

## 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 ~~Director's~~ Technical Rules as the water budgets were completed based on the 2008 ~~Director's~~ 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 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.

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:

1. Where is the water? (i.e. where are the various watershed hydrologic elements (e.g. soils, aquifers, streams, lakes, located?))
2. How does the water move between these elements? (i.e. what are the pathways through which the water travels?)
3. What and where are the stresses on the water? (i.e. where are the water takings?)
4. What are the trends? (i.e. are the 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:

- Conceptual Water Budget
- Tier One Water Budget and Water Quantity Stress Assessment

- Tier Two Water Budget and Water Quantity Stress Assessment
- 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, existing, 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 Nottawasaga Valley Source Protection Area.

Those subwatersheds that were identified as exceeding the proscribed 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 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:

- Innisfil Creek
- Willow Creek
- Pine River
- Middle Nottawasaga 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 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 water source (e.g., stream, lake, or aquifer).

The City of Barrie municipal systems will be proceeding 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. As these systems are in close proximity it is recommended that the evaluation is completed as part of one study (AquaResource and Golder, 2010). This will include the following subwatersheds:

- Innisfil Creek
- Middle Nottawasaga River
- Willow Creek

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 3.9.

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

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System (Yes/No)	Conceptual/ Tier 1	Tier 2	Tier 3
Blue Mountain	Simcoe County	Township of Clearview	Yes (GW)	Yes		
Blue Mountain	Simcoe County	Town of Collingwood	Yes (SW)	Yes		
Blue Mountain	Simcoe County	Town of Wasaga Beach	Yes (GW)*	Yes		
Blue Mountain	Grey County	The Town of Blue Mountains	No	Yes		
Blue Mountain	Grey County	The Municipality of Grey Highlands	No	Yes		
Boyne River	Simcoe County	Township of Adjala-Tosorontio	Yes (GW)	Yes		
Boyne River	Simcoe County	Town of New Tecumseth	Yes (GW)	Yes		
Boyne River	Simcoe County	Township of Essa	Yes (GW)*	Yes		
Boyne River	Dufferin County	Town of Shelburne	Yes (GW)	Yes		
Boyne River	Dufferin County	Town of Mono	Yes (GW)*	Yes		
Boyne River	Dufferin County	Township of Mulmur	Yes (GW)*	Yes		

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System (Yes/No)	Conceptual/ Tier 1	Tier 2	Tier 3
Boyne River	Dufferin County	Township of Amaranth	No	Yes		
Innisfil Creeks	Simcoe County	Town of New Tecumseth	Yes (GW)	Yes	Yes	
Innisfil Creeks	Simcoe County	Town of Innisfil	Yes (GW)	Yes	Yes	
Innisfil Creeks	Simcoe County	Township of Adjala-Tosorontio	Yes (GW)	Yes	Yes	
Innisfil Creeks	Simcoe County	Town of Bradford West Gwillimbury	Yes (GW)*	Yes		
Innisfil Creeks	Simcoe County	Township of Essa	Yes (GW)*	Yes		
Innisfil Creeks	Peel Region	Town of Caledon	Yes (GW)	Yes	Yes	
Innisfil Creeks	York Region	Township of King	Yes (GW)*	Yes		
Lower Nottawasaga River	Simcoe County	Township of Springwater	Yes (GW)	Yes		
Lower Nottawasaga River	Simcoe County	Township of Clearview	Yes (GW)	Yes		

<b>Subwatershed</b>	<b>Upper Tier Municipality</b>	<b>Lower Tier Municipality</b>	<b>Municipal Drinking Water System (Yes/No)</b>	<b>Conceptual/ Tier 1</b>	<b>Tier 2</b>	<b>Tier 3</b>
<b>Lower Nottawasaga River</b>	<b>Simcoe County</b>	<b>Town of Wasaga Beach</b>	<b>Yes (GW)</b>	<b>Yes</b>		
<b>Lower Nottawasaga River</b>	<b>Simcoe County</b>	<b>Township of Tiny</b>	<b>Yes (GW)*</b>	<b>Yes</b>		
<b>Mad River</b>	<b>Simcoe County</b>	<b>Township of Clearview</b>	<b>Yes (GW)</b>	<b>Yes</b>		
<b>Mad River</b>	<b>Simcoe County</b>	<b>Township of Essa</b>	<b>Yes (GW)*</b>	<b>Yes</b>		
<b>Mad River</b>	<b>Simcoe County</b>	<b>Township of Adjala-Tosorontio</b>	<b>Yes (GW)*</b>	<b>Yes</b>		
<b>Mad River</b>	<b>Simcoe County</b>	<b>Municipality of Grey</b>	<b>No</b>	<b>Yes</b>		
<b>Mad River</b>	<b>Simcoe County</b>	<b>Township of Mulmur</b>	<b>Yes (GW)*</b>	<b>Yes</b>		
<b>Mad River</b>	<b>Simcoe County</b>	<b>Township of Melancthon</b>	<b>No</b>	<b>Yes</b>		
<b>Middle Nottawasaga River</b>	<b>Simcoe County</b>	<b>Township of Essa</b>	<b>Yes (GW)</b>	<b>Yes</b>	<b>Yes</b>	

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System (Yes/No)	Conceptual/ Tier 1	Tier 2	Tier 3
Middle Nottawasaga River	Simcoe County	Town of New Tecumseth	Yes (GW)	Yes	Yes	
Middle Nottawasaga River	Simcoe County	Township of Essa	Yes (GW)*	Yes		
Middle Nottawasaga River	Simcoe County	Town of Innisfil	Yes (GW and SW)*	Yes		
Middle Nottawasaga River	Simcoe County	Township of Springwater	Yes (GW)*	Yes		
Middle Nottawasaga River	City of Barrie	City of Barrie	Yes (GW and SW)*	Yes		
Pine River	Dufferin County	Township of Mulmur	Yes (GW)	Yes	Yes	

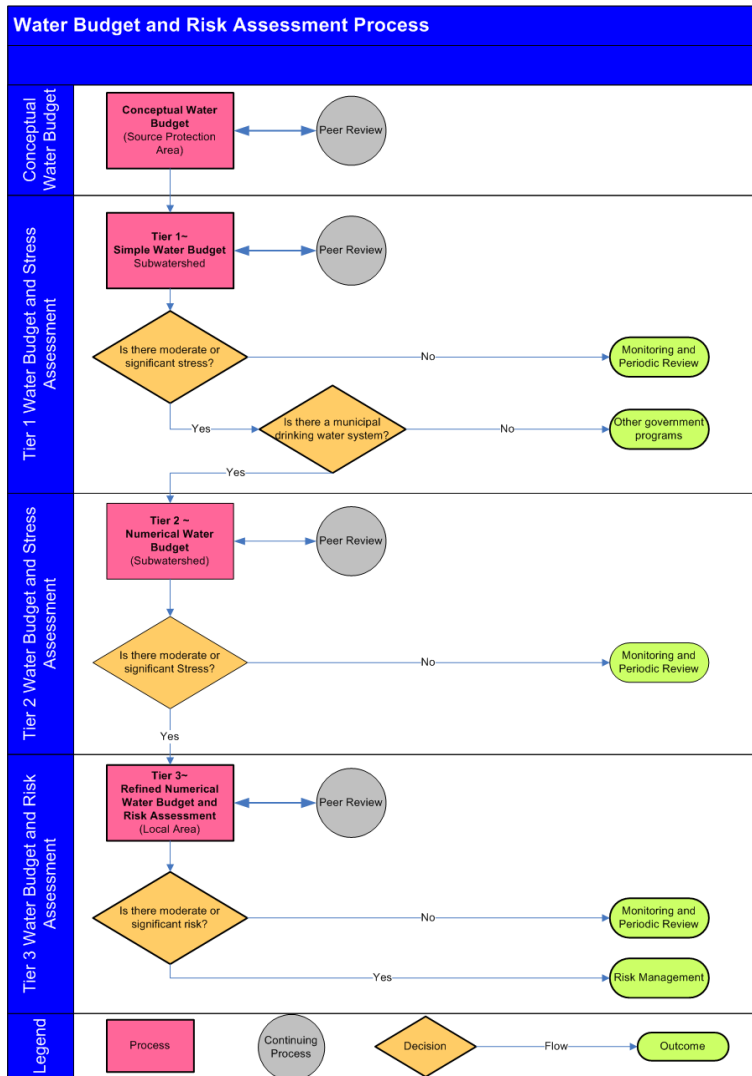
Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System (Yes/No)	Conceptual/ Tier 1	Tier 2	Tier 3
Pine River	Simcoe County	Township of Adjala-Tosorontio	Yes (GW)	Yes	Yes	
Pine River	Simcoe County	Township of Essa	Yes (GW)	Yes	Yes	
Pine River	Simcoe County	Township of Melancthon	Yes (GW)*	Yes		
Pine River	Simcoe County	Township of Clearview	Yes (GW)*	Yes		
Upper Nottawasaga River	Simcoe County	Township of Adjala-Tosorontio	Yes (GW)	Yes		
Upper Nottawasaga River	Simcoe County	Town of New Tecumseth	Yes (GW)	Yes		
Upper Nottawasaga River	Dufferin County	Town of Mono	Yes (GW)	Yes		Yes**
Upper Nottawasaga River	Dufferin County	Township of Amaranth	No	Yes		

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System (Yes/No)	Conceptual/ Tier 1	Tier 2	Tier 3
Upper Nottawasaga River	Dufferin County	Township of Mulmur	Yes (GW)*	Yes		
Willow Creek	Simcoe County	Township of Oro-Medonte	Yes (GW)	Yes	Yes	
Willow Creek	Simcoe County	Township of Springwater	Yes (GW)	Yes	Yes	
Willow Creek	City of Barrie	City of Barrie	Yes (GW)	Yes	Yes	Yes***

Notes to the table above:

1. All subwatersheds are required to undergo a Conceptual and Tier 1 analysis. Subwatersheds that are not moving beyond a Tier 1 analysis do not have a municipal groundwater system, and/or were found not to be stressed
2. \* The municipal drinking water system is not located within this subwatershed
3. \*\* Cardinal Woods in Dufferin was included in the Orangeville Tier 3 Water Budget Study as it fell within the local area. The Orangeville Tier 3 can be found within the Credit Valley, Toronto & Region and Central Lake Ontario (CTC) Source Protection Region Assessment Report
4. \*\*\* Barrie will be proceeding to a Tier 3 Water Quantity Risk Assessment because the majority of the system's supply wells are located within the stressed subwatersheds of Barrie and Lovers Creek Subwatershed within the adjacent Source Protection Area (Lake Simcoe Watershed)

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 various components of the hydrologic cycle. These components include:

- precipitation, evaporation and transpiration
- infiltration (water that 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 diversions, etc)
- 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.

#### 3.1.1 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 Nottawasaga Valley 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 ([PTTW](#)) Process, 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 (1984), the first leading reserachers to map the physiography of Southern Ontario. 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 Nottawasaga Valley Watershed is located within four (4) regional-scale physiographic regions as defined by Chapman and Putnam (1984). These regions include the Horseshoe Moraines, Peterborough Drumlin Field, Simcoe Lowlands and the Simcoe Uplands (Chapman and Putnam, 1984; (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 Nottawasaga Valley 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).

### **Horseshoe Moraines**

The Horseshoe moraines also referred to as the Port Huron Moraine system (Chapman and Putnam, 1984), form the central portion of the horseshoe-shaped region that flanks the uplands located east of the Niagara Escarpment. Three moraines, predominantly composed of stratified sands and gravels, have been identified within this region (Chapman and Putnam, 1984). From oldest to youngest, they are the Singhampton Moraine, the Gibraltar Moraine and the Banks Moraine.

The Singhampton Moraine is defined by Chapman and Putnam (1984) as a single crested till ridge superimposed on a drumlinized till plain that marks the northern limb of the Port Huron Moraine system. The Gibraltar Moraine is morphologically similar to the Singhampton Moraine with its crest reaching 274 mASL. It is located behind (north) of the Singhampton Moraine and is predominantly composed of stratified sands and gravels that are capped by a boulder-rich sandy till. The youngest of the three, the Banks moraine, lies immediately behind (north of) the Gibraltar moraine. Morphologically, it is very similar to the Singhampton and the Gibraltar moraines but is described by Chapman and Putnam (1984) as being less developed. This moraine marks the southern limit of the Arran Drumlin Field and like the Singhampton and the Gibraltar is composed of stratified sands and gravels and diamictons (i.e. debris flow units).

### **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 can be determined (Chapman and Putnam, 1984). 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 Peterborough Drumlin Field occurs in the eastern reaches of the watershed. It is defined by a rolling drumlinized till plain. Drumlins that occupy the area between the Oak Ridges Moraine and Cooks Bay are on average oriented 60° west of south or 240° azimuth. The drumlins are composed of a stone-rich, slightly silty to fine to medium-grained sand till.

### **Simcoe Uplands**

The Simcoe Uplands comprise of a series of broad, rolling drumlinized till plains that are separated by numerous steep-walled, flat-floored valleys. The uplands occupy a total surface area of 1 035 km<sup>2</sup> and are located south of the community of Barrie, north of Alliston and in the northern portions of Oro-Medonte and Springwater Townships. The Uplands are commonly encircled by numerous shorelines and other morphological features associated with glacial Lake Algonquin and its successors. The Oro Moraine is located within the Simcoe uplands physiographic regime extending from Midhurst to Bass Lake.

### **Simcoe Lowlands**

The Simcoe Lowlands physiographic region ranges in elevation from 265 meters above sea level (mASL) near Orangeville to 176 mASL at Wasaga Beach (AquaResources and Golder Associates, 2009). Morphologically, this region is characterized by flat, low-lying plains composed of silts, clays and fine to medium-grained sands deposited within glacial Lake Algonquin (12, 500 years B.P.). The Georgian Bay fringe occupies the areas of Nottawasaga, Wasaga Beach and the Townships of Tiny and Tay. It is characterized by sand dunes and boulder beaches cut into till headlands in Wasaga Beach (AquaResources and Golder Associates, 2009).

### **Prominent Surficial Physiographic Features**

#### **Niagara Escarpment**

The Niagara Escarpment is the most prominent physiographic feature in the Nottawasaga Valley. The Escarpment trends in a northwest-southeast direction, rising in elevation near the community of Collingwood, and continues in a northward direction toward the Beaver and

Bighead River Valleys, Owen Sound, Wiarton extending along the northeastern margins of the Bruce Peninsula to Tobermory (Chapman and Putnam, 1984).

The Escarpment is predominantly composed of interbedded units of limestone, dolostone, sandstone and shale. Erosion of these rocks has resulted in a nearly vertical Escarpment face which is particularly evident when viewed, from west to east across the brow of the Escarpment. In some areas, the bedrock topography of the Escarpment is subdued and covered with overburden rather than the steep bedrock face described above. An example of this topography is located near the community of Fevorsham.

Also included in the Niagara Escarpment physiographic region is the limestone/ dolostone plain occupying the areas west of (above) the cuesta. Overburden along this portion of the Niagara Escarpment, especially along the Bruce Peninsula, is very thin or non-existent. As a result, karst topography including caves, sinkholes and other similar dissolution features are common in this physiographic region.

#### **Orangeville Moraine**

The moraine was formed between the Georgian Bay lobe of the Laurentide Ice Sheet to the west and northwest, the Lake Simcoe lobe to the northeast, and the Lake Ontario Lobe to the east and southeast. Drainage flowing between the ice lobes deposited sand and gravel, resulting in this interlobate moraine. Present in the municipalities of Mono and Amaranth in the NVCA watershed, it has been suggested that the Orangeville Moraine was one of the first land forms to appear in southern Ontario when the Georgian Bay and Lake Ontario ice lobes separated (Chapman and Putman, 1984). The moraine forms a nearly flat-topped feature that has been strongly dissected by fluvial erosion and consists mainly of ice-contact stratified drift which includes stratified sand, silt and gravel. The majority of the moraine exceeds 50 m in thickness. Tavistock till flanks and overlies the western parts of the Orangeville Moraine in the Townships of East Garafraxa and Amaranth. The Orangeville Moraine forms a regional significant recharge area and is in the headwater area of the Nottawasaga River (NVCA & LSRCA, 2008).

#### **Topography:**

Ground surface topography within the Nottawasaga Valley watershed ranges from approximately 542 metres above mean sea level (mASL) in the west to 160 mASL at Georgian Bay. The topography closely corresponds to the physiographic regions that make up the watershed. Areas of hummocky topography with their associated closed depressions are unique areas, typically found in moraines (AquaResources and Golder Associates, 2009). They

are important from a groundwater perspective in that they tend to focus recharge (Davies et al, 2008). The topography of the Nottawasaga Valley 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 within 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 due to the inability of many materials to readily move through non-porous materials. The geology of the Nottawasaga Valley basin is generally comprised of unconsolidated overburden, deposited during the Quaternary Period, overlying Paleozoic and Precambrian bedrock. The bedrock geology within the Nottawasaga Valley watershed is illustrated on Figure 3.1-4, and the bedrock topography can be seen on Figure 3.1-5. Below is a more detailed explanation of both the bedrock and quaternary geology.

### **Bedrock Geology**

#### **Precambrian Bedrock**

At depth Precambrian-aged rocks of the Grenville Structural Province likely occur, and are assumed to be similar to those found within the Grenville Structural Province, located north of the study area. These rocks are subdivided into the Grenville Front Tectonic Zone, the Central Gneiss Belt and the Central Metasedimentary Belt (CMS) that is characterized by a suite of metasedimentary rocks (Sanford and Baer, 1981). Rocks of the Central Gneiss Belt are located in the north and north-western regions of the study area and are separated from rocks of the CMS trend by a series of north-west trending faults. Outcrops of metasedimentary rocks are observed in the north-eastern portion of the study area. The Central Metasedimentary Belt is comprised of the following units in the area:

- clastic metasedimentary rocks, predominantly conglomerates, wackestones, limestones and mudstones
- early felsic plutonic rocks such as granodiorite and derived gneisses (Sanford and Baer, 1981)

The Central Gneiss Belt is predominantly composed of three different rock units within the study area. These are

- undifferentiated gneisses and migmatites
- anorthosites and alkalic igneous rocks
- felsic igneous rocks that may contain mineral deposits of tonalite, granodiorite, monzonite, syenite and derived gneisses (Sanford and Baer, 1981)

### **Paleozoic Bedrock**

The prominent bedrock geology of the Nottawasaga Valley watershed is defined as the Paleozoic sedimentary rocks deposited during the Ordovician and Silurian geological periods (Table 3.1- 1). Elevation of the bedrock ranges from over 500 mASL at the Niagara Escarpment to about 130 mASL along the basin's eastern margin; regionally dipping towards the southwest. Outcrop exposure is limited to the western part of the watershed, corresponding largely to the Niagara Escarpment.

### **Middle Ordovician**

The oldest Paleozoic strata within the basin are the limestone and shales of the Simcoe Group, which predominates in the eastern part of the watershed. The Bobcaygeon formation is the oldest unit of the Simcoe Group. It ranges in thickness from 7 m to 87 m, and is dominated by limestone and shale lithologies. It is overlain by the Verulam Formation which consists of limestone with shale interbedding, and is 32 to 65 m thick. The youngest unit in the Simcoe Group sequence is the Lindsay Formation which has a thickness of roughly 67 m and is composed of two members. The lower unnamed member consists of limestones and the upper Collingwood Member consists of limestones and calcareous shales. Collectively the units of the Simcoe Group correspond to shallow sea deposition in the Lapetus Ocean.

### **Upper Ordovician**

Overlying the Simcoe Group is the Blue Mountains, Georgian Bay and Queenston Formations which are of Upper Ordovician age. These formations are exposed in the western portion of the watershed. The Blue Mountain Formation consists of shales, and has a maximum thickness of 60m. The Georgian Bay Formation is also comprised of shales with minor interbeds of siltstones and limestones, with an average thickness of 100 m. The youngest unit is the Queenston Formation, which has thickness range of 45 to 335 m. This formation is dominated by shales with interbeds of limestones and calcareous siltstones. Together the units represent a significant change in the depositional regime with respect to the Simcoe Group. The units

correspond to sedimentation from a relatively proximal, eastward-lying island arc, with the Queenston formation representing deltaic sedimentation from the respective mountain range.

**Silurian**

Overlying the Ordovician rocks are dolostones, shales, limestones, and sandstones of the Lower Silurian Cataract Group which includes the Whirlpool, Manitoulin, and Cabot Head Formations. The Whirlpool Formation is comprised of up to 9 m of sandstone. The Manitoulin Formation along the Niagara Escarpment occurs extensively in the subsurface of southwestern Ontario. It consists of dolostones with a maximum thickness of 25 m and often contains fossils such as brachiopods, crinoids, and corals. The Cabot Head Formation occurs throughout southwestern Ontario and the Niagara Peninsula. It consists of 10 to 39 m of non-calcareous shales with minor calcareous sandstones, dolostones, and limestones.

The youngest Paleozoic rocks within the basin are dolomite from the Amabel and Guelph formations of Middle Silurian age which extends from the Niagara Escarpment to the western boundaries of the basin. The dolomites are up to 38 m thick and are very fossiliferous. These units correspond to quiet water sedimentation in a shallow marine environment within the Michigan Basin.

**Table 3.1- 1: Paleozoic Stratigraphy of the NVCA Watershed**

Series	Stratigraphic Unit
Middle Silurian	Guelph Formation
Middle Silurian	Amabel Formation
Middle Silurian	Fossil Hill Formation
Lower Silurian	Clinton-Cataract Group, Cabot Head Formation
Lower Silurian	Clinton-Cataract Group, Manitoulin Formation
Lower Silurian	Clinton-Cataract Group, Whirlpool Formation
Upper Ordovician	Queenston Formation
Upper Ordovician	Georgian Bay Formation

Series	Stratigraphic Unit
Upper Ordovician	Blue Mountain Formation
Middle Ordovician	Simcoe Group, Collingwood Member Lindsay Formation
Middle Ordovician	Simcoe Group, Verulam Formation
Middle Ordovician	Simcoe Group, Bobcaygeon Formation

**Quaternary Geology:**

The Quaternary geology is represented as the surficial geology within the Nottawasaga Valley watershed, with the exception of the Niagara Escarpment. The surficial geology of the Nottawasaga Valley watershed consists of glacial sediments deposited in the Quaternary period (Figure 3.1-6), and the Niagara Escarpment which is Silurian in age. The glacial deposits in the study area were most likely deposited from the Northern and Georgian Bay lobes of the Laurentide Ice Sheet during or after the Port Bruce Stadial (Deane, 1950; Gravenor, 1957). However, pre-late Wisconsinan deposits likely exist at depth (Barnett, 1991). 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 the Paleozoic sediment, the Paleozoic bedrock topography also appears to 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 east and south sides of the watershed.

**Stratigraphy**

The stratigraphy of the Nottawasaga Valley watershed is dominated by glacial deposits, underlain by weathered bedrock, the exception being the Niagara escarpment where the Paleozoic bedrock is present at the surface. Surficial mapping of glacial tills is useful in understanding the glacial history of an area; it is also helpful in determining groundwater

resources. The types of material present in the subsurface affect the storage, flow direction and rates of groundwater. The stratigraphic framework of the Nottawasaga Valley 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
13. Precambrian Bedrock

#### **York Till**

The Don Formation and underlying York Till have not been mapped within the Nottawasaga Valley 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).

### **Thornccliffe Formation**

The Thornccliffe Formation (also referred to as the Thornccliffe Aquifer Complex) represents glaciofluvial deposition of sand and silty sand generally within lows in the underlying stratigraphy. The Thornccliffe Formation was deposited approximately 45,000 years ago and consists of sedimentary deposits of silt-clay rhythmites 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 an 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).

### **Tavistock Till**

The Tavistock till is found within the watershed over the Niagara Escarpment plateau. The till occurs as gently rolling ground moraine, and was deposited by the Huron-Georgian Bay lobes during the Port Bruce stadial. It is a blocky “reddish” brown clayey silt to gritty silt till comprised of approximately 16% sand, 53% silt, and 32% clay. It is fine grained due to the incorporation of an abundance of lacustrine sediment, which was deposited in waters held up by retreating Catfish Creek and advancing Tavistock Ice. Overall, the till has a low stone content.

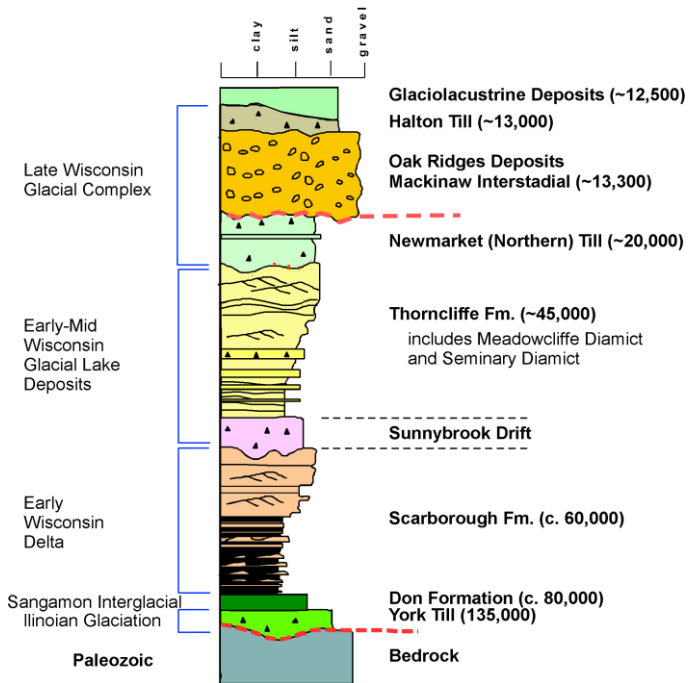
Tavistock till comprises a component of the Dundalk till Plain, which is characterized by a fluted till plain and swamps or bogs and by poorly drained depressions. The Dundalk Till Plain forms the headwater areas of several large Nottawasaga River headwater streams including; the Mad, Noisy, Pine and Boyne Rivers as well as the North and South headwater branches of the Upper Nottawasaga River. This headwater area generally supports a significant groundwater recharge/discharge cycle and supports coldwater fisheries habitats supporting native brook trout.

### **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 3.1-1 below is a schematic representation of the stratigraphy in the Toronto area; this diagram is also representative of the Nottawasaga Valley 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 as well as, 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 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 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 this soils map and the textural data

included within the quaternary geological mapping from the 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 the reader is referred to the 2007 South Georgian Bay-Lake Simcoe Conceptual Water Budget (SGBLS, 2007).

### **3.1.2 Surface Water**

#### **Surface Water System**

The Nottawasaga Valley watershed lies within the Counties of Simcoe, Dufferin, and Grey. The watershed is bounded to the south by the Humber and Credit River Watersheds. In the west the Niagara Escarpment forms part of the western boundary, separating the Nottawasaga Valley from the Grand and Saugeen watersheds. To the east, the Nottawasaga Valley Watershed is bounded by the numerous streams, which drain into Lake Simcoe.

The Nottawasaga River is approximately 122 km in length along its main channel and has a drainage area of 3,147 km<sup>2</sup>. The main branch of the river's headwaters is derived in the till moraines of Amaranth Township, at an elevation of almost 490 mASL. The Nottawasaga River has a total drop of 310 meters to its outlet at Georgian Bay and has an average gradient of 2.6 meters per km. However, in the upper reaches of the river, the gradient is as much as 19 meters per km. The Nottawasaga River has 13 primary tributaries. An unusual characteristic of the Nottawasaga Valley Watershed is its virtual lack of natural lakes. The Nottawasaga Valley watershed has been divided into nine subwatersheds (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. Figure 3.1-11 shows the bathymetry and shoreline of Georgian Bay.

#### **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.

Surface water flows are measured at 12 locations across the Nottawasaga Valley watershed Figure 3.1-12. Table 3.1- 2, shows the location, name and period of record for the streamflow stations used as index stations within the study area. The following six stations were chosen as index stations due to their long period of record.

**Table 3.1- 2: Streamflow Stations in the Nottawasaga Valley Watershed**

Station Location	Station Number	Period of Record*
Boyne River gauge at Earl Row Provincial Park	02ED102	1960-2004
Innisfil Creek gauge at Beeton	02ED004	1960-2004
Mad River gauge at Avening	02ED015	1963-2004
Middle Nottawasaga River gauge at Baxter	02ED003	1951-2004
Pine River gauge at Everett	02ED014	1963-2004
Upper Nottawasaga River gauge at Alliston	02ED101	1963-2004

Note for table above:

1. \*Period of record used in the Tier 1 water budget and stress assessment

**Methods 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 and 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 Stream Flow**

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 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 Nottawasaga River gauge at Baxter was used as the index station. It has the longest and most complete record in the watershed. The Lower Nottawasaga River subwatershed does not have major hydraulic structures upstream of the gauge that may impact the flow regime in the river. 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- 3 displays the mean annual stream flows at the gauging stations.

**Table 3.1- 3: Mean Annual Streamflows of the Nottawasaga Valley Subwatersheds**

Subwatershed	Gauged	Mean Annual Streamflow at Gauge (m <sup>3</sup> /s)	Mean Annual Streamflow at Mouth (m <sup>3</sup> /s)
Innisfil Creek	Yes (Bailey Creek)	1.41	4.46
Upper Nottawasaga	Yes (at Hockley)	1.58	3.67
Boyne River	Yes	2.07	2.71
Pine River	Yes	2.23	3.99
Mad River	Yes	3.19	5.27
Coates Creek	No	Not applicable	1.09
McIntyre Creek	No	Not applicable	1.24
Blue Mountain	No	Not applicable	2.07

Subwatershed	Gauged	Mean Annual Streamflow at Gauge (m <sup>3</sup> /s)	Mean Annual Streamflow at Mouth (m <sup>3</sup> /s)
Nottawasaga	Yes	22.42	23.42
Bear Creek	No	Not applicable	0.9
Willow Creek	No	Not applicable	1.13
Marl Creek	No	Not applicable	1.12
Matheson Creek	Yes (Willow Creek)	0.92	2.79

**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 the 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 baseflow were obtained by calculating the arithmetic mean for each year of record. The results are included below in Table 3.1- 4.

**Table 3.1- 4: Mean Annual Baseflows for the Nottawasaga Valley subwatersheds**

Subwatershed	Gauged	Mean Annual Baseflow (m <sup>3</sup> /s)	Mean Annual Baseflow (mm/yr)
Innisfil Creek	Yes (Bailey Creek)	0.57	36.68
Upper Nottawasaga	Yes (at Hockley)	1.07	92.86
Boyne River	Yes	1.04	136.69
Pine River	Yes	1.45	130.47
Mad River	Yes	1.79	159.63
Coates Creek	No	0.57*	219.48
McIntyre Creek	No	0.59*	155.19
Blue Mountain	No	0.95*	128.30
Nottawasaga	Yes	14.86	158.53
Bear Creek	No	0.41*	149.53
Willow Creek	No	0.61*	57.47
Marl Creek	No	0.58*	205.31
Matheson Creek	Yes (Willow Creek)	1.44	174.21

Notes for table above:

1. (\*) denotes baseflow estimate obtained from gauge

### 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 summarized in Appendix WB-3A; they are based on the 2006 MNR LIO database. Surface water control structures exist, among other reasons, to:

- control flooding
- irrigate crops
- produce electricity
- create transportation pathways

The majority of the surface water control structures present in the watershed are small structures, owned and operated by private owners. Some structures are maintained and operated by the Nottawasaga Valley Conservation Authority to control flooding during seasonal events. These structures are therefore exempt from operational plans (however, the Nottawasaga Valley Conservation Authority is currently creating operational plans for their structures). These structures restrict the surface flow temporarily, mainly diverting water for irrigation purposes. On-line, off-line and by-pass ponds are generally constructed for irrigation purposes.

**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.

### **Surface Water Takings**

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 the majority of overall demand. The permitted and non- permitted surface water takings are summarized in Appendix WB-3B.

### **3.1.3 Ground Water**

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**

A 2003 report from Singer et al. (2003) has identified seven overburden aquifer complexes within the Nottawasaga Valley watershed. These include:

1. Kame and Outwash Aquifer Complex composed of sand and gravel deposits
2. Lake Algonquin Sand Aquifer
3. Thorton Sand Aquifer
4. Glaciolacustrine Aquifer Complex, comprised of sand
5. Alliston Aquifer Complex, comprised of sand
6. Hockley Valley Aquifer, comprised of gravel
7. Oro-Medonte Aquifer, comprised of sand

Table 3.1- 5 summarizes the properties of the overburden aquifer complexes. The extent of the aquifers present in the Nottawasaga Valley watershed is shown in a series of figures ( Figure 3.1-16 to Figure 3.1-19).

**Table 3.1- 5: Aquifer Properties: Nottawasaga Valley Watershed (Singer et al, 2003)**

Aquifer	Spatial Distribution	Type	Estimated Thickness (m)	Elevation (mASL)
Kame and Outwash Aquifer Complex	Surficial East of Escarpment	Unconfined	10 to 30	Surface
Lake Algonquin Sand Aquifer	Throughout watershed, except north-central portion	Unconfined	10	225 to 230
Thornton Sand Aquifer	Innisfil and Essa	Confined	2 to 30	248 to 265
Glaciolacustrine Aquifer Complex	Innisfil, Essa and New Tecumseth	Not applicable	>8	175 to 205
Alliston Aquifer Complex	Innisfil Creek to Wasaga Beach	Regional, Confined	>7	120 to 150 where bedrock surface is above 150
Hockley Valley Aquifer	Bedrock channel under Nottawasaga River	Confined	0 to 150	-
Oro-Medonte Aquifer	Oro-Medonte, Springwater and Innisfil	Unconfined/ Confined	25 to >100	275 to 360

A 2009 interim report from AquaResources and Golder Associates has concluded that the Nottawasaga Valley watershed can be lumped into four regional principal aquifer units, and two bedrock units. The units are briefly summarized below. For a more detailed description of the aquifer characteristics the reader is referred to Nottawasaga Valley Conservation Authority

Water Budget Model- Geological/ Hydrostratigraphic Model Development Interim Report (AquaResources and Golder Associates, 2009).

### **Regional Aquifers**

**A1:** The A1 aquifer is typically found at an elevation of 250 mASL; however, it has been mapped as low as 220 mASL in lowland areas, and as high as 350 mASL in some regions. This aquifer exists mainly as an unconfined surficial aquifer; however, it can be locally confined. It is composed of coarse-grained glacial and interglacial sediments. A1 has a unit thickness ranging from 10-50 m. Overall this aquifer is considered to be a recharge unit.

**A2:** The A2 aquifer is typically found at elevations between 180- 250 mASL; however, it has been mapped as low as 150 mASL in some lowland areas. This aquifer can be absent or very thin in valleys, or very thick in upland areas. In Wasaga beach, Stayner and Angus the aquifer is unconfined. In the Thorton area this aquifer has been combined with the A1 aquifer and is locally known as the Thorton aquifer. This aquifer is typically used for private well water supply.

**A3:** The A3 aquifer is typically found at elevations between 130-210 mASL. It is composed of medium to coarse-grained sediments, with some gravel and silt layers. This unit is generally 35 m thick; however, north of the Oro moraine this unit is found up to 70 m thick. This aquifer supplies water to Alliston, Angus, Barrie, Colgan, Horseshoe Valley, Midhurst, Orillia, Stroud, Tottenham and Wasaga Beach.

**A4:** The A4 aquifer is typically found at elevations below 150 mASL. In the Barrie area this aquifer is characterized by deep tunnel channel sediments. It is composed of medium sized coarse-grained sand and gravel. When defined as a regional unit in the Alliston-Tottenham area the aquifer is thinner, and composed of a finer grained sand or silty sand mix. This aquifer is not continuous across the watershed, and ranges in thickness from 3-30 m.

**Bedrock Aquifers:** The Guelph/Amabel and Clinton-Contact bedrock aquifers exist in the watershed area. They are considered to be confined aquifer units with the exception of karst features along the Niagara Escarpment. The elevation of these aquifers ranges from 250 mASL - 525 mASL.

### **Groundwater Flow**

In the Nottawasaga Valley watershed, the migration of groundwater in the shallow and deep aquifer regime generally follows the ground surface topography and the surface drainage. Groundwater migration in Simcoe County is generally towards the Nottawasaga River and its tributaries, or Georgian Bay. According to Golder Associates (2004b), the elevation of the shallow water table ranges from approximately 510 mASL (obtained from the top of the

Niagara Escarpment) to 180 mASL near the eastern shore of Georgian Bay. The elevation of the potentiometric surface ranges from approximately 510 mASL in the vicinity of the Niagara Escarpment to less than 180 mASL near the shore of Georgian Bay. In addition, the potentiometric surface ranges from approximately 250-330 mASL in the Simcoe Upland areas and on the Oro Moraine (Golder Associates 2004b). Figure 3.1-20 illustrates the shallow water table elevation of the Nottawasaga Valley watershed.

Figure 3.1-21 illustrates the shallow groundwater flow of the Nottawasaga Valley watershed. In Dufferin County, the migration of groundwater coincides with ground surface topography in the Townships of Mulmur and Mono. Groundwater flow is generally towards the east in Mono and Mulmur, where the elevation of the water table ranges from approximately 480 mASL to less than 240 mASL. The elevation of the potentiometric surface in Mono and Mulmur was observed to be similar to the water table elevation (R.J. Burnside Environmental, 2001).

In the vicinity of Amaranth, the water table elevation ranges from approximately 460 mASL to 495 mASL and an apparent shallow groundwater divide was identified along the east portion of the study area where the groundwater flows towards the Nottawasaga and Credit River watersheds (R.J. Burnside Environmental, 2001a). The elevation of the potentiometric surface in Amaranth ranges from approximately 500 mASL to 440 mASL. A potentiometric divide is located west of the Nottawasaga Valley watershed, just west of Luther Marsh in the Township of East Luther/Grand Valley (R.J. Burnside Environmental, 2001a).

An analysis of basin transfer was undertaken by Greenland (2001) as part of the AEMOT study. This analysis indicated that groundwater movement from the Grand River Watershed into the Boyne River Watershed, located within Dufferin County, may be occurring (according to groundwater flow directions). In addition, within Dufferin and Grey Counties, groundwater transfer between sub-basins, such as from the Mad River Basin to the Noisy River Basin, may be occurring along the southern boundary of the Mad River Basin (Greenland, 2001). Further details are provided in the AEMOT study prepared by Greenland. A map of the hydraulic potentials of the regional groundwater flow system is presented by Greenland (2001).

According to Golder Associates (2004b), although large shallow groundwater gradients (39 m/km) are found between the top and bottom of the Niagara Escarpment, typical gradients are observed to be between 4 m/km and 6 m/km in the majority of Simcoe County.

Golder Associates (2004b) identified the presence of downward vertical hydraulic gradients across most of the watershed. These gradients were observed to be greatest in the vicinity of the Simcoe Uplands including the Oro Moraine and on parts of the Niagara Escarpment. In addition, upward hydraulic gradients were observed in areas of lower elevation such as

Minesing Swamp and along portions of the Nottawasaga River and its tributaries (Golder Associates, 2004b). In the vicinity of Mono and Mulmur, downward vertical gradients are present in the elevated portions of these areas. Upward gradients were observed in the vicinity of the Boyne and Pine Rivers in Mulmur and along the Nottawasaga River in Mono. In Amaranth, upward vertical gradients and flowing wells were observed at several locations. A summary of vertical gradients measured in monitoring wells located in Dufferin County are presented in R.J. Burnside Environmental (2001a).

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 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 50,000L/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 uses, 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) 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 50,000L/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 purpose 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. Having said that, 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.

### **3.1.4 Interactions between Ground and Surface Water**

#### **Recharge**

Figure 3.1-22 represents potential recharge across the watershed region as a function of geology (permeable materials) and hydraulic gradient (downward gradients from the water well records). This map was considered preliminary and has been refined in further water budget efforts documented in Sections 3.2.2 and 3.4.2.

In the Nottawasaga Valley watershed the Oro Sand Hills, the uplands near Barrie and portions of the Niagara Escarpment are considered to be regionally significant recharge areas. According to Golder Associates (2004b), the mean annual groundwater recharge in Simcoe County ranges from 70 mm to 335 mm; the highest recharge rates occur in the lower Pine River, Willow Creek and Lower Nottawasaga River subwatersheds. The lowest recharge rates occur in the upper Nottawasaga River watershed (Golder Associates, 2004b).

Within Grey County and portions of Dufferin County, Greenland (2001) reported that recharge areas occur where moraine deposits are found and that recharge is greatest on top of the Escarpment in areas where ice-contact glacial deposits and moraines are present. Recharge areas were identified in Mono, Mulmur and Amaranth in Dufferin County, using significant downward gradients, and are generally located in areas of elevated topography with permeable sand and gravel formations (R.J. Burnside Environmental, 2001; R.J. Burnside Environmental, 2001a; R.J. Burnside Environmental, 2001b). Maps illustrating the recharge areas for the above communities are presented in the above referenced reports.

### **Discharge**

Discharge areas are presented in Figure 3.1-22, which correspond well with stream valleys and wetlands. Areas of shallow groundwater discharge in Simcoe County were identified by Golder Associates (2004b) by comparing the elevation of the shallow water table with the ground surface elevation across the study area. Identified discharge areas include the flanks of the Simcoe Uplands, which provide baseflow to streams that feed into the Nottawasaga River and are located along the base of the Niagara Escarpment, and the Minesing Swamp.

According to Golder Associates (2004), the Minesing Swamp acts as a major regional discharge area for both the shallow and deep groundwater aquifers. Artesian conditions are common in the vicinity of the Minesing Swamp. Discharge areas were identified in Dufferin County by R.J. Burnside Environmental (2001b). In Amaranth, groundwater discharge areas were identified in the southern and northern portions of the town.

Discharge areas within Grey and Dufferin Counties were identified by Greenland (2001) and include the following major river systems: the Boyne River, Mad River, Pretty River and Noisy River. Baseflow measurements for various watercourses within the watershed were collected by Greenland (2001) and indicated that groundwater contributes a significant portion of flow to the watercourses. According to Greenland (2001), within the AEMOT study area, 95% of infiltration discharges locally to streams and rivers and the remaining 5% contributes to regional flow. Further details regarding groundwater discharge and flow are presented in Greenland (2001) including a map of the discharge areas for the AEMOT study area.

According to Greenland (2001), the Osprey Wetlands, a large Provincially Significant Wetland, is also a significant groundwater discharge area. This wetland provides baseflow to the Mad River (Greenland, 2001).

### **Aquatic Habitat**

Both coldwater and warmwater aquatic habitats are found within the Nottawasaga Valley watershed. A detailed description of the habitats can be found in Section 2.1.1.1, along with a map of coldwater and warmwater 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 3.1-23 is

a map of groundwater discharge overlaid by coldwater, warmwater fisheries map. Areas of coldwater habitat can confirm the presence of groundwater discharge.

### **3.1.5 Land Use and Land Cover in the Source Water 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. Some portions of the watershed are experiencing an increase in residential development. 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 coldwater 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 area. 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.

### **3.1.6 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 SWP project area occurs within three climatic regions including; the Dundalk Upland, Simcoe and Kawartha Lakes, and Muskoka. The majority of the Nottawasaga Valley watershed is within the Simcoe and Kawartha Lakes climatic region. Precipitation in the watershed area is somewhat lighter than that of the areas located around it because of the rain-shadow effect created by the western uplands.

#### **Climate Stations**

Climate data is collected by Environment Canada (EC) at twelve active stations in the SWP area. Seven of which are located in the Nottawasaga Valley watershed. In addition to the EC stations, the Ministry of the Environment, Nottawasaga Valley Conservation Authority, Lake Simcoe

Region Conservation Authority and the Severn Sound Environmental Association maintain and operate several precipitation stations in the SWP area.

In addition to the above mentioned data sources, historic data has been collected from active and inactive stations within and adjacent to the SWP study area. Table 3.1- 6 shows the Environment Canada monitoring stations in the watershed. Additional details regarding climate normals and the precipitation gauge network are presented in Appendix WB-3A.

**Table 3.1- 6: Environment Canada: Climate Monitoring Stations in the South Georgian Bay Lake Simcoe Source Protection Region**

Watershed	ID	Station Name	Begin (Year)	End (Year)	Period (Years)	Status	Latitude North	Longitude West	Elevation (mASL)
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	15	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

Watershed	ID	Station Name	Begin (Year)	End (Year)	Period (Years)	Status	Latitude North	Longitude West	Elevation (mASL)
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° 55'	80° 05'	412
Nottawasaga Valley	6118002	Borden AWOS	1996	2006	11	Active	44° 16'	79° 54'	222.5
Nottawasaga Valley	6110218	Alliston	1973	2006	34	Active	44° 9'	79° 52'	221

Watershed	ID	Station Name	Begin (Year)	End (Year)	Period (Years)	Status	Latitude North	Longitude West	Elevation (mASL)
Nottawasaga Valley	6111792	Collingwood	1974	2006	33	Active	44° 30'	80° 13'	179.8
Nottawasaga Valley	6.11E+03	Egbert CS	2000	2006	7	Active	44° 15'	79° 46'	251
Severn Sound	6113490	Honey HBR Beausoleil*	1974	2000	27	Active	44° 51'	79° 52'	183
Severn Sound	6115127	Midland WPCP	1974	2000	27	Active			
Severn Sound	6111769	Coldwater Warminister	1971	2000	30	Active	44° 38'	79° 32'	285

Notes for the table above:

1. (\*) denotes the station is located outside of the SWP study area

### **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 (bull's-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-3A.

Analysis of the average annual 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 T~~the MNR ~~has~~ initiated a study to infill temporal and spatial gaps in climatological data across the province. The results of the study have been 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 caused 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) A6 (2006) report for Lake Simcoe (Scott et al, 2006). The LSEMS reported values are derived from a climate model that incorporates elevation, latitude, longitude, temperature, relative humidity, solar radiation, vapour pressure and dew point temperature data. The areal extent of surface water bodies, as determined from GIS layers, was then multiplied by the annual evaporation depth estimated for Nottawasaga Valley 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 <sup>2</sup> )	Annual Evaporation (mm/m <sup>2</sup> )	Annual Evaporation (mm <sup>2</sup> )
Nottawasaga	Water	9.19	672	6.17
Nottawasaga	Wetlands	53.34	Not applicable	Not applicable
Nottawasaga	Vegetation	2718	Not applicable	Not applicable
Nottawasaga	Urban	358	Not applicable	Not applicable

**Evapotranspiration**

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration. Evapotranspiration 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 generally coincide with the summer season, when water may be in short supply. Evapotranspiration rates are also dependent 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 more or less 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), Penman-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 method used was the Hamon reference ET method since air temperature data is available at all the climate stations in the study area. The Hamon Reference method is shown below.

Hamon Equation:

$$ET_{\text{Hamon}} = 13.97dD2Wt$$

where:

$ET_{\text{Hamon}}$  is the 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 12h and

$Wt$  is a saturated water vapour density term calculated by  $Wt = (4.95 e^{0.062T})/100$

where:

$T$  is the monthly mean temperature in °C

The ET derived from the reference crop using the 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 the MNR (1984, page 23) for the region of this study.

**Table 3.1- 8: NVCA Watershed Mean Monthly and Annual Actual ET and Annual Reference ET**

Month	Mean Actual Evapotranspiration from the Watershed (mm)
January	7.86
February	9.95
March	20.06
April	41.16
May	73.69
June	100.39
July	120.20
August	94.51
September	57.26
October	29.91
November	15.36
December	8.97
Annual Total - Ref. ET	579.32
Annual Total - Actual ET	556.15

**Potential Impacts of Climate Change**

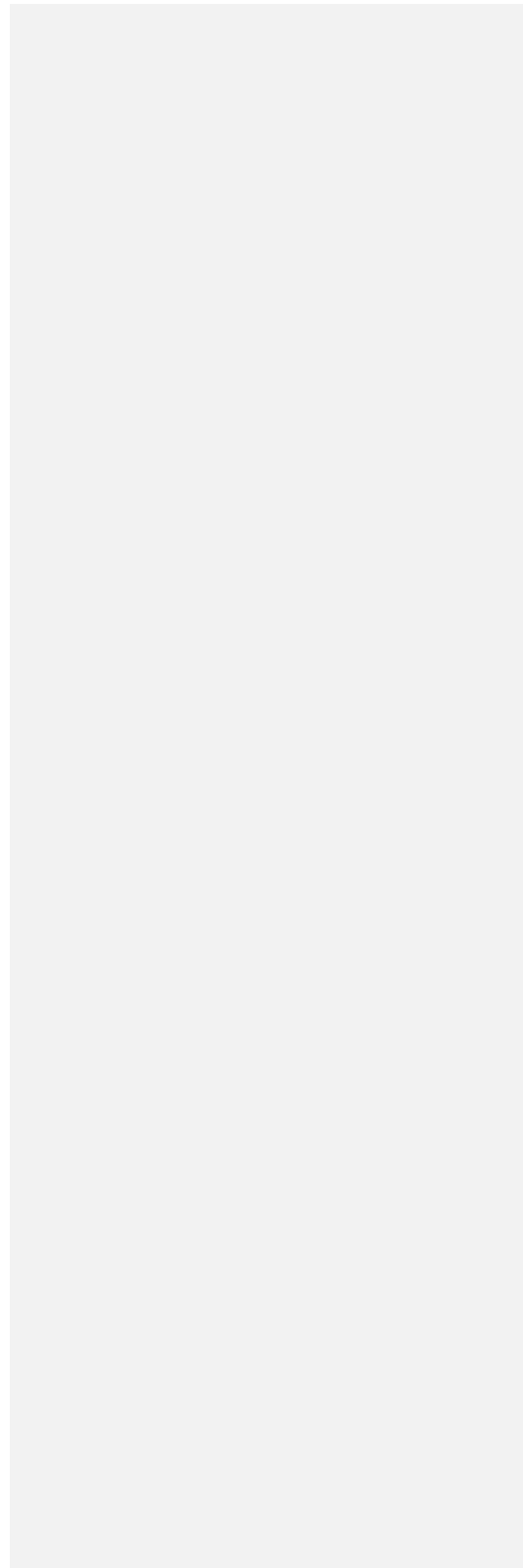
The potential impacts of climate change, as well as current climate trends within the Nottawasaga Valley watershed will be discussed in Chapter 18: The Assessment Report in Context.

**Figure 3.1-1: Physiographic Regions**

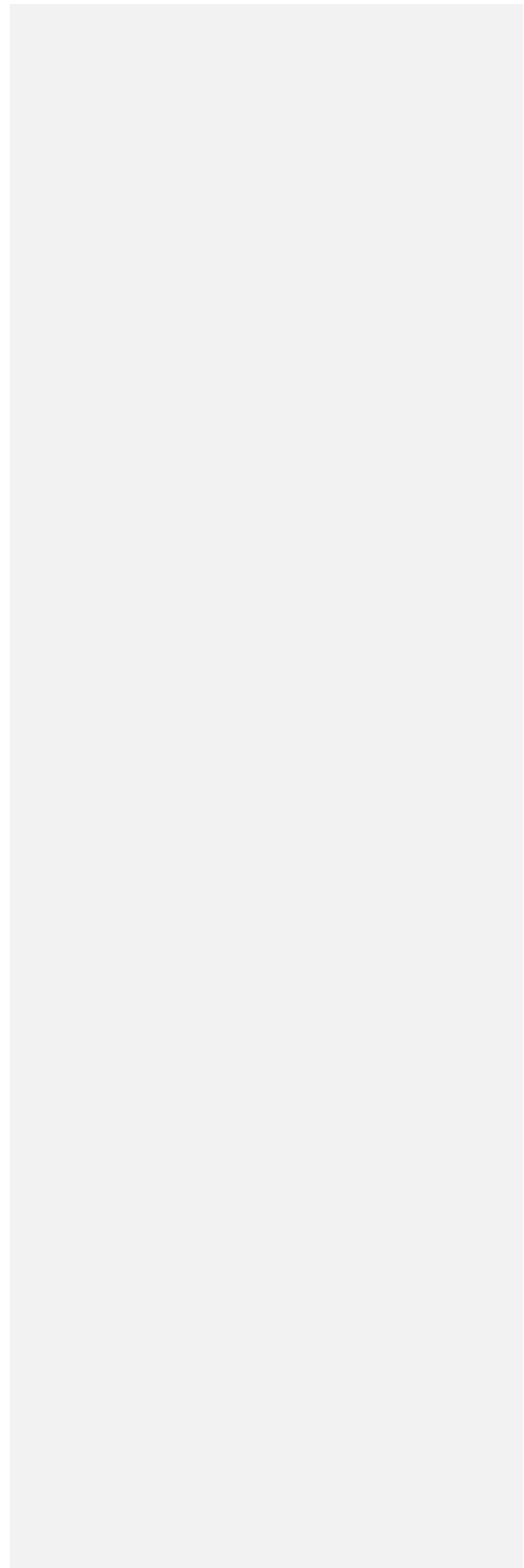
**Figure 3.1-2: Ground Surface Topography**

**Figure 3.1-3: Hummocky Topography**

**Figure 3.1-4: Bedrock Geology**

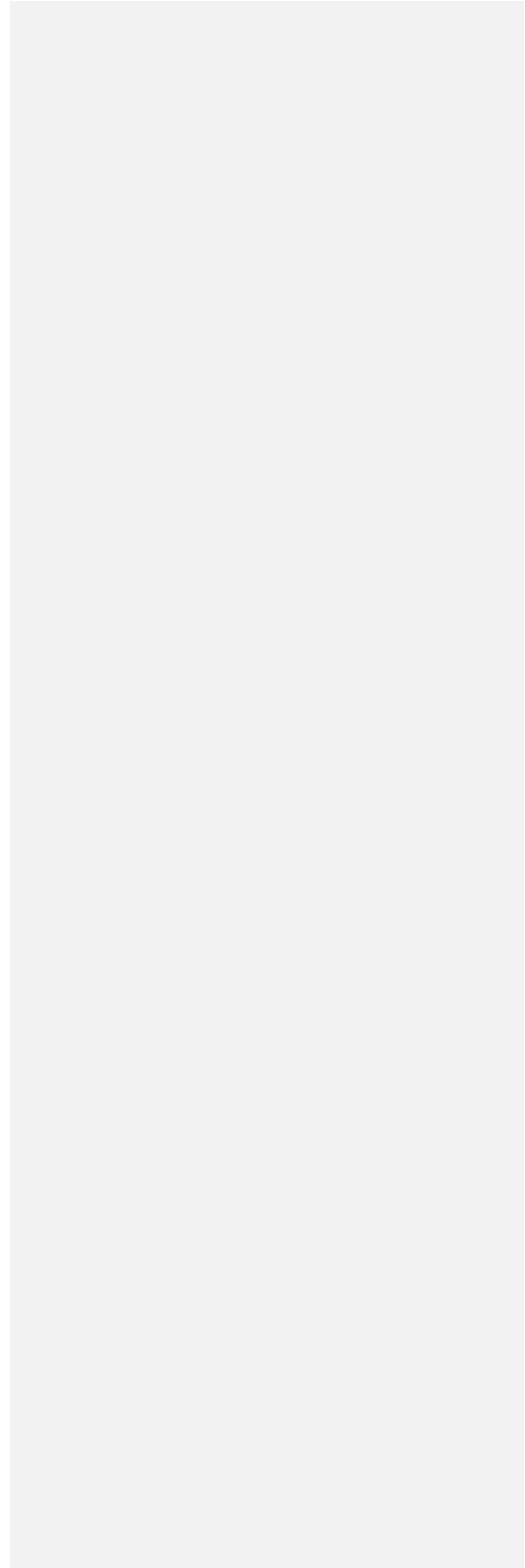


**Figure 3.1-5: Bedrock Topography**



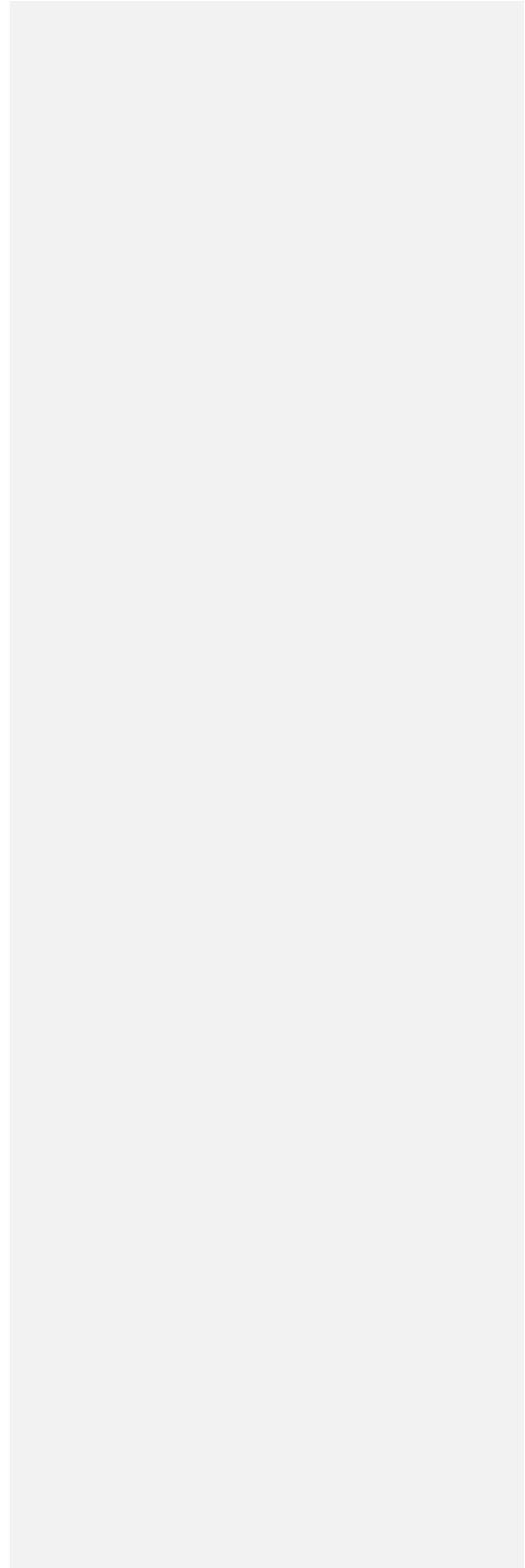
**Figure 3.1-6: Surficial Geology**

**Figure 3.1-7: Overburden Thickness**



**Figure 3.1-8: North-South Cross-Section**

**Figure 3.1-9: East-West Cross-Section**



**Figure 3.1-10: Soils**

**Figure 3.1-11: Bathymetry of Georgian Bay**

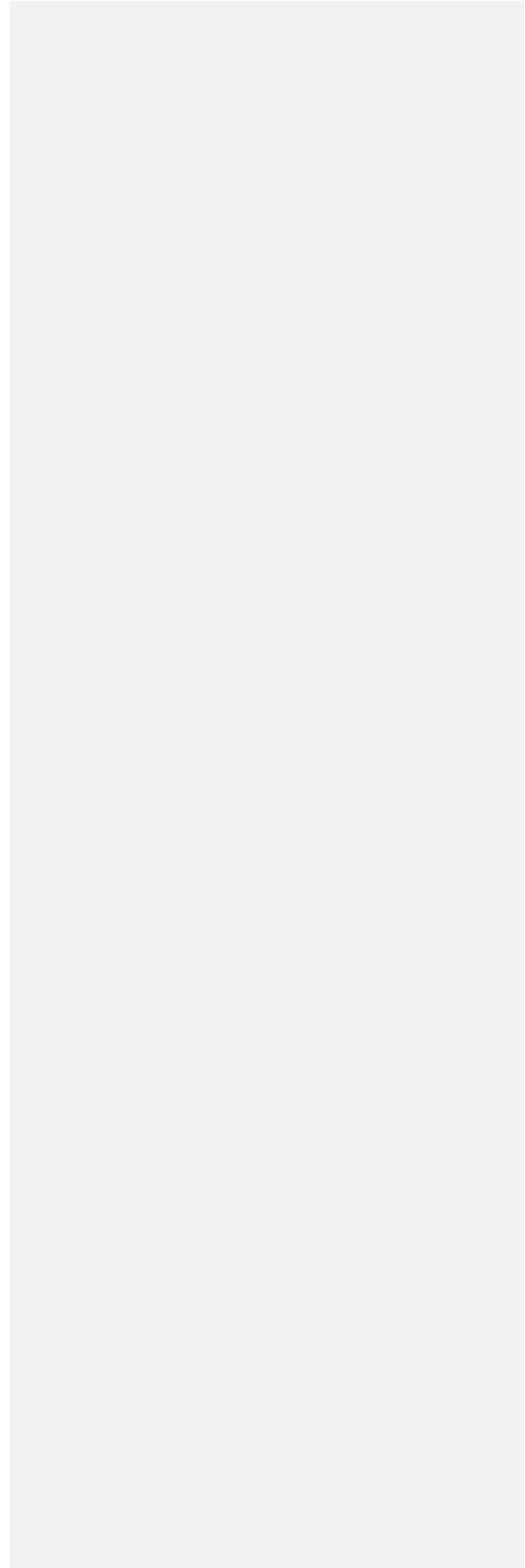
**Figure 3.1-12: Streamflow Gauging Stations**

**Figure 3.1-13: Surface water control structures**

**Figure 3.1-14: Municipal surface and groundwater taking locations.**

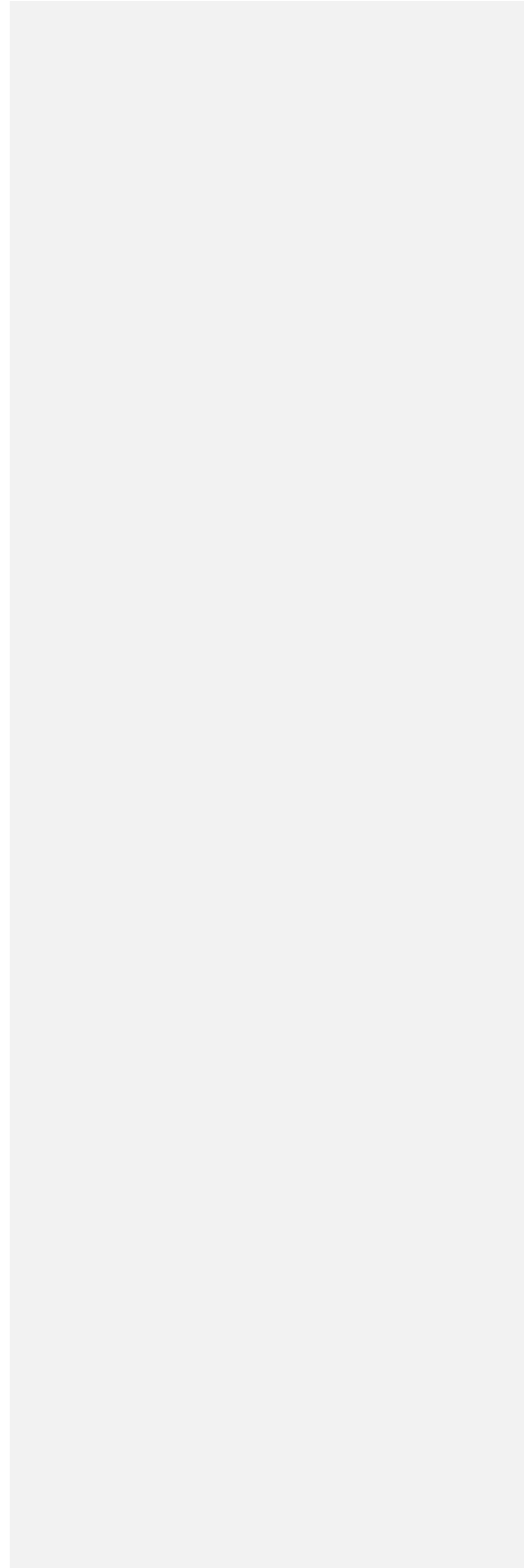
**Figure 3.1-15: Non-municipal surface and groundwater taking locations.**

**Figure 3.1-16: A1 Aquifer Extent**



**Figure 3.1-17: A2 Aquifer Extent**

**Figure 3.1-18: A3 Aquifer Extent**



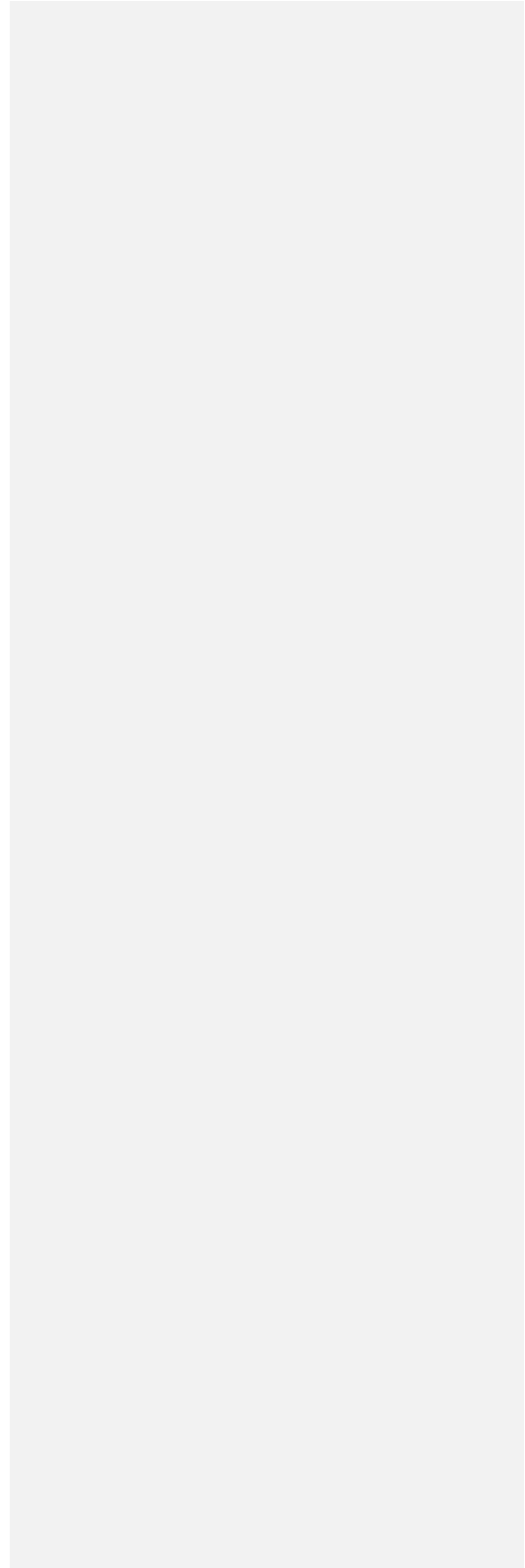
**Figure 3.1-19: A4 Aquifer Extent**

**Figure 3.1-20: Shallow Water Table Elevation**

**Figure 3.1-21: Groundwater flow direction**

**Figure 3.1-22: Potential groundwater recharge and discharge areas**

**Figure 3.1-23: Aquatic Habitat**



### **3.2 Tier 1 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 water 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 Nottawasaga Valley 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.

#### **3.2.1 Study Area and Physical Setting**

The Nottawasaga Valley watershed has been divided into nine subwatersheds or hydrological units, each drained by one or more tributaries, as outlined in Section 2.2. The subwatersheds range in size from 220 to 490 km<sup>2</sup> and cross political boundaries. The largest unit is the Innisfil Creek subwatershed at 490 km<sup>2</sup>. It is found within four Upper Tier and 8 Lower Tier municipalities. As previously mentioned, the total area of the Nottawasaga Valley watershed is 3,147 km<sup>2</sup>. An unusual characteristic of the Nottawasaga Valley watershed is its virtual lack of natural lakes.

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 3.1.3 and Figure 3.1-20).

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 flow divides and 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 Nottawasaga Valley Conservation Authority (NVCA), 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 databases were used for this evaluation: precipitation data from 1950 to 2005; temperature data from 1970 to 2000; and streamflow data from 1985 to 2005 (a preliminary check of the data shoed no significant difference in the 20 year versus 55 year streamflow data sets). Surface water evaluations are monthly summations and statistics (median monthly and annual) on daily measured stream flow (or estimated flows are described in subsequent sections).

### **3.2.2 Water Supply**

This section is a summary of the methods used in the South Georgian Bay-Lake Simcoe Tier 1 Water Budget and Water Quantity Stress Assessment: Nottawasaga Valley watershed study; herein referred to as the Tier 1. More detail on the methods and assumptions used in the Tier 1 can be found within the report (SGBLS, 2009).

The following sections outline the components of a Water Budget and the methods used to derive each. In addition, this section discusses the calculations used and the variables which have not been considered within this phase of the Water Budget. Information collected throughout the peer review of the Conceptual Water Budget (SGBLS, 2007) have been incorporated into the Tier 1 report, in an attempt to increase the certainty and refine all of the aspects of the water budget and quantity stress assessment.

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.

For surface water resources, available supply is considered to be a proportion of streamflow, which is monitored at a number of stations across the Nottawasaga Valley watershed. 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:

1.  $P-ET = \text{Rech} + \text{Roff}$     *or*     $\text{Rech} = P-ET-\text{Roff}$
2.  $\text{SWO} = \text{Roff} + \text{BF}$     *or*     $\text{Roff} = \text{SWO}-\text{BF}$

Substituting Equation 2 into Equation 1 yields;

3.  $\text{Rech} = P - ET - \text{SWO} + \text{BF}$

where:

P    is precipitation

ET    is evapotranspiration

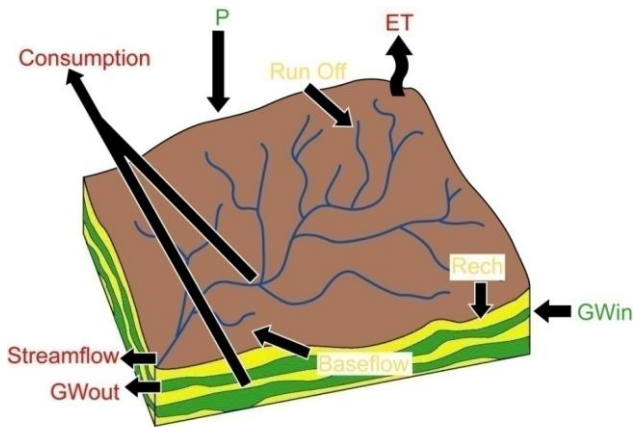
SWO    is total Streamflow out of a subwatershed

BF    is baseflow or groundwater discharge component of streamflow

Rech    is groundwater recharge

Roff    is runoff

The following Diagram 3.2- 1 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.



**Diagram 3.2-1: Water balance budget**

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 (assumes no basin transfers). 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**

Precipitation is monitored at 8 climate stations within the Nottawasaga Valley watershed and at 96 stations within the SWP region. This network provides a reasonable coverage across the Nottawasaga Valley watershed, 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 1 assessment were collected by Environment Canada and modified based on the 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 (mm) by Subwatershed**

Subwatershed	Gauged or Ungauged	Area (km <sup>2</sup> )	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Boyne River	Gauged	240	72	64	66	70	75	76	80	89	79	75	84	75	905
Innisfil Creek	Gauged	490	57	52	56	66	72	74	77	86	72	67	74	65	818
Mad River	Gauged	452	84	67	67	68	75	77	79	87	86	78	90	84	944
Middle Nottawasaga	Gauged	297	67	55	55	65	71	73	78	85	77	69	78	73	846
Pine River	Gauged	347	78	66	69	69	75	75	80	88	81	77	88	78	923
Upper Nottawasaga	Gauged	338	69	61	65	70	75	77	80	89	78	72	83	73	892
Lower Nottawasaga	Ungauged	455	85	60	58	64	75	80	78	83	90	78	87	84	922
Blue Mountain Watersheds	Ungauged	221	91	62	62	66	78	77	76	83	89	78	91	91	943
Willow Creek	Ungauged	307	84	61	58	65	75	82	79	85	91	79	86	81	925

Notes for the above table:

1. Values rounded for presentation purposes. All values in (mm) except where noted

### 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 these data calculated using the Thornthwaite method to the ET previously calculated with 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 evapotranspiration.

**Table 3.2- 2: Monthly and Annual Potential Evapotranspiration**

Subwatershed	Gauged or Ungauged	Area (km <sup>2</sup> )	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Boyne River	Gauged	240	0	0	1	28	78	110	123	110	76	37	8	0	572
Innisfil Creek	Gauged	490	0	0	1	30	79	112	125	111	77	38	9	0	583
Mad River	Gauged	452	0	0	1	28	76	110	122	109	76	38	8	0	567
Middle Nottawasaga	Gauged	297	0	0	1	30	78	112	126	112	77	38	9	0	581
Pine River	Gauged	347	0	0	1	28	77	110	122	109	75	37	7	0	565
Upper Nottawasaga	Gauged	338	0	0	1	28	77	110	123	109	76	37	8	0	569
Lower Nottawasaga	Ungauged	455	0	0	1	29	77	112	126	113	78	39	10	0	584
Blue Mountain Watersheds	Ungauged	221	0	0	1	29	76	111	125	112	79	41	11	0	584
Willow Creek	Ungauged	307	0	0	1	29	78	113	128	114	77	38	9	0	586

Notes for above table:

1. Values rounded for presentation purposes. All values in (mm) except where noted

**Table 3.2- 3: Monthly and Annual Actual Evapotranspiration**

Subwatershed	Gauged or Ungauged	Area (km <sup>2</sup> )	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Boyne River	Guaged	240	0	0	1	27	75	106	118	105	73	36	7	0	549
Innisfil Creek	Guaged	490	0	0	1	29	76	108	120	107	74	36	9	0	560
Mad River	Guaged	452	0	0	1	27	73	105	117	105	73	36	8	0	545
Middle Nottawasaga	Guaged	297	0	0	1	29	75	108	121	107	74	36	9	0	558
Pine River	Guaged	347	0	0	1	27	74	106	117	104	72	35	7	0	543
Upper Nottawasaga	Guaged	338	0	0	1	27	74	105	118	105	73	36	8	0	546
Lower Nottawasaga	Ungauged	455	0	0	1	28	74	107	121	108	74	37	9	0	560
Blue Mountain Watersheds	Ungauged	221	0	0	1	28	73	106	120	108	76	39	11	0	560
Willow Creek	Ungauged	307	0	0	1	27	75	108	123	109	74	36	9	0	562

Notes for above table:

1. Values rounded for presentation purposes. All values in (mm) except where noted

### **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 that 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 12 sites across the Nottawasaga Valley watershed (Figure 3.2-3). The streamflow data used in this evaluation was collected from 1960 to 2004. 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 (See Table 3.2- 4)

**Table 3.2- 4: Index Streamflow Station Information**

Station Location	Station Number	Period of Record
Boyne River gauge at Earl Rowe Provincial Park	02ED102	1960-2004
Innisfil Creek gauge at Beeton	02ED <del>100015</del>	1960-2004
Mad River gauge at Avening	02ED015	1963-2004
Middle Nottawasaga River gauge at Baxter	02ED003	1951-2004
Pine River gauge at Everett	02ED014	1963-2004
Upper Nottawasaga River gauge at Alliston	02ED101	1963-2004

Mean and median monthly streamflow values are presented in Table 3.2- 5 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 coefficient with their neighbouring index station.

**Method Used to Estimate Missing Streamflow Data in Gauged Subwatersheds**

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. 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  $N_2$  years. 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 12 currently gauged locations in the Nottawasaga Valley watershed (Figure 3.2-3). Application involved the quantification of basin characteristics. This quantification required or 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 (Figure 3.2- 5) 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 (below) illustrates observed and estimated data<sup>1</sup>

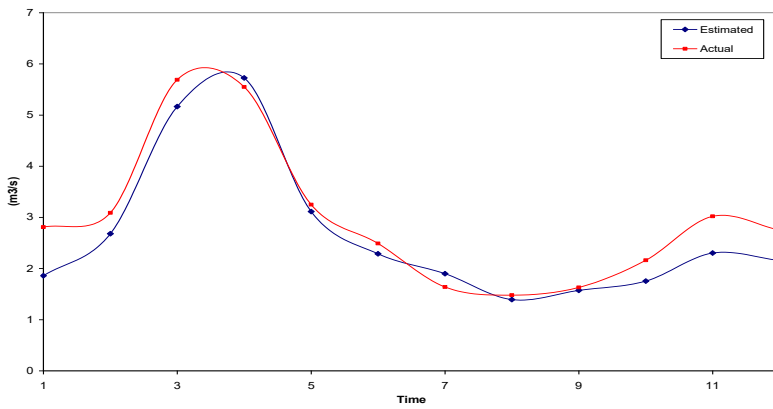


Figure 3.2-a. Hydrograph

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<sup>1</sup> 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	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual
Boyne River	Gauged	1.8	2.3	4.6	5.2	2.4	1.6	1.1	0.9	1.1	1.4	1.9	1.9	2.2
Innisfil Creek	Gauged	2.0	2.8	8.4	7.2	3.4	2.3	1.4	1.1	1.3	1.8	2.2	2.3	3.0
Mad River	Gauged	4.5	4.9	11.4	16.7	7.4	4.2	2.9	2.1	2.3	3.0	4.5	4.8	5.7
Middle Nottawasaga	Gauged	8.3	10.3	24.4	27.0	11.7	7.0	5.0	4.1	4.8	6.8	9.0	9.1	10.6
Pine River	Gauged	3.1	3.4	6.6	7.9	4.8	3.5	2.7	2.2	2.1	2.5	2.8	3.2	3.7
Upper Nottawasaga	Gauged	2.9	3.8	6.8	6.6	3.6	2.5	1.8	1.7	1.9	2.3	3.1	3.1	3.3
Lower Nottawasaga	Ungauged	5.2	4.6	11.0	10.9	5.2	3.0	1.8	1.4	2.4	3.1	5.9	4.9	4.9
Blue Mountain Watersheds	Ungauged	1.8	1.4	3.3	3.2	1.5	1.0	0.6	0.7	1.1	1.1	1.9	1.7	1.6
Willow Creek	Ungauged	3.2	2.8	5.6	5.5	3.0	2.1	1.3	1.2	1.9	2.1	3.0	2.9	2.9

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/s except where noted
2. Total flow from the Middle Nottawasaga River, includes upper subwatershed flows from Innisfil, Boyne, and Upper Nottawasaga

**Table 3.2- 6: Monthly Median Streamflow**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual
Boyne River	Gauged	1.3	1.4	2.8	3.4	1.8	1.2	0.8	0.7	0.8	1.0	1.5	1.5	1.3
Innisfil Creek	Gauged	1.2	1.3	4.3	4.5	2.4	1.4	0.8	0.8	0.9	1.3	1.7	1.7	1.5
Mad River	Gauged	3.6	3.4	8.1	13.4	6.2	3.7	2.3	1.8	1.8	2.3	3.6	3.8	3.5
Middle Nottawasaga	Gauged	5.8	6.0	15.5	18.0	8.9	5.3	3.6	3.3	3.6	4.8	6.8	6.9	6.1
Pine River	Gauged	2.6	2.6	5.1	6.7	4.5	3.3	2.4	2.0	1.9	2.2	2.5	2.7	2.8
Upper Nottawasaga	Gauged	2.1	2.2	4.5	4.8	3.0	2.1	1.6	1.5	1.4	1.9	2.5	2.6	2.2
Lower Nottawasaga	Ungauged	2.8	2.5	5.5	8.1	3.8	1.5	1.2	1.0	1.3	2.1	3.7	3.4	3.1
Blue Mountain Watersheds	Ungauged	0.9	0.8	1.5	1.6	1.0	0.7	0.5	0.5	0.5	0.6	0.9	0.9	0.9
Willow Creek	Ungauged	1.6	1.5	2.9	3.7	2.1	1.3	1.0	0.8	0.9	1.2	1.9	1.8	1.7

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/s except where noted

### **Mean Annual Baseflow**

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 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 National Water Research Institute and Meteorological Service of Canada (Piggott *et al.*, 2005) was used. This method has revisions resolving two aspects of the original 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	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual
Boyne River	Gauged	1.3	1.4	2.0	2.2	1.4	1.0	0.7	0.7	0.8	1.0	1.3	1.3	1.3
Innisfil Creek	Gauged	1.2	1.4	2.5	3.0	1.8	1.2	0.7	0.6	0.9	1.2	1.5	1.6	1.5
Mad River	Gauged	3.1	3.1	5.4	8.1	5.0	3.2	2.2	1.6	1.6	2.3	3.3	3.2	3.5
Middle Nottawasaga	Gauged	5.7	6.2	9.5	11.5	7.2	4.9	3.3	3.0	3.7	4.8	6.3	6.7	6.1
Pine River	Gauged	2.2	2.3	3.5	4.8	3.6	2.7	2.1	1.7	1.7	2.0	2.2	2.3	2.6
Upper Nottawasaga	Gauged	2.0	2.1	2.8	3.4	2.4	1.8	1.4	1.3	1.4	1.8	2.2	2.3	2.1
Lower Nottawasaga	Ungauged	2.8	2.7	4.1	6.1	2.8	1.2	0.8	0.7	1.3	1.9	3.0	3.1	2.5
Blue Mountain Watersheds	Ungauged	0.9	0.8	1.1	1.5	0.8	0.3	0.3	0.2	0.5	0.6	0.9	1.0	0.7
Willow Creek	Ungauged	1.7	1.6	2.2	2.8	1.6	0.8	0.7	0.6	1.0	1.3	1.7	1.8	1.5

Notes for above table:

1. Values rounded for presentation purposes (methods of summing will alter totals slightly). All values in m<sup>3</sup>/s except where noted
2. Total flow from the Middle Nottawasaga River, includes upper subwatershed flows from Innisfil, Boyne, and Upper Nottawasaga

**Water Budget Reserve:**

Within the 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 10<sup>th</sup> percentile of stream flow (Q<sub>90</sub>) 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.

**Surface Water Reserve Estimation**

The methods recommended within Technical Rules (MOE, 2008a) to estimate the water reserve include 10<sup>th</sup> percentile streamflow (Q<sub>90</sub>), 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 (MAF) to local hydrologic and biologic conditions including monthly variability.

As noted within the MOE Guidance Module 7 (MOE, 2006), 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, although not required for this assessment. This has been done based on the MOE Guidance Module 7 (MOE, 2006), 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.

**Table 3.2- 8: Surface Water Reserve Estimates**

Subwatershed	Gauged (Qp90) or Ungauged (Tess mann)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Boyne River	Gauged	0.85	0.84	1.06	1.56	1.03	0.64	0.47	0.50	0.52	0.60	0.84	0.85	0.63
Innisfil Creek	Gauged	0.63	0.64	1.14	2.21	1.20	0.66	0.39	0.44	0.51	0.74	0.96	1.00	0.62
Mad River	Gauged	1.69	1.95	2.73	6.43	3.86	2.36	1.41	1.14	1.02	1.20	1.45	1.87	1.47
Middle Nottawasaga	Gauged	3.51	3.45	5.56	8.55	4.94	3.11	2.22	2.24	2.49	3.04	3.77	4.07	2.94
Pine River	Gauged	1.58	1.58	2.15	3.69	2.80	2.12	1.50	1.37	1.30	1.46	1.57	1.73	1.58
Upper Nottawasaga	Gauged	1.41	1.36	1.94	2.65	1.89	1.35	1.08	0.99	1.0	1.20	1.61	1.62	1.26
Lower Nottawasaga	Ungauged	1.98	1.85	1.98	1.98	1.98	1.20	0.72	0.54	0.96	1.23	1.98	1.94	1.53
Blue Mountain Watersheds	Ungauged	0.64	0.58	0.64	0.64	0.61	0.39	0.25	0.26	0.43	0.45	0.64	0.64	0.52
Willow Creek	Ungauged	1.16	1.12	1.16	1.16	1.16	0.85	0.51	0.50	0.78	0.84	1.16	1.16	0.96

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/s except where noted

### **Groundwater Reserve Estimation**

The Technical Rules (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 3.1.4), for gauged and simulated stream hydrographs. The baseflow separation results have been included in Table 3.2- 9.

**Table 3.2- 9: Groundwater Reserve Estimates**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual
Boyne River	Gauged	0.13	0.14	0.20	0.22	0.14	0.10	0.07	0.07	0.08	0.10	0.13	0.13	0.13
Innisfil Creek	Gauged	0.12	0.14	0.25	0.30	0.18	0.12	0.07	0.06	0.09	0.12	0.15	0.16	0.15
Mad River	Gauged	0.31	0.31	0.54	0.81	0.50	0.32	0.22	0.16	0.16	0.23	0.33	0.32	0.35
Middle Nottawasaga	Gauged	0.57	0.62	0.95	1.15	0.72	0.49	0.33	0.30	0.37	0.48	0.63	0.67	0.61
Pine River	Gauged	0.22	0.23	0.35	0.48	0.36	0.27	0.21	0.17	0.17	0.20	0.22	0.23	0.26
Upper Nottawasaga	Gauged	0.20	0.21	0.28	0.34	0.24	0.18	0.14	0.13	0.14	0.18	0.22	0.23	0.21
Lower Nottawasaga	Ungauged	0.28	0.27	0.41	0.61	0.28	0.12	0.08	0.07	0.13	0.19	0.30	0.31	0.25
Blue Mountain Watersheds	Ungauged	0.09	0.08	0.11	0.15	0.08	0.03	0.03	0.02	0.05	0.06	0.09	0.10	0.07
Willow Creek	Ungauged	0.17	0.16	0.22	0.28	0.16	0.08	0.07	0.06	0.10	0.13	0.17	0.18	0.15

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/s except where noted

### **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 have been recommended within the Guidance Module 7 (MOE, 2006). 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- 22, 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 -1% to approximately 13% 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 rationale 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 not gauged data is available; however, use of this method introduces uncertainty.

### **3.2.3 Water Demand**

The following sections outline the methods used to estimate various water demands. The demand estimates for the existing 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. 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 as per the following section. A summary of the existing surface water use estimates are included in Table 3.2- 12.

**Table 3.2- 10: Existing Groundwater Consumption**

Subwatershed	Gauged or Ungaaged	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Boyne River	Gauged	1,395,000	41,000	831,000	266,000	2,533,000
Innisfil Creek	Gauged	1,860,000	558,000	2,360,000	1,648,000	6,426,000
Mad River	Gauged	611,000	100,000	347,000	245,000	1,303,000
Middle Nottawasaga	Gauged	253,000	190,000	1,234,000	1,210,000	2,887,000
Pine River	Gauged	3,228,000	95,000	2,130,000	434,000	5,887,000
Upper Nottawasaga	Gauged	1,698,000	116,000	2,351,000	302,000	4,467,000
Lower Nottawasaga	Ungaaged	2,609,000	193,000	449,000	197,000	3,448,000
Blue Mountain Watersheds	Ungaaged	148,000	36,000	324,000	141,000	649,000
Willow Creek	Ungaaged	5,847,000	201,000	1,554,000	78,000	7,680,000

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/a

**Table 3.2- 11: Future Groundwater Consumption**

Subwatershed	Gauged or Ungaaged	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Boyne River	Gauged	1,451,000	57,000	831,000	266,000	2,605,000
Innisfil Creek	Gauged	2,633,000	781,000	2,360,000	1,648,000	7,422,000
Mad River	Gauged	1,083,000	140,000	347,000	245,000	1,815,000
Middle Nottawasaga	Gauged	706,000	265,000	1,234,000	1,210,000	3,415,000
Pine River	Gauged	5,433,000	133,000	2,130,000	434,000	8,130,000
Upper Nottawasaga	Gauged	1,786,000	162,000	2,351,000	302,000	4,601,000
Lower Nottawasaga	Ungaaged	2,413,000	270,000	449,000	197,000	3,329,000
Blue Mountain Watersheds	Ungaaged	116,000	51,000	324,000	141,000	632,000
Willow Creek	Ungaaged	6,350,000	282,000	1,554,000	78,000	8,264,000

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/a

**Table 3.2- 12: Existing Surface Water Consumption**

Subwatershed	Gauged or Ungauged	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Boyne River	Gauged	-	-	5,199,000	266,000	5,465,000
Innisfil Creek	Gauged	-	-	18,090,000	1,648,000	19,738,000
Mad River	Gauged	-	-	1,052,000	245,000	1,297,000
Middle Nottawasaga	Gauged	-	-	7,091,000	1,210,000	8,301,000
Pine River	Gauged	-	-	3,189,000	434,000	3,623,000
Upper Nottawasaga	Gauged	-	-	5,669,000	302,000	5,971,000
Lower Nottawasaga	Ungauged	-	-	765,000	197,000	962,000
Blue Mountain Watersheds	Ungauged	-	-	2,079,000	141,000	2,220,000
Willow Creek	Ungauged	-	-	1,932,000	78,000	2,010,000

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>/a

### **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 appropriated and provided to SWP staff by the MNR. As part of this assessment, the database has been 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, the 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, this 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 is generally presented as a maximum taking over a permitted period of time and this value has been identified as often being much higher than the actual taking. Several attempts have been made to acquire values that are more reflective of actual taking.

During 2006 and 2007, NVCA 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. The response to this program within the watershed was minimal; as a result, the maximum taking as per the PTTW database has been used. This provides a conservative water consumption estimate and although it is known that these values are likely not being taken at this time, future consumption could increase to this maximum allowable taking.

The MNR ~~has~~ provided a consumption assessment tool with the database discussed above, which provides estimates of the water usage based on each permit. 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-2B and are depicted in Figures Figure 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) 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.

#### **Town of Collingwood**

The Town of Collingwood is the sole surface water intake within the watershed. This system takes water from Georgian Bay and returns to it treated wastewater. Due to the size of Georgian Bay and the low rate of consumption associated with the taking (the vast majority of the water is returned to the source). Technical Rule 4 indicates that surface water bodies within the Great Lakes are not included within the water budget analysis and therefore the municipal systems taking from these supplies do not require further water budget efforts.

#### **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, 2006) has suggested using water use coefficients documented by de Loe

(2002, 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 all townships and totals have been compiled for each subwatershed. This differs from the recommended methodology outlined by de Loe (2002), in that area weighting assumes that the agricultural area is evenly distributed within each subwatershed.

The coefficients derived by de Loe (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 2 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 groundwater used for domestic purposes the 2001 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 335 L/day, based on the recommendation within Guidance Module 7 (MOE, 2006). 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 (Table 3.2- 13).

**Table 3.2- 13: Unserviced Water Consumption Estimates**

Subwatershed	Gauged or Ungauged	Population: Current Scenario	Consumptive Use: Current Scenario	Estimated Growth %	Population: Future Scenario	Consumptive Use: Future Scenario
Boyne River	Gauged	1,678	41,035	40	2,349	57,445
Innisfil Creek	Gauged	22,808	557,770	40	31,931	780,873
Mad River	Gauged	4,102	100,314	40	5,743	140,445
Middle Nottawasaga	Gauged	7,752	189,575	40	10,853	265,410
Pine River	Gauged	3,887	95,057	40	5,442	133,084
Upper Nottawasaga	Gauged	4,733	115,746	40	6,626	162,039
Lower Nottawasaga	Ungauged	7,893	193,023	40	11,050	270,228
Blue Mountain Watersheds	Ungauged	1,486	36,340	40	2,080	50,866
Willow Creek	Ungauged	8,223	201,093	40	11,512	281,526

Notes for above table:

1. Future Population estimates are rounded off. All consumptive use values in m<sup>3</sup>/a

### **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 Guidance Module 7 (MOE, 2006), 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 and municipal pumping has been increased by the forecasts outlined within the previously mentioned groundwater studies. It is acknowledged that this is likely an exaggeration of water use increase 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 existing and future population and calculated water use for un-serviced users.

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 Georgian Bay. In addition, all private domestic use is assumed to be groundwater and therefore, the existing surface water supply estimate will not be increased for future forecasts.

### **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 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 Nottawasaga Valley 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 (Appendix WB-3B).

**Table 3.2- 14: Consumptive Use Factors**

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	0.10
Agricultural	Nursery	0.90	Miscellaneous	Dams and Reservoirs	0.10
Agricultural	Other - Agricultural	0.80	Miscellaneous	Heat Pumps	1.00
Agricultural	Sod Farm	0.90	Miscellaneous	Other - Miscellaneous	0.10
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	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
Dewatering	Other - Dewatering	0.25	Remediation	Other – Remediation	0.25
Dewatering	Pits and Quarries	0.25	Water Supply	Campgrounds	0.20
Industrial	Aggregate	0.10	Water Supply	Communal	0.20
Industrial	Brewing and Soft Drinks	1.00	Water Supply	Municipal	0.20

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.20
Industrial	Food Processing	1.00	-	-	-

### **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 Module 7 (MOE, 2006), was used when the months of water taking was 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- 15, 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 groundwater and surface water consumption based on the previous sections and usage factors have been included as Table 3.2- 16 and Table 3.2- 17, respectively. The values in Table 3.2- 16 are a summary of the monthly PTTW calculations derived using the above mentioned assumptions and 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- 15: Monthly Water Consumption Adjustments**

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

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
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
Water Supply	Other - Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

Notes for above table:

1. "1" indicates that water is consumed during the indicated month.

**Table 3.2- 16: Monthly Existing Groundwater Consumption**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Boyne River	Gauged	132,000	119,000	132,000	127,000	236,000	293,000	303,000	303,000	294,000	236,000	228,000	132,000	2,535,000
Innisfil Creek	Gauged	227,000	205,000	227,000	219,000	227,000	709,000	1,615,000	1,615,000	709,000	227,000	219,000	227,000	6,426,000
Mad River	Gauged	61,000	55,000	61,000	59,000	82,000	140,000	243,000	243,000	140,000	82,000	79,000	61,000	1,306,000
Middle Nottawasaga	Gauged	44,000	40,000	44,000	43,000	45,000	379,000	890,000	890,000	379,000	44,000	43,000	44,000	2,885,000
Pine River	Gauged	287,000	259,000	283,000	274,000	283,000	381,000	1,448,000	1,448,000	381,000	283,000	274,000	287,000	5,888,000
Upper Nottawasaga	Gauged	232,000	209,000	198,000	192,000	198,000	356,000	1,052,000	1,052,000	356,000	198,000	192,000	232,000	4,467,000
Lower Nottawasaga	Ungauged	253,000	228,000	253,000	244,000	262,000	315,000	407,000	407,000	315,000	260,000	252,000	253,000	3,449,000
Blue Mountain Watersheds	Ungauged	23,000	21,000	23,000	22,000	23,000	102,000	133,000	133,000	102,000	23,000	22,000	23,000	650,000
Willow Creek	Ungauged	563,000	508,000	563,000	545,000	563,000	804,000	831,000	831,000	804,000	563,000	545,000	563,000	7,683,000

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>

**Table 3.2- 17: Monthly Existing Surface Water Consumption**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Boyne River	Gauged	15,000	14,000	15,000	14,000	81,000	631,000	1,945,000	1,945,000	631,000	81,000	78,000	15,000	5,465,000
Innisfil Creek	Gauged	12,000	11,000	12,000	12,000	12,000	3,389,000	6,433,000	6,433,000	3,389,000	12,000	12,000	12,000	19,739,000
Mad River	Gauged	149,000	135,000	13,000	13,000	13,000	73,000	326,000	326,000	73,000	13,000	13,000	149,000	1,296,000
Middle Nottawasaga	Gauged	-	-	-	-	-	1,199,000	2,952,000	2,952,000	1,199,000	-	-	-	8,302,000
Pine River	Gauged	186,000	168,000	11,000	11,000	11,000	294,000	1,219,000	1,219,000	294,000	11,000	11,000	186,000	3,621,000
Upper Nottawasaga	Gauged	127,000	114,000	46,000	44,000	46,000	119,000	2,571,000	2,571,000	119,000	46,000	44,000	127,000	5,974,000
Lower Nottawasaga	Ungauged	29,000	26,000	29,000	28,000	29,000	94,000	274,000	274,000	94,000	29,000	28,000	29,000	963,000
Blue Mountain Watersheds	Ungauged	51,000	46,000	-	-	-	491,000	545,000	545,000	491,000	-	-	51,000	2,220,000
Willow Creek	Ungauged	423,000	382,000	4,000	4,000	4,000	88,000	294,000	294,000	88,000	4,000	4,000	423,000	2,012,000

Notes for above table:

1. Values rounded for presentation purposes. All values in m<sup>3</sup>

### **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, 2006). 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 (2002, 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.

### **3.2.4 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.

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 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

The percent water demand has been evaluated independently for both groundwater and surface water. The subwatershed stress level was then determined for both the groundwater and surface water systems. The individual stress levels within the surface and groundwater systems indicated whether further water budget requirements were needed. For example, only areas identified as having a moderate or significant groundwater stress were advanced to a more detailed groundwater modelling assessment (Tier Two).

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 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

Based on the percent water demand equation below, each subwatershed was assigned a stress level for groundwater and for surface water (See Table 3.2- 19). 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.

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

where:

$Q_{Demand}$ = the amount of water (surface water or groundwater) consumed as described in Section 3.2.4;

$Q_{Supply}$ = 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 3.2.3;

$Q_{Reserve}$ = the proportion of available surface water or groundwater that is to be maintained for other needs such as navigation, assimilative capacity, ecosystem health ect. (to be estimated as a proportion of baseflow and low-flow statistics 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%

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 Nottawasaga Valley 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**

##### Percent Annual Water Demand-Groundwater:

Based on the results of the groundwater stress assessment discussed above, under existing conditions, one subwatershed within the Nottawasaga Valley watershed exceeds the threshold for moderate quantity stress (Table 3.2- 20 and Figure 3.2-6). Water demand within Willow Creek is primarily for meeting municipal water supply requirements for the City of Barrie.

##### 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- 21. Detailed monthly groundwater stress assessments are located in appendix WB-3B. Innisfil Creek has been identified as exceeding the threshold for moderate water quantity stress, during the months of July and August. All of the seasonal 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 “pro-rated”<sup>2</sup> annual supply within the monthly stress assessments tends to “average” the influences as presented in Table 3.2- 21.

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<sup>2</sup> 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.

**Table 3.2- 20: Existing Annual Groundwater Stress Assessment**

Parameter	Boyne River	Innisfil Creek	Mad River	Middle Nottawasaga	Pine River	Upper Nottawasaga	Lower Nottawasaga	Blue Mountains Watersheds	Willow Creek
Area (km <sup>2</sup> )	240	490	452	297	347	338	455	221	307
Precipitation (mm/a)	905	818	944	846	923	892	922	943	925
Evapotranspiration (mm/a)	549	560	545	558	543	546	560	560	562
Surplus Water (mm/a)	357	258	399	288	381	345	362	383	363
Annual Mean Flow (m <sup>3</sup> /s)	2.2	3.0	5.7	2.1	3.7	3.3	4.9	1.6	2.9
Annual Mean Flow (mm/a)	285	194	398	223	338	310	343	230	298
Baseflow (m <sup>3</sup> /a)	1.3	1.5	3.5	1.2	2.6	2.1	2.5	0.7	1.5
Baseflow (mm/a)	167	94	244	133	235	194	176	106	152
Available Groundwater Supply (mm/a)	238	159	246	197	278	230	195	258	218
Available Groundwater Supply (m <sup>3</sup> /s)	1.8	2.5	3.5	1.9	3.1	2.5	2.8	1.8	2.1
Available Surface Water Supply (mm/a)	172	96	242	643	252	208	214	124	178
Available Surface Water Supply (m <sup>3</sup> /s)	1.3	1.5	3.5	6.1	2.8	2.2	3.1	0.9	1.7
Groundwater Reserve (mm/a)	17	9	24	64	24	19	18	11	15
Groundwater Reserve (m <sup>3</sup> /s)	0.1	0.1	0.4	0.6	0.3	0.2	0.3	0.1	0.1
Surface Water Reserve (mm/a)	83	40	103	312	144	118	106	74	99
Surface Water Reserve (m <sup>3</sup> /s)	0.6	0.6	1.5	2.9	1.6	1.3	1.5	0.5	1.0
Groundwater Consumption (m <sup>3</sup> /a)	2,533,000	6,426,000	1,303,000	2,887,000	5,887,000	4,467,000	3,448,000	649,000	7,680,000
Groundwater Consumption (mm/a)	11	13	3	10	17	13	8	3	25
Groundwater Stress* (%)	5	9	1	7	7	6	4	1	12

Notes for above table:

1. >10% is considered moderately stressed, >25% is considered significantly stressed
2. For subwatershed evaluation Middle Nottawasaga River data can be determined by subtracting the sum of the Upper Nottawasaga River, Boyne River and Innisfil Creek data
3. Values rounded for presentation purposes

**Table 3.2- 21: Monthly Existing Stress Assessment Summary-Groundwater**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boyne River	Gauged	3%	3%	3%	3%	5%	7%	7%	7%	6%	5%	5%	3%
Innisfil Creek	Gauged	4%	3%	4%	4%	4%	11%	26%	26%	11%	4%	4%	4%
Mad River	Gauged	1%	1%	1%	1%	1%	2%	3%	3%	2%	1%	1%	1%
Middle Nottawasaga	Gauged	1%	1%	2%	2%	2%	11%	22%	22%	10%	1%	1%	1%
Pine River	Gauged	4%	3%	4%	4%	4%	5%	19%	19%	5%	4%	4%	4%
Upper Nottawasaga	Gauged	4%	4%	3%	3%	3%	6%	17%	17%	6%	3%	3%	4%
Lower Nottawasaga	Ungauged	4%	3%	4%	4%	4%	4%	6%	6%	4%	4%	4%	4%
Blue Mountain Watersheds	Ungauged	1%	0%	1%	1%	1%	2%	3%	3%	2%	1%	0%	1%
Willow Creek	Ungauged	11%	10%	11%	11%	11%	15%	15%	15%	15%	11%	11%	11%

Notes for above table:

1. >25% is considered moderately stressed, >50% is considered significantly stressed

### 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- 22 and Figure 3.2-7. Detailed monthly surface water stress assessments are located in Appendix WB-3A. These elevated values are attributed to low available supply values calculated using the Tessmann method. It can also 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. The Innisfil Creek subwatershed is particularly stressed and has over 80 permitted surface water takings primarily for agricultural activities representing an estimated 18 million m<sup>3</sup> per annum (SGBLS, 2009). The Boyne River and Upper Nottawasaga River subwatersheds also report surface water taking stress level in excess of 100% during the summer months. It is also noted that the Willow Creek subwatershed is stressed in the winter months due to snowmaking activities.

No subwatersheds within the Nottawasaga Valley watershed have advanced to a Tier 2 assessment for surface water stress<sup>3</sup>.

All of the municipal surface water systems within the watershed take water from Georgian Bay. Technical Rule 4s (MOE, 2008a) has prescribed that subwatersheds that take water 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 (Table 3.2- 22). 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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<sup>3</sup> With respect to municipal drinking water supply per Clean Water Act guidance (MOE, 2006)

**Table 3.2- 22: Monthly Existing Stress Assessment Summary-Surface Water**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boyne River	Gauged	1%	1%	0%	0%	4%	46%	234%	316%	87%	7%	4%	1%
Innisfil Creek	Gauged	1%	1%	0%	0%	0%	177%	600%	728%	374%	1%	1%	1%
Mad River	Gauged	3%	4%	0%	0%	0%	2%	14%	17%	4%	0%	0%	3%
Middle Nottawasaga	Gauged	0%	0%	0%	0%	0%	21%	80%	103%	41%	0%	0%	0%
Pine River	Gauged	7%	7%	0%	0%	0%	10%	52%	72%	20%	1%	0%	7%
Upper Nottawasaga	Gauged	7%	6%	1%	1%	2%	6%	196%	204%	11%	3%	2%	5%
Lower Nottawasaga	Ungauged	1%	2%	0%	0%	1%	11%	21%	21%	11%	1%	1%	1%
Blue Mountain Watersheds	Ungauged	8%	10%	0%	0%	0%	53%	68%	101%	252%	0%	0%	6%
Willow Creek	Ungauged	35%	41%	0%	0%	0%	7%	22%	33%	20%	0%	0%	23%

Notes for above table:

1. >20% -<50% 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. As well, the Pine River and Middle Nottawasaga River subwatersheds fall within a range that requires a sensitivity analysis (i.e., 8% to 10% threshold of supply Table 3.2- 23). Subwatersheds that fall within this range can be considered for a Tier Two analysis if the sensitivity analysis increases the subwatershed stress level to greater than 10%. Two sensitivity analysis scenarios were completed for these subwatersheds. One reduced the volume of precipitation received by 10%, and the other increased the consumption rate by 10%. Both subwatersheds exceeded the 10% threshold during the sensitivity analysis for future conditions.

**Table 3.2- 23: Future Annual Groundwater Stress Assessment**

Parameter	Boyne River	Innisfil Creek	Mad River	Middle Nottawasaga	Pine River	Upper Nottawasaga	Lower Nottawasaga	Blue Mountains Watersheds	Willow Creek
Area (km <sup>2</sup> )	240	490	452	297	347	338	455	221	307
Precipitation (mm/a)	905	818	944	846	923	892	922	943	925
Evapotranspiration (mm/a)	549	560	545	558	543	546	560	560	562
Surplus Water (mm/a)	357	258	399	288	381	345	362	383	363
Annual Mean Flow (m <sup>3</sup> /s)	2.2	3.0	5.7	2.1	3.7	3.3	4.9	1.6	2.9
Annual Mean Flow (mm/a)	285	194	398	223	338	310	343	230	298
Baseflow (m <sup>3</sup> /a)	1.3	1.5	3.5	1.2	2.6	2.1	2.5	0.7	1.5
Baseflow (mm/a)	167	94	244	133	235	194	176	106	152
Available Groundwater Supply (mm/a)	238	159	24	197	278	230	195	258	218
Available Groundwater Supply (m <sup>3</sup> /s)	1.8	2.5	3.5	1.9	3.1	2.5	2.8	1.8	2.1
Available Surface Water Supply (mm/a)	172	96	242	643	252	208	214	124	178
Available Surface Water Supply (m <sup>3</sup> /s)	1.3	1.5	3.5	6.1	2.8	2.2	3.1	0.9	1.7
Groundwater Reserve (mm/a)	17	9	24	64	24	19	18	11	15
Groundwater Reserve (m <sup>3</sup> /s)	0.1	0.1	0.4	0.6	0.3	0.2	0.3	0.1	0.1
Surface Water Reserve (mm/a)	83	40	103	312	144	118	106	74	99
Surface Water Reserve (m <sup>3</sup> /s)	0.6	0.6	1.5	2.9	1.6	1.3	1.5	0.5	1.0
Groundwater Consumption (m <sup>3</sup> /a)	2,605,000	7,422,000	1,815,000	3,415,000	8,130,000	4,601,000	3,329,000	632,000	8,264,000
Groundwater Consumption (mm/a)	11	15	4	12	23	14	7	3	27
Groundwater Stress* (%)	5	10	2	9	9	6	4	1	13

Notes for above table:

1. >10% is considered moderately stressed, >25% is considered significantly stressed
2. For subwatershed evaluation Middle Nottawasaga River data can be determined by subtracting the sum of the Upper Nottawasaga River, Boyne River and Innisfil Creek data
3. Values rounded for presentation purposes

**Percent Monthly Water Demand- Groundwater**

In addition to the above mentioned future annual stress, as outlined within Table 3.2- 24 , no additional monthly occurrences of groundwater stress have been identified within the Nottawasaga Valley Watershed. The future monthly stress assessments are located within Appendix WB-3, and summarized in Table 3.2- 24.

**Table 3.2- 24: Future Monthly Groundwater Stress Assessment Summary**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boyne River	Gauged	5%	6%	6%	6%	6%	5%	5%	5%	5%	5%	5%	5%
Innisfil Creek	Gauged	12%	12%	13%	13%	12%	12%	12%	12%	12%	12%	12%	12%
Mad River	Gauged	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Middle Nottawasaga	Gauged	10%	11%	16%	23%	12%	9%	8%	8%	9%	9%	11%	11%
Pine River	Gauged	10%	10%	10%	11%	11%	10%	10%	10%	10%	10%	10%	10%
Upper Nottawasaga	Gauged	7%	7%	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%
Lower Nottawasaga	Ungauged	5%	5%	5%	6%	5%	4%	4%	4%	4%	5%	5%	4%
Blue Mountain Watersheds	Ungauged	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Willow Creek	Ungauged	15%	15%	16%	16%	15%	15%	14%	14%	15%	15%	15%	13%

Notes for above table:

1. >20% -<50% is considered moderately stressed, >50% is considered significantly stressed

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- 25 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 the Boyne River in July has a total flow value of 1.1m<sup>3</sup>/s and the value calculated for reserve using Tessmann’s method for reserve is 0.5m<sup>3</sup>/s. This estimates the available supply to be 0.8m<sup>3</sup>/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.

The Innisfil Creek subwatershed is particularly stressed and has over 80 permitted surface water takings primarily for agricultural activities representing an estimated 18 million m<sup>3</sup> per annum. The Boyne River and Upper Nottawasaga River subwatersheds also report surface water taking stress levels in excess of 100% during the summer months. It is also noted that the Willow Creek subwatershed is stressed in the winter months due to snowmaking activities.

**Table 3.2- 25: Future Monthly Surface Water Stress Assessment Summary**

Subwatershed	Gauged or Ungauged	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boyne River	Gauged	1%	1%	0%	0%	44%	44%	234%	316%	87%	7%	4%	1%
Innisfil Creek	Gauged	1%	1%	0%	0%	171%	171%	600%	728%	374%	1%	1%	1%
Mad River	Gauged	3%	4%	0%	0%	2%	2%	14%	17%	4%	0%	0%	3%
Middle Nottawasaga	Gauged	0%	0%	0%	0%	20%	20%	80%	103%	41%	0%	0%	0%
Pine River	Gauged	7%	7%	0%	0%	10%	10%	52%	72%	20%	1%	0%	7%
Upper Nottawasaga	Gauged	7%	6%	1%	1%	6%	6%	196%	204%	10%	3%	2%	5%
Lower Nottawasaga	Ungauged	1%	2%	0%	0%	10%	10%	21%	21%	11%	1%	1%	1%
Blue Mountain Watersheds	Ungauged	8%	10%	0%	0%	51%	51%	68%	101%	252%	0%	0%	6%
Willow Creek	Ungauged	35%	41%	0%	0%	7%	7%	22%	33%	20%	0%	0%	23%

Notes for above table:

1. >20% -<50% is considered moderately stressed, >50% is considered significantly stressed

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. Three subwatersheds were identified as having the percent water demand between 8% and 10%, The Pine River, Innisfil Creek and the Middle Nottawasaga River within either the current or future annual groundwater scenarios.

It is recognized that 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.

The results of the sensitivity analysis are presented in Table 3.2- 26. Decreasing the precipitation by 10% caused all three subwatersheds to become moderately stressed in both the current and future scenarios. While the increase of demand by 10% only brought Innisfil Creek above the moderate threshold in the future scenario. This sensitivity to climatic parameters and consumption rates was considered sufficient to recommend both subwatersheds for a Tier Two evaluation.

**Table 3.2- 26: Groundwater Sensitivity Analysis Results**

Subwatershed	Scenario: Current Annual	Scenario: Future Annual	Sensitivity Analysis (Decrease Precipitation by 10%): Current	Sensitivity Analysis (Decrease Precipitation by 10%): Future	Sensitivity Analysis (Increase Demand by 10%): Current	Sensitivity Analysis (Increase Demand by 10%): Future
Innisfil Creek	9%	10%	19%	22%	10%	11%
Middle Nottawasaga	7%	9%	20%	24%	8%	10%
Pine River	7%	9%	11%	14%	7%	10%

### **Uncertainty Analysis**

The methods used to develop an understanding of the total amount of water supply and demand within the subwatershed have been discussed within the previous sections. The data interpretation and manipulation that have been considered to estimate the parameters required to complete the supply side of the water quantity stress assessment have resulted in an understanding of the flow of the water within each subwatershed.

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 discussed above in Section 3.2.2.

The terms of this equation for each subwatershed on an annual scale have been included in Table 3.2-27, 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 ~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.

**Table 3.2-27: Annual Water Balance.**

Parameter	Boyne River	Innisfil Creek	Mad River	Middle Nottawasaga	Pine River	Upper Nottawasaga	Lower Nottawasaga	Blue Mountain Watersheds	Willow Creek
Area (km <sup>2</sup> )	240	490	452	297	347	338	455	221	307
Precipitation (mm/a)	905	818	944	846	923	892	922	943	925
Anthropogenic Inputs (mm/a)	-	-	-	-	-	-	-	-	-
Surface Water Inputs (mm/a)	-	-	-	-	-	-	-	-	-
Evapotranspiration (mm/a)	549	560	545	558	543	546	560	560	562
Anthropogenic Outputs - Waste (mm/a)	-	-	-	-	-	-	-	-	-
Anthropogenic Outputs - Consumption (mm/a)	11	13	3	10	17	13	8	3	25
Surface Water Outputs (mm/a)	285	194	398	223	338	310	343	230	298
Water Balance - Net Difference (mm/a)	61	51	-2	55	26	23	11	150	40
Water Balance - % Difference	7%	6%	0%	6%	3%	3%	1%	16%	4%

Notes for above table:

1. Anthropogenic inputs, surface water inputs and anthropogenic outputs do not occur in the Nottawasaga Valley subwatershed
2. Consumption refers to that water that is lost from the subwatershed

**Tier One Stress Assessment Summary**

Table 3.2- 28 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. The Pine River and Middle Nottawasaga River subwatersheds are projected to move from a low potential to a moderate potential for stress under future conditions. 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- 28: 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	Tier 2 Recommended: Groundwater	Tier 2 Recommended: Surface Water
Boyne River	5%	5%	-	Jun-Sept	-	May-Sept	Yes	No	No	No
Innisfil Creek	9%	10%	Jul-Aug	Jun-Sept		May-Sept	Yes	No	Yes	No
Mad River	1%	2%	-	-	-		Yes	No	No	No
Middle Nottawasaga	7%	9%	Jul-Aug	Jun-Sept	-	May-Sept	Yes	No	Yes	No
Pine River	7%	9%	-	Jul- Sept	-	Jul- Sept	Yes	No	Yes	No
Upper Nottawasaga	6%	6%	-	Jul-Aug	-	-	Yes	No	No	No
Lower Nottawasaga	5%	5%	-	Jul-Aug	-	Jul-Aug	Yes	No	No	No
Blue Mountain Watersheds	1%	1%	-	Jun- Sept	-	May-Sept	Yes	Yes	No	No
Willow Creek	12%	13%	-	Various	-	Various	Yes	No	Yes	No
Moderate Stress Conditions	>10%	>10%	>25%	>20%	>25%	>20%	-	-	-	-
Significant Threat Conditions	>=25%	>=25%	>=50%	>=50%	>=50%	>=50%	-	-	-	-

### 3.2.5 Uncertainty

In applying these methods, attempts have been made to be both consistent and conservative, in order to produce stress assessments 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 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.

The 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 rationale 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 biased 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 Demand 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.

### **3.2.6 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 the refinements could include the actual water taking data currently collected by MOE under regulation 387/07, a more complete understanding of agricultural use based on actual farming practices, and improved seasonal water taking for certain land uses.

For the purpose 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.

### **3.2.7 Conclusions and Recommendations**

The objective of this report 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 focuses and results to be refined.

The Nottawasaga Valley Conservation Authority has previously developed a FEFLOW numerical basin model, which will continue to be used in the Tier Two assessment work. The focus of the assessment work will focus on the stressed subwatersheds within this model. As a result of the findings presented in this report and summarized in Table 3.2-27 and Figure 3.2-8 it is recommended that;

- A group investigation using the existing FEFLOE basin model is recommended for the moderately stressed subwatersheds identified in this study
- The Innisfil Creek subwatershed be further studied in a Tier Two assessment and that this assessment focus on seasonal low water concerns
- The Pine River subwatershed be further studied in a Tier Two assessment in terms of the future potential growth of the municipal supply
- The Middle Nottawasaga River subwatershed be further studied in a Tier Two assessment due to the stress created primarily by agricultural activities
- The Willow Creek subwatershed will be studied in a Tier Two assessment, as it is influenced by the groundwater takings by the City of Barrie, and
- The results of this exercise be used to inform and support the Permit to Take Water program

**Figure 3.2-1: Mean Annual Precipitation Distribution.**

**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 Assessment.**

### **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 groundwater stress in the Tier One Water Budget and Water Quantity Stress Assessment. The goal of the Tier Two Water Budget and 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, 2006). 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 Budget and Water Quantity Stress Assessment fit into the overall Water Budget and Risk Assessment Process is illustrated in the flow chart below.

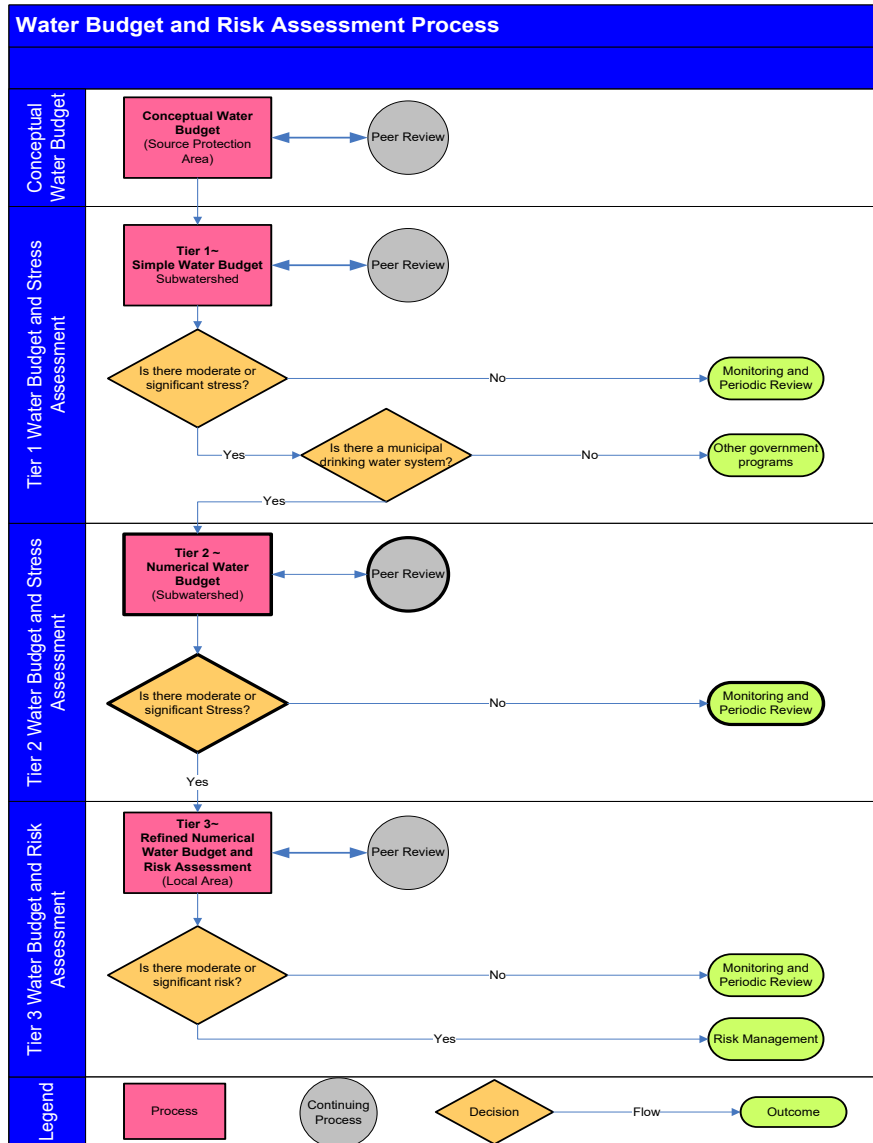


Figure 3.3-1: Water Budget and Risk Assessment Process (How the Tier Two fits in).

### 3.3.1 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, Planned and Future Percent Water Demand Scenarios

The percent water demand for the existing, planned and future 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) and the Guidance Module for Water Budgets (MOE, 2007), the Percent Water Demand is calculated using the following formula:

$$\text{Percent Water Demand} = \frac{Q_{\text{Demand}}}{Q_{\text{Supply}} - Q_{\text{Reserve}}} \times 100\%$$

where;

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

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

$Q_{\text{Reserve}}$  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 the Technical Rules. 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%

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 allows the percent water demand to be elevated to a moderate potential for stress.

The planned system scenario is conducted in areas where a municipal water system is planned. To meet the technical requirements for a planned scenario, a planned municipal water supply system must have undergone an Environmental Assessment and is intended to be used in the immediate future. It should be noted that the City of Barrie has one planned well within the Nottawasaga Valley Watershed.

The future water demand scenario considers the evaluation future consumptive water demand estimates for a future 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 (MOE, 2008a) if either of the following two conditions have been met in the recorded history of the 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, 2008) 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.

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, it was applied. The minimum monthly flow conditions simulated would then be used to represent the worst-case flows expected during drought conditions (MOE, 2006). The methodology and results of this scenario are further discussed in Section 3.4.

### **3.3.2 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 Two 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 for 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 Takings (Source: MOE, 2006)**

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
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

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

### **Consumptive Use Factors**

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	Institutional	Hospitals	0.25
Agricultural	Fruit Orchards	0.8	Institutional	Other - Industrial	0.25
Agricultural	Market Gardens/Flowers	0.9	Institutional	Schools	0.25
Agricultural	Nursery	0.9	Miscellaneous	Dams and Reservoirs	0.1
Agricultural	Other - Agricultural	0.8	Miscellaneous	Heat Pumps	0.1
Agricultural	Sod Farm	0.9	Miscellaneous	Other - Miscellaneous	1
Agricultural	Tender Fruit	0.8	Miscellaneous	Pumping Test	0.1
Agricultural	Tobacco	0.9	Miscellaneous	Wildlife Conservation	0.25
Commercial	Aquaculture	0.1	Recreational	Aesthetics	0.25
Commercial	Bottled Water	1	Industrial	Manufacturing	0.25
Commercial	Golf Course Irrigation	0.7	Industrial	Other- Industrial	0.25
Commercial	Mall/Business	0.25	Industrial	Pipeline Testing	0.25
Commercial	Other Commercial	1	Industrial	Power Production	0.1
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
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	0.2
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.2
Industrial	Food Processing	1	-	-	-

### **3.3.3 Nottawasaga Valley Source Protection Area Tier Two Summary**

As noted in the Tier One Water Budget and Stress Assessment: Nottawasaga Valley watershed the Middle Nottawasaga, Innisfil Creek, Pine River, and Willow Creek subwatersheds in the NVCA SPA 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 one project. This project expands the Nottawasaga Valley and Severn Sound Source Protection Areas in their entirety, and captures the western extent of the Lake Simcoe Source Protection Area. An overview of the municipal drinking water systems that underwent a Tier Two evaluation in the Nottawasaga Valley Source Protection Area are summarized in Table 3.3- 4 below.

**Table 3.3- 4: Summary of Municipal Drinking Water Systems that Underwent a Tier Two Evaluation in the Nottawasaga Valley Source Protection Area**

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed
Regional Municipality of Peel	Town of Caledon	Palgrave	Innisfil Creek
County of Simcoe	Town of Innisfil	Churchill Well Supply	Innisfil Creek
County of Simcoe	Town of Innisfil	Cookstwon Well Supply	Innisfil Creek
County of Simcoe	Town of New Tecumseth	Tottenham Well Supply	Innisfil Creek
County of Simcoe	Township of Adjala-Tosorontio	Colgan Well Supply	Innisfil Creek
County of Simcoe	Township of Adjala-Tosorontio	Loretto Heights Well Supply	Innisfil Creek
County of Simcoe	Township of Adjala-Tosorontio	Weca Well Supply	Innisfil Creek
County of Simcoe	Township of Adjala-Tosorontio	Everett Well Supply	Pine River
County of Simcoe	Township of Adjala-Tosorontio	Lisle Well Supply	Pine River
County of Simcoe	Township of Adjala-Tosorontio	Mansfield Well Supply	Pine River
County of Simcoe	Township of Essa	Angus Well Supply	Pine River and Middle Nottawasaga River
County of Simcoe	Township of Essa	Glen Ave (Thornton Well Supply)	Middle Nottawasaga River
County of Simcoe	Town of New Tecumseth	Hillcrest Subdivision Well Supply	Middle Nottawasaga River

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed
City of Barrie	City of Barrie	Barrie	Middle Nottawasaga River and Willow Creek
County of Simcoe	Township of Oro-Medonte	Craighurst Well Supply	Willow Creek
County of Simcoe	Township of Springwater	Del Trend Well Supply	Willow Creek
County of Simcoe	Township of Springwater	Midhurst Well Supply	Willow Creek
County of Simcoe	Township of Springwater	Snow Valley Highlands Well Supply	Willow Creek

### **3.4 Tier Two Water Budget and Water Quantity Stress Assessment- Innisfil Creek, Willow Creek, Pine River and Middle Nottawasaga River**

The Tier One Stress Assessment identified several subwatersheds as having a moderate or significant potential for stress (shown in Figure 3.2-6) and as a result, Tier Two Stress Assessments were completed for these subwatersheds. This section provides an overview of the Innisfil Creek, Willow Creek, Pine River and the Middle Nottawasaga River Tier Two Water Budget and Quantity Stress Assessment, which was completed as part of the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResources 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 Two Study Area (AquaResource and Golder, 2010) that was completed in compliance with the Technical Rules prepared by the Ministry of the Environment (MOE, 2008a) ([now the Ministry of the Environment, Conservation and Parks \(MECP\)](#)) 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.

#### **3.4.1 Study Area and Physical Setting**

##### **Location**

The study area within the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResources and Golder, 2010) encompasses the Nottawasaga Valley, Severn Sound and a portion of the Lake Simcoe Source Protection Areas (Figure 3.4-1). This section of the assessment report will focus on the study area located within the Nottawasaga Valley Source Protection Area and the Innisfil Creek, Willow Creek, Pine Rive and Middle Nottawasaga River subwatersheds in particular. The Severn Sound and Lake Simcoe subwatersheds will be discussed in their respective assessment reports.

The Nottawasaga Valley watershed covers an area of 3,200 km<sup>2</sup> and encompasses portions of four Upper Tier Municipalities. The watershed originates in the upland areas of the Oak Ridges, Oro and Orangeville Moraines, as well as the Niagara Escarpment (AquaResource and Golder, 2010). A unique characteristic of the Nottawasaga Valley watershed is its virtual lack of natural lakes. All of the Nottawasaga Valley subwatersheds are located within the South Georgian Bay-Lake Simcoe Tier Two study area; however, only those subwatersheds (i.e. Pine River, Middle

Nottawasaga River, Innisfil Creek and Willow Creek) indicated as having a moderate or significant potential for stress within the Tier One Stress Assessment were further evaluated in this Tier Two Water Budget and Stress Assessment.

The subwatershed boundaries were modified from those used within the Tier One Stress Assessment as listed in Table 3.4- 1 (Figure 3.4-2). 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, 2006). For this study, the larger subwatersheds were subdivided to have areas of roughly 150-200 km<sup>2</sup>. 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 3.4- 1: Subwatershed Boundary changes for the Innisfil Creek, Willow Creek, Pine River and Middle Nottawasaga River Tier Two**

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Tier 2 Subwatershed Name	Tier 1 Subwatershed Name	Reason for Boundary Change
Simcoe County	Township of Adjala-Tosorontio	<a href="#">Loretto Heights and Weca Supplies</a>	Innisfil Creek-Tottenham	Innisfil Creek	Creation of Subwatershed with an area approximately 150 km <sup>2</sup> ; Separate Tottenham water supply from agricultural permits
Simcoe County	Township of New Tecumseth	Tottenham	Innisfil Creek-Tottenham	Innisfil Creek	Creation of Subwatershed with an area approximately 150 km <sup>2</sup> ; Separate Tottenham water supply from agricultural permits
Simcoe County	Town of Innisfil	No Municipal Drinking Supply	Innisfil Creek-Beeton	Innisfil Creek	Creation of Subwatershed with an area approximately 150 km <sup>2</sup> ; Separate Tottenham water supply from agricultural permits
Simcoe County	Town of Innisfil	Churchill	Innisfil Creek-Cookstown	Innisfil Creek	Creation of Subwatershed with an area approximately 150 km <sup>2</sup> ; Separate Tottenham water supply from agricultural permits
Simcoe County	Town of Innisfil	Cookstown	Innisfil Creek-Cookstown	Innisfil Creek	Creation of Subwatershed with an area approximately 150 km <sup>2</sup> ; Separate Tottenham water supply from agricultural permits
City of Barrie	Barrie	Barrie	Middle Nottawasaga	Middle Nottawasaga River	No Change*
Simcoe County	Township of Essa	Angus Well Supply	Middle Nottawasaga	Middle Nottawasaga River	No Change*

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Tier 2 Subwatershed Name	Tier 1 Subwatershed Name	Reason for Boundary Change
Simcoe County	Township of Essa	Angus Well Supply	Pine River-Borden	Pine River	Creation of separate subwatershed above the Escarpment, Town of Mansfield and snow making facility
Simcoe County	Township of Mulmur	Mansfield	Pine River-Mansfield	Pine River	Creation of separate subwatershed below the Escarpment with with an area approximately 150 km <sup>2</sup> ; Contains irrigation permits, CFB Borden and Angus
Simcoe County	Township of Oro-Medonte and Township of Springwater	No municipal drinking water system	Willow Creek-Shanty Bay	Willow Creek	Separate rural eastern portion of the subwatershed from the wast area where there is more development
Simcoe County	Township of Oro-Medonte and Township of Springwater	Craighurst	Willow Creek-Midhurst	Willow Creek	Separate rural northern portion of the subwatershed from the southern area; excluded Barrie wells

Notes for the above table:

1. \* Boundary deviates slightly from the Tier One Boundary as the model is following groundwater divides and not surface water divides

### **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. 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 Nottawasaga Valley study area are generally unconfined. The Barrie-Borden aquifer is situated ideally for water supply. It is confined within a deep tunnel channel valley overlaid 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.

### **3.4.2 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 5416km<sup>2</sup> (Figure 3.4-3) (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 Nottawasaga Valley and Severn Sound area a HSP-F model was developed by the Nottawasaga Valley Conservation Authority. In the Lake Simcoe portion of the study area a PRMS model developed by Earthfx in 2009 for the Lake Simcoe watershed was used. The surface water models will be discussed in detail in Appendix WB-4. The estimated groundwater recharge used in the stress assessment is illustrated in Figure 3.4-4.

#### **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 3.4- 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 all subwatersheds 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 all of the Nottawasaga Valley subwatersheds undergoing the Tier Two evaluation. A positive value for inter-basin transfer indicates that the subwatershed is experiencing a net in-flux of groundwater. This is observed in the Middle Nottawasaga River and Innisfil Creek-Beeton subwatersheds. Conversely a negative net in-flux value indicates that a subwatershed is experiencing a net loss of groundwater flow. This is observed in Willow Creek- Shanty Bay, Willow Creek-Midhurst, Pine River- Mansfield, Pine River-Border, Innisfil Creek- Tottenham, and Innisfil Creek-Cookstown. The values in the water budget form the foundation for the stress assessment calculations.

**Table 3.4- 2: Water Budget Summary by Subwatershed (AquaResource and Golder, 2010)**

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstown
ID	9	7	17	5	3	20	2	6
Area (km <sup>2</sup> )	115	164	216	139	305	165	167	162
Groundwater Recharge (L/s)	679	1319	1594	958	1706	929	845	752
Groundwater Takings* (L/s)	-3	-77	-11	-48	-59	-22	-48	-40
Inter-Basin Transfer (L/s)	-501	-133	-215	-74	206	-269	117	-106
Cross- Boundary Transfer (L/s)	0	0	0	0	0	-41	0	0
Tool Discharge to Surface Water (L/s)	-182	-1128	-1368	-840	-1876	-598	-914	-611
Breakdown of Groundwater Discharge to Surface Water (L/s): Discharge to Streams	-137	-1128	-1368	-840	-1878	-598	-914	-611

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstown
Breakdown of Groundwater Discharge to Surface Water (L/s): Discharge to Wetlands and Inland Lakes	0	0	0	0	2	0	0	0
Breakdown of Groundwater Discharge to Surface Water (L/s): Discharge to Georgian Bay	0	0	0	0	0	0	0	0
Breakdown of Groundwater Discharge to Surface Water (L/s): Discharge to Lake Simcoe	-45	0	0	0	0	0	0	0

### Uncertainty Discussion

All models developed to represent natural systems are simplifications of the natural environment and the hydraulic processes within the environment. This simplification results in inherent uncertainty in many of these 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 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.

### 3.4.3 Water Demand

This section provides a summary of the consumptive groundwater demands for Innisfil Creek, Willow Creek, Pine River and the Middle Nottawasaga River 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 3.4-5 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 3.4-6 and Figure 3.4-7 show 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). Table 3.4- 3 shows the number of groundwater takings by subwatershed and water use sector and Table 3.4- 4 shows the maximum permitted takings by watershed.

Actual estimated pumping rates were used to generate the municipal demand, which was a refinement to the estimates used in the Tier One study. While reported pumping rates were used to estimate other permitted water demand by combining the permitted rate with the months of expended 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). Further refinement to the demand estimates due to the lack of actual water taking data being available at the time of this study. 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. 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 2009 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 3.4- 3: Number of Groundwater Takings by Subwatershed and Water Use Sector (AquaResource and Golder, 2010)**

Subwatershed	ID	Agricultural	Commercial	Industrial	Miscellaneous	Recreational	Remediation	Water Supply	Total
Willow Creek-Shanty Bay	9	0	2	1	3	0	0	4	10
Willow Creek-Midhurst	7	0	13	0	0	2	0	17	32
Pine River-Mansfield	17	1	3	1	0	0	0	4	9
Pine River-Borden	5	12	2	0	0	0	0	8	22
Middle Nottawasaga	3	7	4	0	0	0	0	24	35
Innisfil Creek-Tottenham	20	0	0	0	0	0	0	13	13
Innisfil Creek-Beeton	2	6	5	0	0	0	0	3	14
Innisfil Creek-Cookstown	6	8	2	0	0	0	0	9	19

**Table 3.4- 4: Maximum Permitted Takings by Subwatershed (AquaResource and Golder, 2010)**

Subwatershed	ID	Area (Km)	Maximum Permitted Takings (L/s)	Maximum Permitted Takings (mm/yr)
Willow Creek-Shanty Bay	9	115	133	37
Willow Creek-Midhurst	7	164	580	112
Pine River-Mansfield	17	216	109	16
Pine River-Borden	5	139	432	98
Middle Nottawasaga	3	305	572	59
Innisfil Creek-Tottenham	20	165	103	20
Innisfil Creek-Beeton	2	167	609	115
Innisfil Creek-Cookstown	6	162	371	72

**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 3.4- 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 3.4- 6 summarizes the total municipal groundwater takings by subwatershed for municipal water supply purposes. As seen in these tables, the highest municipal demand for the Nottawasaga Valley watershed is in the Pine River-Borden subwatershed followed by the Willow Creek-Midhurst subwatershed. The communities located within these subwatersheds are currently experiencing growth or are expecting to grow in the near future.

**Table 3.4- 5: Summary of Municipal Systems (AquaResource and Golder, 2010)**

Municipality	Community	Municipal Systmen/ Wellfield	Subwatershed	Year of Data	Source of Data	Average Annual Pumping Rate (L/s)
Adjala-Tosorontio	Colgan	Colgan	Innisfil Creek - Tottenham	2008	NVCA	1.3
Adjala-Tosorontio	Everett	Everett Grohal	Pine River - Borden	2008	NVCA	5.0
Adjala-Tosorontio	Lisle	Lisle	Pine River - Borden	2008	NVCA	5.3
Adjala-Tosorontio	Loretto	Loretto Heights	Innisfil Creek - Tottenham	2008	NVCA	0.3
Adjala-Tosorontio	Loretto	Weca	Innisfil Creek - Tottenham	2008	NVCA	1.4
Barrie	Barrie	Barrie	Middle Nottawasaga	2008	NVCA	0.0
Essa	Angus	Brownley	Middle Nottawasaga	2008	NVCA	0.0

Municipality	Community	Municipal System/ Wellfield	Subwatershed	Year of Data	Source of Data	Average Annual Pumping Rate (L/s)
Essa	Angus	Centre Street	Middle Nottawasaga	2008	NVCA	6.8
Essa	Angus	Mill Street	Pine River- Borden	2008	NVCA	18.7
Essa	Thornton	Glen Avenue	Middle Nottawasaga	2008	NVCA	2.6
Essa	Thornton	Thornton Estates	Middle Nottawasaga	2008	NVCA	1.6
Innisfil	Churchill	Churchill	Innisfil Creek - Cookstown	2002	Golder	6.3
Innisfil	Cookstown	Cookstown	Innisfil Creek - Cookstown	2008	Town of Innisfil	2.3
Mulmur	Mansfield	Mansfield	Pine River - Mansfield	2008, estimated	NVCA	6.0
New Tecumseth	Alliston	Hillcrest	Middle Nottawasaga	2008	NVCA	0.0

Municipality	Community	Municipal System/ Wellfield	Subwatershed	Year of Data	Source of Data	Average Annual Pumping Rate (L/s)
New Tecumseth	Tottenham	Tottenham	Innisfil Creek - Tottenham	2008	NVCA	17.2
Oro-Medonte	Craighurst	Craighurst	Willow Creek - Midhurst	2008	SSEA	0.4
Springwater	Elmvale	Elmvale	Wye River	2006	SSEA	8.0
Springwater	Midhurst	Carson Road	Willow Creek - Midhurst	2008	NVCA	3.5
Springwater	Midhurst	Paddy Dunn's Circle	Willow Creek - Midhurst	2008	NVCA	1.2
Springwater	Midhurst	Idlewood	Willow Creek - Midhurst	2008	NVCA	6.5
Springwater	Midhurst	Greenpine	Willow Creek - Midhurst	2008	NVCA	2.4
Springwater	Snow Valley	Snow Valley	Willow Creek - Midhurst	2008	NVCA	3.3

Municipality	Community	Municipal System/ Wellfield	Subwatershed	Year of Data	Source of Data	Average Annual Pumping Rate (L/s)
Springwater	Vespra Downs	Vespra Downs	Middle Nottawasaga	2008	NVCA	0.5

**Table 3.4- 6: Summary of Municipal Groundwater Demands by Subwatershed (AquaResource and Golder, 2010)**

Subwatershed	ID	Area (Km <sup>2</sup> )	Average Municipal Groundwater Demand (L/s)	Average Municipal Groundwater Demand (mm/yr)
Willow Creek-Shanty Bay	9	115	2	<1
Willow Creek-Midhurst	7	164	17	3
Pine River-Mansfield	17	216	6	1
Pine River-Borden	5	139	29	7
Middle Nottawasaga	3	305	12	1
Innisfil Creek-Tottenham	20	165	20	4
Innisfil Creek-Beeton	2	167	N/A	N/A
Innisfil Creek-Cookstown	6	162	9	2

**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 and a summary of the other permitted water demand is provided in Table 3.4- 7. It should be noted that Table 3.4- 7 highlights the maximum permitted taking values for each subwatershed.

**Table 3.4- 7: Summary of Non-Municipal Permitted Water Demand (AquaResource and Golder, 2010)**

Subwatershed	ID	Area (Km <sup>2</sup> )	Average Municipal Groundwater Demand (L/s)	Average Municipal Groundwater Demand (mm/yr)
Willow Creek-Shanty Bay	9	115	133	37
Willow Creek-Midhurst	7	164	580	112
Pine River-Mansfield	17	216	109	16
Pine River-Borden	5	139	432	98
Middle Nottawasaga	3	305	572	59
Innisfil Creek-Tottenham	20	165	103	20
Innisfil Creek-Beeton	2	167	609	115
Innisfil Creek-Cookstown	6	162	371	72

**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 Nottawasaga Valley watershed include agriculture needs and unserviced domestic use. The non-permitted water takings are found in Table 3.4- 8

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 Budget 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 a census-based estimation technique it is not possible to 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 unserved domestic water use includes any household water use that is not supplied by a municipal water source. An estimate of the unserved 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 new subwatersheds. The unserved 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 and therefore would not be considered 100% consumptive. A consumptive factor of 0.2 was used, which assumes that 20% of water is either consumed or not returned to the same aquifer source (i.e. deeper aquifer system).

**Table 3.4- 8: Non-permitted Agricultural and Un-served Domestic Water Use (AquaResource and Golder, 2010)**

Subwatershed	ID	Non-Permitted Agricultural Demand (L/s)	Un-served Domestic Water Use (L/s)	Total Non-Permitted Water Use (L/s)	Total Non-Permitted Water Use (mm/yr)
Willow Creek-Shanty Bay	9	0.5	2.4	2.9	0.8
Willow Creek-Midhurst	7	0.7	3.8	4.6	0.9
Pine River-Mansfield	17	4.3	1.9	6.2	0.9
Pine River-Borden	5	3.3	1.4	4.7	1.1
Middle Nottawasaga	3	18.4	5.9	24.3	2.5
Innisfil Creek-Tottenham	20	8.6	5.8	14.5	2.8
Innisfil Creek-Beeton	2	8.8	5.9	14.7	2.8
Innisfil Creek-Cookstown	6	8.4	5.7	14.1	2.7

### **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. 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 3.4.4).

Table 3.4- 9 indicates that the Willow Creek-Midhurst and Middle Nottawasaga River subwatersheds have a relatively high demand for almost every month, with the highest demands observed in the summer months. Table 3.4- 10 shows the consumptive demand by sector per subwatershed.

**Table 3.4- 9: Consumptive Demand by Subwatershed (AquaResouce and Golder, 2010)**

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstwon
ID	9	7	17	5	3	20	2	6
Consumptive Demand (L/s): Jan	4	85	13	30	25	26	7	14
Consumptive Demand (L/s): Feb	4	80	13	32	25	27	7	14
Consumptive Demand (L/s): Mar	4	37	11	31	24	26	7	14
Consumptive Demand (L/s): Apr	5	40	13	33	25	29	72	16
Consumptive Demand (L/s): May	5	77	14	41	75	29	75	43
Consumptive Demand (L/s): Jun	7	105	27	91	150	56	112	118
Consumptive Demand (L/s): Jul	9	116	27	138	212	57	113	130
Consumptive Demand (L/s): Aug	8	121	27	99	241	55	169	137
Consumptive Demand (L/s): Sep	7	88	26	47	145	54	103	118
Consumptive Demand (L/s): Oct	5	52	11	33	30	26	75	15
Consumptive Demand (L/s): Nov	4	57	11	30	25	25	7	14
Consumptive Demand (L/s): Dec	4	121	13	31	26	24	7	15

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstown
Consumptive Demand (L/s): Avg	6	81	17	53	84	36	63	54
Consumptive Demand (L/s): Max	9	121	27	138	241	57	169	137

**Table 3.4- 10: Percentage of Consumptive Water Demand by Sector per Subwatershed**

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstown
ID	9	7	17	5	3	20	2	6
Agricultural Est.	-	-	-	24%	42%	-	12%	48%
Agricultural Rep.	-	-	<1%	5%	<1%	-	1%	2%
Commercial Est.	-	61%	28%	7%	2%	-	63%	8%
Commercial Rep.	11%	8%	-	1%	2%	-	-	-
Industrial Est.	-	-	<1%	-	-	-	-	-
Industrial Rep.	4%	-	-	-	-	-	-	-
Miscellaneous Est.	<1%	-	-	-	-	-	-	-
Recreation Rep.	-	3%	-	-	-	-	-	-
Remediation Rep.	-	-	-	-	-	-	-	-
Private Water Supply Est.	3%	<1%	1%	<1%	11%	4%	2%	-
Private Water Supply Rep.	-	-	-	-	<1%	-	-	<1%
Municipal Water Supply Rep.	30%	21%	35%	55%	14%	56%	-	16%
Livestock and Rural Domestic Est.	51%	6%	36%	9%	29%	40%	23%	26%
Total Estimated Est.	55%	67%	64%	39%	84%	44%	99%	82%
Total Reported Rep.	45%	33%	35%	60%	16%	56%	<1%	18%

### **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 3.4.3). 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).

#### **3.4.4 Tier Two Stress Assessment**

The Tier Two Stress Assessment has only been conducted for groundwater systems since no in-land municipal surface water systems exist within the Source Protection Area. The groundwater systems in the study area that have undergone the stress assessment are shown in Table 3.4-11 and Figure 3.4-1.

**Table 3.4- 11: Groundwater Systems in the Study Area that have Undergone the Stress Assessment**

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Tier 2 Subwatershed
Regional Municipality of Peel	Town of Caledon	Palgrave	Innisfil Creek
County of Simcoe	Town of Innisfil	Churchill Well Supply	Innisfil Creek- Cookstown
County of Simcoe	Town of New Tecumseth	Tottenham Well Supply	Innisfil Creek- Tottenham
County of Simcoe	Township of Adjala-Tosorontio	Colgan Well Supply	Innisfil Creek- Tottenham
County of Simcoe	Township of Adjala-Tosorontio	Loretto Heights Well Supply	Innisfil Creek- Tottenham
County of Simcoe	Township of Adjala-Tosorontio	Weca Well Supply	Innisfil Creek- Tottenham
County of Simcoe	Township of Adjala-Tosorontio	Everett Well Supply	Pine River- Borden
County of Simcoe	Township of Adjala-Tosorontio	Lisle Well Supply	Pine River- Borden
County of Simcoe	Township of Adjala-Tosorontio	Mansfield Well Supply	Pine River- Mansfield
County of Simcoe	Township of Essa	Angus Well Supply	Pine River- Borden and Middle Nottawasaga
County of Simcoe	Township of Essa	Glen Ave (Thornton) Well Supply	Middle Nottawasaga
County of Simcoe	Town of New Tecumseth	Hillcrest Subdivision Well Supply	Middle Nottawasaga
County of Simcoe	City of Barrie	Barrie	Middle Nottawasaga and Barrie Creeks
County of Simcoe	Township of Oro-Medonte	Craighurst Well Supply	Willow Creek- Midhurst
County of Simcoe	Township of Springwater	Del Trend Well Supply	Willow Creek- Midhurst
County of Simcoe	Township of Springwater	Midhurst Well Supply	Willow Creek- Midhurst
County of Simcoe	Township of Springwater	Snow Valley Highlands Well Supply	Willow Creek- Midhurst

### Existing Conditions

The percent water demand was calculated for the Innisfil Creek, Willow Creek, Pine River and Middle Nottawasaga River subwatersheds using estimates of groundwater supply, reserve and consumptive demand. The water demand used in the stress assessment is discussed above in Section 3.4.3. 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 3.4-8. The figure illustrates that the Nottawasaga Valley portion of the study area discharges a high volume of groundwater over 2,500 L/s on an annual basis for some subwatersheds, when compared to portions of the Lake Simcoe watershed where some subwatersheds discharge less than 500L/s on an annual basis.

The results of the existing conditions stress assessment are shown on Table 3.4-12 and Table 3.4-13. The existing conditions stress assessment indicated that two subwatershed Willow Creek-Midhurst and Innisfil Creek-Beeton are within 2% of the moderate potential for stress threshold. Therefore, these subwatersheds are required to undergo an uncertainty assessment; however, as the Innisfil Creek-Beeton subwatershed contains no municipal drinking water system it is not required to undergo any further assessment as per the Technical Rules (MOE, 2006).

**Table 3.4- 12: Groundwater Stress Assessment-Existing Conditions (AquaResource and Golder, 2010)**

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstwon
ID	9	7	17	5	3	20	2	6
Groundwater Supply (L/s): Recharge	679	1319	1594	958	1706	929	845	752
Groundwater Supply (L/s): Flow In	0	339	50	222	392	28	326	79
Groundwater Supply (L/s): Total Supply	679	1658	1644	1180	2099	957	1172	831
Groundwater Reserve (L/s)	14	113	137	84	188	60	91	61
Consumptive Demand (L/s): Annual Average	6	81	17	53	84	36	63	54
Consumptive Demand (L/s): Monthly Maximum	9	121	27	138	241	57	169	137
Month of Max Demand	July	December	July	July	August	July	August	August
Percent Water Demand (%): Average Average	1%	5%	1%	5%	4%	4%	6%	7%
Percent Water Demand (%): Monthly Maximum	1%	8%	2%	13%	13%	6%	16%	18%

**Table 3.4- 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
9	Willow Creek- Shanty Bay	Low	Low	Yes	Shanty Bay
7	Willow Creek- Midhurst	Low	Low	Yes	Midhurst, Snow Valley, Craighurst
17	Pine River- Mansfield	Low	Low	Yes	Mansfield
5	Pine River- Borden	Low	Low	Yes	Angus, Everett, Lisle
3	Middle Nottawasaga	Low	Low	Yes	Angus, Vespra Downs, Glen Avenue, Hillcrest, Barrie
20	Innisfil Creek- Tottenham	Low	Low	Yes	Tottenham, Colgan, Weca, Loretto Heights
2	Innisfil Creek- Beeton	Low	Low	No	None
6	Innisfil Creek- Cookstown	Low	Low	Yes	Cookstown, Churchill

### **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. All subwatersheds with the exception of Innisfil Creek-Beeton underwent the future pumping scenario, as it does not contain a municipal system. The projected municipal demand was obtained from LSRCA, NVCA, SSEA and the local municipalities. In areas where projections were unavailable future pumping rates were estimated from official growth plans and population estimates (Table 3.4-14).

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 recharge rates were assumed to be based on the 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 3.4-15.

The results of the future conditions stress assessment are shown on Table 3.4-16 and Table 3.4-17. The future conditions indicate that all subwatersheds undergoing the Tier Two evaluation located in the Nottawasaga Valley watershed remain at a low potential for stress. The Willow Creek-Midhurst subwatershed remains within the 2% threshold for becoming moderately stressed. As a result, all of the subwatersheds are required to undergo the drought assessment scenario.

**Table 3.4- 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
Adjala-Tosorontio	Colgan	Colgan	Innisfil Creek-Tottenham	1.3	2.0	LSRCA
Adjala-Tosorontio	Everett	Everett Grohal	Pine River-Borden	5.0	16.5	LSRCA
Adjala-Tosorontio	Lisle	Lisle	Pine River-Borden	5.3	0.3	LSRCA (verifying why future is lower)
Adjala-Tosorontio	Loretto	Loretto Heights	Innisfil Creek-Tottenham	0.3	0.3	LSRCA
Adjala-Tosorontio	Loretto	Weca	Innisfil Creek-Tottenham	1.4	1.4	LSRCA
Barrie	Barrie	Barrie	Middle Nottawasaga	0.0	48.4	LSRCA, New well 19
Essa	Angus	Brownley	Middle Nottawasaga	0.0	23.6	Planned System and Essa Twp Projected Population Growth from 2021-2031

Municipality	Community	Wellfield	Subwatershed	Existing Volume Pumped (L/s)	Future Volume Pumped (L/s)	Data Source and Comment on Increase in Future Demand
Essa	Angus	Centre Street	Middle Nottawasaga	6.8	10.7	Essa Twp Projected Population Growth from 2006-2031
Essa	Angus	Mill Street	Pine River-Borden	18.7	29.3	Essa Twp Projected Population Growth from 2006-2031
Essa	Thornton	Glen Avenue	Middle Nottawasaga	4.3	6.7	Essa Twp Projected Population Growth from 2006-2031
Innisfil	Churchill	Churchill	Innisfil Creek-Cookstown	6.3	9.8	MTO Population Growth
Innisfil	Cookstown	Cookstown	Innisfil Creek-Cookstown	2.3	3.7	MTO Population Growth
Mulmur	Mansfield	Mansfield	Pine River-Mansfield	6.0	12.0	Missing Data, assumed double
New Tecumseth	Alliston	Hillcrest	Middle Nottawasaga	0.0	9.5	LSRCA

Municipality	Community	Wellfield	Subwatershed	Existing Volume Pumped (L/s)	Future Volume Pumped (L/s)	Data Source and Comment on Increase in Future Demand
New Tecumseth	Tottenham	Tottenham	Innisfil Creek-Tottenham	17.2	46.4	LSRCA
Oro-Medonte	Craighurst	Craighurst	Willow Creek-Midhurst	0.4	4.1	LSRCA
Oro-Medonte	Shanty Bay	Shanty Bay	Willow Creek-Shanty Bay	1.7	5.7	LSRCA
Springwater	Midhurst	Midhurst	Willow Creek-Midhurst	13.7	14.0	Based on Residential Development Plans
Springwater	Snow Valley	Snow Valley	Willow Creek-Midhurst	3.3	4.0	Based on Residential Development Plans
Springwater	Vespra Downs	Vespra Downs	Middle Nottawasaga	0.5	0.5	Based on Residential Development Plans

**Table 3.4-15: Future land uses changes and recharge 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 (%)
9	Willow Creek-Shanty-Bay	2.2%	679	186	671	184	-1%
7	Willow Creek-Midhurst	2.2%	1319	254	1304	251	-1%
17	Pine River-Mansfield	2.4%	1594	233	1575	230	-1%
5	Pine River-Borden	5.3%	958	218	933	212	-3%
3	Middle Nottawasaga	3.8%	1706	177	1674	173	-2%
20	Innisfil Creek-Tottenham	8.4%	929	177	890	170	-4%
6	Innisfil Creek-Cookstown	0.8%	752	146	749	146	0%

**Table 3.4- 16: Groundwater Stress Assessment-Future Conditions (AquaResource and Golder, 2010)**

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Cookstown
ID	9	7	17	5	3	20	6
Future Groundwater Supply (L/s): Recharge	671	1304	1575	933	1674	890	749
Future Groundwater Supply (L/s): Flow In	0	339	50	222	392	28	79
Future Groundwater Supply (L/s): Total Supply	671	1643	1625	1155	2066	918	828
Groundwater Reserve (L/s)	14	113	137	84	188	60	61
Future Consumptive Demand (L/s): Annual Average	10	86	23	70	171	66	59
Future Consumptive Demand (L/s): Monthly Maximum	12	135	26	153	311	77	127
Future Percent Water Demand: Annual Average	1%	6%	2%	7%	9%	8%	8%
Future Percent Water Demand: Monthly Maximum	2%	9%	2%	14%	17%	9%	17%

**Table 3.4-17: Groundwater Stress Classification-Future Conditions (AquaResource and Golder, 2010).**

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Evaluate Drought Conditions	Major Municipal Water Supply System
9	Willow Creek - Shanty Bay	Low	Low	Yes	Shanty Bay
7	Willow Creek - Midhurst	Low	Low	Yes	Midhurst, Snow Valley, Craighurst
17	Pine River - Mansfield	Low	Low	Yes	Mansfield
5	Pine River - Borden	Low	Low	Yes	Angus, Everett, Lisle
3	Middle Nottawasaga	Low	Low	Yes	Angus, Vespra Downs, Glen Avenue, Hillcrest, Barrie
20	Innisfil Creek - Tottenham	Low	Low	Yes	Tottenham, Colgan, Weca, Loretto Heights
2	Innisfil Creek - Cookstown	Low	Low	Yes	Cookstown, Churchill

**Planned and Future Conditions**

The City of Barrie has one planned municipal well (well #19) located within the study area (Table 3.4-18). However, this well was not evaluated in the planned scenario as the anticipated pumping rate was included in the future demand scenario. (AquaResource and Golder, 2010).

**Table 3.4-18: 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

**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 relieve pressure on groundwater sources. As well, the Township of Adjala-Tosorontio has had to add additional wells for the Colgan well supply and the Town of Innisfil for the Cookstown well supply to supply the growing demand for water. As a result, no subwatersheds would be classified as moderately stressed due to historical conditions, in the Nottawasaga Valley portion of the study area.

**Drought Scenario**

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

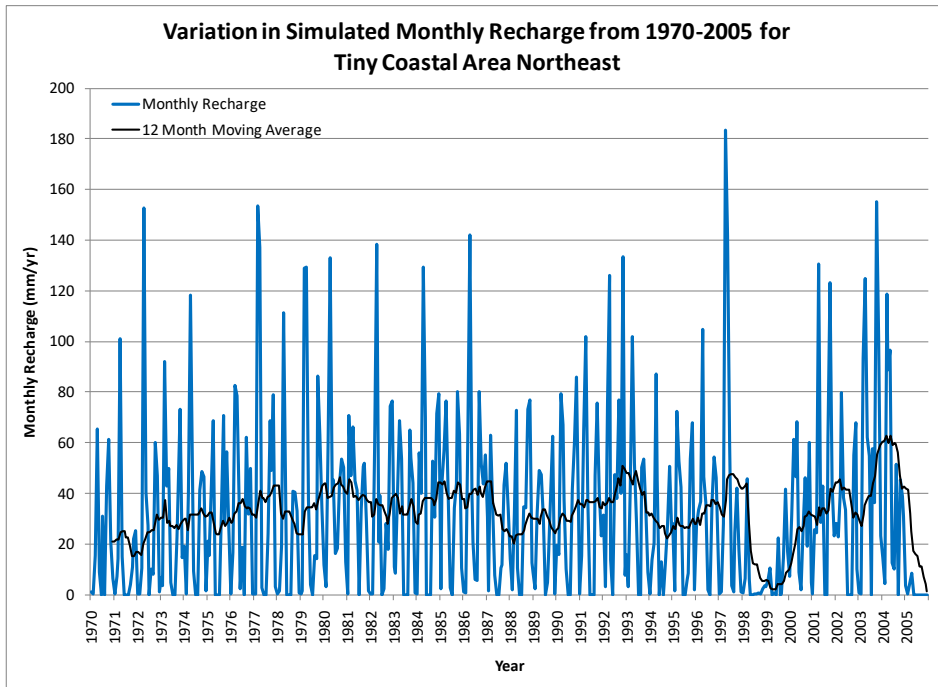
The years of 1998-1999 represent a recorded period of low precipitation, for which estimated recharge is available from the HSP-F and PRMS simulations. Since this information is readily available, the two-year and ten-year scenarios were evaluated simultaneously.

### **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 (FORa).

In addition to average annual recharge, a time series of monthly simulated recharge rates for the 1970-2005 period was available from the HSP-F continuous streamflow-generation model across the NVCA and SSEA. Annual average recharge was preserved across the Study Area when completing this exercise. Thus, a monthly time series was generated across the Study Area for each HSP-F model catchment in the NVCA and SSEA watersheds. Utilizing monthly average recharge rates assumes that recharge is constant throughout the month. While in reality, the rates are not constant, they do reflect the relative changes in stress occurring throughout a 2-year or 10-year drought period.

Graph 3.4-1 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 3.4-1: 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 time step 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 3.4-2). This can be generated for any well within the Study Area.

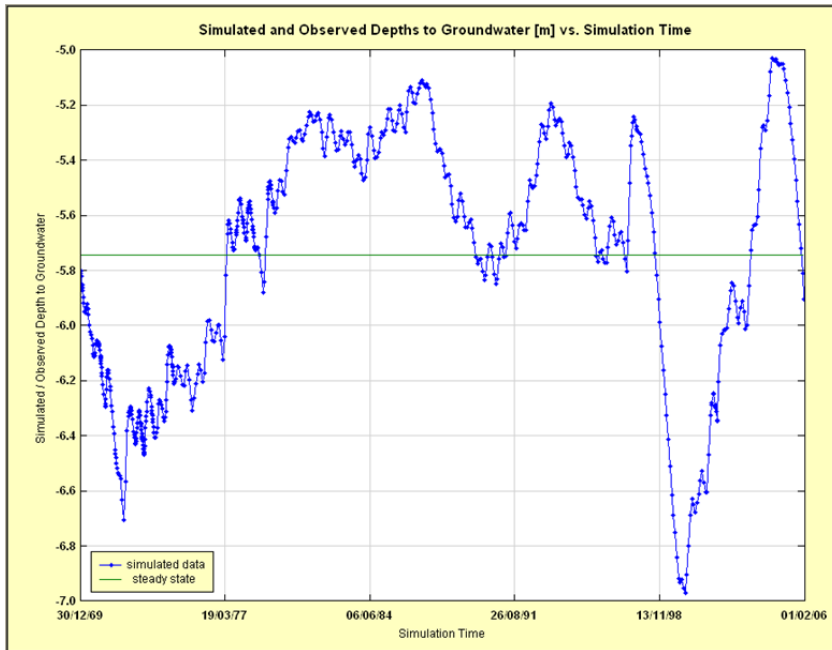
**Results**

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 3.4-2 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 the impact of 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 1998-1999 (by approximately 1 m), 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 3.4-2: Simulated Well Response from 1970 to 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 3.4-19. The results of the drought assessment are shown in Table 3.4-19, 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 3.4-19, there are no 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 and all subwatersheds listed below remain at a low potential for stress.

**Table 3.4-19: Results of Groundwater Drought Scenario-Maximum Drawdown**

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
Willow Creek - Shanty Bay	Oro-Medonte	Shanty Bay	Shanty Bay	Well 1	34	2	34	2	N
Willow Creek - Shanty Bay	Oro-Medonte	Shanty Bay	Shanty Bay	Well 2	21	4	21	4	N
Willow Creek - Shanty Bay	Oro-Medonte	Shanty Bay	Shanty Bay	Well 3	38	2	38	2	N
Willow Creek - Midhurst	Oro-Medonte	Craighurst	Craighurst	Well 1	15	2	15	2	N
Willow Creek - Midhurst	Oro-Medonte	Craighurst	Craighurst	Well 2	14	4	14	4	N
Willow Creek - Midhurst	Oro-Medonte	Craighurst	Craighurst	Well 3	19	2	19	2	N
Willow Creek - Midhurst	Springwater	Carson Road	Midhurst	Well 5	61	5	61	5	N
Willow Creek - Midhurst	Springwater	Greenpine	Midhurst	Well 4	62	3	62	3	N
Willow Creek - Midhurst	Springwater	Idlewood	Midhurst	Well 2	66	5	66	5	N
Willow Creek - Midhurst	Springwater	Idlewood	Midhurst	Well 3	64	6	64	6	N

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
Willow Creek - Midhurst	Springwater	Paddy Dunn's Circle	Midhurst	Del Trend Well 1	56	3	56	3	N
Willow Creek - Midhurst	Springwater	Paddy Dunn's Circle	Midhurst	Del Trend Well 2	52	3	52	3	N
Willow Creek - Midhurst	Springwater	Paddy Dunn's Circle	Midhurst	Del Trend Well 3	49	3	49	3	N
Willow Creek - Midhurst	Springwater	Snow Valley	Snow Valley	Well 1	43	7	43	7	N
Willow Creek - Midhurst	Springwater	Snow Valley	Snow Valley	Well 2	44	7	44	7	N
Willow Creek - Midhurst	Springwater	Snow Valley	Snow Valley	Well 3	74	7	74	7	N
Willow Creek - Midhurst	Springwater	Snow Valley	Snow Valley	Well 4	45	7	45	7	N
Pine River - Mansfield	Mulmur	Mansfield	Mansfield	Well 1	23	1	23	1	N
Pine River - Mansfield	Mulmur	Mansfield	Mansfield	Well 2	21	4	21	4	N

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
Pine River - Mansfield	Mulmur	Mansfield	Mansfield	Well 3	14	1	14	1	N
Pine River - Borden	Adjala-Tosorontio	Everett Grohal	Everett	Well (Ballpark )	38	4	38	4	N
Pine River - Borden	Adjala-Tosorontio	Everett Grohal	Everett	Well (Grohal)	42	3	42	3	N
Pine River - Borden	Adjala-Tosorontio	Everett Grohal	Everett	Well (Standby )	39	3	39	3	N
Pine River - Borden	Adjala-Tosorontio	Lisle	Lisle	Well 1	49	6	49	6	N
Pine River - Borden	Adjala-Tosorontio	Lisle	Lisle	Well 2	46	6	46	6	N
Pine River - Borden	Essa	Mill Street	Angus	Well 3	44	<1	44	<1	N
Middle Nottawasaga	Barrie	Barrie	Barrie	Well 19	32	1	31	13	N
Middle Nottawasaga	Essa	Brownley	Angus	Well 4	25	<1	25	2	N
Middle Nottawasaga	Essa	Brownley	Angus	Well 5	25	<1	25	2	N

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
Middle Nottawasaga	Essa	Brownley	Angus	Well 6	27	<1	27	2	N
Middle Nottawasaga	Essa	Centre Street	Angus	Well 1	42	<1	42	<1	N
Middle Nottawasaga	Essa	Centre Street	Angus	Well 2	42	<1	42	<1	N
Middle Nottawasaga	Essa	Glen Avenue	Thornton	Well 1	26	8	26	8	N
Middle Nottawasaga	Essa	Glen Avenue	Thornton	Well 2	24	8	24	8	N
Middle Nottawasaga	Essa	Glen Avenue	Thornton	Well 3	16	3	16	3	N
Middle Nottawasaga	Essa	Glen Avenue	Thornton	Well 4	15	1	15	1	N
Middle Nottawasaga	New Tecumseth	Hillcrest	Alliston	Hillcrest Well	71	5	71	5	N
Middle Nottawasaga	Springwater	Vespra Downs	Vespra Downs	Well 1-91	45	3	45	3	N
Middle Nottawasaga	Springwater	Vespra Downs	Vespra Downs	Well 1-93	46	2	46	2	N
Innisfil Creek - Tottenham	Adjala-Tosorontio	Colgan	Colgan	Well 1	55	2	55	2	N

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
Innisfil Creek - Tottenham	Adjala-Tosorontio	Colgan	Colgan	Well 1	39	2	39	2	N
Innisfil Creek - Tottenham	Adjala-Tosorontio	Colgan	Colgan	Well 2	38	2	38	2	N
Innisfil Creek - Tottenham	Adjala-Tosorontio	Loretto Heights	Loretto	Well 1	15	2	15	2	N
Innisfil Creek - Tottenham	Adjala-Tosorontio	Weca	Loretto	Well 1	18	2	18	2	N
Innisfil Creek - Tottenham	Adjala-Tosorontio	Weca	Loretto	Well 2	25	2	25	2	N
Innisfil Creek - Tottenham	New Tecumseth	Tottenham	Tottenham	Well 4	63	4	63	4	N
Innisfil Creek - Tottenham	New Tecumseth	Tottenham	Tottenham	Well 5	59	4	59	4	N
Innisfil Creek - Tottenham	New Tecumseth	Tottenham	Tottenham	Well 6	75	14	75	14	N
Innisfil Creek - Tottenham	New Tecumseth	Tottenham	Tottenham	Well 7	68	8	68	8	N
Innisfil Creek - Cookstown	Innisfil	Churchill	Churchill	Well 1	103	12	103	12	N
Innisfil Creek - Cookstown	Innisfil	Churchill	Churchill	Well 2	10	3	10	3	N

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
Innisfil Creek - Cookstown	Innisfil	Churchill	Churchill	Well 3	100	5	100	5	N
Innisfil Creek - Cookstown	Innisfil	Cookstown	Cookstown	Well 1	6	<1	6	<1	N
Innisfil Creek - Cookstown	Innisfil	Cookstown	Cookstown	Well 2	62	<1	62	<1	N
Innisfil Creek - Cookstown	Innisfil	Cookstown	Cookstown	Well 3R	6	1	6	1	N
Innisfil Creek - Cookstown	Innisfil	Cookstown	Cookstown	Well 4	32	<1	32	<1	N

### **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 (Aqua Resource 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 3.4- 20. For each subwatershed, the stress classification under the two sensitivity analysis scenarios did not differ from the stress classification existing conditions. 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 3.4- 20: Groundwater Sensitivity Analysis- Existing Conditions (AquaResource and Golder, 2010)**

Subwatershed	Willow Creek-Shanty Bay	Willow Creek-Midhurst	Pine River-Mansfield	Pine River-Borden	Middle Nottawasaga	Innisfil Creek-Tottenham	Innisfil Creek-Beeton	Innisfil Creek-Cookstown
Existing Conditions, % Water Demand, Avg Annual	1%	5%	1%	5%	4%	4%	6%	7%
Existing Conditions, % Water Demand, Max Month	1%	8%	2%	13%	13%	6%	16%	18%
Groundwater Agricultural Demand 100% Consumptive, % Water Demand, Avg Annual	1%	5%	1%	5%	5%	4%	6%	8%
Groundwater Agricultural Demand 100% Consumptive, % Water Demand, Max Month	1%	8%	2%	14%	14%	6%	17%	20%
10% Less Recharge, % Water Demand, Avg Annual	1%	6%	1%	5%	5%	4%	6%	8%
10% Less Recharge, % Water Demand, Max Month	1%	9%	2%	14%	14%	7%	17%	20%
Sensitivity Level	Low	Low	Low	Low	Low	Low	Low	Low

## Stress Assessment Results

[Table 3.4-21](#) shows the summary of subwatershed groundwater stress classification.

### *Willow Creek-Shanty Bay*

The Willow Creek-Shanty Bay subwatershed contains the municipal groundwater systems for the community of Shanty Bay. Under existing conditions, the subwatershed has a Percent Water Demand of 2% under average demand and 3% under maximum monthly demand. Under future and planned conditions the stress levels remained the exact same. During the drought scenario the wells did not experience any significant drawdowns. This results in a classification of a low potential for stress.

The largest groundwater takings within the Willow Creek-Shanty Bay subwatershed are commercial and industrial (~12% and 48% respectively). The municipal supplies for Shanty Bay comprise approximately 9% of the groundwater takings, and the remaining approximately 16% for non-permitted users.

Under the requirements of the Clean Water Act, the Willow Creek-Shanty Bay subwatershed is not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

### *Willow Creek-Midhurst*

The Willow Creek-Midhurst subwatershed contains the municipal groundwater systems for Midhurst, Snow Valley and Craighurst. Under existing conditions, the subwatershed has a Percent Water Demand of 8% under average demand and 13% under the maximum monthly demand. Under the future and planned conditions all stress levels remain the same except the monthly maximum stress which increased to 14% under the future scenario. During the drought scenario the wells did not experience any significant drawdowns. This results in a classification of a low potential for stress.

The largest groundwater takings within the Willow Creek-Midhurst subwatershed are for commercial uses approximately 69%. The municipal supplies for Midhurst, Snow valley and Craighurst account for 13% of the groundwater takings.

Under the requirements of the Clean Water Act, Midhurst, Snow Valley and Craighurst municipal systems are not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater. It is noted that, given the proximity of these systems to Barrie along with its hydrogeological link, this area will be incorporated into the model domain for the Barrie and Innisfil Tier 3 Water Budget exercise.

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#### *Pine River- Mansfield*

The Pine River-Mansfield subwatershed contains the municipal groundwater systems for the community of Mansfield. Under existing conditions, the subwatershed has a Percent Water Demand of 1% under average demand and 1% under maximum monthly demand. The results of the stress assessment throughout all scenarios remained very similar. Under the future and planned scenarios the stress levels remained the same. During the drought scenario the wells did not experience any significant draw downs. This results in its classification of a low potential for stress.

The largest groundwater takings within the subwatershed are for commercial and agriculture purposes (approximately 20% and 26% respectively). The municipal supplies account for approximately 12% of the groundwater takings.

Under the requirements of the Clean Water Act, the Mansfield municipal system is not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

#### *Pine River-Borden*

The Pine River-Borden subwatershed contains the municipal groundwater systems for the communities of Angus, Everett, and Lisle. Under existing conditions, the subwatershed has a Percent Water Demand of 5% under average demand and 17% under maximum monthly demand. Under planned conditions the stress levels remained the same. While during the future demand scenario the stress levels increased to 7% under average demand and 18% under maximum monthly demand. During the drought scenario the wells did not experience any significant draw downs. This results in a classification of a low potential for stress.

The largest groundwater takings within the subwatershed are for municipal supplies at approximately 40%, followed closely by agricultural takings at 39%.

Under the requirements of the Clean Water Act, the Angus, Everett and Lisle well supplies are not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

#### *Middle Nottawasaga*

The Middle Nottawasaga River subwatershed contains the municipal groundwater takings for the communities of Angus, Vespra Downs, Glen Avenue, Hillcrest and Barrie. Under existing conditions, the subwatershed has a Percent Water Demand of 4% under average demand and 11% under maximum monthly demand. Under the future and planned conditions the stress levels increased to 6% under average demand and 12% and 13% respectively under maximum

monthly demand. During the drought scenario the wells did not experience any significant draw downs. This results in a classification of a low potential for stress.

The largest groundwater takings within the Middle Nottawasaga subwatershed are for agricultural purposes at approximately 29%. The municipal supplies account for approximately 9%.

Under the requirements of the Clean Water Act, the Angus, Vespra Downs, Glen Avenue and Hillcrest municipal supplies are not subject to completion of a Tier Three Water Quantity and Risk Assessment. The City of Barrie is required to undergo a Tier Three Assessment, as the results of the neighbouring Barrie Creek subwatershed stress assessment found the city's municipal well supplies to have the potential to be significantly stressed.

#### *Innisfil Creek-Tottenham*

The Innisfil Creek- Tottenham subwatershed contains the municipal groundwater systems for Tottenham, Colgan, Weca and Loretto Heights. Under existing conditions, the subwatershed has a percent water demand of 3% under average demand and 4% under maximum monthly demand. Under planned conditions the stress levels remained the same. Under future conditions the stress levels increased to 4% under average demand and 5% under monthly maximum demand. During the drought scenario the wells did not experience any significant draw downs. This results in a classification of a low potential for stress.

Municipal water supplies account for the largest groundwater takings within the Innisfil Creek-Tottenham subwatershed at approximately 40%. The next largest groundwater takers within the subwatershed are for livestock watering purposes.

Under the requirements of the Clean Water Act, the Tottenham, Colgan, Weca and Loretto Heights municipal systems are not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

#### *Innisfil Creek-Beeton*

The Innisfil Creek-Beeton subwatershed contains no municipal water supply systems. Under existing conditions the subwatershed has a percent water demand of 6% under average demand and 16% under maximum monthly demand.

Under the requirements of the Clean Water Act, the Innisfil Creek-Beeton subwatershed is not required to complete a Tier Three Water Quantity Risk Assessment for groundwater as it contains no municipal systems.

*Innisfil Creek-Cookstown*

The Innisfil Creek-Cookstown subwatershed contains the municipal groundwater systems for Cookstown and Churchill. Under existing conditions, the subwatershed has a Percent Water Demand of 6% under average demand and 16% under maximum monthly demand. Under planned and future conditions the stress levels remained the same. During the drought scenario the wells did not experience any significant draw downs. This results in a classification of a low potential for stress.

The largest groundwater takings within the Innisfil Creek-Cookstown subwatershed are for agricultural purposes at approximately 50%. The municipal supplies for Cookstown and Churchill comprise on 10% of the takings.

Under the requirements of the Clean Water Act, the Cookstown and Churchill municipal systems are not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

**Table 3.4-21: Summary of subwatershed groundwater stress classification**

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Max Demand)	Future	Planned	Drought Concern (Y/N)	Municipal Water Supply Systems
9	Willow Creek - Shanty Bay	Low	Low	Low	N/A	N	Shanty Bay
7	Willow Creek - Midhurst	Low	Low	Low	N/A	N	Midhurst, Snow Valley, Craighurst
17	Pine River - Mansfield	Low	Low	Low	N/A	N	Mansfield
5	Pine River - Borden	Low	Low	Low	N/A	N	Angus, Everett, Lisle
3	Middle Nottawasaga	Low	Low	Low	N/A	N	Angus, Vespra Downs, Glen Avenue, Hillcrest, Barrie
20	Innisfil Creek - Tottenham	Low	Low	Low	N/A	N	Tottenham, Colgan, Weca, Loretto Heights
2	Innisfil Creek - Beeton	Low	Low	N/A	N/A	N	None
6	Innisfil Creek - Cookstown	Low	Low	Low	N/A	N	Cookstown, Churchill

### 3.4.5 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 Nottawasaga Valley Source Protection Area, including:

- physical description of the watershed
- consumptive water demand estimates
- groundwater model description
- 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 in the Lake Simcoe portion of the Study Area was classified as having a moderate or significant potential for hydrologic stress. The results of the Tier Two

Stress Assessment are consistent with expectations. The areas identified through this assessment are primarily driven by focused municipal takings within the most densely populated areas. i.e. Barrie. The municipal systems located in the Barrie Creeks subwatershed are classified as having a significant potential for stress

Based on the analyses completed and presented in the Tier Two report, it is recommended that the City of Barrie municipal systems 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. As these systems are in close proximity it is recommended that the evaluation is completed as part of one study (AquaResource and Golder, 2010).

**Figure 3.4-1: Study Area.**

**Figure 3.4-2: Subwatershed Boundaries.**

**Figure 3.4-3: Numerical Model Domain.**

**Figure 3.4-4: Model Recharge per Hydrologic Response Unit.**

**Figure 3.4-5: Permitted Groundwater Takings.**

**Figure 3.4-6: Average Groundwater Consumptive Demand.**

**Figure 3.4-7: Maximum Groundwater Consumptive Demand.**

**Figure 3.4-8: Groundwater Discharge along Streams.**

**Figure 3.4-9: Subwatershed Groundwater Stress Assessment Results.**

**Figure 3.4-10: Subwatersheds Recommended for Tier 3 Analysis.**

### 3.5 Tier Three Water Budget & Local Area Stress Assessment – City of Barrie

The Tier Two Subwatershed Stress Assessment, completed by Golder Associates and AquaResource, 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.

### 3.5.1 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 3.5-1). The Study Area is located south of Georgian Bay, west of Lake Simcoe, and lies within two major watersheds; the Nottawasaga River Watershed and the Lake Simcoe Watershed, as seen in Figure 3.5- 2. With a surface area of 800 km<sup>2</sup>, 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 all 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 3.5- 3. Currently the City operates fourteen 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 hydrostratigraphy 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 3.5- 1 and Figure 3.5- 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 3.5- 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 3.5- 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 3.5- 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

Hydrostratigraphic Unit	Description
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	

**Table 3.5- 2 : Location of Municipal Well Screens (Municipal Wells and associated aquifers (AquaResource et al., 2013)**

Pressure Zone	Well Name	Pumped Aquifer
Pressure Zone 1 – Core Area	3A (Anne Street)	A4
Pressure Zone 1 – Core Area	4 (Perry Street)	A3
Pressure Zone 1 – Core Area	5 (John Street)	A4
Pressure Zone 1 – Core Area	7 (Tiffin Street)	A3/A4
Pressure Zone 1 – Core Area	11 (Heritage Park)	A3/A4
Pressure Zone 1 – Core Area	12 (Centennial Park)	A4

Pressure Zone	Well Name	Pumped Aquifer
Pressure Zone 1 – Core Area	14 (Heritage Park)	A3/A4
Pressure Zone 1 – Core Area	15 (Centennial Park)	A3/A4
Pressure Zone 1 – Core Area	17 (Cross Street)	A3/A4
Pressure Zone 1 – Core Area	18 (Cross Street)	A3/A4
Pressure Zone 1 – Core Area	19 (Boulton Court)	A3/A4
Pressure Zone 2 - North	9 (Johnson Street)	A3/A4
Pressure Zone 2 - North	13 (Johnson Street)	A3/A4
Pressure Zone 2 - North	16 (Brownwood)	A3
Pressure Zone 2 - South	10 (Huron Road)	A3

### 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 3.5- 5 illustrates groundwater recharge as simulated by the groundwater flow model. More information regarding inflow and outflow rates is provided in Section 3.5.4 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 3.5- 6, while planned land use is shown in Figure 3.5- 7. Figure 3.5- 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 3.5.5 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.

### **3.5.2 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 3.5.1 .

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.

### **3.5.3 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 3.5- 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 3.5- 3: City of Barrie Water Supply Wells (AquaResource et al., 2013)**

Pressure Zone	Well Name	Pumped Aquifer	Maximum Permitted Capacity (m <sup>3</sup> /day)	Operating Capacity (m <sup>3</sup> /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

Pressure Zone	Well Name	Pumped Aquifer	Maximum Permitted Capacity (m <sup>3</sup> /day)	Operating Capacity (m <sup>3</sup> /day)	Operator Comments
Pressure Zone 1 – Core Area	17 (Cross Street)	A3/A4	11,232	10,800*	Largest Yielding Well in System
Pressure Zone 1 – Core Area	18 (Cross Street)	A3/A4	11,232	10,800*	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	
	Total		113,900	81,302	

Notes for the above table:

- \* 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 Environmental Assessment (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 3.5- 4.

The 2012 existing demand estimates presented in Table 3.5- 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 3.5- 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 3.5- 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 3.5- 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 3.5- 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 3.5- 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 3.5- 4: Municipal Water Demand – City of Barrie (AquaResource et al.,2013).**

Pressure Zone	Well Name	Demand ((m <sup>3</sup> /day): Pre-Surface Water Intake (2010, Observed) <sup>1</sup>	Demand (m <sup>3</sup> /day): Existing (2012, Estimate): Average	Demand (m <sup>3</sup> /day): Existing (2012, Estimate): Monthly Standard Deviation <sup>2</sup>	Demand (m <sup>3</sup> /day): Allocated and Planned Demand (2031, Estimated): Average	Demand (m <sup>3</sup> /day): Allocated and Planned Demand (2031, Estimated): Monthly Standard Deviation <sup>2</sup>	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	Well Name	Demand ((m <sup>3</sup> /day): Pre-Surface Water Intake (2010, Observed) <sup>1</sup>	Demand (m <sup>3</sup> /day): Existing (2012, Estimate): Average	Demand (m <sup>3</sup> /day): Existing (2012, Estimate): Monthly Standard Deviation <sup>2</sup>	Demand (m <sup>3</sup> /day): Allocated and Planned Demand (2031, Estimated): Average	Demand (m <sup>3</sup> /day): Allocated and Planned Demand (2031, Estimated): Monthly Standard Deviation <sup>2</sup>	Comments
Pressure Zone 1 – Core Area	18	2,888	2,405	740	3,321	998	
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	
	<b>Total</b>	<b>40,208</b>	<b>32,465</b>		<b>44,746</b>		

Notes for the above table:

1. <sup>1</sup> 2010 rates provided to illustrate the drop in demand at individual wells when the surface water plant was brought online.
2. <sup>2</sup> Monthly range presented as a standard deviation. Monthly pumping projections based on historic pumping from 2007.
3. \*Existing and Committed demand estimates.

### 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 3.5- 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 3.5- 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 3.5- 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 -5.

It is important to note that the Safe Available Drawdown values calculated for this study are relative to 2010 pumping conditions. Safe Additional 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 additional drawdown reflect the period prior to the surface water intake. Table 3.5- 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 3.5.5).

**Table 3.5- 5: Safe 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	<b>51</b>	76
Well 4	179.1	187.6	221	217	211	<b>29</b>	32
Well 5	144.5	170.1	222	220	216	<b>50</b>	71
Well 7	149.3	161.9	222	218	215	<b>56</b>	66
Well 9	182.7	198.4	230	225	215	<b>27</b>	32
Well 11	173.5	185.6	218	208	192	22	<b>19</b>
Well 12	155.5	168.9	218	214	204	<b>45</b>	48
Well 13	177.6	193.8	230	225	215	<b>31</b>	37
Well 14	178.7	185.6	218	210	196	24	<b>17</b>

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 15	174.7	175.6	218	212	209	36	<b>34</b>
Well 16	191.4	202.3	235	233	227	<b>31</b>	36
Well 17	148.3	168.4	222	217	212	<b>49</b>	64
Well 18	147.7	169.6	222	217	212	<b>47</b>	64
Well 19	152.0	165.4	222	217	210	<b>52</b>	58

Notes for the above table:

1. 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 permits. Figure 3.5- 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 3.5- 6 summarizes these permitted water users and their average and maximum permitted pumping rates.

**Table 3.5- 6: Private Permitted Groundwater Takings (AquaResource et al.,2013)**

Category	Purpose	Well Name	Pumping Rate (m <sup>3</sup> /day): Average for 2008	Pumping Rate (m <sup>3</sup> /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

Category	Purpose	Well Name	Pumping Rate (m <sup>3</sup> /day): Average for 2008	Pumping Rate (m <sup>3</sup> /day): Maximum Permitted	Permit Number
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
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

Category	Purpose	Well Name	Pumping Rate (m <sup>3</sup> /day): Average for 2008	Pumping Rate (m <sup>3</sup> /day): Maximum Permitted	Permit Number
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
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

Category	Purpose	Well Name	Pumping Rate (m <sup>3</sup> /day): Average for 2008	Pumping Rate (m <sup>3</sup> /day): Maximum Permitted	Permit Number
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

Notes of the above table:

- \*- 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 3.5- 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<sup>3</sup>/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 3.5- 2 illustrates the coldwater streams that were considered during the groundwater discharge assessment presented in Section 3.5.5. 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, 2008a),(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 3.5- 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.

### **3.5.4 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 3.5.2. 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 3.5- 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 3.5- 7: Summary of Cross Boundary Groundwater Flow (AquaResource et al.,2013)**

Boundary	Cross Boundary Flow (m <sup>3</sup> /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

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 3.5- 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 3.5- 8, modeling results indicate that more than 60% of groundwater flows into the subwatershed across 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 WPC 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<sup>3</sup>/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 3.5- 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<sup>3</sup>/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<sup>3</sup>/day or 119 mm/year. Approximately 41,100 m<sup>3</sup>/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 3.5- 8: Overall Water Balance Table (Barrie Creeks Subwatershed)(AquaResource et al.,2013)**

Inflows	Flow (m <sup>3</sup> /d)	Flow (mm/year)
Precipitation	133,800	910
Overland Flow In	1,000	7
Groundwater Flow In	43,700	297
<b>Total Inflow</b>	<b>178,500</b>	<b>1,214</b>
Outflows	Flow (m <sup>3</sup> /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
<b>Total Outflow</b>	<b>178,500</b>	<b>1,214</b>

**Table 3.5- 9: Water Balance, Groundwater (Barrie Creeks Subwatershed) (AquaResource et al., 2013)**

Inflows	Flow (m <sup>3</sup> /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 <sup>3</sup> /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

### 3.5.5 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, 2008a), 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 3.5.2. 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 3.5- 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 3.5- 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 3.5- 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 3.5- 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.

#### **Local Area Risk Assessment Scenarios**

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 3.5- 10. Where scenario simulation results indicate that municipal wells may not be able to supply their allocated rates, the Local Area (described in section 3.5.5) 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 (2008a) 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 3.5- 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 3.5- 10: Risk Assessment Model Scenarios (AquaResource et al., 2013)**

Scenario	Time Period	Model Scenario Details: Land Cover of the Local Area	Model Scenario Details: Water Demand	Model Scenario Details: Model Simulation
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

Scenario	Time Period	Model Scenario Details: Land Cover of the Local Area	Model Scenario Details: Water Demand	Model Scenario Details: Model Simulation
H(3)	Ten year drought period	Planned, reductions in Recharge	Existing*	Transient, using monthly recharge and monthly pumping

Notes for the above table:

1. \*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 3.5.2 .

#### **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 3.5.3) (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 3.5- 11 and Figure 3.5- 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 3.5- 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 3.5- 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 et al., 2013). A decrease in 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 3.5- 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- 11. 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 3.5- 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 3.5- 11 and Figure 3.5- 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 3.5- 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 3.5- 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 3.5- 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 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 3.5- 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 3.5- 11: Risk Assessment Drawdown Results (AquaResource et al., 2013).**

Well Name	Safe Additional Available Drawdown (2010): Pre- Surface Water Intake	Safe Additional Available Drawdown (2010): Diminished Well Conditions	Average Climate (Steady State): Simulated Drawdown (m): C <sup>1</sup> : Existing Demand (2012)- Post Surface Water Intake	Average Climate (Steady State): Simulated Drawdown (m): G(1): Recharge Reduction, Increased Demand	Average Climate (Steady State): Simulated Drawdown (m): G(2): Increased Demand	Average Climate (Steady State): Simulated Drawdown (m): G(3): Recharge Reduction	Drought (Transient): Simulated Maximum Drawdown (m): D: Existing Demand / Recharge, Post-SW Intake	Drought (Transient): Simulated Maximum Drawdown (m): H(1): Recharge Reduction, Increased Demand	Drought (Transient): Simulated Maximum Drawdown (m): H(2): Increased Demand	Drought (Transient): Simulated Maximum Drawdown (m): H(3): Recharge Reduction
Well 3A	51	51	-2.5	1.4	1.3	-2.4	0.4	2.8	2.7	0.4
Well 4	29	29	-2.0	2.0	1.9	-1.9	1.0	4.0	3.9	1.0
Well 5	50	50	-2.9	1.1	1.0	-2.8	0.0	2.5	2.5	0.0
Well 7	56	56	-3.2	0.9	0.8	-3.1	0.0	2.4	2.4	0.0
Well 9	27	27	-1.4	-0.1	-0.2	-1.2	0.8	2.0	1.9	0.9
Well 11	19*	5*	4.9	<b>8.6</b>	<b>8.6</b>	5.0	<b>8.5</b>	<b>11.4</b>	<b>11.4</b>	<b>8.6</b>
Well 12	45	42*	-3.1	0.5	0.4	-3.0	0.0	1.9	1.8	0.0
Well 13	31	31	-1.5	-0.3	-0.4	-1.3	0.7	1.8	1.8	0.7
Well 14	17*	12*	-4.1	-0.2	-0.3	-4.0	0.0	1.9	1.8	0.0
Well 15	34*	32*	-3.3	0.4	0.3	-3.2	0.0	2.4	2.3	0.0
Well 16	31	31	0.7	1.7	1.6	0.8	3.9	5.0	5.0	3.9
Well 17	49	49	-2.5	1.9	1.8	-2.3	0.5	3.5	3.5	0.5
Well 18	47	47	-2.6	1.7	1.6	-2.5	0.3	3.2	3.2	0.4
Well 19	52	52	-2.2	3.4	3.3	-2.1	0.4	4.9	4.8	0.5

Notes for the above table:

1. <sup>1</sup>Existing Demand included here to compare expected drawdown conditions post-surface water intake with those prior to the surface water intake (2010). This is important as the safe additional available drawdown is representative of conditions prior to the surface water intake. The safe available additional drawdown post surface water intake would be safe additional drawdown in 2010 plus the simulated water level rise post-surface water intake (e.g., SAAD for Well 3A post 2012 would be 51+2.5 = 53.5m)
2. \*Additional drawdown available is calculated using the water levels within the well rather than aquifer
3. **Bolded values indicate pumped drawdown close to, or greater than, the Safe Available Drawdown under diminished well conditions**

### 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 3.5- 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 3.5- 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 3.5- 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 3.5- 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 3.5- 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 3.5- 12 Impacts to Groundwater Discharge Scenarios C and G (AquaResource et al., 2013)**

Stream/ Reach	Pre Surface Water Intake Demand: 2010: GW Discharge (L/s)	Scenario C – Existing Demand (Post SW Intake): GW Discharge (L/s)	Scenario C – Existing Demand (Post SW Intake): Percent Reduction (%)	Scenario G(1): (Increased Demand and Recharge Reduction): GW Discharge (L/s)	Scenario G(1): (Increased Demand and Recharge Reduction): Percent Reduction (%)	Scenario G(2): (Increased Demand): GW Discharge (L/s)	Scenario G(2): (Increased Demand): GW Discharge (L/s)	Scenario G(3): (Recharge Reduction): GW Discharge (L/s)	Scenario G(3): (Recharge Reduction): Percent Reduction (%)
Upper Bear Creek	992	1007	Increase	971	2%	982	1%	996	Increase
Lower Lover's Creek	669	672	Increase	656	2%	667	0%	661	1%
Willow Creek and Little Lake	626	626	No Change	617	1%	623	<1%	619	1%
Barrie Creeks	62	65	Increase	57	8%	60	3%	62	No Change

Notes for the above table:

1. Impacts to groundwater discharge are presented relative to conditions prior to commencement of pumping from the surface water intake (e.g., 2010 conditions)

### Uncertainty Analysis

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 3.5- 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 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 3.5- 13: Data Gap/Uncertainty Alternative Calibration Model Drawdown Results (AquaResource et al., 2013)**

Well Name	Safe Additional Available Drawdown (2010)	Safe Additional Available Drawdown (2010) Diminished Well Conditions	FEFLOW Groundwater Model Scenario Drawdown (m): Average Climate: C: Existing Demand	FEFLOW Groundwater Model Scenario Drawdown (m): Average Climate: G(1): Recharge Reduction, Increased Demand	FEFLOW Groundwater Model Scenario Drawdown (m): Average Climate: G(2): Increased Demand	FEFLOW Groundwater Model Scenario Drawdown (m): Average Climate: G(3): Recharge Reduction	FEFLOW Groundwater Model Scenario Drawdown (m): Drought: D: Existing Recharge, Demand	FEFLOW Groundwater Model Scenario Drawdown (m): Drought: H(1): Recharge Reduction, Increased Demand	FEFLOW Groundwater Model Scenario Drawdown (m): Drought: H(2): Increased Demand	FEFLOW Groundwater Model Scenario Drawdown (m): Drought: H(3): Recharge Reduction
Well 3A	51	51	-3.8	1.9	1.7	-3.6	0.0	3.3	3.3	0.0
Well 4	29	29	-3.2	2.5	2.3	-3.1	0.6	4.5	4.4	0.4
Well 5	50	50	-4.1	1.6	1.4	-3.9	0.0	3.0	2.9	0.0
Well 7	56	56	-4.4	1.4	1.2	-4.2	0.0	2.9	2.8	0.0
Well 9	27	27	-1.3	-0.1	-0.3	-1.2	0.8	2.0	2.0	0.7
Well 11	19*	5*	4.2	9.1	9.0	4.3	8.4	12.0	12.0	7.4
Well 12	45	42*	-4.5	1.0	0.9	-4.4	0.0	2.5	2.4	0.0
Well 13	31	31	-1.4	-0.3	-0.4	-1.3	0.7	1.9	1.8	0.6
Well 14	17*	12*	-4.8	0.3	0.2	-4.7	0.0	2.5	2.4	0.0
Well 15	34*	32*	-4.7	0.9	0.7	-4.5	0.0	3.0	2.9	0.0
Well 16	31	31	0.7	1.7	1.6	0.8	4.0	5.1	5.1	3.9
Well 17	49	49	-3.6	2.4	2.2	-3.5	0.1	4.0	3.9	0.0
Well 18	47	47	-3.7	2.2	2.1	-3.6	0.0	3.7	3.6	0.0
Well 19	52	52	-3.4	4.0	3.8	-3.2	0.0	5.3	5.2	0.0

Notes for the above table:

1. \*Additional drawdown available is calculated using the water levels within the well rather than aquifer

### 3.5.6 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 3.5- 14.

The Local Area associated with the City of Barrie municipal drinking water system was assigned a low risk level because the Safe 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.

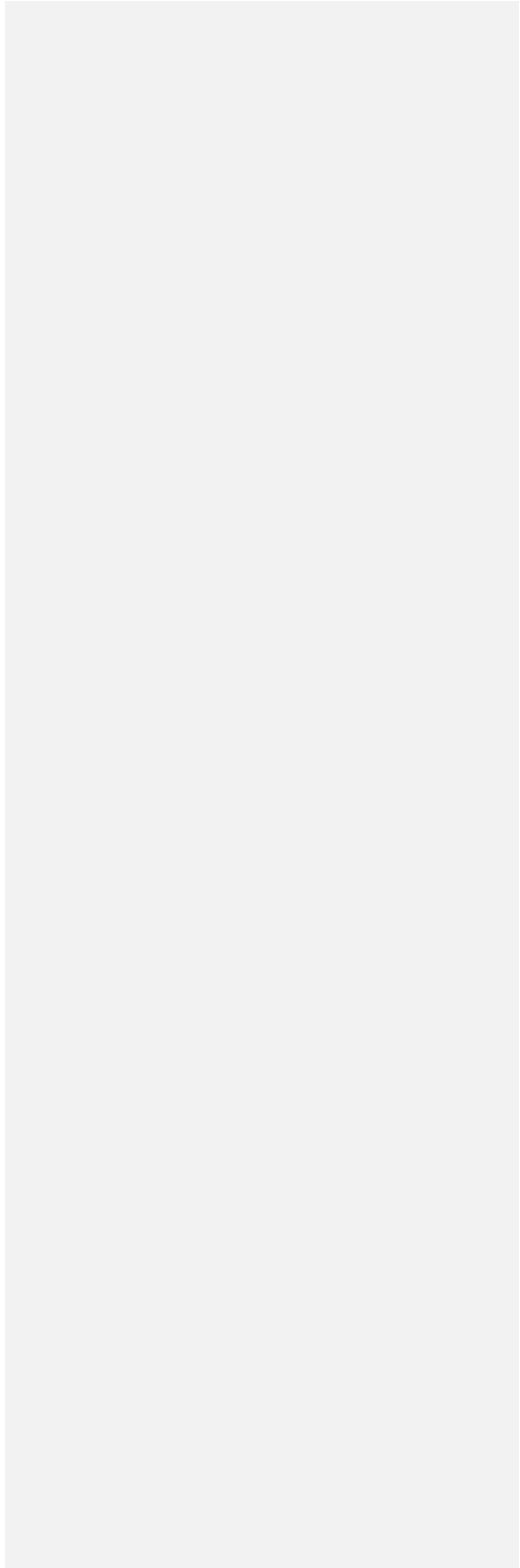
In summary, due to the system's ability to meet existing and allocated demand without affecting other water uses, the Local Area for the City of Barrie was assigned a low risk level.

**Table 3.5- 14: Significant Risk Level Circumstances (MOE, 2013).**

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<b>Significant Risk-Groundwater</b>		
<b>Scenario</b>	<b>Circumstances</b>	<b>Results</b>
Planned or Existing plus Committed System with future land use and average annual climate (G) or 10-year drought (H)	The quantity of water that can be taken from groundwater in the Local Area would not be sufficient to meet the allocated quantity of water for those wells	None
Planned or Existing plus Committed System – average annual climate (G)	The quantity of water that can be taken from groundwater in the Local Area would be sufficient to meet the allocated quantity of water for those wells and one or more of the following circumstance exists:  (i) the reduction in existing groundwater levels and/or flows results in unacceptable impacts to existing regulated water levels and/or flows or permits.  (ii) the reduction in existing groundwater discharge into a coldwater watercourse by a threshold calculated as greater than 20 percent as compared to the existing estimated monthly streamflow Qp80 (the flow that is exceeded 80 percent of the time) or the average monthly baseflow of the watercourse or another threshold that has already been defined as a condition in an existing permit.  (iii) the reduction in existing groundwater levels and/or flows results in unacceptable impacts to provincially significant wetlands.(MOE 2009)	None

**Figure 3.5-1: Barrie and Area Tier Three Study Area.**



**Figure 3.5- 2: Surface Water Features and Watershed Boundaries**

**Figure 3.5- 3: Municipal Systems**

**Figure 3.5- 4: Hydrostratigraphic Cross Section**

**Figure 3.5- 5: Groundwater Recharge**

**Figure 3.5- 6: Current Conditions Land Use**

**Figure 3.5- 7: Official Plan Land Use**

**Figure 3.5- 8: Land Use Change (Existing to Official Plan)**

**Figure 3.5- 9: Safe Additional Drawdown Calculation (Well 3A)**

**Figure 3.5- 10: Groundwater Demand**

**Figure 3.5- 11: Domestic Water Use**

**Figure 3.5- 12: WHPA- Q1**

**Figure 3.5- 13: WHPA Q2 and Local Area**

**Figure 3.5- 14: Model Predicted Drawdown Risk Assessment**

**Figure 3.5- 15: Drawdown Scenario C (relative to 2010 conditions)**

**Figure 3.5- 16: Drawdown Scenario G1 (relative to 2010 conditions)**

**Figure 3.5- 17: Water Level Reductions – Scenario G(3) (relative to 2010 conditions)**

**Figure 3.5- 18: Model Simulated Baseflow Impact Areas**

**Figure 3.5- 19: Model Simulated Baseflow**

**Figure 3.5- 20 Baseflow Reductions**

### **3.6 Water Budgets That Cross Source Protection Regions**

A Tier Three Water Budget and Local Area Risk Assessment is undertaken for municipal groundwater wells and surface water intakes that are located within subwatersheds that were assigned a Moderate or Significant Water Quantity Stress Level in the Tier Two Assessment, or that have had a historical issue with the water sources meeting municipal water demands (AquaResource, 2011).

The objective of the Tier Three Assessment is to estimate the likelihood that a municipality will be able to meet its planned water quantity requirements considering increased municipal water demand, future land development, drought conditions, and other water uses. The Tier Three Assessment uses refined surface and/or groundwater flow models and involves a much more detailed study of the available groundwater or surface water sources. Various scenarios are evaluated with the models assessing the groundwater and the surface water flows and levels, and the interactions between them.

The CTC Source Protection Region has completed a Tier Three Water Budget and Risk Assessment for the Town of Orangeville, Mono and Amaranth. The local study area for the Orangeville, Mono and Amaranth Tier Three encompasses a small portion of South Georgian Bay-Lake Simcoe Source Protection Region in Dufferin County. The study included Well 3 from the Cardinal Woods municipal well supply located within the Nottawasaga Valley Source Protection Area (Figure 3.6- 1). This municipal supply system was identified as having a low potential for stress in the Tier One Water Budget and Water Quantity Stress Assessment (SGBLS, 2009). The well was incorporated into the Orangeville Tier Three as it was located within the local drawdown area of the Orangeville wells.

The work described herein is a summary of the Risk Assessment Results for Cardinal Woods Well 3. The work was completed in compliance with the Technical Rules prepared by the MOE (2008a) for the preparation of Assessment Reports under the Clean Water Act. For detailed information pertaining to the water budget and other aspects of the Tier Three Assessment the reader is referred to the Tier Three Water Budget and Local Area Risk Assessment report (AquaResource, 2011) as well as, the Credit Valley Source Protection Area Assessment Report.

#### **3.6.1 Study Area and Physical Setting**

##### **Location**

The extent of the Study Area examined in this Tier Three Assessment encompasses the Town of Orangeville, and portions of the Towns of Mono and Caledon and the Townships of East Garafraxa and Amaranth. The study area lies within the headwaters of the Credit, Humber,

Nottawasaga and Grand Rivers, and is often referred to as “Headwaters Country”. A small portion of the Nottawasaga Valley Source Protection Area is located within the local study area.

All of the communities located within the study area are entirely reliant on groundwater for their municipal drinking water needs.

### **Conceptual Model**

Tier Three Water Budgets and Risk Assessments require that a numerical model be developed to simulate complex hydrologic and hydrogeologic processes. 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 Orangeville, Mono, and Amaranth Tier Three study area conveys the understanding of the hydrology and hydrogeology of the area. The conceptual model describes interactions of groundwater and surface water (AquaResource, 2011).

While the conceptual water budget model represents the characterization of flow systems, it lacks the temporal and spatial data that are necessary to make informed decisions regarding whether a particular activity poses a threat to the municipal drinking water sources. As such, numerical tools are created to more closely examine the water sources within the area. The Conceptual Models are translated into numerical groundwater and surface water flow models that attempt to simulate complex hydrologic and hydrogeologic processes using mathematical equations (AquaResource, 2011).

### **3.6.2 Local Area Risk Assessment**

A Tier Three Water Budget and Local Area Risk Assessment (Tier Three Assessment) is completed to estimate the likelihood that a municipality’s drinking water wells or surface water intakes will be able to supply their allocated pumping rates while considering increased municipal water demand, future land development, drought conditions, and other water uses.

According to the Technical Rules (Part III.2) a Tier Three Assessment must be completed for all Type I, II, and III drinking water systems where:

- 1) There have been historical issues with water sources meeting demand, or
- 2) The Tier Two subwatershed stress level is Moderate or Significant.

The water budget models are used to delineate the ‘Local Area’ for groundwater wells or surface water intakes which form the basis for the Local Area Risk Assessment. In this assessment, the water budget models are used to estimate the impact to a well or surface water intake in response to a series of water demand, climate and land use scenarios. Where

these scenarios identify wells or intakes that potentially will not be able to supply their allocated rates, the Local Area is assigned a 'Moderate' or 'Significant' Water Quantity Risk Level. Consumptive water uses and reductions in groundwater recharge within the Local Area will be identified as Moderate or Significant drinking water threats. The risk scenarios consider the need to meet the water demand requirements of other surrounding uses, particularly those that are required to be maintained by provincial or federal law such as wastewater assimilation flows or the ecological flow requirements of a coldwater fish habitat.

The term, 'Local Area', is introduced in the MOE Directors Rules (Part III.2) to focus the water budget assessment around drinking water wells or intakes. Local Areas for surface water or groundwater systems are vulnerable areas. For a surface water intake, the Local Area corresponds to the drainage area that contributes surface water to the intake and the area that provides recharge to an aquifer that contributes groundwater discharge to the drainage area.

With respect to groundwater wells, the Local Area is the combination of the following areas:

- (i) The cone of influence of the well;
- (ii) The cones of influence resulting from other water takings where those cones of influence intersect that of the well; and
- (iii) The areas where a reduction in recharge would have a measurable impact on the cone of influence of the well.

For one or more wells that draw water from an aquifer, the cone of influence is the projection to ground surface of the cone of depression created in the water table or potentiometric surface when the wells are pumped at a rate equivalent to their allocated rates.

#### **Delineation of Vulnerable Areas**

One of the deliverables of the Tier Three Assessment is the delineation of areas that are vulnerable from a municipal drinking water quantity perspective. Similar to the water quality vulnerable areas, the water quantity vulnerable areas (WHPA-Q1 and WHPA-Q2) are delineated to protect the quantity of water required by a municipality to meet their current or future water supply needs. The Technical Rules (MOE, 2008a) require that WHPA-Q1 and WHPA-Q2 areas be delineated for all municipal water supply wells that extract water from a subwatershed assigned a groundwater stress level of Moderate or Significant in the Tier Two Subwatersheds Stress Assessment.

The WHPA-Q1 is delineated as the combined area that is the cone of influence of the well and the whole of the cones of influence of all other wells that intersect that area (MOE, 2008a). The cone of influence for the well(s) was estimated by calculating the difference in the

potentiometric heads in the municipal aquifer under Existing plus Committed plus Planned municipal demands and current land use versus the potentiometric surface in the municipal aquifer without municipal pumping (Risk Assessment Scenario G(2)). The extent of the cone of influence is determined by selecting an appropriate drawdown threshold, which considers several factors including observed seasonal aquifer water level fluctuations (e.g., 0.5 m to 1.0 m) and available field observations of pumping induced drawdown around the municipal wells. Five WHPA-Q1 areas lie within the Orangeville, Mono and Amaranth area. Cardinal Woods Well 3 is located within WHPA-Q1-A2 outlined on (AquaResource, 2011).

The WHPA-Q2 is delineated as the WHPA-Q1 plus any area where a future reduction in recharge would have a measurable impact on the cone of influence of the municipal wells. Areas where future reduction in recharge may occur were identified using the Official Plans, and the maximum recharge reduction that may result from the land use developments was considered. Cardinal Woods Well 3 is located within WHPA-Q2-A2 outlined on Figure 3.6- 3.

For this assessment, the Local Area was delineated by combining the following areas:

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

The cone of influence is the area within the depression created in the water table or potentiometric surface when the wells are pumped at a rate equivalent to their allocated quantity of water. In this assessment, no non-municipal water takers exist near the municipal supply wells which have a cone of influence that intersects the cones of influence of the municipal wells.

The Local Areas for this study are illustrated on Figure 3.6- 4. The WHPA-Q2-A1 and WHPA-Q2-A2 areas lie in close proximity to one another, and the wells in the two areas extract water from the same bedrock source. As the two systems are closely integrated, one Local Area (Local Area A) that encompasses the WHPA-Q2-A1 and WHPA-Q2-A2 areas was delineated to ensure water quantity threats in this area are managed together (AquaResource, 2011).

#### **Risk Assessment Scenarios**

The Technical Rules outline that the scenarios presented in Table 3.6- 1 below must be evaluated in the Risk Assessment Process.

**Table 3.6- 1: Summary of Risk Assessment Scenarios (MOE, 2008a).**

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

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

Table 3.6- 2 below summarizes the scenarios conducted for the Tier Three assessment. These scenarios are designed primarily to assist in identifying the potential impacts from each of the planned water takings, land use, and drought on current hydrogeological conditions.

**Table 3.6- 2: Risk Assessment Model Scenarios (AquaResource, 2011)**

<b>Scenario</b>	<b>Time Period</b>	<b>Model Scenario Details: Land Cover</b>	<b>Model Scenario Details: Municipal Pumping</b>	<b>Model Scenario Details: Model Simulation</b>
C	Period for which climate and stream flow data are available for the Local Area (2008)	Existing	Existing	Steady-state, Average Annual Recharge.
D	10 year drought period	Existing	Existing	Transient (1960-2006); Monthly recharge rates (HSP-F)
G(1)	Period for which climate and stream flow data are available for the Local Area (2008).	Planned or existing plus committed (Official Plan)	Planned plus Existing plus Committed	Groundwater Recharge Reduction and Increases in Demand; Steady-state, Average Annual Recharge
G(2)	Period for which climate and stream flow data are available for the Local Area (2008).	Existing	Planned plus Existing plus Committed	Groundwater Discharge Reduction from Increases in Demand: Steady-state, Average Annual Recharge
G(3)	Period for which climate and stream flow data are available for the Local Area (2008).	Planned or existing plus committed (Official Plan)	Existing	Groundwater Recharge Reduction: Steady-state, Average Annual Recharge
H(1)	10 year drought period	Planned or existing plus committed (Official Plan)	Planned plus Existing plus Committed	Groundwater Recharge Reduction and Increase in Demand; Transient (1960-2006); Monthly recharge rates (HSP-F)
H(2)	10 year drought period	Existing	Planned plus Existing plus Committed	Groundwater Discharge Reduction from Increase in Demand; Transient (1960-2006); Monthly recharge rates (HSP-F)

Scenario	Time Period	Model Scenario Details: Land Cover	Model Scenario Details: Municipal Pumping	Model Scenario Details: Model Simulation
H(3)	10 year drought period	Planned or existing plus committed (Official Plan)	Existing	Groundwater Recharge Reduction; Transient (1960-2006); Monthly recharge rates (HSP-F)

**Model Predicted Scenario Results**

The drawdown under each of the Risk Assessment model scenarios was calculated and compared to the estimated safe additional drawdown at each municipal well. The drawdown at each well was calculated relative to the existing conditions (Scenario C) simulated heads. For the steady state models (Scenarios G(1), G(2) and G(3)), the difference between the water levels at the well in Scenario C and those at the end of each model scenario were recorded as the model scenario drawdown (Table 3.6- 3). For the transient scenarios, the lowest simulated water level elevation in the aquifer at each municipal pumping well was compared to the water level in the existing conditions scenario (Scenario C) and this value was also recorded on Table 3.6- 3. The model simulated drawdown was then compared to the field-based safe additional drawdown to identify municipal wells where there is a potential that the wells will be unable to pump their allocated rates. The table identifies the scenarios where these conditions may occur for Cardinal Woods Well 3 (AquaResource, 2011).

**Table 3.6- 3: Risk Assessment Drawdown Results (AquaResource, 2011)**

WHPA-Q1 Area	Well Name	Safe Additional Aquifer Drawdown (2008)	MODFLOW Groundwater Model Scenario Drawdown (m): Average Climate: G(1): Recharge Reduction, Increased Demand	MODFLOW Groundwater Model Scenario Drawdown (m): Average Climate: G(2): Increased Demand	MODFLOW Groundwater Model Scenario Drawdown (m): Average Climate: G(3): Recharge Reduction	MODFLOW Groundwater Model Scenario Drawdown (m): Drought: D: Existing Recharge, Demand	MODFLOW Groundwater Model Scenario Drawdown (m): Drought: H(1): Recharge Reduction, Increased Demand	MODFLOW Groundwater Model Scenario Drawdown (m): Drought: H(2): Increased Demand	MODFLOW Groundwater Model Scenario Drawdown (m): Drought: H(3): Recharge Reduction
A2	Cardinal Woods Well 3	3.0	2.4	2.0	0.3	0.8	3.1 <sup>1</sup>	2.8	1.0

Notes for the above table:

1. <sup>1</sup> Safe additional drawdown level predicted to be exceeded 7.2% of the time (3.3 years in the 46-year simulation).

The model predicted drawdown in the aquifers was less than the estimated safe additional drawdown at Cardinal Woods Well 3 for each scenario except for Scenario H. Scenario H examined the model predicted fluctuations in hydraulic head measurements at each of the municipal wells under drought conditions. Scenario H(1) evaluated the cumulative impact of increased municipal pumping rates and reductions in recharge, while Scenario H(2) only evaluated the increased pumping, and Scenario H(3) evaluated only the reductions in recharge.

The lowest hydraulic head elevation (in the aquifer at each municipal well) predicted by the model during each of the model scenarios was recorded. The difference between this elevation and the head elevation in the aquifer at each well under scenario C were tabulated and compared to the safe additional drawdown estimated at each municipal well (Table 3.6- 3). The model predicted drawdown in the aquifer at Cardinal Woods Well 3 is close to, or greater than, the safe additional drawdown following the 1960's drought periods for scenarios H (1) and H (2) (Figure 3.6- 5) (AquaResource, 2011).

#### **Local Area Risk Assessment Results**

Local Area A which includes Cardinal Woods Well 3 was assigned a 'Significant' Risk Level based on the following circumstances:

1. The allocated quantity of water for Orangeville Well 5/5A is not met in Scenario G (1). Most of the drawdown impact in this scenario is due to recharge reduction;
2. The allocated quantity of water for Orangeville Wells 5/5A, Well 6, Wells 9A/9B and Cardinal Woods Well 3 is not met in Scenario H(1) (Drought). Drawdown at Wells 5/5A and Well 9 is impacted primarily due to recharge reductions. Well 6 and Cardinal Woods Well 3 are influenced more by planned pumping rates;
3. The allocated quantity of water for Orangeville Well 6 and Cardinal Woods Well 3 is not met in Scenario H(2) (Drought, Planned Pumping); and
4. Groundwater discharge to Mill Creek, a designated coldwater stream, is reduced by more than 20% in Scenario G (2) (Average Climate, Planned Pumping).

The sensitivity analysis indicates that the above conclusions would still be made after considering the range of variability in model input parameters (AquaResource, 2011).

#### **Uncertainty Assessment**

The uncertainty analysis examined the range of potential hydraulic conductivity and recharge distributions that would produce calibrated models. The predications made by models with acceptable ranges of parameters produced consistent model results. The Risk Levels assigned to

the Local Areas are considered appropriate. Consequently, the uncertainty associated with the Risk Levels applied to each of the Local Areas is Low (AquaResource, 2011).

### 3.6.3 Water Quantity Threats

As outlined in the MOE Technical Rules (MOE, 2008a), the definition of a drinking water quantity threat is any activity that reduces groundwater recharge to an aquifer or any consumptive water demand. Consumptive demands are activities that extract water from an aquifer or surface water body without returning that water to the same aquifer or surface water body.

#### Consumptive Water Demands

For each vulnerable area identified under clause 15 (2) (d) or (e) of the Clean Water Act (2006), drinking water threats that are or would be classified as Moderate or Significant, need to be identified within each vulnerable area. Local Area A was assigned a Risk Level of Significant; as such, all consumptive demands lying within Local Area A are classified as Significant Water Quantity Threats (Figure 3.6- 6 and Table 3.6- 4) (AquaResource, 2011).

#### Reductions in Recharge

The Technical Rules (MOE, 2008a) specify that reductions in groundwater recharge are a potential water quantity threat within the Local Area. The Tier Three Scenarios considered the impact of existing and future land development on groundwater recharge and the resulting impact on water levels in the municipal aquifer at the wells. All reductions in groundwater recharge within Local Area A are also classified as Significant Water Quantity Threats (Figure 3.6- 6 and Table 3.6- 4). Proposed land use developments (or groundwater recharge reduction activities) include residential subdivisions, employment areas, industrial and institutional areas, and undifferentiated suburban lands (Figure 3.6- 6) (AquaResource, 2011).

**Table 3.6- 4: Summary of Significant Water Quantity Threats within the Nottawasaga Valley SPA**

	# of Significant Water Quantity Threats
Municipal Well(s)	1
Non-Municipal Permitted Well(s)	0
Non-Municipal Non-Permitted Well(s)	59
Recharge Reduction	2
Total	62

Notes for the above table:

1. One recharge reduction threat was assigned to each municipality, rather than assigning one to each individual parcel within the vulnerable area.

#### **3.6.4 Summary and Conclusions**

The Tier Two Assessment completed for the Credit River Watershed (AquaResource, 2009b) identified the Headwaters Subwatersheds (Subwatershed 19) as having a Moderate groundwater stress level. The identification of a Moderate stress level lead to the requirement of a Tier Three Assessment for the Towns of Orangeville and Mono and the Township of Amaranth as most of their municipal wells are located within this subwatershed. To date Orangeville, Mono and Amaranth have not had any issues meeting their water quantity requirements.

The numerical models used within the Tier Two Assessment were used as the basis from which to develop the Tier Three models. The HSP-F surface water model was refined from that used for the Tier Two Assessment model by updating the hydrologic response units, representing Island Lake outflow controls, and improving the model calibration within Subwatershed 19.

The watershed-scale FEFLOW groundwater flow model that was used in the Tier Two Assessment was considered too broad in scale to be used in the Tier Three Assessment to adequately assess impacts at a wellfield scale. As such, a new groundwater flow model (using the MODFLOW-2000 code) was developed building on data compiled for the Tier Two model as well as the geological characterization used to define model layers for that model. Specific updates undertaken in the Tier Three Assessment included the interpretation of local-scale cross-sections across the study area to refine the subsurface geology, and the assignment of hydrogeologic parameters consistent with local hydraulic testing results within the subwatershed and surrounding areas. The groundwater flow model was calibrated to a finer level of detail with close attention to observations at high quality monitoring wells. The Tier Three model was calibrated at the municipal wellfield-scale to both steady state (long term average) and transient (time-varying) conditions.

Four distinct Local Areas were delineated surrounding the municipal supply wells in the Study Area (Local Areas A through D; Figure 3.6-4). These areas were delineated following the Province's Technical Rules (MOE, 2008a) based a combination of the cone of influence of each municipal well, as well as land areas where recharge has the potential to have a measurable impact on the municipal wells.

A series of Risk Assessment scenarios were derived to represent the municipal allocated quantity of water (existing plus committed plus planned pumping rates); and current and planned land uses. The calibrated surface water and groundwater flow models were used to estimate both the changes in water levels in the municipal supply aquifer and the impacts to groundwater discharge and baseflow under average and drought climate conditions.

Based on the results of the Risk Assessment scenarios, Local Area A was classified as having a Significant Risk Level. Local Area A, includes many of the Town of Orangeville's municipal supply wells located in the western half of the Subwatershed 19, as well as the Town of Mono's Cardinal Woods Wells and Amaranths Pullen Well (Figure 3.6- 4). Local Area A was classified as having a Significant Water Quantity Risk Level due to a combination of factors, including the impacts of pumping the allocated quantity of water (Existing plus Committed plus Planned) and groundwater recharge reductions under both average recharge and drought conditions. Increased pumping within this Local Area also resulted in reductions to groundwater discharge in coldwater streams that exceeded the Province's thresholds.

While the Tier Three Assessment scenarios resulted in a Significant Water Quantity Risk Level for one of the Local Areas (Local Area A), the Town of Orangeville and Town of Mono have never had problems pumping their municipal wells, even during periods of higher water demand prior to the implementation of water conservation measures. The Water Quantity Risk Level categories do not indicate a problem associated with current municipal wells and their current pumping rates; rather, they reflect a need to manage the drinking water resources in the Local Areas as future stresses arise. Furthermore, the results indicate a need to manage the drinking water as a regional resource shared by the Towns of Orangeville, Mono and Amaranth (AquaResource, 2011).

Following the Technical Rules, all consumptive water users and reductions to groundwater recharge within Local Area A are classified as Significant Water Quantity Threats. These consumptive water users include the permitted water demands (e.g., municipal pumping) and non-permitted water demands (e.g., domestic water wells) (AquaResource, 2011).

### **3.6.5 Recommendations**

The following recommendations are made based on the Tier Three Assessment results:

- 1) Maintain and enhance Water Conservation Programs. The Town of Orangeville has implemented a very successful water conservation program. This program should be maintained to ensure that per-capita water demand does not increase and to encourage decreases. Any opportunities to reduce water demand within the Town should be considered to reduce the threat placed on their future water supply sources.

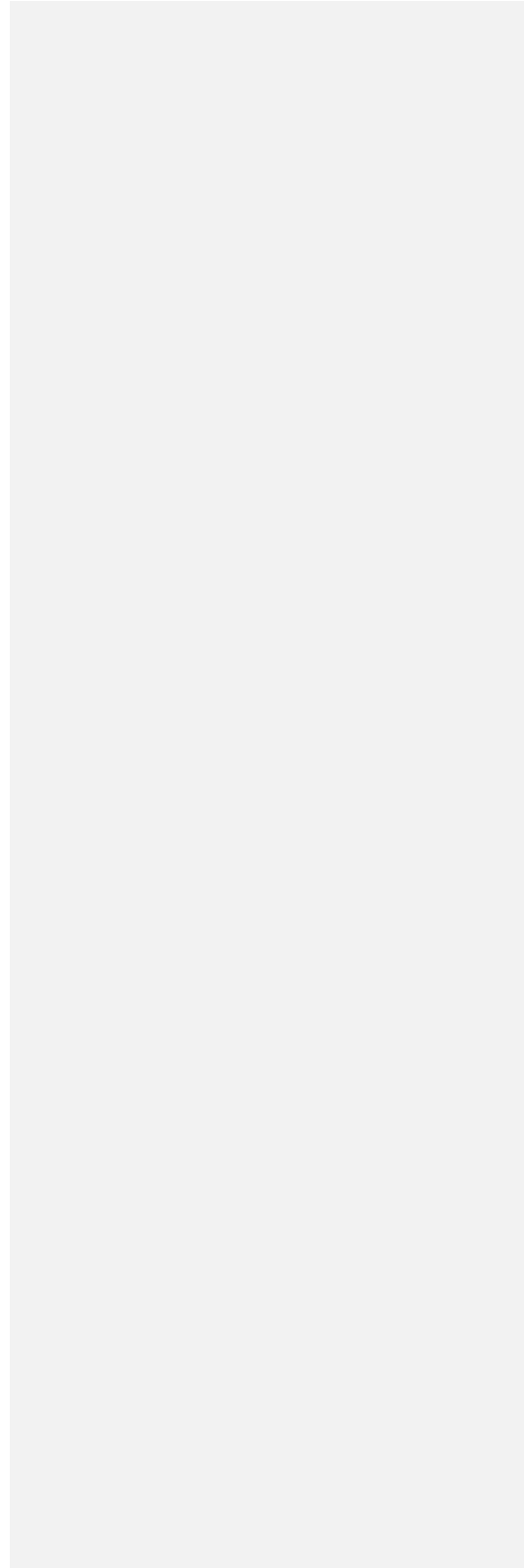
- 2) **Maintain and Enhance Monitoring Programs.** The Tier Three Assessment identifies the potential for planned water demands to impact groundwater discharge to coldwater streams. Monitoring and reporting programs associated with Permits to Take Water are already in place and should be maintained and completed by a team that is aware of their implications to not only the Permit to Take Water Program but the Tier Three Assessment. Continuous flow gauging stations should be added to key surface water features such as Mill or Monora Creek, and south of the Island Lake Reservoir to monitor the long term trends in surface water features. This data could be used in the groundwater flow model to support the model calibration.
- 3) **Develop a Regional Water Supply Strategy.** This Tier Three Assessment illustrates that the groundwater resource relied upon by the Towns of Orangeville and Mono and the Township of Amaranth is a shared water supply and ecological resource that does not follow municipal boundaries. The Local Area A, classified as having a Significant Water Quantity Risk Level, has management activities including permitting and monitoring that would be best completed collaboratively by the three municipalities. A regional approach to groundwater management activities may also include working with the Ministry of the Environment to put in place new well field permits that replace individual permits and provide more flexibility to modify pumping rates within the Local Areas. The regional water supply strategy should also seek to identify and test potential future drinking water supplies as needed to promote growth and also to protect against risks that may affect existing supplies and other uses;
- 4) **Protect Recharge Areas.** The Tier Three Assessment clearly illustrates the potential for recharge reductions to affect some of the municipal wells. The Towns of Orangeville and Mono and the Township of Amaranth should ensure that any future land developments do not have a negative impact on groundwater recharge and, where possible, attempt to enhance groundwater recharge; and
- 5) **Update Regional Water Budget Models.** The CVC calibrates and maintains water budget modelling tools to effectively manage and protect the water resources across the watershed. The CVC should update their regional-scale groundwater and surface water models with hydrogeologic and hydrologic insights gained from this Tier Three Assessment (AquaResource and Golder, 2011).

**Figure 3.6- 1: Orangeville, Mono and Amaranth Tier Three Water Budget and Local Area Risk Assessment**

**Figure 3.6- 2: WHPA-Q1**

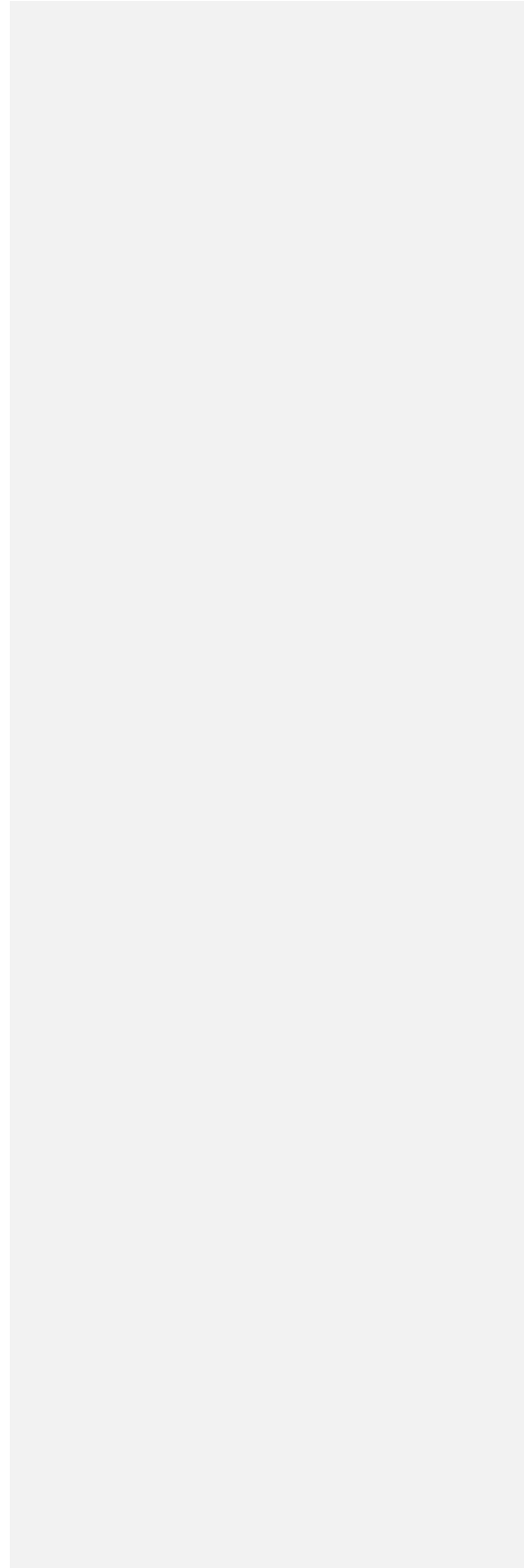
**Figure 3.6- 3: WHPA-Q2**

**Figure 3.6- 4: Local Areas**



**Figure 3.6- 5: Scenario H Drought Scenario, Cardinal Woods Well 3**

**Figure 3.6- 6: Water Quantity Threats**



### 3.7 Peer Review Process

The water budgets within this document were prepared as indicated in the MOE 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. The following table outlines who the peer reviewers were for each water budget, highlights their qualifications to peer review these water budgets, and states the date of approval.

**Table 3.7-1: Water Budget Peer Reviewers in the Nottawasaga Valley Watershed.**

	Peer Reviewer	Title
Tier 1 Water Budget and Stress Assessment Summary	Dillon Consulting	Robert Muir, M.A.Sc., P.Eng, (Surface water expert)
Tier 1 Water Budget and Stress Assessment Summary	Dillon Consulting	Igor Iskra, Ph.D., P.Eng
Tier 1 Water Budget and Stress Assessment Summary	Richard Gerber	Richard Gerber, Ph.D., Pigeon (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.
Tier 1 Water Budget and Stress Assessment Summary	York Region	Tammy Silverstone, M.Eng., P.Eng - Program co-ordinator Water Resources and Environmental Services
Tier 2 Water Budgets (Nottawasaga Valley Watershed)	Dillon Consulting	Robert Muir, M.A.Sc., P.Eng, (Surface water expert)
Tier 2 Water Budgets (Nottawasaga Valley Watershed)	Dillon Consulting	Igor Iskra, Ph.D., P.Eng
Tier 2 Water Budgets (Nottawasaga Valley Watershed)	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 Budgets (Nottawasaga Valley Watershed)	York Region	Tom Bradley Water Resources Technologist.
Tier 2 Water Budgets (Nottawasaga Valley Watershed)	York Region	Tammy Silverstone, M.Eng., P.Eng - Program co-ordinator Water Resources and Environmental Services
Tier 3 Water Budget (City of Barrie)	Stantec Consulting	Igor Iskra, Ph.D., P.Eng
Tier 3 Water Budget (City of Barrie)	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)

	Peer Reviewer	Title
Tier 3 Water Budget (City of Barrie)	S.S.Papadopoulos & Associates	Christopher Neville, M.Sc., P.Eng. (Hydrogeological Expertise)

**Table 3.7-2: Peer Review Water Budget Project Status.**

Water Budget	Peer Review Status
Tier 1 Water Budget and Stress Assessment Summary	Complete
Tier 2 Water Budget (South Georgian Bay West Lake Simcoe)	Complete
Tier 3 Water Budget and Risk Assessment Barrie and Area	Complete