanding the groundwater and surface water flow systems. Information used to complete this section of the report has been obtained from Chapman and Putnam [1](1984). The physiographic regions identified by Chapman and Putnam (1984) were the result of a regional scale investigation that encompassed all of Southern and Eastern Ontario.

The Lake Simcoe watershed is located within six regional- scale physiographic regions as defined by Chapman and Putnam (1984). These regions are the Simcoe Lowlands, Simcoe Uplands, Peterborough Drumlin Field, Schomberg Clay Plain, Oak Ridges Moraine and the Carden Plain (Figure 3.1-1; figures are located at the end of each water budget). The following is a brief description of the physiographic regions found within the Lake Simcoe watershed. For more detail pertaining to the glacial formation of the regions the reader is referred to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984).

Simcoe Lowlands

The Simcoe Lowlands are characterized by flat, low-lying plains comprised of silts, clays and fine to medium grained sands. This physiographic region extends from Lake Couchiching, southward along the western edge of Lake Simcoe continuing southward toward the community of Bolton. A small portion of this regime is also located east of Lake Simcoe near the communities of Sunderland and Mount Albert.

Simcoe Uplands

The Simcoe Uplands are comprised of a series of broad, rolling drumlinized till plains that are separated by numerous steep-walled, flat-floored valleys. The Simcoe Uplands occupy a total surface area of 1035 km^2, and are located south of the community of Barrie, north of Alliston and in the northern portions of Oro-Medonte and Springwater Townships.

Peterborough Drumlin Field

Drumlin is a Celtic word meaning little hill. They are typically oval shaped hills with smooth convex contours. In areas where drumlins are pointing in the same direction, the direction of movement of a glacier during the last ice age can be determined (Chapman and Putnam, 1984).

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[1] Chapman and Putnam were the first leading researchers to map the physiography of Southern Ontario. There work has been and still is considered to be a vital reference in understanding the physical structure of Southern Ontario.

The Peterborough drumlin field is characterized as a rolling drumlinized till plain. The drumlins are on average 20-75 m in width and 100-450 m in length. The drumlins are composed of a stone-rich, slightly silty to medium grained sand till. A portion of the Peterborough drumlin field occurs south of Kempenfelt Bay (west of Cooks Bay) and within south central and eastern portions of the study area as observed on Figure 3.1-1.

Schomberg Clay Plain

The Schomberg Clay Plain is characterized by thick deposits of fine-grained sediments that drape over an irregular till plain which are typically 15 m in thickness. The Schomberg Clay Plain is located north of the Oak Ridges Moraine near the communities of Schomberg and Newmarket.

Oak Ridges Moraine (ORM)

The Oak Ridges Moraine (ORM) is a large ridge extending 160km eastward from the Niagara Escarpment to Trenton as four sediment wedges (Sharpe et al, 1997). The moraine is bounded in the west by the Niagara Escarpment and to the east by the Trent River and Rice Lake (Chapman and Putnam, 1984). The ORM generally rises in elevation from east to west peaking in elevation near the community of Uxbridge. This is a result of the western portion of the moraine receiving earlier and more frequent sedimentary deposition than the eastern portion, as the ice lobes which controlled the moraine's eastern formation slowly retreated.

Carden Plain

The Carden Plain is a bedrock plain composed of limestone and dolostone that occurs at the surface. Numerous fractures, as well as evidence of dissolution weathering are characteristic features of the Carden Plain. Glacial sediments within the plain occur as a discontinuous veneer of diamicton (slightly silty to silty sand) which is typically less than 1m in thickness. The Carden Plain is a minor physiographic regime within the Lake Simcoe watershed occurring in the north-eastern boundaries of the watershed.

Topography

Ground surface topography within the Lake Simcoe Watershed ranges from approximately 218 metres above mean sea level (mASL) at Lake Simcoe to approximately 395 mASL in the extreme southeast portion of the watershed on the height of the ORM. Areas of hummocky topography with their associated closed depressions are unique areas, typically found in moraines. They are important from a groundwater perspective in they tend to focus groundwater recharge (Davies et al, 2008). The topography of the Lake Simcoe watershed is depicted on Figure 3.1-2 and the hummocky topography of the watershed is depicted on Figure 3.1-3.

Geology

An understanding of how water moves through a watershed is at the heart of Source Water Protection. In order to assess groundwater processes, as well as, interactions between groundwater and surface water, a thorough understanding of the geological setting in a watershed is necessary. The bedrock, sediments and soils present in the watershed will determine how and where the groundwater will flow. They will also influence the vulnerability an aquifer may have to potential contaminants. For example, an aquifer capped with a non-porous material such as clay will have a lower vulnerability score than one capped with a porous material. This is to due to inability of many materials to readily move though non-porous materials. The geology of the Lake Simcoe basin can generally be described as sedimentary bedrock units overlain by unconsolidated overburden materials that have been deposited and modified by glacial, fluvial and lacustrine processes (Gartner Lee et al, 2004). Below is a more detailed explanation of both the bedrock and quaternary geology.

Bedrock Geology

The bedrock geology within the Lake Simcoe watershed is illustrated on Figure 3.1-4, and the bedrock topography can be seen on Figure 3.1-5. All of the bedrock units within the watershed are of Upper to Middle Ordovician age and represent a record of the marine transgression over the Precambrian basement (Johnson *et al*., 1992; Armstrong, 1999). The Middle Ordovician deposits are made up of the Simcoe Group, whereas the Upper Ordovician deposits consist of the Georgian Bay–Blue Mountain Formation.

The Middle Ordovician Simcoe Group consists of five formations which are discussed from oldest to youngest (Davies et al, 2008):

Shadow Lake Formation
This formation consists of transgressive shales, argillaceous siltstones, sandstones and conglomerates. The Shadow Lake Formation was previously assigned to the Middle Ordovician Basal Group (Armstrong, 1999).

Gull River Formation
The Gull River Formation contains an upper member and a lower member. The upper member consists of fine-grained limestones and shales. The lower member is mainly carbonaceous carbonate that is capped by a distinctive green dolomitic marker bed (Armstrong, 1995).

Bobcaygeon Formation

This formation is subdivided into three members (lower, middle and upper) generally reflecting carbonate deposition on a deepening shelf environment with some silisiclastic deposition (Armstrong, 1995).

<u>Verulam Formation</u>

This formation consists of a lower member made up of interbedded shale and limestones and a coarse-grained limestone upper member.

<u>Lindsay Formation</u>

This formation contains a thick lower member made up of fairly coarse-grained limestones and a thin upper unit, called the Collingwood Member, which is a fine-grained, organic rich shale, also known as an “oil-shale”.

These formations tend to on-lap each other towards the Canadian Shield to the north and all five members have been identified in drill holes in the watershed. Only the Bobcaygeon, Verulam and Lindsay Formations exist as surficial Middle Ordovician bedrock units within the watershed. There is a small area of mapped Gull River Formation at the extreme north end of the watershed and the Shadow Lake Formation sub-crops to the north.

Overlying the Simcoe group are the Upper Ordovician shales of the Georgian Bay – Blue Mountain Formation. The progression from the older limestones of the Simcoe Group to the younger shales of the Georgian Bay – Blue Mountain Formation is evidence of a deepening shelf environment. This formation represents a combination of the previously mapped Georgian Bay and Blue Mountain Formations (the former Whitby Formation that is present on some older maps). Overall, this combined formation tends to grade from blue grey non-calcareous shales of the Blue Mountain Formation to a more carbonate rich blue grey shale of the former Georgian Bay Formation. This reflects the gradual change back to shallow carbonate sedimentation, which is characteristic of the Silurian deposits to the southwest above the Niagara Escarpment.

Quaternary Geology

The Quaternary geology is represented as the surficial geology within the Lake Simcoe watershed. The surficial geology consists of glacial sediments deposited in the Quaternary period (Figure 3.1-6). This study area is known to have been ice-covered up the time of the Mackinaw Interstadial of the Lake Wisconsin substage, at approximately 13,300 B.P (Dremanis, 1977). The glacial deposits in the study area were most likely deposited from the Northern and Georgian Bay lobes of the Laurentide Ice Sheet (LIS) during or after the Port Bruce Stadial (Deane 1950, Gravenor, 1957). A detailed discussion on the Glacial History of the South

Georgian Bay- Lake Simcoe Source Protection Area is found in the 2007 SGBLS Conceptual Water Budget (SGBLS).

Overburden Thickness

The Quaternary sediment thickness reflects the difference between the ground surface and the interpolated bedrock surface. The Quaternary sediment thickness map for the watershed is illustrated on Figure 3.1-7. In a similar fashion to how the top of the Precambrian surface influenced the accumulation of Paleozoic sediment, the Paleozoic bedrock topography also appears to strongly influence the overlying Quaternary sediment thickness distribution creating the Hummocky Topography (Figure 3.1-3). Thicker Quaternary sediment occurs in bedrock topographical lows to the west and south sides of the watershed.

Stratigraphy

The stratigraphy of the surficial deposits within the Lake Simcoe watershed is complex as a result of the glacial history. There are a number of ongoing initiatives to understand the stratigraphy of the watershed. The studies have found that the stratigraphy of the watershed is dominated by glacial deposits underlaid by weathered bedrock. The types of material present in the subsurface affect the storage, flow direction and rates of movement of groundwater. The stratigraphic frame work of the Lake Simcoe watershed from youngest to oldest is (Davies et al, 2008):

1) Oro Moraine Deposits;
2) Glacial Lake Algonquin Sediments;
3) Glacial Lake Schomberg Sediments (3a) and Kettleby Till (3b);
4) ORM deposits (4a) and Tunnel Channel- Fill Deposits (4b);
5) Upper Newmarket Till;
6) Inter- Newmarket Till;
7) Lower Newmarket Till;
8) Thorncliffe Formation;
9) Sunnybrook Drift;
10) Scarborough Formation;
11) York Till;
12) Paleozoic Bedrock; and

13) Precambrian Bedrock.

York Till

The Don Formation and underlying York Till have not been mapped within the Lake Simcoe watershed due to a lack of deep borehole information that would be necessary to delineate these deposits since they are only within lows on the bedrock surface.

Scarborough Formation

The oldest Quaternary deposit, of significant (mappable) thickness present within the watershed is the Scarborough Formation (*also referred to as the Scarborough Aquifer Complex*). The Scarborough Formation marks the start of the Wisconsinan glaciations, approximately 100,000 years ago.

The Scarborough Formation was formed by fluvio-deltaic processes leading to deposition of a lower clay layer overlain by sands showing varieties of cross-beddings. This unit is mainly found within bedrock valleys and thins laterally away from the valleys (Earthfx and Gerber, 2008).

Sunnybrook Drift

The Sunnybrook Drift overlies the Scarborough Formation and consists of clast-poor silt and clay deposited by glacial and lacustrine processes. The formation was deposited in close proximity to an ice sheet (Earthfx and Gerber, 2008).

Thorncliffe Formation

The Thorncliffe Formation (*also referred to as the Thorncliffe Aquifer Complex*) represents glaciofluvial deposition of sand and silty sand generally within lows in the underlying stratigraphy. The Thorncliffe Formation was deposited approximately 45,000 years ago and consists of sedimentary deposits of silt-clay rhymites and cross-laminated and cross-bedded sands (Earthfx and Gerber, 2008).

Newmarket Till

The Newmarket Till overlies the lower sedimentary sequences described above. The Newmarket Till is a dense diamict unit deposited when the Laurentide ice sheet was its maximum extent, approximately 18-20,000 years ago. This unit can be up to 100m thick but is generally 20-30m thick. The Newmarket Till is an important formation as it hydraulically separates the upper and lower aquifers and serves as a protective barrier to the deeper groundwater resources in the area.

Channel Sediments

Following its deposition, the Newmarket Till was subject to erosional processes by glacial meltwater that modified the upper surface of the till. In some locations, the processes fully or partially eroded entirely through the till. In some locations, the processes fully or partially eroded entirely through the till. These features have been termed tunnel channels by the GSC, who believe these erosional events occurred beneath glacial till (Sharpe *et al.,* 2004). These channels cover much of the southern Lake Simcoe watershed, as major erosional channels occur beneath the Holland Marsh extending from Lake Simcoe through Schomberg, and within the Aurora and Newmarket area. These erosional channels were largely infilled with sand and silt deposits as meltwater energy waned. Extensive work was carried out to identify these channels and map the upper silt layer that frequently occurs within them. The nature of the infill material is important for understanding the groundwater flow system as it determines the degree of hydraulic communication between the shallow and deeper aquifer systems.

Oak Ridges Aquifer complex and/or Mackinaw Interstadial deposits

The Oak Ridges aquifer complex occurs above the Newmarket Till and is the most prominent geologic feature in the southern portion of the watershed. The Oak Ridges aquifer complex is an interlobate glacial deposit that largely consists of sand and gravel layers that can be up to 150m thick. To the north and south of the ORM, sand units overlying the Newmarket Till have been categorized as belonging to the Mackinaw Interstadial deposits. Mackinaw Interstadial sediments generally only occur locally within areas of low topography upon the surface of the underlying Newmarket Till (Earthfx and Gerber, 2008).

Surficial deposits

The last glacial advance in the area, approximately 13,000 years ago, led to deposition of the Halton and Kettleby Tills which generally have a silt to clayey-silt matrix. These till deposits overlie the ORM and Mackinaw Interstadial units. The uppermost units, which form and intermittent surficial veneer over the underlying till deposits consist of glaciolacustrine sand, silt, and clay associated with local ponding of glacial meltwater, and with Glacial Lake Schomberg and subsequently Glacial Lake Algonquin (Earthfx and Gerber, 2008).

Oro Moraine Deposits

The Oro Moraine (*also referred to as the Oro Sand Hills*) is included within the Simcoe Uplands physiographic regions, although the moraine is predominantly stratified sands and gravels and not till. The moraine extends for approximately 32 km from the City of Orillia west to Highway 400. The morphology of the Oro Moraine is similar to that of the Oak Ridges Moraine in that it is characterized by rolling to hummocky terrain and by numerous wetlands and kettle lakes that occupy topographic lows throughout the moraine. The crest of the Oro Moraine is 375 mASL (Slattery *et al.,* 2009).

Not every stratigraphic unit is present everywhere across the watershed. Some units occur only in specific geographical locations. For example, the Oak Ridges and Oro Moraine are units that occur in localized areas on opposite ends of the watershed. While other units such as the Kettleby and York Tills have limited continuity across the watershed (Davies et al, 2008). Diagram 3.1-1below is a schematic representation of the stratigraphy in the Toronto area; this diagram is also representative of the southern Lake Simcoe watershed. A north-south cross-section of the watershed is depicted on Figure 3.1-8 and Figure 3.1-9 represents the east-west cross-section of the watershed.

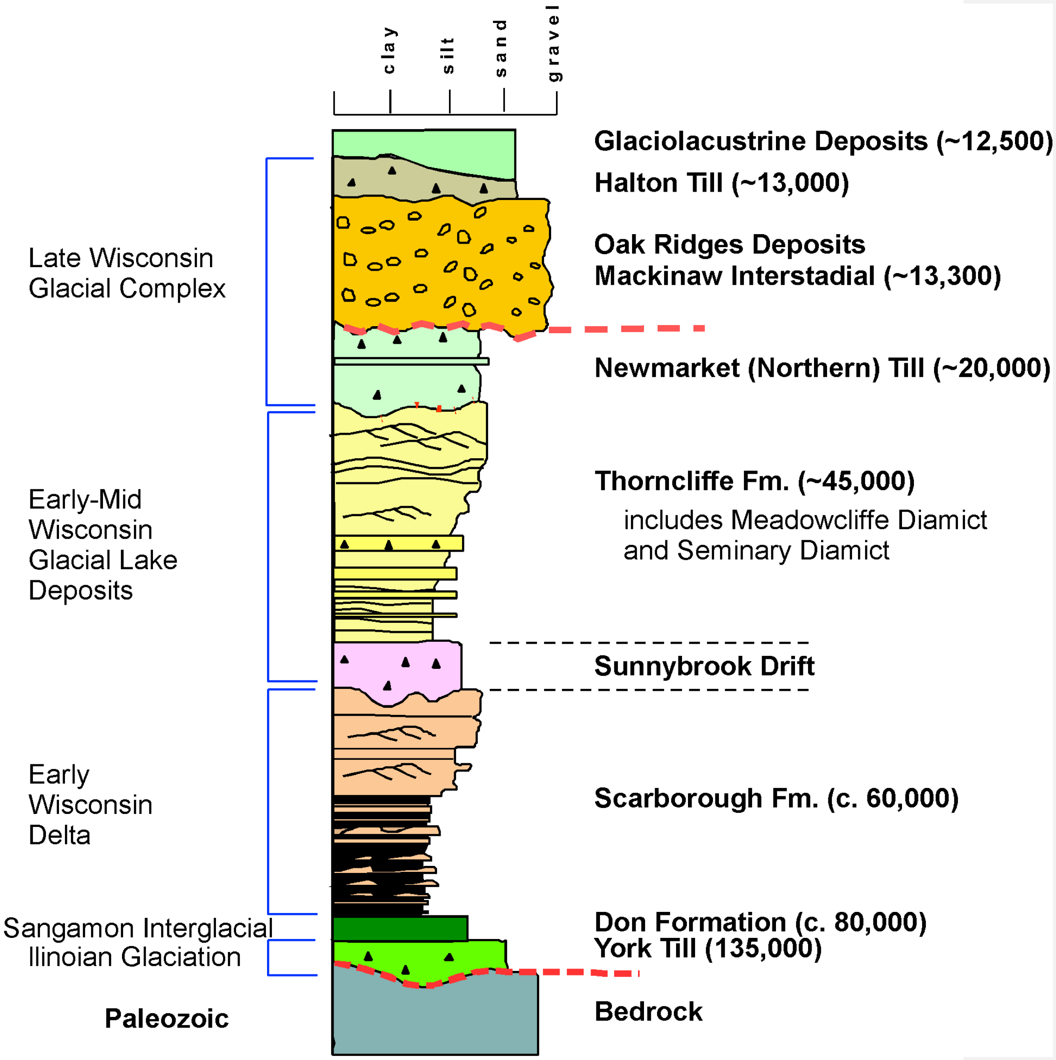

Diagram 3.1-1: Quaternary Deposits found within the Toronto Area (Eyles, 2002).

Soils

Soils are an integral part of the environment as they support vegetation communities. They also influence the quality and quantity of water entering the ground and running along the surface. Traditionally, soils within the watershed have been characterized based on the coarseness of their texture. Soil texture influences the rate at which water can infiltrate or seep into the ground. Generally, coarse-textured soils (gravel and sand) allow water to infiltrate better than finer-textured soils (silty loam, clay) do. This property of soil texture is extremely important because it has a major influence on the landscape's ability to generate runoff. For example, during a heavy thunderstorm, rainfall that cannot infiltrate the ground will pool on the surface. Once enough water has collected it will begin to flow overland as a result of gravity and in so doing can erode soil particles, washing them into ditches, streams and lakes.

Figure 3.1-10 depicts the spatial distribution of soil types throughout the watersheds in the study area. Future work will consider the attributes of the soils map, and the textural data included within the quaternary geological mapping from the Ontario Geologic Survey (OGS), in terms of which is a more appropriate data set to utilize for runoff estimation. For the purposes of this document and the runoff calculations herein, the soils map and associated hydraulic attributes were used. For a more detailed description of soil classification, and hydraulic attributes the reader is referred to the 2007 South Georgian Bay-Lake Simcoe Conceptual Water Budget (SGBLS, 2007).

Surface Water

Surface Water System

Lake Simcoe is the largest water-body in the watershed and Southern Ontario based on water volume and surface area, excluding the Great Lakes. The surface area of the lake is 722 km^2 with an approximate volume of 11,600m^3. The mean depth is 15 m and the maximum is 41 m. The surface water elevation is 218 mASL and the normal range of annual water level fluctuation is 0.5 m. Figure 3.1-11 shows the bathymetry and shoreline of the lake.

The hydraulic retention time (or flush rate) of a lake is defined as the average time water remains in the lake. The lake's size, water source, and watershed size primarily determine the retention time. Several methods are used to estimate water residence time of a lake. The most accurate approach is to measure all the flows into and from a lake. Only in rare cases is this level of detail available. The most common method of calculating residence time is to assign a unit runoff coefficient to the watershed and estimate the volume of water entering the lake, then divide the volume of influent water by the lake volume.

In Lake Simcoe an estimated hydraulic retention time of 16 years has been reported. It should be noted that hydraulic retention time of a lake is affected by the natural variability in weather conditions as well as the methodology of the estimates.

The Lake Simcoe watershed has been divided into 18 subwatershed (as described in Section 2.2), which allows for more detailed analysis and research, including modeling the influence of land use on water quality and quantity.

Surface Water Monitoring Network

Streamflow monitoring is an essential means of obtaining and maintaining records of a watershed's surface water resources. Information collected within the study area is used in source protection planning to develop resource targets, identify existing conditions, determine trends over time and evaluate the effectiveness of remedial activities. Monitoring is also used to calibrate analytical models, which predict the impact of possible contaminants, especially during low flows, and to evaluate the impact on water resources due to changes in land use or management activities.

Water Survey of Canada (WSC), in partnership with the Ontario Ministry of Natural Resources (MNR) and Conservation Authorities have developed a comprehensive surface water monitoring program within watersheds of the South Georgian Bay-Lake Simcoe Source Protection Region. However, the existing network was not built for the Source Water Protection program, and it may be necessary to evaluate the adequacy of the existing network for Source Water Protection projects. Due to the high cost of installing stream gauging equipment and provincial guidance for water budget initiatives, the Source Protection Committee decided to use the existing stream gauging network, noting that there may be some data gaps and uncertainty in the water budget projects.

Table 3.1-1 shows location, name and period of record for the streamflow stations within the study area, and Figure 3.1-12 shows their location. Some of the gauges shown in the table; however, are currently inactive representing gaps in the monitoring network. In addition to reviving some of the critically located historical Environment Canada gauges, the Lake Simcoe watershed needs a gauge at the mouth of the Talbot River and Whites Creek. A means of flow monitoring is also required for the lake outflow at Atherly Narrows. These streams are important either because of their role in the water budget or due to the close proximity of the river mouths to surface water intakes on Lake Simcoe.

Table 3.1-1: Streamflow Stations in the Lake Simcoe watershed.

Station Location	Station No.	Period of Record
East Holland gauge at Holland Landing;	02EC009	1965 to 2008
Upper Schomberg gauge at Schomberg	02EC010	1966 to 2008
Beaver River gauge on Conc. 2 in Brock Twp	02EC011	1966 to 2008
Pefferlaw River gauge at Udora.	02EC018	1966 to 2008

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Method Used to Estimate Missing Streamflow Data

A modified drainage-area ratio method, a maintenance of variance extension type 1 (MOVE.1) method, and a multiple linear regression method were used in this study to estimate streamflow for ungauged sites and for gauged sites that had missing data. Correlation between the base (index) station and the site of interest was tested before applying the MOVE.1 method. Since log-transformed estimates are superior to linear estimates for the assessment of streamflow (Hirsch, 1979), the streamflow data used to estimate the missing data for this study were log transformed prior to applying the equation. Streamflow values of zero were treated as missing values. For a detailed explanation of the methods used to estimate the missing streamflow data the reader is referred to the 2007 SGBLS CWB Section 5.5.2.

Mean Annual Streamflow

The mean annual streamflow is defined as the average of the series of annual average streamflow values. The monthly mean streamflows according to the Canadian Climate Normals for the stations of each watershed are given in Appendix WB-3A. As mentioned above, there are data gaps in the monitoring network. The missing data and/or short records make the mean annual flows estimated for those stations not representative. The mean annual flow should be determined from long-term streamflow data to reduce any bias; summer discharges in particular may be biased high.

The East Holland gauge at Holland Landing was used as the index station. It has the longest and most complete record in the watershed. The East Holland subwatershed has several hydraulic structures upstream of the gauge, including storm water management facilities (dry ponds, extended wet ponds and constructed wetlands), Rogers Reservoir and Fairy Lake Dam. The flow recorded at the gauge is therefore regulated. Furthermore, Earthfx and Gerber Geosciences Inc. (May 2005) showed that the trend of cumulative annual streamflow at the Holland Landing stream gauging station (02EC009) exhibited a slight change in slope around 1982; a period they state corresponded to a change in the quantities of treated effluent being discharged to the East Holland River. However, the flows recorded at gauges in the other subwatersheds show a very good (generally >70%) moving (monthly) correlation with this gauge. The results should be acceptable at this level of the investigation to provide mean annual flows based on long term records. Table 3.1-2 displays the mean annual streamflows and baseflows at the gauging stations.

Streamflow during the period of record has fluctuated around the mean annual flow showing cycles of periods of dry spell (flows below the mean annual for the period of record) and wet years (flows above the mean annual flow for the period of record).

Table 3.1-2: Mean Annual Streamflows of the Lake Simcoe subwatersheds

Subwatershed	Gauged	Mean Annual Streamflow - Gauge (m^3/s)	Mean Annual Streamflow - Mouth (m^3/s)
Barrie Creeks	No	n/a	0.27
Beaver River	Yes	2.79	3.11
Black River	Yes	2.76	3.47
East Holland	Yes	1.32	2.35
Georgina Creeks	No	n/a	0.34
Hawkestone Creek	No	n/a	0.29
Hewitts Creek	No	n/a	0.12
Innisfil Creeks	No	n/a	0.97
Lovers Creek	No	n/a	0.39
Maskinonge River	No	n/a	0.44
Oro Creeks North	No	n/a	0.57
Oro Creeks South	No	n/a	0.43
Pefferlaw Brook	Yes	3.25	4.01

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Subwatershed	Gauged	Mean Annual Streamflow - Gauge (m^3/s)	Mean Annual Streamflow - Mouth (m^3/s)
Uxbridge Brook	Yes	0.36	1.17
Ramara Creeks	No	n/a	1.32
Talbot River	No	n/a	3.13
West Holland	Yes	0.37	3.4
Whites Creek	No	n/a	0.78

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Baseflow

Baseflow is considered to be the groundwater contribution to streamflow, and is important in source water protection studies for:

- The management of water quality through the regulation of watershed discharges to receiving waters. Low flows during summer months allow the stream to heat up rapidly in warm weather while in the fall and winter temperatures may plummet rapidly. Low flow conditions are less conducive to oxygenation. When water temperature is high, dissolved oxygen levels can become critically low. Furthermore, the ability of streams to assimilate additional loading from wastewater discharges is reduced by the low flow condition.
- Estimating surface water availability for domestic, agricultural, industrial and recreational purposes. The estimate provides an indication of the adequacy of natural flow to meet a given demand.

Estimates of the amount of baseflow can be derived from streamflow records. These estimates are critical in the assessment of low flow characteristics of streams.

Baseflow estimation is obtained by hydrograph separation, which has traditionally been done manually. Two commonly used methods are baseflow recession and curve fitting (Linsley et al. 1975). However, different hydrologists using the same manual hydrograph separation method commonly produce different baseflow estimates. The use of a computer program removes the inconsistencies inherent in manual methods and substantially reduces the time required for hydrograph separation. The automated baseflow separation technique described in Arnold et al. (1995), using a digital filter was used in this study.

Daily streamflow data from HYDAT were used and the annual mean baseflows were obtained by calculating the arithmetic mean for each year of record. The results are included below in Table 3.1-3.

Table 3.1-3: Mean Annual Baseflows for the Lake Simcoe subwatersheds.

Subwatershed	Gauged	Mean Annual Baseflow (m^3/s)	Mean Annual Baseflow (mm/yr)
Barrie Creeks	No	0.17**	142.85
Beaver River	Yes	0.27*	122.39
Black River	Yes	1.19*	99.98
East Holland	Yes	0.55*	70.18
Georgina Creeks	No	0.10**	63.93
Hawkestone Creek	No	0.11**	72.51
Hewitts Creek	No	0.03**	54.00
Innisfil Creeks	No	0.20**	58.86
Lovers Creek	No	0.13**	68.38
Maskinonge River	No	0.20**	99.37
Oro Creeks North	No	0.19**	79.62
Oro Creeks South	No	0.18**	98.91
Pefferlaw Brook	Yes	1.79*	198.14
Uxbridge Brook	Yes	0.28*	54.73
Ramara Creeks	No	1.00*	219.75
Talbot River	No	1.15**	98.60
West Holland	Yes	0.14*	12.55
Whites Creek	No	0.29**	87.06

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(*) denotes baseflow estimate obtained from gauge

(**) denotes baseflow estimate calculated from mouth of stream

Surface Water Control Structures

It is important to consider surface water control structures when creating a water budget, as they disrupt the natural flow of water throughout a watershed. The surface water control structures present in the watershed include lock gates, a water power generation station, dams and beaver dams. The structures are depicted on (Figure 3.1-13) and are based on the 2006 MNR LIO database. Surface water control structures exist, among other reasons, to:

- Control flooding;
- Irrigate crops;
- Produce electricity; and
- Create transportation pathways;

Lock gate structures transport boats between bodies of water at different elevations. A lock gate structure works by controlling the volume of water within the lock. When water levels are raised the vessel can move to a watercourse at higher elevations, and lower elevations when the water level is lowered. The lock gate structures present within the Lake Simcoe watershed are part of the Trent Severn waterway, which is a canal system constructed to transport vessels from Lake Ontario to Georgian Bay. The system is owned and operated by Parks Canada, information pertaining to the operation of the waterway can be found at www.pc.gc.ca.

A historical mill is located along the banks of Pefferlaw Brook. This 19thc mill created power for local industries. Although the mill is no longer in operation, evidence of the structure still exists in the channel banks today (Town of Georgina, 2009).The majority of the surface water control structures present in the watershed are small structures, owned and operated by private owners[2]. These structures are therefore exempt from operational plans. These structures restrict the surface flow temporarily, mainly diverting water for irrigation purposes. The types of small structures present in the watershed include; on-line, off-line and by-pass ponds (which are generally constructed for irrigation purposes), hardened channels and beaver dams.

- On-Line ponds are constructed within a watercourse. They allow water to flow in and out of the pond; however, a berm and/ or water level control structure are built-in (LSRCA, 2009).
- Off-Line ponds are constructed away from a watercourse for irrigation and are common in golf courses. Surface water is diverted from the watercourse or groundwater is intercepted to control the water levels in these ponds. Off-Line ponds can affect the base flow of a stream by intercepting the groundwater flow (LSRCA, 2009).
- By-Pass ponds are constructed near a watercourse. Water is diverted from the main watercourse by a channel to the pond then flows back to the watercourse through another channel, once it has served its purpose (LSRCA, 2009).
- Hardened channel systems often increase the flow of the surface water. Hardened channel systems often straighten the channel stopping the river or stream from meandering. This type of structure is found most often in urban settings.

The removal or construction of a dam in the Lake Simcoe watershed requires a permit from the MNR, the LSRCA, and a review by the Department of Fisheries and Oceans (LSRCA, 2009). This extensive permit and review process ensures that aquatic habitats are not destroyed by a sudden influx of water, sediment, and other contaminants.

Surface Water Takings

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[2] Some structures may be historic and not in operation; however, their presence in a watercourse may still alter the natural flow.

Associated with land use is the extraction of water from groundwater or surface water sources for a variety of reasons. The MOE is the agency responsible for regulating water withdrawals within the study area through their Permit to Take Water (PTTW) Program. Active water taking permits are in place for a number of land use activities including but not limited to potable water supply, industrial use, pit and quarry use, golf course operations, and agricultural use.

Withdrawal of water for municipal supply and irrigation (which includes both agricultural and golf course users) in the watershed, account for approximately 63% of overall demand. The permitted and non-permitted surface water takings are summarized in Appendix WB-2.

Groundwater

In this Watershed Region, groundwater is used for municipal water supply, agricultural and industrial use, golf course irrigation and private water supplies. Figure 3.1-14 illustrates municipal surface and groundwater takings and Figure 3.1-15 illustrates non-municipal water takings across the region.

Hydrogeologic Setting

According to Singer et al. (2003) the following aquifer complexes have been identified in the Lake Simcoe watershed: (1) The Oak Ridges Moraine Hydrogeologic System; (2) The Yonge Street Aquifer; (3) The Alliston Aquifer Complex; (4) The Mount Albert Aquifer Complex; (5) The Holt Aquifer Complex; (6) The Schomberg Aquifer Complex; (7) The Algonquin Aquifer Complex; and (8) The Kame Outwash Aquifer Complex. A brief overview of these hydrogeologic systems is presented below in Table 3.1-4. The extent of the aquifers present in the Lake Simcoe watershed is shown in a series of figures. Figure 3.1-16,Figure 3.1-17,Figure 3.1-18, and Figure 3.1-19 represents the western portion of the watershed, and Figure 3.1-20, Figure 3.1-21 and Figure 3.1-22 represents the Oak Ridges Moraine area.

Table 3.1-4: Aquifer Properties: Lake Simcoe Watershed (Singer et al. 2003).

Aquifer	Spatial Distribution	Type	Thickness (m)	Elevation (mASL)	Transmissivity (m^2/day)
Yonge Street Aquifer	Along Yonge Street core	Confined channel aquifer	-	150 to 200	> 38 640
Alliston Aquifer Complex	Northwest of Kempenfelt Bay, west of Cook's Bay, south to ORM and east to Aurora and Newmarket	-	5	165	3 to 15000

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Aquifer	Spatial Distribution	Type	Thickness (m)	Elevation (mASL)	Transmissivity (m^2/day)
Mount Albert Aquifer Complex	Mount Albert	Local	3	215	5 to 210
Holt Aquifer Complex	Aurora to Mount Albert	-	3	205 to 245	1.5 to 150
Schomberg Aquifer Complex	Holland Marsh	-	3	205 to 245	1.5 to 150
Algonquin Aquifer Complex	Lower portion of Black Watershed	-	4	245 to 315	15 to 450
Kame Outwash Aquifer Complex	Southwestern boundary of watershed	-	5	245 to 315	15 to 450

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Oak Ridges Moraine (ORM)

The Oak Ridges Moraine (ORM) is a significant hydrogeologic feature located in the Lake Simcoe watershed. The ORM is a very important hydrogeologic feature with respect to groundwater, as many people rely on the water stored within the moraines aquifers for their drinking water. A coalition of municipalities and conservation authorities, known as the Conservation Authorities Moraine Coalition York-Peel- Durham-Toronto (CAMC-YPDT) study group was formed to obtain a detailed understanding of flow systems associated with the ORM. A database, containing streamflow, climate, borehole and water well information, and two numerical groundwater flow models were constructed to study groundwater flow in the ORM area. For more information on the modelling of the ORM the reader is referred to the 2007 South Georgian Bay-Lake Simcoe Conceptual Water Budget (SGBLS, 2007). The following presents an overview of the ORM complex. For a more detailed description of the regional geology and hydrostratigraphy of the study area the reader is referred to Russell et al. (2003) and EarthFX (2006).

For numerical modeling purposes, the hydrostratigraphy of the ORM complex was divided into the following eight layers: (1) surficial deposits and/or weathered Halton Till; (2) Halton Till or Kettleby Till; (3) Oak Ridges Aquifer Complex; (4) Newmarket Till; (5) Thorncliffe Aquifer Complex; (6) Sunnybrook Drift; (7) Scarborough Aquifer Complex; and (8) Weathered Bedrock. The above eight hydrostratigraphic units are summarized in Table 3.1-5 and Diagram 3.1-2 below.

Table 3.1-5: Hydrostratigraphic Units in York Region (Earthfx, 2006).

Layer	Name	Function	Description
1	Recent glaciolacustrine deposits	Aquitard	Thin deposits of sands, silts and clays; generally of low permeability and only used locally for minor water supply to private homes
2	Halton Till or Kettleby Till	Aquitard	Sandy silt to clayey silt till, typically 3 to 6 m thick but can range up to 30 m, low permeability
3	Oak Ridges Aquifer Complex	Aquifer	Mainly granular sediments interlayed with finer materials, up to 100 m thick, generally medium to high permeability, forms important local and regional aquifers
4	Newmarket Till	Aquitard	Dense, sandy silt to clayey silt till, up to 50 m thick, of low permeability. In lateral tunnel areas the infill material is primarily low permeability silts.
5	Thorncliffe Aquifer Complex	Aquifer	Sands and silt, up to 60 m thick in some areas, generally high permeability, forms important regional aquifers
6	Sunnybrook Drift	Aquitard	Silts and clays, generally less than 20 m thick, low permeability

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Layer	Name	Function	Description
7	Scarborough Aquifer Complex	Aquifer	Sands, silts and clays, up to 60 m thick, variable permeability, forms important aquifers in localized areas
8	Weathered Bedrock	Aquifer	Limestone and shale; limestone in northern part of Region act as an aquifer for private supplies

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As indicated above, three significant aquifers have been identified in the ORM study area including: (1) the ORM aquifer complex; (2) the Thorncliffe Aquifer complex and (3) the Scarborough Aquifer complex. Studies completed by EarthFX (2006) identified two regional aquitards or confining units within the study area: (1) the Newmarket Till, which divides the shallow aquifer regime (ORM sediments) from the deeper aquifer regime (Thorncliffe and Scarborough Aquifer complexes); and (2) the Sunnybrook Drift.

According to Russell et al. (2003) and EarthFX (2006), the flow of groundwater through the ORM complex is influenced by four main factors. These factors are: (1) the orientation and connection of the bedrock valleys and other cross-cutting “channel features”; (2) the Newmarket Till; (3) the thickness and location of the ORM deposits and Halton Till confining unit; and (4) channel infill sediments present in tunnel channels where the Newmarket Till has been completely eroded by sub-glacial meltwater.

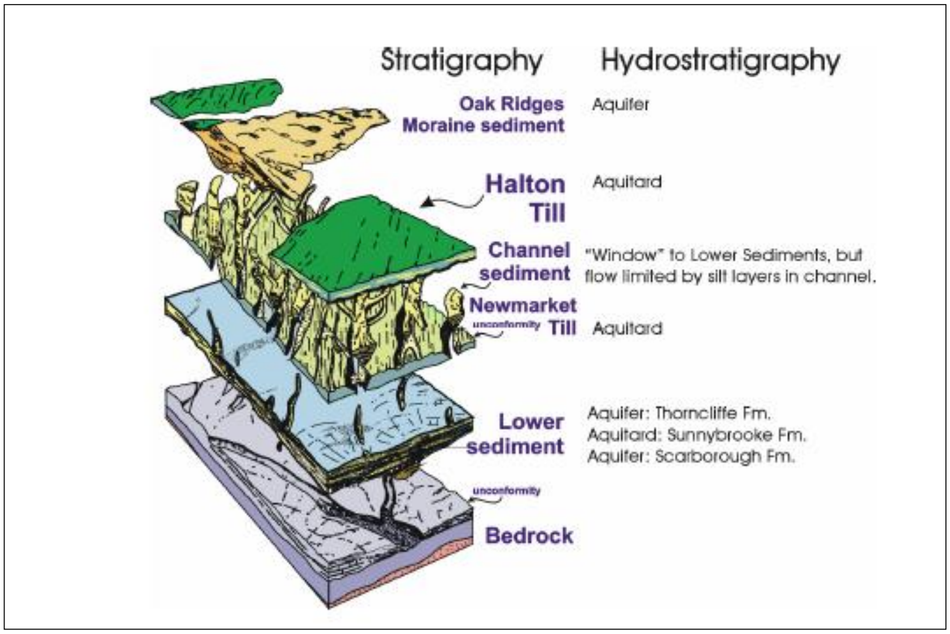

Diagram 3.1-2: Hydrostratigraphic Framework of the Oak Ridges Moraine (Sharpe et al., 1999).

Groundwater Flow

According to Gartner Lee Limited (2004) and EarthFX (2006), the migration of shallow groundwater generally coincides with surface topography and water table divides correspond to surface water flow divides. Numerical groundwater modeling studies on the ORM complex by Gartner Lee Limited (2004) indicates that cross watershed flow occurs in the north where the Maskinonge River intercepts north-flowing groundwater from the Black River watershed. A more detailed assessment of groundwater flow patterns for the ORM complex is presented in EarthFX (2006). According to EarthFX (2006), downward hydraulic gradients are present between the ORM and Thorncliffe aquifers, with a significant downward gradient occurring immediately west of Newmarket. In addition, the gradient between the Thorncliffe and Scarborough aquifers is generally downward with a significant gradient occurring in the eastern portion of York Region under the ORM. Additional studies completed during the Tier One and Tier Two assessments of this watershed will aid in understanding the complex groundwater flow patterns in this area.

It is not uncommon to have groundwater divides that do not coincide with surface water divides resulting in inter-basin transfers of groundwater. Differences in surface water divides and groundwater divides can also be influenced by groundwater extraction near a watershed boundary (i.e. municipal water supply wells or irrigation wells).

Figure 3.1-23 illustrates the shallow water table elevation of the Lake Simcoe watershed. Figure 3.1-24 illustrates the shallow groundwater flow of the Lake Simcoe watershed. Based on the figure, numerous cross-boundary groundwater fluxes occur across both subwatershed and primary watershed boundaries through the watershed region. This is in agreement with previous work completed by Golder Associates (2004). In this study Golder demonstrated that significant groundwater fluxes occur across surface water boundaries in the subwatersheds surrounding the City of Barrie, most of which are recharged from the uplands north of the city in the Oro Moraine. There were instances, noted by EarthFx (2004), where groundwater from within the southern portion of LSRCA flowed south across the surface water divide. Both the Credit Valley Conservation and the Grand River Conservation Authority groundwater models predict cross-boundary groundwater fluxes between the watersheds of those Conservation Authorities and the Nottawasaga Valley watershed.

For the purposes of the Conceptual Water Budget and Tier One Water Budget, cross-boundary groundwater gains were assumed to be equal to cross-boundary groundwater losses. Tier Two water budget efforts will consider cross-boundary groundwater inflow and, the Tier Three will consider cross-boundary fluxes.

Groundwater Takings

The Ontario Water Resources Act Regulation 387 (Water Taking and Transfer) states that any user extracting more than 50,000 L/day is required to have a permit to take water (PTTW). Each permit will have a maximum extraction rate assigned to it based on the user's individual needs. It should be noted that permitted extraction rarely reaches the maximum extraction rates. However, permitted extraction is frequently far greater than the average use because, the provincial system requires that the permit reflect the maximum potential extraction on any one day, regardless of how frequently that extraction rate is achieved. This is due to seasonal variances in water demands. For other water users, surveys of PTTW holders were completed within the watershed region. Estimates of actual use from those permit holders surveyed (between 50 and 80% of PTTW holders by primary watershed) will be extrapolated to like land uses to prepare more reasonable estimates of extraction in future water budget efforts. The surveys should also help address seasonal uses, which are permitted for extraction all year, and therefore compound the overestimation inherent in the PTTW database.

There exist a number of non-permitted water takings related to agricultural use, construction (dust control), and other uses that do not require permits, either because they use less than 50,000 L/day or are for the purpose of livestock watering. While uses less than 50,000 L/day will not be explicitly considered for water budget estimates, livestock watering extraction will be estimated in future water budget efforts using the University of Guelph work (DeLoe, 2005). Differentiation between surface water and groundwater supplies for these non-permitted uses will be based upon proximity of the land parcel to surface water supplies.

For the purposes of water budgeting, it is also important to understand what proportion of the water that is taken is lost from the watershed versus that proportion that is returned locally. Consumptive use guidelines have been provided by the province to address the issue of 'net extraction', which will be considered for future water budget refinement and stress assessment efforts. However, the entire volume of extraction should be considered for groundwater uses from confined municipal aquifers as these withdrawals, although often returned to the surface water system or shallow aquifer locally, represent a complete loss from the unit supplying the municipality.

There are 290 individual municipal wells within the source protection region which have been assessed to determine Wellhead Protection Areas (WHPA).Good records of actual water taking from these wells have been obtained for water budget efforts. The permitted and non-permitted ground water takings are summarized in Appendix WB-2.

Interactions between Ground and Surface Water

Recharge

Figure 3.1-25 represents potential recharge areas across the watershed region as a function of geology (permeable materials) and hydraulic gradient (downward gradients from the water well records). This map is considered preliminary and will be refined in future iterations to reflect other factors that influence recharge such as land cover and slope. Annual average recharge values for various Quaternary-aged sediments in the southern portion of watershed are presented in EarthFX (2006). The highest estimated recharge rates occurred over the ORM (360 mm/year) and the lowest recharge rates occurred in areas where lake sediments or organic deposits are present (60 mm/year).

In the Lake Simcoe watershed, the ORM is considered to be high recharge area. According to Gartner Lee Limited (2004), recharge rates through the coarse grained sediments at the top of the ORM are more than four times greater than recharge rates occurring on the flanks of the ORM. The majority of recharge that occurs on the ORM ultimately discharges to the stream network on the flanks of the moraine, with less than 5% of the recharge discharging directly into Lake Ontario and Lake Simcoe (Gartner Lee Limited, 2004). A map illustrating the distribution of recharge in the Regional Model area is presented in EarthFX (2006).

Discharge

The location of discharge areas for portions of the Lake Simcoe watershed, more specifically, the communities of Innisfil, Barrie, Bradford-West Gwillimbury and Oro-Medonte were identified by Golder Associates (2004) in the South Simcoe Groundwater Study. Discharge areas identified by LSRCA that are illustrated in Figure 3.1-25 coincide with those identified by Golder Associates (2004) and with stream networks and wetland areas.

Aquatic Habitat

Both cold and warmwater aquatic habitats are found within the Lake Simcoe Watershed. A detailed description of the habitats can be found in Section 2.1.1.1, along with a map of cold vs. warm water aquatic habitats, and a table listing the species found within each.

Aquatic habitats can be a key indicator of groundwater discharge in a region. A cold water habitat indicates the presence of baseflow. Baseflow is often cool in temperature as it is supplied to the stream from groundwater flow; therefore indicating groundwater discharge is occurring. Warmwater habitats indicate the absence of groundwater discharge. Figure 3.1-26 is a map of groundwater discharge overlaid by cold water, warmwater fisheries map. Areas of cold water habitat can confirm the presence of groundwater discharge.

Land Use and Land Cover in the Source Protection Area

The current land use and land cover conditions of the watershed are described in Section 2.4.2. Land cover and land use practices can affect the components of a water budget in different ways. The watershed is currently experiencing widespread development, predominantly residential. Areas which have traditionally been forest cover or agricultural lands have slowly been developed over time creating numerous impervious surfaces. The presence of impervious surfaces impedes infiltration and changes the recharge volume to aquifers. The decrease in infiltration to recharge the aquifers could decrease the amount of groundwater discharging to streams, which would cause a decrease in the baseflow, potentially eliminating the cold water aquatic habitats. The increase in impervious surfaces also leads to increased runoff rates. Increased runoff rates can decrease the time to peak flow after a precipitation event, increasing the risk for flooding in urban areas. The type of land cover also affects the amount of evaporation and evapotranspiration occurring in the watershed. Areas covered by plants will have more evapotranspiration occurring than developed areas with impervious surfaces.

Climate and Climate Change

Climate

The climate of Southern Ontario is characterized by moderate winters, warm summers, and a long growing season with usually reliable precipitation. It is influenced by the proximity to Georgian Bay and Lake Simcoe. The local differences in climate reflect variations in topography, proximity to large water bodies and prevailing winds. The annual variations are dependent on the nature and frequency of weather systems that cross the area.

According to Brown et al. (1980), the Source Protection study area contains three climatic regions. These include the Dundalk Upland, Simcoe and Kawartha Lakes, and Muskoka. The majority of the Lake Simcoe watershed is located within the Simcoe and Kawartha Lakes climatic region. Precipitation in the project area is somewhat lighter than that of the areas around it because of the rain-shadow effect created by the western uplands.

Climate Stations

Climate data including precipitation data are collected by Environment Canada (EC) at twelve active meteorological stations located in the SWP study area. In addition to the EC stations, the Ministry of the Environment, LSRCA, the Nottawasaga Valley Conservation Authority (NVCA) and the Severn Sound environmental association maintain and operate several precipitation stations in the SWP area. More specifically, the LSRCA collects data from five locations in the Lake Simcoe Watershed including the Newmarket Office, Scanlon Creek, Ramara, Beaver River and Baldwin Conservation area. These stations started collecting data in 2003. Data obtained from all of these stations was used in this study.

In addition to the above mentioned data sources, historic data collected from five stations within and adjacent to the Lake Simcoe SWP study area was compiled for analysis and used to supplement the existing precipitation database. Information regarding station name, location, and period of record is presented below in Table 3.1-6. Additional details regarding climate normal's and the precipitation gauge network are presented in Appendix WB-1.

Table 3.1-6: Environment Canada: Climate Monitoring Stations in the Lake Simcoe Watershed.

Watershed	Station ID	Station Name	Begin Year	End Year	Period (years)	Status	Latitude - North	Longitude - West	Elevation
Black-Severn River	6115525	Muskoka A*	1953	2000	48	Inactive	44° 58’	78° 18’	281.9
Black-Severn River	6115524	Muskoka AWO*	2000	2006	7	Active	44° 58’	78° 18’	281.9
Black-Severn River	6112072	Dorset MOE*	1976	2002	47	Inactive	45° 13’	78° 55’	323.1
Black-Severn River	6115820	Orillia Brain	1992	2006		Active	44° 36’	79° 26’	250
Lake Simcoe	6110557	Barrie WPCC	1977	2006	30	Active	44° 22’	79° 41’	221
Lake Simcoe	6116902	Ravenshoe	1971	1992	22	Inactive	44° 13’	79° 24’	251
Lake Simcoe	6117684	Shanty Bay	1973	2006	34	Active	44° 24’	79° 37’	252
Lake Simcoe	6119055	Udora	1989	2006	18	Active	44° 15’	79° 9’	262
Lake Simcoe	6150863	Bradford Muck Res.	1974	1998	25	Inactive	44° 1’	79° 36’	221
Lake Simcoe	6151750	Cold Creek*	1971	1991	21	Inactive	43° 55’	79° 42’	251
Lake Simcoe	6154130	King Smoke Tree*	1974	2003	30	Inactive	44° 1’	79° 31’	352
Lake Simcoe	6155807	Sharon*	1971	1999	29	Inactive	44° 6’	79° 25’	262
Lake Simcoe	6158082	Stouffville WPCP*	1971	1992	22	Inactive	43° 58’	79° 15’	267
Nottawasaga Valley	6111859	Cookstown	1972	2006	35	Active	44° 12’	79° 41’	244
Nottawasaga Valley	6112340	Essa Ont. Hydro	1971	2000	30	Inactive	44° 21’	79° 49’	216
Nottawasaga Valley	6115099	Midhurst	1971	1996	23	Inactive	44° 45’	79° 46’	226
Nottawasaga Valley	6142991	Grand Valley WPCP*	1974	1994	21	Inactive	43° 52’	80° 19’	465
Nottawasaga Valley	6146939	Ruskview	1986	2006	21	Active	44° 14’	80° 08’	472
Nottawasaga Valley	6150100	Albion*	1971	2000	30	Inactive	43° 56’	79° 50’	274
Nottawasaga Valley	6150103	Albion field Centre*	1971	2000	30	Inactive	43° 92’	79° 50’	282
Nottawasaga Valley	6151080	Glen Haffy Mono Mills*	1971	2000	30	Inactive	43° 56’	79° 57’	434
Nottawasaga Valley	6155788	Orangeville MOE*	1971	2006	36	Active	43 o 55’	80 o 05’	412

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Watershed	Station ID	Station Name	Begin Year	End Year	Period (years)	Status	Latitude - North	Longitude - West	Elevation
Nottawasaga Valley	611B002	Borden AWOS	1996	2006	11	Active	44o 16’	79 o 54’	222.5
Nottawasaga Valley	6110218	Alliston	1973	2006	34	Active	44o 9’	79 o 52’	221
Nottawasaga Valley	6111792	Collingwood	1974	2006	33	Active	44o 30’	80 o 13’	179.8
Nottawasaga Valley	6110E+03	Egbert CS	2000	2006	7	Active	44o 15’	79o 46’	251
Severn Sound	6113490	Honey HBR Beausoleil*	1974	2000	27	Active	44 o 51’	79 o 52’	183
Severn Sound	6115127	Midland WPCP	1974	2000	27	Active			
Severn Sound	6111769	Coldwater Warminister	1970	2000	30	Active	44o 38’	79o 32’	285

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Precipitation

Several methods are commonly used to calculate basin average rainfall from an assumption of aerial (i.e., spatial) distribution using point rainfall from the gauge network. Precipitation depths were interpolated between measured points within and immediately surrounding the watershed region using spherical Kriging, and values for each subwatershed were estimated from geostatistical analyses. Spatial gaps in the data used in the interpolation resulted in what are assumed to be anomalies (bulls-eyes in the interpolated surface). These areas will be re-examined following the receipt of the in-filled data from the provincial climate assessment. Climate normals have been included in Appendix WB-1.

Analysis of the annual average precipitation for the study area was completed using data collected from EC stations. Periods of data (i.e. months or years) are absent from the EC database at all stations from 1971 to 2000. The methodology used to compensate for these data gaps is discussed below. ~~It is recognized that the~~The MNR ~~has~~ initiated a study to infill temporal and spatial gaps in climatological data across the province. Once completed, the results of this study will be incorporated into future iterations of water budget estimates.

Annual average precipitation calculated from short records of data may not reflect long-term variations in precipitation within a watershed, or the mean may be biased by an extreme event that occurred during the short period of data. The technique of infilling missing data or extending the historic record at a precipitation gauging station through a correlation between that station and a longer-term reference station is used to improve statistical measures of precipitation at the short-term station by reducing error and bias. The reference station is derived from a larger study of many stations for which a common reference period of analysis is required. The correlation is used to estimate precipitation at the short-term station from the known precipitation at the index station. The linear regression calculation used in this study is described by Allen et al. (1998) and will not be discussed further.

Evaporation

Evaporation from surface water bodies including lakes and reservoirs were estimated using the unit area evaporation calculated in the Lake Simcoe Environmental Management Strategy (LSEMS) A.6 (2006) report for Lake Simcoe (Scott et al, 2006). The LSEMS reported values derived from a climate model that incorporates elevation, latitude, longitude, temperature, relative humidity, solar radiation, vapour pressure and dew point temperature data, all of which are measured at two locations in the Lake Simcoe watershed (Bradford and Ramara). The areal extent of surface water bodies, as determined from GIS layers, was then multiplied by the annual evaporation depth estimated for Lake Simcoe in the above-noted report to obtain the volume of water lost (Table 3.1-7).

Table 3.1-7: Water Losses through Evaporation.

Watershed	Land Use	Area (km^2)	Annual Evaporation mm/m^2	Annual Evaporation m~~M~~m^3
Lake Simcoe	Lake Simcoe	722	672	485.1
Lake Simcoe	Other water	8.3	672	5.57
Lake Simcoe	Wetlands	79.66	-	-
Lake Simcoe	Vegetation	1914	-	-
Lake Simcoe	Urban	590	-	-

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Evapotranspiration

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration. Evapotranspiration (ET) is the water lost to the atmosphere by two processes, evaporation and transpiration. Evaporation is the loss from open bodies of water, such as lakes and reservoirs, wetlands, bare soil, and snow cover; transpiration is the loss from living-plant surfaces. Several factors other than the physical characteristics of the water, soil, snow, and plant surface also affect the evapotranspiration process.

The seasonal trend of evapotranspiration within a given climatic region follows the seasonal trend of solar radiation and air temperature. Minimum evapotranspiration rates generally occur during the coldest months of the year; maximum rates, which generally coincide with the summer season, when water may be in short supply, also depend on the availability of soil moisture and plant maturity. However, the seasonal maximum evapotranspiration actually may precede or follow the seasonal maximum solar radiation and air temperature by several weeks. Daily fluctuations in evapotranspiration also occur. On clear days, the rate of transpiration increases rapidly in the morning and reaches a maximum usually in early afternoon or mid afternoon. The midday warmth can cause closure of plant stomata, which results in a decrease in transpiration.

A complete cover by a green crop is considered to return water to the atmosphere by transpiration, and evaporation from the soil, at a peak or ‘reference or potential’ rate when the water supply is unlimited; the water used is referred to as ‘reference or potential evapotranspiration’. In general, watersheds are not entirely covered by well-watered short-green crops. Actual evapotranspiration is the amount or rate of ET occurring in the watershed and it is the value we want to estimate. In practice, actual evapotranspiration (AET) is obtained from first calculating the reference crop evapotranspiration and then multiplying by suitable crop coefficients to estimate the actual crop evapotranspiration.

Determining Evapotranspiration

A large number of empirical methods have been developed over the last fifty years by numerous scientists and specialists worldwide to estimate evapotranspiration from different meteorological variables, these include Blaney-Criddle (1977), Lincare (1967), Priestley-Taylor (1972), Pennman-Montieth (1998), Kohler–Parmale (1967) and Hamon PET (1961). The modified Penman method is considered to offer the best results with minimum possible error in relation to a living grass reference crop. The method has not been used here because of insufficient meteorological data. For this study, the Hamon reference ET method was used since air temperature data is available at all the climate stations in the study area. The Hamon method is shown in the textbox below.

Hamon Reference Evapotranspiration

Hamon Equation

$$ET_{Hamon} = 13.97 d D^2 Wt$$

Where : ET_{Hamon} is Hamon reference evapotranspiration in mm per month,

d is the number of days in a month,

D is the mean monthly hours of daylight in units of 12 h, and

Wt is a saturated water vapour density term calculated by

$$Wt = (4.95\ e^{0.062T})/100$$

The ET derived from the reference crop using WDMUtil software is not reflective of the watershed. As it assumes the entire watershed is covered in grass with specific characteristics and a constant supply of water. To make it more reflective of the actual evapotranspiration occurring in the watershed ET was multiplied by the crop coefficient (K_c). The characteristics that distinguish field crops from grass are integrated into the crop coefficient.

As the crop develops, the ground cover, crop height and the leaf area change. Due to differences in evapotranspiration during the various growth stages, the K_c for a given crop will vary over the growing period. The growing period can be divided into four distinct growth stages: initial, crop development, mid-season and late season. Local K_c values were not available; however, an average K_c value was estimated at 0.96 based upon reported regional climate study results, and the measured difference between local reference and actual ET (Brown et. al., 1980). The results are shown in Table 3.1-8 and the actual ET isolines are shown in Figure 2.4 of the South Georgian

Bay Lake Simcoe Conceptual Water Budget (SGBLS, 2007). The results are similar to the values reported by MNR (1984, page 23) for the region of this study.

Table 3.1-8: LSRCA Watershed Mean Monthly Annual Reference ET and Actual ET.

Month	Mean Actual Evapotranspiration from the Watershed (mm)
January	8.66
February	10.07
March	20.86
April	42.66
May	71.83
June	102.07
July	120.11
August	95.12
September	56.38
October	30.02
November	15.35
December	8.69
Annual Total - Ref. ET	523.04
Annual Total - Actual ET	502.12

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Potential Impacts of Climate Change

The potential impacts of climate change, as well as current climate trends within the Lake Simcoe watershed will be discussed in Chapter 14: The Assessment Report in Context.

Figure 3.1-1: Physiographic Regions

Figure 3.1-2: Ground Surface Topography

Figure 3.1-3: Hummocky Topography

Figure 3.1-4: Bedrock Geology

Figure 3.1-5: Bedrock Topography

Figure 3.1-6: Surficial Geology

Figure 3.1-7: Overburden Thickness

Figure 3.1-8: East-West Cross Section

Figure 3.1-9: North-South Cross Section

Figure 3.1-10: Soils

Figure 3.1-11: Bathymetry of Lake Simcoe

Figure 3.1-12: Streamflow Gauging Stations

Figure 3.1-13: Surface water control structures

Figure 3.1-14: Municipal surface and groundwater taking locations

Figure 3.1-15: Non-municipal surface and groundwater taking locations

Figure 3.1-16: A1 Aquifer Extent

Figure 3.1-17: A2 Aquifer Extent

Figure 3.1-18: A3 Aquifer Extent

Figure 3.1-19: A4 Aquifer Extent

Figure 3.1-20: Oak Ridges Moraine Aquifer (ORM Area)

Figure 3.1-21: Thorncliffe Aquifer (ORM Area)

Figure 3.1-22: Scarborough Aquifer (ORM Area)

Figure 3.1-23: Shallow water table elevation

Figure 3.1-24: Groundwater flow direction

Figure 3.1-25: Potential groundwater recharge and discharge areas

Figure 3.1-26: Aquatic Habitat

3.2 Tier One Water Budget and Water Quantity Stress Assessment

The Tier One Water Budget and Water Quantity Stress Assessment is the second step in the water budget process. This step is a high level screening that provides an understanding of the available groundwater and surface water resources on an annual and monthly basis within the subwatershed and provides a standard approach for evaluating the level of stress for each subwatershed.

Similarly, water demand is estimated on an annual and monthly basis within each subwatershed. These estimates of supply and demand provide insights into potential stress on existing and future municipal water supplies. Where demand for water exceeds a prescribed threshold of supply and municipal supplies exist or are planned, more detailed analyses (Tier Two water budgets) are deemed appropriate to ensure an adequate understanding of the system and potential stresses to water quantity. In turn, areas that are not stressed from a water quantity perspective, or do not contain municipal drinking water supplies, are excluded from further study in this planning cycle within the Source Water Protection program.

The Tier One Water Budget and Water Quantity Stress Assessment of the Lake Simcoe watershed (SGBLS, 2009) was completed per the MOE Technical Rules (2008a) and is the guiding document for the following section. The document can be referred to for more detailed information.

Study Area and Physical Setting

The Lake Simcoe watershed has been divided into 18 subwatersheds or hydrological units, each drained by one or more tributaries, as outlined in Section 2.2. The subwatersheds range in size from tens to hundreds of square kilometers. The largest unit is the Black River subwatershed at 375 km^2. It is found within two regional municipalities and four local municipalities.

As previously mentioned, the total area of the Lake Simcoe watershed is 3,621 km^2. Of this, 18.9 km^2 is made up by islands within Lake Simcoe, which have not been included in this study. It should be noted that within previous reports the Upper Talbot River subwatershed has been included, but going forward the Upper Talbot will be included in the Black-Severn River water budget assessments.

It is recognized that, in some portions of the study area, subwatershed boundaries differ from groundwater divides, resulting in groundwater movement between subwatersheds. The difference between surface water divides and groundwater divides can also be influenced by groundwater taking (i.e. municipal water supply wells or irrigation wells) near a watershed boundary. These differences: however, are generally not significant based upon comparison of subwatershed boundaries and groundwater divides inferred from water table elevations (Section 3.1.4.2 and Figure 3.1-23).

As a result, it was deemed appropriate to use surface water divides for this assessment, and assume that groundwater inflows to a subwatershed are equivalent to groundwater outflows. The difference between surface water and groundwater divides, as well as associated groundwater movement between subwatersheds, among other things, will be included in Tier Two and Tier Three studies, where they are required.

It is also recognized that the size of subwatersheds analyzed can impact estimated water quantity stress results. A given series of water takings may represent a significant portion of supply if the area of study is local to those takings. Conversely, a potential stress could be overlooked if the study area used is too large, and the affects of the stress are distributed across a large area that does not, in reality, contribute to the supply. The units of study for this assessment mimic the subwatershed delineations of the Lake Simcoe Region Conservation Authority (LSRCA), which have been deemed appropriate for a variety of watershed management efforts.

Four separate analyses were required in this report; groundwater existing conditions, surface water existing conditions, groundwater future conditions and surface water future conditions. The groundwater evaluations are based on both average annual and average monthly conditions from climate and streamflow data (methods described below). In general, the following data were used for this evaluation: precipitation data from 1950 to 2005; temperature data from 1970 to 2000; and streamflow data from 1985 to 2005[3]. Surface water evaluations are monthly summations and statistics (median monthly and annual) on daily measured stream flow (or estimated flows as described in subsequent sections).

Water Supply

The following sections outline the components of a water budget and the methods used to derive each. More detail on the methods and assumptions used in the Tier 1 Water Budget and Water Quantity Stress Assessment of the Lake Simcoe watershed; herein referred to as the Tier One can be found within the report (SGBLS, 2009).

As noted above, the objective of this assessment is to identify those subwatersheds that may experience water quantity stress as a result of existing or future water taking. The steps to assessing potential water quantity stress involve quantifying supply and demand.

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[3] A preliminary check of the data showed no significant difference in the 20 year versus 55 year streamflow data sets.

For surface water resources, available supply is considered to be a proportion of streamflow, which is monitored at a number of stations across the Lake Simcoe basin. Surface water supply thus involved the interpolation of gauge data to the outlets of subwatersheds in gauged systems, and interpolation from similar subwatersheds for ungauged systems (described in Section 3.1.3.2).

For groundwater resources, the available supply for a subwatershed is considered to be recharge. Recharge is a difficult parameter to measure as there is significant variability as a function of land use and cover (e.g. vegetation), slope, geology and hydraulic gradient. In order to estimate recharge across large subwatershed areas in the absence of site specific investigation, the following relationships between readily available data were relied upon;

$P-ET = Rech + Roff$ *or* $Rech = P-ET-Roff$ (1)

$SWO = Roff + BF$ *or* $Roff = SWO-BF$(2)

Substituting Equation 2 into Equation 1 yields;

$Rech = P - ET - SWO + BF$ (3)

where:

P = Precipitation

ET = Evapotranspiration

SWO = Total Streamflow out of a subwatershed

BF = Baseflow or groundwater discharge component of streamflow

Rech = Groundwater Recharge

Roff = Runoff

The following figure outlines the relationship of the above variables. The variables outlined in red are losses to the watershed, green are gains and yellow are internal movement of water which remain within the subwatershed and are accounted for as such.

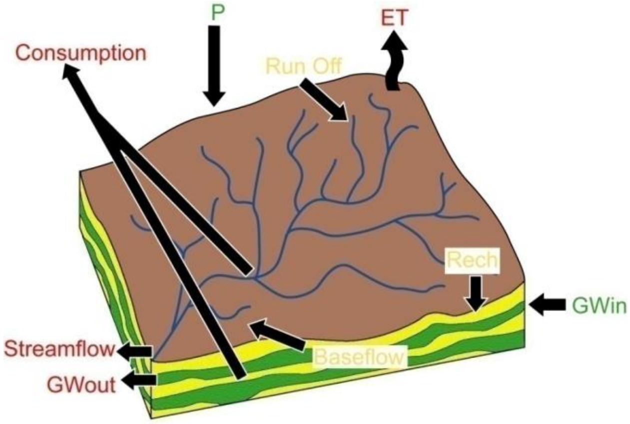

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Figure 3-1. Water Balance Diagram

Equation 3 was utilized in the South Simcoe Groundwater Studies (Golder, 2004) to estimate recharge, and was selected for this analysis. It should be noted that, where a surface water divide and groundwater divide are identical, and no consumption of groundwater occurs, recharge should be equal to baseflow[4]. Where groundwater movement to or from a subwatershed, or consumption removes groundwater, baseflow may be more or less than recharge. Thus, although groundwater gains and losses and consumptive water takings are not explicitly considered in the calculation, Equation 3 will reflect some of those gains and losses where they are occurring in gauged systems, and be extrapolated across the ungauged systems.

The following sections outline the components of the Water Budget required to estimate recharge per Equation 3, and surface water supplies along with the specific methods used to derive each.

Water Budget Elements

The water budget supply elements consist of precipitation, evaporation, stream flow and baseflow. This section is a summary of the methods used to estimate the supply elements used in the Tier One Water Budget and Water Quantity Stress Assessment (SGBLS, 2009).

Precipitation

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[4] Assumes no basin transfers

Precipitation is monitored at 12 climate stations within the Lake Simcoe watershed and at 96 stations within the SWP region. This network provides a reasonable coverage across the Lake Simcoe basin, although some temporal gaps exist in various records, as discussed in Section (3.1.7.1.2).

The meteorological data used to complete the Tier One assessment were collected by Environment Canada, and modified based on methodology for filling gaps in meteorological data sets outlined by Schroeter et al, (2000). Schroeter *et al.* (2000) describes practical techniques for estimating missing values in daily climate records, and in hourly rainfall depths. The daily climate data 'fill-in' procedure uses the relationship between monthly climate normals for a surrogate station, and the station under consideration. The data was infilled to reflect a period of record from 1950 to 2005.

This modified precipitation data set has then been interpolated across the basin by a method known as kriging. This addressed spatial gaps in monitoring and provided an estimate of the distribution throughout the region (Figure 3.2-1). Annual means were then determined for each subwatershed. These average data have been used within the stress assessment and are included in (Table 3.2-1).

Table 3.2-1: Monthly and Annual Precipitation by Subwatershed.

Subwatershed	Gauged or Ungauged (G / UG)	Area (km^2)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Apr. (mm)	May (mm)	Jun. (mm)	Jul. (mm)	Aug. (mm)	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Total (mm)
West Holland	G	352	55	50	55	66	73	75	77	84	71	67	73	52	**809**
East Holland	G	247	54	51	56	66	75	73	74	85	70	68	75	66	**816**
Black River	G	375	60	52	59	66	78	81	76	86	76	69	77	68	**848**
Pefferlaw Brook	G	285	62	52	58	67	78	81	76	86	77	69	78	67	**852**
Uxbridge Brook	G	161	57	50	57	67	76	79	78	86	75	66	75	64	**831**
Beaver River	G	327	75	56	61	69	82	86	75	85	84	73	86	72	**904**
Innisfil Creek	UG	107	71	57	59	65	76	78	76	86	79	73	80	75	**875**
Lovers Creek	UG	60	74	58	57	65	74	76	76	86	79	72	79	77	**873**
Talbot River	UG	71	92	64	63	70	82	83	71	87	87	78	93	87	**957**
Whites Creek	UG	105	92	64	64	71	85	85	69	88	88	79	94	84	**962**
Barrie Creeks	UG	38	84	61	59	64	75	78	76	84	84	75	81	81	**905**
Georgina Creeks	UG	49	69	56	61	65	78	82	77	81	81	73	80	74	**882**
Hewitts Creek	UG	18	79	59	59	65	75	78	76	81	81	73	80	79	**890**
Hawkestone Creek	UG	48	92	64	61	67	77	83	78	90	90	82	91	88	**960**
Maskinonge River	UG	63	60	54	61	65	78	81	77	78	78	71	78	72	**863**
Oro Creeks North	UG	75	95	66	62	68	78	82	79	89	89	83	92	94	**975**
Oro Creeks South	UG	57	87	62	60	66	77	83	77	89	89	80	88	83	**940**
Ramara Creeks	UG	144	93	65	62	69	79	82	76	87	86	82	91	91	**962**

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Evapotranspiration

The Thornthwaite method has been used to estimate the potential evapotranspiration (ET). This method is based on an empirical relationship between potential ET and mean air temperature. While this method has limitations, it provides reasonably accurate estimates of potential ET (Palmer and Havens, 1958).

This method is commonly used because the only input requirements are air temperature and hours of sunshine, although it is known that the Thornthwaite method underestimates ET in arid regions, and overestimates ET in humid regions (Alkaeed *et al.,* 2006).

The calculated potential evapotranspiration values using monthly data have been included in Table 3.2-2. A comparison of the ET calculated using the Thornthwaite method to the ET previously calculated in the Conceptual Water Budget (SGBLS, 2007) using the Hamon method, indicates that both methods yield very similar results.

To estimate the actual evapotranspiration (AET) a crop coefficient (K_c) was used. Crop coefficients (K_c) are crop specific evapotranspiration values. They are generated through research using reference evapotranspiration data, to estimate the crop evapotranspiration requirement (ET_c). The actual ET for the crop (ET_c) is calculated by multiplying the crop coefficient (K_c) by the reference evapotranspiration value (ET_o).

In the absence of available local values, a K_c value for the watershed was determined using published potential and actual evapotranspiration values for Southern Ontario (Brown *et al.*, 1980). An average coefficient of 0.96 was estimated as representative of the watershed. A summary of AET is included in Table 3.2-3 and in Figure 3.2-2. A ratio of 0.96 could be higher than average and during this study a summary of the stations within the SWP area as well as some additional stations were considered and alternate statistical methods were used to calculate AET. The lowest average ratio calculated was 0.84. Due to the conservative approach to this assessment the higher ratio was used, which would be the worst case scenario for evaportranspiration.

Table 3.2-2: Monthly and Annual Potential Evapotranspiration.

Subwatershed	Gauged or Ungauged (G / UG)	Area (km^2)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Apr. (mm)	May (mm)	Jun. (mm)	Jul. (mm)	Aug. (mm)	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Total (mm)
West Holland	G	352	0	0	1	31	79	113	127	112	77	38	9	0	588
East Holland	G	247	0	0	1	31	80	114	128	112	77	38	9	0	590
Black River	G	375	0	0	1	30	80	113	126	112	77	38	9	0	585
Pefferlaw Brook	G	285	0	0	1	30	80	114	126	112	77	38	8	0	585
Uxbridge Brook	G	161	0	0	1	30	80	114	125	111	77	38	8	0	583
Beaver River	G	327	0	0	1	30	80	114	126	112	76	37	8	0	584
Innisfil Creek	UG	107	0	0	1	29	79	113	127	113	77	37	9	0	584
Lovers Creek	UG	60	0	0	1	29	78	112	126	112	77	38	9	0	583
Talbot River	UG	71	0	0	1	29	81	113	127	112	75	36	7	0	581
Whites Creek	UG	105	0	0	1	29	81	114	127	112	75	35	7	0	581
Barrie Creeks	UG	38	0	0	1	28	78	113	128	114	77	38	9	0	587
Georgina Creeks	UG	49	0	0	1	30	79	113	126	113	77	38	8	0	585
Hewitts Creek	UG	18	0	0	1	29	79	113	127	114	77	38	9	0	586
Hawkestone Creek	UG	48	0	0	1	29	79	113	128	114	77	37	8	0	586
Maskinonge River	UG	63	0	0	1	31	80	112	126	113	76	37	8	0	585
Oro Creeks North	UG	75	0	0	0	29	80	112	129	114	77	37	8	0	587
Oro Creeks South	UG	57	0	0	1	29	79	113	128	114	77	37	8	0	587
Ramara Creeks	UG	144	0	0	0	29	81	112	128	112	76	36	7	0	581

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Table 3.2-3: Monthly and Annual Actual Evapotranspiration.

Subwatershed	Gauged or Ungauged (G / UG)	Area (km^2)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Apr. (mm)	May (mm)	Jun. (mm)	Jul. (mm)	Aug. (mm)	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Total (mm)
West Holland	G	352	0	0	1	30	76	109	122	108	74	36	9	0	564
East Holland	G	247	0	0	1	29	77	109	122	108	74	36	9	0	566
Black River	G	375	0	0	1	29	76	108	121	108	74	36	8	0	562
Pefferlaw Brook	G	285	0	0	1	29	77	109	121	107	74	36	8	0	561
Uxbridge Brook	G	161	0	0	1	29	77	109	120	107	73	36	8	0	560
Beaver River	G	327	0	0	1	29	77	109	121	107	73	36	7	0	560
Innisfil Creek	UG	107	0	0	1	28	76	108	122	109	74	36	8	0	561
Lovers Creek	UG	60	0	0	1	28	75	108	121	108	74	34	9	0	560
Talbot River	UG	71	0	0	1	28	78	109	122	107	72	36	7	0	557
Whites Creek	UG	105	0	0	1	28	78	109	122	107	72	34	6	0	557
Barrie Creeks	UG	38	0	0	1	27	75	108	123	110	74	36	9	0	563
Georgina Creeks	UG	49	0	0	1	29	76	108	121	109	74	36	8	0	561
Hewitts Creek	UG	18	0	0	1	28	75	108	122	109	74	36	9	0	562
Hawkestone Creek	UG	48	0	0	0	28	76	108	123	110	74	35	8	0	563
Maskinonge River	UG	63	0	0	1	29	77	108	121	108	73	36	8	0	561
Oro Creeks North	UG	75	0	0	0	28	77	108	124	110	74	36	8	0	564
Oro Creeks South	UG	57	0	0	1	28	76	109	123	110	74	36	8	0	563
Ramara Creeks	UG	144	0	0	0	27	77	109	122	108	73	35	78	0	558

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Aerial Distribution (Precipitation and Evapotranspiration)

Several methods are commonly used to calculate watershed average rainfall from an assumption of aerial (i.e., spatial) distribution using point rainfall from the gauge network. Precipitation depths have been interpolated between measured points within and immediately surrounding the watershed region using kriging, and values for each subwatershed were estimated from geostatistical analyses.

The mean annual precipitation (Figure 3.2-1) and mean annual AET (Figure 3.2-2) raster surfaces have been created using ordinary kriging. This method was selected since it is possible to evaluate the suitability of the selected model to the data being interpolated by means of cross-validation. Ninety-six data points throughout the entire South Georgian Bay-Lake Simcoe SWP region were included in the interpolations for precipitation and AET discussed above.

The entire SWP area was kriged so that the maximum number of data points (96 Stations) could be used in the calculations. These surfaces were then scaled down to the watershed areas to create figures for each report.

A spherical function was used to model the spatial variation of precipitation, rather than a circular search neighbourhood, to determine points to be included in the calculations. The search neighbourhood was adjusted, directionally, to account for the predominant weather patterns in the area, with most weather systems coming from the west-north-west.

The interpolation for mean annual AET also used a spherical function to model the spatial variation. In this case, a circular search neighbourhood was used to determine data points to be included in each calculation. This search neighbourhood method is considered to more accurately reflect the distribution of the data than an elliptical neighbourhood.

The parameters used in both the precipitation and AET interpolations were determined to most effectively capture the spatial variation. A variety of parameter combinations were explored, including using circular, exponential, and Gaussian functions to model variation, as well as simple kriging. A variety of search neighbourhood sizes were investigated as well. The parameters explored were evaluated based on both the prediction error statistics, which are generated by the cross-validation, as well as a visual corroboration of the resulting surface.

Annual Stream Flow

Surface water flows are measured at 9 sites by the Water Survey of Canada and 6 sites by the LSRCA across the Lake Simcoe basin (Figure 3.2-3). The streamflow data used in this evaluation was collected from 1965 to 2008. For the purposes of estimating monthly streamflow, statistics to represent surface water supply streamflow record-extension and regional regression techniques have been used to estimate missing temporal data and estimate flow in ungauged streams as discussed below.

To apply the stream flow record-extension technique, the establishment of index stations is required. The long-term index station for record extension must satisfy several criteria, including that it be unregulated. The following streamflow stations were used as index stations due to the length and quality of information available.

Table 3.2-4: Index Streamflow Station Information.

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Station Location	Station No.	Period of Record
East Holland gauge at Holland Landing	02EC009	1965-2008
Upper Schomberg gauge at Schomberg[5]	02EC010	1966-2008
Beaver River gauge Concession 2 in Brock Township	02EC011	1966-2008
Pefferlaw River gauge at Udora	02EC018	1966-2008

Mean and median monthly streamflow values are presented in Table 3.2-5: Monthly Mean Streamflow; and Table 3.2-6, which includes the results of the infilling of spatial data gaps. It should be noted that all of the subwatersheds outlined above have hydraulic structures upstream of the gauge including stormwater management facilities (dry ponds, extended wet ponds and constructed wetlands) and dams. However, the flows recorded at gauges in the other subwatersheds show a good (generally >0.70) daily correlation with their neighbouring index station.

<u>Method Used to Estimate Missing Streamflow Data in Gauged Subwatersheds</u>

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[5] West Holland tributary

A modified drainage-area ratio method, a maintenance of variance extension type 1 (MOVE.1) method, and a multiple linear regression method were used in this study to estimate streamflow for ungauged sites and gauged sites that had missing data. The drainage-area ratio method (Hirsch, 1979) is based on the assumption that streamflow for a site of interest can be estimated by multiplying the ratio of the drainage area for the site of interest and the drainage area for a nearby gauged site by streamflow for the nearby gauged site.

The MOVE.1 method is used when streamflow data are available for a site of interest for a period of N_1 years and for a base station for the same N_1 years plus an additional N_2 year. Hirsch (1982) showed that the MOVE.1 method, which is similar to regression methods, reproduces the statistical characteristics of the actual data more accurately than traditional regression methods because the MOVE.1 method reproduces sample estimates of the mean of the variance from the historic data (N_1 years).

Correlation between the base (index) station and the site of interest was tested before applying the MOVE.1 method.

Since log-transformed estimates are superior to linear estimates for the assessment of streamflow (Hirsch, 1979), the streamflow data used to estimate the missing data for this study were log transformed prior to applying the equation. Streamflow values of zero were treated as missing values.

Method Used to Estimate Streamflow in Ungauged Subwatersheds

Statistical multiple-regression analyses have been performed to define relations between selected streamflow characteristics (e.g. flow and baseflow), climate (e.g. precipitation), and watershed characteristics (e.g. geology). Various regression models to estimate mean annual stream flows and base flows at gauged stream sites have been tested. Studies in which equations were presented for estimating streamflow statistics for streams have been completed by Dudley (2004); Koltun and Whitehead (2002) and Perry *et al.* (2002).

Explanatory variables that could potentially influence stream flow (i.e. potential ET, basin area, basin length, channel length, channel slope, air temperature, geology, permeability, gaining and losing reaches of the streams, and overburden thickness) have been compiled for the ten currently gauged locations in the Lake Simcoe Watershed (Figure 3.2-3). Application involved the quantification of basin characteristics. The quantification required was facilitated by use of geographic information systems. A 20-year mean of flow for each gauged station was used as the dependent variable (i.e., 1985 to 2005 dataset). In addition, all variables have been tested statistically for normality and graphically for homogeneity of variances and linearity. Only variables meeting these criteria were included in the regression model.

From the linear regression analyses, a regression equation was calculated for each month using the statistically significant explanatory variables. The validity of each equation was tested by calculating an estimated flow for each station and comparing it to the actual recorded flow at the corresponding station. An independent t-test was used for this comparison and it was concluded that there was no significant difference between the estimated flow and the actual flow.

The regression equation was then used to estimate flow in ungauged basins of the watershed (Table 3.2-7) and the process for baseflow estimates discussed below was applied to these data. The flow and baseflow estimates calculated for ungauged basins were accepted as valid as they were comparable to field observations. The hydrograph (adjacent) illustrates observed and estimated data[6]

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[6] Example provided is the average monthly mean flow in the Black River (1980-2008) compared with the estimated flow.

Table 3.2-5: Monthly Mean Streamflow.

Subwatershed	Gauged or Ungauged (G/UG)	Jan. (m3/s)	Feb. (m3/s)	Mar. (m3/s)	Apr. (m3/s)	May (m3/s)	Jun. (m3/s)	Jul. (m3/s)	Aug. (m3/s)	Sep. (m3/s)	Oct. (m3/s)	Nov. (m3/s)	Dec. (m3/s)	Mean Annual
West Holland	G	2.6	2.7	6.9	7.2	3.3	2	1.2	1	1.5	1.9	3.3	2.6	**3**
East Holland	G	1.6	2	4	3.6	2	1.2	1.1	0.9	1	1.2	1.8	1.6	**1.8**
Black River	G	3.1	3	5.1	5.7	2.5	1.7	1.2	1.1	1.1	1.4	2.3	2	**2.5**
Pefferlaw Brook	G	2.1	2.7	5.3	4.9	2.5	1.8	1.4	1.3	1.5	1.8	2.3	2.3	**2.5**
Uxbridge Brook	G	1.4	1.7	3.4	1.6	1.1	0.8	0.8	0.9	1.1	1.5	1.5	1.6	**1.6**
Beaver River	G	2.6	3.3	8.4	8.8	3.3	1.4	1	0.8	1.2	1.7	2.9	3	**3.2**
Innisfil Creek	UG	0.6	0.6	1.3	1.3	0.6	0.4	0.3	0.3	0.4	0.5	0.6	0.6	**0.6**
Lovers Creek	UG	0.5	0.4	1	0.9	0.5	0.3	0.2	0.2	0.2	0.3	0.3	0.4	**0.4**
Talbot River	UG	0.6	0.5	1.2	1.2	0.5	0.3	0.2	0.2	0.3	0.3	0.6	0.5	**0.5**
Whites Creek	UG	0.9	0.8	2	1.8	0.9	0.2	0.3	0.2	0.4	0.5	1	0.7	**0.8**
Barrie Creeks	UG	0.3	0.3	0.6	0.5	0.3	0.3	0.1	0.1	0.2	0.2	0.2	0.2	**0.3**
Georgina Creeks	UG	0.3	0.3	0.7	0.7	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.3	**0.3**
Hewitts Creek	UG	0.1	0.1	0.4	0.3	0.1	0.1	0.1	0	0	0.1	0.1	0.1	**0.1**
Hawkestone Creek	UG	0.4	0.4	0.9	0.8	0.4	0.1	0.2	0.1	0.2	0.2	0.4	0.3	**0.4**
Maskinonge River	UG	0.4	0.4	1.1	1	0.5	0.2	0.2	0.1	0.2	0.3	0.4	0.4	**0.4**
Oro Creeks North	UG	0.7	0.6	1.3	1.2	0.6	.4.3	0.3	0.3	0.4	0.4	0.6	0.6	**0.6**
Oro Creeks South	UG	0.4	0.3	0.9	0.8	0.3	0.2	0.1	0.1	0.2	0.2	0.4	0.3	**0.3**
Ramara Creeks	UG	0.9	0.7	2	2	0.7	0.4	0.2	0.2	0.4	0.5	1.1	0.8	**0.8**

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Table 3.2-6: Monthly Median Streamflow.

Subwatershed	Gauged or Ungauged (G/UG)	Jan. (m3/s)	Feb. (m3/s)	Mar. (m3/s)	Apr. (m3/s)	May (m3/s)	Jun. (m3/s)	Jul. (m3/s)	Aug. (m3/s)	Sep. (m3/s)	Oct. (m3/s)	Nov. (m3/s)	Dec. (m3/s)	Mean Annual
West Holland	G	1.5	1.4	3.4	4.3	2.1	0.8	0.8	0.7	0.7	1.2	2	1.9	**1.8**
East Holland	G	0.9	0.9	2.2	2.4	1.4	0.8	0.6	0.6	0.6	0.7	1.2	1.1	**1.1**
Black River	G	1.8	1.4	2.9	4	1.9	1	1	0.6	0.6	0.7	1	1.6	**1.5**
Pefferlaw Brook	G	1.6	1.5	3.2	3.7	2	1.3	1.1	1.1	1.2	1.6	2	2	**1.9**
Uxbridge Brook	G	1.1	1	2.1	2.4	1.3	0.8	0.6	0.7	0.7	1	1.3	1.3	**1.2**
Beaver River	G	1.6	1.5	4.8	6.6	2.5	0.8	0.6	0.5	0.7	1.3	2.3	2.3	**2.1**
Innisfil Creek	UG	0.4	0.3	0.8	0.7	0.4	0.4	0.3	0.2	0.2	0.3	0.4	0.4	**0.4**
Lovers Creek	UG	0.3	0.3	0.8	0.9	0.4	0.2	0.1	0.1	0.2	0.2	0.4	.	**0.4**
Talbot River	UG	0.4	0.3	0.9	1	0.4	0.2	0.2	0.1	0.2	0.3	0.4	0.4	**0.4**
Whites Creek	UG	0.5	0.4	1.2	1.2	0.6	0.3	0.2	0.2	0.2	0.3	0.6	0.6	**0.5**
Barrie Creeks	UG	0.2	0.2	0.6	0.6	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.3	**0.3**
Georgina Creeks	UG	0.2	0.2	0.6	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	**0.2**
Hewitts Creek	UG	0.1	0.1	0.5	0.5	0.2	0	0	0	0	0.1	0.2	0.2	**0.2**
Hawkestone Creek	UG	0.3	0.2	0.7	0.8	0.3	0.2	0.1	0.1	.1.2	0.2	0.3	0.3	**0.3**
Maskinonge River	UG	0.3	0.3	0.9	1	0.4	0.2	0.1	0.1	0.2	0.2	0.4	0.4	**0.4**
Oro Creeks North	UG	0.4	0.4	0.9	1	0.5	0.3	0.2	0.2	0.3	0.3	0.4	0.5	**0.4**
Oro Creeks South	UG	0.2	0.2	0.6	0.6	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	**0.2**
Ramara Creeks	UG	0.4	0.3	0.9	0.8	0.4	0.3	0.2	0.2	0.2	0.3	0.4	0.5	**0.3**

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Mean Annual Baseflow

Estimates of the amount of baseflow can be derived from streamflow records. These estimates are critical in the assessment of the low flow characteristics of streams. Baseflow is obtained by hydrograph separation, which has traditionally been done manually. Two commonly used methods are baseflow recession and curve fitting (Linsley *et al.,* 1975). However, different hydrologists using the same manual hydrograph separation method commonly produce different baseflow estimates.

The use of digital filtering removes the inconsistencies inherent in manual methods and substantially reduces the time required for hydrograph separation. Lyne and Hollick (1979) appear to have been the first to suggest the use of a digital filter. Many researchers implement this method, including Chapman (1987), Nathan and McMahon (1990), O'Loughlin *et al.* (1982), and Arnold *et al.* (1995). This method has been used to calculate baseflow for both gauged and ungauged systems. In addition, a modified United Kingdom Institute of Hydrology method devised by the National Water Research Institute and Meteorological Service of Canada (Piggott *et al.,* 2005) was used. This method has revisions resolving two aspects of the method that lead to less than optimal results; that is, the calculation of values of baseflow that exceed the corresponding values of streamflow and the dependence of the calculated values on the origin of the five-day segmentation of the input streamflow data.

The new approach was demonstrated using streamflow monitoring information that is typical for areas of southern Ontario, where baseflow is primarily due to groundwater discharge. This method has recently been applied to length-of-record streamflow monitoring information for roughly four-thousand gauges in the Great Lakes region and has proven to be as efficient and robust as the other approaches in the processing of this streamflow data (Piggott *et al.,* 2005). Baseflow separation results are presented in Table 3.2-7.

Table 3.2-7: Monthly Mean Baseflow.

Subwatershed	Gauged or Ungauged (G/UG)	Jan. (m3/s)	Feb. (m3/s)	Mar. (m3/s)	Apr. (m3/s)	May (m3/s)	Jun. (m3/s)	Jul. (m3/s)	Aug. (m3/s)	Sep. (m3/s)	Oct. (m3/s)	Nov. (m3/s)	Dec. (m3/s)	Mean Annual
West Holland	G	1.4	1.5	2.5	3.8	1.7	0.8	0.6	0.5	0.8	1.2	1.7	1.6	**1.5**
East Holland	G	0.6	0.7	1.2	1.5	0.9	0.5	0.4	0.3	0.4	0.6	0.8	0.8	**0.7**
Black River	G	1.3	1.3	2.2	3.1	1.5	0.9	0.6	0.6	0.7	1	1.4	1.4	**1.4**
Pefferlaw Brook	G	1.3	1.3	1.9	2.5	1.5	0.9	0.8	0.8	0.9	1.3	1.5	1.5	**1.4**
Uxbridge Brook	G	0.9	0.9	1.3	1.6	1	0.6	0.5	0.5	0.6	0.9	1	1	**0.9**
Beaver River	G	1.6	1.7	3.1	4.3	1.9	0.8	0.8	0.6	0.8	1.4	1.9	1.8	**1.7**
Innisfil Creek	UG	0.3	0.3	0.4	0.5	0.3	0.2	0.1	0.1	0.2	0.2	0.3	0.3	**0.3**
Lovers Creek	UG	0.2	0.2	0.3	0.4	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	**0.2**
Talbot River	UG	0.3	0.2	0.3	0.5	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.3	**0.2**
Whites Creek	UG	0.4	0.4	0.6	0.8	0.4	0.2	0.1	0.1	0.2	0.3	0.4	0.4	**0.4**
Barrie Creeks	UG	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	**0.1**
Georgina Creeks	UG	0.1	0.1	0.2	0.3	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	**0.1**
Hewitts Creek	UG	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.1	**0.1**
Hawkestone Creek	UG	0.2	0.2	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	**0.2**
Maskinonge River	UG	0.2	0.2	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	**0.2**
Oro Creeks North	UG	0.3	0.3	0.4	0.5	0.3	0.2	0.2	0.1	0.2	0.3	0.3	0.4	**0.3**
Oro Creeks South	UG	0.1	0.1	0.2	0.4	0.2	0.1	0	0	0.1	0.1	0.2	0.2	**0.1**
Ramara Creeks	UG	0.4	0.3	0.5	0.9	0.3	0.1	0.1	0.1	0.2	0.3	0.4	0.4	**0.3**

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Water Budget Reserve

Within Technical Rules (MOE, 2008a) water reserve is defined as the water that is required to be "protected" to support other uses within the watershed including ecosystem needs and other human uses such as sewage assimilation, hydroelectric power production and navigation. This reserve value is calculated as 10% of groundwater discharge. For surface water, within subwatersheds that have gauged flow stations, the 10th percentile of stream flow (Q_{90}) was used as the reserve value (

Table 3.2-8). For surface water within ungauged subwatersheds the Tessmann (1980) method was used to estimate instream flow, which is documented in the Guidance Module 7 (MOE, 2007).

Surface Water Reserve Estimation

The methods recommended to estimate the water reserve include 10th percentile streamflow (Q_{90}), which has been used within gauged subwatersheds (

Table 3.2-8). This flow value is most representative for reserve, as it is the flow value that is exceeded 90 percent of the time.

Within ungauged subwatersheds the Tessmann method has been applied to estimate streamflow values. Tessmann (1980) adapted Tennant's (1976) seasonal flow recommendations to calibrate the percentage of monthly available flow to local hydrologic and biologic conditions including monthly variability.

As noted within the MOE Guidance Module 7 (MOE, 2007), when using the Tessmann method the estimated reserve value may be larger than the water supply calculated for summer low flows. To mitigate this, a reserve value of 30% of the monthly streamflow would be applied in place of the Tessmann equation. This has been done based on the MOE Guidance Module 7 (MOE, 2007), which indicates that this reserve value is designed to add a buffer to already conservative percent demand thresholds. Surface water reserve values have been included in

Table 3.2-8.

Groundwater Reserve Estimation

Technical Rule 3 (MOE, 2008a), indicates that 10% of the existing groundwater discharge should be considered as the groundwater reserve component for each subwatershed. Groundwater discharge has been calculated using a baseflow separation technique (described in Section

3.1.3.1.5), for gauged and simulated stream hydrographs. The baseflow separation results have been included in Table 3.2-9.

Table 3.2-8: Surface Water Reserve Estimates.

Subwatershed	Guaged or Ungauged (G/UG)	Jan. (m3/s)	Feb. (m3/s)	Mar. (m3/s)	Apr. (m3/s)	May (m3/s)	Jun. (m3/s)	Jul. (m3/s)	Aug. (m3/s)	Sep. (m3/s)	Oct. (m3/s)	Nov. (m3/s)	Dec. (m3/s)	Annual Mean
West Holland	G	0.91	0.72	1.79	1.69	0.96	0.52	0.51	0.36	0.35	0.42	0.36	0.91	**0.55**
East Holland	G	0.43	0.43	0.79	1.24	0.72	0.39	0.24	0.24	0.27	0.4	0.57	0.55	**0.4**
Black River	G	0.55	0.57	0.93	1.4	0.76	0.42	0.3	0.27	0.34	0.48	0.66	0.84	**0.47**
Pefferlaw Brook	G	0.91	0.85	1.17	2.07	1.21	0.83	0.68	0.71	0.74	1.03	1.23	1.28	**0.87**
Uxbridge Brook	G	0.6	0.56	0.76	1.32	0.77	0.51	0.42	0.44	0.45	0.64	0.83	0.85	**0.55**
Beaver River	G	0.72	0.69	1.17	2.95	0.99	0.3	0.18	0.19	0.23	0.44	0.82	1.02	**0.39**
Innisfil Creek	UG	0.25	0.23	0.25	0.25	0.25	0.17	0.11	0.12	0.17	0.18	0.25	0.24	**0.21**
Lovers Creek	UG	0.18	0.17	0.18	0.18	0.18	0.12	0.08	0.07	0.09	0.11	0.17	0.16	**0.14**
Talbot River	UG	0.21	0.2	0.21	0.21	0.21	0.12	0.08	0.07	0.1	0.13	0.21	0.19	**0.16**
Whites Creek	UG	0.33	0.3	0.33	0.33	0.33	0.19	0.11	0.1	0.16	0.2	0.33	0.3	**0.25**
Barrie Creeks	UG	0.11	0.11	0.11	0.11	0.11	0.08	0.05	0.05	0.6	0.07	0.09	0.1	**0.09**
Georgina Creeks	UG	0.11	0.11	0.12	0.12	0.12	0.07	0.05	0.04	0.06	0.07	0.12	0.1	**0.09**
Hewitts Creek	UG	0.05	0.05	0.05	0.05	0.05	0.03	0.02	0.01	0.02	0.03	0.05	0.04	**0.04**
Hawkestone Creek	UG	0.15	0.15	0.15	0.15	0.15	0.1	0.06	0.05	0.08	0.09	0.15	0.14	**0.12**
Maskinonge River	UG	0.16	0.16	0.18	0.18	0.18	0.11	0.07	0.06	0.08	0.11	0.18	0.15	**0.14**
Oro Creeks North	UG	0.24	0.24	0.24	0.24	0.24	0.17	0.11	0.1	0.14	0.17	0.24	0.24	**0.2**
Oro Creeks South	UG	0.14	0.12	0.14	0.14	0.13	0.07	0.04	0.03	0.06	0.08	0.14	0.12	**0.1**
Ramara Creeks	UG	0.33	0.28	0.33	0.33	0.3	0.15	0.1	0.09	0.16	0.21	0.33	0.33	**0.24**

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Table 3.2-9: Groundwater Reserve Estimates.

Subwatershed	Gauged or Ungauged (G/UG)	Jan. (m3/s)	Feb. (m3/s)	Mar. (m3/s)	Apr. (m3/s)	May (m3/s)	Jun. (m3/s)	Jul. (m3/s)	Aug. (m3/s)	Sep. (m3/s)	Oct. (m3/s)	Nov. (m3/s)	Dec. (m3/s)	Annual Mean
West Holland	G	0.14	0.15	0.25	0.38	0.17	0.08	0.06	0.05	0.08	0.12	0.17	0.16	**0.15**
East Holland	G	0.06	0.07	0.12	0.15	0.09	0.05	0.04	0.03	0.04	0.06	0.08	0.08	**0.07**
Black River	G	0.13	0.13	0.22	0.31	0.15	0.09	0.06	0.06	0.07	0.1	0.14	0.14	**0.13**
Pefferlaw Brook	G	0.3	0.13	0.19	0.25	0.15	0.09	0.08	0.08	0.09	0.13	0.15	0.15	**0.14**
Uxbridge Brook	G	0.09	0.09	0.13	0.16	0.1	0.06	0.05	0.05	0.06	0.09	0.1	0.1	**0.09**
Beaver River	G	0.16	0.17	0.31	0.43	0.19	0.08	0.06	0.06	0.08	0.14	0.19	0.18	**0.17**
Innisfil Creek	UG	0.03	0.03	0.04	0.05	0.03	0.02	0.01	0.01	0.02	0.02	0.03	0.03	**0.03**
Lovers Creek	UG	0.02	0.02	0.03	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	**0.02**
Talbot River	UG	0.03	0.02	0.04	0.05	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.03	**0.02**
Whites Creek	UG	0.04	0.04	0.06	0.08	0.04	0.02	0.01	0.01	0.02	0.02	0.04	0.04	**0.04**
Barrie Creeks	UG	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	**0.01**
Georgina Creeks	UG	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.01**
Hewitts Creek	UG	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0.01	0.01	**0.01**
Hawkestone Creek	UG	0.02	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	**0.02**
Maskinonge River	UG	0.02	0.02	0.03	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	**0.02**
Oro Creeks North	UG	0.03	0.03	0.04	0.05	0.03	0.02	0.02	0.01	0.02	0.03	0.03	0.04	**0.03**
Oro Creeks South	UG	0.01	0.01	0.2	0.04	0.02	0.01	0	0	0.01	0.01	0.02	0.02	**0.01**
Ramara Creeks	UG	0.04	0.03	0.05	0.09	0.03	0.01	0.01	0.01	0.02	0.03	0.04	0.04	**0.03**

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Uncertainty in Water Supply Estimates

The above sections discuss data interpretation and manipulation that have been completed to estimate the parameters required to complete the supply side of the water quantity stress assessment. The result is an understanding of the flow of water within each subwatershed.

Within each method there are assumptions made which reduce the certainty of these estimations including; in-filling long term precipitation data, estimating the areal distribution, calculating streamflow within ungauged watercourses and error inherent in automated baseflow separation techniques. These methods; however, are widely used and were originally recommended within the Guidance Module 7 (MOE, 2007). They are considered appropriate for the broad purposes of this assessment. Further study to refine these methods will be completed within the Tier Two assessment, where necessary, based upon estimated water quantity stresses.

As an additional check, the components of the hydrologic cycle used in the estimates of recharge for the stress assessment have been used to solve a simple water balance equation.

The terms of this equation for each subwatershed on an annual scale have been included in Table 3.2-24, the net difference calculated by subwatershed, and the percent difference quantified as a proportion of precipitation.

The tabulated water balance results indicate that the methods used are quite reasonable for the gauged subwatersheds, yielding less than 10% difference for all of the monitored systems.

For ungauged systems, the interpolation methods described in the report are expectedly less reliable than monitoring streamflow, with water surplus ranging from 5% to approximately 25% of precipitation. While the uncertainty associated with the ungauged systems is acknowledged, the conservatism in the component parts of the stress assessment adequately balances this uncertainty. As a result, the authors of the Tier One report are confident that all of the potentially stressed subwatersheds, according to the water budget guidance are flagged as such in this report.

The objective of the Tier One is to be conservative to ensure that all possible stress is identified. The further more refined Tier Two is intended to confirm or negate this stress. Throughout the report methods which have inherent uncertainty have been identified, these methods and the rational for use have been discussed above in the methods section. The following discusses the uncertainty of each method.

Areal distribution

Using several gauges over a large land area generalizes the results making them possibly bias high or low. The calculated precipitation and AET have been compared to other published work in an attempt to reduce uncertainty.

Ungauged Stream Flow

The method used is considered the best available science in situations where no gauged data is available; however, use of this method introduces uncertainty.

Water Demand

The following sections outline the methods used to estimate various water demands. These demand estimates for the existing groundwater use scenario have been outlined on Table 3.2-10. In addition, future use has also been estimated using various methods to calculate the demand increase into the future as defined by the Technical Rules (MOE, 2008a). These estimates have been included in Table 3.2-11.

Surface water taking has also been assessed, as there are no municipal surface water treatment facilities which are to be considered within this report and all un-serviced domestic use is assumed to be private wells, only agricultural and permitted use has been assessed. The agricultural demand has been calculated based on de Loe’s 2005 methodology, and the permit to take water database has been assessed per the following section. A summary of the existing are included in Table 3.2-12.

Table 3.2-10: Existing Groundwater Consumption.

Watershed Name	Gauged or Ungauged (G/UG)	Municipal	Domestic	PTTW	Agricultural	Total Consumption
West Holland	G	3,043,000	163,000	139,000	728,000	4,073,000
East Holland	G	13,661,000	179,000	2,132,000	555,000	16,527,000
Black River	G	297,000	351,000	566,000	1,421,000	2,635,000
Pefferlaw Brook	G	-	108,000		418,000	1,865,000
Uxbridge Brook	G	1,111,000	93,000	1,339,000	127,000	1,438,000
Beaver River	G	553,000	6,800	107,000	158,000	889,000
Innisfil Creeks	UG	257,000	202,000	109,000	34,000	493,000
Lovers Creeks	UG	71,000	23,000	-	13,000	611,000
Talbot River	UG	-	7,000	503,000	19,000	761,000
Whites Creek	UG	-	29,000	735,000	32,000	61,000
Barrie Creeks	UG	13,159,000	28,000	32,000	600	13,187,000
Georgina Creeks	UG	-	198,000	7,000	291,000	497,000
Hewitts Creek	UG	226,000	27,000	-	4,000	257,000
Hawestone Creek	UG	5,000	33,000	21,000	10,000	70,000
Maskingonge River	UG	1,821,000	30,000	23,000	296,000	2,170,000
Oro Creeks North	UG	32,000	64,000	7,000	15,000	118,000
Oro Creeks South	UG	78,000	117,000	7,000	13,000	215,000
Ramara Creeks	UG	158,000	82,000	1,000	14,000	255,000

*Note: Values rounded for presentation purposes. All values in m^3/a.

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Table 3.2-11: Future Groundwater Consumption.

Watershed Name	Gauged or Ungauged (G/UG)	Municipal	Domestic	PTTW	Agricultural	Total Consumption
West Holland	G	3,387,000	229,000	139,000	728,000	4,483,000
East Holland	G	15,330,000	251,000	2,132,000	555,000	18,268,000
Black River	G	622,000	492,000	566,000	1,421,000	3,101,000
Pefferlaw Brook	G	-	146,000	1,339,000	418,000	1,903,000
Uxbridge Brook	G	3,011,615	125,000	107,000	127,000	3,371,000
Beaver River	G	1,372,000	92,000	109,000	158,000	1,731,000
Innisfil Creeks	UG	362,000	282,000	-	34,000	678,000
Lovers Creeks	UG	380,000	32,000	503,000	13,000	928,000
Talbot River	UG	-	9,000	735,000	19,000	763,000
Whites Creek	UG	-	39,000	-	32,000	71,000
Barrie Creeks	UG	13,159,000	39,000	32,000	600	13,231,000
Georgina Creeks	UG	-	278,000	7,000	291,000	576,000
Hewitts Creek	UG	316,000	37,000	-	4,000	357,000
Hawestone Creek	UG	72,000	46,000	21,000	10,000	149,000
Maskingonge River	UG	1,821,000	42,000	23,000	296,000	2,182,000
Oro Creeks North	UG	34,000	90,000	7,000	15,000	146,000
Oro Creeks South	UG	692,000	692,000	7,000	13,000	876,000
Ramara Creeks	UG	158,000	115,000	1,000	14,000	288,000

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*Note: Values rounded for presentation purposes. All values in m^3/a.

Table 3.2-12: Existing Surface Water Consumption.

Watershed Name	Gauged or Ungauged (G/UG)	Municipal	Domestic	PTTW	Agricultural	Total Consumption
West Holland	G	-	-	2,666,000	1,742,000	4,408,000
East Holland	G	-	-	1,929,000	1,328,000	3,257,000
Black River	G	-	-	154,000	3,401,000	3,555,000
Pefferlaw Brook	G	-	-	345,000	1,000,000	1,345,000
Uxbridge Brook	G	-	-	19,000	305,000	324,000
Beaver River	G	-	-	264,000	379,000	643,000
Innisfil Creeks	UG	-	-	242,000	8,100	323,000
Lovers Creeks	UG	-	-	26,000	32,000	58,000
Talbot River	UG	-	-	29,000	45,000	74,000
Whites Creek	UG	-	-	-	77,000	77,000
Barrie Creeks	UG	-	-	32,000	1,000	33,000
Georgina Creeks	UG	-	-	785,000	697,000	1,482,000
Hewitts Creek	UG	-	-	-	10,000	10,000
Hawestone Creek	UG	-	-	12,000	25,000	37,000
Maskingonge River	UG	-	-	353,000	709,000	1,062,000
Oro Creeks North	UG	-	-	207,000	35,000	242,000
Oro Creeks South	UG	-	-	38,000	30,000	68,000
Ramara Creeks	UG	-	-	100	34,000	34,100

*Note: Values rounded for presentation purposes. All values in m^3/a.

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Permits to Take Water

The MOE permit to take water (PTTW) database is a valuable tool in water use estimates. The ‘copy’ of the database used in the Tier One assessment is current to July 2006. This copy was deemed appropriate and provided to SWP staff by the MNR. As part of the assessment, the database was modified in a consistent manner to improve the accuracy of information based upon field investigations. The modifications include removing any permits within the database that are known to have been revoked or replaced. Expired permits have been considered on a case by case basis and removed if it was likely that the permit was no longer being used; this included specific use (i.e. temporary construction or pumping tests were considered to be short term permits and removed). Location searches were also completed and when several permits with the same location were found, the most recent was retained and the others were considered to have been revoked and replaced.

Within permits where multiple sources may have been included and prescribed only one pumping rate, this rate has been divided by the number of sources; for example if there are two wells and one pumping rate of 500 L/day a pumping rate of 250 L/day would be applied to each well. Also, where it could be identified that well water was being pumped to a pond or reservoir to be held for later use, it was considered groundwater taking so that it was not considered twice.

A search of the Environmental Bill of Rights (EBR) website for the study area identified PTTW proposals and decisions that have been issued within the past three years. This search provides location, type of taking and maximum allowable taking. This data has been included in the database discussed above.

The quantities of permitted water taking in the database are generally presented as a maximum taking over a permitted period of time. This maximum taking value has been identified as often being much higher than the actual taking. Several attempts were made to acquire values that are more reflective of actual taking.

During 2005, LSRCA completed a field study, which included site visits to permitted water taking locations to verify a variety of information, most importantly the amount and schedule of the water taking. This included interviewing owners or site staff to discuss water use. It is noted that although the intent was to focus on known permitted locations, information was also collected at several locations, which did not have permits, however these data have not been included in the water taking estimates. The information collected during this study has been used to provide more accurate water taking values than the database.

The MNR ~~has~~ provided a consumption assessment tool with the database discussed above, which provides estimates of the water usage based on each permit. In instances where it has been identified that the permit is likely in use and it was not captured in the LSRCA study, this consumption assessment tool was used as the best available estimate of water use. These values have been adjusted using seasonal and consumptive demand modifiers. Although this tool is a more reasonable approach than using the maximum allowable taking per permit, the value is calculated based on the only value currently available, which is maximum taking.

Every attempt has been made to use the most conservative measures and consistently apply the techniques described above. However, it is known that until a database is produced based on the actual water taking data being collected by the MOE (as a requirement of Regulation 450/07) this variable of the water use estimate will be the source of high uncertainty. A summary of the permits deemed to be in use has been included as Appendix WB-3B and are depicted in Figures 3.2-4 and Figure 3.2-5.

Municipal Water Use

Municipal water taking data have been obtained through previously published reports including; North Simcoe Groundwater Study (Golder, 2005), South Simcoe Groundwater Study (Golder, 2004), Groundwater Modelling of the ORM (Earthfx and Gerber, 2008; Earthfx, 2006), and various other well head protection reports from across the source protection region. The coordinates and reported pumping rates as documented within the above mentioned studies are outlined in Appendix WB-3B. Where possible the actual municipal water taking rates have been used. Some notable water taking scenarios are briefly described below.

City of Barrie

The City of Barrie is currently constructing a surface water treatment plant to provide additional drinking water supplies. Currently, the City of Barrie relies solely on groundwater. The surface water plant is intended to satisfy the demand associated with growth within the city. As a result, existing groundwater use, as summarized in the South Simcoe Groundwater Study (Golder, 2004) was used in the stress assessment for both existing and future conditions.

York Region

York Region is responsible for water supply, production, treatment, storage and distribution, and is the wholesale supplier of water to the nine area municipalities. Groundwater is supplied from municipal wells in Aurora, Newmarket, Holland Landing, Sharon, Queensville, Mount Albert, King City, Nobleton, Schomberg, Stouffville, Ballantrae/Musselman Lake, Ansnorveldt and Kleinburg. Lake Simcoe surface water treatment plants provide municipal water supply for Sutton and Keswick.

In addition to the above, surface water from Lake Ontario is supplementing groundwater supplies in the communities of Aurora and Newmarket, and will most likely be used to satisfy the additional water demand associated with growth.

In 2004, the MOE issued a PTTW to York Region which included Condition (3.3a), which limits the annual average taking to 42,000 m^3/day per year within the municipal drinking water system known as the Young Street Aquifer (Aurora, Newmarket, Holland Landing and Sharon/Queensville). The average pumping rates for 2007 has been acquired from the York Region Staff. The future use, therefore assumes the 42,000 m^3/day will not be exceeded.

City of Kawartha Lakes

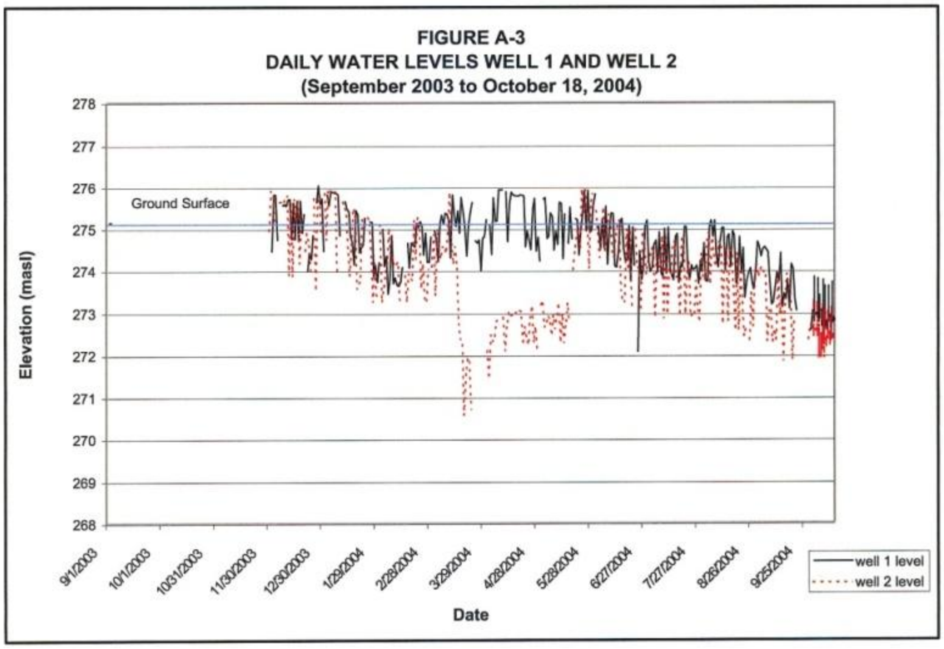

Figure 3-2~~3-1~~: Daily Water Levels Well 1 and 2 (2003-2004)

The City of Kawartha Lakes has confirmed that the municipality historically has imposed water restrictions within the Village of Woodville because the existing municipal water wells cannot adequately meet the demands of the community. The water wells came online in 2003 and since then the water levels have been steadily declining and the wells were never able to meet the demand (410 L/min) they were designed to achieve (Jagger Hims, 1999). The municipal wells are under “stress” from an external influence of unknown origin (Jagger Hims, 2004; 2006). The City of Kawartha Lakes is currently exploring alternatives including the re-development of the former municipal wells which adequately supplied the community, but had been impacted by agricultural influences (i.e., nitrate) (Jagger Hims, 1999). However, according to City of Kawartha Lakes staff, it has been suggested that these agricultural sources are fewer and may not be influencing these wells as in the past. The Village of Woodville lies within the Beaver River subwatershed of the Lake Simcoe basin. This subwatershed is the second largest in size and it is reasoned that the water quantity limitations likely represent a localized situation.

Municipal Surface Water Intakes

Although there are several surface water intakes within the watershed, all of these systems take water from Lake Simcoe and return to it as treated wastewater. Due to the size of the lake, and the low rate of consumption associated with the taking (the vast majority of the water is returned to source), water quantity relative to these municipal intakes within the Source Water Protection Program (MOE, 2008a) is not considered a concern within the scope of this project.

Non-Permitted Water Use

Agriculture Consumption

Under the Ontario Water Resources Act (Revised Statutes of Ontario 1990, Chapter O.40), farmers using 50,000 litres or less per day, and farmers who are taking water for livestock watering but not storing the water, are exempt from obtaining a PTTW, and are therefore non-permitted agricultural consumers. To estimate this agricultural consumption MOE Guidance Module 7 (MOE, 2007) has suggested using water use coefficients documented by de Loe (2001, 2005). The 2001 data compiled by de Loe has been allocated to subwatersheds using area weighting to estimate subwatershed water use as per the following process.

Census data calculated based on municipalities has been used to derive the area within a subwatershed which is agricultural. Area-weighting was then used to determine how to allocate the above calculated areas to subwatersheds. For example, if 50% of Township A is in subwatershed X, then the assumption is that 50% of the water use in Township A occurs within subwatershed X. Since most subwatersheds cross municipal boundaries, the above calculations have been completed for all subwatersheds and townships, and totals have been compiled for each subwatershed. This differs from the recommended methodology outlined by deLoe (2002), in that area weighting assumes that the agricultural area is evenly distributed within each subwatershed.

The coefficients derived by deLoe (2005) have then been applied to each type of agricultural use, to provide a total seasonal and total annual average for each subwatershed. Although this method provides an estimate of water consumption, there is no method to differentiate what is taken from groundwater versus surface water. For the purposes of this report, estimated agricultural taking was considered in both the surface water and groundwater stress assessments to yield the most conservative estimate. Refinement of the agricultural taking through subwatershed-specific Statistics Canada census data will be undertaken in the Tier Two analysis for those parts of the region that are identified as having a water quantity stress.

Unserviced Domestic Water Use

For the purposes of this report an assumption has been made that all households in the study area not serviced by municipal water are obtaining water from a private well. To derive an estimate of the average volume of groundwater used for domestic purposes, the 2006 Statistics Canada census data were used to determine the “un-serviced” population within each subwatershed relying on private wells. This un-serviced population was then multiplied by a per-capita usage of 335 L/day, based on the recommendation within Guidance Module 7 (MOE, 2007). A relatively low consumptive factor (0.2) has been used to calculate water consumption, as residences on private wells most often utilize a private septic system, which returns the majority of water used to the local subsurface. This variable of the water consumption calculation is a relatively small proportion of the overall subwatershed demand and therefore the variation of household use is not a factor that will change the outcome of the stress assessment significantly; therefore this somewhat simple method is suitable for this assessment.

Future Water Use Estimates

Forecasting a future water balance calculation includes many assumptions, such as land use, water use, population growth, changes to municipal servicing and implementation of water conservation and other Best Management Practices to name a few. In accordance with MOE Technical Rules (MOE, 2008a), the methodology to calculate the future demand within the Tier One assessment includes an estimate of increased human consumption.

Population growth forecasts have been applied to domestic use calculations. The anticipated growth as outlined within the respective growth plans for Simcoe County, York and Durham Regions have been applied to the population to provide an estimate of future use over the next 25-years. It is acknowledged that this is likely an exaggeration of water use increases within private domestic use, as the majority of growth will obtain water from municipal servicing. However, the consumptive use calculated are relatively low and do not significantly affect the stress assessment. Table 3.2-13 outlines the current and future population and calculated water use for un-serviced users.

Municipal pumping has been increased by the forecasts outlined within previously mentioned groundwater studies. Exceptions to the forecast in municipal increase in taking are relevant to the East Holland and Barrie Creeks subwatersheds, as noted above.

There are no municipal surface water treatment and supply facilities taking from rivers within the study subwatersheds. All municipal surface water taking is directly from Lake Simcoe. In addition, all private domestic use is assumed to be groundwater and therefore, the current surface water supply estimate will not be increased for future forecasts.

Table 3.2-13: Unserviced Water Consumption Estimates.

Watershed Name	Gauged or Ungauged (G/UG)	Population: Current Scenario	Consumptive Use: Current Scenario	Estimated Growth %	Population: Future Scenario	Consumptive Use: Future Scenario
West Holland	G	6,682	163,000	40%	9,354	229,000
East Holland	G	7,320	179,000	40%	10,249	251,000
Black River	G	14,367	351,000	40%	20,114	492,000
Pefferlaw Brook	G	4,425	108,000	35%	5,974	146,000
Uxbridge Brook	G	3,785	93,000	35%	5,110	125,000
Beaver River	G	2,800	68,000	35%	3,780	92,000
Innisfil Creeks	UG	8,246	202,000	40%	11,544	282,000
Lovers Creeks	UG	942	23,000	40%	1,319	32,000
Talbot River	UG	275	7,000	35%	371	9,000
Whites Creek	UG	1,195	29,000	35%	1,613	39,000
Barrie Creeks	UG	1,127	28,000	40%	1,578	39,000
Georgina Creeks	UG	8,111	198,000	40%	11,356	278,000
Hewitts Creek	UG	1,084	27,000	40%	1,518	37,000
Hawestone Creek	UG	1,357	33,000	40%	1,900	46,000
Maskingonge River	UG	1,222	30,000	40%	1,711	42,000
Oro Creeks North	UG	2,633	64,000	40%	3,686	90,000
Oro Creeks South	UG	4,804	117,000	40%	6,726	164,000
Ramara Creeks	UG	3,357	82,000	40%	4,700	115,000

*Note: Values rounded for presentation purposes. All consumptive use values in m3/a.

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Consumptive Water Use Methodology

The above section outlines the methods used to determine the amount of anthropogenic water taking from each subwatershed. An understanding of the hydrologic cycle substantiates that all of the water being extracted is not being removed from that system. To develop a more conservative and accurate representation, water consumption has been calculated and used within the stress assessment using factors outlined in Table 3.2-14.

Estimating consumptive water demand requires consideration of the hydrologic regime as well as the water use and subsequent discharge. Some water taking, such as, construction dewatering, removes water from a shallow unconfined aquifer and discharges it in close proximity allowing for re-infiltration. In this example, a small percentage of the water is lost. In contrast to this, water being used within a process such as food processing would be a very high loss, as the water is being physically removed with no opportunity to return to the system it has been taken from.

Within this assessment specific water uses have been reviewed and consumptive factors have been applied as deemed appropriate. This includes 100% consumption when water is removed and not returned to the source that it is being taken from; and a lesser consumption factor when a portion of this water is being returned to the same source.

For example, consumptive with respect to the source is defined within MOE Guidance Module 7 (MOE, 2007) as; “Water taken from a source and not returned to that same source, this taking is assumed to be 100% consumptive with respect to the source. Groundwater taking from deep aquifers returned to surface water features fall into this category”.

It is important to note that municipal groundwater taking within the Lake Simcoe watershed is from confined or semi-confined aquifer settings. Municipal water being taken from deep aquifers, and subsequently discharged via sewage treatment, is not being returned to the same groundwater source and possibly not the same subwatershed. Therefore, municipal taking has been considered to be completely consumptive within this stress assessment. Consumptive factors assigned to all other non-municipal water takings have not considered deep aquifer system removal.

Table 3.2-14: Consumptive Use Factors (MOE, 2007).

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Agricultural	Field and Pasture Crops	0.80	Institutional	Hospitals	0.25
Agricultural	Fruit Orchards	0.80	Institutional	Other - Institutional	0.25
Agricultural	Market Gardens / Flowers	0.90	Institutional	Schools	0.25
Agricultural	Nursery	0.90	Miscellaneous	Dams and Reservoirs	0.10
Agricultural	Other - Agricultural	0.80	Miscellaneous	Heat Pumps	0.10
Agricultural	Sod Farm	0.90	Miscellaneous	Other - Miscellaneous	1.00
Agricultural	Tender Fruit	0.80	Miscellaneous	Pumping Test	0.10
Agricultural	Tobacco	0.90	Miscellaneous	Wildlife Conservation	0.25
Commercial	Aquaculture	0.10	Recreational	Aesthetics	0.25
Commercial	Bottled Water	1.00	Industrial	Manufacturing	0.25
Commercial	Golf Course Irrigation	0.70	Industrial	Other - Industrial	0.25
Commercial	Mall / Business	0.25	Industrial	Pipeline Testing	0.25
Commercial	Other - Commercial	1.00	Industrial	Power Production	0.10
Commercial	Snowmaking	0.50	Recreational	Fish Ponds	0.25
Construction	Other - Construction	0.75	Recreational	Other - Recreational	0.10
Construction	Road Building	0.75	Recreational	Wetlands	0.10
Dewatering	Construction	0.25	Remediation	Groundwater	0.50

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Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Dewatering	Other - Dewatering	0.25	Remediation	Other – Remediation	0.25
Dewatering	Pits and Quarries	0.25	Water Supply	Campgrounds	0.20
Industrial	Aggregate Washing	0.10	Water Supply	Communal	0.20
Industrial	Brewing and Soft Drinks	1.00	Water Supply	Municipal	0.20
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.20
Industrial	Food Processing	1.00	-	-	-

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Table 3.2-15: Monthly Water Consumption Adjustments (MOE, 2007).

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural	Field and Pasture	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Fruit Orchards	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Market Gardens/Flowers	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Nursery	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Sod Farm	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tender Fruit	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Tobacco	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Other - Agriculture	0	0	0	0	0	0	1	1	0	0	0	0
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Bottled Water	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Mall/Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Snowmaking	1	1	0	0	0	0	0	0	0	0	0	1
Commercial	Power Production	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Fish Ponds	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other - Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Road Building	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Other - Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1

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General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Pipeline Testing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Hospital	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Schools	1	1	1	1	1	1	0	0	1	1	1	1
Institutional	Other - Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Dams and Reservoirs	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Heat Pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Pumping Test	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Wildlife Conservation	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other - Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Aesthetics	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Wetlands	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Other - Recreational	1	1	1	1	1	1	1	1	1	1	1	1
Remediatipn	Groundwater	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Other - Remediation	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Municipal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Other - Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

*Note: “1” indicates that water is consumed during the indicated month.

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Monthly Usage Factors

Monthly estimates of water use and supply are required to evaluate the transient stress level within a subwatershed. Knowledge of the available water and water use requirements allow for water management during times of the year when it is required. In the study area, low flow, and the majority of pumping are likely to occur during summer months.

The monthly use table, provided within the MOE Guidance Document (MOE, 2007), was used when the months of water taking was otherwise not known. This table is a list of coefficients that have been applied to each permit based on the specific purpose listed. The table has been included as Table 3.2-14, and indicates when water taking is assumed to be active. An assumption has also been made that during these times, water is being taken every day during that month. For the “non-permitted agricultural” consumption, an equivalent taking over a four month period was estimated for this assessment.

A summary of monthly groundwater and surface water consumption based on the previous sections and usage factors have been included as Table 3.2-16and Table 3.2-17 respectively. The values in Table 3.2-16 and Table 3.2-17 are a summary of the monthly PTTW calculations derived using the above mentioned assumptions and the calculated monthly domestic, municipal and agricultural use. The surface water demand is a monthly summary of the PTTW and agricultural calculations. The methods used to determine these values have been discussed within Section 3.2. 3.

Table 3.2-16: Monthly Existing Groundwater Consumption.

Watershed Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
West Holland	28,000	253,000	280,000	271,000	280,000	451,000	487,000	487,000	451,000	280,000	271,000	280,000	4,073,000
East Holland	1,267,000	1,145,000	1,267,000	1,226,000	1,267,000	1,621,000	1,675,000	167,000	1,621,000	1,267,000	1,226,000	1,267,000	16,527,000
Black River	58,000	53,000	58,000	56,000	59,000	536,000	553,000	553,000	536,000	58,000	56,000	58,000	2,635,000
Pefferlaw Brook	30,000	27,000	30,000	29,000	33,000	399,000	412,000	412,000	399,000	33,000	32,000	30,000	1,865,000
Uxbridge Brook	102,000	102,000	102,000	99,000	107,000	153,000	15,900	159,000	153,000	107,000	103,000	102,000	1,438,000
Beaver River	56,000	50,000	56,000	54,000	56,000	111,000	115,000	115,000	111,000	56,000	54,000	56,000	889,000
Innisfil Creeks	39,000	35,000	39,000	38,000	39,000	46,000	48,000	48,000	46,000	39,000	38,000	39,000	493,000
Lovers Creeks	41,000	37,000	41,000	40,000	41,000	71,000	73,000	73,000	71,000	41,000	40,000	41,000	611,000
Talbot River	55,000	49,000	55,000	53,000	55,000	82,000	84,000	84,000	82,000	55,000	53,000	55,000	761,000
Whites Creek	2,000	2,000	200	2,000	200	10,000	11,000	11,000	10,000	2,000	2,000	2,000	61,000
Barrie Creeks	1,123,000	1,014,000	1,123,000	1,086,000	1,123,000	1,087,000	1,123,000	1,123,000	1,087,000	1,123,000	1,086,000	1,123,000	13,187,000
Georgina Creeks	17,000	15,000	17,000	16,000	17,000	90,000	93,000	93,000	90,000	17,000	16,000	1,700	497,000
Hewitts Creek	21,000	19,000	21,000	21,000	21,000	22,000	22,000	22,000	22,000	21,000	21,000	21,000	31,000
Hawestone Creek	8,000	7,000	3,000	3,000	4,000	7,000	7,000	7,000	7,000	4,000	4,000	8,000	70,000
Maskingonge River	157,000	142,000	157,000	152,000	157,000	231,000	238,000	238,000	231,000	157,000	152,000	157,000	2,170,000
Oro Creeks North	9,000	8,000	9,000	8,000	9,000	12,000	13,000	13,000	12,000	9,000	8,000	9,000	118,000
Oro Creeks South	17,000	15,000	17,000	17,000	17,000	20,000	20,000	20,000	20,000	17,000	17,000	17,000	215,000
Ramara Creeks	20,000	18,000	20,000	20,000	20,000	24,000	24,000	24,000	24,000	20,000	20,000	20,000	255,000

*Note: Values rounded for presentation purposes. All values in cubic meters.

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Table 3.2-17: Monthly Existing Surface Water Consumption.

Watershed Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
West Holland	3,000	3,000	3,000	3,000	3,000	693,000	1,499,000	1,499,000	693,000	3,000	3,000	3,000	4,408,000
East Holland	20,000	18,000	20,000	20,000	20,000	767,000	782,000	782,000	767,000	20,000	20,000	20,000	3,256,000
Black River	1000	1,000	1,000	1,000	1,000	872,000	902,000	902,000	872,000	1,000	1,000	1,000	3,556,000
Pefferlaw Brook	-	-	-	-	4,000	332,000	335,000	335,000	332,000	4,000	3,000	-	134,500
Uxbridge Brook	-	-	-	-	-	81,000	81,000	81,000	81,000	-	-	-	324,000
Beaver River	2,000	2,000	2,000	2,000	7,000	102,000	204,000	204,000	102,000	7,000	7,000	2,000	643,000
Innisfil Creeks	100	100	100	100	100	69,500	91,600	91,600	69,500	100	100	100	323,000
Lovers Creeks	-	-	-	-	-	14,000	15,000	15,000	14,000	-	-	-	58,000
Talbot River	1,000	1,000	1,000	1,000	1,000	15,000	15,000	15,000	15,000	1,000	1,000	1,000	68,000
Whites Creek	-	-	-	-	-	19,000	19,000	19,000	19,000	-	-	-	76,000
Barrie Creeks	-	-	-	-	-	-	-	-	-	-	-	-	-
Georgina Creeks	44,000	40,000	440,000	42,000	44,000	283,000	287,000	287,000	283,000	44,000	42,000	44,000	1,484,000
Hewitts Creek	-	-	-	-	-	2,000	2,000	2,000	2,000	-	-	-	8,000
Hawestone Creek	1,000	1,000	1,000	1,000	1,000	7,000	7,000	7,000	7,000	1,000	1,000	1,000	36,000
Maskingonge River	-	-	-	-	-	264,000	267,000	267,000	264,000	-	-	-	1,062,000
Oro Creeks North	-	-	-	-	30,000	37,000	38,000	38,000	37,000	30,000	29,000	-	239,000
Oro Creeks South	3,000	3,000	3,000	3,000	3,000	12,000	12,000	12,000	12,000	3,000	3,000	3,000	72,000
Ramara Creeks	-	-	-	-	-	9,000	9,000	9,000	9,000	-	-	-	36,000

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Uncertainty

Water demand estimates are subject to various levels of uncertainty. The methods used to develop an understanding of the total amount of water demand within each subwatershed have been discussed within the previous sections. In applying these methods, attempts have been made to be both consistent and conservative, in order to produce a stress assessment as accurately as possible. In accordance with that, the limitations and assumptions of each data source should be recognized.

Attempts to verify water use within subwatersheds have made the PTTW database more accurate; however, it is known that the maximum permitted taking values used are exaggerating the actual taking. This 'as high as possible' value has been used to ensure that all possibly stressed subwatersheds are identified within the Tier One.

Now all municipal drinking water facilities are required to keep and report records of water takings. This information has been obtained directly from the municipalities, and is considered accurate and complete. The level of certainty within this data is a benefit as municipal wells are often the most significant water takers within a subwatershed.

The simple method of applying a consumptive usage factor to population data has been used to estimate non-municipal domestic water use, as suggested in the Guidance Module 7 (MOE, 2007). This method is effective for this level of assessment; however, there is uncertainty as individual water use will vary significantly between households.

Non-permitted agricultural demand has been calculated based on coefficients and Statistics Canada census data, as it is a general calculation uncertainty is inherent. A modified version of methodology outlined by de Loe (2001, 2005) to estimate water use based on agricultural land use has been used. This method is a general estimate of water use and, although the uncertainty of these calculations is higher than other water demand estimates, they are considered adequate for the purposes of this Tier One screening level stress assessment.

Water Quantity Stress Assessment

The Tier One stress assessment is designed to efficiently screen subwatersheds and highlight those where the degree of stress warrants refined water budget efforts for risk characterization. The stress assessment evaluates the ratio of the consumptive water demand for permitted and non-permitted users to available water supplies, minus water reserves within a subwatershed.

The percent water demand has been evaluated independently for both groundwater and surface water. At the Tier One level two scenarios are evaluated for each subwatershed: 1) existing conditions; and 2) future demand. The goal of the existing conditions scenario is to identify subwatersheds that are under stress as a result of existing water takings. Whereas the goal of the future scenario is to identify additional subwatersheds that may become stressed as a result of additional drinking water requirements.

Table 3.2-18 presents the list of scenarios for groundwater and surface water supplies. As this table indicates, groundwater systems are evaluated for both average annual and monthly conditions, whereas surface water conditions are evaluated monthly. An annual average surface water flow would not be appropriate for a stress assessment, as stream flow changes rapidly based on variables such as precipitation, spring freshet, and summer drought. The prescribed approach for determining the surface water quantity stress takes into consideration seasonal variability and is therefore evaluated using an estimate of expected monthly values. Conversely, an evaluation of the average annual conditions for groundwater is useful for evaluating potential long-term stress conditions. The water demand is calculated for each month, and the largest monthly stress is selected for comparison against the threshold criteria.

Table 3.2-18: Tier One Stress Assessment Scenarios.

Time Period	Average Annual % Water Demand	Highest Monthly % Water Demand
Existing Conditions	Groundwater Sources	Groundwater & Surface Water Sources
Future Conditions	Groundwater Sources	Groundwater & Surface Water Sources

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Based on the percent water demand equation below, each subwatershed was assigned a stress level for groundwater and for surface water. Those subwatersheds receiving a low level of stress will require no further water budgeting or water quantity risk assessment work.

Those areas identified as having a moderate to significant level of stress will be subject to further water budget evaluation under Tier Two, provided that the subwatershed contains a municipal water supply system.

$$(\%)WaterDemand = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} \qquad (4)$$

where;

Q_{Demand} = the amount of water (surface water or groundwater) consumed as described in Section 3.2.3;

Q_{Supply} = recharge for groundwater uses assuming any subwatershed groundwater inflow is balanced by groundwater outflow and median monthly streamflow for surface water takings as described in Section 3.2.2;

$Q_{Reserve}$ = the proportion of available surface water or groundwater that is to be maintained for other needs such as navigation, assimilative capacity, ecosystem health etc. (to be estimated as a proportion of baseflow and a low-flow statistic for groundwater and surface water, respectively) as described in Section 3.2.2.

Table 3.2-19: Stress Assessment Thresholds.

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

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The monthly maximum conditions for the groundwater stress thresholds are higher than average annual thresholds because groundwater supplies can typically tolerate short-term water demands that may not be sustainable over the entire year. Therefore, the groundwater stress level assignment is the maximum of the existing and future assessment values for both conditions.

It should be noted that these thresholds are intended to be conservative to ensure that areas potentially under hydrologic stress will be identified for additional study.

Tier One Stress Assessment

Municipal groundwater taking within the Lake Simcoe watershed is from confined or semi-confined aquifer settings. Municipal water being taken from deep aquifers, and subsequently discharged via sewage treatment, is not being returned to the same groundwater source and possibly not the same subwatershed. Therefore municipal taking has been considered to be completely consumptive within this stress assessment.

It should be noted that in some cases the amount of stress identified within a subwatershed is greater than 100%. A stress greater than 100% is a result of the amount of water being taken is larger than the amount that has been identified as being available. Although this is not physically possible, it does indicate that if the entire permitted water taking within a subwatershed was considered as cumulative and maximum takings were needed, there would not likely be enough water to supply all users. This is also a result of many of permitted water users taking during the same time of year (summer months), instead of being spread over the entire year, which coincides with non-permitted takings (e.g. agricultural uses) during the same time of year. The stresses greater than 100% identified within this report are a result of conservative water demand estimates that are known to be the worst case scenario.

Existing Conditions

<u>Percent Annual Water Demand-Groundwater</u>

Based on the results of the groundwater stress assessment discussed above, under existing conditions, four subwatersheds within the Lake Simcoe watershed exceed the threshold for moderate water quantity stress (Table 3.2-22, Figure 3.2-6). The East Holland River and Barrie Creeks are within the significantly stressed threshold and the Maskinonge River and West Holland River is within the moderately stressed threshold. In addition, the Beaver River subwatershed would be added since the Woodville Water Supply wells have not been in normal operation since 2004, when the municipality imposed water quantity restrictions due to the declining water levels in the municipal and neighboring wells.

Municipal water taking is considered to be 100 percent consumptive because it is being extracted from confined or semi-confined aquifers, and subsequently discharged directly to surface water. Within the East Holland subwatershed municipal water supply represents the primary water demand, with additional demand attributed to agriculture. The MOE has historically expressed concern regarding the sustainability of the water takings from the East Holland subwatershed, given the number and quantity of groundwater takings in the Yonge Street Aquifer area. As a result, several studies have been completed for the Yonge Street aquifer to assess both the water quantity and quality effects of the groundwater takings, and to determine the sustainable yield of the aquifer. The municipal consumption of groundwater from the Yonge Street Aquifer was limited in 2005 by the existing PTTW, and additional water demand for this area is being met with surface water. As a result, general groundwater level trends in the area, over the past several years, reflect this stabilization in groundwater usage. The municipal taking in the Barrie Creeks subwatershed constitutes the primary demand. Hydrogeological investigations in previous efforts suggest that the recharge area for the aquifer is broader than the subwatershed itself, resulting in the exaggerated stress calculation.

Water demand within the Maskinonge River subwatershed is primarily for meeting municipal water supply and irrigation requirements. Recently, flow in the Maskinonge River during dry summer periods ceases for all practical purposes, and significant concerns over associated ecological impacts have been raised by community groups in the watershed.

Percent Monthly Water Demand-Groundwater

In addition to the above mentioned existing annual stress monthly occurrences of groundwater stress have been identified and are summarized on Table 3.2-20. Detailed monthly groundwater stress assessments are located in appendix WB-3B. All of the identified seasonal groundwater stresses are a result of increased pumping for irrigation (domestically or commercially or for agriculture); and less available water during dryer summer months. The use of a "pro-rated" [7]annual supply within the monthly stress assessments tends to "average" the influences as presented in Table 3.2-20.

Percent Monthly Water Demand-Surface Water

Within the summer months, surface water stress assessments indicate elevated stress values within several subwatersheds summarized on Table 3.2-21 and Figure 3.2-7. Detailed monthly surface water stress assessments are located in Appendix WB-3B. These elevated values are attributed to low available supply values calculated using the Tessmann method. For example, Hewitt's Creek in July has a total flow value of 0.026 m^3/s and the value calculated using Tessmann's method for reserve is 0.023 m^3/s. This estimates the available supply to be 0.003 m^3/s. It can be seen that this available supply affords very little taking before it is considered stressed. Although it has been recognized that these values are exaggerated they have not been adjusted to a lower reserve, as the outcome will not induce a Tier Two study and the stress within these systems is considered valid during summer months.

It is also noted that the estimated water taking within the Black and Holland River subwatersheds is considerably higher than surrounding subwatersheds within July and August. This high taking is attributed to agricultural use in the area of the Holland Marsh and surrounding lands. Although there are permit holders in this area it is known that additional non-permitted water is being taken. An Environmental Assessment completed in the area of the Holland Marsh Polder (CH_2MHill, 2004), estimated that the main pumping station used to control water within the marsh pumps 438.5 million litres per day. It is possible, due to the high amount of pumping and the elevation of the pumping station, that this station is extracting back-water from Lake Simcoe during times when the river is low, although gauging data are not available.

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[7] Pro-rated annual supply refers to methodology prescribed in Technical Rule 1(2) which states; "Groundwater supply is calculated as the estimated annual groundwater recharge rate plus the annual estimated groundwater inflow into a subwatershed. To establish monthly amounts the annual amount shall be divided by 12." This methodology tends to average the estimated monthly stress assessments.

If this seasonal water taking is largely backwater from Lake Simcoe, the estimated stress on the Holland subwatershed from Table 3.2-21 is likely overestimated. Further, although stress has been identified within this subwatershed, there are no municipal surface water supplies within the subwatershed. Therefore, further study as part of the Source Water Protection program is not required.

Although ten subwatersheds within the Lake Simcoe watershed were identified as having a moderate or significant potential for stress with respect to surface water, no subwatersheds will be undergoing a Tier Two surface water assessment for a surface water supply. This is because they do not contain a municipal drinking water supply source or are exempt from consideration in the water budget process per Technical Rule 4[8] (MOE, 2008a).

All of the municipal surface water systems within the watershed take water from Lake Simcoe. The Technical Rules (MOE, 2008a), has prescribed that subwatersheds that take from the large lakes, including of course the Great Lakes, should not be included in the stress assessment.

Although, the terms of this program do not require further surface water stress assessment within this watershed, the monthly stress assessments indicate that water taking is causing stress in various subwatersheds (Appendix WB-3). It appears, from the review of the PTTW database, the field studies completed, and the stress assessments in this report, that the permitting system could be improved to better reflect actual and cumulative water taking relative to annual and seasonal supplies.

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[8] Technical Rule 4: “An area represented by a conceptual water budget or water budget prepared in accordance with rule 3 shall not include any part of a surface water body that is a Great Lake, a connecting channel, Lake Simcoe, Lake Nipissing, Lake St.Clair or the Ottawa River (MOE, 2008a)”.

Table 3.2-20: Monthly Groundwater Stress Assessment Summary.

Subwatershed	Gauged or Ungauged (G / UG)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West Holland	G	10%	9%	11%	12%	10%	15%	16%	16%	15%	10%	10%	10%
East Holland	G	62%	56%	66%	67%	64%	77%	79%	78%	77%	61%	61%	63%
Black River	G	1%	1%	1%	1%	1%	10%	10%	10%	9%	1%	1%	1%
Pefferlaw Brook	G	1%	1%	1%	1%	1%	11%	11%	11%	11%	1%	1%	1%
Uxbridge Brook	G	6%	6%	7%	7%	7%	9%	9%	9%	9%	6%	6%	6%
Beaver River	G	1%	1%	1%	1%	1%	2%	2%	2%	2%	1%	1%	1%
Innisfil Creeks	UG	2%	2%	2%	2%	2%	2%	3%	3%	3%	2%	2%	2%
Lovers Creek	UG	5%	4%	5%	5%	5%	8%	8%	8%	8%	5%	4%	5%
Talbot River	UG	4%	3%	4%	4%	4%	5%	5%	5%	5%	4%	3%	4%
Whites Creek	UG	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Barrie Creeks	UG	169%	152%	171%	168%	169%	161%	165%	165%	160%	167%	163%	169%
Georgina Creeks	UG	2%	2%	2%	2%	2%	10%	11%	11%	10%	2%	2%	2%
Hewitts Creek	UG	8%	7%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Hawkestone Creek	UG	1%	1%	0%	0%	0%	1%	1%	1%	1%	0%	0%	1%
Maskinonge River	UG	17%	16%	18%	18%	18%	25%	26%	26%	25%	17%	17%	18%
Oro Creeks North	UG	1%	0%	1%	0%	1%	1%	1%	1%	1%	1%	0%	1%
Oro Creeks South	UG	1%	1%	1%	1%	1%	2%	2%	2%	2%	1%	1%	1%
Ramara Creeks	UG	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

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***>25% is considered moderately stressed, >50% is considered significantly stressed**

Table 3.2-21: Monthly Surface Water Stress Assessment Summary.

Subwatershed	Gauged or Ungauged (G / UG)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West Holland	G	0%	0%	0%	0%	0%	54%	219%	182%	66%	0%	0%	0%
East Holland	G	2%	2%	1%	1%	1%	65%	86%	81%	82%	3%	1%	1%
Black River	G	0%	0%	0%	0%	0%	58%	50%	91%	125%	0%	0%	0%
Pefferlaw Brook	G	0%	0%	0%	0%	0%	25%	34%	34%	27%	0%	0%	0%
Uxbridge Brook	G	0%	0%	0%	0%	0%	10%	14%	14%	10%	0%	0%	0%
Beaver River	G	0%	0%	0%	0%	0%	8%	21%	22%	9%	0%	0%	0%
Innisfil Creeks	UG	0%	0%	0%	0%	0%	13%	24%	35%	46%	0%	0%	0%
Lovers Creek	UG	0%	0%	0%	0%	0%	6%	10%	9%	9%	0%	0%	0%
Talbot River	UG	0%	0%	0%	0%	0%	5%	7%	7%	8%	0%	0%	0%
Whites Creek	UG	0%	0%	0%	0%	0%	7%	11%	9%	14%	0%	0%	0%
Barrie Creeks	UG	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Georgina Creeks	UG	19%	19%	4%	4%	13%	143%	255%	231%	265%	21%	13%	11%
Hewitts Creek	UG	0%	0%	0%	0%	0%	6%	21%	5%	4%	0%	0%	0%
Hawkestone Creek	UG	0%	0%	0%	0%	0%	5%	8%	6%	7%	0%	0%	0%
Maskinonge River	UG	0%	0%	0%	0%	0%	93%	148%	132%	134%	0%	0%	0%
Oro Creeks North	UG	0%	0%	0%	0%	5%	11%	16%	18%	22%	9%	5%	0%
Oro Creeks South	UG	1%	2%	0%	0%	1%	9%	18%	13%	18%	2%	1%	1%
Ramara Creeks	UG	0%	0%	0%	0%	0%	3%	5%	5%	26%	0%	0%	0%

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***>25% is considered moderately stressed, >50% is considered significantly stressed**

Table 3.2-22: Existing Annual Groundwater Stress Assessment.

Parameter	West Holland	East Holland	Black River	Pefferlaw Brook	Uxbridge Brook	Beaver River	Innisfil Creeks	Lovers Creek	Talbot River
Area (km2)	352	247	375	285	161	327	107	60	71
Precipitation (mm/a)	809	816	848	852	831	904	875	873	957
Evapotranspiration (mm/a)	564	566	562	561	560	560	561	560	557
Surplus Water (mm/a)	245	250	286	291	271	344	315	313	400
Annual Mean Flow (mm/a)	3.0	1.8	2.5	2.5	1.6	3.2	0.6	0.4	0.5
Annual Mean Flow (m3/s)	270	234	212	275	311	307	186	232	235
Baseflow (mm/a)	1.5	0.7	1.4	1.4	0.9	1.7	0.3	0.2	0.2
Baseflow (m3/s)	134	92	113	151	180	165	82	110	107
Available Groundwater Supply (mm/a)	109	108	187	166	140	202	211	192	272
Available Groundwater Supply (m3/s)	1.2	8.0	2.2	1.5	0.7	2.1	0.7	0.4	0.6
Available Surface Water Supply (mm/a)	157	144	129	206	234	204	109	195	181
Available Surface Water Supply (m3/s)	1.8	1.1	1.5	1.9	1.2	2.1	0.4	0.4	0.4
Groundwater Reserve (mm/a)	13	9	11	15	18	16	8	11	11
Groundwater Reserve (m3/s)	0.15	0.07	0.13	0.14	0.09	0.17	0.03	0.02	0.02
Surface Water Reserve (mm/a)	49	51	39	96	108	38	61	74	72
Surface Water Reserve (m3/s)	0.6	0.4	0.5	0.9	0.6	0.4	0.2	0.1	0.2
Groundwater Consumption (m3/a)	4,073,000	16,527,000	2,635,000	1,865,000	1,438,000	888,000	493,000	610,000	761,000
Groundwater Consumption (mm/a)	12	67	7	7	9	3	5	10	11
Groundwater Stress* (%)	**12%**	**68%**	**4%**	**4%**	**7%**	**1%**	**2%**	**6%**	**4%**

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Parameter	Whites Creek	Barrie Creeks	Georgina Creeks	Hewitts Creek	Hawkestone Creek	Maskinonge River	Oro Creeks North	Oro Creeks South	Ramara Creeks
Area (km2)	105	38	49	18	48	63	75	57	144
Precipitation (mm/a)	962	905	882	890	960	863	975	940	962
Evapotranspiration (mm/a)	557	563	561	562	563	561	564	563	558
Surplus Water (mm/a)	405	341	320	328	397	301	411	377	404
Annual Mean Flow (mm/a)	0.8	0.3	0.3	0.1	0.4	0.4	0.6	0.3	0.8
Annual Mean Flow (m3/s)	247	226	188	240	246	222	254	191	182
Baseflow (mm/a)	0.4	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.3
Baseflow (m3/s)	114	109	83	108	119	99	12	77	73
Available Groundwater Supply (mm/a)	271	225	215	196	269	179	279	263	294
Available Groundwater Supply (m3/s)	0.9	0.3	0.3	0.1	0.4	0.4	0.7	0.5	1.3
Available Surface Water Supply (mm/a)	149	218	147	302	199	196	180	122	75
Available Surface Water Supply (m3/s)	0.5	0.3	0.2	0.2	0.3	0.4	0.4	0.2	0.3
Groundwater Reserve (mm/a)	11	11	8	11	12	10	12	8	7
Groundwater Reserve (m3/s)	0.04	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.03
Surface Water Reserve (mm/a)	75	73	57	71	78	67	83	56	54
Surface Water Reserve (m3/s)	0.3	0.1	0.1	0.04	0.1	0.1	0.2	0.1	0.1
Groundwater Consumption (m3/a)	61,000	13,220,000	496,000	257,000	69,000	2,170,000	118,000	215,000	255,000
Groundwater Consumption (mm/a)	1	352	10	15	1	34	2	4	2
Groundwater Stress* (%)	**0%**	**165%**	**5%**	**8%**	**1%**	**20%**	**1%**	**1%**	**1%**

*>25% is considered moderately stressed, >50% is considered significantly stressed.

Future Conditions

Percent Annual Water Demand – Groundwater

The results of this estimated future scenario indicate that the subwatersheds subject to an existing stress remain stressed or see an elevation in the stress threshold. Additionally, based upon forecast demand, the Uxbridge Brook, and Hewitts Creek subwatersheds reached the 10% threshold of supply.

As well, the Lovers Creek subwatershed falls within a "zone of uncertainty" (i.e., 8% to 10% threshold of supply). Subwatersheds that fall within this zone can be considered if they reach the 10% threshold in the sensitivity analysis, since the evaluation while presumably conservative is simplistic.

Percent Monthly Water Demand- Groundwater

In addition to the above mentioned future annual stress, as outlined within Table 3.2-23 above, monthly occurrences of groundwater stress have been identified for East Holland, and Barrie Creek subwatersheds. The future monthly stress assessments are located within Appendix WB-3.

Percent Monthly Water Demand- Surface Water

Future surface water monthly stress assessments indicated East and West Holland, Pefferlaw Brook, Georgina Creeks, Black River, Innisfil Creek, Ramara Creeks, Beaver River, Hewitts Creek, Oro Creeks North and the Maskinonge River had monthly occurrences of surface water stress. However, there are no municipal intakes within these subwatersheds and therefore are exempt from further evaluation per Technical Rule 4 [9](MOE, 2008a). These tables are also shown in Appendix WB-3.

Sensitivity Analysis

A sensitivity analysis was completed for those subwatersheds that reached a percent water demand of 8% but were still below the 10% threshold. It is recognized that slight variations in some parameter estimates could alter the stress assessment sufficiently such that the subwatershed stress level could exceed the 10% threshold. The sensitivity analysis included two different scenarios, increasing the water demand by 10% or decreasing the precipitation by 10% to determine if the percent water demand would reach the 10% threshold.

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[9] Technical Rule 4: An area represented by a conceptual water budget or water budget prepared in accordance with rule 3 shall not include any part of a surface water body that is a Great Lake, a connecting channel, Lake Simcoe, Lake Nipissing, Lake St.Clair or the Ottawa River.

However, only a 5% decline in the average precipitation resulted in the Lovers Creek subwatersheds exceeding the 10% threshold value. This sensitivity level was considered sufficiently small enough to recommend that this additional subwatershed area also be considered for a Tier Two evaluation.

Table 3.2- 23: Future Annual Groundwater Stress Assessment.

Parameter	West Holland	East Holland	Black River	Pefferlaw Brook	Uxbridge Brook	Beaver River	Innisfil Creeks	Lovers Creek	Talbot River
Area (km2)	352	247	375	285	161	327	107	60	71
Precipitation (mm/a)	809	816	848	852	831	904	875	873	957
Evapotranspiration (mm/a)	564	566	562	56	560	560	561	560	557
Surplus Water (mm/a)	245	250	286	291	271	344	315	313	400
Annual Mean Flow (mm/a)	3.0	1.8	2.5	0.5	1.6	3.2	0.6	0.4	0.5
Annual Mean Flow (m3/s)	270	234	212	275	311	307	186	323	235
Baseflow (mm/a)	1.5	0.7	1.4	1.4	0.9	1.7	0.3	0.2	0.2
Baseflow (m3/s)	134	92	113	151	180	165	82	110	107
Available Groundwater Supply (mm/a)	109	108	187	166	140	202	211	192	272
Available Groundwater Supply (m3/s)	1.2	0.8	2.2	1.5	0.7	2.1	0.7	0.4	0.6
Available Surface Water Supply (mm/a)	157	144	129	206	234	204	109	195	181
Available Surface Water Supply (m3/s)	1.8	1.1	1.5	1.9	1.2	2.1	0.4	0.4	0.4
Groundwater Reserve (mm/a)	13	9	11	15	18	16	8	11	11

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Groundwater Reserve (m3/s)	0.15	0.07	0.13	0.14	0.09	0.17	0.03	0.02	0.02
Surface Water Reserve (mm/a)	49	51	39	96	108	38	61	74	72
Surface Water Reserve (m3/s)	0.6	0.4	0.5	0.9	0.6	0.4	0.2	0.1	0.2
Groundwater Consumption (m3/a)	4,483,000	18,268,000	3,101,000	1,903,000	3,370,615	1,731,000	678,000	928,000	763,000
Groundwater Consumption (mm/a)	13	74	8	7	21	5	6	15	11
Groundwater Stress* (%)	**13%**	**75%**	**5%**	**4%**	**17%**	**3%**	**3%**	**9%**	**4%**

Parameter	Whites Creek	Barrie Creeks	Georgina Creeks	Hewitts Creek	Hawkestone Creek	Maskinonge River	Oro Creeks North	Oro Creeks South	Ramara Creeks
Area (km2)	105	38	49	18	48	63	75	57	144
Precipitation (mm/a)	962	905	882	890	960	863	975	940	962
Evapotranspiration (mm/a)	557	563	561	562	563	561	564	563	558
Surplus Water (mm/a)	405	341	320	328	397	301	411	377	404
Annual Mean Flow (mm/a)	0.8	0.3	0.3	0.1	0.4	0.4	0.6	0.3	0.8
Annual Mean Flow (m3/s)	247	226	188	240	246	222	254	191	182
Baseflow (mm/a)	0.4	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.3
Baseflow (m3/s)	114	109	83	108	119	99	122	191	182

Available Groundwater Supply (mm/a)	271	225	215	196	269	279	279	263	294
Available Groundwater Supply (m3/s)	0.9	0.3	0.3	0.1	0.4	0.4	0.7	0.5	1.3
Available Surface Water Supply (mm/a)	149	218	147	302	199	196	180	122	75
Available Surface Water Supply (m3/s)	0.5	0.3	0.2	0.2	0.3	0.4	0.4	0.2	0.3
Groundwater Reserve (mm/a)	11	11	8	11	12	10	12	8	7
Groundwater Reserve (m3/s)	0.04	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.03
Surface Water Reserve (mm/a)	75	73	57	71	78	67	83	56	54
Surface Water Reserve (m3/s)	0.3	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.2
Groundwater Consumption (m3/a)	71,000	13,231,000	576,000	357,000	149,000	2,182,000	146,000	876,000	288,000
Groundwater Consumption (mm/a)	1	353	12	20	3	34	2	15	2
Groundwater Stress* (%)	**0%**	**165%**	**6%**	**11%**	**1%**	**20%**	**1%**	**6%**	**1%**

***>25% is considered moderately stressed, >50% is considered significantly stressed.**

Table 3.2-24: Annual Water Balance.

Parameter	West Holland	East Holland	Black River	Pefferlaw Brook	Uxbridge Brook	Beaver River	Innisfil Creeks	Lovers Creek	Talbot River
Area (km2)	352	247	375	285	161	327	107	60	71
Precipitation (mm/a)	809	816	848	852	831	904	875	873	957
Anthropogenic Inputs (mm/a)	-	0.2	-	-	-	-	-	-	-
Surface Water Inputs (mm/a)	-	-	-	-	-	-	-	-	2.2
Evapotranspiration (mm/a)	564	566	562	561	560	560	561	560	557
Anthropogenic Outputs - Waste (mm/a)	-	4.6	-	-	-	-	-	-	-
Anthropogenic Outputs - Consumption (mm/a)	12	67	7	7	9	3	5	10	11
Surface Water Outputs (mm/a)	270	234	212	275	311	307	186	232	235
Water Balance - Net Difference (mm/a)	-37	-55	67	9	-49	35	124	71	156
Water Balance - % Difference	-5%	-7%	8%	1%	-6%	4%	14%	8%	16%
Parameter	**Whites Creek**	**Barrie Creeks**	**Georgina Creeks**	**Hewitts Creek**	**Hawkestone Creek**	**Maskinonge River**	**Oro Creeks North**	**Oro Creeks South**	**Ramara Creeks**
Area (km2)	105	38	49	18	48	63	75	57	144
Precipitation (mm/a)	962	905	882	890	960	863	975	940	962
Anthropogenic Inputs (mm/a)	-	-	-	-	-	-	-	-	-
Surface Water Inputs (mm/a)	-	-	-	-	-	-	-	-	-
Evapotrans-piration (mm/a)	557	563	561	562	563	561	564	563	558

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Anthropogenic Outputs - Waste (mm/a)	-	-	-	-	-	-	-	-	-
Anthropogenic Outputs - Consumption (mm/a)	1	352	10	15	1	34	2	4	2
Surface Water Outputs (mm/a)	247	226	188	240	246	222	254	191	182
Water Balance - Net Difference (mm/a)	157	-236	122	73	149	46	156	183	220
Water Balance - % Difference	16%	-26%	14%	8%	16%	5%	16%	19%	23%

Tier One Stress Assessment Summary

Table 3.2-24 summarizes the results of the Tier One Stress Assessment. Subwatersheds which currently exceed the moderate and significant thresholds for potential stress are also projected to exceed the thresholds in the future. Identified monthly groundwater and surface water stress is a result of increased demand for municipal supplies, industrial and commercial practices as well as agricultural irrigation. The subwatersheds identified as having a monthly surface water stress beyond the moderate threshold are exempt from undergoing the Tier Two process as per MOE Technical Rule 4 (MOE, 2008a).

Table 3.2- 25: Tier One Stress Assessment Summary.

Subwatershed	Current Annual Conditions: Groundwater	Future Annual Conditions: Groundwater	Current Monthly Conditions: Groundwater	Current Monthly Conditions: Surface Water	Future Monthly Conditions: Groundwater	Future Monthly Conditions: Surface Water	Municipal System: Groundwater	Municipal System: Surface Water
West Holland	12%	13%	-	Jun-Sept	All	Jun-Sept	Yes	No
East Holland	68%	75%	All	Jun-Sept	All	Jun-Sept	Yes	No
Black River	4%	5%	-	Jun-Sept	-	Jul-Sept	Yes	No
Pefferlaw Brook	4%	4%	-	Jun-Sept	-	Jul-Sept	No	No
Uxbridge Brook	7%	17%	-	-	All	-	Yes	No
Beaver River	1%	3%	-	Jul-Aug	-	-	Yes	No
Innisfil Creeks	2%	3%	-	Jul-Sept	-	Aug-Sept	Yes	No
Lovers Creek	6%	9%	**	-	-	-	Yes	No
Talbot River	4%	4%	-	-	-	-	No	No
Whites Creek	0%	0%	-	-	-	-	No	No
Barrie Creeks	165%	165%	All	-	All	-	Yes	No
Georgina Creeks	5%	6%	-	Jun-Sept	-	Jul-Sept	No	No

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Subwatershed	Current Annual Conditions: Groundwater	Future Annual Conditions: Groundwater	Current Monthly Conditions: Groundwater	Current Monthly Conditions: Surface Water	Future Monthly Conditions: Groundwater	Future Monthly Conditions: Surface Water	Municipal System: Groundwater	Municipal System: Surface Water
Hewitts Creek	8%	11%	-	Jul	All	-	Yes	No
Hawkestone Creek	1%	1%	-	-	-	-	Yes	No
Maskinonge River	20%	20%	Jul-Aug	Jun-Sept	All	Jun-Sept	Yes	No
Oro Creeks North	1%	1%	-	Sept	-	-	Yes	No
Oro Creeks South	1%	6%	-	-	-	-	Yes	No
Ramara Creeks	1%	1%	-	Sept	-	Sept	Yes	No
Moderate Stress Conditions	***>10%***	***>10%***	***>25%***	***>20%***	***>25%***	***>20%***	**-**	**-**
Significant Threat Conditions	***>=25%***	***>=25%***	***>=50%***	***>=50%***	***>=50%***	***>=50%***	**-**	**-**

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* as per technical rule 33 (2) 9c) (i)(ii)

** a 5% decline in the average precipitation results in the Lovers Creek subwatershed exceeding the 10%. Therefore the Subwatershed is recommended for a Tier Two Assessment.

Note: Some communities built surface water intakes after the completion of the Tier 1 Study, for example, the City of Barrie.

Uncertainty

In applying these methods, attempts have been made to be both consistent and conservative, in order to produce a stress assessment as accurately as possible. In accordance with that, the limitations and assumptions of each data source should be recognized. The assumptions made that reduce the certainty of the estimations include; in-filling long term precipitation data, estimating the areal distribution, calculating streamflow within ungauged watercourses, and errors inherent in automated baseflow separation techniques. These methods are widely used, have been recommended within MOE Guidance Module 7 (MOE, 2007). They have been deemed appropriate for the broad purposes of the assessment report. Further study to refine these methods will be completed within the Tier Two assessment, where necessary, based upon estimated water quantity stresses.

Tier One screening assessments are intended to be conservative such that all areas of potentially moderate to significant stress are captured and moved forward for further study. As a result of this conservative approach, a high level of confidence can be placed on the identification of potentially stressed subwatersheds. All methods discussed in this report have been derived from published literature, considerably refined in some cases, and the data produced evaluated against previous studies as a check on the validity of results.

The objective of the Tier One is to be conservative to ensure that all possible stress is identified. The further more refined Tier Two is intended to confirm or negate this stress. Throughout the report methods which have inherent uncertainty have been identified, these methods and the rational for use have been discussed above in the methods section. The following discusses the uncertainty and rationale for each method used.

Areal Distribution

Using several gauges over a large land area generalizes the results making them possibly bias high or low. The calculated precipitation and AET have been compared to other published work in an attempt to reduce uncertainty.

Ungauged Streamflow

The method used is considered the best available science in situations where no gauged data is available; however, use of this method introduces uncertainty.

Water Supply Estimates

Attempts to verify water use within subwatersheds have made the PTTW database more accurate; however, it is known that the maximum permitted taking values used are exaggerating the actual taking. This ‘as high as possible’ value has been used to ensure that all possibly stressed subwatersheds are identified within the Tier One.

Non-permitted agricultural demand has been calculated based on coefficients and Statistics Canada census data, as it is a general calculation uncertainty is inherent.

Domestic use has been determined based on an average number and population data. Variation between household and changes in population introduce uncertainty to this method.

Monthly Demand Adjustments

These are general values based on industry averages and could change significantly from year to year based on changes within industry.

Consumptive Demand Factors

These are general factors based on use averages and could change significantly depending on the water management within each user organization.

In all of the above methods the most conservative approach has been used, in order to ensure all possibly stressed subwatersheds are identified.

Data and Knowledge Gaps

One of the most difficult variables of the Tier One Water Budget to quantify is water demand. The methods used within this report are the best available and provide reasonable results. However, the variables included in these methods introduce uncertainty which should be reduced in more complex assessments. Some of these refinements could include the actual water taking data currently being collected by the MOE under Regulation 387/04, a more complete understanding of agricultural use based on actual farming practices, and improved seasonal water taking for certain land uses.

For the purposes of this assessment, quantification of groundwater movement into and out of subwatersheds has been excluded, as has movement between aquifer units within a subwatershed which is important when considering pumping from deep confined aquifers. To quantify stresses upon confined groundwater supplies, an understanding of not only groundwater recharge, but aquifer recharge and discharge is required.

Conclusions and Recommendations

The objective of the Tier One was to identify, through a recommended screening process, subwatersheds which are and are not under stress as a result of water use. The conservative methods used and data obtained as described in the report are adequate to identify these stressed and unstressed subwatersheds. As a result, additional study is required on only half of the study area. This reduction of the spatial scale provides a narrower scope for the Tier Two projects, allowing resources to be focused and results to be refined.

As a result of the findings presented in this report and summarized in Table 3.2- 25 and Figure 3.2-8 it is recommended that;

- The East Holland, West Holland, and Maskinonge River subwatersheds be further studied in a Tier Two assessment as a grouped investigation,
- The Maskinonge River Tier Two assessment focus on seasonal low water concerns,
- The Barrie Creeks, Lovers Creek and Hewitts Creek be further studied in a Tier Two assessment as a grouped investigation (Kempenfelt Bay area assessment),
- This Kempenfelt Bay area assessment will be sufficiently scoped in size to address groundwater and surface water divide differences,
- The Uxbridge Brook be further studied in a Tier Two assessment,
- The Beaver River Tier Two assessment focus on the reported water quantity restrictions in the Village of Woodville, and
- The results of this exercise be used to inform and support the Permit to Take Water programs.

Figure 3.2-1: Mean Annual Precipitation

Figure 3.2-2: Actual Evapotranspiration Distribution

Figure 3.2-3: Surface Water Monitoring Locations

Figure 3.2-4: Permitted Groundwater Takings

Figure 3.2-5: Permitted Surface Water Takings

Figure 3.2-6: Subwatershed Groundwater Stress Assessment Results

Figure 3.2-7: Subwatershed Surface Water Stress Assessment Results

Figure 3.2-8: Subwatersheds Identified for Tier Two Analysis

3.3 Tier Two Water Budget Summary and Methods

Tier Two Water Budgets and Stress Assessments have been undertaken in those subwatersheds that were determined to have a moderate or significant potential for stress, in the Tier One Water Budget and Water Quantity Stress Assessment. The goal of the Tier Two Water Budget and Water Quantity Stress Assessment is to confirm or negate the stress assignment completed in the Tier One using a more detailed approach that includes detailed and complex modelling tools to estimate water flow volumes to compare to the consumptive demand estimates (MOE, 2008a). The role of the Tier Two is to refine the estimation of water budget components to facilitate a more reliable stress assessment and allow subwatersheds with marginal stress levels to avoid the detailed local assessments required in the Tier Three. Should the elevated stress levels be confirmed in the Tier Two assessment, an even more detailed Tier Three water budget and water quantity risk assessment is required. How the Tier Two Water Budgets and Water Quantity Stress Assessments fit into the overall Water Budget and Risk Assessment Process is illustrated in the flow chart below.

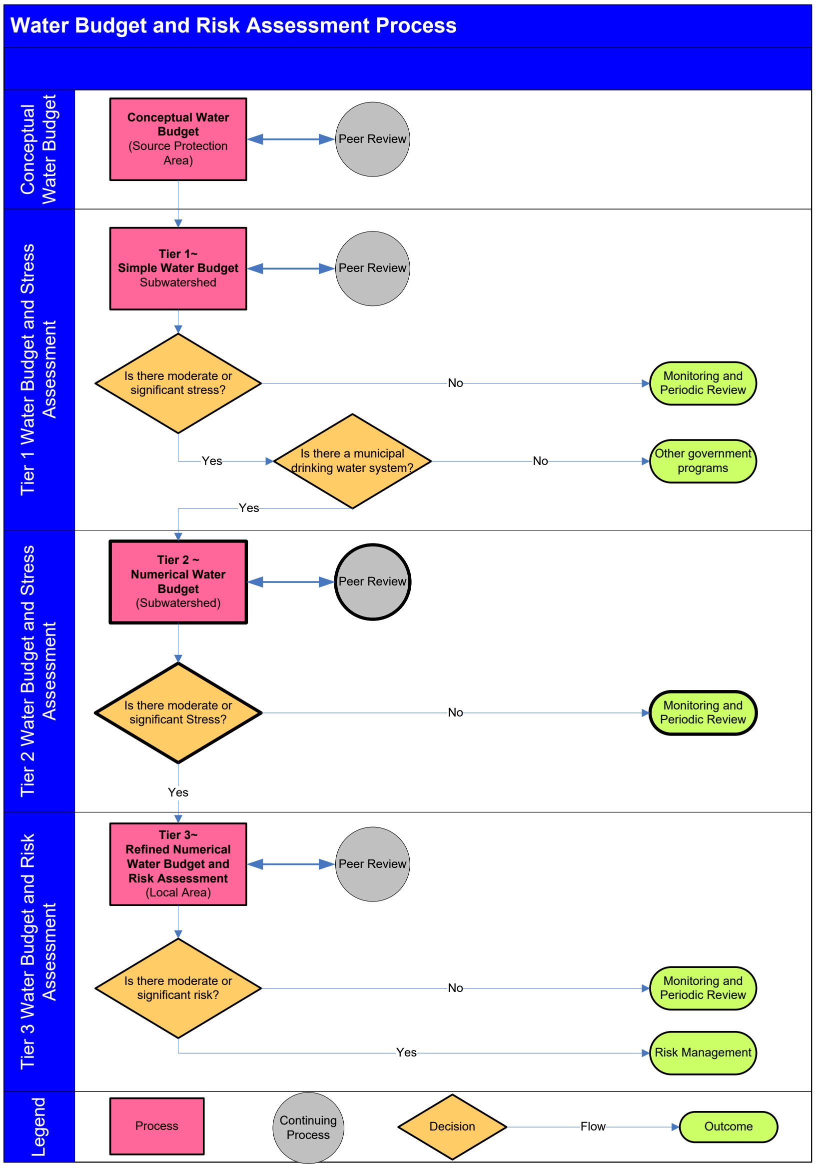

Figure 3.3-1: Water Budget and Risk Assessment Process (*How the Tier Two fits in*).

Tier Two Stress Assessment Methodology

The Technical Rules (MOE, 2008a) describe three scenarios used to determine a subwatershed's potential for stress as indicated below. Based on these scenarios each subwatershed is classified as having a low, moderate, or significant potential for stress. Under the direction of the Technical Rules, when a subwatershed is designated as having a moderate or significant potential for stress under any one of the three scenarios, municipal systems located in the subwatershed meet the conditions required for moving on to a Tier Three Water Quantity Risk Assessment Study.

Existing, Future and Planned Percent Water Demand Scenarios

The percent water demand for the existing, future and planned scenarios will be calculated using the same formula and methods that were used in the Tier One Stress Assessment (Section 3.2.4). As outlined in the Technical Rules (MOE, 2008a), the Percent Water Demand is calculated using the following formula:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{\mathrm{Re}\,serve}} \times 100\%$$

where;

Q_{Demand} is equal to the consumptive demand calculated as the estimated rate of locally consumptive takings;

Q_{Supply} is the water supply term, calculated for groundwater supplies as the estimated annual recharge rate plus the estimated groundwater inflow to a subwatershed.

$Q_{Reserve}$ is the water reserve, defined as the specified amount of water that does not contribute to the available water supply. Groundwater reserve is calculated as 10% of the total estimated groundwater discharge within a subwatershed.

For groundwater systems the stress assessment is conducted using the average annual demand conditions and the monthly maximum demand conditions. The groundwater supply will be considered constant for the conditions as per Technical Rule 1(2) (MOE, 2008a). The potential groundwater stress thresholds are outlined in Table 3.3-1.

Table 3.3-1: Potential Groundwater Stress Thresholds.

Groundwater Potential Stress Level	Average Annual Percent Water Demand	Monthly Maximum Percent Water Demand
Significant	>25%	>50%
Moderate	>10%	>25%
Low	0-10%	0-25%

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The Technical Rules (MOE, 2008a) require further evaluation for subwatersheds found to have stress levels close to the moderate stress (i.e. between 8-9% for average annual demand, or between 23-24% for maximum monthly demand), and have high level of uncertainty associated with them. These subwatersheds undergo a sensitivity analysis that can allow the percent water demand to be elevated to a moderate potential for stress.

The future water demand scenario considers the evaluation of future consumptive water demand estimates for a forecasted population throughout each municipality's planning horizon. In general, this planning horizon is intended to extend to the year 2031; however, in some cases the municipal planning horizons do not extend that far. In this case, the best available information is utilized.

Historic Conditions

According to the Technical Rules 32 (2)(b)(i) and (ii) (MOE, 2008a) if either of the following two conditions have been met any time after January 1, 1990 at a municipal groundwater well, the subwatershed would be classified as having a moderate potential for stress:

I. The groundwater level in the vicinity of a well was not at a level sufficient for the normal operation of the well; or

II. The operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

Drought Scenario

One of the scenarios to assess for the subwatershed stress assessment will be the hydrologic stress that may be expected to occur within a long period of drought. The Technical Rules (MOE, 2008a) identify the need for both a two year and a ten year drought scenario (Rule 35.2.f/g). These scenarios are designed to capture probable periods of drought conditions; both short and long duration droughts. However, if a subwatershed is already identified as requiring a Tier 3 assessment the drought scenario is not needed. This is an example of the East and West Holland and Maskinonge subwatersheds which were identified as potentially stressed under the existing and/or future scenarios and therefore did not require future evaluation.

The most reliable way to evaluate the effects of a drought is to simulate the time-varying recharge conditions, which result in a drought followed by the long-term recovery once recharge conditions have recovered to normal levels. Where this time varying (transient simulation) approach was required by the Technical Rules (MOE, 2008a), it was applied. The minimum monthly flow conditions simulated would then be used to represent the worst-case flows expected during drought conditions (MOE, 2007). The methodology and results of this scenario are further discussed in Tier Two Sections (Sections 3.4-3.6).

Water Demand

Monthly Usage Factors

Monthly estimates of water use are required to represent the seasonal changes in total water use across a subwatershed. All water demand reported in the Tier 2 Stress Assessments have been adjusted per Table 3.3-2, where 1 designates the permit is active, and 0 designates it is inactive. This facilitates the estimate of actual water used in a subwatershed, as it recognizes that many types of water taking operations only take water during a specific time period each year (e.g., snow making generally is active December, January and February).

Table 3.3-2: Monthly Demand Adjustments based on active months of taking (MOE, 2007).

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural	Field and Pasture Crops	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Fruit Orchards	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Market Gardens/Flowers	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Nursery	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Other - Agricultural	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Sod Farm	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tender Fruit	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tobacco	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Bottled Water	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Mall/Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Snow Making	1	1	0	0	0	0	0	0	0	0	0	1
Construction	Other - Construction	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Road building	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1

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General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Pipeline Testing	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Other - Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Schools	1	1	1	1	1	1	0	0	1	1	1	1
Miscellaneous	Dams and Reservoirs	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Heat Pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other - Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Pumping Test	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Wildlife Conservation	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Groundwater	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Other - Remediation	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Municipal	1	1	1	1	1	1	1	1	1	1	1	1

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General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Supply	Other - Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

*note: 1 indicates that waster is used for that purpose in the indicated month

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Consumptive Use Factors

As discussed in detail in Appendix D of the Water Budget and Water Quantity Risk Assessment, water consumption refers to the amount of water removed from a hydrological system and not returned back to the same system in a reasonable time period. To assess the portion of pumped water that is being removed from the hydrologic system, estimates of water demand must consider consumptive use, as opposed to the total amount of water that may be pumped from a system (AquaResource and Golder, 2010).

Estimating consumptive water demand requires a proper consideration of scale, as well as the physical water taking operation. Some water takers may have large extraction volumes associated with their permits while actually consuming very little of that water. As an example, aggregate washing operations are permitted to pump large volumes of water between washing and settling ponds, and a relatively small percentage is lost to evaporation, or is removed offsite within the washed material. Another example is a dewatering activity where groundwater that is pumped to lower the water table is discharged to a nearby creek. At the scale of a subwatershed very little of this water is actually consumed; however, this water taking would be fully consumptive with respect to the pumped aquifer (AquaResource and Golder, 2010).

The percent water demand calculation requires the estimate of water which is consumed and not returned to the original source within a reasonable amount of time. Therefore, for a groundwater assessment, if water is removed from the groundwater system and not returned to the groundwater system, the taking is assumed to be 100% consumptive. Groundwater takings are typically 100% consumptive, since wastewater is seldom returned to the groundwater system, but rather discharged to surface water systems. Exceptions would include irrigation, where a portion of the applied irrigation water would saturate surficial soils and percolate beneath the evaporative root zone, returning to the groundwater system. Table 3.3-3 provides a list of consumptive use factors (MOE, 2007) that are used for water takings where water is returned to the same source from which it is taken. These values correspond to the ‘Specific Purpose’ assigned by the MOE to each permit. Where water was not returned to the same source, a consumptive factor of 1 is used.

Table 3.3-3: Consumptive Use Factors (Source: MOE, 2007)

General Purpose	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Agricultural	Field and Pasture Crops	0.8	Industrial	Manufacturing	0.25
Agricultural	Fruit Orchards	0.8	Industrial	Other - Industrial	0.25
Agricultural	Market Gardens/Flowers	0.9	Industrial	Pipeline Testing	0.25
Agricultural	Nursery	0.9	Industrial	Power Production	0.1
Agricultural	Other - Agricultural	0.8	Institutional	Hospitals	0.25
Agricultural	Sod Farm	0.9	Institutional	Other - Institutional	0.25
Agricultural	Tender Fruit	0.8	Institutional	Schools	0.25
Agricultural	Tobacco	0.9	Miscellaneous	Dams and Reservoirs	0.1
Commercial	Aquaculture	0.1	Miscellaneous	Heat Pumps	0.1
Commercial	Bottled Water	1	Miscellaneous	Other - Miscellaneous	1
Commercial	Golf Course Irrigation	0.7	Miscellaneous	Pumping Test	0.1
Commercial	Mall/Business	0.25	Miscellaneous	Wildlife Conservation	0.25
Commercial	Other Commercial	1	Recreational	Aesthetics	0.25
Commercial	Snow Making	0.5	Recreational	Fish Ponds	0.25
Construction	Other - Construction	0.75	Recreational	Other - Recreational	0.1
Construction	Road Building	0.75	Recreational	Wetlands	0.1
Dewatering	Construction	0.25	Remediation	Groundwater	0.5

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General Purpose	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Dewatering	Other - Dewatering	0.25	Remediation	Other - Remediation	0.25
Dewatering	Pits and Quarries	0.25	Water Supply	Campgrounds	0.2
Industrial	Aggregate Washing	0.1	Water Supply	Communal	0.2
Industrial	Brewing and Soft Drinks	1	Water Supply	Municipal	2
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.2
Industrial	Food Processing	1	-	-	-

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Lake Simcoe Watershed Tier Two Summary

As noted in the Tier One Water Budget and Stress Assessment: Lake Simcoe watershed the East Holland, West Holland, Maskinonge, Uxbridge, Beaver, Lovers, Barrie, and Hewitt's Creek subwatersheds in the LSRCA watershed (Figure 3.2-8) are moderately to significantly stressed and should be evaluated at a Tier Two assessment level. It should be noted that the Tier One Stress Assessment (Section 3.2) determined only municipal systems using groundwater sources to be potentially stressed; therefore the Tier Two Stress Assessment was only carried out for groundwater not surface water systems.

The Tier Two studies for these subwatersheds have been completed as three separate projects due to the availability of numerical models and studies that have already been developed within portions of the study area. In addition, some of the Tier Two assessments have been completed in conjunction with those within the neighbouring Source Protection Areas (i.e. Nottawasaga Valley and Severn Sound Source Protection Areas). These studies are summarized in Table 3.3-4 below and are discussed in more detail with Section 3.4, 3.5 and 3.6.

Table 3.3-4: Summary of Tier Two Water Budgets and Water Quantity Stress Assessments completed in the Lake Simcoe Source Protection Area.

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed	Tier 2 Project
York Region	Town of Aurora	Aurora Well Supply	East Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
York Region	Town of Newmarket	Newmarket Well Supply	East Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
York Region	Town of Whitchurch-Stouffville	Ballantrae-Musslemans Well Supply	East Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
York Region	Town of East Gwilliumbury	Holland Landing Well Supply	East Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds

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Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed	Tier 2 Project
York Region	Town of East Gwilliumbury	Queensville Well Supply	East Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
York Region	Town of East Gwilliumbury	Queensville Well Supply	Maskinonge	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
York Region	Township of King	Ansnorveldt Well Supply	West Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
York Region	Township of King	Schomberg Well Supply	West Holland	Tier 2 Water Budget Assessment of the Holland and Maskinonge River Watersheds
Simcoe County	Town of Bradford-West Gwillimbury	Bradford/Bondhead Distribution & Well Supply	West Holland	South Georgian Bay West Lake Simcoe Tier 2 Water Budget and Stress Assessment

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Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed	Tier 2 Project
Simcoe County	Town of Innisfil	Stroud Well Supply	Hewitts Creek	South Georgian Bay West Lake Simcoe Tier 2 Water Budget and Stress Assessment
City of Barrie	City of Barrie	Barrie Well Supply	Barrie Creeks	South Georgian Bay West Lake Simcoe Tier 2 Water Budget and Stress Assessment
Regional Municipality of Durham	Township of Uxbridge	Uxbridge Well Supply	Uxbridge Brook	Uxbridge Tier 2 Water Budget and Stress Assessment
Regional Municipality of Durham	Township of Brock	Cannington Well Supply	Beaver River	Uxbridge Tier 2 Water Budget and Stress Assessment
Regional Municipality of Durham	Township of Brock	Sunderland Well Supply	Beaver River	Uxbridge Tier 2 Water Budget and Stress Assessment
City of Kawartha Lakes	City of Kawartha Lakes	Woodville Well Supply	Beaver River	Uxbridge Tier 2 Water Budget and Stress Assessment

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3.4 Tier Two Water Budget- Holland and Maskinonge River

The Tier One Stress Assessment identified several subwatersheds as having a moderate or significant potential for stress (shown in Figure 3.2-8) and as a result, Tier Two Stress Assessments were completed for these subwatersheds. This section provides an overview of the East and West Holland River and Maskinonge River subwatersheds, which was completed in three separate stages. The first stage of the Holland and Maskinonge River Tier Two involved the creation of a detailed conceptual and numerical model. This task was completed in 2006 as an initiative lead by the CAMC-YPDT group to understand the groundwater resources of the Oak Ridge's Moraine Area (Earthfx, 2006). A numerical model based on the conceptual understanding was then used to complete a Water Budget Study of the Holland River, Maskinonge River and Black River subwatersheds (Earthfx, 2008). The results of the 2008 Water Budget study were used to complete a Stress Assessment of the Holland and Maskinonge River subwatersheds in 2010 using demand estimates from the SGBLS Tier 1 Water Budget and Water Quantity Stress Assessment: Lake Simcoe Watershed, with some minor modifications to demand estimates. The Tier 1 assessment already included a refinement to the permit to take water database and it was felt that further refinements in the Tier 2 assessment weren't possible.

The work described herein is a summary of the following three reports;

- Earthfx, 2006, Groundwater modelling of the Oak Ridges Moraine area: CAMC-YPDT Technical Report #01-06.
- Earthfx Inc. and Gerber Geosciences Inc., 2008, Holland River, Maskinonge River, and Black River Watersheds Water Budget Study: prepared for Lake Simcoe Region Conservation Authority.
- Earthfx, 2010(a), Tier Two Water Budget Assessment of the Holland and Maskinonge River Watersheds: prepared for South Georgian Bay-Lake Simcoe Source Protection Region.

The work completed for the Tier Two Water Budget and Stress Assessment of the Holland and Maskinonge River subwatersheds was in compliance with the Technical Rules prepared by the Ministry of the Environment[10] (MOE, 2008a) for the preparation of Assessment Reports under

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[10] Now, the Ministry of the Environment, Conservation and Parks (MECP)

the Clean Water Act, and provincial guidance (MOE, 2007). It is recommended that the above three reports be referred to for additional detail.

Study Area and Physical Setting

Location

The study area within the Holland and Maskinonge River subwatersheds Stress Assessment (Earthfx, 2010) encompasses the majority of York Region located within the Lake Simcoe Source Protection Area. The Lake Simcoe watershed covers a total area of 3,621 km^2, approximately 663 km^2 of which was included in the Holland and Maskinonge Tier Two watershed study (Figure 3.4-1). This area includes numerous small tributaries that originate on the flanks of the Oak Ridges Moraine, as a result of groundwater discharge and surface water runoff. The small tributaries drain the land and pass through areas of urban and rural land use practices, while flowing towards and into the main branches of the Holland and Maskinonge Rivers, which drain into Cooks Bay.

Conceptual Model

Tier Two Water Budgets and Stress Assessments require that a numerical model be developed to assess the parameters for the percent water demand in the stress calculations. The first step to creating the numerical water budget involves enhancing the conceptual understanding of the study area through the creation of a detailed geological conceptual model. An overview of the conceptual model will be discussed below and a detailed description of the conceptual model can be found in the Groundwater Modelling of the Oak Ridges Moraine Area (CAMC-YPDT) groundwater management study (Earthfx, 2006). The hydrogeologic conceptual model created for the study area was a result of an initiative of four municipalities and six conservation authorities to understand the groundwater resources of the Oak Ridges Moraine.

The goal of the hydrogeologic conceptual model was to review the stratigraphic layers from the ORM Regional Model from a hydrogeologic perspective for input into the Core Model (Earthfx, 2006). An emphasis was placed on understanding the permeability and continuity of the materials present in the aquifer and aquitard layers throughout the Core Model area (Figure 3.4-2).

Through the creation of the enhanced conceptual understanding the following stratigraphic features were considered to be strongly influencing the flow of groundwater throughout the study area.

1. The orientation and connectivity of bedrock valleys;

2. The thickness and continuity of the Newmarket till[11];
3. The location of tunnel channels as well as, the composition of the infill material; and
4. The thickness and continuity of the ORM deposits (Earthfx, 2006).

The conceptual model exercise resulted in an understanding that the Core Model study area can be divided into eight regional hydrostratigraphic layers. Three of which are principal aquifer units (Oak Ridges aquifer complex, Thorncliffe aquifer complex and the Scarborough aquifer complex). The following hydrostratigraphic units were considered to represent the study area;

1) Glaciolacustrine deposits (sand, silt and clay): aquifer or aquitard;
2) Halton/ Kettleby Aquitard;
3) Oak Ridges Aquifer Complex;
4) Regional Unconformity-tunnel channel infill deposits;
5) Newmarket Aquitard;
6) Thorncliffe Aquifer Complex;
7) Sunny Brook Aquitard (or equivalent);
8) Scarborough Aquifer Complex ; and
9) Bedrock Aquifer or Aquitard (Earthfx, 2006).

Water Supply

The water supply component of the stress assessment was estimated using a numerical groundwater flow model developed for the YPDT Groundwater Study and used for the Holland, Maskinonge study area. This groundwater model incorporated the enhanced knowledge of the geologic surface and sub-surface gained from the conceptual model discussed in the previous section. The model domain encompasses an area extending from Lake Ontario to the Southern shores of Lake Simcoe and includes the Holland and Maskinonge River watersheds in their entirety (Figure 3.4-2) (Earthfx, 2006).

This groundwater model incorporated the enhanced knowledge of the eight hydrostratigraphic layers discussed in the previous section. The model is summarized in Appendix WB-4B and is described in detail in the Groundwater modelling of the Oak Ridges Moraine area: CAMC-YPDT Technical Report #01-06 (Earthfx, 2006).

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[11] The Newmarket till separates the shallow aquifer system from the deep aquifer system.

The Core model was built using the United States Geological Survey MODFLOW modelling code. This modelling code was selected because it is well-suited for modelling regional flow in complex multi-layered aquifer systems. In addition the MODFLOW code is recognized worldwide and has been extensively peer reviewed to verify for accuracy in groundwater flow simulation. The model was calibrated to match the observed stream baseflow measurements as well as, observed water levels (Earthfx, 2006). The model is also able to accurately predict drawdown at a pumping well (Earthfx, 2006).

Recharge

The MODFLOW modelling code is unable to calculate groundwater recharge from climatic data. Therefore, estimates of groundwater recharge must be supplied to the model as input data (Earthfx, 2008). Groundwater recharge was initially estimated using land use, climate and soil properties, and was later updated by conducting a water balance analysis using a VL-WABAS model spreadsheet program (Earthfx, 2008). The outputs of the VL-WABAS simulation program were compared to the gauged streamflow data and observed groundwater discharge from hydrograph separation. The comparison was done to ensure that the simulated water balance parameters including groundwater recharge were reasonable (Earthfx, 2010). More detail on the surface water model can be found within Appendix WB-4.

Water Budget Results

The water budgets and stress assessment are calculated using the estimated values for groundwater supply and reserve simulated in the numerical Core Model. Water budgets and stress assessments are conducted to determine a subwatershed potential stress, with the ultimate goal of sustaining a water supply.

The parameters used to complete the groundwater budget were simulated using both the surface water (VL-WABAS) and groundwater (Core Model) flow models. The simulated volume of groundwater infiltration per year from the surface water model was input into the Core model as the volume of groundwater recharge that is occurring. Inputting the groundwater infiltration component determined from the surface water model into the Core model allows for the climatic parameters to be accounted for in the groundwater budget.

The results of the water budget are shown on Table 3.4-1 and Table 3.4-2. The value for groundwater recharge indicates how much recharge the subwatersheds were simulated to receive annually. The value of GWI in Table 3.4-1 was used as the estimate for groundwater recharge in the Tier 2 Stress Assessments.

Table 3.4-1: Simulated VL-WABAS (Surface Water) Water Budget (Earth*fx*, 2010 (data from Earthfx & Gerber Geosciences, 2008)

Catchment	Catchment Area (km^2)	Precipitation (mm/a)	Evapotrans-piration (mm/a)	Overland Runoff (mm/a)	Groundwater Infiltration (mm/a)	Groundwater Infiltration (m^3/s)	Error[1] (mm/a)
West Holland River	358.9	794	536	99	164	1.87	-5
East Holland River	244.1	802	517	119	172	1.33	-6
Maskinonge River	68.4	838	549	112	180	0.39	-3

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Table 3.4-2: Simulated MODFLOW Groundwater Budget. All units in m^3/s (Eartfx, 2010 (data from Earthfx and Gerber Geosciences, 2008)

Watershed	East Holland	West Holland	Maskinonge	All Catchments
Areal Recharge	1.33	1.87	0.39	3.59
Lateral Inflow	0.51	0.31	0.15	0.71
Groundwater Discharge to Streams	0.81	1.90	0.27	2.98
Groundwater Discharge to Lake	0.003	0.004	0.01	0.02
Groundwater Discharge to Wells	0.44	0.09	0.05	0.58
Lateral Outflow	0.59	0.14	0.22	0.69

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Water Reserve Estimates

The Technical Rules (MOE, 2008a) and MOE Guidance Module 7 (MOE, March 2007) defines “reserve” as a quantity of water needed for other ecological and anthropogenic needs not considered within the stress calculations. For groundwater, this quantity is related to the quantity of groundwater discharge to streams within the subwatershed needed for ecological needs (e.g., minimum flows in reaches with sensitive coldwater fish habitat) and anthropogenic needs (e.g., minimum flows for diluting sewage treatment plant discharge). Guidance Module 7 indicates that the appropriate groundwater reserve quantity for a subwatershed should be discussed with the peer review committee and be based upon local conditions and needs. In all cases, the groundwater reserve should be at least 10% of the existing groundwater discharge within a subwatershed (as calculated with the calibrated groundwater model) (Earthfx, 2010).

Estimates of groundwater discharge are available from both the Tier 1 and ORMCP studies. The Tier 1 study used a USGS technique for estimating synthetic streamflow data for ungauged watersheds (such as Maskinonge Creek) (SGBLS, 2009). A second estimate is available from the MODFLOW groundwater model simulations performed in the ORMCP water budget study (Earthfx and Gerber, 2008). Both of these estimates are presented in for comparison in Table 3.3-3. For the purposes of this Tier 2 study the groundwater reserve is estimated as 10% of the ORMCP MODFLOW baseflow estimate (Table 3.3.1-3).

Uncertainty Discussion

The observed static water levels contained within the MOE water well record database are known to contain numerous errors. The observed average groundwater potentials from York Region and the PGMN monitoring network are considered more reliable for analyzing the absolute error at specific locations; however, they have a very limited areal coverage (Earthfx, 2008). It should be noted that streamflow measurements can be affected by flow regulation devices and urban effects such as sewer discharge to streams and leakage into or out of the infrastructure. For example, the simulated discharge to streams is less than the observed discharge for the Holland River at Holland Landing, and greater than the observed discharge for the Holland River at Schomberg (Earthfx, 2008).

Overall, the results from the Core model indicated that direct recharge accounted for most of the inflow within the study area. The results also indicated that the majority of groundwater discharges to streams. The overall, mass balance error was less than 1%. Further details regarding the Core Model and Calibration are found within Earthfx 2006, and Earthfx, 2008.

Water Demand

This section provides a summary of the consumptive groundwater demands for the East Holland, West Holland and Maskinonge River subwatersheds assessed as part of the Tier Two Water Budget Assessment (Earthfx, 2010).

Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. aquifer) within a reasonable amount of time. Understanding this type of water demand is critical to the development of a water budget framework. An estimate of the extent and variability of water use throughout the Study Area is required to identify the subwatersheds that may be under the highest degree of potential hydrologic stress, and to guide future efforts to refine water budget tools in those areas (AquaResource and Golder, 2010).

The consumptive groundwater demand was estimated for permitted municipal, industrial, commercial, and other water users. In addition consumptive groundwater demand was estimated for non-permitted groundwater takings, which includes domestic and agriculture users extracting less than 50,000 L/day. The consumptive factors used are outlined in Section 3.3.2 Table 3.3-3.

The water demand values used in the Tier One Water Budget and Stress Assessment (SGBLS, 2009) were also used to conduct the Tier 2 Stress Assessment. Some refinements were made to the agricultural demand estimates (Earthfx, 2010). The Tier 1 assessment already included a refinement to the permit to take water database and it was felt that further refinements in the Tier 2 assessment weren’t possible. In addition, the demand estimates used in the Tier One Water Budget and Stress Assessment were deemed appropriate for use as the PTTW for York Region has a condition assigned to it limiting the groundwater extraction rate to 42,000 m^3/day

(SGBLS, 2009). It was therefore assumed that the extraction rate of 42,000 m^3/day will not be exceeded.

Permits to Take Water

Information from the July 2006 permit to take water program database was used to estimate actual water demand. As part of the Tier One assessment, the database was modified in a consistent manner to improve the accuracy of information based upon field investigations (Figure 3.2-4 and Figure 3.2-5). The modifications to the database included removing any permits that were known to have been revoked or replaced. Expired permits were considered on a case by case basis and removed if it was likely that the permit was no longer in use. Locations searches were also completed and when several permits with the same location were found the most recent was retained and the others were considered to have been revoked and replaced. Within permits where multiple sources may have been included and prescribed only one pumping rate, the pumping rate was divided by the number of sources.

Table 3.4-3: Estimates of Annual Existing Consumptive Groundwater Use (modified from SGBLS, 2009).

Catchment	Municipal (m^3/a)	Domestic (m^3/a)	Permits (m^3/a)	Agriculture (m^3/a)	Total (m^3/a)	Total (m^3/s)
East Holland River	13,661,000	179,000	2,536,000	2,287,000	18,663,000	0.592

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Catchment	Municipal (m^3/a)	Domestic (m^3/a)	Permits (m^3/a)	Agriculture (m^3/a)	Total (m^3/a)	Total (m^3/s)
West Holland River	3,043,000	163,000	217,000	2,850,000	6,273,000	0.199

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Catchment	Municipal (m^3/a)	Domestic (m^3/a)	Permits (m^3/a)	Agriculture (m^3/a)	Total (m^3/a)	Total (m^3/s)
Maskinonge River	1,821,000	30,000	19,000	502,000	2,372,000	0.075

Municipal Water Demand

Municipal water supplies represent the largest water use within the study area. As such, accurate estimates of municipal water use are a critical component of the consumptive water demand estimate. For the Tier Two Assessment reported municipal rates were obtained from the SGBLS Tier One Water Budget and Water Quantity Stress Assessment (SGBLS, 2009).

Other Permitted Water Demand

Non-municipal permitted water taking types included in the assessment are agriculture, commercial, industrial, recreational and remediation activities. The other permitted water takings by subwatershed are outlined in Appendix WB-2B.

Non-Permitted Water Demand

Non-permitted private well domestic consumption was estimated in the Tier One Water Budget and Stress Assessment (SGBLS, 2009). To determine the number of non-permitted domestic consumers the 2006 Statistics Canada census data was used to determine the "un-serviced" population. The un-serviced population was then multiplied by 335 L/day, based on the recommendation within MOE Guidance Module 7 (2007). A relatively low consumptive factor of 0.2 was then applied. The non-permitted water takings are found in Table 3.4-4.

The non-permitted agriculture water demand was modified from the Tier One using two techniques to improve the estimate. This included clipping of land use polygons that extend offshore into Lake Simcoe. The allocation of DeLoe's (2002) average annual demands has been corrected over the summer months.

Table 3.4-4: Non-permitted water demand.

Catchment	Domestic (m^3/a)	Agriculture (m^3/a)	Total (m^3/a)	Total (m^3/s)
East Holland River	179,000	2,287,000	2,466,000	0.078
West Holland River	163,000	2,850,000	3,013,000	0.096
Maskinonge River	30,000	502,000	532,000	0.017

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Monthly Usage and Consumptive Use Factors

Section 3.3.2.1 summarizes the monthly usage and consumptive use factors that were utilized within the Tier Two Assessments. While these factors are generalized, they provide a consistent approach for the initial estimation of consumptive water use. Monthly estimates of water use and supply are required to evaluate the transient stress level within a subwatershed. Knowledge of the available water and water use requirements allow for water management during times of the year when it is required. In the study area, low flow, and the majority of pumping are likely to occur during summer months.

Uncertainty

Water demand estimates are subject to various levels of uncertainty. The methods used to develop and understanding of the total amount of water demand within each subwatershed have been discussed within the previous sections and the Lake Simcoe Tier One (SGBLS, 2009).

In applying these methods, attempts have been made to be both consistent and conservative, in order to produce a stress assessment as accurately as possible. In accordance with that, the limitations and assumptions of each data source should be recognized.

Now all municipal drinking water facilities are required to keep and maintain records of water takings. This information has been obtained directly from the municipalities, and is considered accurate and complete. The level of certainty within these data is directly related to the uncertainty of the stress assessment as municipal wells are often the most significant takers within a subwatershed.

The simple method of applying a consumptive usage factor to population data has been used to estimate non-municipal domestic water use, as suggested in Guidance Module 7 (MOE, 2007). This method is effective for this level of assessment; however, there is uncertainty as individual water use will vary significantly between households.

The non-permitted agriculture demand was modified from the Tier One using two techniques to improve the estimate, and reduce the overall uncertainty. This included the clipping of land use polygons that extended offshore into Lake Simcoe. The allocation of DeLoe's (2002) average annual demands has been corrected over the summer months.

The PTTW database provided by the MOE has been modified as discussed in previous sections. Although this database is being updated to include actual water takings, the data were not available for the preparation of this report. Instead, the PTTW database provides a maximum allowable taking over time. This maximum taking has been used to make assumptions regarding the actual taking, when actual water-taking rates were unavailable. A complete listing of municipal supplies can be found in Appendix WB-3B. The following notes some of the uncertainty associated with these data:

- Seasonal water use has not been considered in the database; therefore assumptions have been made as necessary.
- Assumptions have been made on how to allocate water for permits with multiple sources.
- Although the PTTW program has been in place for many years, it is likely that not all users have a current permit.
- The version of the PTTW database provided to Conservation Authorities is current to 2006; therefore assumptions have been made regarding permits that have been renewed.

Despite these uncertainties, the data and assumptions were considered adequate for the purposes of the Tier Two assessment.

Tier Two Stress Assessment

The Tier Two Stress Assessment has only been conducted for groundwater systems since no surface water systems were found to be moderately or significantly stressed in the Tier 1 Water Budget and Stress Assessment for the Lake Simcoe Watershed. The groundwater systems in the study area that have undergone the stress assessment are shown in Table 3.4-5 and Figure 3.4-1.

Table 3.4-5: Municipal Groundwater Systems within the Study Area

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Drinking Water System
Maskinonge	York Region	Town of East Gwillimbury	Queensville Well Supply
East Holland	York Region	Town of East Gwillimbury	Holland Landing Wells Supply
East Holland	York Region	Town of Aurora	Aurora Well Supply
East Holland	York Region	Town of Newmarket	Newmarket Well Supply
East Holland	York Region	Town of Whitchurch-Stouffville	Ballantrae-Mussleman's Well Supply
West Holland	York Region	Township of King	Ansnorveldt Well Supply
West Holland	York Region	Township of King	Shomberg Well Supply
West Holland	Simcoe County	Town of Bradford-West Gwillimbury	Bradford/Bondhead Distribution and Supply

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Existing Conditions

The percent water demand calculated for the Maskinonge, East and West Holland Rivers subwatersheds using estimates of groundwater supply, reserve and consumptive demand. The water demand used in the stress assessment is discussed above in Section 3.4.4. The estimated consumptive demand for permitted and non-permitted users was used in calculating the subwatersheds potential for stress under existing conditions. The groundwater supply component for the stress assessment was calculated as being the sum of recharge calculated from the VL-WABAS simulation and subsurface inflows calculated from MODFLOW simulations. The groundwater reserve component of the stress assessment was calculated to be 10% of the groundwater discharge to streams. The volume of groundwater discharge to streams was estimated using the MODFLOW numerical model and is illustrated on Figure 3.4-3(Earthfx 2008).

The results of the existing annual conditions stress assessment are shown on Table 3.4-6. The existing conditions stress assessment indicated that the East Holland River subwatershed was identified as having the potential to be significantly stressed, the Maskinonge River subwatershed as having the potential to be moderately stressed and the West Holland River as having a low potential for stress. As per the Technical Rules, the East Holland and Maskinonge River subwatershed will be required to undergo a Tier 3 analysis. As a result, these subwatersheds do not require any further analysis under planned, future, historical or drought conditions in the Tier Two assessment as per the Technical Rules. The results of the Existing monthly stress assessments are included in Appendix WB-3B.

Table 3.4-6: Existing Annual Stress Assessment (Earthfx, 2010a).

Catchment	$Q_{RECHARGE}$ (m^3/s)	Q_{IN} (m^3/s)	$Q_{RESERVE}$ (m^3/s)	Q_{DEMAND} (m^3/s)	Water Demand (%)
West Holland River	1.87	0.31	0.19	0.18	9.0%
East Holland River	1.33	0.51	0.08	0.56	**32.1%**
Maskinonge River	0.39	0.15	0.03	0.07	14.1%

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Future Conditions

The future demand scenario was completed for all three subwatersheds even though the East Holland and Maskinonge Rivers subwatersheds were not required to undergo this analysis as per the Technical Rules. The stress levels of all subwatersheds increased slightly under future conditions; however, they all remained within the same stress threshold as observed in Table 3.4-7.

Table 3.4-7: Future Annual Stress Assessment (Earthfx, 2010a).

Catchment	$Q_{RECHARGE}$ (m^3/s)	Q_{IN} (m^3/s)	$Q_{RESERVE}$ (m^3/s)	Q_{DEMAND} (m^3/s)	Water Demand (%)
West Holland River	1.87	0.31	0.19	0.19	9.6%
East Holland River	1.33	0.51	0.08	0.62	**35.2%**
Maskinonge River	0.39	0.15	0.03	0.07	14.1%

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Since the stress level for the West Holland during the future scenario is 0.4% away from being classified as moderately stressed, an uncertainty analysis was performed simply by considering 100% consumptive use for agriculture. By doing this, the stress assessment presented here is applied with greater conservatism, and does push the subwatershed to become moderately stressed. Based on these thresholds, the following stress classifications are determined for future demand conditions (Table 3.4- 8).

Table 3.4- 8: Future Annual Stress Assessment with 100% Agricultural Consumption (Earthfx, 2010a).

Catchment	Water Demand (%)	Stress Level: Future Conditions (100% agricultural consumption)
East Holland River	36.0	**Significant**
West Holland River	10.5	Moderate
Maskinonge River	14.7	Moderate

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Planned and Future Conditions

No planed municipal systems exist within this portion of the Lake Simcoe Source Protection Area.

Historical Conditions

There are no known historical conditions as defined by the Technical Rules (MOE, 2008a), where pumping at municipal wells was affected by low groundwater levels in any of the subwatersheds.

Drought Scenario

According to the Technical Rules (MOE, 2008a), subwatersheds can also be identified as having a potential for moderate stress if either of the following circumstances occurs within the subwatershed during either observed or simulated drought conditions (Rule 35.(2)(e). As the uncertainty analysis, for future conditions with 100% agriculture consumptive demand pushed the West Holland subwatershed into the moderate potential for stress threshold the drought scenario was not required for this study.

Uncertainty in Groundwater Stress Classifications

The following factors outline the uncertainty associated with the stress assessment:

- There is uncertainty associated with the lateral inflows (Q_{in}), and there is a significant lateral flow between the subwatersheds in this study area.
- Large municipal pumping wells, particularly those located near the subwatershed boundaries increase the Q_{in} component of the Water Supply by drawing water across the subwatershed boundary.
- High pumping rates reduce the baseflow discharge, effectively reducing the “reserve” estimate (reserve is 10% of baseflow discharge). The greater the pumping, the lower the reserve.

For a detailed and scientific discussion of the watershed conditions, including a breakdown of flows on an aquifer basis, the reader is referred to Earthfx and Gerber, 2008.

Stress Assessment Results

East Holland Subwatershed

The East Holland subwatershed contains the municipal groundwater systems for communities of Holland Landing, Aurora, Newmarket, Ballantrae and a portion of the Queensville well supplies. Under existing average annual demand conditions the maximum percent water demand is 32.1%. Under the future average annual demand conditions the maximum percent water demand increases to 35.2%. This results in a significant potential for stress in the East Holland River subwatershed (Figure 3.4-4).

West Holland Subwatershed

The West Holland subwatershed contains the municipal groundwater systems for the communities of Ansnorveldt, Schomberg as well as, Bradford/Bondhead. Under the existing average annual demand conditions the maximum percent water demand is 9.0%. Under the future average annual demand conditions the maximum percent water demand is 9.6%. The stress levels of 9.0 and 9.6 cause the West Holland subwatershed to be on the verge of having the potential to be moderately stressed by falling within the 8 to 10% threshold range. As per MOE Technical Rules (MOE, 2008a) the West Holland subwatershed was then required to undergo a sensitivity analysis. For the sensitivity analysis the agricultural demand estimate was considered to be 100% consumptive due to the high agriculture uses within this subwatershed and the uncertainty around its use. This resulted in pushing the West Holland subwatershed into the moderate potential for stress range (Figure 3.4-4).

Maskinonge River Subwatershed

The Maskinonge River subwatershed contains a portion of the Queensville municipal well supply. Under the existing average annual demand conditions the maximum percent water demand is 14.1%. Under the future annual demand conditions the maximum percent water demand was found to be 14.1% as well. This results in moderate potential for stress in the Maskinonge River subwatershed (Figure 3.4-4).

Conclusions and Recommendations

The Tier 2 Water Budget and Stress Assessment for the Maskinonge and East and West Holland Rivers subwatershed was completed in accordance with the MOE Technical Rules. The results of the Tier One Water Budget and Stress Assessment were confirmed, and all three subwatersheds will be required to undergo a Tier Three assessment (Figure 3.4-5).

Figure 3.4-1: Study Area.

Figure 3.4-2: Core Model Boundary.

Figure 3.4-3: Groundwater Discharge to Streams.

Figure 3.4-4: Subwatershed Groundwater Stress Assessment Results.

Figure 3.4-5: Subwatersheds Identified for Tier 3.

3.5 Tier Two Water Budget and Water Quantity Stress Assessment- Barrie, Lovers, Hewitts Creek

The Tier One Stress Assessment identified several subwatersheds as having a moderate or significant potential for stress (shown in Figure 3.2-8) and as a result, Tier 2 Stress Assessments were completed for these subwatersheds. This section provides an overview of the Barrie, Lovers and Hewitts Creek Tier 2 Water Budget and Water Quantity Stress Assessment, which was completed as part of the larger Tier 2 study referred to as the South Georgian Bay West Lake Simcoe Tier 2 Water Budget and Stress Assessment (AquaResouces and Golder, 2010).

The work described herein is a summary of the conceptual geologic and hydrostratigraphic modeling (AquaResource and Golder, 2009) and the water budget tool developed for the South Georgian Bay West Lake Simcoe Tier 2 Study Area (AquaResource and Golder, 2010) that was completed in compliance with the Technical Rules prepared by the Ministry of Environment (MOE, 2008a) for the preparation of Assessment Reports under the Clean Water Act and provincial guidance (MOE, 2007). It is recommended that the above two reports be referred to for additional detail.

Study Area and Physical Setting

Location

The study area within the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResouces and Golder, 2010) encompasses the Nottawasaga Valley, Severn Sound, and portions of the Lake Simcoe Source Protection Areas (Figure 3.5-1). This section of the assessment report will focus on the study area located within the Lake Simcoe Source Protection Region and the Barrie, Lovers and Hewitt Creek subwatersheds in particular. The Nottawasaga Valley and Severn Sound watersheds will be discussed in their respective assessment reports.

The Lake Simcoe watershed covers a total area of 3621 km^2, approximately 600 km2 of which was included in the South Georgian Bay West Lake Simcoe Tier 2 Water Budget study. This area includes numerous small streams flowing to the west shores of Cooks Bay, Kempenfelt Bay and the north-east shore of Lake Simcoe. The Lake Simcoe subwatersheds located within the study area are: Oro Creeks North, Hawkestone Creek, Oro Creeks South, Innisfil Creeks, Hewitts Creek, Lovers Creek, Barrie Creeks and a portion of the West Holland. However, only those subwatersheds (i.e. Hewitts Creek, Lovers Creek, and Barrie Creeks) indicated as having a moderate or significant potential for stress within the Tier One Stress Assessment were further evaluated in this Tier 2 Water Budget and Stress Assessment.

The subwatershed boundaries were modified from those used within the Tier One Stress Assessment as listed in Table 3.5-1 (Figure 3.5-2). The size of the Tier One subwatersheds was a concern for the stress assessment process; therefore, the subwatershed boundaries were re-evaluated to be consistent with the Guidance (MOE, 2007). For this study, small subwatesheds were combined (e.g. Lovers and Hewitts Creek), while larger subwatersheds were subdivided to have areas of roughly 150-200 km^2. The revision of the subwatershed boundaries was also done to facilitate independent stress assessments of municipal systems where neighbouring systems are understood to be hydraulically isolated or to isolate major urban and rural water systems (AquaResource and Golder Associates, 2010).

Table 3.5-1: Subwatershed Boundary changes for the Barrie, Lovers, Hewitts Creek Tier Two.

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Drinking Water System
Hewitts Creek	Simcoe County	Town of Innisfil	Innisfil Heights Well Supply
Hewitts Creek	Simcoe County	Town of Innisfil	Stroud Well Supply
Barrie Creeks	City of Barrie	City of Barrie	Barrie Well Supply

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Conceptual Model

Tier 2 Water Budgets and Stress Assessments require that a numerical model be developed to assess the parameters for the percent water demand in the stress calculations. The first step to creating the numerical water budget involves enhancing the conceptual understanding of the study area through the creation of a detailed geological conceptual model. The conceptual model created for the South Georgian Bay West Lake Simcoe study area builds on various models developed for the North and South Simcoe groundwater studies and geological work completed by the Lake Simcoe Region Conservation Authority (LSRCA). An effort was also made to obtain the information required to conduct water budgeting along the model edge boundaries (AquaResource and Golder, 2009).

An overview of the conceptual model is discussed in this section. A detailed description of the conceptual model can be found in the Nottawasaga Valley Conservation Authority Water Budget Model- Geological/Hydrostratigraphic Model Development Interim Report (AquaResource and Golder, 2009). The goals of the conceptual model were to a) develop a hydrostratigraphic model framework based on the analyses and results of the previous groundwater studies; b) complete bedrock surfaces using sub-regional models and adjacent regional models; c) combine all surfaces and fill gaps with data from bedrock sub-crop maps, NVCA and SSEA data and borehole data; d) develop hydrostratigraphic model layers suitable for numerical model implementation (AquaResource and Golder, 2009).

The understanding of the regional hydrostratigraphy has increased through the creation of the conceptual model. On a regional scale the occurrence of groundwater and groundwater flow within the study area is controlled by precipitation, ground surface topography, water table elevation, surficial geology units, the spatial distribution and connectivity of geologic units. Precipitation was found to be the main source of groundwater recharge throughout the study area. The groundwater recharge is controlled by the hydraulic conductivity of the surficial geology, the slope of the topography, land use and soil moisture content (AquaResource and Golder, 2009). The updated knowledge of the hydrostratigraphy was key in the development of the layers used in the groundwater model.

The study area contains both overburden and bedrock aquifers that can be used for water supply. The aquifers present in the Lake Simcoe study area are generally unconfined. The Barrie- Borden aquifer is situated ideally for water supply. It is confined within a deep tunnel channel valley over laid by fine-grained deposits. The fine-grained deposits such as the till plains are aquitards impeding the vertical movement of water and potential contaminants to the underlying aquifers.

Water Supply

The water supply component of the stress assessment was estimated using a numerical groundwater flow model developed for the South Georgian Bay West Lake Simcoe (SGBWLS) study area. This groundwater model incorporated the enhanced knowledge of the geologic surface and sub-surface gained from the conceptual model discussed in the previous section. The model domain encompasses the Nottawasaga Valley and Severn Sound watersheds in their entirety as well as the western portion of the Lake Simcoe watershed. Additionally, the model was also built to extend to the areas beneath Georgian Bay and Kempenfelt Bay, resulting in a total coverage area of 5416 km^2 (Figure 3.5-3) (AquaResource and Golder, 2010).

The FEFLOW modelling code was selected for use because of its ability to simulate physical features, and follow naturally complex boundary conditions. This model runs very efficiently requiring fewer calculation points to achieve the same level of precision as with finite difference model codes. The model elements also have the ability to conform to the pronounced vertical variation of the hydrostratigraphic layers. The stable water table simulation the model performs allows for a more accurate depiction of the shallow subsurface, this allows the modeler to focus on conceptual issues rather than numerical issues. The model is summarized in Appendix WB-4B and described in more detail in the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResource and Golder, 2010), which can be referred to for further reasoning on why this model was chosen for the Tier Two assessment.

The water budgets and stress assessment are calculated using the estimated values for groundwater supply and reserve simulated in the numerical FEFLOW model described in Section 3.5.3. Water budgets and stress assessments are conducted to determine a subwatersheds potential stress level, with the ultimate goal of sustaining a water supply.

Recharge

Groundwater recharge in the model was obtained from two surface water models within the study area. Within the Lake Simcoe area a PRMS model developed by Earthfx in 2009 for the Lake Simcoe watershed was used. The rest of the study area obtained recharge values from and HSP-F model developed by the Nottawasaga Valley Conservation Authority in 2009. The surface water models are discussed in detail in Appendix WB-4B. The estimated groundwater recharge used in the stress assessment is illustrated in Figure 3.5-4.

Water Budget Results

The parameters used in the water budget were simulated using the numerical FEFLOW model. This included simulations of groundwater recharge under steady state conditions, consumptive demand estimates determined from recorded pumping rates, groundwater discharge to streams, and the inter-basin transfer of groundwater.

The results of the water budget are shown on Table 3.5-2. The value for groundwater recharge indicates how much recharge the subwatersheds were simulated to receive annually. The negative values for groundwater takings indicate that both Barrie Creeks and Hewitts Creek subwatershed are experiencing a net loss of water due to groundwater pumping. A negative value for groundwater discharge to streams indicates that flow is leaving the groundwater system and entering the surface water system. This is observed in both Barrie Creeks and Hewitts Creek subwatersheds. A positive value for inter-basin transfer indicates that the subwatershed is experiencing a net in-flux of groundwater. This is observed in the Barrie Creeks subwatershed. Conversely a negative net in-flux value indicates that a subwatershed is experiencing a net loss of groundwater flow. This is observed in Hewitts Creek subwatershed. The values in the water budget form the foundation for the stress assessment calculations.

Table 3.5-2: Water Budget Summary by Subwatershed (AquaResource and Golder, 2010).

ID	Subwatershed	Area (km^2)	Groundwater Recharge (L/s)	Groundwater Takings* (L/s)	Inter-Basin Transfer (L/s)	Cross-Boundary Transfer (L/s)	Total Discharge to Surface Water (L/s)	Discharge to Streams (L/s)	Discharge to Wetlands and Inland Lakes (L/s)	Discharge to Georgian Bay (L/s)	Discharge to Lake Simcoe (L/s)
28	Hewitts Creek	74	312	-19	-97	0	-200	-191	0	0	-9
22	Barrie Creeks	53	251	-468	339	0	-125	-5	-100	0	-21

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Uncertainty Discussion

All models developed to represent natural systems are simplifications of the natural environment and the hydraulic processes within that environment. This simplification results in inherent uncertainty in many of the elements in the groundwater model. As a result of the groundwater model being designed to incorporate the key hydrogeologic features in the study area, the estimation of groundwater flow on a smaller scale may not accurately represent the local area. The scale of the calibration effort was kept consistent with the scale of the model; as such the model was calibrated on a subwatershed level. The calibration water level calibration target only included information provided in the Ministry of the Environment [Conservation and Parks]'s water well database. The expected range of uncertainty associated with these records is 5 m. Since fluctuations in groundwater levels are generally minor, carefully measured water levels were considered to be more certain.

Groundwater discharge is expected to be a component of baseflow in most streams, with the remaining baseflow being supplied by other storage mechanisms (i.e. wetlands). Since the proportion of groundwater discharge to wetland discharge is rarely known this is one source of uncertainty. The numerical representation and simulation of groundwater flow systems also contains limitations. Model simulation uncertainty comes from both the approximate solution of the equations using a finite element method, as well as the limitations surrounding finite discretization and assumptions of steady state.

Water Demand

This section provides a summary of the consumptive groundwater demands for Barrie, Hewitts and Lovers Creek subwatersheds assessed as part of the Tier Two Stress Assessment (AquaResource and Golder, 2010).

Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. aquifer) within a reasonable amount of time. Understanding this type of water demand is critical to the development of a water budget framework. An estimate of the extent and variability of water use throughout the Study Area is required to identify the subwatersheds that may be under the highest degree of potential hydrologic stress, and to guide future efforts to refine water budget tools in those areas (AquaResource and Golder, 2010).

The consumptive groundwater demand was estimated for both permitted (e.g. municipal, industrial and commercial water users) and non-permitted groundwater takings (i.e. domestic water users extracting less than 50,000 L/day and agricultural water users). Figure 3.5-5 shows the locations of all permitted groundwater takings within the Study Area. Only those within the

Tier Two Stress Assessment subwatersheds were considered in this assessment. Figure 3.5-6 and Figure 3.5-7show the average annual and monthly maximum consumptive groundwater demand estimates, respectively, for each Tier Two Stress Assessment subwatershed. These estimates are used to compute the subwatershed potential stress under existing conditions (AquaResource and Golder, 2010).

Reported pumping rates were used to generate the municipal demand, other permitted water demand was estimated by combining the permitted rate with the months of expected active taking. Lastly, non-permitted water demand was estimated by area pro-rating the non-permitted demand estimate from the Tier One stress assessments (SGBLS, 2009). Future consumptive demand was also estimated for the subwatersheds not identified as potentially stressed under existing conditions. After the consumptive demand was estimated a consumptive factor was applied to determine the proportion of groundwater not returned to the original source within a reasonable amount of time. Existing and future water demand can be found in Appendix WB-2. The consumptive factors used are outlined in Table 3.3-3.

There are a number of non-consumptive water users within the study area. However, since they return water to the source from which it was taken they were not considered to be water takers within this Tier Two Assessment (AquaResource and Golder, 2010).

Permits to Take Water

Information from the January 2006 permit to take water program database was used to estimate actual water demands. Only permits representing sustained water takings were used in the assessment, temporary permits such as pumping tests were not included. The permit to take water program is now requiring users to report actual pumping rates; however, this updated information was not available for this study. Since the actual pumping rates were unavailable some considerations were taken into account when using the data base.

1) Permit holders often request a volume that exceeds their requirements to be listed on the permit. This is often done to ensure compliance in dry years, or to secure sufficient water for possible future expansion.
2) The permitted volume is often derived from the capacity of the pumping equipment rather than the requirements of the user, which can drastically overestimate the users demand.
3) The database does not maintain a record of whether the permit is just for seasonal use.

4) Multiple sources may be included on a particular permit, and the total refers to all sources associated with the permit. To estimate the total demand, the total permitted rate should be logically divided amongst the active source locations.
5) The spatial location of the water taking sources is not always accurate.
6) The PTTW database is not current with respect to the MOE's actual permitting activities.
7) Historic water takings may be "grandfathered" and do not require a permit. As a result, there may be some significant water takers not accounted for.

Table 3.5-3: Number of Groundwater Takings by Subwatershed and Water Use Sector.

ID	Subwatershed	Agricultural	Commercial	Industrial	Miscellaneous
28	Hewitts Creek	0	12	0	0
22	Barrie Creeks	0	0	1	2

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Table 3.5-4(con't): Number of Groundwater Takings by Subwatershed and Water Use Sector.

ID	Subwatershed	Recreational	Remediation	Water Supply	Total
28	Hewitts Creek	0	0	5	17
22	Barrie Creeks	0	5	14	22

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Table 3.5-5: Maximum Permitted Takings by Subwatershed.

ID	Subwatershed	Ares (Km^2)	Maximum Permitted Takings (L/s)	Maximum Permitted Takings (mm/yr)
28	Hewitts Creek	74	182	77
22	Barrie Creeks	53	1,308	771

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Municipal Water Demand

Municipal water supplies represent the largest water use within the study area. As such, accurate estimates of municipal water use are a critical component of the consumptive water demand estimate. For the Tier Two Stress Assessment, reported municipal pumping rates were obtained from a variety of sources. Table 3.5-5 lists the municipal systems within the Tier Two Stress Assessment, as well as the source and year of the reported pumping rates. The most recent reported rates were utilized where multiple reported rates were available. Table 3.5-5 summarizes the total municipal groundwater takings by subwatershed for municipal water supply purposes. As seen in these tables, the highest municipal demand is in Barrie Creeks despite the fact that it is the smallest subwatershed (AquaResource and Golder, 2010).

Table 3.5-6: Summary of Municipal Systems (AquaResource and Golder, 2010).

Municipality	Community	Municipal System / Wellfield	Subwatershed(s)	Year of Data	Source of Data	Annual Volume Pumped (L/s)
City of Barrie	Barrie	Barrie Well System	Middle Nottawasaga	2008	NVCA	0.0
City of Barrie	Barrie	Barrie Well System	Barrie Creeks	2008, 2009	NVCA, City of Barrie	458.3
Innisfil	Innisfil Heights	Innisfil Heights	Hewitts Creek	2008	Town of Innisfil	3.9
Innisfil	Stroud	Stroud	Hewitts Creek	2008	Town of Innisfil	5.8

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Table 3.5-7: Summary of Municipal Groundwater Demands by Subwatershed (AquaResource and Golder, 2010).

ID	Subwatershed	Ares (Km^2)	Municipal Groundwater Demand (L/s)	Municipal Groundwater Demand (mm/yr)
28	Hewitts Creek	74	10	4
22	Barrie Creeks	53	458	270

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Other Permitted Water Demand

Non-municipal permitted water taking types included in the assessment are: agriculture, commercial, dewatering, industrial, miscellaneous, recreational and remediation activities. The other permitted water takings are outlined in Appendix WB-2B.

Non-Permitted Water Demand

Non-permitted water demand was estimated by area pro-rating the non-permitted water demand estimated in the Tier One Water Budget and Stress Assessment. The estimated non-permitted water takings in the Lake Simcoe watershed include agriculture needs and unserviced domestic use. The non-permitted water takings are found in Table 3.5-7.

The non-permitted estimated agriculture water demand includes water used for livestock watering, equipment washing, and any other agriculture water use excluding water used for irrigation. Non-permitted agriculture water demand was estimated as part of the Tier One Water Budgets and Stress Assessments. The estimates were area pro-rated to match the boundaries of the Tier Two subwatersheds. It should also be noted that since the non-permitted agriculture demand was based off of a census-based estimation technique it is not possible accurately determine the source of water used. For the Tier Two assessment it was assumed that half of the water would be supplied from a surface source and half would be supplied from a groundwater source. The consumptive nature of non-permitted agriculture water use is also hard to determine, as the water can be used for so many different things. To be on the conservative side all non-permitted agriculture water takings were assumed to be 100% consumptive.

The unserviced domestic water use includes any household water use that is not supplied by a municipal water source. An estimate of the unserviced domestic water use was calculated as part of the Tier One Water Budgets and Stress Assessments. The estimates from the Tier One were also area pro-rated to the boundaries of the new subwatersheds. The unserviced domestic water use was assumed to be 20% consumptive in the Tier Two assessment. This assumption was made because the majority of unserviced domestic water use comes from rural areas, supplied by private wells. Since these takers are generally in rural areas the water taken would be returned to the groundwater system through the septic system.

Table 3.5-8: Non-permitted Agriculture and Unserviced Domestic Water Use (AquaResource and Golder, 2010).

ID	Subwatershed	Non-Permitted Agricultural Demand (L/s)	Unserviced Domestic Water Use (L/s)	Total Non-Permitted Water Use (L/s)	Total Non-Permitted Water Use (mm/yr)
28	Hewitts Creek	0.4	1.4	1.8	0.8
22	Barrie Creeks	0.7	0.9	1.7	1.0

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Monthly Usage and Consumptive Use Factors

Section 3.3.2 summarizes the monthly usage and consumptive use factors that were utilized within the Tier 2 assessments. While these factors are generalized, they provide a consistent approach for the initial estimation of consumptive water use. It is recognized that within a specific water use sector the proportion of pumped water consumed may significantly vary between individual operations; the generalized factors, presented in Table 3.3-3, represent a significant source of uncertainty. As such, they were modified as part of a sensitivity analysis to ensure the uncertainty does not affect the stress level assignment (Section 3.5.4).

Table 3.5-9 indicates that the Barrie Creeks subwatershed has a high demand for every month. This is because the Barrie Creeks subwatershed is supplying the all of the municipal water for the City of Barrie with the exception of one well located in the Willow Creek subwatershed. Hewitts Creek subwatershed has increased consumptive demand from May to September. This is a result of increased agricultural water demand during the growing season.

Table 3.5-9: Consumptive Demand by Subwatershed.

ID	Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
28	Hewitts Creek	14	14	14	16	24	30	30	28	28	21	14	14	21	30

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ID	Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
22	Barrie Creeks	447	417	432	473	510	514	522	498	495	460	437	428	470	522

Table 3.5-10: Percentage of Consumptive Water Demand by Sector per Subwatershed.

Sector	Estimated or Reported (E/R)	Hewitts Creek Subwatershed (ID 28)	Subwatershed Barrie Creek (ID 22)
Agricultural	E	-	-
Agricultural	R	-	-
Commercial	E	39%	-
Commercial	R	5%	-
Industrial	E	-	<1%
Industrial	R	-	-
Miscellaneous	E	<1%	-
Recreation	R	-	-
Private Water Supply	R	-	-
Private Water Supply	E	-	-
Municipal Water Supply	E	47%	98%
Livestock and Rural Domestic	E	9%	<1%
Total Estimated	**E**	**48%**	**<1%**
Total Reported	**R**	**52%**	**99%**

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Uncertainty

Some uncertainty exists with the water demand estimates used in the Tier Two Assessment. Using reported pumping rates for municipal water supply reduces the uncertainty in the municipal water demand. There is still some inherent uncertainty associated with the generated consumptive water demand estimates. The uncertainty associated with the non-municipal permitted water takers will be the highest due to the reliability of the permit to take water database discussed in the proceeding section (Section 3.5.3). Some uncertainty will also exist in the non-permitted water taking estimates. However, since these water users take relatively small rates and with the conservative approach taken with respect to the consumptive nature of these taking types, the impact of this uncertainty is not significant with respect to the stress assessment (AquaResource and Golder, 2010).

Tier Two Stress Assessment

The Tier Two Stress Assessment has only been conducted for groundwater systems since no surface water systems were found to be moderately or significantly stressed in the Tier One Water Budget and Stress Assessment for the Lake Simcoe watershed. The groundwater systems in the study area that have undergone the stress assessment are shown in Table 3.5-10 and Figure 3.5-1.

Table 3.5-11: Groundwater systems in the study area that have undergone the stress assessment.

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Drinking Water System
Hewitts Creek	Simcoe County	Town of Innisfil	Innisfil Heights Well Supply
Hewitts Creek	Simcoe County	Town of Innisfil	Stroud Well Supply
Barrie Creeks	City of Barrie	City of Barrie	Barrie Well Supply

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Existing Conditions

The percent water demand was calculated for the Barrie Creeks and Hewitts Creek subwatersheds using estimates of groundwater supply, reserve and consumptive demand. The water demand used in the stress assessment is discussed above in section 3.5.3. The estimated consumptive demand for permitted and non-permitted users was used in calculating the subwatersheds potential for stress under existing conditions. The groundwater supply component for the stress assessment was calculated as being the average annual recharge plus the lateral inflow of groundwater to the subwatershed. The groundwater reserve component of the stress assessment was calculated to be 10% of the estimated groundwater discharge to streams. The volume of groundwater discharge on a subwatershed basis was estimated using the FEFLOW numerical model and is illustrated on Figure 3.5-8. The figure illustrates that the Lake Simcoe portion of the study area discharges very little groundwater on an annual basis less than 500 L/s , when compared to portions of the Nottawasaga Valley watershed where some subwatersheds discharge over 2500 L/s on an annual basis.

The results of the existing conditions stress assessment are shown on Table 3.5-11 and Table 3.5-12. The existing conditions stress assessment indicated that Hewitts Creek subwatershed was identified as having the potential to be moderately stressed, and the Barrie Creeks subwatershed as having the potential to be significantly stressed. As per the technical rules these subwatersheds will automatically be required undergo a Tier Three analysis. As a result, these subwatersheds do not require any further analysis under planned, future, or drought conditions in the Tier Two assessment as per the Technical Rules (MOE, 2007).

Table 3.5-12: Groundwater Stress Assessment-Existing Conditions (AquaResource and Golder, 2010).

Parameter	Details	Hewitts Creek Subwatershed (ID 28)	Subwatershed Barrie Creek (ID 22)
Groundwater Supply	Recharge (L/s)	312	251
Groundwater Supply	Flow In (L/s)	0	362
Groundwater Supply	Total Supply (L/s)	312	614
Groundwater Reserve	(L/s)	19	0
Consumptive Demand	Annual Average (L/s)	21	470
Consumptive Demand	Monthly Maximum (L/s)	30	522
Time of Max Demand	(Month)	June	July
Percent Water Demand	**Annual Average (%)**	**7%**	**77%**
Percent Water Demand	**Monthly Maximum (%)**	**10%**	**85%**

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Table 3.5-13: Groundwater Stress Classification-Existing Conditions (AquaResource and Golder, 2010).

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Evaluate Planned Conditions	Municipal Water Supply Systems
28	Hewitts Creek	Low	Low	**Yes**	Innisfil Heights, Stroud
22	Barrie Creeks	**Significant**	**Significant**	No	Barrie

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Future Conditions

The future water demand scenario considers the evaluation of future consumptive water demand estimates for a future population throughout each municipality's planning horizon. The projected municipal demand was obtained from LSRCA, NVCA, SSEA and the local municipality's. In areas where projections were unavailable future pumping rates were estimated from official growth plans and population estimates (TABLE 3.4-13).

Future land use conditions were also estimated to determine a future average annual recharge rate to be used as the water supply term in the stress assessment calculations. Any changes to future rates were assumed to be based on change in urban land use alone (AquaResource and

Golder, 2010). The estimated future recharge rates as a function of land use changes are displayed in Table 3.4-14.

The results of the future conditions stress assessment are shown on Table 3.4-15 and Table 3.4-16. The future conditions indicate that the Hewitts Creek subwatershed remains at a low potential for stress. As a result, the Hewitts Creek subwatershed is required to undergo the drought assessment scenario.

Table 3.5- 14: Future Groundwater Municipal Demand Estimates (AquaResource and Golder, 2010).

Municipality	Community	Wellfield	Subwatershed	Existing Volume Pumped (L/s)	Future Volume Pumped (L/s)	Data Source and Comment on Increase in Future Demand
Innisfil	Innisfil Heights	Innisfil Heights	Hewitts Creek	3.9	6.2	MTO Population Growth
Innisfil	Stroud	Stroud	Hewitts Creek	5.8	9.0	MTO Population Growth

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Table 3.5- 15: Future Land Use Changes and Recharge Rate Estimates (AquaResource and Golder, 2010).

ID	Subwatershed	Percent Increase in Urban Area (%)	Estimated Existing Average Recharge (L/s)	Estimated Existing Average Recharge (mm/yr)	Estimated Future Average Recharge (L/s)	Estimated Future Average Recharge (mm/yr)	Percent Change in Recharge (%)
28	Hewitts Creek	7.2%	312	133	301	123	-4

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Table 3.5- 16: Groundwater Stress Assessment-Future Conditions (AquaResource and Golder, 2010).

Parameter	Details	Hewitts Creek Subwatershed (ID 28)
Future Groundwater Supply	Recharge (L/s)	301
Future Groundwater Supply	Flow In (L/s)	0
Future Groundwater Supply	Total Supply (L/s)	301
Groundwater Reserve	(L/s)	19
Future Consumptive Demand	Annual Average (L/s)	26
Future Consumptive Demand	Monthly Maximum (L/s)	36
Future Percent Water Demand	**Annual Average (%)**	**9%**
Future Percent Water Demand	**Monthly Maximum (%)**	**13%**

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Table 3.5- 17: Groundwater Stress Classification-Future Conditions (AquaResource and Golder, 2010).

-	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Evaluate Drought Conditions	Major Municipal Water Supply System
28	Hewitts Creek	Low	Low	**Yes**	Innisfil Heights, Stroud

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Planned and Future Conditions

No planned municipal systems exist with the Lake Simcoe portion of the study area. The City of Barrie has one planned municipal well (well #19) that is located just outside of the study area in the Nottawasaga Valley watershed (Table 3.5-17). However, this well was not evaluated in the planned scenario due to the Barrie Water Supply System being identified as significantly stressed in the existing conditions scenario (AquaResource and Golder, 2010).

Table 3.5-18: Summary of Planned Systems.

Municipality	Community	Municipal System	Subwatershed	Source of Data	Annual Volume Pumped (L/s)
Barrie	Barrie	Barrie	Middle Nottawasaga	City of Barrie (2009)	48

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Historical Conditions

There are no known historical conditions as defined by the Technical Rules (MOE, 2008a), where pumping at municipal wells was affected by low groundwater levels in any of the subwatersheds. However, the City of Barrie has added surface water supplies to supplement groundwater supplies, and to relieve pressure on groundwater sources. No subwatersheds would be classified as moderately stressed due to historical conditions, in the Lake Simcoe watershed portion of the study area.

Drought Scenario

According to the Technical Rules (MOE, 2008a), a subwatershed can also be identified as having a potential for moderate stress if either of the following circumstances occurs within the subwatershed during either observed or simulated drought conditions (Rule 35.2e).

(i) the groundwater level in the vicinity of a well was not at a level sufficient for the normal operation of the well; or

(ii) the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

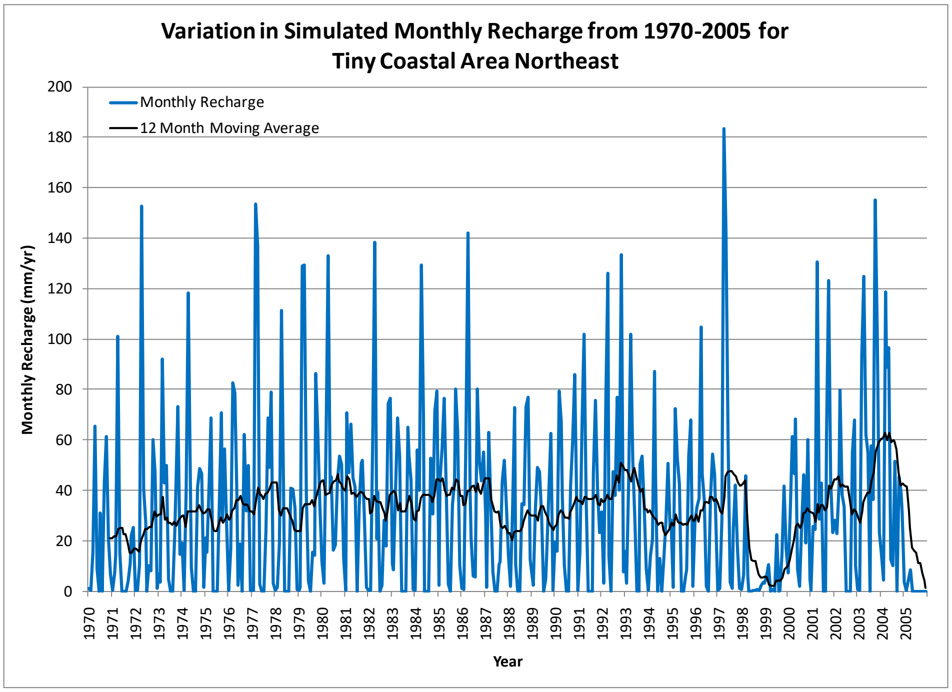
The Technical Rules identify the need for both a two year and ten year drought scenario (Rule 35.2. f/g). These scenarios are designed to capture probable periods of drought conditions; both short- and long- duration droughts. With the surface water simulation producing groundwater recharge estimates for the 1970-2005 time period, the impacts of short and long duration drought within this time period can be assessed. Furthermore, the scenarios need to be assessed for both existing and planned systems.

The years of 1998-1999 represent a recorded period of low precipitation, for which estimated recharge is available from the HSP-F and PRMS simulations. Since this information is readily available, the two-year and ten-year scenarios were evaluated simultaneously.

Methodology

To complete the drought assessment, simulated continuous groundwater recharge from the HSP-F and PRMS streamflow generation models is used as transient recharge input to the FEFLOW groundwater flow model. Groundwater recharge is simulated based on units of similar hydrologic response (i.e. areas with similar soil type, land use and climate) for both models. For the purposes of the groundwater drought scenario, the most dominant response unit was used as a representative hydrologic response over the study area, namely forested areas over coarser soils (for a).

Graph 3.5- 1 illustrates the typical variability in monthly recharge estimated from the 1970-2005 simulation for a sample area called Tiny Coastal Area Northeast. This sample area includes the municipal systems of Sawlog, Georgian Bay Estates and Cooks Lake. The figure below also shows a 12-month moving average of the monthly recharge, which removes monthly variability to highlight more significant trends. The 1998-1999 drought is clearly evident in this figure, as is the relatively low recharge conditions that occurred throughout the 1970s.



Graph 3.5- 1: Typical Monthly Recharge Variability over the 1970-2005 Simulation Period.

The FEFLOW steady-state groundwater flow model was configured to use the time series of monthly recharge for the complete 1970-2005 simulation. Water levels resulting from the steady-state groundwater flow simulation were set as initial conditions for the 1970-2005 transient simulation. Within each month, the FEFLOW groundwater flow model adjusts the simulation timestep automatically to achieve a proper numerical solution. The groundwater-flow model was configured to export the minimum simulated groundwater level at each municipal well during the simulation. For discussion purposes, the simulated well response for the entire period for a sample well, namely Sawlog Well 16-2, was also exported (See Graph 3.5- 1). This can be generated for any well within the Study Area.

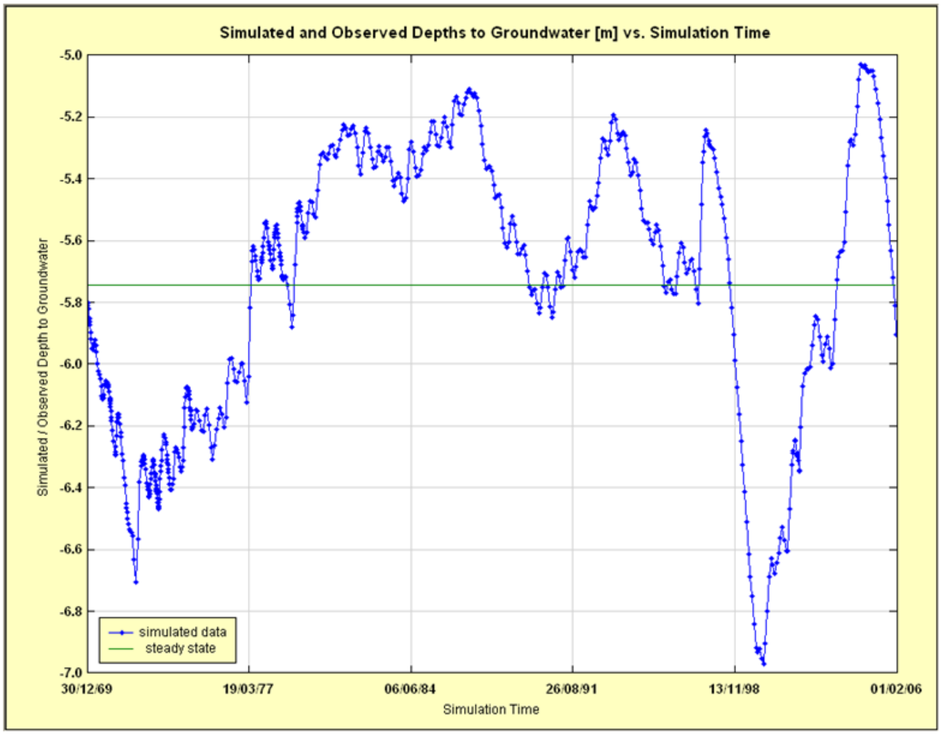
Results

With respect to the Technical Rules, the purpose of the drought scenario is to identify any subwatershed having municipal wells with the potential to be affected by a drought. If such is the case, the subwatershed is classified as having a moderate potential for stress.

Subwatersheds already classified as having a moderate or significant potential for stress cannot be affected by the results of the drought scenario.

Graph 3.5- 2 illustrates groundwater levels simulated at the sample municipal well of Sawlog. This well was chosen for discussion purposes only. The chart also shows the average water level computed for this pumping well under steady state recharge conditions (green line). The time period shown on the figure is 1970 to 2005, which includes the 1998-1999 drought period. The simulation also assumes constant pumping from each of the wells and therefore the estimated water level fluctuations do not include variations in pumping rates.

From this figure, the impact of lower recharge throughout the 1970s as well as during the 1998-1999 drought are quite relevant. There is a clear drop in water levels during the drought in 1198-1999 (by approximately 1m), with climbing water levels during the recovery in the early 2000s. Similarly, the water levels throughout the 1970s were simulated to be below the long term steady-state conditions by about 1m and slowly recover throughout the decade.



Graph 3.5- 2: Simulated Well Response from 1970-2005 at Sawlog Well 16-2.

As noted above, the drought assessment is performed using transient recharge rates coupled with both existing and planned pumping rates for the municipal wells within subwatersheds listed in Table 3.4-20. The results of the drought assessment are shown in Table 3.4-20, where planned systems are shown in bold. In this table, the estimated available drawdown and the maximum simulated drawdown over the 1970-2005 period are shown for each municipal well. The available drawdown was estimated based on the assumption that the pump intake is located 2 m above the top of the screened interval (as reported in the WWIS or estimated from available information). If the maximum drawdown is greater than the available drawdown, the well is interpreted to be susceptible to drought conditions and could potentially experience climatic conditions that would deplete its ability to pump at the specified rate. As seen in Table 3.4-20, there are not municipal wells susceptible to drought conditions under existing or planned pumping conditions; no wells are predicted to experience drawdown that would exceed their estimated available drawdown. As such, the drought assessment does not affect the overall stress level assignment the Hewitts Creek subwatershed remains at a low potential for stress.

Table 3.5- 19: Results of Groundwater Drought Scenario-Maximum Drawdown (AquaResource and Golder, 2010).

Subwatershed	Municipality	Municipal System	Community	Well Name	Existing Pumping - Available Drawdown (m)	Existing Pumping - Maximum Drawdown (m)	Planned Pumping - Available Drawdown (m)	Planned Pumping - Maximum Drawdown (m)	Drought Concern
Hewitts Creek	Innisfil	Innisfil Heights	Innisfil Heights	Well 2	41	28	41	28	N
Hewitts Creek	Innisfil	Innisfil Heights	Innisfil Heights	Well 3	35	29	35	29	N
Hewitts Creek	Innisfil	Stroud	Stroud	Well 1	83	49	83	49	N
Hewitts Creek	Innisfil	Stroud	Stroud	Well 2 Standby	79	42	79	42	N
Hewitts Creek	Innisfil	Stroud	Stroud	Well 3	82	46	82	46	N

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Uncertainty in Groundwater Stress Classifications

A sensitivity analysis was conducted to evaluate the uncertainty associated with the water demand or supply components associated with the percent demand calculations. The sensitivity analysis will determine if the uncertainty associated with the stress assessment components is enough to modify the assigned stress level. Each subwatershed will be assigned a low or high uncertainty level as per the Technical Rules.

Where the sensitivity analysis indicates that the classification may change from moderate to low potential, or low to moderate potential, an uncertainty classification of high is assigned. For subwatersheds that do not change stress levels within the sensitivity analysis, an uncertainty classification of low is assigned (AquaResource and Golder, 2010).

While the consumptive use factors (Table 3.3-3) allow for a more realistic estimate of actual amounts of water which are not returned to the same source, these factors do represent a source of uncertainty. Within the Study Area, groundwater takings for agricultural irrigation purposes are assigned a consumptive factor of 80-90%. It is possible that in reality, none of the irrigation water is returned to the groundwater system, for example, due to tile drainage systems collecting water and discharging it to surface water systems. As such, the following sensitivity analysis presents the percent water demand whereby the average annual and monthly maximum consumptive demands were estimated assuming agricultural takings were 100% consumptive (AquaResource and Golder, 2010).

A second source of uncertainty is the recharge simulated by the surface water models. To ensure the potential stress level for each subwatershed is not sensitive to small changes in recharge, for the second sensitivity scenario, groundwater recharge for each subwatershed was decreased by 10%. This represents a reasonable level of variation in recharge that could be due to differences in characterization, calibration and model capabilities between the HSP-F and PRMS models (AquaResource and Golder, 2010).

The sensitivity scenarios were completed for both the annual and maximum monthly existing demand conditions and are shown in Table 3.5-19. For each subwatershed, the stress classification under the two sensitivity analysis scenarios did not differ from the stress classification assigned in the existing conditions scenario. The sensitivity analysis shows that the stress assessment results are not sensitive to uncertainty associated with water demand and groundwater recharge estimates. This confirmation of the stress classification provides additional confidence in the Tier Two Stress Assessment (AquaResource and Golder, 2010).

Table 3.5-20: Groundwater Sensitivity Analysis-Existing Conditions (AquaResource and Golder, 2010).

Condition /Sensitivity	%Water Demand	Hewitts Creek	Barrie Creeks
Existing Conditions	Average Annual	7%	77%
Existing Conditions	Max Month	10%	85%
Groundwater Agricultural Demand 100% Consumptive	Average Annual	7%	77%
Groundwater Agricultural Demand 100% Consumptive	Max Month	10%	85%
10% Less Recharge	Average Annual	8%	80%
10% Less Recharge	Max Month	11%	89%
Sensitivity Level	-	Low	Low

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Stress Assessment Results

Barrie Creeks Subwatershed

The Barrie Creeks subwatershed contains the municipal groundwater systems for the City of Barrie. Under average demand conditions the Percent Water Demand is 77%; under maximum monthly conditions the Percent Water Demand is 85%. This results in a significant potential for stress for Barrie Creeks subwatershed.

Groundwater takings within this subwatershed are almost entirely for the City of Barrie municipal supplies (~98%). Additional takings are for groundwater remediation (~2%) and industrial cooling water (<1%) purposes. Evidently, the municipal supplies are driving the potential stress in this subwatershed. There is low uncertainty associated the stress classification for this subwatershed.

Under the requirements of the Clean Water Act, the City of Barrie municipal system is subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

Hewitts Creek Subwatershed

The Hewitts Creek subwatershed contains the municipal groundwater systems of Innisfil Heights and Stroud. Under existing conditions, the subwatershed has a Percent Water Demand of 7% under average demand and 10% under maximum monthly demand. This results in its classification of a low potential for stress.

The largest groundwater taking within the Hewitts Creek subwatershed are for municipal water supplies at approximately 47%. The next largest takers are for commercial uses (~39%), namely bottled water and golf course irrigation, and the remaining 14% is divided between livestock and rural domestic water supplies.

Under the requirements of the Clean Water Act, the Hewitts Creek subwatershed is not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater. However, it has been recommended that that it be included within the study area for the Tier Three being conducted for the Barrie municipal supply system.

Table 3.5-21: Summary of Subwatershed Groundwater Stress Classification.

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Municipal Water Supply Systems
28	**Hewitts Creek**	Low	Low	Innisfil Heights, Stroud
22	**Barrie Creeks**	**Significant**	**Significant**	**Barrie**

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Conclusions and Recommendations

This Tier Two Water Quantity Stress Assessment, which has been prepared to meet the requirements of the Province of Ontario's Clean Water Act (2006 contains information relating to the water budget and stress assessment for the South Georgian Bay, West Lake Simcoe Study Area, including:

- Physical description of the watershed;
- Consumptive water demand estimates;
- Groundwater model description; and
- Subwatershed-scale stress assessment.

The subwatershed stress assessment presented in this section provides the required evaluation to determine those areas where a Tier Three Risk Assessment is warranted. This Tier Two Stress Assessment was focused entirely on groundwater resources, as no surface water intakes were required to be evaluated.

All of the above conditions were considered in determining the stress classification for each subwatershed. Any one of the conditions that determines the subwatershed to be at a moderate or significant degree of stress is sufficient to identify that subwatershed as requiring a Tier Three Risk Assessment. An uncertainty assessment was also performed to evaluate the realistic potential change in the classification, given the uncertainty in the primary input data (i.e., groundwater recharge and demand estimates).

The groundwater water budget tool developed for the Study Area provides a physical means of evaluating groundwater flows throughout the watershed. As such, its potential applications extend beyond Ontario’s Source Protection initiatives and include long-term water management throughout the watershed. Herein the groundwater model is applied to meet the requirements of the Tier Two Stress Assessment through the calculation of inter-basin flows and groundwater discharge rates to surface water resources. Groundwater demand included in the model is consistent with the demand estimates described in Section 3 of this report. Recharge to the groundwater model was derived from a concurrent surface water modelling study as described in NVCA (2009). The estimates of groundwater demand (based on permitted and non-permitted takings), supply (based on recharge and inter-basin flows), and reserve (based on simulated groundwater discharge) provide the subwatershed scale components required to complete the stress assessment (AquaResource and Golder, 2010).

The Barrie Creeks subwatershed was classified as having a percent water demand of 77% for existing annual demand conditions and 85% under existing monthly maximum demand conditions. These analyses are primarily driven by the local demand for groundwater resources for municipal use within this subwatershed. They suggest that a large proportion of the water flowing through the subwatershed is being captured by municipal well. This percent water demand does not suggest unsustainable conditions; however, it does reflect significant groundwater use and the potential for local water quantity issues such as pumping sustainability and groundwater impacts to surface water resources. As a result, the subwatershed is classified as having a significant potential for hydrologic stress and there is a need for the City of Barrie to proceed with a Tier Three Water Quantity Risk Assessment (Figure 3.5-10) (AquaResource and Golder, 2010).

The Hewitts Creek subwatershed was classified as having a Percent Water Demand of 7% for existing average annual demand conditions and 10% under existing monthly maximum demand conditions. As a result, the subwatershed was classified as having a low potential for hydrologic stress, and; therefore, a detailed Tier Three analysis is not required for this subwatershed (AquaResource and Golder, 2010).

Based on the analyses completed and presented in this report, it is recommended that the City of Barrie municipal systems should proceed to a Tier Three Water Quantity Risk Assessment. This assessment should encompass the area surrounding the City that currently or potentially may contribute to the municipal system sustainability, including the Midhurst area to the north, the area west toward the Minesing Swamp and the area to the south that includes the Stroud and Innisfil Heights municipal systems. (AquaResource and Golder, 2010).

Figure 3.5-1: Study Area

Figure 3.5-2: Subwatershed Boundaries

Figure 3.5-3: Numerical Model Domain

Figure 3.5-4: Model Recharge per Hydrologic Response Unit

Figure 3.5-5: Permitted Groundwater Takings

Figure 3.5-6: Average Groundwater Consumptive Demand

Figure 3.5-7: Maximum Groundwater Consumptive Demand

Figure 3.5-8: Groundwater Discharge along Streams

Figure 3.5-9: Subwatershed Groundwater Stress Assessment Results

Figure 3.5-10: Subwatersheds Recommended for Tier 3 Analysis.

3.6 Tier Two Water Budget and Water Quantity Stress Assessment-Uxbridge Brook and Beaver River

The Tier One Stress Assessment identified several subwatersheds as having a moderate or significant potential for stress (shown in Figure 3.2-8) and as a result, Tier 2 Stress Assessments were completed for the Uxbridge Brook and Beaver River subwatersheds. This section provides an overview of the Tier Two Water Budget and Stress Assessment for these subwatersheds.

The work described herein is a summary of the Earthfx (2010b) report on the Uxbridge Brook and Beaver River subwatersheds Tier Two Water Budget and Stress Assessment. The Water Budget was completed in compliance with the Technical Rules prepared by the Ministry of Environment (MOE, 2008a) for the preparation of Assessment Reports under the Clean Water Act and Provincial Guidance (MOE, 2007). It is recommended that the above report be referred to for additional detail.

Study Area and Physical Setting

Location

The study area within the Uxbridge Brook and Beaver River subwatersheds Stress Assessment (Earthfx, 2010b) encompasses three communities within the Regional Municipality of Durham, and one within the City of Kawartha Lakes which draw groundwater for their drinking water supply (Figure 3.6-1). The community of Uxbridge lies within the Uxbridge Brook subwatershed and the communities of Woodville, Cannington and Sunderland are found within the Beaver River subwatershed.

The Lake Simcoe watershed covers a total area of 3621 km^2, approximately 489 km^2 of which was included in the Uxbridge Brook and Beaver River Tier 2 Water Budget Study. This area includes numerous small streams originating on the flanks of the Oak Ridge's Moraine; which form the headwaters for the Beaver River and Uxbridge Brook.

The hydrologic characteristics of the study area are strongly influenced by the physiography of the study area. The Oak Ridge's Moraine serves as a high recharge area within Durham Region. While the Peterborough drumlin field strongly influences the drainage of the area. The drumlins limit the amount of recharge occurring in portions of the study area by increasing run-off rates and confining the streams to the low lying areas between the drumlins. Many of the valleys between the drumlins also contain wetlands.

Conceptual Model

The Technical Rules (MOE, 2008a) require that a numerical model be developed to assess the parameters used in the percent water demand calculation for a Tier Two Assessment. The first step to creating the numerical model involves enhancing the conceptual understanding of the study area through the creation of a detailed geological conceptual model. An overview of the conceptual model will be discussed below and a detailed description of the conceptual model can be found in Groundwater Modelling of the Oak Ridges Moraine Area (CAMC-YPDT) groundwater management study (Earthfx, 2006) and a 2009 study completed by Earthfx discussing the extension of the Core Model into Durham Region. The Tier Two Water Budget and Water Quantity Stress Assessment documents the update to the Durham model.

The first study documents the creation of the Core Model, which covered the Region of York, portions of Durham Region, and the City of Toronto, along with portions of the Toronto and Region Conservation Authority and Lake Simcoe Region Conservation Authority. This study provided the important technical foundation to build upon to extend the Core Model across Durham Region, thus creating the Durham Model (Earthfx, 2009). Lastly, the Tier Two water budget analysis of the Uxbridge Brook and Beaver River subwatersheds document updates made to the Durham Model (Earthfx, 2010b).

The Durham model consists of ten hydrostratigraphic units, six of which represent aquifers or aquifer complexes, while the other four represent aquitards. The term aquifer complex refers to units with mostly moderate to high permeability sediments that may or may not be laterally continuous but are likely derived from similar depositional processes (Earthfx, 2010b). The ten hydrostratigraphic model layers which compose the Durham model are listed in the Table 3.6-1 below.

Table 3.6-1: Hydrostratigraphic layers of the Durham Model (Earthfx, 2010b).

Layer 1	Recent Deposits and or weathered Halton Aquitard
Layer 2	Halton Aquitard (south of ORM); Late Stage Lacustrine (north of ORM)
Layer 3	Oak Ridges Aquifer Complex (ORAC)
Layer 4	Upper Newmarket Aquitard or Tunnel Channel Silts
Layer 5	Inter-Newmarket Sediments (INS) or Tunnel Channel Sands
Layer 6	Lower Newmarket Aquitard
Layer 7	Thorncliffe Aquifer Complex (TAC)
Layer 8	Sunnybrook Aquitard
Layer 9	Scarborough Aquifer Complex (SAC)
Layer 10	Weathered Bedrock

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Water Supply

The water supply component of the stress assessment was estimated using a numerical groundwater flow model developed for the CAMC-YPDT Groundwater Management project for the Regional Municipality of Durham. The groundwater model incorporated the enhanced knowledge of the geologic surface and sub-surface gained from the conceptual model discussed in the previous section. The model domain encompasses a large area extending from the South of Lake Simcoe down to Lake Ontario, East of Highway 48 (Markham Rd.) to beyond Lake Scugog (Figure 3.6-2).

The model has a uniform 100-m cell size to better represent spatial variability of aquifer properties and groundwater interaction with streams. The model simulates groundwater flow in multiple subwatersheds surrounding the Uxbridge Brook and Beaver River catchments that are the focus of this study and; therefore, provides an independent means of estimating lateral inflows and outflows across subwatershed boundaries. This model was originally constructed as a steady state model to simulate long-term average flows. The model was refined and modified, for the purposes of this study, to analyze transient groundwater response to drought conditions as required in the Tier 2 water budget analysis (Earthfx, 2010). The model is summarized in Appendix WB-4C and described in detail in the Tier Two Water Budget Analysis for Uxbridge Brook and Beaver River subwatersheds (Earthfx, 2010b).

The Durham model was built using the United States Geological Survey MODFLOW modelling code. This modelling code was selected because it is well-suited for modelling regional flow in complex multi-layered aquifer systems. In addition the MODFLOW code is recognized worldwide and has been extensively peer reviewed to verify for accuracy in groundwater flow simulation. The model was calibrated to match the observed stream baseflow measurements as well as, observed water levels (Earthfx, 2010b). The model is also able to accurately predict drawdown at a pumping well (Earthfx, 2006).

Recharge

The MODFLOW modelling code is unable to calculate groundwater recharge from climatic data. Therefore, estimates of groundwater recharge must be supplied to the model as input data (Earthfx, 2008). The groundwater recharge rates supplied to the model were based on annual average recharge as predicted by the Precipitation-Runoff Modelling System (PRMS) model (Earthfx, 2010c). Simulated baseflows using initial estimates of recharge were analyzed and the recharge rates were adjusted until a good match was achieved with values determined by baseflow separation. A map showing the final, calibrated recharge distribution for the study area is shown in Figure 3.6-3. More detail on the surface water model can be found within Appendix WB-4C.

Water Budget Results

The water budget and stress assessment are calculated using the estimated values for groundwater supply and reserve simulated in the numerical Durham Model. Water budgets and stress assessments are conducted to determine a subwatersheds potential stress, with the ultimate goal of sustaining a water supply.

The parameters used to complete the groundwater budget were simulated using both the surface water (PRMS) and groundwater (Durham Model) flow models. The simulated volume of groundwater infiltration per year is an output from the surface water model and was used as the recharge input into the groundwater model. Inputting the groundwater infiltration component determined from the surface water model into the groundwater model allows for the climatic parameters to be accounted for in the groundwater budget.

The parameters of the water budget are shown in the existing and future annual stress assessment (Table 3.6-5 and Table 3.6-6 respectively), and are discussed below in Section 3.6.4.

Water Reserve Estimates

Guidance Module 7 (MOE, 2007) defines “water reserve” as that portion of water required to support other water uses within the watershed including both ecosystem requirements (instream flow needs) as well as other human uses (aside from permitted uses). Examples of other human uses could include dilution for sewage treatment plant (STP) discharge, hydroelectric power needs, recreation, and navigation needs. Ecological needs include sustaining groundwater discharge to sensitive coldwater fish habitat. The reserve quantity is subtracted from the total water source supply prior to evaluating the percent water demand.

The Technical Rules (MOE, 2008a) recognizes that groundwater discharge to streams must be maintained to sustain baseflow throughout a watershed. Instream flow requirements are used to estimate the ecological component of the surface water reserve term for the Tier 2 stress assessment. As it is difficult to separate out the groundwater and surface water components of the instream requirements, the Technical Rules (MOE, 2008a) recommends a simplified estimation method whereby the reserve is estimated as at least 10% of the existing groundwater discharge.

Guidance Module 7 offers several alternative methods for estimating groundwater discharge. Discharge can be determined either through (1) a groundwater flow model, if available; (2) baseflow separation applied to long-term flow gauge data, or (3) from spot flow measurements if no other are data available. While separated baseflow values for Pefferlaw Brook and Beaver River are provided in Table 3.6-2; the MODFLOW model provides a better estimate of groundwater discharge to streams.

The groundwater reserve was estimated as 10% of the MODFLOW simulated groundwater discharge to streams. This baseflow estimate is shown spatially in Figure 3.6-4. Estimated reserves for the two Tier 2 subwatersheds are provided in Table 3.6-2. Since the model was run under steady-state conditions, these values represent long-term average flows.

Table 3.6-2: Baseflow estimates for gauged catchments. Please not that both equivalent recharge and Baseflow Index (BFI) were calculated based on estimated average baseflow (Earthfx, 2010b).

Gauge ID	Gauge Location	Average Total Flow (m^3/s)	Estimated Minimum Average Baseflow (m^3/s)	Estimated Maximum Average Baseflow (m^3/s)	Equivalent Recharge (mm/yr)	BFI
02EC011	Beaverton River Near Beaverton	2.838	1.407	2.346	221	0.70
02EC018	Pefferlaw Brook Near Udora	2.945	1.441	2.489	197	0.71
02EC101	Uxbridge Brook at Uxbridge	0.364	0.178	0.332	389	0.82
02EC103	Pefferlaw Brook near Udora	3.285	1.499	2.792	216	0.69

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Water Demand

This section provides a summary of the consumptive groundwater demands for the Uxbridge Brook and Beaver River subwatersheds assessed as part of the Tier Two Water Budget Assessment (Earthfx, 2010b).

Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. aquifer) within a reasonable amount of time. Understanding this type of water demand is critical to the development of a water budget framework. An estimate of the extent and variability of water use throughout the Study Area is required to identify the subwatersheds that may be under the highest degree of potential hydrologic stress, and to guide future efforts to refine water budget tools in those areas.

The water demand values used in the Tier One Water Budget and Stress Assessment (SGBLS, 2009) were reviewed and refined were necessary for use in the Tier Two Assessment. Estimates of actual water use were not available for the permits within the study subwatersheds, so the maximum permitted rates were used in this analysis, with the exception of municipal demand.

The consumptive groundwater demand was estimated for permitted municipal, industrial, commercial, and other water users. In addition consumptive groundwater demand was estimated for non-permitted groundwater takings, which includes domestic and agriculture users extracting less than 50,000 L/day. The consumptive factors used are outlined in Section 3.3.2, Table 3.3-3.

Permits to Take Water

Information from the July 2006 permit to take water program database was used to estimate actual water demand. As part of the Tier One assessment, the database was modified in a consistent manner to improve the accuracy of information based upon field investigations. The modifications to the database included removing any permits that were known to have been revoked or replaced. Expired permits were considered on a case by case basis and removed if it was likely that the permit was no longer in use. Location searches were also completed and when several permits with the same location were found the most recent was retained and the others were considered to have been revoked and replaced. The existing consumptive groundwater use within the watershed is presented in Table 3.6-3 detailed demand estimates are found within Appendix WB-2.

Table 3.6-3: Estimates of annual existing consumptive groundwater use (m^3/year) (Earthfx, 2010b).

Subwatershed	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Beaver River	409,000	69,000	109,000	1,009,000	1,596,000
Uxbridge Brook	1,025,000	93,000	77,000	417,000	1,612,000

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Municipal Water Demand

Municipal water supplies represent the largest water use within the Study Area. As such, accurate estimates of municipal water use are a critical component of the consumptive water demand estimate. For the Tier Two Assessment reported municipal rates were obtained from the municipalities.

Other Permitted Water Demand

Non-municipal permitted water taking types included in the assessment are commercial, industrial, recreational and remediation activities. The other permitted takings are outlined in Appendix WB-2.

Non-Permitted Water Demand

Non-permitted private well domestic consumption was estimated based on the 2006 Statistics Canada census data provided by Durham Region. The un-serviced domestic water use was calculated by combining population density estimates with typical per-capita water use rates. Demand was estimated using the recommended rate of 335L/day/person (MOE, 2007). This was corrected for actual consumption because a significant portion (80%) of this water would be returned to the groundwater system through the septic field. The unserviced population was adjusted for the future scenario based on a growth rate of 35% over a 25 year period, as was done in the Tier 1 (SGBLS, 2009).[12]

Non-permitted agriculture water demand was modified from the Tier One using two techniques to improve the estimate. This included the clipping of land use polygons that extended offshore into Lake Simcoe. The allocation of DeLoe's (2002) average annual demands has been corrected and spread out over all months. After remediation of these discrepancies, the estimated agricultural demand increased significantly from 1,623 to 3,450 m^3/yr and 1,306 to 1,427 m^3/yr for Beaver River and Uxbridge Brook, respectively (Earthfx, 2010b).

Monthly Usage and Consumptive Use Factors

Section 3.3.2 summarizes the monthly usage and consumptive use factors that were utilized within the Tier Two Assessments. While these factors are generalized, they provide a consistent approach for the initial estimation of consumptive water use. Monthly estimates of water use and supply are required to evaluate the transient stress level within a subwatershed. Knowledge of the available water and water use requirements allow for water management during times of the year when it is required. In the study area, low flow, and the majority of pumping are likely to occur during summer months.

Tier Two Stress Assessment

The Tier Two Stress Assessment has only been conducted for groundwater systems since no surface water systems were found to be moderately or significantly stressed in the Tier One Water Budget and Stress Assessment for the Lake Simcoe Watershed. The groundwater systems in the study area that have undergone the stress assessment are shown in Table 3.6-4 and Figure 3.6-1.

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[12] Multiple projections are available, for example, the projected growth in Durham Region for 2004 to 2031 (25years) is 52.58% according to Statistics Canada and 35% according to SGBLS, 2009. No other demand estimates were adjusted for population growth.

Table 3.6-4: Groundwater systems in the study area that have undergone the stress assessment.

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Drinking Water System
Uxbridge Brook	Durham Region	Township of Uxbridge	Uxbridge Well Supply
Beaver River	Durham Region	Township of Brock	Cannington Well Supply
Beaver River	Durham Region	Township of Brock	Sunderland Well Supply
Beaver River	City of Kawartha Lakes	City of Kawartha Lakes	Woodville Well Supply

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<u>Existing Conditions</u>

The percent water demand calculated for the Uxbridge Brook and Beaver River subwatersheds using estimates of groundwater supply, reserve and consumptive demand. The water demand used in the stress assessment is discussed above in Section 3.6.3. The estimated consumptive demand for permitted and non-permitted users was used in calculating the subwatersheds potential for stress under existing conditions. The groundwater supply component for the stress assessment was calculated as being the sum of recharge calculated from the PRMS simulation and subsurface inflows calculated from the MODFLOW simulations. The groundwater reserve component of the stress assessment was calculated to be 10% of the groundwater discharge to streams. The volume of groundwater discharge to streams was estimated using the MODFLOW numerical model and is illustrated on Figure 3.6-4.

The results of the existing conditions annual stress assessment are shown on Table 3.6-5. The existing conditions monthly stress assessment indicated that during no months were either subwatersheds moderately or significantly stressed (Appendix WB-3D).

Table 3.6-5: Existing annual stress assessment (Earthfx, 2010b).

Parameter-	Beaver River	Uxbridge Brook
Area (km^2)	327.2	161.3
Model Recharge (mm/a)	103	171
Model Recharge (m^3/s)	1.07	0.87
Q_{in} (mm/a)	27	91
Q_{in} (m^3/s)	0.28	0.47
Baseflow (mm/a)	96	153
Baseflow (m^3/s)	0.99	0.78
Reserve [10% of Baseflow] (mm/a)	10	15
Reserve [10% of Baseflow] (m^3/s)	0.099	0.078
Groundwater Demand (m^3/a)	1,596,000	1,612,000
Groundwater Demand (mm/a)	4.9	10
Groundwater Stress %	4%	4%

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Future Conditions

The future water demand scenario considers the evaluation of future consumptive water demand estimates for a future population throughout each municipality’s planning horizon. The results of the future annual stress assessment are shown in Table 3.6-6. The results of the future monthly stress assessments indicated that during no months was either of the subwatersheds moderately or significantly stressed (Appendix WB-3D).

Table 3.6-6: Future annual stress assessment (Earthfx, 2010b).

Parameter-	Beaver River	Uxbridge Brook
Area (km^2)	327.2	161.3
Model Recharge (mm/a)	103	171
Model Recharge (m^3/s)	1.07	0.87
Q_{in} (mm/a)	27	92
Q_{in} (m^3/s)	0.28	0.47
Baseflow (mm/a)	95	147
Baseflow (m^3/s)	0.98	0.75
Reserve [10% of Baseflow] (mm/a)	9	15
Reserve [10% of Baseflow] (m^3/s)	0.098	0.075
Groundwater Demand (m^3/a)	1,847,000	1,978,000
Groundwater Demand (mm/a)	5.6	12.3
Groundwater Stress %	5%	5%

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Planned and Future Conditions

No planned municipal systems exist within this portion of the Lakes Simcoe and Couchiching-Black River Source Protection Area.

Historical Conditions

As prescribed in the Technical Rules (MOE, 2008a) a subwatershed can be considered to be moderately stressed if, at any time after January 1, 1990, either:

1) The groundwater level in the vicinity of the well was not at a level sufficient for the normal operation of the well; or
2) The operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

The community of Woodville is identified as having the potential to be moderately stressed under this Technical Rule. Issues with the Woodville Water Supply were identified and discussed in the Tier 1 study (SGBLS, 2009). The following discussion provides additional information about the development of the wells and the problems encountered (Earthfx, 2010b).

In 1999, the Town of Woodville, Ontario was in the process of locating a new municipal water supply source because the existing wells were found to have nitrate levels near or above the drinking water limit. The Town of Woodville hired KMK Consultants Limited to perform an Environmental Assessment (EA) with respect to the replacement of their municipal water supply. KMK Consultants Limited contracted Jagger Hims Limited (JHL) in 1999 to perform a groundwater investigation for possible alternative municipal well locations. JHL drilled four test wells and one observation well at the southeast corner of Highway 46 and The Glen Road, due south of the Woodville community.

Test well TW99-2, currently known as Woodville Well 1 (WW1), was selected as the replacement supply well. After a 72-hour aquifer test was performed in May 1999, it was determined that WW1 could sustain a long-term yield of 410 litres per minute (L/min) (JHL, 1999). It was also concluded that six months of continuous pumping at a rate of 220 m^3/day would result in a local drawdown of 0.8 metres. In October, 1999, a fifth test well was installed (TW99-5) and a 52-hour pump test was subsequently performed at a rate of 228 L/min (JHL, 2004). TW99-5 subsequently became the Woodville standby well. The new Woodville wellfield operates under permit to take water (PTTW) number 3545-6WVT2L3 with a maximum permitted yield of 409 L/min (Genivar, 2010c). WW1 was placed online in September 2003. Since the activation of WW1, the Town of Woodville has extracted 220 L/min on an average basis.

Woodville Well 2 (WW2), also known as TW03-1, later replaced the Woodville standby well TW99-5 because of "a casing failure during wellhead modifications that resulted in an uncontrolled release of groundwater" (JHL, 2006). TW99-5 was depressurized, grouted, and taken offline. WW2 was placed near TW99-5.

The Woodville wells extract water from a fractured limestone bedrock aquifer that lies between 5 to 10 m below the wellfield ground surface (JHL, 2006). Overburden consists of a thin (1 to 2 m) sand and gravel, deemed "lower aquifer," followed by a silt/clayey-silt/clay "leaky aquitard" (JHL, 2006) that extends to the surface, which lies at an elevation of approximately 275 mASL.

By September 2004, a declining trend in water levels was observed in the bedrock aquifer (JHL, 2006). The decline became more pronounced in 2005. In response to this decline, a Phase 2 water restriction was imposed on the town of Woodville, which limits water usage by restricting lawn watering and car washing using a garden hose, amongst others. The town of Woodville also lowered their maximum pumping rate from 410 L/min to 275 L/min. The water restriction continues until today because the source of well interference has yet to be determined. Transducers were installed in each production well on September 30, 2004, and have been recording water levels at 10 minute intervals ever since; daily water levels were measured prior to this date (JHL, 2004). An additional 4 monitoring wells have since been installed (JHL, 2006).

In summary, the reason for the decline in the water levels remains unknown at this time, although some theories have been put forward. Whether or not the reason is known, however, under Technical Rule 35(2)(e) the fact that a water restriction did occur causes the Beaver River subwatershed to advance to a Tier Three study (Earthfx, 2010b).

Drought Scenario

According to the Technical Rules (MOE, 2008a), subwatersheds can also be identified as having a potential for moderate stress if either of the following circumstances occurs within the subwatershed during either observed or simulated drought conditions (Rule 35.2.e):

(i) the groundwater level in the vicinity of a well was not at a level sufficient for the normal operation of the well; or

(ii) the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

The "two-year drought" for a groundwater assessment is defined in the Technical Rules as "...a simulated two-year period with no groundwater recharge" (MOE, 2008a). A ten-year drought analysis requires the simulation of a historic ten-year period for which precipitation records indicate the lowest mean annual precipitation. The objective of the drought analyses are to determine whether either (1) the groundwater level in the vicinity of a municipal well falls below a level sufficient for the normal operation of the well; or (ii) the operation of a well pump would be terminated because of an insufficient quantity of water being supplied to the well during the drought simulations. A July 2009 Technical Bulletin on Tier Two Subwatershed Stress Assessment Groundwater Drought Scenarios clarified the rules to indicate that the two-year drought was intended as a "worst-case" analysis, and that the ten-year drought should be simulated only if the wells fail in either of the two-year simulations (*existing and future conditions*) (Earthfx, 2010b).

Methodology

Groundwater flow is governed by the Law of Conservation of Mass which states that:

Σ Inflows to groundwater - Σ Outflows from Groundwater = Change in Groundwater Storage

Under steady-state conditions the system is assumed to be in a dynamic equilibrium where changes in storage are assumed to be negligible. If inflows are decreased (under drought conditions, for example) the system will no longer be in equilibrium and a portion of the outflow will be made up by the release of water from storage. The amount of water coming from storage will be high at early times and then decrease over time as available storage is depleted. If the change in inflow is long-term, a new equilibrium will be established with reduced outflows and with an overall decrease in the volume of water held in storage.

Storage in a confined aquifer is derived from two sources. Water is slightly compressible and will expand slightly as the pressures in the aquifer drop. The soil matrix is also slightly compressible and water can be squeezed from the pore space when pressures in the aquifer decrease. This occurs because, when the fluid pressure decreases, the inter-granular stresses increases to balance the constant overburden stress and the aquifer matrix is compressed. In an unconfined aquifer, the water yielded by gravity drainage as the water table declines is also considered to be a form of release of water from groundwater storage. The amount of water yielded from unconfined storage is generally orders of magnitude larger than that released from compressive storage.

From a practical point of view, the effect of groundwater storage is to reduce the drawdowns (i.e. changes in head) at early time. If the drought is of short duration, storage can serve to minimize the impact on the municipal wells and local streams. The confined aquifers in the study area have low storativity and the time to reach steady-state conditions is relatively short (measured in weeks to months). As noted, storativity in the unconfined aquifers is several orders of magnitude larger and the time to reach equilibrium can be measured in months to years. Whether the system comes to equilibrium within the two year period depends on the values of transmissivity, aquifer geometry, storativity, leakage factors, and distance to boundaries and is best evaluated with the numerical model.

When recharge is cut off, as in the 2-year drought simulation, water will be released from storage in the immediate vicinity of the well. Simultaneously, the decrease in head locally will induce additional lateral inflow towards the well. The ratio of how much water comes from lateral inflow to how much is derived from local storage as groundwater continues to discharge to streams and lakes and across the lateral boundaries as the heads begin to decline. The release of water from storage, in turn, slows the rate of decline. The magnitude and rate of drawdown in the aquifer depends on the values of the transmissivity and storativity. Typically, the amount coming from storage will be higher at early times. Over time, storage will be depleted and drawdowns will increase until a new equilibrium condition is achieved between lateral inflows and outflows.

Determining whether the water levels in the vicinity of a municipal well fall below a level sufficient for the normal operation of the well requires some additional analysis. The predicted water level in the model must be reviewed both from a model resolution and accuracy perspective as well as from a well efficiency standpoint. The model calculates the drawdown in the centre of the 100 m finite-difference cell containing the well. This drawdown represents the average water level over the 100 m cell, so smaller cells in the wellfield area would better delineate (i.e. predict a larger drawdown) at the well location. Prickett and Lonquist (1971) provide a methodology to correct for the model cell averaging and estimate the actual well drawdown.

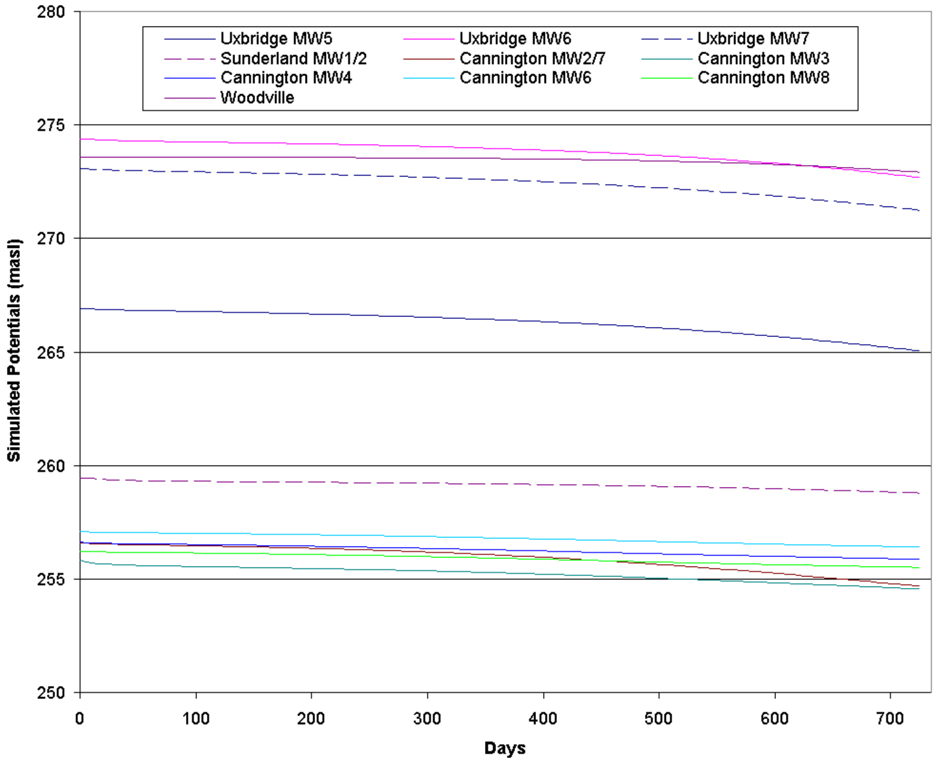
Additional drawdowns can occur due to well loss caused by clogging of the screen and by turbulence (“well efficiency”). However as noted above, there are complex issues surrounding the Woodville system that remains under investigation and monitoring. Given these complexities, additional corrections and analysis of the model prediction was factored into the drawdown calculation (Earthfx, 2010b).

For the transient drought simulations pumping rates for the existing demand drought scenario were identical to those used in the calibration simulations. Pumping rates for the future demand drought scenario were identical to those used in future demand.

Results

The groundwater model was run using a starting time step size of 0.5 days. The size of the time step was increased by a factor of 1.025 for each of the 146 time steps used to simulate the two year drought period. Recharge over the study area was set to zero to simulate a short but severe drought.

The focus of the analysis was the drawdown in the wells over the 2 year simulation. Simulated heads in the municipal wells over the simulation period are shown in Graph 3.6-1for the existing pumping simulation. Total drawdowns in both the Uxbridge and Woodville municipal wells are less than 2 m. The drawdowns for each of the wellfields, at existing pumping rates, are shown spatially in Figure 3.6-5 and Figure 3.6-6.



Graph 3.6-1: Simulated Heads at the municipal wells 2-year drought with existing pumping rates (Earthfx, 2010b).

As can be seen, the largest drawdowns in the Tier 2 study area (Figure 3.6-5) occur near the inter-stream divides and south of the Uxbridge under the Oak Ridge's Moraine. Drawdowns are generally less than 4 m due to the large storage in the aquifer. Discharge areas, such as near the major streams, exhibit no drawdown (shown as white areas on Figure 3.6-5). In summary, drawdowns in the vicinity of all the wells (including Uxbridge, Cannington, Sunderland, and Woodville) are less than 3 m (Graph 3.6-1).

The simulated heads in the municipal wells over the course of the simulation are shown in Graph 3.6-1 for the future pumping scenario. The total drawdowns in both the Uxbridge and Woodville municipal wells were observed to be less than 2 m. The drawdowns for each of the wellfields, at future pumping rates, are shown spatially in Figure 3.6-7 and Figure 3.6-8.

Transient simulation results show that because of the high available storage, the available drawdown in the wells, and the relatively short drought period, the wells do not fail under drought conditions and the stress levels assigned under the above scenarios do not need to be changed. Based on this analysis, according to the Technical Rules, there is no need to simulate a ten-year drought with actual climate data (Earthfx, 2010b).

Uncertainty in Groundwater Stress Classifications

Uncertainty is inherent in the water budget estimation process. The accuracy of estimates is reliant on the (1) quantity and quality of the input data (e.g., related to streamflow, climate, well records); (2) conceptual understanding of the subwatersheds; and (3) modelling calculation methodology.

Overall, the issues related to uncertainty, data, and knowledge gaps are complex and highly qualitative. There is a degree of uncertainty associated with every aspect of the water budget analyses; however, it is impossible to provide a quantitative assessment of the level of uncertainty. Rather, one can only say, in very general terms, that the level is low, moderate, or high.

The MOE SWP Guidance documents suggest that it would be reasonable to expect a low level of uncertainty in areas where data density is high, where hydrogeologic studies have been conducted, and where numerical models have been developed. This Tier Two study generally satisfies all three of these criteria. It is recognized that all hydrogeologic analyses have an intrinsic level of uncertainty because one can never have enough data to fully know how conditions vary in the subsurface.

Development of the Durham Model entailed a comprehensive process of (1) collecting and filtering the large amount of water well, monitoring well, and other geologic data; (2) interpreting the geologic logs as best as possible and building a conceptual geologic model; (3) assigning initial estimates of aquifer properties and recharge rates and then refining the estimates through model calibration; and (4) performing statistical and sensitivity analyses to demonstrate the validity of the model calibration. This study builds on regional analysis performed in the development of that model and locally refines and updates the analysis (Earthfx, 2010b).

There is still the recognition that geologic data are always incomplete and that the WWIS data used in a large part to develop the models has a high degree of error and uncertainty. Data obtained from municipal monitoring networks and other high-quality sources have less uncertainty and have provided useful information in the vicinity of the municipal wellfields. The number of wells and spatial coverage of high-quality data are limited compared to the

WWIS data. However, it is recommended that LSRCA continue to improve its monitoring network over time and incorporate the available high-quality data, especially within the higher stressed subwatersheds, and thereby reduce the level of uncertainty associated with the numerical models. Similarly, the number of long term stream gauges in the study area is very limited and more gauges are recommended (Earthfx, 2010b).

Some of the limitations of the PRMS model are a consequence of the simplification required in creating a consistent, regionalized large-scale model. Most of the uncertainty would be circumvented if this model were to be fully-coupled with a transient groundwater model, as this would aid in the representation of cross watershed boundary flow and stream gauge underflow (Earthfx, 2010b).

In summary, this analysis is based on a solid foundation of regional scale analysis which has subsequently (in this study) been locally refined and improved. In general terms the uncertainty is lower in the Uxbridge Brook subwatershed because of the additional stream gauges and groundwater monitoring data. Although the overall uncertainty of the Beaver subwatershed stress analysis is also likely low, given that the Woodville well performance issues have not been fully explained we must conclude that the Woodville well drought simulation uncertainty is high. It is recommended that this uncertainty be addressed as part of the Woodville Tier 3 investigations (Earthfx, 2010b).

Stress Assessment Results

Uxbridge Brook

The Uxbridge Brook subwatershed contains the municipal groundwater systems for the community of Uxbridge. Under existing annual and monthly demand conditions the maximum percent water demand is 4%. Under the future annual and monthly demand conditions the maximum percent water demand rises to 5%. This results in low potential for stress in the Uxbridge Brook subwatershed (Figure 3.6-9). The two year drought simulation indicated that the stress levels assigned in the existing and future assessment do not need to be changed as the wells did not observe any significant drawdown.

Beaver River

The Beaver River subwatershed contains the municipal groundwater systems for the communities of Sunderland, Cannington and Town of Woodville. Under existing annual and monthly demand conditions the maximum percent water demand is 4%. Under the future annual and monthly demand conditions the maximum percent water demand remains at 5%. This results in a low potential for stress in the Beaver River subwatershed. The two year drought simulation indicated that the stress levels assigned in the existing and future assessments do not need to be changed as the wells did not observe any significant drawdown. However, due to historical conditions of not being able to meet water demand in the Town of Woodville, the Woodville well supply has raised the potential stress level to moderate for the Beaver River subwatershed Figure 3.6-10

Conclusions and Recommendations

This Tier Two Water Quantity Stress Assessment, which has been prepared to meet the requirements of the Province of Ontario's Clean Water Act (2006) contains information relating to the water budget and stress assessment for the Uxbridge Brook and Beaver River subwatersheds study area, including:

- Physical description of the watershed;
- Consumptive water demand estimates;
- Groundwater model description; and
- Subwatershed-scale stress assessment.

The subwatershed stress assessment presented in this section provides the required evaluation to determine those areas where a Tier Three Risk Assessment is warranted. This Tier Two Stress Assessment was focused entirely on groundwater resources, as no surface water intakes were required to be evaluated.

The water supply estimates used in the Tier Two stress assessments were from the Tier 1 study, with some local refinements, updated data and corrections.

The Stress Assessment indicates that both the Uxbridge Brook and Beaver subwatersheds receive a low stress assessment.

The uncertainty for the subwatershed scale analysis is considered low; however, there are some data gaps, particularly in the surface water monitoring network that might require additional attention. Uncertainly related to the Woodville well operation is considered high, although those issues should be addressed as part of the required Tier Three assessment.

Under Technical Rule 35(2) (e), it is recommended that the Beaver River subwatershed proceed to a Tier 3 based on the Community of Woodville municipal well restriction (Figure 3.6-10). Based on the stress assessment documented herein Uxbridge Brook should not proceed to a Tier 3.

Figure 3.6-1: Study Area (Earthfx, 2010b).

Figure 3.6-2: Durham Model Domain (Earthfx, 2010b).

Figure 3.6-3: PRMS-estimated annual average recharge (Earthfx, 2010b).

Figure 3.6-4: Simulated groundwater discharge to streams (Earthfx, 2010).

Figure 3.6-5: Simulated drawdown at end of 2-year drought-existing pumping conditions Uxbridge (Earthfx, 2010).

Figure 3.6-6: Simulated drawdown at end of 2-year drought existing pumping-Woodville (Earthfx, 2010).

Figure 3.6-7: Simulated drawdown at end of 2-year drought, future pumping-Uxbridge (Earthfx, 2010).

Figure 3.6-8: Simulated drawdown at end of 2-year drought, future pumping-Woodville (Earthfx, 2010).

Figure 3.6-9: Subwatershed Groundwater Stress Assessment Results.

Figure 3.6-10: Subwatersheds Identified for Tier Three.

3.7 Tier Three Water Budget and Local Area Risk Assessment- York Region

The Tier Two Subwatershed Stress Assessment completed by Earthfx, 2010a for the South Georgian Bay Lake Simcoe (SGBLS) source protection region, identified the East Holland, West Holland, and Maskinonge Creek subwatersheds, located within the Regional Municipality of York, as potentially moderately or significantly stressed. As a result, under the Technical Rules (MOE, 2008a), the municipal water supply systems within these subwatersheds were required to undergo a Tier Three Water Budget and Local Area Risk Assessment. Additional subwatersheds located within York's regional boundary, but outside of the South Georgian Bay Lake Simcoe (SGBLS) source protection region were also identified as having a moderate potential for stress and were flagged for Tier Three Analysis. These additional catchments include the Little Rouge River and Stouffville/ Reesor Creek catchments within the Credit Valley, Toronto and Region, and Central Lake Ontario (CTC) source protection region. In an attempt to combine efforts, a coordinated approach was undertaken to integrate the Tier Three studies required for each source protection region. The integrated Tier Three study presents the Tier 3 analysis results for the subwatersheds in both source protection regions. The text in this section specifically addresses the Tier Three Water Budget and Local Area Risk Assessment results for the stressed subwatersheds within the SGBLS source protection region. For details regarding the Tier Three analysis results for the subwatersheds located outside of the SGBLS regional boundary, refer to the complete "Tier Three Water Budget and Local Area Risk Assessment for the Region of York Municipal Systems" study completed by Earthfx, 2014.

A Tier Three Assessment evaluates the long term reliability of a municipality's drinking water sources by determining whether the municipality is able to meet its current and planned water quantity requirements, while accounting for increased municipal demand, future land development, drought conditions, and other water uses. The Tier Three Assessment requires the identification of threats to drinking water sources found to be under moderate or significant water quantity risk. While the Tier Two Stress Assessment focused on the subwatershed scale and evaluated the total consumptive water demand and water supply for the subwatershed, Tier Three Water Budgets and Risk Assessments focus on the area which provides water to the well/intake. For groundwater wells this area includes the lands contributing water to the wells, in addition to sensitive features near the wells.

The Tier Three Assessment relies on refined numerical models to simulate ground and surface water flows and levels (and the interactions between them) under a variety of conditions and scenarios. The models developed for this Tier Three Assessment represent a comprehensive conceptualization of the hydrology and hydrogeology that influences water supplies in the York

Region subwatersheds. In comparison to the Tier Two Assessment, the Tier Three Assessment represents a much more detailed study of the flow systems within the subwatershed.

This section provides an overview of the methodology and results of the Tier Three Water Budget and Local Area Risk Assessment carried out for the Regional Municipality of York. The work described herein is a summary of the conceptual and numerical hydrologic and hydrogeologic modeling and water budget tool developed by Earthfx, 2014. The Assessment was completed in compliance with the *Technical Rules for the preparation of Assessment Reports under the Clean Water Act* (MOE, 2008a) and the *Water Budget and Water Quantity Assessment Guide* (MNR and MOE, 2011). The complete study is documented in the "Tier Three Water Budget and Local Area Risk Assessment for the Region of York Municipal Systems" report completed by Earthfx, 2014. It is recommended that the report be referred to for additional insight.

Study Area and Physical Setting

The Study Area for the York Region Tier Three Water Budget and Local Area Risk Assessment includes watersheds in the South Georgian Bay Lake Simcoe (SGBLS) Source Protection Region, as well as the Credit Valley, Toronto and Region, Central Lake Ontario (CTC) Source Protection Region. As mentioned above, the text within this report only details the Tier Three results for the subwatersheds contained within the boundaries of the SGBLS region.

At a minimum, a Tier Three Assessment Study Area is required to include the watersheds or catchments identified as moderately or significantly stressed during a Tier 2 analysis. For this assessment the East Holland River, West Holland River, and Maskinonge Creek subwatersheds with the SGBLS source protection region, and the Little Rouge and Stoufville/Reesor Creek catchments within the CTC source protection region were identified as potentially stressed, and therefore served as the foundation on which the Study Area was built upon. The purpose of the Tier Three Assessment is to evaluate the sustainability of municipal pumping wells located within these potentially stressed subwatersheds at a Tier Three level. Municipal wells within these stressed subwatersheds serve the communities of Aurora, Newmarket, Holland Landing, Queensville, Sharon, Schomberg, and Bradford West Gwillimbury in the SGBLS source protection region, and Stouffville, and Uxville in the CTC source protection region. Figure 3.7 - 1 illustrates the location of the municipal wells and major stress assessment catchments evaluated in this study.

The extent of the final selected Study Area was defined to correspond with the natural hydrologic boundaries of the area, including the shorelines of Lake Ontario and Lake Simcoe, and the topographic divides to the east and west. Figure 3.7 - 2 illustrates the extent of the final selected Study Area, as well as the boundaries of the two source protection regions in which the major subwatersheds of interest are located in. Additional wells located outside of stressed watersheds were also included in the Tier Three Study Area. These additional wells include those that serve the communities Uxbridge, and Mount Albert in the SGBLS source protection region, and the communities of Kleinberg, Nobleton, King City, Palgrave, and Caledon in the CTC source protection region.

Conceptual Model

Tier Three Water Budgets and Local Area Risk Assessments require that detailed numerical models be developed to assess ground and surface water flows under a number of scenarios. The first step to creating these numerical models involves enhancing the conceptual understanding of the Study Area through the creation of a detailed conceptual model. This section details the refined conceptual model developed for the York Region Tier Three Water Budget and Local Area Risk Assessment study.

Physiography

The primary physiographic feature of the Study Area is the Oak Ridges Moraine. Due to the predominantly sandy surface soils and hummocky topography that characterize this physiographic feature, the Oak Ridges Moraine represents the most significant groundwater recharge area in the Study Area. The moraine also serves as the source of the majority of the headwaters for most of the major streams in the area.

North of the moraine, the topography is characterized by the drumlinized uplands of the Peterborough drumlin fields. The Peterborough Drumlin Fields are separated by lowland valley areas commonly referred to as the Simcoe Lowlands. These valleys and their infilled lowland areas are thought to be the result of tunnel channel formation that occurred during high energy subglacial events. The northern portion of the Study Area was later flooded by Glacial Lake Algonquin which left behind flat-lying deposits of lacustrine sand, silt and clay.

Other key portions of the Study Area including the Newmarket and Schomberg well fields are located in the Schomberg Clay Plain physiographic region, which is characterized by deposits of stratified clay and silt that also occupied the tunnel channels and former glacial lake basins of the area. Figure 3.7 - 3 illustrates the major physiographic units of the Study Area.

Geology

Due to the multiple phases of glaciation, and fluvial erosion that occurred across the Study Area, the quaternary and surficial geology in the region is characterized by a highly complex array of sediments and deposits. The majority of the sediments in the Study Area were deposited during the Wisconsonian Glaciation which roughly began around 25,000 years ago. Sediments deposited during this glaciation were often the result of glacial meltwater streams, or ice-marginal and ice-dammed lakes.

The major geologic unit in the portion of the Study Area found north of the Oak Ridges Moraine is informally referred to as the ‘Lower Newmarket Till”. This coarse grained till is described as very compact, pebbly to silt sand, and can be traced from the Niagara Escarpment to as far as Lake Scugog. In regions where the Lower Newmarket Till is exposed, south-westerly oriented drumlins overlying the Lower Newmarket Till, make up a unit known as the “ Upper Newmarket Till” . In the upland areas, this upper till often overlies stratified subaqueous fan or glaciolacustrine deposits known as the “Inter-Newmarket Sediments”. South of the Oak Ridges Moraine these sediments are largely absent and the Upper and Lower Newmarket tills cannot be distinguished as separate units (Earthfx, 2014).

Other prominent geologic features in the Study Area include discrete till upland areas formed by high energy, subglacial events that occurred approximately 13,000 to 15,000 years ago during the Mackinaw Phase of the Wisconsonian Glaciation. These upland areas are the result of the creation of a system of major erosional features known as tunnel channels. The formation of subglacial tunnel channels deeply dissected the underlying Newmarket Till plain, leaving behind discrete till upland areas. As flow moved through the tunnel channels, sediments ranging in size from cobbles to boulder lag were deposited, resulting in the partial infilling of the channel features. Shortly after the erosion and sedimentation of the tunnel channels, the east-west trending Oak Ridges Moraine was formed. This important physiographic and hydrogeologic feature formed as a re-entrant which developed between the Lake Ontario basin glacier ice and the northern ice lobe (Earthfx, 2014). During the formation of the moraine, sedimentation was rapid and took place in subglacial, ice-marginal, and proglacial lacustrine environments. Although the sediments of the moraine are predominantly classified as sand, there are numerous significant zones of silt or very silty sand within the moraine.

In the southern portion of the Study Area, an extensive, texturally variable diamiction known as the Halton Till characterizes much of the surficial geology. Ranging from sandy silt till to silty clay till, the Halton Till unit plays a complex role in the recharge to the underlying aquifers. This unit is the result of the advancement of the Lake Ontario Ice Lobe, during the Port Huron Phase of the Wisconsonian glaciation.

Other quaternary geologic units in the Study Area include the Kettleby Till, a sparsely distributed, clay rich diamicton, deposited by the northern ice lobe north of the Oak Ridges Moraine.

Glaciolacustrine sands, silts, and clay deposits resulting from sedimentation occurring in ice-marginal and ice dammed lakes during the last glacial recession also contribute to the geology of the area. More recent sediments found in the area include modern alluvial deposits of sand, gravel and silt, lacustrine sediments, Aeolian (wind-blown) sands, and organic deposits. The surficial geology of the area is illustrated in Figure 3.7 - 4 .

Hydrology

Figure 3.7 - 5 highlights the major watersheds, streams, lakes, and wetlands which drain the Study Area. The extent of the Study Area was determined by the location of natural hydrologic boundaries that included the shorelines of Lake Ontario, Lake Simcoe and the topographic divides to the east and west. Five major catchments including the East Holland River, West Holland River, and Maskinonge Creek subwatersheds within the South Georgian Bay Lake Simcoe (SGBLS) Source Protection Area, and the Little Rouge River and Stouffville/Reesor Creek subwatersheds within the Credit Valley Toronto and Region, Central Lake Ontario (CTC) Source Protection Region were identified as potentially stressed during the Tier 2 Water Budget analysis. At a minimum, these watersheds must be included in the in the Tier Three Study Area; however the boundaries for this Tier Three study were expanded to incorporate additional subwatersheds including the Black River, Uxbridge and Pefferlaw Brock subwatersheds in the SGBLS source protection region, and the Mimico Creek, Duffins Creek, Don River, Highland Creek, Humber River, and the Petticoat and Frenchman's Bay subwatersheds in the CTC source protection region.

The Study Area encompasses a total of 4450km of mapped streams, all of which are represented in the conceptual flow model. Wetlands and wetland complexes are also largely present in the area, and primarily found within the hummocky topography of the Oak Ridges Moraine, and in the low lying north eastern portion of the Study Area near Lake Simcoe.

Stream flow data for the Study Area was obtained from 23 hydrometric gauges run by the Water Survey of Canada (Figure 3.7 - 6) as well as information supplied by both the Lake Simcoe Region and Toronto Region Conservation Authorities. Stream flow data indicated that the seasonal flow regime (seasonal changes in water flow) varies greatly due to the presence of urbanization and variation in land use across the Study Area. This is further highlighted by the monthly deviation from yearly averages between study gauges.

Climate across the Study Area varies considerably both spatially and temporally with local variation created by such factors as topography, prevailing winds, and proximity to large lakes. Long-term climate data, including daily maximum and minimum temperature, precipitation, and solar radiation, were obtained from Environment Canada for a 23-year period from

October 1, 1986 to September 30, 2009 (Earthfx, 2013). Other than the fact that the winter months (December to March) in the last 23 years experienced lower than annual average precipitation (as either rain or snow), seasonal variation in observed precipitation is not great; however, variation between climate stations in the Study Area does appear to vary greatly during summer months (Earthfx, 2013).

The Study Area rarely experiences precipitation events of any significant magnitude, however when it does, high-intensity convective storms tend to occur during the summer months of June to September, when the least amount of recharge occurs. This indicates that rain intensity is likely un-correlated with predicted seasonal recharge in the Study Area (Earthfx, 2013). A more detailed explanation of the hydrology in the Study Area is provided in the Model Development and Calibration Report for the Tier Three Water Budget – Water Quantity Risk Level Assignment Study for York Region completed by Earthfx, 2013.

Hydrostratigraphy

An understanding of the hydrostratigraphy of the area was essential during the development of the layers used in the numerical groundwater model. The regional hydrostratigraphy of the Study Area is defined based on the Quaternary geologic deposits found in the region.

Municipal wells in the Study Area pump groundwater from highly transmissive geologic units called aquifers. Aquifers are layers of permeable overburden deposits primarily composed of coarse grained sediments; higher transmissivity bedrock units are also referred to as aquifers.

Geologic units that act to impede the flow of groundwater from one aquifer to another are called aquitards. Aquitards are generally composed of lower permeability overburden materials such as clay or fine grained tills, and can also be found in poorly transmissive bedrock units.

The aquifer system in the Study Area is characterized by three major units referred to as the Oak Ridges Aquifer Complex (ORAC), the Thorncliffe Aquifer Complex (TAC), and the Scarborough Aquifer Complex (SAC). The Oak Ridges Moraine Aquifer Complex (ORAC) is the shallowest of the aquifers, while the Scarborough Aquifer Complex (SAC) is the deepest.

The ORAC is primarily characterized by silty sands with interbedded sands and gravel; it serves as the main source of groundwater for the domestic wells in the Study Area and is generally unconfined northward of the moraine. Sediments that make up the ORAC can be up to 100m thick along the core of the moraine, but generally tend to thin rapidly toward the flanks. Groundwater discharge originating from the ORAC contributes baseflow to the headwater streams originating on the slopes of the Oak Ridges Moraine.

The other major aquifer underlying the Study Area is made up of sediments of Thorncliffe Formation and is known as the Thorncliffe Aquifer Complex (TAC). The Thorncliffe Formation is present throughout much of York Region but varies in thickness throughout the Study Area. Unlike the ORAC, the TAC is confined and protected by the overlying Newmarket Till aquitard and is therefore more frequently utilized for municipal water supplies.

The deepest of the aquifers is the Scarborough Aquifer Complex (SAC) which is primarily made up of sandy sediments from the Scarborough formation. Although the Scarborough Formation deposits are found throughout the majority of the western part of the model area, the unit is absent or thin in areas with relatively high bedrock surface elevations. This unit is documented to be thickest in the bedrock valleys.

The general stratigraphic layers that comprise the conceptual model for the Study Area are illustrated in Figure 3.7 - 7 . Figure 3.7 - 7 is a sketch illustrating a north- south cross section through the Oak Ridges Moraine.

Land Use and Land Use Change

Tier Three modeling must consider the impact of existing and future land use on groundwater recharge in order to identify potential impacts to water quantity and other water uses. Existing land use information was obtained from the municipalities within the Study Area, the Ministry of Natural Resources, and the local Conservation Authorities. Land use information indicated that the predominant land use in the Study Area is agriculture. Agricultural lands cover approximately 37% of the Study Area, while forest and wetlands and developed/settled areas (including urban, rural, transportation, parks, industrial, and commercial landuses) cover 28%, and 32% of the Study Area , respectively. Non-natural land uses, such as urban and industrial areas are generally associated with greater areas of imperviousness, which in turn is indicative of decreased levels of groundwater recharge. The existing distribution of percent imperviousness in the Study Area is illustrated in Figure 3.7 - 8.

Projected land use information for the Study Area (illustrated in Figure 3.7 - 9) was obtained from official land use plans for the municipalities of York, Peel, Durham, and the Bradford West Gwillimbury. Official Plans indicated that future land use changes predominantly included infilling of both high and low intensity urbanized land. To represent future land use conditions during the simulation of the future risk assessment scenarios, model inputs were adjusted to include representative levels or urbanization within proposed development areas. Models for the Tier Three Assessment represent changes in land use by reducing the amount of groundwater recharge according to the amount of impervious area associated with proposed land use change. As mentioned above, the conversion of natural to non-natural land use generally increases the amount of impervious cover. For future development scenarios, land use inputs were modified to represent a minimum of 65% land imperviousness in areas slated for future urban development.

Numerical Models

The modeling approach used to complete the Tier Three Assessment requires the development of detailed numerical models that integrate both surface and ground water components of the local flow system to evaluate the sustainability of municipal water sources under a variety of scenarios. The numerical models developed for the York Region Tier Three study are based on the refined conceptual understanding of ground and surface water systems in the Study Area, as discussed in Section 3.7.1.

For this Tier Three Assessment, the numerical modeling approach was designed to integrate the inputs and outputs of the surface and groundwater systems in order to represent the hydrologic and hydrogeologic conditions and processes of the Study Area.

To develop an integrated ground and surface water model capable of addressing the requirements of the Tier Three Assessment, a multi-stage model development and calibration approach was followed. The staged development approach included building independent surface and groundwater models before linking them together to form the final integrated GSFLOW surface-groundwater model.

To represent the surface water component of the integrated model, The United States Geological Survey's (USGS) PRMS (Precipitation-Runoff Modelling System) model was used to simulate soil moisture balance, groundwater recharge, and runoff to streams in the Study Area. The groundwater component of the study was developed using the MODFLOW code, a groundwater flow simulation code also developed by the USGS. The MODFLOW-based groundwater model used for this study was built on earlier work from the CAMC-YPDT model developed by Kassenaar and Wexler, 2006 for a study undertaken for the Oak Ridges Moraine. The groundwater model developed for this study focused on the enhancement and review of this CAMC-YPDT model. The MODFLOW model represents numerous processes including unsaturated and saturated groundwater flow through the complex hydrogeological layers that underlie the Study Area, as well as lake and wetland water balance and groundwater interaction, and streamflow routing.

The independent (uncoupled) PRMS and MODFLOW models represent an interim calibration step in the final development of an integrated surface-groundwater model using the GSFLOW code (Earthfx, 2014). The GSFLOW code is a coupled ground and surface water flow model developed by the USGS. The final GSFLOW model for this study is a fully integrated ground and surface water model that allows for the simultaneous modelling of both surficial and sub-surficial process; this in turn allows for the responses of each sub-model to interact as they would naturally (Earthfx, 2014). This fully integrated model represents significant modelling improvements and therefore allows for the modelling of a wide range of feedback mechanisms and surface-groundwater interactions that were beyond the capabilities of previous Tier 1 and 2 models. As part of the Tier Three Assessment the major objective of the integrated model was to simulate the 3D groundwater flow system within the Study Area under the risk assessment scenarios required to evaluate the sustainability of municipal wells. Risk assessment scenario simulations are further discussed in Section 3.7.5.

Water Demand

The development of representative Tier Three Models is dependent on accurate estimates of water demand in the Study Area. An estimate of the extent and variability of consumptive water demand is essential for the calculation of Tier Three water budgets for the subwatersheds of interest, simulation of various risk scenarios, and the overall identification of aquifers under hydrologic stress. This section provides a summary of the consumptive groundwater demands within the Study Area. Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. an aquifer) within a reasonable amount of time. Consumptive water demand was estimated for both permitted and non-permitted water takings within the Study Area. Permitted water takings are generally carried out by large municipal, industrial, and commercial water users, while non-permitted groundwater takings tend to be attributed to domestic and agricultural uses. In addition to consumptive groundwater takings, there are several non-consumptive water uses that also rely on groundwater supplies within the York Region Tier Three Study Area. Such uses may include surface water features that rely on groundwater discharge for sustaining coldwater fisheries and provincially significant wetlands, as well as uses associated with recreation. Non-consumptive water uses often rely on ground and surface water systems to maintain minimum flow or water levels. Due to their reliance on ground and surface water flows, non-consumptive water uses are also considered during the Tier Three Risk Assessment.

Municipal Demand

The accurate estimation of existing, allocated, and planned municipal water demand is essential for the simulation of the various risk scenarios required under the Tier Three Assessment. The pumping rates used as inputs for the simulation of these scenarios must reflect current demand conditions (existing demand), and future demand conditions including any additional water takings that will be required to meet the needs of an approved settlement area (committed demand), or any additional demand that may be required as a result of projected growth identified within a Master Plan or Class EA (Planned Demand) (MOE, 2013). The following section further describes the components of the demand calculations required for this Tier Three Assessment.

Existing Demand refers to the average pumping rate during the year the Tier Three Assessment was conducted. For this study, the existing demand calculation was conducted for the years of 2010 and 2011.

Committed demand refers to an amount, greater than the existing demand that is necessary to meet the needs of an approved Settlement Area identified within an Official Plan. The portion of this amount that is within the current lawful Permit to Take Water is part of the Allocated Quantity of Water; a parameter used as an input during the modelling of the Risk Assessment scenarios. Any amount greater than the current lawful permitted water taking is considered part of the Planned Quantity of Water (MOE,2013).

Planned Demand refers to a specific amount of water required to meet the projected growth identified within a Master Plan or Class Environmental Assessment, but is not already linked to growth within an Official Plan (MOE, 2013). This type of demand was not identified within York Region.

Planned Quantity of Water includes any amount of water that meets the definition of a planned system in O.Reg 287/07 and any amount of water that is needed to meet a Committed Demand above the Current Lawful Permit to Take Water Taking (MOE, 2013). As described above, the Committed demand for the well systems in this study are within the currently permitted taking rates, and therefore there is no Planned Quantity of Water.

The Allocated Quantity of Water refers to the combined amount of existing and committed demand up to the current lawful Permit to Take Water Taking. For this study, the allocated quantity of water (existing plus committed demand) was used as an input during the simulation of the Risk Assessment scenarios to determine how increases in demand would impact water supplies. The Allocated Quantity of Water can often be determined from population growth estimates, official plan data, and planning documents provided by municipalities. The allocated quantity of water used in the model scenarios for this Tier Three Assessment has been assigned using information and planning documents provided by the municipalities of York, Durham, and Bradford West Gwillimbury. The following section describes the existing and allocated water demand for the municipal well fields located in the SGBLS source protection area. These municipal wellfields include well systems contained within the Regional Municipality of York, as well as two municipal wells located in Uxbridge (a lower Tier municipality of Durham Region). Additionally, a number of wells that are located within York Region’s boundary, but supply the

Town of Bradford West Gwillimbury were also evaluated. The years of 2010 and 2011 were selected for quantifying existing demand as they are most representative of current groundwater takings.

The wells specifically addressed in this assessment are highlighted in Figure 3.7 - 1 . It should be noted that despite their location outside of a potentially stressed assessment watershed, the Uxbridge wells in Durham Region, and the Mount Albert wells in York Region, were simulated in the Tier Three model, however, only the municipal wells in the East Holland River, West Holland River, and Maskinonge Creek subwatersheds in the SGBLS source protection region, and the municipal wells in the Rouge River and Stoufville/Reesor Creek subwatersheds in the CTC source protection region were subject to the Risk Assessment discussed in Section 3.7.5.

York Region

York Region operates 42 wells in 13 towns under 9 Permits to Take Water issued by the Ministry of the Environment [Conservation and Parks]. The communities of Holland Landing, Sharon-Queensville, Newmarket and Aurora are operated under a single Permit to Take Water commonly referred to as the Yonge Street Aquifer permit.

The existing demand for the York Region was determined using 2010 and 2011 pumping data taken from York Region’s 2009 Water and Wastewater Master Plan. The Region’s Master Plan summarizes the projected water allocation rates across York Region’s municipal wells through to the year 2031. Table 3.7 - 1 provides the permit details of each municipal well in the Region, while Table 3.7 - 2 presents the average daily 2010/2011 pumping rates (existing demand) for the Region’s municipal well systems. Longer term pumping data indicates that in general, groundwater takings in York Region have generally decreased due to an increase in the amount of water being piped from surface water supplies in Toronto and Peel region.

Table 3.7 - 2 also presents the 2016 water demand values for each municipal well system evaluated in the SGBLS source protection region. It should be noted that the municipal systems serving the communities of Aurora, Newmarket, Queensville, and Holland Landing are blended systems that obtain water from both surface and groundwater supplies. Table 3.7 - 3 presents the Committed demand values for each municipal well in the Tier Three Study Area. Committed demand values were determined by calculating the difference between the existing demand and the 2016 groundwater taking projections highlighted in the approved Water and Wastewater Master Plan mentioned above, and presented in Table 3.7 - 2. Committed demand values reflect anticipated growth that is contained within York Region’s Official Plan, and the official plans for the lower tier municipalities. Table 3.7 - 3 also presents the planned demand anticipated in York Region. As presented in the Table, there was no planned demand identified

for the Region due to the fact that increased demand projections in Official Plans were not expected to exceed current permitted rates.

Within the SGBLS source protection region, only the municipalities of Schomberg and Mount Albert have constructed new wells since the commencement of this study. These wells have now been brought online; as a result these wells were not considered to be ‘planned systems’ in this report (Earthfx, 2014). It is important to note that of these two systems, only the Schomberg wells are located within a catchment identified for Tier Three analysis due to a potential stress assignment made during Tier 2 analysis.

Table 3.7 - 3 also lists the allocated and planned quantity of water for each municipal well system. As mentioned above, the allocated quantity of water represents the sum of the existing and committed demand, while the planned quantity of water represents the sum of existing, committed, and planned demand. As noted above, there was no planned demand identified for any of the well fields in York Region; as a result the Planned Quantity of Water is equal to the Allocated Quantity of Water. The Allocated Quantity of Water was used as an input during the simulation of the future (increased) demand scenarios described in Section 3.7.5. During the simulation of scenarios, future increases in the pumping were allocated equally among the wells in a well field. For example, the committed demand for the Yonge Street area wells is 15,439 m^3/d indicating that the allocated quantity of water would increase from the existing 26,560 m^3/d to 42,000 m^3/d or an increase of 58%. Each well in the Yonge Street area was therefore increased by 58% to simulate future (allocated quantity of water) demand (Earthfx, 2014). Even with these increases, no well exceeded its individual maximum permitted rate. Where a new well was added to the wellfield, the committed pumping rate was allocated equally among the new and old wells (Earthfx, 2014).

The existing and allocated values used in the simulation of the Risk Assessment scenarios are presented in Table 3.7 - 4.

It is important to note that the York Region wells have considerable operation flexibility and can easily shift demand between individual wells and even between nearby wellfields when required.

Table 3.7 - 1: York Region Permit to Take Water Summary (Earthfx, 2014).

Municipal Well(s)	PTTW No.	Permit Issued	Permit Expiry	Maximum Permitted Taking (L/min)	Maximum Permitted Taking (L/day)	Comments
Ansnorveldt PW1, PW2, PW3	1831-8M3HSH	26-Sep-11	31-Dec-21	Ansnorveldt: PW1 70; PW2 128; PW3 80	Ansnorveldt: PW1 100,800; PW 184,320; PW3 115,200	No change in permitted water taking from previous PTTW (Ref No. 02-P-3050). In the future, Ansnorveldt PW 3 will replace Ansnorveldt PW 1.
Aurora PW1, PW2, PW3, PW4, PW5, PW6	6623-68QQ6L	31-Mar-05	31-Mar-15	Aurora: PW1 2,273; PW2 4,091.5; PW3 3,636.9; PW4 5,455.3; PW5 4,091.5; PW6 2409.4	Aurora: PW1 3,273,120; PW2 5,891,760; PW3 5,237,136; PW4 7,855,632; PW5 5,891,760; PW6 3,469,536	The wells located in Aurora, Newmarket, Queensville and Holland Landing are all listed on the same PTTW. This permit is referred to as the Yonge Street Aquifer PTTW. The PTTW allows an annual daily average water taking of 42,000 L/d. During peak demand periods the PTTW permits an average day withdrawal of 67,200 L/d and a maximum daily withdrawal of 87,656 L/d (equivalent to the sum of maximum daily takings for each well on the Permit).
Newmarket PW1, PW2, PW13, PW14, PW15, PW16	6623-68QQ6L	31-Mar-05	31-Mar-15	Newmarket: PW1 1,591.1; PW2 3,182.3; PW13 4,091.5; PW14 1,591.1; PW15 2,273; PW16 3,909.6	Newmarket: PW1 2,291,184; PW2 4,582,512; PW13 5,891,760; PW14 2,291,184; PW15 3,273,120; PW16 5,629,824	The wells located in Aurora, Newmarket, Queensville and Holland Landing are all listed on the same PTTW. This permit is referred to as the Yonge Street Aquifer PTTW. The PTTW allows an annual daily average water taking of 42,000 L/d. During peak demand periods the PTTW permits an average day withdrawal of 67,200 L/d and a maximum daily withdrawal of 87,656 L/d (equivalent to the sum of maximum daily takings for each well on the Permit).

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Municipal Well(s)	PTTW No.	Permit Issued	Permit Expiry	Maximum Permitted Taking (L/min)	Maximum Permitted Taking (L/day)	Comments
Holland Landing PW1, PW2, PW3	6623-68QQ6L	31-Mar-05	31-Mar-15	Holland Landing: PW1 1,591.1; PW2 2,500.3	Holland Landing: PW1 2,291,184; PW2 3,600,432	The wells located in Aurora, Newmarket, Queensville and Holland Landing are all listed on the same PTTW. This permit is referred to as the Yonge Street Aquifer PTTW. The PTTW allows an annual daily average water taking of 42,000 L/d. During peak demand periods the PTTW permits an average day withdrawal of 67,200 L/d and a maximum daily withdrawal of 87,656 L/d (equivalent to the sum of maximum daily takings for each well on the Permit).
Queensville PW1, PW2, PW3, PW4	6623-68QQ6L	31-Mar-05	31-Mar-15	Queensville: PW1 4,546.1; PW2 4,546.1; PW3 4,546.1; PW4 4,546.1	Queensville: PW1 6,546,384; PW2 6.546.384; PW3 6,546,384; PW4 6,546,384	During peak demand periods the PTTW permits an average day withdrawal of 67,200 L/d and a maximum daily withdrawal of 87,656 L/d (equivalent to the sum of maximum daily takings for each well on the Permit).
Ballantrae PW1, PW2, PW3	2030-8KDJCG	03-Aug-11	31-Mar-15	Ballantrae: PW1 1,818; PW2 1,818; PW3 1,818	Ballantrae: all wells combined 4,580,000	Permit issued in 2011 added PW 3 to the system which has been commissioned and will be added to the Ballantrae system in 2013. The PTTW restricts the daily water takings to 4,580,000 L/d. The wells can be used in any combination.
Mt. Albert PW1, PW2, PW3	0050-7FCMMY	09-Jun-08	31-Mar-18	Mt. Albert: PW1 2,273; PW2 2,273; PW3 2,273	Mt. Albert: all wells combined 4,990,000	Similar to the Ballantrae system, the Permit restricts the daily water takings to 4,990,000 L/d. The wells can be used in any combination.
Schomberg PW2, PW3, PW4	0706-7E8T5G	03-Jun-08	30-Apr-18	Schomberg: PW2 1,137; PW3 1,591; PW4 1,047	Schomberg: PW2 1,636,560; PW3 2,290,000; PW4 1,507,680	No operational restrictions.

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Table 3.7 - 2 : York Region Current and Future Water Demand (Earthfx, 2014).

Municipal Well	Maximum Permitted Pumping	Water	Existing Demand (2010-2011) Well Annual Average Pumping (m3/day)	Existing Demand (2010-2011) System Annual Average Pumping (m3/day)	2016 Water System Demand (m3/day)	2031 Water System Demand (m3/day)	Water System Demand (m3/day)	Notes
Ansnorveldt PW1	100.8	285.1 combined	15.6	44.3 combined	100 combined	100 combined	Groundwater	Water System is designed to meet 2031 build out.
Ansnorveldt PW2	184.3	285.1 combined	28.7	44.3 combined	100 combined	100 combined	Groundwater	Water System is designed to meet 2031 build out.
Ansnorveldt PW3	115.2	285.1 combined	0	44.3 combined	100 combined	100 combined	Groundwater	Water System is designed to meet 2031 build out.
Aurora PW1	3,273.10	42,000 combined	735.7	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Current permit restricts water taking to an annual combined average of 42,000 m^3/d.
Aurora PW2	5,891.80	42,000 combined	1,394.20	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Aurora PW3	5,237.10	42,000 combined	1,130.40	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Aurora PW4	7,855.60	42,000 combined	1,679.20	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Current permit restricts water taking to an annual combined average of 42,000 m^3/d.
Aurora PW5	5,891.80	42,000 combined	1,433.80	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Current permit restricts water taking to an annual combined average of 42,000 m^3/d.
Aurora PW6	3,469.50	42,000 combined	740.3	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Newmarket PW1	2,291.20	42,000 combined	577	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Current permit restricts water taking to an annual combined average of 42,000 m^3/d.
Newmarket PW2	4,582.50	42,000 combined	1,731.80	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.

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Municipal Well	Maximum Permitted Pumping	Water	Existing Demand (2010-2011) Well Annual Average Pumping (m3/day)	Existing Demand (2010-2011) System Annual Average Pumping (m3/day)	2016 Water System Demand (m3/day)	2031 Water System Demand (m3/day)	Water System Demand (m3/day)	Notes
Newmarket PW13	5,891.80	42,000 combined	1,304.40	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Newmarket PW14	2,291.20	42,000 combined	7.6	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Current permit restricts water taking to an annual combined average of 42,000 m^3/d.
Newmarket PW15	3,273.10	42,000 combined	1,211.50	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Newmarket PW16	5,629.80	42,000 combined	1,807.90	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Holland Landing PW1	2,291.20	42,000 combined	376.7	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Current permit restricts water taking to an annual combined average of 42,000 m^3/d.
		42,000 combined		26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Holland Landing PW2	3,600.40	42,000 combined	839.4	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Queensville PW1	6,546.40	42,000 combined	1,902.20	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Queensville PW2	6,546.40	42,000 combined	2,342.90	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Queensville PW3	6,546.40	42,000 combined	3,484.30	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.

Municipal Well	Maximum Permitted Pumping	Water	Existing Demand (2010-2011) Well Annual Average Pumping (m3/day)	Existing Demand (2010-2011) System Annual Average Pumping (m3/day)	2016 Water System Demand (m3/day)	2031 Water System Demand (m3/day)	Water System Demand (m3/day)	Notes
Queensville PW4	6,546.40	42,000 combined	3,860.90	26560.1 combined	42000 combined	42000 combined	Lake Ontario	Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Ballantrae PW1	2,617.90	4580 combined	468.7	1086.8 combined	1760 combined	1760 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out.
Ballantrae PW2	2,617.90	4581 combined	618.1	1086.8 combined	1760 combined	1760 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out.
Ballantrae PW3	2,617.90	4582 combined	Not constructed	1086.8 combined	1760 combined	1760 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out.
Mt. Albert PW1	3,273.10	4990 combined	357.1	1393.1 combined	1370 combined	1420 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Mt. Albert PW2	3,273.10	4991 combined	422.6	1393.1 combined	1370 combined	1420 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Mt. Albert PW3	3,273.10	4992 combined	613.4	1393.1 combined	1370 combined	1420 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Schomberg PW2	1,636.60	5434.2 combined	181	747.4 combined	1470 combined	1830 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Schomberg PW3	2,290.00	5434.2 combined	240.5	747.4 combined	1470 combined	1830 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.
Schomberg PW4	1,507.70	5434.2 combined	325.9	747.4 combined	1470 combined	1830 combined	Groundwater	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.

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Notes: Ansnorveldt, Schomberg, Mount Albert and Ballantrae water supply systems are designed and constructed to meet 2031 build out. Planned average demand for 2031 is based on population, employment data, and water consumption unit rates (252 L/capita/d and 225 L/d for employment use per the 2008 Unit Rates study completed for the master plan). York Region Master Plan average day demand is the PTTW maximum permitted taking divided by the peaking factor. The demand data presented are annual average day values.

Table 3.7 - 3: York Region Allocated Pumping Rate Summary (Earthfx, 2014).

Municipal Wells	Water Demand Water System Classification	System Max. Permitted Pumping (m^3/d)	Existing Demand (m^3/d)	Committed Demand (m^3/d)	Planned Demand (m^3/d)	Allocated Quantity of Water (m^3/d)	Planned Quantity of Water (m3/d)	Notes
Ansnorveldt PW1, PW2, PW3	Committed and No Planned	285.1	44.3	55.7	0.0	100.0	100.0	Water system designed to meet 2031 build out.
Aurora PW1, PW2, PW3, PW4, PW5, PW6; Newmarket PW1, PW2, PW13, PW15, PW16; Holland Landing PW1, PW2; Queensville PW1, PW2, PW3, PW4	Committed and No Planned	42,000	26,560.1	15,439.9	0.0	42,000	42,000	Current permit restricts water taking to an annual combined average of 42,000 m^3/d. Future water demand will be accommodated by water conservation strategies and Lake Ontario supply.
Ballantrae PW1, PW2, PW3	Committed and No Planned	4,580.0	1,086.8	673.2	0.0	1,760.0	1,760.0	Water system is designed and constructed to meet 2031 build-out.
Mt. Albert PW1, PW2, PW3	Committed and No Planned	4,990.0	1,393.1	26.9	0.0	1,420.0	1,420.0	Water system is designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.

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Municipal Wells	Water Demand Water System Classification	System Max. Permitted Pumping (m³/d)	Existing Demand (m³/d)	Committed Demand (m³/d)	Planned Demand (m³/d)	Allocated Quantity of Water (m³/d)	Planned Quantity of Water (m3/d)	Notes
Schomberg PW2, PW3, PW4	Committed and No Planned	5,434.2	747.4	1,082.6	0.0	1,830.0	1,830.0	Water system designed and constructed to meet 2031 build-out. Increases can be accommodated with current infrastructure and permitted water taking.

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Notes: Values presented are annual daily averages. Existing demand calculated as the average daily demand for 2010 and 2011. Ansnorveldt, Schomberg, Mount Albert and Ballantrae water supply systems are designed and constructed to meet the 2031 build out. Planned average demand for 2031 is based on population, employment data and per capita water consumption unit rates (252 L/capita/d and 225 L/d for employment use per the 2008 Unit Rates study completed for the master plan).

Table 3.7 - 4: Average Municipal Pumping Rates used in the Steady State Model (Earthfx, 2014).

Municipal Well	Existing Demand (m^3/d)	Allocated Quantity of Water (m^3/d)	Notes
Ansnorveldt PW1	15.6	35.2	% increase distributed uniformly to all wells in Ansnorvelt
Ansnorveldt PW2	28.7	64.7	% increase distributed uniformly to all wells in Ansnorvelt
Ansnorveldt PW3	0	0	% increase distributed uniformly to all wells in Ansnorvelt
Aurora PW1	735.7	1,163.4	% increase distributed uniformly to all wells in Newmarket / Aurora
Aurora PW2	1,394.2	2,204.6	% increase distributed uniformly to all wells in Newmarket / Aurora
Aurora PW3	1,130.4	1,787.5	% increase distributed uniformly to all wells in Newmarket / Aurora
Aurora PW4	1,679.2	2,655.4	% increase distributed uniformly to all wells in Newmarket / Aurora
Aurora PW5	1,433.8	2,267.3	% increase distributed uniformly to all wells in Newmarket / Aurora
Aurora PW6	740.3	1,170.6	% increase distributed uniformly to all wells in Newmarket / Aurora
Newmarket PW1	577.0	912.5	% increase distributed uniformly to all wells in Newmarket / Aurora
Newmarket PW2	1,731.8	2,738.6	% increase distributed uniformly to all wells in Newmarket / Aurora
Newmarket PW13	1,304.4	2,062.6	% increase distributed uniformly to all wells in Newmarket / Aurora
Newmarket PW14	7.57	12.0	% increase distributed uniformly to all wells in Newmarket / Aurora
Newmarket PW15	1,211.5	1,915.8	% increase distributed uniformly to all wells in Newmarket / Aurora
Newmarket PW16	1,807.9	2,858.9	% increase distributed uniformly to all wells in Newmarket / Aurora
Holland Landing PW1	376.7	595.7	% increase distributed uniformly to all wells in Newmarket / Aurora
Holland Landing PW2	839.4	1,327.4	% increase distributed uniformly to all wells in Newmarket / Aurora

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Municipal Well	Existing Demand (m^3/d)	Allocated Quantity of Water (m^3/d)	Notes
Queensville PW1	1,902.2	3,008.0	% increase distributed uniformly to all wells in Newmarket / Aurora
Queensville PW2	2,342.9	3,704.8	% increase distributed uniformly to all wells in Newmarket / Aurora
Queensville PW3	3,484.3	5,509.8	% increase distributed uniformly to all wells in Newmarket / Aurora
Queensville PW4	3,860.9	6,105.3	% increase distributed uniformly to all wells in Newmarket / Aurora
Ballantrae PW1	468.72	586.7	Future pumping allocated equally between old and new wells in Ballantrae
Ballantrae PW2	618.1	586.7	Future pumping allocated equally between old and new wells in Ballantrae
Ballantrae PW3	0	586.7	Future pumping allocated equally between old and new wells in Ballantrae
Mt. Albert PW1	357.1	364.0	% increase distributed uniformly to all wells in Mt. Albert
Mt. Albert PW2	422.6	430.7	% increase distributed uniformly to all wells in Mt. Albert
Mt. Albert PW3	613.4	625.3	% increase distributed uniformly to all wells in Mt. Albert
Schomberg PW2	181.0	443.2	% increase distributed uniformly to all wells in Shomberg
Schomberg PW3	240.5	588.9	% increase distributed uniformly to all wells in Shomberg
Schomberg PW4	325.9	797.9	% increase distributed uniformly to all wells in Shomberg
Church Well No. 1	887.6	887.6	No change
Church Well No. 2	2,773.4	2,773.4	No change

Town of Bradford - West Gwillimbury

During the Tier Three Assessment, eight wells operating under one Permit to Take Water in the Town of Bradford West Gwillimbury were flagged for Tier 3 analysis due to their location within the potentially stressed West Holland Watershed in the SGBLS source protection region. A total of 6 of the 8 wells are slated for decommissioning and as a result, no longer supply water to the town. The remaining two Church Wells are still in operation and serve as the primary supply wells for the Town. Despite serving the Town of Bradford –West Gwillimbury, these two wells are located within York Region's municipal boundaries, outside of the Town. It should be noted that the decrease in groundwater pumping in Town is due to the Town's increased reliance on surface water supplies. Currently, the town operates a mixed surface water/groundwater system, with a large majority of the supply coming from a surface water intake located in Lake Simcoe. Table 3.7 - 5 summarizes the existing demand for the Town of Bradford West Gwillimbury for the years of 2010 and 2011. Pumping data was supplied by the Town of Bradford West Gwillimbury. As presented in the Table 7, potable water is pumped exclusively from the Church Street wells in York Region; the other minimal amounts of pumping at the other wells is conducted for maintenance, this minimal amount of pumping will cease once the wells are decommissioned in 2014.

The allocated quantity of water for the Town of Bradford West Gwillimbury is equal to the existing demand as there are no additional future committed or planned demands. Additional population growth will be serviced through surface water supplies obtained from Lake Simcoe. Due to the impending decommissionings, and minimal amount of pumping currently conducted at the Soda Pop, Bingham, Simcoe, Doane, and Hambly wells, only the takings from the Church Street wells are simulated in the Tier Three model.

Table 3.7 - 5: Town of Bradford - West Gwillimbury Allocated Water Summary (Earthfx, 2014).

Municipal Well	Water Demand Water System Classification	Water System Maximum Permitted Pumping (m^3/d)	Existing Demand (m^3/d)	Committed Demand (m^3/d)	Planned Demand (m^3/d)	Allocated Quantity of Water (m^3/d)	Planned Quantity of Water (m^3/d)	Notes
Soda Pop Well	No Existing, No Committed, and No Planned	786.2	0.0	0.0	0.0	0.0	0.0	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.
Bingham Well	No Existing, No Committed, and No Planned	589.0	0.1	0.0	0.0	0.1	0.1	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.
Simcoe Street Well	No Existing, No Committed, and No Planned	1,047.0	0.1	0.0	0.0	0.1	0.1	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.
Simcoe Replacement Well	No Existing, No Committed, and No Planned	1,047.0	0.0	0.0	0.0	Combined with above	Combined with above	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.

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Municipal Well	Water Demand Water System Classification	Water System Maximum Permitted Pumping (m³/d)	Existing Demand (m³/d)	Committed Demand (m³/d)	Planned Demand (m³/d)	Allocated Quantity of Water (m³/d)	Planned Quantity of Water (m³/d)	Notes
Doane Well	No Existing, No Committed, and No Planned	2,618.0	0.0	0.0	0.0	0.0	0.0	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.
Hambly Well (8th Line)	No Existing, No Committed, and No Planned	1,637.3	0.2	0.0	0.0	0.2	0.2	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.
Church Well No. 1	No Committed and No Planned	1,637.3	887.6	0.0	0.0	887.6	887.6	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.
Church Well No. 2	No Committed and No Planned	4,911.8	2,773.4	0.0	0.0	2,773.4	2,773.4	Bradford is a blended system. Water supply for the community is provided by Church Well No. 1 and 2 and Lake Simcoe.

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Durham Region

The Regional Municipality of Durham operates a total of 8 municipal water supply systems; three wells within the Town of Uxbridge, were represented in the York Tier 3 integrated surface water/groundwater model, despite their location outside of a watershed identified as potentially stressed at the Tier 2 level. The three Uxbridge wells (Wells MW5, MW6, and MW7) were simulated at their consumptive rates, which were determined by multiplying estimated takings at the well by usage factors that account for the return flow of water back to the aquifer from which they were extracted. The consumptive use values were estimated from 2007 pumping data provided by the Region of Durham. The municipal water use in 2007 was selected as representative for calibration purposes. Consumptive rates simulated in the Tier Three model are presented in Table 3.7 - 6

Table 3.7 - 6 : Consumptive Use in Durham Region Simulated in the Tier Three Model. (Earthfx, 2013).

Well Name	Permit #	2007 Taking (m^3/yr)	Consumptive Use Factor	Consumptive Use (m^3/yr)
*Uxbridge-MW5	3588-6TKLAA	455280	.2	91056
*Uxbridge-MW6	3588-6TKLAA	653577	.2	130715
*Uxbridge-MW7	3588-6TKLAA	0	.2	0

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*These wells are now operated under PTTW # 1474-8FAJE3

Safe Available Drawdown

The Tier Three Assessment requires the calculation of an analytical parameter called Safe Available Drawdown. Safe Available Drawdown refers to the additional depth that the water level within a pumping well could drop and still maintain the well's allocated pumping rate. Safe Available Drawdown levels are used as the criteria against which Risk Assessment scenario results are evaluated. Additional drawdown values defined during the simulation of Risk Assessment scenarios are compared against Safe Available Drawdown values. Additional drawdown is the amount of drawdown available beyond the drawdown created by existing (or baseline) conditions. If additional drawdown exceeds *Safe Available Drawdown* at a well, the local area in which it is located is assigned a significant risk.

Safe Available Drawdown is calculated as the difference between existing (2010/2011) average water level and the safe water level in a pumping well. Safe water level is defined as the lowest elevation that a well can be pumped to, and is constrained by a number of operational limitations depending on whether the well's operation is limited by in-well conditions, or in-aquifer conditions. In well constraints include the elevation of the well screen, pump intake, or other operational limitations. If in-aquifer conditions constrain the well's operation, it is necessary to ensure that the dewatering of the aquifer is prevented. Depending on the constraints that limit the well's operation, the safe water level is defined by either the:

- the elevation of the pump intake or well screen or
- the level at the top of the aquifer

Depending on the constraints that limit the well's operation, the Safe Water level in a well is calculated as either:

- the additional available drawdown in the well, determined by the difference between the current operating level in the well and top of the well screen or pump intake or
- the additional available drawdown in the supply aquifer , as determined by the difference between existing aquifer water levels and the top of the aquifer

The criteria that results in the smaller additional available drawdown is used to calculate the *Safe Available Drawdown* - which is determined as the difference between existing (2010/2011) average water level and the selected safe water level in a pumping well. During the Risk Assessment scenarios (explained in Section 3.7.5.), the calculated Safe Available Drawdown is compared to the drawdowns that result under the simulation of the Tier Three Scenarios. If the drawdowns experienced under the scenarios exceed safe available drawdown, the wells are flagged with a moderate or significant risk depending on the circumstance triggered in the Technical Rules, and potential threats are assigned accordingly. The Safe Available Drawdown values for each of the municipal wells evaluated for this Tier Three Study are provided in Table 3.7 - 7 and Table 3.7 - 8 below.

Figure 3.7 - 10 provides a sample Safe Available Drawdown calculation for Aurora Well PW-1. For well PW-1, the level of the top of the aquifer was the criterion used to determine the Safe Available Drawdown. As illustrated in Figure 3.7 - 10, to calculate the Safe Available Drawdown, the level of the top of the aquifer (181.2m) (the Safe Water Level) is subtracted from the level of the aquifer during pumping (238.1m) (the average water level during pumping); the resulting difference indicates the amount of Safe Available Drawdown that accessible before the top of the aquifer is reached. For Aurora well PW-1 the Safe Available Drawdown was determined to be 56.9 m. In circumstances where the level of the top of the screen is the criteria used to calculate the Safe Available Drawdown, the level of the top of the well screen is subtracted from the pumped water level in the well. The resulting difference is representative of the Safe Available Drawdown accessible before the well screen is reached. The Safe Available Drawdown

calculations for all of the wells evaluated in this Tier Three Assessment are provided in Appendix WB-5A. The Safe Available Drawdown values for the municipal wells evaluated for this Tier Three study are presented in Table 3.7 - 7 and Table 3.7 - 8.

Table 3.7 - 7: Safe Available Drawdown at York Region Municipal Wells (Earthfx, 2014).

Municipal Well	***Safe Water Level (masl): Lowest Pump Intake***	***Safe Water Level (masl): Top of Aquifer***	***Existing Water Level (masl): Average In-well Level***	***Existing Water Level (masl): Average Aquifer Level***	***Safe Available Drawdown (m): In-well Drawdown***	***Safe Available Drawdown (m): Aquifer Drawdown***
Ansnorveldt PW1	146.54	147.15	201.24	203.10	**54.69**	55.95
Ansnorveldt PW2	134.31	148.93	202.98	203.10	68.67	**54.17**
Ansnorveldt PW3 [1]	-	150.71	-	202.40	-	**51.69**
Aurora PW1	161.65	181.15	234.85	238.06	73.20	**56.90**
Aurora PW2	162.39	162.39	231.69	238.06	**69.30**	75.67
Aurora PW3	161.84	183.18	234.71	238.06	72.87	**54.88**
Aurora PW4	164.28	175.57	233.47	238.06	69.19	**62.48**
Aurora PW5 [2]	175.35	186.16	234.21	236.56	58.86	**50.40**
Aurora PW6	179.35	218.15	236.70	246.40	57.35	**28.25**
Ballantrae PW1	235.33	248.44	296.28	301.67	60.95	**53.23**
Ballantrae PW2	229.47	239.22	301.02	301.67	71.55	**62.45**
Ballantrae PW3 [3]	244.96	257.77	-	-	-	-
Holland Landing PW1	177.32	189.54	215.24	216.30	37.92	**26.76**

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Municipal Well	***Safe Water Level (masl): Lowest Pump Intake***	***Safe Water Level (masl): Top of Aquifer***	***Existing Water Level (masl): Average In-well Level***	***Existing Water Level (masl): Average Aquifer Level***	***Safe Available Drawdown (m): In-well Drawdown***	***Safe Available Drawdown (m): Aquifer Drawdown***
Holland Landing PW2	176.40	193.90	215.59	216.97	39.19	**23.06**
Newmarket PW1 [2]	189.32	185.97	226.96	227.99	**37.63**	42.02
Newmarket PW2 [2]	193.48	185.96	227.62	227.99	**34.14**	42.03
Newmarket PW13 [2]	180.00	170.93	232.99	233.71	**52.99**	62.78
Newmarket PW14	244.71	258.73	268.50	269.57	23.79	**10.84**
Newmarket PW15 [2]	191.30	188.27	224.63	226.61	**33.33**	38.34
Newmarket PW16 [2]	183.19	176.79	230.68	233.71	**47.49**	56.92
Queensville PW1 [2]	192.84	193.86	214.18	217.08	**21.34**	23.22
Queensville PW2 [2]	192.94	190.50	214.81	216.87	**21.87**	26.37
Queensville PW3 [2]	180.69	193.25	210.41	214.73	29.72	**21.48**
Queensville PW4 [2]	180.30	190.50	210.31	214.73	30.01	**24.23**
Schomberg PW2 [2]	159.08	163.32	238.24	238.24	79.16	**74.92**
Schomberg PW3 [2]	159.59	152.90	238.24	238.24	**78.65**	85.34
Schomberg PW4 [2]	160.22	164.80	238.24	238.24	78.02	**73.44**

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Notes:

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

[1] Ansnorveldt PW#3 has no pumping or aquifer drawdown data; this is a replacement well for Ansnorveldt PW #1.

[2] These wells have a telescoping casing that restricts the depth to which the pump can be lowered; the value for “lowest pump intake” represents the top of the 200-250 mm diameter casing.

[3] Ballantrae PW#3 was not yet completed at the time of this report. An additional drawdown equal to the aquifer safe additional drawdown for Ballantrae PW#2 was used.

Table 3.7 - 8: Safe Available Drawdown at Bradford - West Gwillimbury Municipal Wells (Earthfx, 2014).

Municipal Well	**Safe Water Level (masl):** ***Lowest Pump Intake***[1]	***Safe Water Level (masl): Top of Aquifer***	***Existing Water Level (masl): Average In -well Level***	***Existing Water Level (masl): Average Aquifer Level***	***Safe Available Drawdown (m): In-well Drawdown***	***Safe Available Drawdown (m): Aquifer Drawdown***
8th Line Well	131.18	135.15	198.90	201.01	67.72	**65.86**
Bingham Well	198.79	198.15	227.10	227.10	**28.31**	28.95
Doane Well	198.40	199.58	219.27	219.35	20.87	**19.77**
Simcoe Well	197.37	204.65	223.38	223.38	26.01	**18.73**
Soda Pop Well	146.81	146.50	204.48	204.48	**57.67**	57.98
Church St. Well 1	139.53	159.67	193.35	193.68	53.82	**34.01**
Church St. Well 2	145.15	161.31	192.78	193.68	47.63	**32.37**

Notes: Safe available drawdown for each well emphasized in bold. Corresponds to the more conservative value (smaller safe available drawdown value) provided by considering the in-well drawdown and the aquifer drawdown.[1] Lowest pump intake based on the assumption that the pump can be lowered to the top of the well screen.

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Other Water Uses

The Tier Three Assessment also assesses whether existing and allocated demand can be met while maintaining the water requirements of other users in the area. As part of the Tier Three Assessment it is important to identify all of the other water uses in the area, and estimate their water quantity requirements where possible. Other water uses considered during this study included aquatic habitats, provincially significant wetlands, and other permitted and non-permitted users that may affect local water supplies or be affected by groundwater takings. The following section describes the other water uses identified within the Study Area.

Other Permitted Demand

Municipal wells found outside of stressed subwatersheds, and 272 other permitted takings located in the Study Area were simulated in the integrated Tier Three model using their estimated consumptive rates. Other permitted water takings included both groundwater and combined groundwater/surface water takings. Despite being included in the Tier Three model, the effects of future increases in other water takings were not considered in the risk assessment scenario analysis (Earthfx, 2014).The municipal wells located outside of assessment watersheds are highlighted in Figure 3.7 - 2 , while all permitted non-municipal groundwater takings are illustrated in Figure 3.7 - 11. Data for non-municipal permitted takings was obtained from the Lake Simcoe Region Conservation Authority, the Toronto Region Conservation Authority, and the MOE's Water Taking Reporting System.

A detailed list of all of the other permitted water users in the Study Area is provided in Section 9 and Appendix E of the Development and Calibration Report by Earthfx, 2013.

Non-Permitted Water Uses

Non-permitted water use within the portion of the Study Area located within the South Georgian Bay Lake Simcoe SGBLS source protection region was estimated using agricultural use information used during the Tier 1 and 2 water budget evaluations of catchments in the source protection region. For the portion of the Study Area located within the Credit Valley, Toronto Region, Central Lake Source Protection Region, 286 additional wells in the Study Area were represented in the model. Non-permitted use primarily included domestic wells pumping less than 50 m^3/day, and takings devoted to agricultural use and livestock watering. It should be noted that takings from non-permitted and domestic wells were not represented in the Risk Assessment scenario analysis, as these takings are small and generally assumed to be non-consumptive due to the fact that much of the water that is taken is generally returned to the shallow aquifer (Earthfx, 2014).

Aquatic Habitats

The Tier Three Risk Assessment must also consider whether water demands can be met while maintaining the water needs of aquatic ecosystems in the Study Area. During the Risk Assessment, if a groundwater reduction of 10% or more is predicted at coldwater streams, due to well pumping, the Local Area in which the scenarios are carried out is assigned a moderate Risk Level. A significant risk level can only be assigned if the pumping required to meet planned demand (planned quantity of water) results in a groundwater discharge reduction of 20% or greater. As noted earlier, a planned demand was not identified for this study, and as a result the assignment of a significant risk could not be made.

While no specific thresholds are provided for the evaluation of impacts to warm water streams, in this Tier Three study impacts to these streams were evaluated. A 50% reduction in groundwater discharge was selected as a reasonable threshold for “unacceptable’ impact to a warm water stream, as recommended by the peer review team and supported by the Ministry of Natural Resources. Figure 3.7 - 12 highlights the warm and cold water streams located in the vicinity of the municipal wells evaluated as part of this study.

Provincially Significant Wetlands

The Tier Three Risk Assessment must also consider the impacts on Provincially Significant Wetlands as a result of municipal pumping. As per the Technical Rules (MOE, 2008a),(MNR and MOE, 2011; MOE, 2013) municipal takings should not present an unacceptable impact to other water uses. Unacceptable Impacts to wetland features are determined by evaluating water level changes in the vicinity of the wetland, and the impact of such changes on the function of the wetland. For this Study Area, a 1m fluctuation in water levels was considered normal, therefore a drawdown threshold of more that 1m was selected as appropriate for the evaluation of risk to wetlands. The provincially significant wetlands evaluated during this study are illustrated in Figure 3.7 - 13. For this Tier Three Assessment, only a moderate risk level can be assigned if an unacceptable risk to a wetland is identified. Revisions to the technical rules (MOE and MNR, 2011;2013) indicate that a significant risk level is only possible if pumping required to meet planned demand causes an impact on provincially significant wetlands in the area. As mentioned above, the allocated demand for this study did not exceed currently permitted amounts, and as a result a planned demand could not be identified. As noted earlier, there was no planned demand identified for this study; as a result, a significant risk level could not be assigned solely due to simulated impacts on provincially significant wetlands.

Water Budget

In order to refine the understanding of hydrologic and hydrogeologic flow systems within the Study Area, improved estimates of water budget components were made using the models described in Section 3.7.2. Tier Three Water Budget estimates are considered more reliable than those made under the Tier Two Assessment due to model updates made at the local scale. Results generated from the integrated model create a refined estimate of overall average annual values for various components of the hydrologic cycle within the Study Area. The following section details the results of the water budget assessment.

Water budget components include all of the inflows and outflows within the study watersheds. For this study, inflows included precipitation, and lateral inflow, while outflows include evapotranspiration, lateral outflow, and runoff. Table 3.7 - 9 represents the estimated overall inflow and outflow fluctuations for the Study Area watersheds located within the South Georgian Bay Lake Simcoe source protection region. Water budget values indicate that municipal well pumping in the area represents approximately 1% of the total outflows in the majority of the Study Area watersheds, while the primary influence on the values is the distribution of rainfall and the variation in land use and soil type (Earthfx,2014).

Table 3.7 - 9: Model Water Budget - LSRCA Watersheds (mm/yr) (Earthfx, 2014).

Inflows and Outflow* (mm/yr)	West Holland	East Holland	Maskinonge River	Black River	Pefferlaw Brook	Uxbridge Brook
Precipitation	803	805	818	814	809	807
Lateral Inflow	64	248	258	82	143	70
Inflow	*867*	*1,053*	*1,076*	*896*	*952*	*877*
Well pumping	6	42	27	4	7	7
Lateral outflow	57	281	345	111	184	123
Evapotranspiration	408	390	428	424	436	428
Runoff	396	340	276	356	324	320
Outflow	*867*	*1,053*	*1,076*	*896*	*952*	*877*

Note: Values have been rounded for display purposes

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Local Area Risk Assessment

An essential part of the Tier Three Assessment is the completion of a Local Area Risk Assessment. As per the Technical Rules (MOE, 2009), a Local Area Risk Assessment must be completed for all municipal drinking water systems located within subwatersheds assigned a moderate or significant stress level after undergoing a Tier Two Stress Assessment. More specifically, the Local Area Risk Assessment aims to evaluate the possibility of municipalities being unable to meet their existing and allocated pumping rates under scenarios of increased municipal demand, planned land development, and drought conditions. Moreover, the impacts of municipal pumping on other water uses is also evaluated.

<u>Delineation of Vulnerable Areas</u>

In order to carry out the Risk Assessment, it was first necessary to delineate the 'Local Area' within which the Risk Assessment scenarios would be evaluated. The term 'Local Area' is defined as the area surrounding drinking water wells that must be protected in order to ensure the sustainability of municipal water supplies. The Local Area is delineated using the Tier Three models discussed in Section 3.7.2. To determine the extent of the Local Area, it is necessary to delineate specific vulnerable areas called Wellhead Protection Areas for Quantity (WHPA- Q1 and WHPA- Q2). The WHPA- Q1 and WHPA- Q2 are delineated for all municipal wells located within significantly or moderately stressed subwatersheds identified during a Tier Two Stress Assessment. The WHPA-Q1 is delineated based on modelled aquifer drawdowns, while the WHPA Q2 is delineated based on modelled reductions in recharge.

As per the Technical Rules (MOE, 2008a), the WHPA-Q1 is delineated as the combined area that is the cone of influence of a well and the whole of the cones of influence of all other wells that intersect that area (MNR and MOE, 2011). The cone of influence for a well is determined through simulations carried out under a scenario that considers existing land use and future (existing plus committed) pumping rates. The cone of influence is estimated by calculating the maximum water level drawdown for the scenario as compared to the aquifer drawdown under non-pumping conditions. The drawdown cone used to delineate the WHPA-Q1 should be based on the allocated (existing plus committed) pumping rates for municipal wells. In addition, the drawdown cone will be intersected with the drawdown cone of all other consumptive water users in the Study Area (MNR and MOE, 2011). The extent of the cone of influence should be determined by selecting an appropriate drawdown threshold. When estimating this threshold, several factors should be considered including: observed seasonal fluctuations of the water level in the aquifer, and any field observations of the extent of the cone of influence based on monitoring (MNR and MOE, 2011). For this study, the appropriate threshold was determined to be 1m of drawdown, indicating that 1 m is the practical limit of the cone of influence for the York Tier Three WHPA-Q1 delineation.

The boundary of the WHPA-Q1 for the municipal wells in this Study Area is illustrated in Figure 3.7 - 14. The municipal wells located within the WHPA-Q1 generally draw groundwater from one of the three major aquifers underlying the area. These aquifers include the Oak Ridges Aquifer Complex (ORAC), The Thorncliffe Aquifer Complex/Tunnel Channel Sediments (TAC), and the Scarborough Aquifer Complex (SAC) – more detailed information regarding the aquifers can be found in Section 3.7.1. When defining the WHPA-Q1 area, the cones of influence for each of the municipal wells within each aquifer were calculated and compared (Earthfx, 2014). During the final delineation of the boundary, the furthest extent of the cone of influence within each aquifer was considered. The 1m drawdown contours for each of the three major aquifers are shown in Figure 3.7 - 15. The cones of influence for each of these aquifers were superimposed to delineate the final WHPA Q1 area as shown in Figure 48 (Earthfx, 2014).

As illustrated in Figure 3.7 - 14, the WHPA-Q1 delineation covers approximately a quarter of the Study Area, and extends from Richmond Hill/Markham in the south to north of Queensville in the north, and from Maple in the west to beyond Uxbridge in the east.

The WHPA Q2 is delineated as the WHPA-Q1 area plus any area where a future reduction in recharge would significantly impact that area. When identifying an area where a future reduction in recharge might occur, reference must be made to a municipality's Official Plan to identify lands designated for new development. The proposed land use changes considered during the WHPA Q2 delineation for this study are illustrated in Figure 3.7 - 16.The maximum amount of recharge reduction that might result from these developments must also be considered; any influence from stormwater best management practices should not be accounted for (MNR and MOE, 2011).

To delineate the WHPA- Q2, a simulation modelling the effects of reductions in recharge resulting from new development was performed. The simulation attempts to delineate the effects of drawdown at municipal wells due to projected land cover change. The additional drawdowns in the Lower Oak Ridges Aquifer Complex (ORAC) resulting from reduced recharge due to land use change outside of the WHPA-Q1 are presented in Figure 3.7 - 17.

As a result of the WHPA-Q2 assessment simulations, it was determined that the effects on drawdown at municipal wells due to projected land cover change were generally immeasurable and therefore the WHPA-Q2 area was delineated as being equivalent to the WHPA- Q1 area as illustrated in Figure 3.7 - 14.

The Local Area in which the scenarios are evaluated is delineated to include the cone of influence of the municipal wells (WHPA -Q1) plus the areas where a reduction in recharge would have a measurable impact on the cone of influence (WHPA Q2). For this study, because the WHPA- Q2 was determined to be identical to the WHPA- Q1, the Local Area is equivalent to the WHPA- Q1 delineation as show in Figure 3.7 - 14 (Earthfx, 2014).

<u>Local Area Risk Assessment Scenarios</u>

A Local Area Risk Assessment evaluates the impacts on current hydrogeological conditions in response to various water demand, climate, and land use scenarios. These scenarios are simulated using the numerical models described in Section 3.7.2.

The scenarios that must be evaluated as part of the Local Area Risk Assessment are outlined in Table 3.7 - 10 and Table 3.7 - 11 . Where scenario simulation results indicate that municipal wells may not be able to supply their allocated rates, the Local Area (described above) is assigned a moderate or significant water quantity risk level. Sustainability of the municipal wells was measured in terms of the simulated change in water level in the wells relative to the safe available drawdowns discussed in Section 3.7.3. Consumptive water uses and activities associated with reductions in groundwater recharge within the Local Area are then classified as moderate or significant drinking water threats. Risk scenario simulations also consider the water demand requirements of other water uses in the Local Area, such as the ecological flow requirements of coldwater fish habitats.

Table 3.7 - 10: Summary of Risk Assessment Scenarios (MOE and MNR, 2011).

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

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Table 3.7 - 11: Risk Assessment Scenario Details (MOE and MNR, 2011).

Scenario	Time Period	Land Cover	Municipal Pumping	Model Simulation
C	Average climate conditions	Existing Land Use	Existing demand	Steady-state model with average annual recharge
D	10-year drought	Existing Land Use	Existing demand	Transient model (1954-1966)
G(1)	Average climate conditions	Projected Future Land Use	Allocated quantity of water	Steady-state model with average annual recharge
G(2)	Average climate conditions	Existing Land Use	Allocated quantity of water	Steady-state model with average annual recharge
G(3)	Average climate conditions	Projected Future Land Use	Existing demand	Steady-state model with average annual recharge
H(1)	10-year drought	Projected Future Land Use	Allocated quantity of water	Transient model (1954-1966)

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Scenario	Time Period	Land Cover	Municipal Pumping	Model Simulation
H(2)	10-year drought	Existing Land Use	Allocated quantity of water	Transient model (1954-1966)
H(3)	10-year drought	Projected Future Land Use	Existing demand	Transient model (1954-1966)

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The *Technical Rules (MOE,2009)* outline whether or not each scenario needs to be run in transient or steady state mode. Steady state models simulate the scenarios using average annual recharge (precipitation) and pumping levels. Transient models simulate scenarios using monthly recharge values (precipitation) and monthly pumping levels. Each scenario simulation is also required to evaluate a specific period of time, as indicated in the second column of Table 3.7 - 11. The scenarios are evaluated as follows:

- Scenarios C and G are evaluated under average climate conditions and simulated using a steady state approach
- Scenarios D and H represent drought conditions, and make use of transient simulations to represent the drought of the 1960s.

Risk Assessment Scenario Results

The results of the scenario simulations are assessed with respect to estimated drawdown levels at each municipal well, and the impact on groundwater discharge to coldwater streams and provincially significant wetlands. Impacts on groundwater discharge were only modeled under steady state scenarios (scenarios C and G). The following section details the results of the scenario simulations conducted using the integrated Tier Three Water Budget model discussed in Section 3.7.2. Where simulations indicated that the scenario drawdown was greater than the Safe Available Drawdown, the wells were flagged as potentially not being able to sustain pumping rates under the given scenario. Where the simulated drawdown was less than the Safe Available Drawdown, wells were classified as low risk based on their ability to sustain allocated pumping rates. Table 3.7 - 12 and Table 3.7 - 14 summarize the predicted maximum drawdown for each municipal well, under each of the Risk Assessment scenarios. The following text discusses the results of each scenario in greater detail.

Scenario C

Scenario C models existing demand and land cover under average climate conditions and is therefore intended to verify if municipal wells are able to sustain their pumping under existing conditions. Results simulated under Scenario C are used as baseline values for comparing impacts to wells under the other evaluation scenarios. Consequently, drawdowns under this scenario are equal to zero relative to the drawdowns under the other scenarios. Simulations under this scenario also provide estimates of groundwater discharge to streams and wetlands under current conditions. These estimates are used as baseline conditions for evaluating the effects of increased municipal pumping on aquatic habitats and wetlands (Earthfx, 2014).

The values presented in the column devoted for Scenario C in Table 3.7 - 12 represent the change in water level from pre-development conditions (i.e. no pumping), to current conditions (existing pumping). Table 3.7 - 12 only highlights the simulated drawdowns at each municipal well located in a stressed watershed as recommended by the Tier 2 analysis – simulated drawdowns at other municipal wells not within the stressed watersheds but within the Study Area can be found in Table 3.7 - 13. The calculation of the change in water level between "no-pumping" conditions and current conditions provides a context for analyzing change under future conditions (Earthfx,2014). Simulated drawdowns relative to no pumping conditions in each of the three principal aquifers under Scenario C are illustrated in Figure 3.7 - 18, Figure 3.7 - 19, and Figure 3.7 - 20 .

Based on the results of the simulation, it can be seen that the most prominent drawdown is focused around the Yonge Street area wells, including the wells operating under the Yonge Street Aquifer permit (See York Region Demand section 3.7.3). The Yonge Street area wells include the wells serving the communities of Holland Landing, Sharon-Queensville, Ballantrae, Newmarket and Aurora.

Scenario D

Scenario D evaluates whether municipal wells are able to sustain their existing pumping rates through drought periods. This scenario was simulated in transient mode, and run over the drought period of 1955 to 1966. The period of 1955 to 1966 was determined to be the worst drought period in the available meteorological record due to lower than average precipitation levels, and was therefore selected for use during modelling. Changes in water levels in each of the three supply aquifers under drought conditions are illustrated in Figure 3.7 - 21,Figure 3.7 - 22, and Figure 3.7 - 23. It should be noted that the figures only illustrate declines in water levels greater than 1m – the threshold for a significant impact.

Maximum declines of up to 13m were simulated in the lower ORAC, while smaller maximum declines of up to 10m and 5m were experienced in the Thorncliffe and Scarborough complexes, respectively. It is important to note that despite the declines, additional drawdown around the municipal wells is limited, and Safe Available Drawdown in not exceeded in any of the wells, neglecting the uncertainty associated with model parameters. The greatest declines occur at the regional divide in the ORM and near inter-stream divides (Earthfx,2014). Smaller changes occur in discharge areas near streams, indicating that changes in water level at the pumping wells is primarily dependent on well location (i.e. relative to the regional or inter stream divides) (Earthfx, 2014). In general the ORAC is more sensitive to drought than the two deeper aquifers. Drawdown results at each well in the SGBLS source protection region, under the drought scenario are presented in Table 3.7 - 14.

It is important to note that the York Region wells have considerable operation flexibility and can easily shift demand between individual wells and even between nearby wellfields if the sustainability of pumping at a well is compromised.

Scenario G

Scenario G requires the simulation of three model scenarios that make use of the same average climate inputs, but aim to determine the separate and combined effects of projected demand increases and reductions in recharge due to land cover change. All three category G scenarios are calculated relative to Scenario C results, and compared to the safe available drawdown levels calculated for each well.

Scenario G1 evaluates changes in water level due to reductions in recharge, and increases in demand (allocated quantity of water), using a steady state model. Under Scenario G(1), simulated drawdowns at each of the municipal wells did not exceed safe available drawdown levels, neglecting the uncertainty associated with model parameters. Table 3.7 - 12 presents the drawdown results for each individual well. Figure 3.7 - 24, Figure 3.7 - 25, and Figure 3.7 - 26 illustrate the simulated drawdowns in each of the three supply aquifers. A few larger areas of drawdown can be seen centered around the municipal wells due to the increased pumping simulated in the scenarios. The areas of drawdown that extend further south are due to projected changes in land use (Earthfx, 2014).

Scenario G3 evaluates changes in water level due to reductions in recharge resulting from planned land use development. The simulation is carried out in steady state mode, under average climate conditions and considers existing demand (2010/2011). Results of the simulation indicate that additional drawdowns under this scenario did not exceed Safe Available Drawdown in any of the municipal wells, neglecting the uncertainty associated with model parameters. A drawdown threshold of 1 m was used to define where a reduction in recharge would have a measureable impact on municipal wells. Results indicated that 12 of the 57 wells evaluated exhibited drawdowns greater than 1m. The simulated drawdowns in each of the three supply aquifers are illustrated in Appendix WB-7. As illustrated in the figures, the areas of greatest decline are not centered around the municipal wells but in the south and southeast parts of the Study Area where projected development and land use change is expected to occur. It should also be noted that projected changes in future land use have a more direct impact on the shallow groundwater systems, and less of an impact on the deeper aquifers which serve as the major source of municipal supply.

Scenario G2 evaluates the impact of increased municipal pumping (existing plus committed rates/ allocated demand) under existing land use conditions and average climate. As indicated in Table 3.7 - 12, Safe Available Drawdown was not exceeded in any of the municipal wells, neglecting the uncertainty associated with model parameters. Simulated drawdowns in each of the supply aquifers are illustrated in Figure 3.7 - 27, Figure 3.7 - 28, and Figure 3.7 - 29. The effects of increased pumping are most pronounced around the Yonge Street area wells (Aurora, Ballantrae, Queensville), as well as some of the other municipal wells with significant future increases in pumping (Earthfx, 2014). Under this scenario, the most pronounced drawdown occurs in the deeper aquifers, where the majority of the municipal wells are screened, as illustrated in the Figure 3.7 - 28 and Figure 3.7 - 29.

Scenario H

Scenario H requires the simulation of three scenarios that aim to determine the isolated and combined effects of increased demand and projected land cover change through a drought period, using a transient model. Similar to Scenario D, this scenario was run over the drought period of 1955 to 1966.

Scenario H1 considers the cumulative impact of increased demand and conditions of reduced recharge and drought, and is considered the 'worst case' assessment of potential water level declines. Simulated changes in water level in each of the 3 supply aquifers are shown in Figure 3.7 - 30, Figure 3.7 - 31, and Figure 3.7 - 32. The figures only show water level declines greater than 1m – the threshold for a measurable impact. Results of the simulation indicate maximum declines of 13 m in the ORAC, while declines of 9 m are experienced in the SAC. Drawdowns under this drought scenario are larger than those experienced under scenario D due to the additional effects associated with increased pumping and land use change. Under this scenario, areas of measurable drawdown occur at the municipal wells as well as in areas of proposed land use change. Similar to the effects experienced under the drought scenario (Scenario D), measurable drawdown was also simulated around the regional divide in the Oak Ridges Moraine, and near inter- stream divides (Earthfx, 2014). When considered in unison, these results illustrate the combined impact of the scenario H1 conditions on the supply aquifers. A direct comparison between simulated water levels in the TAC under scenario H1 and D, indicate that the difference in drought response between the two scenarios is primarily due to increased pumping at municipal wells (Earthfx, 2014). Simulated additional drawdowns experienced under scenario H1 are presented in Table 3.7 - 14. Results indicate that Safe Available Drawdown was not exceeded in any of the municipal wells.

Scenarios H2 and H3 are also both evaluated under the transient 10 year drought condition. Scenario H2 evaluates the isolated impact of increased demand, while Scenario H3 evaluates the isolated impact of reductions in recharge due to projected land cover change.

Drawdowns results at municipal wells under Scenario H2 are presented in Table 3.7 - 14. Drawdown values did not exceed safe available drawdown in any of the Study Area municipal wells. Simulated drawdowns experienced at the wells were very close to those experienced under Scenario H1 , confirming that the effect of recharge reductions due to land use change are subdued during a drought (See Appendix WB-7)(Earthfx, 2014).

As explained above, Scenario H3 only evaluated the isolated impact of projected land use change under a drought. The additional drawdown between baseline levels and the simulated levels under Scenario H3 in the three supply aquifers are shown in Appendix WB-7. Simulated drawdown results under Scenario H3 are presented in Table 3.7 - 14. The small change in water level between Scenario H3 and Scenario D indicates that the municipal wells are relatively insensitive to land use change under drought conditions (Earthfx, 2014).

Table 3.7 - 12: Simulated Drawdowns at Municipal Wells in Stressed Watersheds - Scenarios C and G (Earthfx, 2014).

Well	Aquifer	Safe Available Drawdown (m)	Scenario C Drawdown (m)	Simulated Drawdown: Scenario G(1)	Simulated Drawdown: Scenario G(2)	Simulated Drawdown: Scenario G(3)
Ansnorveldt PW1	SAC	54.69	1.68	1.07	0.86	0.20
Ansnorveldt PW2	SAC	54.17	1.63	0.87	0.66	0.20
Aurora PW1	Channel	56.90	9.88	7.03	5.83	1.00
Aurora PW2	Channel	69.30	11.86	8.10	6.88	1.02
Aurora PW3	Channel	54.88	11.56	7.98	6.75	1.02
Aurora PW4	Channel	62.48	12.37	8.50	7.28	1.02
Aurora PW5	TAC	50.40	8.36	5.89	4.90	0.83
Aurora PW6	TAC	28.25	6.32	4.61	3.59	0.88
Ballantrae PW1	Channel	53.23	35.64	5.07	3.79	1.28
Ballantrae PW2	Channel	62.45	36.23	4.40	3.12	1.28
Ballantrae PW3	TAC	-	2.35	12.64	11.11	1.52
Holland Landing PW1	TAC	26.76	5.01	3.17	2.70	0.44
Holland Landing PW2	SAC	23.06	5.61	3.81	3.33	0.46

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Well	Aquifer	Safe Available Drawdown (m)	Scenario C Drawdown (m)	Simulated Drawdown: Scenario G(1)	Simulated Drawdown: Scenario G(2)	Simulated Drawdown: Scenario G(3)
Newmarket PW1	TAC	37.63	9.66	6.39	5.72	0.62
Newmarket PW2	TAC	34.14	10.51	6.91	6.25	0.62
Newmarket PW13	SAC	52.99	8.62	5.76	4.99	0.69
Newmarket PW14	INS	10.84	0.81	0.91	0.44	0.41
Newmarket PW15	SAC	33.33	6.24	4.50	3.99	0.48
Newmarket PW16	SAC	47.49	8.34	5.86	5.09	0.69
Queensville PW1	TAC	21.34	7.90	4.86	4.57	0.20
Queensville PW2	TAC	21.87	8.08	4.93	4.65	0.20
Queensville PW3	TAC	21.48	19.02	11.60	11.15	0.42
Queensville PW4	TAC	24.23	15.91	9.96	9.50	0.43
Schomberg PW2	TAC	74.92	2.16	2.98	2.76	0.20
Schomberg PW3	TAC	78.65	2.64	3.74	3.52	0.20
Schomberg PW4	TAC	73.44	2.76	3.94	3.73	0.20
8th Line Well	SAC	65.86	1.43	0.59	0.45	0.13

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Well	Aquifer	Safe Available Drawdown (m)	Scenario C Drawdown (m)	Simulated Drawdown: Scenario G(1)	Simulated Drawdown: Scenario G(2)	Simulated Drawdown: Scenario G(3)
Bingham Well	TAC	28.31	1.28	0.55	0.41	0.13
Church Well 1	SAC	34.01	4.54	0.72	0.55	0.17
Church Well 2	SAC	32.37	12.61	0.70	0.53	0.16
Doane Well	TAC	19.77	1.03	0.52	0.38	0.13
Simcoe Well	TAC	18.73	1.27	0.55	0.41	0.13
Soda Pop Well	SAC	57.67	1.56	0.68	0.51	0.16

Notes: Drawdowns for Scenario C are expressed relative to no-pumping conditions. Additional drawdowns for Scenario G are expressed relative to Scenario C heads. Ballantrae PW3 only pumped in future scenarios.

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Table 3.7 - 13: Simulated Drawdowns at Municipal Wells located outside of Stressed Watersheds - Scenarios C and G (Earthfx, 2014).

Well	Aquifer	Scenario C Drawdown (m)	Simulated Drawdown: Scenario G(1)	Simulated Drawdown: Scenario G(2)	Simulated Drawdown: Scenario G(3)
Mount Albert PW1	TAC	2.02	0.41	0.18	0.23
Mount Albert PW2	TAC	2.02	0.41	0.18	0.23
Mount Albert PW3	TAC	1.34	0.44	0.17	0.27
Uxbridge-MW5	TAC	3.75	0.15	0.01	0.15

Notes: Additional drawdowns for Scenario C are expressed relative to no-pumping conditions. Additional drawdowns for Scenario G are expressed relative to Scenario C heads.

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Table 3.7 - 14: Simulated Additional Drawdown at Municipal Wells in Stressed Watersheds - Scenarios D and H (Earthfx, 2014).

Well	Aquifer	Safe Available Drawdown (m)	Simulated Drawdown: Scenario D	Simulated Drawdown: Scenario H(1)	Simulated Drawdown: Scenario H(2)	Simulated Drawdown: Scenario H(3)
Ansnorveldt PW1	SAC	54.69	0.88	1.67	1.65	0.90
Ansnorveldt PW2	SAC	54.17	0.88	1.47	1.45	0.90
Aurora PW1	Channel	56.90	6.09	13.14	12.97	6.26
Aurora PW2	Channel	69.30	8.34	17.50	17.31	8.53
Aurora PW3	Channel	54.88	8.34	17.34	17.15	8.53
Aurora PW4	TAC	62.48	8.34	17.94	17.75	8.53
Aurora PW5	TAC	50.40	4.67	10.17	10.03	4.82
Aurora PW6	TAC	28.25	2.97	7.19	7.03	3.13
Ballantrae PW1	Channel	53.23	30.03	35.69	35.53	30.23
Ballantrae PW2	Channel	62.45	30.03	34.92	34.76	30.23
Ballantrae PW3	TAC	-	3.65	17.35	17.06	3.97
Holland Landing PW1	TAC	26.76	2.67	8.32	8.23	2.75
Holland Landing PW2	SAC	23.06	2.75	9.02	8.93	2.83
Newmarket PW1	TAC	37.63	4.56	11.94	11.86	4.64

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Well	Aquifer	Safe Available Drawdown (m)	Simulated Drawdown: Scenario D	Simulated Drawdown: Scenario H(1)	Simulated Drawdown: Scenario H(2)	Simulated Drawdown: Scenario H(3)
Newmarket PW2	TAC	34.14	4.56	12.24	12.16	4.64
Newmarket PW13	SAC	52.99	2.92	8.70	8.59	3.03
Newmarket PW14	SAC	10.84	2.06	2.36	2.36	2.08
Newmarket PW15	SAC	33.33	2.06	6.45	6.38	2.13
Newmarket PW16	SAC	47.49	2.92	8.75	8.64	3.03
Queensville PW1	TAC	21.34	3.64	9.01	8.98	3.67
Queensville PW2	TAC	21.87	3.64	9.11	9.08	3.67
Queensville PW3	TAC	21.48	3.71	11.92	11.85	3.79
Queensville PW4	TAC	24.23	3.71	12.88	12.80	3.79
Schomberg PW2	TAC	74.92	2.56	5.94	5.92	2.58
Schomberg PW3	TAC	78.65	2.71	7.04	7.03	2.73
Schomberg PW4	TAC	73.44	2.71	7.27	7.25	2.73
8th Line Well	SAC	65.86	0.74	1.16	1.14	0.76
Bingham Well	TAC	28.31	0.74	1.08	1.06	0.75
Church Well 1	SAC	34.01	1.48	1.98	1.96	1.50
Church Well 2	SAC	32.37	1.11	1.62	1.60	1.13

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Well	Aquifer	Safe Available Drawdown (m)	Simulated Drawdown: Scenario D	Simulated Drawdown: Scenario H(1)	Simulated Drawdown: Scenario H(2)	Simulated Drawdown: Scenario H(3)
Doane Well	TAC	19.77	0.79	1.11	1.09	0.81
Simcoe Well	TAC	18.73	0.74	1.08	1.07	0.76
Soda Pop Well	SAC	57.67	0.85	1.31	1.29	0.87

Notes: Additional drawdowns for Scenario D and H are expressed relative to September 1956 heads.

Table 3.7 - 15: Simulated Drawdowns at other Municipal Wells - Scenarios D and H (Earthfx, 2014).

Well	Aquifer	Additional Drawdown: Scenario D	Additional Drawdown: Scenario H(1)	Additional Drawdown: Scenario H(2)	Additional Drawdown: Scenario H(3)
Mount Albert PW1	TAC	2.45	2.62	2.60	2.49
Mount Albert PW2	TAC	2.45	2.62	2.60	2.49
Mount Albert PW3	TAC	2.25	2.42	2.38	2.30
Uxbridge-MW5	TAC	2.16	2.18	2.16	2.17

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Impacts to Other Water Uses

The Tier Three Assessment requires that the Tier Three Risk Assessment also consider the impact of pumping at municipal wells on other water uses. More specifically, the assessment must consider whether allocated municipal well demand can be met while maintaining the requirements of other uses in the area (i.e. the maintenance of ecological flow requirements of aquatic habitats). Impacts on groundwater discharge to streams and provincially significant wetlands must be evaluated under scenarios C and G2. Impacts to streams were evaluated by comparing the groundwater discharge simulated under scenario G2 (steady state, projected demand) to groundwater discharge modelled under scenario C baseline conditions (existing conditions). Scenario G2 is the only scenario that isolates the influence of municipal pumping from land development. Since reductions in groundwater discharge (baseflow) resulting from land use development are independent from increased municipal pumping, only the impacts associated with groundwater pumping (i.e. Scenario G2) should be used to assess the impacts to other users such as coldwater streams and wetlands.

Figure 3.7 - 12 illustrates the cold and warm water streams within the vicinity of municipal wells. Simulated groundwater discharge to streams under Scenario C is illustrated in Figure 3.7 - 33. This figure highlights stream reaches where there is a significant groundwater discharge to a stream reach. Figure 3.7 - 34 illustrates the percent decrease in accumulated baseflow between Scenario C (baseline conditions) and Scenario G2. On the map, areas where the colour ranges between yellow and magenta represent locations along the stream where a decrease in accumulated baseflow is simulated to be 10% or greater. If a groundwater reduction of 10% or more is predicted at coldwater streams, the Local Area in which the scenarios are carried out is assigned a moderate Risk Level. While no specific thresholds are provided for the evaluation of impacts to warm water streams, for this Tier Three study impacts to these streams were evaluated, and a 50% reduction in groundwater discharge was selected as a reasonable threshold for “unacceptable’ impact to a warm water stream, as recommended by the peer review team and supported by the Ministry of Natural Resources.

In Figure 3.7 - 34 baseflow reductions greater than 20% are presented in red, while reductions between 10 and 20% are presented in green. As further illustrated in the Figure 3.7 - 35, a limited number of individual cold water reaches were found to have moderate (greater than 10%) decreases in simulated baseflow. The majority of these impacted streams are in proximity to the Yonge Street wells (Aurora, Ballantrae, and Queensville). The figure also illustrates warm water reaches in which a significant decrease in simulated baseflow (50%) occurs (Earthfx, 2014); these warm reaches are delineated with a red circle.

Impacts to Provincially Significant Wetlands

Impacts to Provincially Significant Wetlands, were determined by evaluating the drawdowns in the aquifer beneath the wetland. Drawdowns greater than 1m were considered to have a measurable impact. Figure 3.7 - 13 shows the location of provincially significant wetlands in the vicinity of municipal wells.

Drawdowns were calculated by subtracting the model results generated under Scenario G2 from those obtained under scenario C (Earthfx, 2014). Figure 3.7 - 36 shows the incremental drawdowns experienced in the ORAC, and the location of provincially significant wetlands. As illustrated in the figure, very few wetlands are situated in areas determined to have a drawdown greater than 1m. Figure 3.7 - 37 shows the wetlands that could potentially have reduced outflows or water levels due to increases in pumping at nearby wells.

Impacts to Other Permitted Groundwater Takings

To assess impacts to other permitted water takings, a drawdown of greater than 1 m in the supplying aquifer was defined as a measureable impact. Figure 3.7 - 38 shows the extent of the 1 m incremental drawdown in the ORAC, TAC, and SAC. This incremental drawdown was determined by subtracting the simulated water level determined for Scenario C from water levels determined under Scenario G2 (Earthfx, 2014). The extent of the 1m incremental drawdown zone in each supply aquifer is illustrated in Figure 3.7- 38. The figure also highlights the locations of the other permitted groundwater takings. A total of 10 permits (14 wells) are located within the boundaries of the 1 m incremental drawdown zone as listed in Table 3.7 - 16. This drawdown zone is largely limited to the Yonge Street area. Drawdowns under scenario G2 were calculated for each of these other 14 permitted water takings. Under scenario G2, the simulated drawdown was generally less than 10 % of available drawdown, with the exception of just two permits as listed in the Table 3.7 - 16. As noted earlier, since the allocated demand does not exceed the currently permitted amounts, only a moderate risk level can be assigned to the Local Area.

Table 3.7 - 16: Other Permitted Water Takings within the 1 m Drawdown Cone (Earthfx, 2014).

MOE Permit Number	Well Name	MOE WWIS Number[1]	Easting (m)	Northing (m)	Source Aquifer	Static Water Level (masl)	Screen Top Elv. (masl)	Safe Available Draw-down[4] (m)	Simulated Draw-down (m)
02-P-3009	Well System	6907520	625780	4876010	ORAC	263.69	225.00	38.69	0.37
1151-5TLRLH	PW1	6911605	624740	4885460	TAC	224.14	207.05	17.10	3.99
1417-7TWQQD	Irrigation Well	6926339	619094	4872808	INS	229.35	210.46	18.90	1.71
1417-7TWQQD	East Wells	6920538	619420	4872409	INS	242.57	223.06	19.51	1.25
1417-7TWQQD	West Wells	6920539	619420	4872409	INS	242.57	223.97	18.59	1.25
2005-6TYPT6	PW1 and TW1 combined	6919481	627373	4883966	INS	269.97	253.71	9.25	1.28
2005-6TYPT6	PW1 and TW1 combined	6923555	627373	4883966	INS	264.49	232.38	32.11	1.28
2347-7EDRRH	TW3	6917870	625114	4870603	ORAC	282.67	157.60[2]	125.1	0.82
2347-7EDRRH	TW 4	6917871	623640	4869700	ORAC	282.67	182.56	100.1	1.03
63-P-55	-na-	6901634	619769	4867642	ORAC	287.77	247.01	40.75	0.85

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MOE Permit Number	Well Name	MOE WWIS Number[1]	Easting (m)	Northing (m)	Source Aquifer	Static Water Level (masl)	Screen Top Elv. (masl)	Safe Available Draw-down[4] (m)	Simulated Draw-down (m)
8422-5XJQR8	Production Well No. 1	6907600	627120	4872215	ORAC	261.08	232.43	28.65	0.54
8486-7YDQ8G	King's Riding Clubhouse Well	6921948	620702	4870869	TAC	245.93	182.90	63.03	1.63
8684-7CDJHK	PW 1	6922737	626128	4872901	SAC	245.86	161.78	84.08	1.38
91-P-3086	-na-	6911949	618803	4868195	ORAC	285.0[3]	178.39	106.6	0.83

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[1] MOE well number was inferred from PPTW data, WWIS data, and other secondary information. These numbers and the related well construction data may not be correct.

[2] Screen top elevations were not available and were estimated as borehole bottom elevation minus 2.0 m.

[3] Static water levels were not available and were estimated as ground elevation at the borehole minus 10.0 m.

[4] Available drawdown is based on the reported static water level at the time of drilling. Data on available drawdown under current pumped conditions were not available.

Summary of Local Area Risk Assessment Results

As per the Technical Rules (MOE,2009), following the simulation of various risk scenarios, the Local Areas for which the Risk Assessment was conducted must be assigned a water quantity risk level classification. The classification is assigned based on the Local Area's ability to meet peak demand (Tolerance) as well as the results of the scenario simulations described above (risk level) (Section 3.7.5).

To determine the Risk level associated with each Local Area, the Technical Rules (MOE, 2009), Technical Bulletin: Part IX Local Area Risk Level (MOE, 2011), and MOE Risk Assignment Memorandum (MOE,2013) list a series of circumstances under which the Local Area is assigned a Significant or Moderate Risk level. If any one of the circumstances are met, the Local Area must be assigned a significant or moderate risk level accordingly. The risk level circumstances are summarized in Table 3.7 - 17.

For this study the local area was assigned a risk level of **moderate**. This classification was made due to several reasons. Firstly, the water levels in all municipal wells did not exceed safe available drawdown under any of the modelled scenarios, indicating that the assignment of a significant risk level would not be appropriate. However, in the vicinity of the Yonge St. wells, the coldwater streams were found to be subject to a reduction in baseflow of greater than 20 % (under scenario G2). This result triggered a moderate risk level classification. Moreover, three provincially significant wetlands and several permitted water takings were subject to more than 1 m of drawdown in underlying aquifers – this further highlighted the relevance of the moderate risk level assignment. The assigned risk and tolerance level for the Local Area delineated for this study is summarized in Table 3.7 - 18.

As mentioned above, the risk level assigned to the Local Area is also based on the Local Area's ability to meet peak demand (Tolerance). According to the Technical Rules, if a municipality's system is able to meet existing peak demand, the system's tolerance is considered high; otherwise the tolerance is low. The systems evaluated as part of this Tier Three study were classified as having a high tolerance due to their ability to meet peak demand, even under drought conditions. Moreover, the wells in York Region have the ability to reallocate pumping to other nearby wells or wellfields that have additional available drawdown (Earthfx, 2014). Finally, York Region's ability to supplement groundwater takings in the Yonge St. wells with surface water supplies further highlights the Region's high degree of tolerance.

Table 3.7 - 17: Risk Assessment Scenarios and Circumstances (MOE and MNR, 2011).

Significant Risk	**Groundwater**
Scenarios	**Circumstance**
C - Existing – average annual D - Existing – ten year drought	1) the quantity of water that could have been taken from groundwater in the local area would not have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells. 2) the quantity of water that could have been taken from groundwater in the local area would have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells and the tolerance is Low.
G – Planned system or existing system with committed demand – average annual	1) 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 municipal groundwater wells.
H – Planned system or existing system with committed demand – ten year drought	1) 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 municipal groundwater wells.
Moderate Risk	**Groundwater**
Scenarios	**Circumstance**
G – Planned system or existing system with committed demand – average annual	1) The difference between the Existing Demand and the Allocated Quantity of Water would result in a reduction to flows or levels of water thereby creating a measureable and potentially unacceptable impact 2) The difference between the Existing Demand and the Allocated Quantity of Water would result in a reduction to groundwater discharge to aquatic habitat that is classified as a cold water stream by an amount that is, a. At least 10 percent of the existing estimated stream flow that is exceeded 80 percent of the time (Qp80), or b. At least 10 percent of the existing estimated average monthly baseflow of the stream.

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Table 3.7 - 18: Assigned Risk Levels (Earthfx, 2014).

Local Area	Tolerance	Risk Level
York Tier 3	High	Moderate

<u>Water Quantity Threats</u>

According the MOE Technical Rules, drinking water quantity threats must be identified in every Local Area classified as having a significant risk level. A drinking water quantity threat can only be defined as a consumptive water demand or a reduction in recharge. In Local Areas assigned a moderate risk level, a significant drinking water threat classification can only be made if (when factored into the risk level assessment), an increased/newly permitted water taking increases the Local Area's risk level to significant. As noted earlier, the York Tier Three Local Area was assigned a moderate risk level, indicating that there are no existing significant drinking water threats, and only future significant drinking water threats are possible.

Uncertainty Analysis of Scenarios and Uncertainty Assessment

An evaluation of the uncertainty underlying the Risk Assignment is an essential component of the Tier Three analysis. Uncertainty associated with the risk assignment must be characterized as high or low depending on 3 factors including:

- the distribution, variability, quality, and relevance of the data used to evaluate the scenarios
- the degree to which the methods and models used to evaluate the scenarios accurately reflect the hydrologic system of the local area for both steady state and transient conditions
- the quality assurance and control procedures used in evaluating the scenarios.

Some issues with the data used to evaluate the scenarios were identified. In particular, the quality and temporal/spatial coverage of the groundwater level data was an issue during the calibration of the integrated model; however, static water level data provided good regional coverage for calibrating the steady state model, while the continuous groundwater level data (including PGMN and York Region monitoring data) provided good calibration targets for simulating groundwater response to climate and pumping inputs (Earthfx, 2014).

When evaluating the degree to which the models evaluated the scenarios and reflected the hydrologic system, it was recognized that the integrated model was by design sensitive in its calibration and therefore less subject to uncertainty (Earthfx, 2014).

Finally, the quality assurance and control procedures used in evaluating the scenarios were extensive, and great care was used in setting up, documenting, and conducting each risk assessment scenario. Moreover, a large amount of data analysis and model preparation was undertaken prior to initiating the scenario analysis (Earthfx, 2014).

Based on these factors, it was determined that there is a low uncertainty associated with the Moderate Risk Level classification assigned to the local area (Earthfx, 2014).

Conclusions

The York Region Tier Three Water Budget and Local Area Risk Assessment indicated that the York Tier Three Local Area should be assigned a moderate risk level due to simulated reductions in baseflow to select stream reaches in the Local Area. These modelled reductions in baseflow were determined to be the result of increased municipal pumping needed to meet allocated demand.

The assignment of a moderate risk level classification was further supported by the simulated impact of increased pumping on other water uses. Incremental drawdowns in other permitted wells, and beneath provincially significant wetlands illustrate these impacts.

It is important to note that that due to York Region's ability to supplement groundwater takings with surface water supplies, and reallocate pumping to other nearby wells or wellfields, the Tolerance of the York Region Local Area is high, meaning that York Region's municipal supply system is well equipped to meet peak demands. Moreover, the integrated nature of York's municipal supply system indicates the region's ability to devise pumping strategies to minimize impacts to other water users, while sustainably meeting municipal demand.

Figure 3.7 - 1: Municipal Wells in Stress Assessment Catchments

Figure 3.7 - 2: Study Area showing Model Extent and Municipal Wellfields

Figure 3.7 - 3: Major Physiographic Units in the Study Area

Figure 3.7 - 4: Surficial Geology Mapping for the Study Area

Figure 3.7 - 5: Major Watersheds and Surface Water Features

Figure 3.7 - 6: Water Survey of Canada Streamflow Gauging Stations in the Study Area

Figure 3.7 - 7: York Region Conceptual Geology: N-S Cross Section

Figure 3.7 - 8: Distribution of Percent Imperviousness in the Study Area

Figure 3.7 - 9: Areas of Projected Land Use Change

Figure 3.7 - 10: Sample Well Characterization Graph

Figure 3.7 - 11: Location of Permitted Non-Municipal Water Takings

Figure 3.7 - 12: Cold Water and Warm Water Streams in the Vicinity of Municipal Wells

Figure 3.7 - 13: Provincially Significant Wetlands in the Study Area

Figure 3.7 - 14: WHPA-Q1 Area

Figure 3.7 - 15: Combined Cones of Influence for all Wells in each of the Three Supply Aquifers

Figure 3.7 - 16: Areas of Projected Land Use Change considered for WHPA-Q2 Analysis

Figure 3.7 - 17: Additional Drawdown in the Lower ORAC due to Projected Land Use Change outside the WHPA-Q1

Figure 3.7 - 18: Steady State Drawdown in the Lower ORAC -Scenario C versus No – Pumping

Figure 3.7 - 19: Steady state Drawdown in the Lower TAC/Channel Aquifer - Scenario C versus no pumping

Figure 3.7 - 20: Steady state Drawdown in the SAC - Scenario C versus no pumping

Figure 3.7 - 21: Simulated Decrease in Monthly Average Heads in the Lower ORAC from the start of the 10 year drought

Figure 3.7 - 22: Simulated Decrease in Monthly Average Heads in the TAC from the start of the 10 year drought

Figure 3.7 - 23: Simulated Decrease in Monthly Average Heads in the SAC from the start of the 10 year drought

Figure 3.7 - 24: Simulated Additional Drawdown in the ORAC -Scenario G1

Figure 3.7 - 25: Simulated Additional Drawdown in the TAC/Channel Aquifer - Scenario G1

Figure 3.7 - 26: Simulated Additional Drawdown in SAC -Scenario G1

Figure 3.7 - 27: Simulated Additional Drawdown in the ORAC - Scenario G2

Figure 3.7 - 28: Simulated Additional Drawdown in the TAC - Scenario G2

Figure 3.7 - 29: Simulated Additional Drawdown in the SAC- Scenario G2

Figure 3.7 - 30: Simulated Additional Drawdown in the ORAC - Scenario H1

Figure 3.7 - 31: Simulated Additional Drawdown in the TAC - Scenario H1

Figure 3.7 - 32: Simulated Additional Drawdown in the SAC - Scenario H1

Figure 3.7 - 33: Simulated Cell by Cell Groundwater Discharge in Streams for Scenario C

Figure 3.7 - 34: Percent Decrease in Accumulated Baseflow between Scenario C and Scenario G2

Figure 3.7 - 35: Reaches with Moderate Decreases in Accumulated Baseflow

Figure 3.7 - 36: Areas of Incremental Drawdown Greater than 1 m in the Shallow Aquifer and Location of Wetlands

Figure 3.7 - 37: Wetlands with Potential Decreases in Groundwater Discharge

Figure 3.7 - 38: Permitted Water Takings in the 1 m Drawdown Zone sorted by Aquifer

3.8 Tier Three Water Budget & Local Area Stress Assessment – City of Barrie

The Tier Two Subwatershed Stress Assessment, completed by AquaResource and Golder Associates, 2010 for the South Georgian Bay West Lake Simcoe Region, identified the Barrie Creeks Subwatershed as having a significant potential for stress. This designation was made based on the high volume of local groundwater demand, relative to groundwater flow through the subwatershed. As a result, under the Technical Rules (MOE, 2008a), Barrie's municipal water supply system was required to undergo a Tier Three Assessment.

A Tier Three Water Budget and Local Area Risk Assessment evaluates the long-term reliability of a municipality's drinking water sources by determining whether the municipality is able to meet its water quantity requirements, while accounting for increased municipal demand, future land development, drought conditions, and impacts to other water uses. The Tier Three Assessment requires the identification of threats to drinking water sources found to be under moderate or significant water quantity risk. While the Tier Two Stress Assessment focused on the subwatershed scale and evaluated the total consumptive water demand and water supply for the subwatershed, Tier Three Assessments focus on the area which provides water to the well/intake. For groundwater wells this area includes the lands contributing water to the wells, in addition to sensitive features near the wells.

The Tier Three Assessment relies on detailed numerical models to simulate ground and surface water flows and levels (and the interactions between them) under a variety of conditions and scenarios. The models developed for this Tier Three Assessment represent a comprehensive conceptualization of the hydrology and hydrogeology that influences water supplies in the Barrie Creeks Subwatershed. In comparison to the Tier Two Assessment, the Tier Three Assessment models are more refined and as a result represent a much more detailed study of the flow systems within a subwatershed.

This chapter provides an overview of the Tier Three Water Budget and Local Area Risk Assessment carried out for the City of Barrie. The work described herein is a summary of the conceptual and numerical hydrologic and hydrogeologic modeling and water budget tool developed by AquaResource et al., 2013. The Assessment was completed in compliance with the *Technical Rules for the preparation of Assessment Reports under the Clean Water Act* (MOE, 2008a) and the *Water Budget and Water Quantity Assessment Guide* (MNR and MOE, 2011). The full study is documented in the "City of Barrie Tier Three Water Budget and Local Area Risk Assessment" foundation report completed by AquaResource et al., 2013. It is recommended that the foundation report be referred to for additional insight.

Study Area and Physical Setting

Location

The Study Area for the City of Barrie Tier Three Water Budget and Local Area Risk Assessment encompasses the City of Barrie, and portions of the townships of Essa, Innisfil, Springwater, and Oro-Medonte, all within the County of Simcoe (Figure 3.8- 1). The Study Area is located south of Georgian Bay, west of Lake Simcoe, and lies within two major watersheds; the Lake Simcoe Watershed and the Nottawasaga River Watershed, as seen in Figure 3.8- 2. With a surface area of 800 km^2, the Study Area encompasses numerous subwatersheds including the Willow Creek Subwatershed, which drains a portion of the Oro Moraine and the Snow Valley uplands into the Nottawasaga River and Minesing Wetland. Situated to the south-west of Study Area, the Middle Nottawasaga River Subwatershed contains Bear Creek, which originates from the headwaters located on the southwest side of Barrie and drains westward to the Nottawasaga River. Three additional subwatersheds, including the Lovers Creeks, Hewitts Creeks, and Innisfil Creeks Subwatersheds, are located in the southern region of the study area, and drain into Lake Simcoe.

In the centre of the Study area, the Barrie Creeks Subwatershed is characterized by a number of small creeks that drain through the central portion of the City of Barrie into Kempefelt Bay, Lake Simcoe. The Barrie Creeks Subwatershed provides the majority of the municipal groundwater supply for the City of Barrie. The municipal wellfield for the City of Barrie and the immediate surrounding area is the main focus of this study; however the complete study area for the Tier Three Assessment was delineated to encompass known natural drainage boundaries and therefore incorporates portions of several other subwatersheds, as outlined above.

The locations of the municipal wells for the City of Barrie are illustrated in Figure 3.8- 3. Currently the City operates 14 wells, ten of which are situated within the subwatershed, and four of which are located within 1 km of the Barrie Creeks Subwatershed boundary. In August 2011, a surface water intake was brought online to service the growing population in the southern region of the city. Prior to the addition of this surface water intake, the city was entirely dependent on groundwater to meet municipal drinking water demand. The addition of this intake has decreased the supply demand on municipal wells. The city’s fourteen groundwater supply wells continue to supply the remainder of the population living in the central and northern zones of the city.

Conceptual Model

Tier Three Water Budgets and Local Area Stress Assessments require that detailed numerical models be developed to assess ground and surface water flows under a number of scenarios. The first step to creating these numerical models involves enhancing the conceptual understanding of the study area through the creation of a detailed conceptual model. The conceptual model created for the South Georgian Bay West Lake Simcoe study area builds upon previous geological studies completed throughout the area. This section details the refined conceptual model specifically developed for the City of Barrie Tier Three Water Budget and Local Area Risk Assessment.

Geology

The geology of the Study Area is characterized by quaternary aged deposits set during the last glaciation of the quaternary period, known as the Wisconsinan glaciation. Prior to the Wisconsinan glaciation, temperatures in the region were warmer and a large river, known as the Laurentian River, dominated the terrain. During the Wisconsinan glaciation the flow of this river was interrupted and overlain by the Oak Ridges Moraine. North of the moraine, the remaining Laurentian River Valley was infilled with a succession of glacial deposits (till and diamict), and intervening interglacial deposits of lacustrine and fluvial origin.

During the latter phases of the Wisconsinan glaciation, subglacial catastrophic floods resulted in the formation of the steep sided valleys that currently dominate the topography of the Study Area. These valleys are considered erosional features, and are especially prominent in the areas around Kempenfelt Bay, Willow Creek, and Matheson Creek. The stratigraphy in these valley areas is variable over short distances, and sequences of coarse gravel and soft lacustrine sediments characterize these valley areas. In the upland areas, thick aquifer sequences are generally absent and stratigraphic units are traceable over greater distances than in the valley areas. Underlying the thick unconsolidated quaternary aged deposits in the vicinity of Barrie, the bedrock surface is relatively flat. Understanding of the regional geology is essential to comprehending the hydrostratigraphy of the area.

Hydrostratigraphy

An updated understanding of the hydrostratigraphy of the area was essential during the development of the layers used in the numerical groundwater model. The regional hydostratigraphy of the Study Area is defined based on the quaternary geologic deposits found within the upland area and the lowland valley deposits. Municipal wells in the study area pump groundwater from highly transmissive geologic units called aquifers. Aquifers are layers of permeable overburden deposits primarily composed of coarse grained sediments; higher transmissivity bedrock units are also referred to as aquifers.

Geologic units that act to impede the flow of groundwater from one aquifer to another are called aquitards. Aquitards are generally composed of lower permeability overburden materials such as clay or fine grained tills, and can also be found in poorly transmissive bedrock units.

Overburden aquifers in the Study Area are generally associated with quaternary ice contact deposits, kame moraines, and similar coarse-grained sediments. These deposits create a regionally extensive and complex aquifer system. Localized and regional aquitards that act to impede vertical movement of groundwater are generally represented by till plains found in the study area.

The aquifer system in the study area is characterized by four major sand and gravel aquifer units referred to as A1, A2, A3, and A4. A1 is the shallowest of the aquifers, while A4 is the deepest. Table 3.8- 1 and Figure 3.8- 4 provide a general description of the various hydrostratigraphic units found in the Study Area. The deeper units (aquifers A3 and A4) are most prevalent within the tunnel channel, lowland deposits, and tend to be confined by overlying till sheets and finer grained bedding. The shallowest of the aquifers (A1 and A2) are unconfined in the study area, and are generally constrained to the upland areas (i.e. within the Oro Moraine). Barrie's municipal wells are screened within the deeper, highly-transmissive A3 and A4 aquifers, as listed in Table 3.8- 2. These deep aquifers underlie the central portion of the City of Barrie, and are found within the tunnel-channel deposits associated with the lowland valley area (Figure 3.8- 4). The overlying silt and clay aquitards that confine these deep aquifers create pressure that has historically resulted in local flowing artesian conditions within the wells screened in these aquifers. More comprehensive information on the aquifer system of the Study Area can be found in the Barrie Tier Three Water Budget and Local Area Risk Assessment completed by AquaResource et al., 2013.

Table 3.8- 1: Hydrostratigraphic Conceptual Model Layers (AquaResource et al., 2013).

Hydrostratigraphic Unit	Description
UC	Till pockets
A1	Fine-grained sand aquifer, semi confined, outwash sands overlain by till in some areas
C1	Clayey silt aquitard
A2	Fine-grained sand aquifer, semi-confined, outcrops in some areas
C2	Sandy silt aquitard, bottom extent of Kempenfelt Bay near city centre
A3	Sand/Gravel aquifer, fully confined, thick and combined with A4 along tunnel channel valley
C3	Aquitard
A4	Basal aquifer, discontinuous and fully confined, combined with A3 in some areas
C4	Basal aquitard
Bedrock	

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Table 3.8- 2: Location of Municipal Well Screens (Municipal Wells and associated aquifers (AquaResource et al., 2013).

Well Name	Pumped Aquifer
Pressure Zone 1:	**Core Area**
3A (Anne Street)	A4
4 (Perry Street)	A3
5 (John Street)	A4
7 (Tiffin Street)	A3/A4
11 (Heritage Park)	A3/A4
12 (Centennial Park)	A4
14 (Heritage Park)	A3/A4
15 (Centennial Park)	A3/A4
17 (Cross Street)	A3/A4
18 (Cross Street)	A3/A4
19 (Boulton Court)	A3/A4
Pressure Zone 2:	**North**
9 (Johnson Street)	A3/A4
13 (Johnson Street)	A3/A4
16 (Brownwood)	A3
Pressure Zone 2:	**South**
10 (Huronia Road)	A3

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Hydrology

The development of a Tier Three numerical model is also dependent on a thorough understanding of the hydrology within the Study Area. A hydrologic characterization of the Study Area is needed in order to determine the water balance estimates that are essential to the simulation of various Risk Assessment scenarios.

Characterized by a series of small streams and creeks, the Barrie Creeks Subwatershed is the primary subwatershed of interest for this study. The creeks within this subwatershed drain the central portion of Barrie, into a 14 km long bay called Kempenfelt Bay. To the north, the Willow Creek Subwatershed drains the largest portion of the Study Area, while the Middle Nottawasaga Subwatershed, located to the southwest, is drained via Bear Creek to the Nottawasaga River. In the southern portion of the Study Area, the South Oro, Lover's Creek, Innisfil Creeks, and Hewitt's Creeks all drain the area through numerous small streams that discharge into Lake Simcoe.

In addition to streams, the Study Area also contains several large surface water features, including a number of inland lakes, the largest being Little Lake situated on the northern border of the City of Barrie. The major wetland in the Study Area is the Minesing Wetland Complex, through which approximately 85% of the Nottawasaga River basin is estimated to drain.

The hydrologic process of groundwater recharge is an essential component of Tier Three water budget estimates. Groundwater recharge refers to the downward movement of water from the ground surface to the underlying groundwater flow system. Groundwater recharge is influenced by the hydraulic conductivity of the surficial geology, the slope of the topography, land use, and soil moisture content. In general, the main source of groundwater recharge is precipitation that is not lost to evapotranspiration, interflow, or overland flow to streams. Groundwater recharge is highest in areas with high permeability soils such as sands and gravels, and lowest in tight soils such as silts and clays. Within the Study Area, mean annual precipitation was averaged and estimated to be 910 mm, over a 60 year period. Of this 910 mm, approximately 50% was estimated to leave the subwatershed as evapotranspiration, while 30% was attributed to overland flow; the remainder was predicted to recharge the groundwater system. Estimates of the spatial distribution of groundwater recharge were made using the numerical surface and ground water models. Predicted recharge rates ranged from 0 mm/year in saturated wetlands, to a maximum of 350 mm/year in upland areas such as the Oro Moraine. Figure 3.8- 5 illustrates groundwater recharge as simulated by the groundwater flow model. More information regarding inflow and outflow rates is provided in section 3.8.4 of this report. For more detailed information regarding hydrologic processes in the study area, refer to the City of Barrie Tier Three Water Budget and Risk Assessment foundation report by AquaResource et al., 2013.

Land Use and Land Use Change

Tier Three modeling must consider the impact of existing and future land use on groundwater recharge in order to identify potential impacts to water quantity.

Existing land use within the Study Area is illustrated in Figure 3.8- 6, while planned land use is shown in Figure 3.8- 7. Figure 3.8- 8 illustrates the areas where proposed land use changes would cause decreased water recharge due to increased imperviousness. Existing and planned land use information was obtained from the City of Barrie's Official Plan (2007).

The most significant land use changes proposed to occur in the Study Area are located in the southern zone of the City of Barrie. Some infill development is also scheduled to occur in small pockets located throughout the city core.

Models for the Tier Three Assessment were designed to represent changes in land use by reducing the amount of groundwater recharge proportionately to the amount of impervious area associated with proposed land use changes. According to model predictions, reductions in recharge associated with proposed land use changes are not likely to impact the municipality's well supply; this is because areas devoted to future development are relatively small compared to the total area contributing recharge to the wells. Moreover, proposed development areas are generally not located within high recharge areas. Detailed information regarding the impacts of proposed land uses on groundwater recharge is further explained in the Local Area Risk Assessment found in Section 3.8.5 of this chapter.

It should be noted that in 2010, the City of Barrie annexed lands previously located in the Town of Innisfil, south of the City's former boundary. The City of Barrie is currently working on policies and designs for the future development of these areas. Amendments to Barrie's Official Plan will be made to incorporate these future development plans. For this study, the future development of these annexed lands is beyond what is represented by Tier Three models. Instead, this study only considers the future development projections presented in the City of Barrie 2007 Official Plan.

Numerical Models

An important element of the Tier Three Assessment is a refined evaluation of water budget components at a localized scale. The modeling approach used to complete the assessment requires the development of detailed numerical models that integrate both surface and ground water components of the local flow system to evaluate the sustainability of municipal water sources under a variety of scenarios. The numerical models developed for the Barrie Tier Three study are based on the refined conceptual understanding of ground and surface water systems in the study area, as discussed in Section 3.8.1 .

For this Tier Three Assessment, the numerical modeling approach was designed to:

- Simulate average and drought conditions
- Represent the detailed hydrologic/hydrogeologic conditions of the study area
- Integrate the input and outputs of the surface water and groundwater models

Numerical modeling was conducted to simulate surface water flows using MIKE SHE software, while groundwater flows were simulated using the FEFLOW code. Both models were calibrated to represent typical flow conditions under average (steady-state), and variable (transient) climate conditions. The representation of a wide variety of climatic conditions is necessary to determine if a municipality's water supply will be able to reliably meet water demand under a range of climate conditions. Appendix B of the Barrie Tier Three foundation document (AquaResource et al., 2013) describes the development and calibration of the surface model, while Appendix C describes the groundwater model.

The MIKE SHE surface model was designed to simulate water budget components within the study area under a variety of climate conditions. The three dimensional, integrated model was calibrated using available stream flow data from monitoring gauges within the subwatershed over the time period of 1990-2005. The model was verified using streamflow data from an additional monitoring gauge over the time period of 2006 to 2009.

Additional calibration targets for the surface water model included groundwater elevations and snow depths from snow surveys in the study area. Calibration resulted in a reasonable match between simulated and observed data, which improved confidence in model simulations and assured that model outputs could be applied to the FEFLOW groundwater model. Using the MIKESHE model, the overall water budget and key hydrologic processes were computed and mapped.

The detailed FEFLOW groundwater flow model was created to represent groundwater flow within the study area and interaction with the surface water system. As such, calibration of the model aimed to replicate hydraulic head measurements within municipal aquifers. The model was also calibrated to surface water data in order to effectively represent interaction with surface water. A transient model calibration was undertaken to confirm the performance of the model under transient conditions. The groundwater model was used in the Local Area Risk

Assessment to examine the potential response of aquifers to various scenarios under a variety of climate conditions.

The coupling of surface and groundwater models was used to examine the effect of future land development on water levels in aquifers and reductions in discharge to surface water features. Annual groundwater recharge determined by the MIKE SHE surface model was used as input for the FEFLOW groundwater model, while hydraulic conductivity and interbasin flow estimates from the groundwater model were used for the surface model, until both models were successfully calibrated (AquaResource et al., 2013). The coupling of these models created an improved understanding of the hydrologic and hydrogeologic flow systems in the area.

Water Demand

The development of representative Tier Three Models is dependent on accurate estimates of water demand in the study area. An estimate of the extent and variability of consumptive water demand is essential for the calculation of water budgets, simulation of various risk scenarios, and the overall identification of aquifers under hydrologic stress. This section provides a summary of the consumptive groundwater demands within the study area. Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. an aquifer) within a reasonable amount of time. Consumptive water demand was estimated for both permitted and non-permitted water takings within the study area. Permitted water takings are generally carried out by large municipal, industrial, and commercial water users, while non-permitted groundwater takings tend to be attributed to domestic and agricultural uses.

In addition to consumptive groundwater takings, there are several non-consumptive water uses that also rely on groundwater supplies within the Barrie Creeks Subwatershed. Such uses may include surface water features that rely on groundwater discharge for sustaining aquatic habitats (and other similar environmental/ ecological communities), as well as uses associated with recreation. Non-consumptive water uses often rely on ground and surface water systems to maintain minimum flow or water levels. Due to their reliance on ground and surface water flows, non-consumptive water uses are also considered in the Tier Three Risk Assessment.

Municipal Demand

This section details the municipal groundwater demand calculated for the City of Barrie. Groundwater pumped to supply the municipality is drawn from groundwater aquifers, and discharged to Lake Simcoe by way of the Water Pollution Control Plant. All municipal takings within the City of Barrie are considered 100% consumptive since the water that is pumped is never returned to the source aquifer.

Municipal water takings represent the largest water use within the Study Area, therefore accurate estimates of municipal water use are critical to the estimation of water demand. Table 3.8- 3 lists all of the municipal wells in Barrie, along with their operating and maximum permitted capacities. Operating capacity is an alternative to the maximum permitted number, indicative of the limit each well is capable of pumping based on the wellfield operators' experience (AquaResource et al., 2013).

Table 3.8- 3: City of Barrie Water Supply Wells (AquaResource et al., 2013).

Pressure Zone	Well Name	Pumped Aquifer	Maximum Permitted Capacity (m^3/day)	Operating Capacity (m^3/day)	Operator Comments
Pressure Zone 1: Core Area	3A (Anne Street)	A4	6,552	3,888	Due for Rehabilitation
Pressure Zone 1: Core Area	4 (Perry Street)	A3	6,552	0	Currently Offline
Pressure Zone 1: Core Area	5 (John Street)	A4	6,552	5,184	
Pressure Zone 1: Core Area	7 (Tiffin Street)	A3/A4	6,552	6,048	
Pressure Zone 1: Core Area	11 (Heritage Park)	A3/A4	9,100	8,640	
Pressure Zone 1: Core Area	12 (Centennial Park)	A4	9,100	8,986	
Pressure Zone 1: Core Area	14 (Heritage Park)	A3/A4	9,100	8,986	
Pressure Zone 1: Core Area	15 (Centennial Park)	A3/A4	9,100	8,986	Second Yielding Well in System

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Pressure Zone	Well Name	Pumped Aquifer	Maximum Permitted Capacity (m^3/day)	Operating Capacity (m^3/day)	Operator Comments
Pressure Zone 1: Core Area	17 (Cross Street)	A3/A4	11,232	10,800* combined	Largest Yielding Well in System
Pressure Zone 1: Core Area	18 (Cross Street)	A3/A4	11,232	10,800* combined	System Restrictions
Pressure Zone 1: Core Area	19 (Boulton Court)	A3/A4	7,862	0	Currently Not Commissioned
Pressure Zone 2: North	9 (Johnson Street)	A3/A4	6,552	6,048	
Pressure Zone 2:: North	13 (Johnson Street)	A3/A4	6,552	6,307	
Pressure Zone 2: North	16 (Brownwood)	A3	7,862	7,430	
All	**Total**		**113,900**	**81,302**	

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* Shared operating capacity between Well 17 and 18

The accurate estimation of existing and future municipal water demand is essential for the simulation of the various risk scenarios required under the Tier Three Assessment. The pumping rates used as inputs for the simulation of these scenarios must reflect current demand conditions (existing demand), and future demand conditions including any additional takings that will be required to meet the needs of an approved settlement area (committed demand), and any additional demand that may be required as a result of projected growth identified within a Master Plan or Class EA (Planned Demand)(MOE,2013). The following section further describes the components of the demand calculations required for this Tier Three Assessment.

Existing demand refers to the average pumping rate during the year the Tier Three Assessment was conducted. For this study, the existing demand calculation was conducted for the year 2012 (after the establishment of the surface water intake that was brought online in August 2011). The intake was introduced to supply the southern pressure zone of the city, which makes up approximately 50 % of the municipality’s demand. Since the addition of the intake, demand on the city’s groundwater wells has been reduced.

As part of the Tier Three Assessment, existing demand must be estimated for each municipal well. For this study, it was important for existing demand estimates to reflect the change in groundwater demand that has resulted from the addition of the surface water intake. The methodology used to estimate existing demand is outlined in the text below. Estimated existing demand rates (2012) are presented in Table 3.8- 4.

The 2012 existing demand estimates presented in Table 3.8- 4 were calculated from 2007 pumping volumes provided by the City of Barrie. The application of 2007 pumping volumes was considered to be conservatively high, as pumping from that year was representative of the highest pumped volume in recent years. To estimate existing demand, monthly pumping rates (observed prior to the addition of the surface water intake) were modified by partitioning the 2007 pumped volumes according to the volume distributed to each pressure zone of the city (AquaResource et al., 2013). The pumping portions assigned to the pressure zone now serviced by the surface intake were disregarded. The pumped volumes assigned to the pressure zones not serviced by the surface intake were multiplied by a population growth factor. This calculation allowed for the estimation of existing demand (post surface water intake-2012) presented in Table 3.8- 4.

To illustrate the reduction in demand at individual wells as a result of the surface intake addition, demand rates were also determined for the last complete year the municipal water demand was solely supplied by groundwater. These observed 2010 pumping rates obtained from the City of Barrie, are also presented in Table 3.8- 4. The year 2010 is simulated as a baseline condition, as it is representative of conditions for which the Safe Available Drawdown could be calculated. The definition of Safe Available Drawdown is further detailed below. Recent historic pumping conditions are an important consideration when calculating Safe Available Drawdown. Since a pumping history representative of existing conditions was not available due to the recent addition of the municipal surface water intake, Safe Available Drawdown could not be calculated based on existing (2012) demand conditions, and instead was calculated based on 2010 conditions.

A Tier Three Assessment also considers the hydrologic and hydrogeologic response to an increase in municipal pumping due to committed demand and planned demand. Committed demand refers to an amount, greater than the existing demand that is necessary to meet the needs of an approved settlement area identified within an Official Plan. The portion of this amount that is within the current lawful Permit to Take Water (PTTW) is part of the Allocated Quantity of Water; a parameter used as an input during the modelling of the Risk Assessment scenarios. Planned Demand refers to an amount of water from a new planned well that is required to meet the projected growth identified within a MasterPlan or Class Environmental Assessment, but is not already linked to growth within an Official Plan (MOE, 2013). For this study, only Well 19 was identified as having a planned demand, as it was identified as a newly planned system in a Class Environmental Assessment.

For this study, committed rates were calculated from existing demand to reflect population growth within the study area for 2031, as forecast by population projections provided in the City of Barrie's Official Plan (2007). Committed demand rates were added to existing demand rates to generate the allocated quantity of water for the City of Barrie for 2031. As previously noted, the allocated quantity of water refers to the combined amount of existing and committed demand up to the current lawful Permit to Take Water Taking. For this study, the allocated quantity of water was distributed to individual wells based on their operational capacity (AquaResource et al., 2013).

The Planned Quantity of water is another parameter that must be calculated to ensure that model simulations are able to identify potential water quantity threats under future pumping scenarios. The planned quantity of water includes any amount of water that meets the definition of a planned system in Ontario Regulation 287/07, and any amount of water that is needed to meet a committed demand above the current lawful Permit to Take Water Taking (MOE, 2013). For this study, only Well 19 was identified as a planned system under Ontario Regulation 287/07. At the time of the study, Well 19 underwent an Environmental Assessment and has now been constructed. As Well 19 was the only well that met the definition of a planned system, the planned quantity of water was calculated for this well.

The allocated pumping rates for each municipal well are outlined in Table 3.8- 4. As highlighted above, the calculation of planned pumping rates was only required for Well 19, which was identified as a planned system (according to Ontario Regulation 287/07). Table 3.8- 4 also presents the 2010 demand rates experienced prior to the addition of the surface water intake, as well as estimated existing demand rates. As illustrated in the table, all average pumping rates are within the capacity of each well, and are designed to meet the expected needs of the City of Barrie based on the projected population of 2031. As indicated in the table, some wells are designed to cycle with others, and thus their pumping rates are shared.

Transient pumping rates were also calculated under existing and allocated demand conditions, in order to provide an indication of monthly pumping variability. Transient pumping rates represent the realistic seasonal operation of wells. The monthly standard deviation figures presented in Table 3.8- 4 are indicative of this variability. Transient pumping rates vary from a low of approximately 60% of the calculated average pumping rate, to a high of about 135% of the average, with peak demand occurring from June- September.

Other communities within the Study Area also obtain their municipal water supply for groundwater sources. These systems and their corresponding reported pumping rates are presented in the Barrie Tier Three foundation document by AquaResource et al., 2013.

Table 3.8- 4: Municipal Water Demand (m^3/day) – City of Barrie (AquaResource et al.,2013).

Pressure Zone	Well Name	Pre-Surface Water Intake (2010, Observed)1	2012 Estimated Existing Demand: Average	2012 Estimated Existing Demand: Monthly Standard Deviation^2	2031 Estimated Demand: Average	2031 Estimated Demand: Monthly Standard Deviation^2	Comments
Pressure Zone 1 – Core Area	3A	2,087	2,091	420	2,898	565	Cycles with Well 12*
Pressure Zone 1 – Core Area	4	0	1,535	527	2,150	572	Cycles with Well 14*
Pressure Zone 1 – Core Area	5	2,619	1,292	229	1,823	308	-
Pressure Zone 1 – Core Area	7	5,409	1,922	424	2,670	866	Cycles with Well 15*
Pressure Zone 1 – Core Area	11	0	3,637	229	3,900	566	Limited by operators
Pressure Zone 1 – Core Area	12	4,800	2,090	644	2,898	565	Cycles with Well 3A*
Pressure Zone 1 – Core Area	14	3,761	1,292	420	1,823	308	Cycles with Well 4*
Pressure Zone 1 – Core Area	15	4,131	1,922	644	2,670	866	Cycles with Well 7*
Pressure Zone 1 – Core Area	17	2,364	2,698	855	3,715	1145	-
Pressure Zone 1 – Core Area	18	2,888	2,405	740	3,321	998	-

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Pressure Zone	Well Name	Pre-Surface Water Intake (2010, Observed)1	2012 Estimated Existing Demand: Average	2012 Estimated Existing Demand: Monthly Standard Deviation[2]	2031 Estimated Demand: Average	2031 Estimated Demand: Monthly Standard Deviation[2]	Comments
Pressure Zone 1 – Core Area	19	0	0	0	** 4,178	0	Planned System
Pressure Zone 2 – North	9	3,766	4,191	936	4,589	1006	-
Pressure Zone 2 – North	13	4,130	2,725	689	3,012	740	-
Pressure Zone 2 – North	16	4,253	4,662	1252	5,095	1347	-
All	**Total**	**40,208**	**32,465**	**n/a**	**44,746**	**n/a**	-

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*Existing and Committed demand estimates

[1] 2010 rates provided to illustrate the drop in demand at individual wells when the surface water plant was brought online.

[2] Monthly range presented as a standard deviation. Monthly pumping projections based on historic pumping from 2007.

** Only Well 19 was identified as having a Planned Demand

Safe Available Drawdown

The Tier Three Assessment requires the calculation of an analytical parameter called Safe Available Drawdown. Safe Available Drawdown refers to the additional drop in water level within a pumping well that could be sustained and still maintain the well's allocated pumping rate (AquaResource et al., 2013). Safe Available Drawdown levels are used as the criteria against which Risk Assessment scenario results are evaluated. If well drawdowns simulated under the scenarios exceed Safe Available Drawdown, the well is flagged as a potentially significant water quantity threat.

Safe Available Drawdown is calculated as the additional drawdown that is available over and above the drawdown measured under recent historic pumping conditions (AquaResource et al., 2013). To determine the Safe Available Drawdown at a well it is necessary to calculate a number of components. The following list outlines the components that need to be evaluated as part of the Safe Available Drawdown calculation for each municipal well.

- Safe water level elevations; this is the lowest level within a pumping well that an operator can pump to; this elevation may be related to the well screen elevation, pump intake elevation, or other similar operational limitations
- Observed water level elevations in pumping wells, under normal (good) well performance conditions; this is the elevation of the average annual water level within a municipal well estimated from well hydrographs. The 'good performance water levels' data series presented in Figure 3.8- 9 illustrates this concept.
- Observed water level elevations in the pumping well under diminished well performance conditions estimated from well hydrographs (see 'poor performance water levels' data series in Figure 3.8- 9.

Once the above components have been determined, Safe Available Drawdown calculations will need to consider two main criteria. Firstly, calculations have to ensure that the water level within the pumping well is maintained above the top of the well screen; this is necessary to ensure that potential redox condition changes and precipitation bio –fouling are avoided (AquaResource et al., 2013). Secondly, calculations need to maintain the water level in the pumping well above the top of the aquifer where possible, in order to maintain a confined aquifer response to pumping (AquaResource et al., 2013). The criteria that results in the smaller available drawdown is used to calculate the Safe Available Drawdown. The calculation for Well 3A is illustrated in Figure 3.8- 9.

For Barrie Well 3A, the level of the top of the aquifer was the criterion used to determine the Safe Available Drawdown. As illustrated in Figure 3.8- 9, to calculate the Safe Available

Drawdown, the level of the top of the aquifer (166 masl) is subtracted from the level of the aquifer during pumping (217 masl); the resulting difference indicates the amount of additional drawdown that is available before the top of the aquifer is reached. For Well 3A the Safe Available Drawdown was determined to be 51m. In circumstances where the level of the top of the screen is the criteria used to calculate the Safe Available Drawdown, the level of the top of the well screen is subtracted from the pumped water level in the well under good performance conditions. The resulting difference is representative of the Safe Available Drawdown that is accessible before the well screen is reached. The Safe Available Drawdown calculations for all of the wells in the City of Barrie are provided in Appendix WB -5B.

It is important to note that the Safe Available Drawdown values calculated for this study are relative to 2010 pumping conditions. Safe Available Drawdown is calculated as the additional drawdown that is available over and above the drawdown measured under recent historic pumping conditions. As mentioned above, historic pumping conditions that reflect existing demand were not available for use due to the recent addition of the surface water intake; instead the historic pumping conditions used to calculate safe available drawdown reflect the period prior to the surface water intake. Table 3.8- 5 provides the Safe Available Drawdown assessment for Barrie's municipal wells. These values will be referred to later on in the assessment to provide context for the results of the Risk Assessment scenarios (Section 3.8.5).

Table 3.8- 5: Safe Additional Available Drawdown (Normal Performance Conditions: 1997-2010) (AquaResource et al., 2013).

Well	Top of Screen (m asl)	Top of Aquifer (m asl)	Typical Non Pumping Water Level in Aquifer (m asl)	Typical Pumping Water Level in Aquifer (m asl)	Typical Pumping Water Level in Pumping Well (m asl)	Safe Available Drawdown (m): Aquifer	Safe Available Drawdown (m): Pumping Well
Well 3A	132.5	166.5	221	217	208	**51**	76
Well 4	179.1	187.6	221	217	211	**29**	32
Well 5	144.5	170.1	222	220	216	**50**	71
Well 7	149.3	161.9	222	218	215	**56**	66
Well 9	182.7	198.4	230	225	215	**27**	32
Well 11	173.5	185.6	218	208	192	22	**19**
Well 12	155.5	168.9	218	214	204	**45**	48
Well 13	177.6	193.8	230	225	215	**31**	37
Well 14	178.7	185.6	218	210	196	24	**17**
Well 15	174.7	175.6	218	212	209	36	**34**
Well 16	191.4	202.3	235	233	227	**31**	36
Well 17	148.3	168.4	222	217	212	**49**	64
Well 18	147.7	169.6	222	217	212	**47**	64
Well 19	152.0	165.4	222	217	210	**52**	58

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* Note: Bolded values represent the Safe Available Drawdown for each municipal well.

Other Water Uses

The Local Area Risk Assessment also assesses whether committed and planned demands can be met while maintaining the water requirements of other uses in the area (AquaResource et al., 2013). It is therefore important that the Tier Three Assessment identify all of the other water uses in the area, and estimate their water quantity requirements where possible. Other water uses considered during this study included aquatic habitats, provincially significant wetlands, and other usages that may be affected by groundwater takings. Other water uses can be both permitted and non-permitted. The following section describes the other water uses identified within the Study Area.

Permitted Water Uses

In addition to municipal water takers within the Barrie Creeks Subwatershed, there are a number of other large water takers holding Ministry of the Environment [Conservation and Parks] permits. Figure 3.8- 10 illustrates the locations of non-municipal permitted water users in the study area. A detailed explanation of how these consumptive demands were calculated is provided in detail in the Barrie Tier Three Water Budget and Local Area Risk Assessment foundation report completed by AquaResource et al., 2013. Consumptive water uses for non-municipal water takings were primarily devoted to agriculture, commercial, dewatering, industrial, and groundwater remediation purposes. Table 3.8- 6 summarizes these permitted water users and their average and maximum permitted pumping rates.

Table 3.8- 6: Private Permitted Groundwater Takings (AquaResource et al.,2013).

Category	Purpose	Well Name	Pumping Rate (m^3/day) – 2008 Average	Pumping Rate (m^3/day) – Maximum Permitted	Permit Number
Agricultural	Field and Pasture Crops	Dugout Pond	*161	982	03-P-1069
Agricultural	Field and Pasture Crops	Well 1	*681	2,589	1664-6W3MCU
Agricultural	Other - Agricultural	Dugout Pond	5	681	00-P-1210
Commercial	Bottled Water	Well 1	0	354	5524-6PEK3Q
Commercial	Bottled Water	Well 2	0	792	5524-6PEK3Q
Commercial	Bottled Water	Well 2	*200	400	8141-7BYRP2
Commercial	Bottled Water	Well 3	*200	400	8141-7BYRP2
Commercial	Golf Course Irrigation	Clubhouse Well	1	65	0040-733RE2
Commercial	Golf Course Irrigation	Clubhouse Well	3	7	4755-73RHNU
Commercial	Golf Course Irrigation	Dugout Pond	27	1,091	4755-73RHNU
Commercial	Golf Course Irrigation	Dugout Pond	66	1,818	7455-6QPLB5
Commercial	Golf Course Irrigation	Heritage Pond	42	2,000	3474-759GY9
Commercial	Golf Course Irrigation	Heritage Well	10	200	3474-759GY9
Commercial	Golf Course Irrigation	Irrigation Pond	*753	2,619	0386-7AMLUY
Commercial	Golf Course Irrigation	Irrigation Pond	139	2,946	0040-733RE2
Commercial	Golf Course Irrigation	Irrigation Pond	62	1,137	5813-6U2S3J
Commercial	Golf Course Irrigation	Irrigation Pond	102	2,561	5447-6QWR7W
Commercial	Golf Course Irrigation	Irrigation Well	*339	982	0040-733RE2
Commercial	Golf Course Irrigation	Main Irrigation Pd	*50	218	6824-68XPUW
Commercial	Golf Course Irrigation	Pump House	*130	564	3124-6J5T9M
Commercial	Golf Course Irrigation	Well 1	3	32	5813-6U2S3J
Commercial	Golf Course Irrigation	Well 1	*249	720	8531-6ASQXU
Commercial	Golf Course Irrigation	Well 1/94	*113	327	7542-6P8M92

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Category	Purpose	Well Name	Pumping Rate (m^3/day) – 2008 Average	Pumping Rate (m^3/day) – Maximum Permitted	Permit Number
Commercial	Golf Course Irrigation	Well 1-4/93	*1146	1,637	0386-7AMLUY
Commercial	Golf Course Irrigation	Well 2	0	262	5813-6U2S3J
Commercial	Golf Course Irrigation	Well 2-1/93	*687	982	0386-7AMLUY
Commercial	Golf Course Irrigation	Well 3	0	1,570	5813-6U2S3J
Commercial	Mall / Business	Well 1/06	*39	716	5372-6SYPRA
Commercial	Snowmaking	Berry Hill Pond	*915	5,564	6845-6D7NUT
Commercial	Snowmaking	Pond 1 Winter	32	982	6845-6D7NUT
Commercial	Snowmaking	Pond 2 Winter	27	982	6845-6D7NUT
Commercial	Snowmaking	Pond 3 Winter	32	2,618	6845-6D7NUT
Commercial	Snowmaking	Pond Summer	*143	1,309	6845-6D7NUT
Commercial	Snowmaking	Pond Summer	*323	524	6845-6D7NUT
Commercial	Snowmaking	Pond Winter	348	13,092	6845-6D7NUT
Industrial	Aggregate Washing	Source Pond	20	7,980	4105-7EENGW
Industrial	Cooling Water	Private Well	*181	300	6313-5Z4NC5
Miscellaneous	Heat Pumps	Injection Well 3	*0	0	2677-63PK84
Miscellaneous	Heat Pumps	Well 2	*0	98	92-P-3093
Miscellaneous	Heat Pumps	Well 2	*0	0	2677-63PK84
Miscellaneous	Heat Pumps	Well 2	*0	260	2677-63PK84
Miscellaneous	Heat Pumps	Well 4	*0	0	2677-63PK84
Recreational	Other - Recreational	Artesian Well	119	357	5353-5W4LB8
Recreational	Other - Recreational	Pond	126	1,890	5353-5W4LB8
Remediation	Groundwater	Pump Station 1	0	131	5006-7CVGHZ
Remediation	Groundwater	Pump Station 2	23	589	5006-7CVGHZ
Remediation	Groundwater	Well 1	164	262	1315-6W3QAS

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Category	Purpose	Well Name	Pumping Rate (m^3/day) – 2008 Average	Pumping Rate (m^3/day) – Maximum Permitted	Permit Number
Remediation	Groundwater	Well 2	308	458	1315-6W3QAS
Remediation	Groundwater	Well 3	172	360	1315-6W3QAS
Water Supply	Campgrounds	Well	*12	106	96-P-5022
Water Supply	Campgrounds	Well 1	*4	39	3772-6EQGSY
Water Supply	Campgrounds	Well 3	*7	68	3772-6EQGSY
Water Supply	Campgrounds	Well 4	*5	46	3772-6EQGSY
Water Supply	Communal	House Well	*16	81	1586-62FLP2
Water Supply	Communal	Well 1	*109	547	6334-72JP7N
Water Supply	Communal	Well 1	*371	1,114	87-P-3008
Water Supply	Communal	Well 1	6	327	02-P-1193
Water Supply	Communal	Well 2	*131	655	6334-72JP7N
Water Supply	Communal	Well 2	*371	1,114	87-P-3008
Water Supply	Communal	Well 3	*371	1,114	87-P-3008

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*- indicates pumping rate was estimated based on the permitted rate (PTTW 2009), months of active pumping and consumptive water use.

Non-Permitted Water Uses

Non – permitted water uses considered during this study included water takings intended for domestic uses and some agricultural uses. Figure 3.8- 11 illustrates the locations of domestic wells within the study area. Location information for domestic wells was obtained from the MOE's water well information system. Individual domestic water takings were found to be insignificant when compared to municipal pumping rates. Consumptive water use by domestic water takers was estimated to be $77m^3$/day. This value represents approximately 1% of the total municipal water use within the Barrie Creeks Subwatershed. Due to the relatively minimal amount of water needed to satisfy domestic demand, domestic water takings were not accounted for during water budget calculations or Risk Assessment scenario simulations.

Aquatic Habitat

The Tier Three Risk Assessment must also consider whether water demand can be met while maintaining the water needs of aquatic ecosystems in the Study Area. During the Risk Assessment, if a groundwater reduction of 10% or more is predicted at coldwater streams, due to well pumping, the Local Area in which the scenarios are carried out is assigned a moderate Risk Level. A significant risk level can only be assigned if the pumping required to meet planned demand (planned quantity of water) results in a groundwater discharge reduction of 20% or greater. Figure 3.8- 2 illustrates the coldwater streams that were considered during the groundwater discharge assessment presented in Section 3.8.5. The coldwater streams highlighted in the figure are important habitats for fish communities, and must therefore be evaluated as part of the Tier Three Local Area Risk Assessment.

Provincially Significant Wetlands

The Tier Three Risk Assessment must also consider the impacts on Provincially Significant Wetlands as a result of municipal pumping. As per the Technical Rules (MOE, 2009),(MOE and MNR, 2011;2013) municipal takings should not present an unacceptable impact to other water uses. Unacceptable Impacts to wetland features are determined by evaluating water level changes in the vicinity of the wetland, and the impact of such changes on the function of the wetland (e.g. are discharge conditions being maintained). Figure 3.8- 2 illustrates the provincially significant wetlands found in the vicinity of the Study Area. These wetlands include the Bear Creek Wetland, Little Lake Wetland, and Lover's Creek Wetland.

Water Budget

In order to refine the understanding of hydrologic and hydrogeologic flow systems within the Study Area, improved estimates of water budget components were made using the MIKESHE and FEFLOW models described in Section 3.8.2. Tier Three Water Budget estimates are considered more reliable than those made under the Tier Two Assessment due to model updates made at the local scale. Although the updated MIKE SHE and FEFLOW models represent two separate modeling approaches, the two models were linked through groundwater recharge and interbasin flow components. Results generated from the combination of the two models create a refined estimate of average annual values for various components of the hydrologic cycle within the Study Area. The following section details the results of the water budget assessment.

The estimation of cross boundary groundwater flow between subwatersheds is a key component of water budget calculations. Table 3.8- 7 summarizes the major cross boundary fluxes between the Barrie Creeks Subwatershed and adjacent watersheds as predicted by the groundwater flow model. Flux crossing is strongest through the most transmissive layers; for this study this highly transmissive layer was determined to be Aquifer A3.

Table 3.8- 7: Summary of Cross Boundary Groundwater Flow (AquaResource et al., 2013).

Boundary	Cross Boundary Flow (m^3/d)
Willow Creek Subwatershed (NVCA) into Barrie Creeks Subwatershed (North)	+17,800
Middle Nottawasaga River Subwatershed (NVCA) into Barrie Creeks Subwatershed (West)	+17,500
Lovers Creek Subwatershed into Barrie Creeks Subwatershed (South)	+8,200
Barrie Creeks Subwatershed to Subsurface Below Kempenfelt Bay	-9,600
Net Cross-Boundary Groundwater Flow	**+33,900**

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Cross boundary fluxes into the Barrie Creeks Subwatershed were found to be significant along the Nottawasaga Valley Watershed boundaries located to the west and north of the Barrie Creeks Subwatershed. Model Simulations indicated that flows across the Willow Creek Subwatershed are natural, since the same magnitude of cross boundary flow is experienced even when there is no pumping occurring. However, flows from the Middle Nottawasaga and Lovers Creeks Subwatersheds seem to be induced by hydraulic gradients created from municipal pumping as predicted by simulations carried out with no pumping. The result of these “no pumping” simulations indicate that the natural gradient is actually reversed. Municipal pumping within Barrie’s city core is also predicted to be responsible for the cross boundary flow out of the subwatershed to the surface below Kempenfelt Bay.

As part of the Tier Three Assessment, estimates of individual water budget component fluctuations within the Barrie Creeks Subwatershed were also considered. Water budget components include all of the inflows and outflows within the subwatershed. Inflows include precipitation, interbasin overland flow, and interbasin groundwater flow, while outflows include evapotranspiration, interbasin overland flow, baseflow, overland flow to streams, groundwater pumping, and interbasin groundwater. Table 3.8- 8 summarizes the estimated overall inflow and outflow fluctuations for the Barrie Creeks Subwatershed. Water budget parameters were calculated based on information derived from surface and groundwater flow models for the simulation year 2010 (AquaResource et al., 2013). Basing water budget calculations on 2010 pumping rates facilitated comparison with values from the Tier Two Water Budget, as both sets of calculations are representative of conditions prior to the introduction of the surface water intake.

As presented in Table 3.8- 8, modeling results indicate that more than 60% of groundwater flows into the subwatershed cross subwatershed boundaries, with much of the cross-boundary flow occurring in response to municipal pumping. Average annual precipitation within the subwatershed is approximately 910 mm/year as measured at the Barrie WPCC climate station, while average annual evapotranspiration is approximately 484 mm/year. Average annual streamflow is measured at 278 mm/year, from all streams across the subwatershed. Approximately 9,600 $m^{3/}$day of groundwater flows out of the subwatershed to the subsurface under Kempenfelt Bay. This flow is driven by the hydraulic gradient in the shallow layers of the model (AquaResource et al., 2013).

Table 3.8- 9 summarizes the water balance estimates for groundwater within the subwatershed. Average annual groundwater recharge within the subwatershed is estimated to be 167 mm/year or 24,500 m^3/day. Lateral flow from adjacent subwatersheds illustrates the convergence of groundwater flow toward the Barrie Creeks Subwatershed. This confluence of flow is both induced (due to local pumping), and natural due to Kempenfelt Bay, which serves as a regional discharge area.

Total groundwater discharge to surface water is estimated at 17,500 m^3/day or 119 mm/year. Approximately 41,100 m^3/day of groundwater is pumped by municipal wells; this accounts for the greatest percentage of groundwater outflows in the Barrie Creeks Subwatershed. These values compare well with those estimated for the Tier Two Water Budget model, however discharge estimates to streams are considered more reliable under the Tier Three model (AquaResource et al., 2013).

Table 3.8- 8: Overall Water Balance Table (Barrie Creeks Subwatershed) (AquaResource et al., 2013).

Inflows	Flow (m^3/d)	Flow (mm/year)
Precipitation	133,800	910
Overland Flow In	1,000	7
Groundwater Flow In	43,700	297
Total Inflow	**178,500**	**1,214**
Outflows	**Flow (m^3/d)**	**Flow (mm/year)**
Evapotranspiration	68,800	484
Overland Flow to Streams	40,900	278
Baseflow	17,500	119
Overland Flow Out	600	4
Pumping	41,100	280
Groundwater Flow Out	9,600	65
Total Outflow	**178,500**	**1,214**

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Table 3.8- 9: Water Balance, Groundwater (Barrie Creeks Subwatershed) AquaResource et al., 2013).

Inflows	Flow (m^3/d)	Flow (mm/year)
Groundwater Recharge	24,500	167
Flow from Willow Creek Subwatershed	17,800	121
Flow from Middle Nottawasaga Subwatershed	17,500	119
Flow from Lovers Creek Subwatershed	8,200	56
Total Groundwater Inflow	**68,100**	**463**
Outflows	**Flow (m^3/d)**	**Flow (mm/year)**
Discharge to Surface Water	17,500	119
Permitted Wells	41,100	279
Flow to Kempenfelt Bay	9,600	65
Total Groundwater Outflow	**68,100**	**463**

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Local Area Risk Assessment

An essential part of the Tier Three Assessment is the completion of a Local Area Risk Assessment. As per the Technical Rules (MOE, 2009), a Local Area Risk Assessment must be completed for all municipal drinking water systems located within a subwatershed that is assigned a moderate or significant stress level after undergoing a Tier Two Stress Assessment. More specifically, the Local Area Risk Assessment evaluates the possibility of a municipality being unable to meet its' allocated pumping rates under scenarios of increased municipal demand, planned land development, drought conditions, and other water uses.

Delineation of Vulnerable Areas

In order to carry out the Risk Assessment, it is first necessary to delineate the 'Local Area' within which the Risk Assessment scenarios will be evaluated. The term Local Area is defined as the area surrounding drinking water wells that must be protected in order to ensure the sustainability of municipal water supplies. The Local Area is delineated using the Tier Three models discussed in Section 3.8.2. To determine the extent of the Local Area, it is necessary to delineate specific vulnerable areas called Wellhead Protection Areas for Quantity (WHPA- Q1 and WHPA-Q2). The WHPA- Q1 and WHPA- Q2 are delineated for all municipal wells located within a significantly or moderately stressed subwatershed, as identified under the Tier Two analysis.

As per the technical rules, the WHPA-Q1 is delineated by estimating the cone of influence under an existing land use and future (allocated) pumping rate scenario. The cone of influence is estimated by calculating the maximum water level drawdown for the scenario as compared to the aquifer drawdown under non-pumping conditions. The drawdown cone used to delineate the WHPA-Q1 should be based on the allocated pumping rates for existing and planned municipal wells. The drawdown cone will be intersected with the drawdown cone of all other consumptive water users in the study area (MNR and MOE, 2011). The extent of the cone of influence should be determined by selecting an appropriate drawdown threshold. When estimating this threshold several factors should be considered including observed seasonal fluctuations of the water level in the aquifer, and any field observations of the extent of the cone of influence based on monitoring (MNR and MOE, 2011).

The WHPA-Q1 for the Barrie Creeks subwatershed is illustrated in Figure 3.8- 12. The area covers much of the City of Barrie, and extends north towards Midhurst, west towards Bear Creek and south towards Innisfil.

The WHPA Q2 for the City of Barrie is delineated as the WHPA Q1 area plus any area where a future reduction in recharge would significantly impact that area. When identifying an area where a future reduction in recharge might occur, reference must be made to a municipality's Official Plan to identify lands where new development could occur. The maximum amount of recharge reduction that might result from these developments must also be considered; any influence from stormwater best management practices should not be accounted for (MNR and MOE, 2011). Figure 3.8- 13**.** shows the WHPA- Q1 area and proposed urban development areas. For an area to be delineated as a WHPA-Q2 outside of the WHPA-Q1, it must be shown through simulations, that recharge reductions in that area might result in a measureable impact on water levels at municipal pumping wells (MNR and MOE, 2011). As illustrated in Figure 3.8- 13, the majority of proposed development areas are situated in Barrie's city core, within the WHPA

Q1 area. Much of this proposed development is classified as infilling of high and low intensity urbanized land. Models run to simulate the impacts on water quantity as a result of this infilling, indicated the reductions in hydraulic head to be minimal. The impact on water quantity was far less than the impact associated with seasonal fluctuations in the aquifer, and was therefore considered immeasurable.

Recharge reductions associated with proposed land use developments found to extend beyond the WHPA Q1 boundary were also analyzed during the WHPA-Q2 simulations. For example, as illustrated in Figure 3.8- 13, the proposed development in the Township of Springwater was an area considered during simulations. The reductions in recharge associated with proposed development areas outside of WHPA Q1 were found to be negligible, since drawdown at municipal wells was determined to be less than 1 % of the available drawdown at each well. As a result of the minimal impacts on hydraulic head, the WHPA Q2 was defined as the same area as the WHPA Q1, since development areas outside of the WHPA Q1 (e.g. development in Springwater) were not expected to have a notable impact on municipal well supplies. The Local Area for this study is therefore equal to the WHPA-Q1 delineation.

<u>Local Area Risk Assessment Scenarios</u>

A Local Area Risk Assessment evaluates the impacts on current hydrogeological conditions in response to various water demand, climate, and land use scenarios. These scenarios are simulated using the numerical models described in Section 3.8.2.

The scenarios that must be evaluated as part of the Local Area Risk Assessment are outlined in Table 3.8- 10. Where scenario simulation results indicate that municipal wells may not be able to supply their allocated rates, the Local Area (described in section 3.8.5) is assigned a moderate or significant water quantity risk level. Consumptive water uses and activities associated with reductions in groundwater recharge within the Local Area are then classified as moderate or significant drinking water threats. Risk scenario simulations also consider the water demand requirements of other water uses in the Local Area, such as the ecological flow requirements of coldwater fish habitat.

The following section describes the four major risk scenarios that must be evaluated within Tier Three models. The Technical Rules (2008*a)* outline whether or not each scenario needs to be run in transient or steady state mode. Steady state models simulate the scenarios using average annual recharge and pumping levels. Transient models simulate scenarios using monthly recharge and pumping levels. Each scenario simulation is also required to evaluate a specific period of time, as indicated in the second column of Table 3.8- 10. It is important to note that the term ‘climate data period’ indicates that simulation of the scenario should be representative of the entire period for which adequate climate and stream flow data are available.

The scenarios evaluated include the following:

- Scenarios C and G were evaluated under average climate conditions and simulated using a steady state approach
- Scenarios D and H represent drought conditions, and make use of transient simulations to represent the drought of the 1960s.

Table 3.8- 10: Risk Assessment Model Scenarios (MNR and MOE, 2011).

Scenario	Time Period	Model Scenario Details: Land Cover of the Local Area	Model Scenario Details: Water Demand	Model Simulation Details
C	Climate Data Period	Existing	Existing*	Steady-state, simulate water levels and flows using average annual recharge and pumping
D	Ten year drought period	Existing	Existing*	Transient, using monthly recharge and monthly pumping
G(1)	Climate Data Period	Planned, reduction in recharge	Planned plus Existing* plus Committed	Steady-state, simulate water levels and flows using average annual recharge and pumping
G(2)	Climate Data Period	Existing	Planned plus Existing* plus Committed	Steady-state, simulate water levels and flows using average annual recharge and pumping
G(3)	Climate Data Period	Planned, reduction in recharge	Existing*	Steady-state, simulate water levels and flows using average annual recharge and pumping
H(1)	Ten year drought period	Planned, reduction in recharge	Planned plus Existing* plus Committed	Transient, using monthly recharge and monthly pumping
H(2)	Ten year drought period	Existing	Planned plus Existing* plus Committed	Transient, using monthly recharge and monthly pumping
H(3)	Ten year drought period	Planned, reductions in Recharge	Existing*	Transient, using monthly recharge and monthly pumping

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*Existing Demand estimated for 2012, after the start-up of a surface water supply system

Model Predicted Scenario Results

The results of the scenario simulations are assessed with respect to estimated drawdown levels at each municipal well, and the impact on groundwater discharge to coldwater streams and provincially significant wetlands. Impacts on groundwater discharge were only modeled under steady state scenarios (scenarios C and G). The following section details the results of the scenario simulations conducted using the Tier Three Water Budget models discussed in Section 3.8.2 .

Drawdown

Following the simulation of each Risk Assessment scenarios, the resulting drawdown at each well was calculated and compared to the estimated Safe Available Drawdown at each municipal well (discussed in section 3.8.3) (AquaResource et al., 2013). Where simulations indicated that the scenario drawdown was greater than the Safe Available Drawdown, the wells were flagged as potentially not being able to sustain pumping rates under given scenarios. Where the simulated drawdown was less than the Safe Available Drawdown, wells were classified as low risk based on their ability to sustain allocated pumping rates. Table 3.8- 11 and Figure 3.8- 14 summarize the predicted maximum drawdown for each municipal well, under each of the Risk Assessment scenarios.

The anticipated drawdown in each municipal well during the various simulations was calculated relative to 2010 conditions. For the steady state models, the difference between water levels at the well during 2010, and those at the end of the scenario, were recorded as the scenario drawdown value (AquaResource et al., 2013). For transient scenarios, the lowest simulated water level elevation derived was compared to the water level during 2010 baseline conditions (value in Table 3.8- 11).

Simulations were compared to 2010 pumping conditions to facilitate direct comparison with Safe Available Drawdown values, which were based on the same period.

Comparing conditions present before the surface water intake to scenarios representing existing (2012) and future (allocated) rates yields negative drawdown values (AquaResource et al., 2013). Negative drawdown values represent a rise in water levels due to decreased groundwater demand resulting from the addition of the surface water intake. Comparison of negative scenario drawdown results against Safe Available Additional Drawdown is therefore still an acceptable analysis approach. The following text discusses the results of each scenario in greater detail.

Scenario C

Scenario C evaluates the change in water level from before and after the introduction of the surface water intake, at each municipal well under average climate and existing land use conditions (AquaResource, et al., 2013). The drawdown in the production aquifer for scenario C is illustrated in Figure 3.8- 15. The differences between simulated water levels of this scenario and of the 2010 pumping scenario were calculated for comparison to the Safe Available Drawdown estimate at each well (AquaResource,2013). A decrease is water levels (positive drawdown) was only predicted for well 16. However, the drawdown was not great enough to exceed the Safe Available Drawdown. The remaining area was predicted to experience a water level rise, predominantly due to the decrease in groundwater demand resulting from the introduction of the surface water intake. Table 3.8- 11 presents the drawdown experienced at each municipal well under Scenario C. The results indicate that wells within the Barrie Creeks Subwatershed should be able to continue to pump sustainably under average climate conditions and existing demand and land use, neglecting the uncertainty associated with model parameters.

Scenario D

Scenario D evaluates fluxes in the water table under short and long term drought; more specifically it aims to determine whether each municipal well is able to sustain its existing pumping rate during both long and short term drought periods. This scenario was simulated in transient mode for the period of 1953 to 2009. The lowest water level predicted during the simulation was recorded. For each well in this scenario, the difference between the lowest predicted water level, and the water level under 2010 pumping was tabulated and compared to the Safe Available Drawdown estimated for each well.

Simulation predictions indicated that drawdown under scenario D did not exceed the Safe Available Drawdown in any of the municipal wells as presented in Table 3.5- 31. Therefore, according to results, wells in the Barrie Creeks subwatershed should be able to sustain existing pumping rates under a variety of drought scenarios, assuming existing land use conditions and neglecting the uncertainty associated with model parameters.

As indicated in Table 3.8- 11, drawdown under this scenario does have the potential to exceed Safe Available Drawdown at well 11, if the well experiences diminished performance due to lack of maintenance, this however does not indicate a viable threat, since under the Technical Rules, diminished well conditions do not need to be considered during the risk evaluation. The exceedance of Safe Available Drawdown at well 11 does indicate the need for continued maintenance of the well.

Scenario G

The simulated drawdown results for scenarios G1, G2, and G3 are presented in Table 3.8- 11. Scenario G1 evaluates changes in water level due to reductions in recharge, and increases in demand, using a steady state model. As presented in Table 3.8- 11 and Figure 3.8- 16 the simulated drawdowns resulting from an increase in pumping and reduction in recharge, did not exceed the Safe Available Drawdown at any of municipal wells in the City of Barrie. Under this scenario, a water table rise is expected for wells 9 and 13.

Figure 3.8- 17 illustrates simulation results under scenario G3. This scenario evaluates changes in water level due to reductions in recharge resulting from planned land use development. The simulation is carried out in steady state mode, under average climate conditions and considers existing demand (2012). As presented Table 3.8- 11, all drawdown results predicted under this scenario do not exceed Safe Available Drawdown.

Scenario G2 evaluates the impact of increased municipal pumping (allocated rates) under existing land use conditions and average climate. As indicated in Table 3.8- 11, all drawdown results were below estimated Safe Available Drawdown. Only scenario G2 is considered when evaluating impacts to wetlands or municipal streams, since it is only this scenario that isolates the influence of municipal pumping from land development. Baseflow reductions resulting from land use development are independent from increased municipal pumping, and as outlined by the Technical Rules (2008a), only impacts associated with groundwater pumping (e.g. Scenario G2) should be used to evaluate impacts to other users (AquaResource et al., 2013).

The results of all simulations under scenario G (including G 1, 2 and 3) indicate that under average climatic conditions, drawdown at all wells will not exceed the Safe Additional Available Drawdown. If municipal pumping is increased to meet future (allocated) demand, and reductions in recharge associated with planned development take place, all municipal wells will be able to continue to pump sustainably, neglecting the uncertainty associated with model parameters.

Scenario H

Scenario H evaluates the ability of existing wells to maintain allocated pumping rates through a drought period using a transient model.

Scenario H1 considers the cumulative impact of increased (allocated) demand and conditions of reduced recharge and drought. Scenarios H2 and H3 are both evaluated under drought conditions. Scenario H2 evaluates the isolated impact of increased (allocated) demand, while Scenario H3 evaluates the isolated impact of reductions in recharge.

As outlined in Table 3.8- 11, the model predicted drawdown under all of the Scenario H simulations does not exceed the estimated Safe Available Drawdown for Barrie’s wells. This suggests that all of Barrie’s municipal wells should be able to sustain their allocated pumping rates through both drought periods, and planned land use changes, neglecting the uncertainty associated with model parameters.

Table 3.8- 11: Risk Assessment Drawdown Results (AquaResource et al., 2013).

Risk Assessment Scenario Details	Well 3A	Well 4	Well 5	Well 7	Well 9	Well 11	Well 12	Well 13	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19
Safe Available Drawdown (2010): Pre-Surface Water Plant	51	29	50	56	27	19*	45	31	17*	34*	31	49	47	52
Safe Available Drawdown (2010): Diminished Well Conditions	51	29	50	56	27	5*	42*	31	12*	32*	31	49	47	52
Average Climate - C Existing Demand (2012) Drawdown - Post- Surface Water Intake (m)	-2.5	-2	-2.9	-3.2	-1.4	4.9	-3.1	-1.5	-4.1	-3.3	0.7	-2.5	-2.6	-2.2
Average Climate - G(1) Recharge Reduction, Increased Demand Scenario Drawdown (m)	1.4	2	1.1	0.9	-0.1	8.6	0.5	-0.3	-0.2	0.4	1.7	1.9	1.7	3.4
Average Climate - G(2) Increased Demand Scenario Drawdown (m)	1.3	1.9	1	0.8	-0.2	8.6	0.4	-0.4	-0.3	0.3	1.6	1.8	1.6	3.3
Average Climate - G(3) Recharge Reduction Scenario Drawdown (m)	-2.4	-1.9	-2.8	-3.1	-1.2	5	-3	-1.3	-4	-3.2	0.8	-2.3	-2.5	-2.1
Drought (Transient) - C Existing Demand (2012) Maximum Drawdown - Post- Surface Water Intake (m)	0.4	1	0	0	0.8	8.5	0	0.7	0	0	3.9	0.5	0.3	0.4
Drought (Transient) - G(1) Recharge Reduction, Increased Demand Scenario - Maximum Drawdown (m)	2.8	4	2.5	2.4	2	11.4	1.9	1.8	1.9	2.4	5	3.5	3.2	4.9
Drought (Transient) - G(2) Increased Demand Scenario - Maximum Drawdown (m)	2.7	3.9	2.5	2.4	1.9	11.4	1.8	1.8	1.8	2.3	5	3.5	3.2	4.8
Drought (Transient) - G(3) Recharge Reduction Scenario - Maximum Drawdown (m)	0.4	1	0	0	0.9	8.6	0	0.7	0	0	3.9	0.5	0.4	0.5

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Impacts to Groundwater Discharge

The Tier Three Assessment requires that impacts on groundwater discharge to streams and wetlands of interest be evaluated under scenarios C, G1, G2, and G3. Figure 3.8- 18 highlights the areas within the model where impacts to groundwater discharge were assessed; all of the streams and wetlands considered for the assessment were situated within the WHPA-Q1 Local Area. Impacts were assessed by comparing the groundwater discharge simulated under the scenarios to groundwater discharge simulated under 2010 conditions. As per the Technical Rules (2008a) and Technical Memorandum issued by the MOE, 2013, if a groundwater reduction of 10% or more is predicted at coldwater streams, due to well pumping, the Local Area in which the scenarios are carried out is assigned a moderate Risk Level. A significant risk level can only be assigned if the pumping required to meet planned demand (planned quantity of water) results in a groundwater discharge reduction of 20% or greater.

Table 3.8- 12 presents the model predicted average annual groundwater discharge rates to each reach of the Barrie Creeks under scenarios C, G1, G2, and G3. Figure 3.8- 19 plots the groundwater discharge rate predicted under each of the modeled scenarios. The figure indicates that reductions in baseflow would be experienced under each of the scenarios, with the greatest impact to baseflow occurring under scenario G1 (increased municipal pumping and reductions in recharge).

While impacts to baseflow were assessed under scenarios G1, G2, and G3, the Tier Three Risk Assessment is only required to consider the impacts to groundwater discharge under scenario G2. This is because baseflow reductions from land use development are independent from increased groundwater pumping , and only those impacts associated with groundwater pumping (scenario G2) should be used to evaluate risk levels relating to the impact on streams and wetlands (AquaResource et al., 2013).

Figure 3.8- 20 illustrates the model simulated reduction in groundwater discharge relative to 2010 conditions for scenario G2. Increases in municipal pumping due to future increases in demand are predicted to cause a water table reduction greater than 1 m in the area surrounding Barrie wells 18 and 19; lesser impacts are predicted for surrounding areas. Reductions of up to 0.5m are expected beneath some of the wetlands associated with the Bear Creek Wetland, however discharge conditions to the wetland are predicted to be maintained in all scenarios; as a result, the wetland function would be maintained (AquaResource et al.,2013).

As illustrated in Table 3.8- 12, simulated groundwater discharge reductions for all streams under the G2 scenario are 3% or less, meaning that the Risk Assessment threshold is not met and any potential baseflow reductions due to increased pumping would therefore be minor.

Baseflow reductions associated with reductions in recharge were less than 2% (AquaResource et al.,2013). To simulate scenarios associated with reductions in recharge (G1 and G3), all groundwater recharge was proportionally reduced according to the imperviousness assumed for potential development areas; the modeled scenarios did not consider the influence of any stormwater best management practices (AquaResource et al.,2013). While all of the modeled scenarios are conservative, they indicate the locations where groundwater discharge is slightly sensitive to increased pumping, but not sensitive to land use development alone (AquaResource et al., 2013).

Baseflow reductions at Bear Creek, indicate that Bear Creek is essentially isolated from the lower aquifer and would not be impacted by increased municipal pumping nearby. This conclusion is based on the hydrogeologic setting, which shows separation of the surficial features by a consistent clay-rich confining unit in the area (AquaResource et al.,2013).

Table 3.8- 12: Impacts to Groundwater Discharge Scenarios C and G (AquaResource et al., 2013).

Groundwater Impact Scenario	Upper Bear Creek	Lower Lover's Creek	Willow Creek and Little Lake	Barrie Creeks
Pre- Surface Water Intake (2010) Demand - Groundwater Discharge (L/s)	992	669	626	62
Scenario C - Existing Demand (post-Surface Water Intake) - Groundwater Discharge (L/s)	1007	672	626	65
Scenario C - Existing Demand (post-Surface Water Intake) - Percent Reduction (%)	Increase	Increase	No Change	Increase
Scenario G(1) Increased Demand and Recharge Reduction - Groundwater Discharge (L/s)	971	656	617	57
Scenario G(1) Increased Demand and Recharge Reduction - Percent Reduction (%)	2%	2%	1%	8%
Scenario G(2) Increased Demand - Groundwater Discharge (L/s)	982	667	623	60
Scenario G(2) Increased Demand - Percent Reduction (%)	1%	0%	<1%	3%
Scenario G(3) Recharge Reduction - Groundwater Discharge (L/s)	996	661	619	62
Scenario G(3) Recharge Reduction - Percent Reduction (%)	Increase	1%	1%	No Change

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Uncertainty Analysis of Scenarios

The groundwater flow model applied during the Risk Assessment was calibrated to available hydraulic head data and baseflow measurements using parameters that were consistent with the conceptual model. It should be noted that the set of parameters used to calibrate the model were not the only suitable parameters that could be utilized; other parameter sets could have produced an equally well- calibrated model.

The model used for the Risk Assessment represents one way in which a set of parameters could produce a calibrated model. The model is a generalized representation of a complex hydrogeological system, and the assumptions used to generalize the model have associated uncertainty. Parameter combinations that had little impact on model calibration were noted throughout the calibration process. An uncertainty assessment of these parameters was performed in order to validate model predictions. This section details the findings of the uncertainty assessment.

Following calibration of the groundwater model, it was determined that the most significant parameters associated with uncertainty- (for both additional drawdown and baseflow reduction) were high permeability "windows" found within the confining aquitards that overlie and protect the municipal aquifer (AquaResource et al., 2013). These aquitards separate the deep aquifer system from the shallow system, however the degree of connectivity between the two is uncertain in some areas; including aquitard windows to the west of Barrie well 6, over Barrie wells 9 and 13; and a zone southwest of well 19 beneath the Bear Creek wetland (AquaResource et al.,2013). Some uncertainty is also associated with the connectivity of Kempenfelt Bay with the deeper aquifers. Simulated changes in conductivity within these windows yielded varied baseflow estimates to nearby streams. Without year round baseflow monitoring at these streams, the model created for this assessment was based on professional judgment and local knowledge of stream flow, rather than a hard calibration target.

Since estimates of baseflow contribution to creeks were uncertain, a worst case scenario was simulated, in which the permeability of the aquitard windows was significantly increased while maintaining calibrated water levels. To account for the change, the permeability of the aquitard underlying Kempenfelt Bay was decreased. Under this conservative scenario, the connection between the municipal production aquifer to the surface was high, and the opportunity for aquifer replenishment through a deep connection with Kempenfelt Bay was low, resulting in a more pronounced impact on baseflow and water levels throughout the scenarios.

Allocated (existing plus committed plus planned) municipal pumping rates were used in the conservative worst case model to represent conditions under scenario G2. The model was run and results provided insight on how uncertainty associated with model input parameters could affect predictions. The uncertainty analysis aimed to identify if conditions would cause the hydraulic head in the aquifer at the municipal well to violate the safe additional drawdown levels at the well. Table 3.8- 13 summarizes the results of the simulations. The majority of the model predicted drawdown at the municipal wells was found not to exceed the Safe Additional Drawdown levels; only well 11 exceeded additional drawdown under diminished well conditions. This is consistent with the results of the original model simulation where simulated drawdown exceeded the safe additional available drawdown at that well under diminished well conditions. Since the predictions made by the alternate “worst case’ model are consistent with the findings associated with the original model, uncertainty associated with study was low.

Table 3.8- 13 : Data Gap/Uncertainty Alternative Calibration Model Drawdown Results (AquaResource et al., 2013).

Groundwater Model (FELOW) Scenario Details	Well 3A	Well 4	Well 5	Well 7	Well 9	Well 11	Well 12	Well 13	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19
Safe Available Drawdown (2010)	51	29	50	56	27	19*	45	31	17*	34*	31	49	47	52
Safe Available Drawdown (2010): Diminished Well Conditions	51	29	50	56	27	5*	42*	31	12*	32*	31	49	47	52
Average Climate - Scenario C Drawdown - Existing Demand (m)	-3.8	-3.2	-4.1	-4.4	-1.3	4.2	-4.5	-1.4	-4.8	-4.7	0.7	-3.6	-3.7	-3.4
Average Climate - Scenario G(1) Drawdown - Recharged Reduction and Increased Demand (m)	1.9	2.5	1.6	1.4	-0.1	9.1	1	-0.3	0.3	0.9	1.7	2.4	2.2	4
Average Climate - Scenario G(2) Drawdown - Increased Demand (m)	1.7	2.3	1.4	1.2	-0.3	9	0.9	-0.4	0.2	0.7	1.6	2.2	2.1	3.8
Average Climate - Scenario G(3) Drawdown - Recharged Reduction (m)	-3.6	-3.1	-3.9	-4.2	-1.2	4.3	-4.4	-1.3	-4.7	-4.5	0.8	-3.5	-3.6	-3.2
Drought - Scenario D Drawdown - Existing Demand (m)	0	0.6	0	0	0.8	8.4	0	0.7	0	0	4	0.1	0	0
Drought - Scenario H(1) Drawdown - Recharged Reduction and Increased Demand (m)	3.3	4.5	3	2.9	2	12	2.5	1.9	2.5	3	5.1	4	3.7	5.3

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Groundwater Model (FELOW) Scenario Details	Well 3A	Well 4	Well 5	Well 7	Well 9	Well 11	Well 12	Well 13	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19
Drought - Scenario H(2) Drawdown - Increased Demand (m)	3.3	4.4	2.9	2.8	2	12	2.4	1.8	2.4	2.9	5.1	3.9	3.6	5.2
Drought - Scenario H(3) Drawdown - Recharged Reduction (m)	0	0.4	0	0	0.7	7.4	0	0.6	0	0	3.9	0	0	0

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Summary of Local Area Risk Assessment Results

As per the technical rules, following the simulation of various risk scenarios, the Local Area for which the assessment was conducted must be assigned a water quantity risk level classification. The classification is assigned based on the Local Area's ability to meet peak demand (Tolerance) as well as the results of the scenario simulations described above (risk level).

To determine the Risk level associated with the Local Area, the Technical Rules (2008a), technical bulletin: Part IX Local Area Risk Level (April 2010), and Technical Memorandum (MOE, 2013) list a series of circumstances under which the Local Area is assigned a Significant Risk level. If any one of the circumstances are met, the Local Area must be assigned a significant risk level. The circumstances are summarized in Table 3.8- 14.

The Local Area associated with the City of Barrie municipal drinking water system was assigned a low risk level because the Safe Additional Available Drawdown was not exceeded under any of the simulated scenarios. The simulations carried out determined that all permitted and non-permitted consumptive water uses within the Local Area (including rural domestic water uses) could not be classified as water quantity threats. Groundwater recharge reduction activities such as proposed land use developments were predominantly planned to infill areas within Barrie's city core, while proposed development activities outside the city core were found not to be within areas of significant recharge. As a result, proposed development activities did not significantly impact water levels in municipal aquifers and were therefore also not classified as water quantity threats.

As mentioned above, the risk level assigned to the Local Area is also based on the Local Area's ability to meet peak demand (Tolerance). According to the Technical Rules, if a municipality's system is able to meet existing peak demand, the system is considered to have a high tolerance; otherwise the tolerance is considered low. The City of Barrie is classified as having a high tolerance due to the fact that the city has never experienced water shortage issues, has a redundancy of supply with a capacity that exceeds demand, and has existing storage systems in place to meet peak demand. The recent addition of a surface water intake has also significantly increased the City's tolerance.

In summary, due to the system's ability to meet existing and allocated demand without affecting other water uses, the Local Area for the City of Barrie was assigned a low risk level.

Table 3.8- 14: Significant Risk Level Circumstances (MOE, 2013).

-	Significant Risk - Groundwater
Scenarios	**Circumstance**
C - Existing – average annual D - Existing – ten year drought	1) the quantity of water that could have been taken from groundwater in the Local Area would not have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells. 2) the quantity of water that could have been taken from groundwater in the Local Area would have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells and the tolerance is Low.
G – Planned system or existing system with committed demand – average annual	1) 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 municipal groundwater wells.
H – Planned system or existing system with committed demand – ten year drought	1) 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 municipal groundwater wells.

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Figure 3.8- 1: Barrie Tier Three Study Area.

Figure 3.8- 2: Surface Water Features and Watershed Boundaries .

Figure 3.8- 3: Municipal Systems in Barrie Tier Three Study Area.

Figure 3.8- 4: Hydrostratigraphic Cross Section across Tier Three Study Area.

Figure 3.8- 5: Groundwater Recharge in the Tier Three Study Area.

Figure 3.8- 6: Current Conditions Land Use in the Tier Three Study Area.

Figure 3.8- 7: Official Plan Land Use.

Figure 3.8- 8: Land Use Change (Existing to Official Plan).

Figure 3.8- 9: Safe Additional Drawdown Calculation (Well 3A).

Figure 3.8- 10: Groundwater Demand in the Tier Three Study Area.

Figure 3.8- 11: Domestic Water Use in the Tier Three Study Area.

Figure 3.8- 12: WHPA-Q1 Boundary

Figure 3.8- 13: WHPA Q2 and Local Area.

Figure 3.8- 14: Model Predicted Drawdown Risk Assessment .

Figure 3.8- 15: Simulated Drawdown under Scenario C (relative to 2010 conditions).

Figure 3.8- 16: Simulated Drawdown under Scenario G1 (relative to 2010 conditions).

Figure 3.8- 17: Water Level Reductions - Scenario G3 (relative to 2010 conditions).

Figure 3.8- 18: Model Simulated Baseflow Impact Areas.

Figure 3.8- 19: Model Simulated Baseflow.

Figure 3.8- 20: Baseflow Reductions.

3.9 Tier Three Water Budget- Village of Woodville

The Woodville water supply system located in the Beaver River Subwatershed was identified through the Tier One and Two Water Budget and Stress Assessment analysis as having a historical water supply issue as per Technical Rule 33(2)(c)(i) (MOE, 2008a). As such, the Village of Woodville water supply system qualified for a more rigorous Tier Three Water Budget and Local Area Risk Assessment analyses (herein referred to as Tier Three). The Tier Three is to focus on the area which provides water to the well/intake. For groundwater wells, this area includes the lands contributing water to the wells as well as sensitive features near the wells. The first phase of assessment involves a detailed review of available data such as physiography and land use, geology, surface water and ecological features to develop a preliminary understanding of the overall flow system.

In December of 2011, the Lake Simcoe Region Conservation Authority began the Tier Three assessment for the Village of Woodville Water Supply system. In 2013, the project was discontinued as new information was provided that questioned the original assignment of a historic water supply issue as per the Technical Rules. The information provided below summarizes this historical water supply issue and provides the rationale for discontinuing the Tier Three Assessment.

Summary of Historical Water Supply Issue for the Community of Woodville Water Supply Wells

Issues with the Woodville Water Supply were identified and discussed in the Tier One study (SGBLS, 2009). The following discussion provides additional information about the development of the wells and the problems encountered.

In 1999, the Village of Woodville, Ontario was in the process of locating a new municipal water supply source because the existing wells located closer to the town were found to have nitrate levels near or above the drinking water limit. The village of Woodville hired KMK Consultants Limited to perform an Environmental Assessment (EA) with respect to the replacement of their municipal water supply. KMK Consultants Limited contracted Jagger Hims Limited (JHL) in 1999 to perform a groundwater investigation of possible alternative municipal well locations. JHL drilled four test wells and one observation well at the southeast corner of Highway 46 and The Glen Road, due south of the Woodville community.

Test well TW99-2, currently known as Woodville Well 1 (WW1), was selected as the replacement supply well. After a 72-hour aquifer test was performed in May 1999, it was determined that WW1 could sustain a long-term yield of 410 litres per minute (L/min) (JHL, 1999). It was also concluded that six months of continuous pumping at a rate of 220 m^3/d

would result in a local drawdown of 0.8 metres. In October, 1999, a fifth test well was installed (TW99-5) and a 52-hour pump test was subsequently performed at a rate of 228 L/min (JHL, 2004). TW99-5 subsequently became the Woodville standby well. The new Woodville wellfield operates under Permit To Take Water (PTTW) number 03-P-4043 with a maximum permitted yield of 410 L/min (Jagger Hims, 2004). WW1 was placed online in September 2003. Since the activation of WW1, the village of Woodville has extracted 220 L/min on an average basis.

Woodville Well 2 (WW2), also known as TW03-1, later replaced the Woodville standby well TW99-5 because of "a casing failure during wellhead modifications that resulted in an uncontrolled release of groundwater" (JHL, 2006). TW99-5 was depressurized, grouted, and taken offline. WW2 was placed near TW99-5.

The Woodville wells extract water from a fractured limestone bedrock aquifer that lies between 5 to 10 m below the wellfield ground surface (JHL, 2006). Overburden consists of a thin (1 to 2 m) sand and gravel, deemed "lower aquifer," followed by a silt/clayey-silt/clay "leaky aquitard" (JHL, 2006) that extends to the surface, which lies at an elevation of approximately 275 mASL.

By September 2004, a declining trend in water levels was observed in the bedrock aquifer (JHL, 2006). The decline became more pronounced in 2005. In response to this decline, a Phase 2 water restriction was imposed on the village of Woodville, which limits water usage by restricting lawn watering and car washing using a garden hose, amongst others. The village of Woodville also lowered their maximum pumping rate from 410 L/min to 275 L/min. The water restriction water temporarily lifted in January of 2012 to observe water levels. Transducers were installed in each production well on September 30, 2004, and have been recording water levels at 10 minute intervals ever since; daily water levels were measured prior to this date (JHL, 2004). An additional 4 monitoring wells have since been installed (JHL, 2006).

In summary, although the reason for the decline in the water levels was unknown, under Technical Rule 35(2) (e) the fact that a water restriction did occur caused the Beaver River subwatershed to advance to a Tier Two study and the Village of Woodville water supply to advance to a Tier Three study. Additional details are provided in the Tier 1 report appendices (SGBLS, 2009).

Preliminary Tier Three Assessment

As a result of the identified historical water supply issue, the Tier Three Water Budget and Local Area Risk Assessment for the Village of Woodville water supply system commenced in December of 2011.

The overall progress of the Tier Three assessment was affected by the significant efforts required to compile, assess and analyze historical and new data. The main concern noted by the consulting team and the Peer Reviewers was the limited availability of reliable data. These data gaps were identified as being critical for the development of a defensible groundwater flow model and to diagnose the historical issue of declining groundwater levels.

One of the key uncertainties associated with understanding water supplies and the environmental impact of water takings is the geological and hydrogeological characterization of the subsurface. Earlier studies have identified data gaps and uncertainties relating primarily to groundwater quantity monitoring and limited data to characterize groundwater/surface water interactions within the vicinity of the Woodville wellfield. The historical documentation of pump intake elevations, fracture elevations and available drawdown were noted as critical data gaps for moving forward to establish a defensible groundwater model (Lotowater, 2013a; AECOM, 2013).

In November 2013, the Province approved funding for a field work program to address the critical data gaps identified by the Peer Reviewers.

As per Technical Rule 30.1(1) (MOE, 2008a), a proposed field work program consisting of a pumping test of the Woodville municipal wells along with surveying the elevations of the municipal and monitoring wells was initially proposed to be completed in January 2014. Shortly thereafter in December 2013, it became known that the Grace et al (2012) report documented the results of a 24-hour pumping test completed on the Glen Road Well 2 during February 2010. As a result, there was consensus between the Peer Reviewers, Province, and the City of Kawartha Lakes that the results of a January pumping test during seasonally higher water levels would generally replicate those of February 2010, along with the logistical difficulties associated with conducting a pumping test during the winter (difficulty monitoring pond levels due to ice conditions, discharge water and ice conditions etc.). In addition the Grace et al (2012) report contained additional information that called into question the original assignment of the historical water supply issue:

Storage within the aquifer/groundwater system suggests a sufficient water supply exists to meet the current water use demand. Since the water use restriction was lifted in January 2012, there has been no indication that the Glen Road municipal wells or the Water Treatment Plan operated by the Ontario Clean Water Agency are being operated at a “reduced capacity”. However, completing a pumping test during a seasonal low water level period associated with late summer/early fall would help determine the ‘safe’ production yield of the municipal wells.

The Glen Road wellfield was a small wetland at the time of the initial test well construction. The large storage reservoir within much of the fractured bedrock system is hydraulically connected to the upper flow system (ponds, wetlands) which are either prone to interference or could represent conduits for contamination.

Although the Glen Road wellfield may be capable of pumping at higher rates (Litres/minute), increased pumping rates have the potential to adversely affect water levels in the local private wells and ponds. It is important to determine what level of impact is considered unacceptable since the available storage reservoir functions as one system due to the hydraulic connection between the groundwater and surface water flow systems.

Natural seasonal fluctuations (up to 3.5 metres) occur in this unconfined aquifer. This variability is part of the aquifer's 'character' and does not represent changes in the aquifer properties. When recharge rates are lower than normal, water levels are at a minimum which have been typically noted in September.

Data discrepancies were noted in the reporting of some previous water level measurements which resulted in erroneous water level readings.

In early 2014, the above findings were discussed with the Province and Peer Review Team who confirmed that the Woodville water supply no longer met the test of a historic issue under the Technical Rules. As such, both the groundwater and surface modelling assessments would not be completed as part of this study. Preliminary characterization of the Woodville Water Supply system is documented within the Conceptual Model Report (Aecom et al, 2014). The completion of the preliminary Conceptual Model Report for the Woodville Tier Three Water Budget and Local Area Risk Assessment is based on an investigation and geologic interpretation of available data and will further contribute to the City of Kawartha Lakes overall water supply management.

Next Steps

In keeping with the recommended proposed field work component, discussions took place with the Province regarding the re-allocation of funds to complete an amended field work program for the Woodville wellfield during the summer/early fall 2014. An amended field work program was approved by the Province in March 2014 to assess the sustainability of the aquifer during a period of low water levels and low recharge conditions associated with summer/early fall. The completion of a pumping test during a seasonal low water level period will assist the City of Kawartha Lakes in determining a 'safe' pumping rate for the Glen Road wellfield which will not produce unacceptable impacts to the adjacent ponds and private wells. It is expected the field work program and associated reporting will be completed by December 31, 2014.

Once the long-term potential of this wellfield is determined, the City of Kawartha Lakes can assess alternative resources to meet the Committed Demand. The Committed Demand is the increase in the quantity of water provided by a drinking water system that would be required if the area served by the system were developed in accordance with the area's Official Plans, to an extent that resulted in the greatest use of drinking water (Technical Rules (3.2), 2011).

In addition to the recommendation of assessing the sustainability of the aquifer during a period of low water levels and low recharge, the Grace et al. (2012) report also identified two prospective future areas which could be further evaluated for the development of additional groundwater supplies for the community. It is generally considered that water supplies for a community would best be obtained from more than one wellfield since the community is not relying on a single source or single 'source area'. In this manner, should problem conditions such as low water levels or water quality issues occur, the community could better manage the situation by adjusting pumping rates and schedules, as required. Furthermore, in keeping with the recommendations proposed in the Grace et al. (2012) report, it has been noted that the City of Kawartha Lakes has undertaken numerous operational initiatives, including inspection and repairs to municipal wells and the installation of new transducers in the three production wells and four residential wells. These initiatives will contribute to a better understanding and management of the municipal water supply system for the community of Woodville.

3.10 Peer Review Process

The water budgets within this document were prepared as indicated in the Technical Rules 19-36 and the MOE guidance documents. Each of the water budget studies are undergoing or have been subsequently peer reviewed by qualified professionals. The peer review process ensures there is consistency with the expectations of the Technical Rules for completion of the Assessment Report. That appropriate methodologies are utilized, and that the technical assumptions are necessary and reasonable. The process also ensures that the water budgets are scientifically defensible products. Table 3.10- 1 outlines who the peer reviewers were for each water budget, highlights their qualifications to peer review these water budgets. All water budget projects presented within the Assessment Report have undergone at least one round of peer review. Table 3.10- 2 outlines if the water budget project has completed the full peer review process. The peer review sign-off letters for each completed project can be found within Appendix WB-6.

Table 3.10- 1: Peer Reviewers in the Lake Simcoe Watershed.

Project	Peer Review	Qualification
Tier 1 Water Budget and Stress Assessment Summary	Dillon Consulting	Robert Muir, M. A. Sc., P. Eng. (surface water expert); Igor Iskra, Ph. D. P. Eng.
Tier 1 Water Budget and Stress Assessment Summary	Richard Gerber	Richard Gerber, Ph. D., P. Geo. (hydrogeological expert) - CTC SWP Region - Technical Advisor and Senior Hydrogeologist, Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier 1 Water Budget and Stress Assessment Summary	York Region	Tom Bradley - Water Resources Technologist; Tammy Silverstone, M. Eng., P. Eng. - program Co-ordinator Water Resources and Environmental Services
Tier 2 Water Budget (Holland Landing and Maskinonge River Watersheds)	Dillon Consulting	Robert Muir, M. A. Sc., P. Eng. (surface water expert); Igor Iskra, Ph. D. P. Eng.
Tier 2 Water Budget (Holland Landing and Maskinonge River Watersheds)	Richard Gerber	Richard Gerber, Ph. D., P. Geo. (hydrogeological expert) - CTC SWP Region - Technical Advisor and Senior Hydrogeologist, Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier 2 Water Budget (Holland Landing and Maskinonge River Watersheds)	York Region	Tom Bradley - Water Resources Technologist; Tammy Silverstone, M. Eng., P. Eng. - program Co-ordinator Water Resources and Environmental Services
Tier 2 Water Budget (Uxbridge)	Dillon Consulting	Robert Muir, M. A. Sc., P. Eng. (surface water expert); Igor Iskra, Ph. D. P. Eng.
Tier 2 Water Budget (Uxbridge)	Richard Gerber	Richard Gerber, Ph. D., P. Geo. (hydrogeological expert) - CTC SWP Region - Technical Advisor and Senior Hydrogelogicist, Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier 2 Water Budget (Uxbridge)	York Region	Tom Bradley - Water Resources Technologist; Tammy Silverstone, M. Eng., P. Eng. - program Co-ordinator Water Resources and Environmental Services

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Project	Peer Review	Qualification
Tier 3 Water Budget and Risk Assessment (City of Barrie)	Dillon Consulting	Robert Muir, M. A. Sc., P. Eng. (surface water expert); Igor Iskra, Ph. D. P. Eng.
Tier 3 Water Budget and Risk Assessment (City of Barrie)	Richard Gerber	Richard Gerber, Ph. D., P. Geo. (hydrogeological expert) - CTC SWP Region - Technical Advisor and Senior Hydrogelogicist, Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier 3 Water Budget and Risk Assessment (City of Barrie)	S. S. Papadopulos & Associates Inc.	Chris Neville, M. Sc., M. Eng. (hydrogelogical expertise)
Tier 3 Water Budget and Risk Assessment (York Region)	Stantec Consulting	Igor Iskra, Ph. D., P. Eng.
Tier 3 Water Budget and Risk Assessment (York Region)	Golder Associates Ltd.	Kevin MacKenzie M. Sc., P. Eng. - Water Resources Engineer
Tier 3 Water Budget and Risk Assessment (York Region)	S. S. Papadopulos & Associates Inc.	Chris Neville, M. Sc., M. Eng. (hydrogelogical expertise)
Tier 3 Water Budget and Risk Assessment (York Region)	Richard Gerber	Richard Gerber, Ph. D., P. Geo. (hydrogeological expert) - CTC SWP Region - Technical Advisor and Senior Hydrogelogicist, Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)

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Table 3.10- 2: Peer Review Water Budget Project Status.

Water Budget	Peer Review Status
Tier 1 Water Budget and Stress Assessment Summary	Complete
Tier 2 Water Budget (Holland Maskinonge, River Watersheds)	Complete
Tier 2 Water Budget (Uxbridge/Beaver)	Complete
Tier 2 Water Budget (South Georgian Bay West Lake Simcoe)	Complete
Tier 3 Water Budget and Risk Assessment York Region	Complete
Tier 3 Water Budget and Risk Assessment Barrie and Area	Complete

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