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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 have not been redone since. Therefore, this chapter reflects the 2008 Technical Rules and the names of provincial Ministries at that time.

3 Water Budget and Water Quantity Stress Assessment Summary

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

The water budget aims to determine the location and quantity of water within the various components of the watershed's hydrologic system, and uses data to characterize how the water moves through the watershed. A water budget is used to determine how much water enters the watershed, how much water is stored in it, and how much water leaves it (through natural and human processes).

The water budget analysis in this chapter addresses all of the following questions:

1. Where is the water located?
2. How does the water move between those reservoirs?
3. What and where are the stresses on the water?
4. What are the trends?

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 December, 2008 as amended November, 2009 and have been developed to accommodate all of the following considerations:

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

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

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

This tiered process ensures watershed communities complete the degree of assessment consistent with local water quantity issues. The Conceptual and Tier One evaluations are required for the entire Source Protection Region, and in areas where the availability of water far outweighs the demand, this simplified approach (Tier One) is sufficient for decision-making and further efforts are not required. Whereas Tier Two and Tier Three assessments provide a more thorough understanding of the hydrologic system for managing resources but are only required for those subwatersheds where stress is identified in the previous evaluation (e.g Tier One assessment) and where there is a municipal drinking water 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 Black-Sever River watershed. Tier Two and Tier Three assessments were not required for any subwatersheds in the Black-Severn River watershed due to the lack of stress identified in the Tier One analysis.

Per legislative requirement each of the water budget studies discussed in this chapter have been peer reviewed by a team of qualified professionals. The objective of the peer review process is to ensure consistency with the expectations of the Technical Rules, to ensure appropriate methodologies are utilized, that the technical assumptions used are necessary and reasonable to ensure the products are scientifically defensible. The roles and objective of the peer review team are discussed further in Section 3.10.

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

Watershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System	Conceptual / Tier 1	Tier 2
Lake Couchiching / St. John	Simcoe County	City of Orillia	Yes (GW) & (SW)	√	-
Severn River	Simcoe County	Township of Severn	Yes (GW)	√	-
Severn River	Simcoe County	Township of Ramara	Yes (GW)	√	-
Upper Talbot River	Kawartha Lakes	City of Kawartha Lakes	Yes (GW)	√	-
Black River	Haliburton	Algonquin Highlands	No	√	-
Black River	Haliburton	Minden Hills	No	√	-
Black River	Simcoe County	City of Kawartha Lakes	No	√	-
Black River	Kawartha Lakes	Township of Ramara	No	√	-
Black River	Muskoka	Gravenhurst	No	√	-
Head River	Haliburton	Minden Hills	No	√	-
Head River	Kawartha Lakes	City of Kawartha Lakes	No	√	-
Head River	Simcoe County	Township of Ramara	No	√	-

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Watershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System	Conceptual / Tier 1	Tier 2
Kashe/Gartersnake River	Muskoka	Bracebridge	No	√	-
Kashe/Gartersnake River	Muskoka	Gravenhurst	No	√	-
Kashe/Gartersnake River	Kawartha Lakes	City of Kawartha Lakes	No	√	-
Upper Black River	Haliburton	Dysart Et Al	No	√	-
Upper Black River	Haliburton	Algonquin Highlands	No	√	-
Upper Black River	Haliburton	Minden Hills	No	√	-
Upper Black River	Muskoka	Lake of Bays	No	√	-
Upper Black River	Muskoka	Bracebridge	No	√	-
Upper Black River	Kawartha Lakes	City of Kawartha Lakes	No	√	-

*Note: All subwatershed 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.

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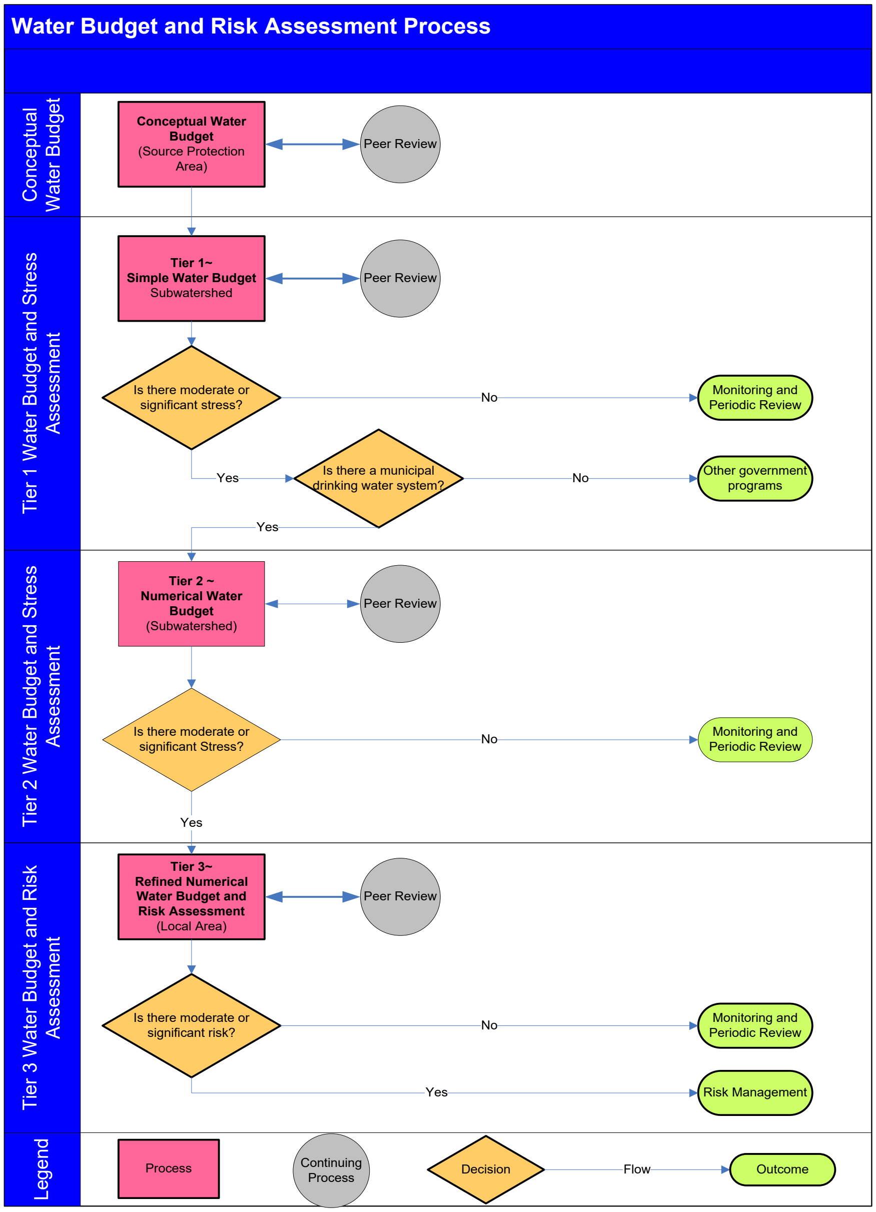

Figure 3.0-1: Water Budget and Water Quantity Risk Assessment Process.

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.); and
- Water takings

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

3.1.1 Geology and Physiography

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 locating areas to drill for well water, and understand how pollutants travel through the groundwater system. Information used to complete this section of the report has been obtained from Chapman and Putnam[1] (1984). The

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

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 Black-Severn River watershed is located within four regional-scale physiographic regions as defined by Chapman and Putnam (1984). These regions are the Number 11 strip, Carden Plain, Simcoe lowlands and the Georgian Bay fringe (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 Black-Severn River 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).

Number 11 Strip

The number 11 strip occupies the area adjacent to Provincial Highway 11 from Gravenhurst to North Bay, only a small portion of this regime exists within the Black- Severn River watershed. The regime is characterized by deposits of clays, silts and fine to medium-grained sands that occupy hollows and depressions within the Precambrian-aged bedrock of the Precambrian Shield (Chapman and Putnam, 1984; Barnett 1992). Topographically the area is located below the shoreline of glacial Lake Algonquin, and as a result sediments within the regime are interpreted as glaciolacustrine sediments deposited within glacial Lake Algonquin (Chapman and Putnam, 1984). Recent excavations due to road construction activities on the Highway 11 corridor have exposed deposits of imbricated boulder-gravels and diffusely bedded medium-grained sands within steep-sided scours. These deposits and sedimentary structures are likely related to a series of subaquatic fans that occupy the Highway 11 corridor rather than sediments deposited in glacial Lake Algonquin and it successors through suspension fallout.

Carden Plain

The Carden Plain also referred to informally as Barren Terrain, is an extensive limestone plain that extends east of Lake Couchiching to the community of Burnt River. The outcrops of limestone and dolostone display numerous fractures that are oriented orthogonal to primary bedding planes, dissolution weathering features, and pop-up structures that are commonly associated with Karst terrain. Glacial sediments within the plain occur as a discontinuous veneer of diamicton (slightly silty to silty sand) that is typically less than 1 m in thickness. Landforms associated with glacial Lake Algonquin, such as beach ridges, and wave-cut notches are present within the regime but are considered rare.

Simcoe Lowlands

The Simcoe Lowlands physiographic region extends from Lake Couchiching, southward along the western edge of Lake Simcoe continuing southward toward the community of Bolton. A small portion of this regime is also located east of Lake Simcoe near the communities of

Sunderland and Mount Albert. 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.; Karrow, 1989). Evidence of glacial Lake Algonquin and its successors is provided by numerous shorelines, wave-cut notches, terraces and beach ridges located throughout the study area.

Georgian Bay Fringe

The Georgian Bay fringe is a broad physiographic regime bordering Georgian Bay. It is characterised by outcrops of Precambrian-aged bedrock and a discontinuous veneer of sediment, typically less than 1 m in thickness. The lack of sediment within this regime is based on two main factors. First, areas in the northern portion of the regime are topographically higher than the highest lake level of glacial Lake Algonquin; therefore, fine-grained glaciolacustrine deposits commonly found in adjacent physiographic regimes are not present. Second, the southern portion of this regime, although topographically lower than the highest Algonquin lake level, is predominantly composed of exposed outcrops of bare bedrock. These have been interpreted as being “washed” products of glacial Lake Algonquin (Chapman and Putnam, 1984).

Topography

Ground surface topography within the Black-Severn River watershed ranges from approximately 172 meters above sea level (mASL) at the shores of Lake Couchiching and Georgian Bay to 461 mASL in the northeast portion of the watershed. The topography of the watershed closely corresponds to the physiographic regions that make up the watershed. Areas of flat topography correspond to the Carden Plain and Barren Terrain. The ground surface topography within the Black-Severn River watershed is depicted on Figure 3.1- 2.

Geology

An understanding of how water moves through a watershed is at the heart of Source Water Protection. In order to assess groundwater processes, as well as, interactions between groundwater and surface water, a thorough understanding of the geological setting in a watershed is necessary. The bedrock, sediments and soils present in the watershed will determine how and where the groundwater will flow. They will also influence the vulnerability an aquifer may have to potential contaminants. For example, an aquifer capped with a non-porous material such as clay will have a lower vulnerability score than one capped with a porous material. This is due to the inability of many materials to readily move through non-porous materials. The geology of the Black-Severn River watershed can generally be described as unconsolidated overburden, deposited during the Quaternary Period, overlying Paleozoic and Precambrian bedrock. Below is a more detailed explanation of both the bedrock and Quaternary geology.

Bedrock Geology

The bedrock geology within the Black-Severn River watershed is illustrated on Figure 3.1- 3, and the bedrock topography can be seen on Figure 3.1- 4. The bedrock units within the watershed are of Precambrian and Middle Ordovician age. Outliers of Precambrian bedrock are present only in the northern part of the study area. In the Townships of Ramara and Oro-Medonte, numerous outcrops consisting of granites, gneisses and migmatite are present (Liberty 1969; Sanford and Baer 1981). According to Chapman and Putnam (1984), outcrops of Precambrian-aged metavolcanics also occur at the surface in this area. In the western portion of the study area outcrops of Middle Ordovician aged bedrock overlie the Precambrian aged bedrock.

Precambrian Bedrock

Outliers of Precambrian bedrock are present only in the northern part of the study area. In the townships of Ramara and Oro-Medonte, numerous outcrops consisting of granites, gneisses and migmatite are present (Liberty 1969; Sanford and Baer, 1981). According to Chapman and Putnam (1984), outcrops of Precambrian-aged metavolcanics also occur at surface in this area.

Precambrian-aged rocks of the Grenville Structural Province that occur within the study area are subdivided into the Grenville Front Tectonic Zone, the Central Gneiss Belt and the Central Metasedimentary Belt 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 northwestern regions of the study area, and are separated from rocks of the Central Medisedimentary Belt by a series of north-west trending faults. Outliers of metasedimentary rocks outcrop at surface in the northeastern portion of the study area. The Central Metasedimentary Belt is comprised of the following units in the area: (1) clastic metasedimentary rocks, predominantly conglomerates, wackestones, limestones and mudstones; and (2) 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 (1) undifferentiated gneisses and migmatites; (2) anorthosites and alkalic igneous rocks; and (3) felsic igneous rocks that may contain tonalite, granodiorite, monzonite, syenite and derived gneisses (Sanford and Baer 1981). In the western portion of the study area, rocks of the Grenville Structural Province are separated from the main body of Paleozoic rocks by the Black River Escarpment. This structure can be traced from Uhthoff, westward through Foxmead to Fesserton (Liberty, 1969). South of the escarpment, younger Paleozoic (Middle Ordovician) rocks of the Simcoe Group unconformably overlie Precambrian rocks. These include the Shadow Lake, Gull River, Bobcaygeon, and Verulam Formations (Johnson et al., 1992).

Paleozoic Bedrock

The Shadow Lake Formation has been referred to as part of the 'Basal Group' by Liberty (1969), as it forms the upper-most unit of a group of sandstones and arkoses that unconformably overlie Precambrian-aged rocks of the Laurentian Shield. The formation is characterized by greenish-grey, coarse-grained sandstones (calcareous arkoses), that are overlain by red and green arenaceous mudstones. The Shadow Lake Formation is overlain by the Gull River, Bobcaygeon, and Verulam formations. These formations are collectively referred to as the Simcoe Group. They are predominantly composed of argillaceous and sublithographic, or lithographic limestone and calcarenite with minor mudstone and claystone (Liberty 1969; Johnson et al., 1992).

Quaternary Geology

The surficial geology of the Black-Severn River watershed consists of bedrock geology of the Precambrian and Paleozoic eras, and glacial deposits from the Quaternary period.

The surficial geology of the northern portion of the study area is composed of Precambrian bedrock and a Precambrian bedrock-drift complex commonly referred to as the Canadian Shield. A shield derived silty to sandy till exists in the northern most tip of the watershed.

Paleozoic bedrock exists at the surface in the western portion of the study area referred to as the Carden plain physiographic region.

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- 5. In a similar fashion to how the top of the Precambrian surface influenced the accumulation of Paleozoic sediment, the Paleozoic bedrock topography also appears to strongly influence the overlying Quaternary sediment thickness distribution. The Quaternary sediment thickness varies greatly over the watershed from 0 m over the rock plains to 65 m in the northern eastern tip of the watershed.

Two distinct till formations have been identified at the surface in the study area by Finamore and Bajc (1984). In order of oldest to youngest, these formations are represented by an unnamed stone-rich sandy till that occurs north and west of Dalrymple Lake and a stone rich, silty very fine-grained sandy to sandy-silt till. Surface exposures of this till are common throughout the study area and occur as drumlins, ground moraine, and hummocky ground moraine. It is considered likely that both of these tills were deposited by the Northern lobe during the latter part of the Port Bruce Stadial.

Soils

Soils are an integral part of the environment as they support vegetation communities and also influence the quality and quantity of water entering the ground and running along the surface. Traditionally, soils within the watershed have been characterized based on 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- 6 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 and hydraulic attributes, the reader is referred to the 2007 SGBLS CWB.

3.1.2 Surface Water

Surface Water System

The Black River is the main tributary of the Severn River and extends from the confluence at Washago north- eastward into Haliburton County. The river originates at elevations of 366 mASL and 396 mASL. It drains several small lakes before it enters Logan Lake where it is joined by Anson Creek. It drains Logan Lake and flows south until it enters Lake St. John. The confluence with Head River is just before Lake St. John. It leaves Lake St.John and flows to enter the North Severn River at Washago.

The division of the Black-Severn River watershed into eight subwatersheds described in Section 2.2 allows for more detailed analysis and research, including modeling the influence of land use on water quantity and quality.

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 current conditions, determine trends over time and evaluate the effectiveness of remedial activities. Monitoring is also used to calibrate analytical models, which predict the impact of possible contaminants, especially during low flows, and to evaluate the impact on water resources due to changes in land use or management activities.

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

Table 3.1- 1 shows the location, name and period of record for the streamflow stations within the study area, and Figure 3.1- 9display the location. These stations were chosen as index stations due to their long period of record. Some of the gauges not shown in the table are currently inactive representing gaps in the monitoring network.

Table 3.1-1: Streamflow stations within the study area.

Station Location	Station No.	Period of Record*
Black River Near Vankoughnet	02EC019	2005-2007
Severn River at Swift Rapids	02EC003	1953-2008
Lake Couchiching Outflow at Washago	02EC017	1926-2004
Black River Near Washago	02EC002	1915-2008

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Method Used to Estimate Missing Streamflow Data

A modified drainage-area ratio method, a maintenance of variance extension type 1 (MOVE.1) method, and a multiple linear regression method were used in this study to estimate streamflow for ungauged 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 Streamflow

The mean annual streamflow is defined as the average of the series of annual average streamflow values. The monthly mean streamflows according to the Canadian Climate Normals for the stations of each watershed are given in Appendix WB-1. 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.

Streamflow record-extension and regional regression techniques have been used to complete missing data and estimate flow in ungauged streams as discussed above. Water Survey of Canada and Parks Canada data were insufficient to allow for regression analysis in this watershed. Streamflow was estimated using available data, although it is noted that the reported flows do not represent long-term means, and temporal gaps were not addressed. Table 3.1- 2 shows the mean annual streamflows in m^3/s for the gauging stations in the subwatershed.

Table 3.1-2: Mean Annual Streamflow Black-Severn River watershed.

Subwatershed	Mean Annual Streamflow (m^3/s)
Black River	22.68
Severn River	55.40
Head River	6.32
Kashe/Gartersnake River	4.21
Upper Talbot River	2.75
Lake St. John	0.79
Upper Black River	8.43

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

Baseflow

Baseflow is considered to be the groundwater contribution to streamflow, and is important in Source Water Protection studies for:

- The management of water quality through the regulation of watershed discharges to receiving waters. Low flows during summer months allow the stream to heat up rapidly in warm weather while in the fall and winter temperatures may plummet rapidly. Low flow conditions are less conducive to oxygenation. When water temperature is high dissolved oxygen levels can become critically low. Furthermore, the ability of streams to assimilate additional loading from wastewater discharges is reduced by the low flow condition.

- Estimating surface water availability for domestic, agricultural, industrial and recreational purposes. The estimate provides an indication of the adequacy of natural flow to meet a given demand.

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

Baseflow 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. An 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.

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, water power generation stations, dams and beaver dams. The structures are depicted on Figure 3.1-9; they are based on the 2006 MNR LIO database. Surface water control structures exist, among other reasons, to:

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

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

Swift Rapids, Big Chute and Wasdell's Falls Dam are the three water power generation stations present in the watershed. The Swift Rapids generating station is located at Lock 43 on the Trent Severn Waterway, and supplies power to the City of Orillia (Orillia Power, 2009). The Wasdells Falls Dam is a historic power generation station that is still present in the watershed; however, it is currently does not produce electricity (Ontario Plaques, 2009).

Beaver Dams represent the vast majority of surface water control structures present within the watershed; these dams impede the natural flow of water. Other small control structures are found the watershed[2]; are operated and maintained by private owners. These structures are therefore exempt from creating operation plans.

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[3] is the agency responsible for regulating water withdrawals within the study area through their Permit to Take Water (PTTW) program. Active water taking permits are in place for a number of land use activities including but not limited to potable water supply, industrial use, pit and quarry use, golf course operations, and agricultural use.

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

3.1.3 Groundwater

In this Watershed Region, groundwater is used for municipal water supply, agricultural and industrial use, golf course irrigation and private water supplies. Figure 3.1-10 illustrates municipal surface and groundwater takings and Figure 3.1-11 non-municipal water takings across the region.

Hydrogeologic Setting

According to Morrison Environmental (2003), two significant regional aquifer systems are present within the City of Kawartha Lakes, Minden Hills and the Algonquin Highlands area including: (1) unconfined aquifers comprised of overburden and shallow bedrock (less than 15 m below grade); and (2) confined aquifers comprised of bedrock located deeper than 15 m below grade. The overburden aquifers are typically comprised of alluvial, glaciofluvial and glaciolacustrine deposits, and are considered to be localized aquifers.

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

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

The physiography (Figure 3.2-1) of the Black-Severn watershed can be used to determine the extent of the shallow aquifer systems. Region 16 on the figure represents an area consisting of bare rock ridges and shallow tills, indicating that an aquifer(s) is likely to be found near the surface. Region 9 on the map is a limestone plain in this region fractured bedrock aquifers will be found. In the regions where shallow tills comprised of sands and gravels are located, aquifers will also be found near the surface (Regions 2, 4, 5, 6, 7, 11 and 13). Lastly, in the areas covered by clay an aquifer will not be found at the surface.

Within the Township of Ramara, a description of the hydrostratigraphic units in the vicinity of the Park Lane and Davy Drive areas is presented in Appendix H of the North Simcoe Municipal Groundwater Study report (Golder Associates, 2004). An igneous/metamorphic bedrock aquifer, comprised of granite, is present in the Davy Drive area. Within the Val Harbour area, a bedrock aquifer comprised of gneissic rocks is present (Golder Associates, 2004). A map illustrating the hydrostratigraphy of the Davy Drive and Park Lane areas is presented in Appendix H of the North Simcoe Municipal Groundwater Study report (Golder Associates, 2004).

Aquifer Characteristics

Information pertaining to the hydraulic characteristic of aquifers within the Black-Severn River watershed is limited. Within the communities of Kawartha Lakes, Minden Hills and the Algonquin Highlands, hydraulic conductivity values for the overburden aquifer units are reported to range from approximately 10^{-3} to 10^{-6} m/s (Morrison Environmental, 2003). In Ramara Township, transmissivity values obtained from bedrock aquifers are approximately 10 m^2/day (Golder Associates 2004).

An investigation completed by Golder Associates (2004) near the City of Orillia, identified two aquifer units. The uppermost aquifer, referred to as the A1 aquifer complex, is characterized by an unconfined overburden aquifer. This aquifer is typically 2 m thick, predominantly composed of sand and is present at an elevation between 210-225 mASL. An intermediate overburden aquifer, referred to as the A2, was also identified in this investigation. The A2 is a confined aquifer that is predominantly composed of sands and gravels and is located at an elevation between 195-222 mASL. The thickness of the A2 aquifer is described as variable by Golder Associates (2004) ranging from 0-20 m.

Groundwater Flow

The overall migration of shallow groundwater in the Black-Severn River watershed generally coincides with surface topography and surface watershed boundaries (Figure 3.1-13). Morrison Environmental (2003) reported that fractures and other structural features, such as karstic terrain, likely influence groundwater migration in this area. Maps illustrating the water table elevation and potentiometric surface are illustrated on Figure 3.1-13 and Figure 3.1-14. Based on these maps, the regional migration of groundwater in the shallow and deep aquifer systems is towards the southwest in the northern portion of the City of Kawartha Lakes, Minden Hills and the Algonquin Highlands. According to Morrison Environmental et al. (2004) the depth to the water table is generally less than 5 m below grade.

A hydrogeologic study completed by Golder Associates (2004) suggests similar results in that the migration of groundwater through the A1 aquifer (uppermost overburden aquifer) generally coincides with surface topography. However, the migration of groundwater through the A2 aquifer (intermediate overburden aquifer) near the community of Orillia is from east to west (toward Lake Couchiching) with a hydraulic gradient of approximately 0.011 m/m.

Groundwater flow maps for the lowermost bedrock aquifer near the communities of Bayshore Village and Val Harbour indicate a potentiometric surface that ranges from approximately 225-219 masl (Golder Associates 2004). The regional hydraulic flow gradient is approximately 0.0002 m/m to the south-east in the vicinity of Bayshore Village and north-east to south-west with a horizontal flow gradient of approximately 0.001 m/m in the vicinity of Val Harbour (Golder Associates 2004).

Groundwater Takings

Table 3.1-3: Permits to Take Water in the Black Severn River Watershed

Permit Type	Groundwater	Surface Water	Mixed Source	Percentage
Municipal	4	4	1	32
Non-Municipal	12	5	2	68

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The Ontario Water Resources Act Regulation 387 (Water Taking and Transfer) states that any user extracting more than 50,000 L/day is required to have a Permit to Take Water (PTTW). Each permit will have a maximum extraction rate assigned to it based on the user's individual needs. It should be noted that permitted extraction rarely reaches the maximum extraction rates. However, permitted extraction is frequently far greater than the average use because, the provincial system requires that the permit reflect the maximum potential extraction on any one day, regardless of how frequently that extraction rate is achieved. This is due to seasonal variances in water demands.

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 water extraction will be estimated in future water budget efforts using the University of Guelph work (DeLow, 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 groundwater takings are summarized in Appendix WB-2.

3.1.4 Interactions between Ground and Surface Water

Recharge

The Black-Severn River watershed compared to the other SGBLS SPR watersheds experiences much less groundwater recharge. The high percentage of forest cover within the watershed limits the amount of recharge, as evaportranspiration rates are higher, and the water that does reach the ground surface is used up by the vegetation within the root zone. This watershed is characterized as having shallow till overlying bedrock or exposed bedrock at the surface. These conditions allow for little infiltration. There are several locations of known aggregate extraction within the watershed located on the Cardin Plain. As a reflection of current development in the province the aggregates are in demand and there is a desire to mine this area for limestone and dolostone. Although the area is not considered to significantly recharge groundwater it is difficult to completely understand the recharge cycle within an area with karst terrain. Figure 3.1-15 represents potential recharge areas across the watershed region as a function of geology (permeable materials) and hydraulic gradient (downward gradients from the water well records). As previously mentioned, this map is considered preliminary and will be refined in future iterations to reflect other factors that influence recharge such as land cover and slope.

Discharge

The Black-Severn River watershed compared to the other watersheds also experiences much less groundwater discharge. The potential discharge areas are concentrated in the southern reaches of the watershed, with smaller areas scattered throughout the north. The discharge areas correspond to the stream valley and wetland areas. Figure 3.1-15 also demonstrates the potential discharge areas within the watershed.

Aquatic Habitat

Groundwater discharge can be a key indicator of coldwater aquatic habitats. Groundwater discharge indicates the presence of baseflow, which is often cool in temperature. The absence of groundwater discharge in a stream is a key indicator of warm water aquatic habits. Both cold and warm water aquatic habitats are found within the Black-Severn River Watershed. A detailed description of the habitats can be found in Section 2.1.1.1, as well as, a table listing the species found within the coldwater and warm water habitats.

3.1.5 Land Use and Land Cover in the Source Protection Area

The current land use and land cover conditions of the watershed are described in Section 2.4.2. Land cover and land use practices can affect the components of a water budget in different ways. Often land being developed will have a higher proportion of impervious surfaces, such as roadways, parking lots, and building roofs. Increased runoff rates result in erosion and reduced infiltration to recharge groundwater reserves. The majority of the Black-Severn River watershed is rural with the exception of the City of Orillia, and several other small communities such as; Rama, Dalton, Carden and Kirkfield. When the populated area is compared to the size of this watershed and the amount of development that is ongoing is considered, it is apparent that urban development is not an immediate concern in the context of Source Water Protection. However, the potential for introduction of contaminants to both groundwater and surface water must be a consideration when a new land use is being proposed.

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. (1968), the study area contains two climatic regions: Simcoe and Kawartha Lakes, and Muskoka. Most of the study area is within the Simcoe and Kawartha Lakes climatic region. Precipitation in this region is somewhat lighter than that of the areas around it because of the rain-shadow effect created by the western uplands. The northern and northwestern parts of the study area are within the Muskoka climatic region.

Climate Stations

Climate data including precipitation data are collected by Environment Canada (EC) at twelve active meteorological stations located within the SWP study area, one of which is located in the Black-Severn River watershed.

In addition to the above mentioned data sources, historic data 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-1.

Table 3.1-6: Environment Canada: Climate Monitoring Stations in the Black- Severn Watershed.

Watershed	ID	Station Name	Start Year	End Year	Period of Years	Status	Latitude (North)	Longitude (West)	Elevation m(asl)
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	14	Active	44 ° 36’	79 ° 26’	250
Lake Simcoe	6110557	Barrie WPCC	1977	2006	30	Active	44 ° 22’	79 ° 41’	221
Lake Simcoe	6116902	Ravenshoe	1971	1992	22	Inactive	44 ° 13’	79 ° 24’	251
Lake Simcoe	6117684	Shanty Bay	1973	2006	34	Active	44 ° 24’	79 ° 37’	252
Lake Simcoe	6119055	Udora	1989	2006	18	Active	44 ° 15’	79 ° 9’	262
Lake Simcoe	6150863	Bradford Muck Res.	1974	1998	25	Inactive	44 ° 1’	79 ° 36’	221
Lake Simcoe	6151750	Cold Creek*	1971	1991	21	Inactive	43 ° 55’	79 ° 42’	251
Lake Simcoe	6154130	King Smoke Tree*	1974	2003	30	Inactive	44 ° 1’	79 ° 31’	352
Lake Simcoe	6155807	Sharon*	1971	1999	29	Inactive	44 ° 6’	79 ° 25’	262
Lake Simcoe	6158082	Stouffville WPCP*	1971	1992	22	Inactive	43 ° 58’	79 ° 15’	267
Nottawasaga Valley	6111859	Cookstown	1972	2006	35	Active	44 ° 12’	79 ° 41’	244
Nottawasaga Valley	6112340	Essa Ont. Hydro	1971	2000	30	Inactive	44 ° 21’	79 ° 49’	216
Nottawasaga Valley	6115099	Midhurst	1971	1996	23	Inactive	44 ° 45’	79 ° 46’	226
Nottawasaga Valley	6142991	Grand Valley WPCP*	1974	1994	21	Inactive	43 ° 52’	80 ° 19’	465
Nottawasaga Valley	6146939	Ruskview	1986	2006	21	Active	44 ° 14’	80 ° 08’	472
Nottawasaga Valley	6150100	Albion*	1971	2000	30	Inactive	43 ° 56’	79 ° 50’	274

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Watershed	ID	Station Name	Start Year	End Year	Period of Years	Status	Latitude (North)	Longitude (West)	Elevation m(asl)
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	611B002	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
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

*station located outside 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 (bulls-eyes in the interpolated surface). These areas will be re-examined following the receipt of the in-filled data from the provincial climate assessment. Climate normals have been included in Appendix WB-1.

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

Annual average precipitation calculated from short records of data may not reflect long-term variations in precipitation within a watershed or the mean may be biased 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) A.6 (2006) report for Lake Simcoe. The LSEMS reported values derived from a climate model that incorporates elevation, latitude, longitude, temperature, relative humidity, solar radiation, vapour pressure and dew point temperature data, all of which are measured at two locations in the Source Protection Region (Bradford and Ramara). The areal extent of surface water bodies, as determined from GIS layers, was then multiplied by the annual evaporation depth estimated for Lake Simcoe in the above-noted report to obtain the volume of water lost (Table 3.1- 3).

Table 3.1-4~~3~~: Water Losses through Evaporation

Watershed	Land Use	Area (Km^2)	Annual Evaporation (mm/m^2)	Annual Evaporation (Mm^3)
Black River	Lake Couchiching & Other Water	200.54	672	134.6
Black River	Wetlands	129.45	-	-
Black River	Vegetation	2058	-	-
Black River	Urban	378.01	-	-

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Evapotranspiration

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

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

A complete cover by a green crop is considered to return water to the atmosphere by transpiration, and evaporation from the soil, at a peak or ‘reference or potential’ rate when the water supply is unlimited; the water used is referred to as ‘reference or potential evapotranspiration’. In general, watersheds are not entirely covered by well-watered short-green crops. Actual evapotranspiration is the amount or rate of ET occurring in the watershed and it is the value we want to estimate. In practice, actual evapotranspiration 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), Pennman-Montieth (1998), Kohler–Parmale (1967) and Hamon PET (1961). The modified Penman method is considered to offer the best results with minimum possible error in relation to a living grass reference crop. The method has not been used here because of insufficient meteorological data. For this study, the Hamon reference ET method was used since air temperature data is available at all the climate stations in the study area. The Hamon method is shown in below.

Hamon Reference Evapotranspiration

Hamon Equation

$$ET_{Hamon} = 13.97dD2Wt$$

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

d is the number of days in a month,

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

Wt is a saturated water vapour density term calculated by

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

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 2.4 and the actual ET isolines are shown in Figure 2.4. The results are similar to the values reported for by MNR (1984, page 23) for the region of this study.

Table 3-1~~2~~ Watershed Mean Monthly Annual Reference ET and Actual ET (mm).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ref. ET	Actual ET
Black-Severn	6.56	8.86	18.2	38.5	71.3	96.18	115.1	89.8	53.1	27.6	13.8	7.78	547.20	525.32

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Potential Impacts of Climate Change

The potential impacts of climate change, as well as current climate trends within the Black-Severn River watershed will be discussed in Chapter 11: The Assessment Report in Context.

Figure 3.1-1: Physiographic Regions

Figure 3.1-2: Ground Surface Topography

Figure 3.1-3: Bedrock Geology

Figure 3.1-4: Bedrock Topography

Figure 3.1-5: Quaternary Geology

Figure 3.1-6: Overburden Thickness

Figure 3.1-7: Soils

Figure 3.1-8: Bathymetry of Lake Couchiching

Figure 3.1-9: Streamflow Gauging Stations

Figure 3.1-10: Surface water control structures

Figure 3.1-11: Municipal surface and groundwater taking locations

Figure 3.1-12: Non-municipal surface and groundwater taking locations

Figure 3.1-13: Shallow water table elevation

Figure 3.1-14: Groundwater flow direction

Figure 3.1-15: Potential groundwater recharge and discharge areas

3.2 Tier One Water budget and Water Quantity Stress Assessment

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

Similarly, water demand is estimated on an annual and monthly basis within each subwatershed. These estimates of supply and demand provide insights into potential stress on existing and future municipal water supplies. Where demand for water exceeds a prescribed threshold of supply and municipal 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 Black-Severn River watershed (Earthfx, 2010) 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

For the purposes of the Tier One assessment, the Black-Severn River watershed has been divided into seven subwatersheds or hydrological units, each drained by one or more tributaries, as outlined in Section 2.2[4]. The subwatersheds range in size[5] from tens to hundreds of square kilometers, and also cross political boundaries. The largest unit is the Head River subwatershed at 607 km^2. It is found in three upper tier municipalities and two local municipalities.

It should be noted that although the Upper Talbot River subwatershed drains into Lake Simcoe it is included in the Black-Severn River Water Budget assessments.

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

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[4] Note that for the Tier 1 analysis the Lake Couchiching and Lake St.John subwatersheds were merged due to their small size.

[5] Note: The areas of some subwatersheds presented within the tables of Section 3.2 will differ from those presented Section 2.2, as Section 3.2 represents the modeled area, not the bounded area.

across a large area that does not, in reality, contribute to the supply. The units of study for this assessment mimic the subwatershed delineations determined by the Ministry of the Environment, which have been deemed appropriate for a variety of watershed management efforts. These boundaries may later be revised during the Tier Two evaluation.

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., irrigation or municipal supply wells) near a watershed boundary. However, these differences are generally not significant based upon comparison of subwatershed boundaries and groundwater divides inferred from water table elevations (Section 3.1.3.2 and Figure 3.1-13).

As a result, it was deemed appropriate to use surface water divides for this assessment, and assume that groundwater inflows to a subwatershed are equivalent to groundwater outflows. The difference between surface water and groundwater divides, as well as associated groundwater movement between subwatersheds, among other things, will be included in Tier 2 and 3 studies, where they are required.

Four separate analyses were required for the Tier One analysis; 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. In general, the following data were used for this evaluation: precipitation data from 1975 to 2002; temperature data from 1975 to 2002; and streamflow data from 1975 to 2002. Surface water evaluations were based on monthly and annual summations and statistics of median flow, as well as, separated baseflows derived for daily simulated streamflow.

3.2.2 Water Supply

The following sections outline the components of a water budget and the methods used to derive each. More detail on the methods and assumptions used in the Tier One Water Budget and Water Quantity Stress Assessment of the Black-Severn River Watershed; herein referred to as the Tier One can be found within the report (Earthfx, 2010).

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 Black-Severn River watershed. Assessing surface water supply involved the construction of a surface water model calibrated locally to three Water Survey of Canada (WSC) stream gauges within the study area. This study was limited to only three gauges because the remaining 10 WSC gauges within the study area either had poor periods of record, or were not representative of their catchment in that they are highly controlled and used to asses seasonal canal discharge (i.e., Trent-Severn Waterway). Interpolation of the three calibrated local models provided the means to estimate hydrologic processes occurring at the regional scale (Earthfx, 2010).

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. Recharge, total catchment discharge, baseflow discharge and evapotranspiration (ET) was determined using the U.S. Geological Service’s (USGS) Precipitation-Runoff Modelling System (PRMS).

The USGS Precipitation-Runoff Modelling System is an open-source modelling code for calculating all components of the hydrologic cycle on a watershed or subwatershed scale. The code is well documented in Leavesley et al., (1983) and has been used in many applications across the U.S. and Europe (Earthfx, 2010). A PRMS model of the Black-Severn River watershed was built to estimate the evapotranspiration, streamflow, baseflow and recharge components of the water budget. A summary of the PRMS modeling efforts undertaken for the Black-Severn River Subwatershed is within Appendix WB-4.

Precipitation-Runoff Modelling System (PRMS) Results

The PRMS model simulations produced outputs that were used in the stress assessment calculations. The following discusses the PRMS model outputs used within the stress assessment.

<u>Precipitation and Evapotranspiration</u>

PRMS interpolation of monthly precipitation and actual evapotranspiration per subwatershed is given in (Table 3.2-1 and Table 3.2-2) respectively, and are illustrated in Figure 3.2-3 and Figure 3.2-4, respectively.

Table 3.2-1: Monthly Precipitation Interpolated by PRMS (Earthfx, 2010).

Subwatershed	Area (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Black River	509	88	61	71	73	88	86	82	88	100	93	103	94	**1,027**
Head River	607	85	59	68	70	85	84	79	88	98	87	97	89	**989**
Kashe/Gartersnake River	246	90	61	72	75	90	85	87	87	106	100	108	98	**1,059**
Lake Couchiching/St. John	102	95	62	67	68	81	85	80	91	98	87	97	94	**1,005**
Severn River	562	92	62	69	71	85	84	82	89	102	92	101	96	**1,025**
Upper Black River	391	91	64	74	73	89	87	84	91	103	97	107	97	**1,057**
Upper Talbot River	285	79	56	65	69	83	83	77	88	95	83	92	83	**953**

Note: Values are rounded for presentation purposes. Values are in mm/mon or mm/yr except where noted.

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Table 3.2-2: Monthly and Actual Evapotranspiration (AET) estimated by PRMS (Earthfx, 2010).

Subwatershed	Area (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Black River	509	7	9	25	47	57	54	51	46	29	19	13	7	**364**
Head River	607	6	9	24	49	61	59	53	49	34	22	13	7	**386**
Kashe/Gartersnake River	246	6	9	23	47	60	57	55	47	30	19	12	7	**372**
Lake Couchiching/St. John	102	4	6	20	47	59	59	53	52	37	23	12	6	**378**
Severn River	562	5	8	22	48	57	55	50	49	34	21	12	6	**367**
Upper Black River	391	7	9	23	50	67	60	58	43	26	16	12	7	**378**
Upper Talbot River	285	5	8	23	52	67	61	54	46	32	21	13	6	**388**

Note: Values are rounded for presentation purposes. Values are in mm/mon or mm/year except where noted.

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Streamflow and Baseflow

Separate runs were performed on each subwatershed in order to estimate daily streamflow from the PRMS model. From these data, monthly mean flow and monthly median flow were determined and are presented in Table 3.2-3 and Table 3.2-4, respectively. Monthly baseflow was also estimated by PRMS and is presented in Table 3.2-5.

Table 3.2-3: Monthly total Streamflow calculated by PRMS (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
Black River	36	25	72	111	45	20	14	11	18	34	54	54	**493**
Head River	37	29	78	89	38	17	12	10	18	32	50	52	**462**
Kashe/Gartersnake River	34	23	70	124	51	21	14	12	20	37	57	56	**518**
Lake Couchiching/St. John	38	30	81	100	44	21	17	15	23	38	54	53	**514**
Severn River	38	27	76	107	40	17	12	11	20	38	56	57	**500**
Upper Black River	29	19	69	141	44	15	8	6	12	27	51	52	**475**
Upper Talbot River	36	28	70	83	37	15	9	7	13	23	40	46	**406**

Note: Values are rounded for presentation purposes. All values are in mm/mon or mm/year.

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Table 3.2-4: Monthly Median Streamflow calculated by PRMS (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
Black River	23	12	48	92	39	18	11	7	10	32	49	46	**388**
Head River	26	16	61	73	33	15	9	7	10	30	44	45	**369**
Kashe/Gartersnake River	23	12	47	105	43	19	10	7	11	34	53	49	**412**
Lake Couchiching/St. John	30	20	72	87	36	18	11	11	14	35	49	4	**434**
Severn River	28	16	61	90	33	15	9	6	10	37	51	52	**406**
Upper Black River	16	8	37	115	36	14	6	3	5	22	45	44	**353**
Upper Talbot River	28	20	63	74	33	12	6	4	7	21	34	42	**345**

Note: Values are rounded for presentation purposes. All values are in mm/mon or mm/yr.

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Table 3.2-5: Monthly Baseflow discharge calculated using PRMS (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
Black River	10	5	13	30	18	8	5	4	8	19	26	22	**167**
Head River	15	10	24	36	18	7	4	3	6	16	26	25	**189**
Kashe/Gartersnake River	10	5	14	33	19	8	5	3	7	19	27	22	**173**
Lake Couchiching/St. John	21	16	42	53	22	8	4	3	7	20	29	30	**257**
Severn River	10	5	13	24	13	6	3	3	6	15	22	19	**139**
Upper Black River	10	4	11	33	21	7	3	2	5	17	29	23	**165**
Upper Talbot River	19	15	35	39	17	5	2	1	3	10	22	26	**194**

Note: Values are rounded for presentation purposes. All values are in mm/mon or mm/yr.

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Recharge

Although the Black-Severn River watershed had limited available gauges for calibration, there were sufficient data to develop the model and build mechanisms that were required to simulate the hydrological processes as observed at the calibration gauges. Previous modeling efforts proved quite difficult in simulating seasonal flow patterns without using unjustified assumptions such as high rates of recharge occurring over the exposed bedrock areas.

With the addition of beaver ponds (a new and, this time justifiable, mechanism of flow attenuation) the model was able to simulate measured discharge to a greater degree than in previous efforts. The manual calibration of this model took approximately 150 model runs, varying between 30 min to 3 hours per run. Considering the lack of physical data, yet the well-calibrated results, this effort has been a great success. Figure 3.2- 8 illustrates the final annual recharge rates for the Black-Severn River watershed (Earthfx, 2010).

Reserve Estimations

Within Guidance Module 7 (MOE, 2007) 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. The monthly surface water stress assessment uses both the Qp90 and Tessman method, where the Qp90 method is not appropriate. For surface water, Qp90 was used in place of the Tessmann method if (1) the difference between supply less reserve was equal to 1mm/month; and (2) for the Port Severn surface water supply. This approach was accepted by the Peer Review Team.

Surface Water Reserve Estimation

The methods recommended in Guidance Module 7 and the Technical Rules (Nov.2009) to estimate surface water reserve include 10th percentile low streamflow (Q_p90). This is the flow value that is considered to be the most representative for a reserve, as it is the flow value that is exceeded 90% of the time. Another recommended option is to employ the Tessmann (1980) method, which is essentially a modification to the Montana method (Tennant, 1976) that recommends a reserve of 30-50% of mean annual flow (MAF) to maintain “excellent instream flow regimens for fish, wildlife, recreation, and related environmental resources.” The Tessmann method essentially puts softer targets on the Montana method’s target of ~40% of MAF such that the instream low flow measure is made applicable to a wider range of streams of varying seasonal flow patterns and basin storage capacities.

Tessmann (1980) pointed out that relying on strict thresholds such as 40% of MAF (and similarly, Q_p90) could lead to spurious results; for example, there are many viable streams in which summer low flows can fall below these thresholds. Tessmann addressed this with the use of mean monthly flows (MMF) and applying a simple rule: if MMF is less than 40% of MAF then use the MMF, otherwise, if MMF is greater than MAF then use 40% of MMF, otherwise, use 40% of MAF (i.e. Montana method). The first part of the rule handles streams with seasonal low flow conditions, while the second part handles streams with seasonal high flow conditions; otherwise, the Montana method is used. A schematic description is shown below.

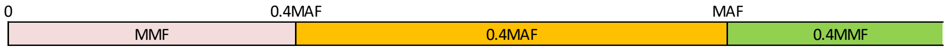

Diagram 3.2-1: Schematic representation of Tessmann method (Earthfx, 2010).

As noted in the Guidance Module 7, when using the Tessmann method, the estimated reserve value may be larger than the water supply calculated as the monthly median flow (Q_p50). To correct for this, a reserve value of the monthly 10th percentile low flow (Q_p90) was applied in place of the Tessmann equation. However, spurious results can even occur if the difference between the calculated supply and reserve is small yet positive; as this difference decreases, the percent water demand can increase significantly. For this reason, it was decided that to best avoid these spurious results, Q_p90 would replace the Tessmann method if the difference between monthly surface water supply and reserve was less than or equal to 1 mm/month (as opposed to less than or equal to 0 mm/month). With these exceptions, the Tessmann method was used to estimate surface water reserve as it is a method that is derived with the consideration of instream flow needs and it is the most conservative estimate compared to Q_p90.

Reserve estimates have been done in keeping with Guidance Module 7 and the Technical Rules, which indicate that the reserve value is designed to add a buffer to already conservative percent demand thresholds. Using the Tessmann (1980) method in place of Q_p90, where applicable, adds extra conservatism. Surface water reserve values have been included in Table 3.2-6, and monthly Q_p90 is reported in Table 3.2- 7.

Table 3.2-6: Surface Water Reserve Estimates using the Tessmann, 1980 method or Q_p90 if Q_{supply}-$Q_{Tessmann}$ <1mm/mon. (mm) (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
Black River	17	2	29	44	18	7	5	3	2	17	21	22	**187**
Head River	16	3	31	36	16	6	4	3	2	16	20	21	**173**
Kashe/Gartersnake River	18	2	28	50	20	8	5	3	2	18	23	22	**199**
Lake Couchiching/St. John	17	16	32	40	17	7	5	4	3	17	21	21	**202**
Severn River	17	3	30	43	17	5	3	2	2	17	22	23	**184**
Upper Black River	4	1	27	57	18	5	3	1	1	16	21	21	**174**
Upper Talbot River	14	13	28	33	15	5	3	2	1	14	16	18	**162**

Table 3.2- 7: Monthly 10th percentile low flows (Q_p90) for each subwatershed (mm).

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual
Black River	7	2	6	38	19	7	5	3	2	8	17	21	**135**
Head River	7	3	9	33	16	6	4	3	2	7	16	22	**127**
Kashe/Gartersnake River	6	2	5	44	21	8	5	3	2	8	16	19	**139**
Lake Couchiching/St. John	7	3	12	39	17	7	5	4	3	8	21	26	**153**
Severn River	7	3	8	37	15	5	3	2	2	8	20	26	**137**
Upper Black River	4	1	3	40	17	5	3	1	1	3	13	14	**105**
Upper Talbot River	7	3	11	32	15	5	3	2	1	4	9	19	**112**

Note: Values are rounded for presentation purposes. All values are in mm/mon or mm/year.

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Groundwater Reserve Estimation

Per Technical Rule 1. (2), 10% of the existing groundwater discharge (calculated using PRMS) has been used for the groundwater reserve estimate within each subwatershed. These values have been included in Table 3.2-8.

Table 3.2-8: Groundwater Reserve Estimates measure as 10% monthly baseflow (mm) (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean Annual
Black River	1.0	0.5	1.3	3.0	1.8	0.8	0.5	0.4	0.8	1.9	2.6	2.2	**1.4**
Head River	1.5	1.0	2.4	3.6	1.8	0.7	0.4	0.3	0.6	1.6	2.6	2.5	**1.6**
Kashe/Gartersnake River	1.0	0.5	1.4	3.3	1.9	0.8	0.5	0.3	0.7	1.9	2.7	2.2	**1.4**
Lake Couchiching/St. John	2.1	1.6	4.2	5.3	2.2	0.8	0.4	0.3	0.7	2.0	2.9	3.0	**2.1**
Severn River	1.0	0.5	1.3	2.4	1.3	0.6	0.3	0.3	0.6	1.5	2.2	1.9	**1.2**
Upper Black River	1.0	0.4	1.1	3.3	2.1	0.7	0.3	0.2	0.5	1.7	2.9	2.3	**1.4**
Upper Talbot River	1.9	1.5	3.5	3.9	1.7	0.5	0.2	0.1	0.3	1.0	2.2	2.6	**1.6**

Note: Values are rounded for presentation purposes. All values are in mm.

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3.2.3 Water Demand

For this study, the MOE permit to take water (PTTW) database, municipal pumping records, prior studies, and statistical population data have been used to estimate water demand. As recommended within the guidance module, the demand from non-permitted agricultural water uses has been estimated using the methodology developed by de Loe (2005).

The following sections outline the methods used to estimate various water demands within the watershed.

Table 3.2-9: Existing Groundwater Consumption (Earthfx, 2010)

Watershed Name	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Black River		200,000		113,000	313,000
Head River		326,000	768,000	257,000	1,351,000
Kashe/Gartersnake River		123,000		7,000	130,000
Lake Couchiching/St. John		76,000	16,000	46,000	138,000
Severn River	15,000	228,000	7,000	111,000	361,000
Upper Black River		105,000		17,000	122,000
Upper Talbot River	251,000	163,000	6,000	140,000	560,000

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Note: Values rounded for presentation purposes (methods of summing will alter totals slightly). All values are in m^3/year.

Table 3.2- 10: Future Groundwater Consumption (Earthfx, 2010)

Watershed Name	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Black River		269,000		113,000	382,000
Head River		440,000	768,000	257,000	1,465,000
Kashe/Gartersnake River		166,000		7,000	173,000
Lake Couchiching/St. John	2,103,130	102,000	16,000	46,000	2,267,130
Severn River	24,455	308,000	7,000	111,000	450,455
Upper Black River		142,000		17,000	159,000
Upper Talbot River	250,390	220,000	6,000	140,000	616,390

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Note: Values rounded for presentation purposes (methods of summing will alter totals slightly). All values are in m^3/year.

Table 3.2-11: Existing Surface Water Consumption (Earthfx, 2010)

Watershed Name	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Black River				113,000	113,000
Head River				257,000	257,000
Kashe/Gartersnake River				7,000	7,000
Lake Couching/St. John	713,000		115,000	46,000	874,000
Severn River	29,000			111,000	140,000
Upper Black River				17,000	17,000
Upper Talbot River			1,200,000	140,000	1,340,000

Note: Values rounded for presentation purposes (methods of summing will alter totals slightly). All values are in m^3/year.

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Table 3.2-12: Future Surface water consumption (Earthfx, 2010)

Watershed Name	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Black River				113,000	113,000
Head River				257,000	257,000
Kashe/Gartersnake River				7,000	7,000
Lake Couching/St. John	13,510,000		115,000	46,000	13,671,000
Severn River	730,000			111,000	841,000
Upper Black River				17,000	17,000
Upper Talbot River			1,200,000	140,000	1,340,000

Note: Values rounded for presentation purposes (methods of summing will alter totals slightly). All values are in m^3/year.

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Permits to Take Water

Under the Ontario Water Resources Act, taking greater than 50,000 litres of water per day require a Permit to take water. The MOE permit to take water (PTTW) database is a valuable tool in water use estimates. The 'copy' of the database used in the Tier One assessment is current to July 2006. This copy was deemed appropriate and provided to SWP staff by the MNR.

As part of the assessment, the database was modified in a consistent manner to improve the accuracy of information. 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 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 as groundwater taking so that it was not considered twice.

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

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.

A considerable effort was made to use the most conservative measures and apply the techniques described above in a consistent manner. However, it is known that until a database is produced based on actual water takings, the water use estimates will be a significant source of uncertainty. A summary of the permits deemed to be in use has been included as Appendix WB-2, the pumping rates coloured red represent maximum permitted rates where actual pumping rates could not be determined. The groundwater and surface water permit locations are depicted in Figure 3.2- 9 and Figure 3.2- 10

Municipal Water Use

Existing and future municipal water taking data were obtained from the North Simcoe Groundwater Study (Golder, 2005), the MOE PTTW database, municipal staff, and various other Well Head Protection Area reports from across the Source Protection Region. Well locations, in UTM coordinates, and reported pumping rates as documented within these studies are outlined in Appendix WB-2. Where actual water takings were unavailable, maximum permitted takings were used.

Demand estimates for the existing groundwater use scenario are outlined in Table 3.2-10. For the future scenario, municipal demand has been estimated from Official Plans, which in many cases project the demand over the next 25-years. These estimates have been included in Table 3.2-11.

Surface water takings for agricultural and other permitted uses have also been assessed. There are currently five municipal surface water treatment facilities within the study area, all of which take water from large waterbodies and were excluded from the surface water stress assessment as per Technical Rule 4 (MOE, 2008a) which states:

> *"An area represented by a conceptual water budget or water budget prepared in accordance with rule 3 shall not include any part of a surface water body that is a Great Lake, a connecting channel, Lake Simcoe, Lake Nipissing, Lake St.Clair or the Ottawa River."*

A summary of the existing and future surface water use estimates are included in Table 3.2-12 and Table 3.2-13 respectively.

Non-Permitted Water Use

Agriculture Consumption

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

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 consumptive use for each subwatershed. Although this method provides an estimate of total annual water consumption, there is no way to discretize these estimates seasonally nor is there any method to differentiate what is taken from groundwater versus surface water. For the purpose of this report, estimated agricultural taking was considered in both surface water and groundwater stress assessments to yield the most conservative estimate. Refinement of the agricultural taking through subwatershed specific Statistics Canada census data will be undertaken in the Tier Two analysis for those parts of the region that are identified as having a water quantity stress.

Unserviced Domestic Water Use

For the purpose of this report, an assumption was made that all households in the study area not serviced by municipal water obtain water from a private well. To derive an estimate of the average groundwater used for domestic purposes, the 2006 Statistics Canada census data were used to determine the "un-serviced" population within each subwatershed relying on private wells. This un-serviced population was then multiplied by a per-capita usage of 335 L/day, based on recommendations in the Guidance Module 7 (MOE, 2007). A relatively low consumptive use 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 pumped back to the local subsurface.

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 the Technical Rules (MOE, 2008a), the methods used to calculate the future demand within the Tier One assessment includes an estimate of increased human consumption.

An anticipated growth rate of 35% was applied to the domestic population to provide an estimate of future water use over the next 25-years. It is recognized that this is a very conservative estimate of future increase in private domestic use, as the majority of population growth will likely occur in urbanized areas which obtain water from municipal servicing. However, the consumptive use values calculated are relatively low and do not significantly affect the outcome of the stress assessment. Table 3.2-14 outlines the current and future population and calculated water use for un-serviced users. Municipal pumping has been increased based on 25-year forecasts provided by municipalities within the study area to the LSRCA.

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 and Lake Couchiching. In addition, all private domestic use is assumed to be groundwater and therefore, future surface water demand estimates were increased for municipal supplies only.

Table 3.2-13: Unserviced Water Consumption Estimates (Earthfx, 2010)

Watershed Name	Current Scenario Population	Current Scenario Consumptive Use	Estimated Growth %	Future Scenario Population	Future Scenario Consumptive Use
Black River	8,157	199,485	35	11,012	269,305
Head River	13,341	326,256	35	18,010	440,446
Kashe/Gartersnake River	5,040	123,263	35	6,805	166,405
Lake Couchiching/St. John	3,087	75,489	35	4,167	101,910
Severn River	9,315	227,797	35	12,575	307,526
Upper Black River	4,301	105,190	35	5,807	142,007
Upper Talbot River	6,650	162,626	35	8,978	219,546

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Consumptive Water Use Methodology

The above section outlines the methods used to determine the amount of anthropogenic water taking from each subwatershed. An understanding of the hydrologic cycle substantiates that all of the water being extracted is not being removed from that system. To develop a more conservative and accurate representation, water consumption has been calculated and used within the stress assessment using consumptive factors outlined in Table 3.2-15.

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

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”.

Consumptive with respect to the subwatershed is defined within the MOE Guidance Module 7 (MOE, 2007) as; “Water taken and not returned to a water body within the same sub-basin it is assumed to be 100% consumptive at the sub-basin scale. If; however, water is returned within the same sub-basin the consumptive factors outlined on Table 3.2-15 are applied to the total taking. Some examples of this are domestic usage which is returned to the local system via on-site septic systems".

Consumptive with respect to the watershed is defined within the MOE Guidance Module 7 (MOE, 2007) as; "Water taking that removes water from the watershed is 100% consumptive at that scale. Water bottling operations and other operations that use water for commercial products fall into this category".

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 from 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.

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

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

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Agricultural	Field and Pasture	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 & Reservoirs	0.10
Agricultural	Other – Agriculture	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 & Quarries	0.25	Water Supply	Campgrounds	0.20
Industrial	Aggregate Washing	0.25	Water Supply	Communal	0.20
Industrial	Brewing Soft Drinks	1.00	Water Supply	Municipal	0.20
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.20
Industrial	Food Processing	1.00			

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Monthly Usage Factors

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

The monthly use table, provided within the MOE Guidance Document (MOE, 2007), was used when the months of water taking was otherwise not known. This table is a list of coefficients that have been applied to each permit based on the specific purpose listed. The table has been included as Table 3.2-16, and indicates when water taking is assumed to be active. An assumption has also been made that during these times, water is being taken everyday during that month. For the “non-permitted agricultural” consumption, an equivalent taking over a four month period was estimated for this assessment.

A summary of monthly groundwater and surface water consumption based on the previous sections and usage factors have been included as Table 3.2-17 and Table 3.2-18. The values in Table 3.2-17 summarize the monthly PTTW calculations derived using the above mentioned assumptions, as well as, the calculated monthly domestic, municipal, and agricultural usage. The surface water demand is a summary of the PTTW and agricultural calculations. The methods used to determine these values have been discussed within Section 3.2.4.

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

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

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General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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	0	0	1	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
Water Supply	Municipal - Basin Transfer	1	1	1	1	1	1	1	1	1	1	1	1

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Table 3.2-16: Monthly Groundwater Consumption

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Black River	27,000	24,000	27,000	26,000	27,000	26,000	27,000	27,000	26,000	27,000	26,000	27,000	313,000
Head River	115,000	105,000	115,000	111,000	115,000	111,000	115,000	115,000	111,000	115,000	111,000	115,000	1,351,000
Kashe/ Gartersnake River	11,000	10,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	130,000
Lake Couchiching/ St. John	11,000	10,000	11,000	11,000	13,000	12,000	13,000	13,000	12,000	11,000	11,000	11,000	138,000
Severn River	30,000	27,000	30,000	29,000	31,000	30,000	31,000	31,000	30,000	30,000	29,000	30,000	361,000
Upper Black River	10,000	9,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	122,000
Upper Talbot River	47,000	43,000	47,000	45,000	47,000	47,000	48,000	48,000	47,000	47,000	45,000	47,000	559,000

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Note: Values are rounded for presentation purposes (methods of summing will alter totals slightly). All values are in m^3/month.

Table 3.2-17: Monthly Surface Water Consumption

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Black River	10,000	9,000	10,000	9,000	10,000	9,000	10,000	10,000	9,000	10,000	9,000	10,000	113,000
Head River	22,000	20,000	22,000	21,000	22,000	21,000	22,000	22,000	21,000	22,000	21,000	22,000	257,000
Kashe/ Gartersnake River	600	500	600	500	600	500	600	600	500	600	500	600	6,600
Lake Couchiching/ St. John	73,000	66,000	73,000	70,000	73,000	75,000	77,000	77,000	75,000	73,000	70,000	73,000	875,000
Severn River	12,000	11,000	12,000	11,000	12,000	11,000	12,000	12,000	11,000	12,000	11,000	12,000	140,000
Upper Black River	1,400	1,300	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	16,500
Upper Talbot River	109,000	99,000	109,000	105,000	109,000	119,000	123,000	123,000	119,000	109,000	105,000	109,000	1,340,000

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Note: Values are rounded for presentation purposes (methods of summing will alter totals slightly). All values are in m^3/month.

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.

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 these data is directly related to the uncertainty of the stress assessment as municipal wells are often the most significant takers within a subwatershed.

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

The methodology outlined by de Loe (2002, 2005) was used to estimate agricultural water use. The 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 the Tier One screening level stress assessment.

The PTTW database provided by the MOE has been modified as discussed in previous sections. Although this database is being updated to include actual water takings, the data were not available for the preparation of this report. Instead, the PTTW database provides a maximum allowable taking over time. This maximum taking has been used to make assumptions regarding the actual taking, when actual water-taking rates were unavailable. A complete listing of municipal supplies can be found within Appendix WB-2; red values indicate maximum permitted used when actual water-taking rates were unavailable. The following notes some of the uncertainty associated with these data:

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

- The version of the PTTW database provided to Conservation Authorities is current to 2006; therefore assumptions have been made regarding permits that have been renewed.

Despite these uncertainties, the data and assumptions were considered adequate for the purposes of the Tier 1 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 conditions. The goal of the existing conditions scenario is to identify subwatersheds that are under stress as a result of existing water takings. Whereas, the goal of the future scenario is to identify subwatersheds that may become stressed as a result of additional drinking water resources needed to support future development outlined in municipal official plans.

The percent water demand has been evaluated independently for both groundwater and surface water. The groundwater use evaluations are based on both average annual and average monthly conditions, while the surface water use evaluations are based on monthly summations and statistics (median monthly and annual) or daily measured stream flow.

Table 3.2-19 presents the list of scenarios for groundwater and surface water supplies. As this table indicates, groundwater systems are evaluated for both average annual and monthly conditions, whereas surface water conditions are evaluated monthly. An annual average surface water flow would not be appropriate for a stress assessment, as stream flow changes rapidly based on variables such as precipitation, spring freshet, and summer drought. The prescribed approach for determining the surface water quantity stress takes into consideration seasonal variability and is therefore evaluated using an estimate of expected monthly values. Conversely, an evaluation of the average annual conditions for groundwater is useful for evaluating potential long-term stress conditions. The water demand is calculated for each month, and the largest monthly stress is selected for comparison against the threshold criteria.

Table 3.2-18: Tier One Stress Assessment Scenarios

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

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

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

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

where;

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

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

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

Table 3.2-19: Stress Assessment Thresholds

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

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

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

Tier One Stress Assessment

Percent Annual Water Demand- Existing Conditions

Groundwater

Based on the results of the groundwater stress assessment discussed above, under existing conditions, none of the subwatersheds exceed the threshold for moderate water quantity stress (Table 3.2-22).

Percent Monthly Water Demand- Existing Conditions

Groundwater

In addition to the above mentioned existing annual stress, none of the subwatersheds exceed the threshold for moderate water quantity stress. The results of the monthly stress assessments are located in Appendix WB-3 and summarized in Table 3.2-20.

Surface Water

The results of the monthly surface water stress assessments are located in Appendix WB-3 and summarized in Table 3.2-21.

All of the municipal surface water systems within the watershed take water from either Georgian Bay or Lake Couchiching. Technical Rule 4 (MOE, 2008a) has prescribed that subwatersheds that take from the large lakes, such as Lake Simcoe or the Great Lakes, should not be included in the stress assessment. Since both Georgian Bay and Lake Couchiching are hydraulically connected (i.e., no change in stage due to dams or streams) to Lake Huron and Lake Simcoe, respectively, all municipal water was concluded as being taken from large lakes and thus was excluded from the stress assessment.

Within the summer months, surface water stress assessments indicate elevated stress values in June for subwatershed Lake Simcoe/Lake St. John and in August for Upper Talbot River (Table 3.2-21). It must be noted that these elevated stress levels are discrepancies due to the methods outlined Section 3.2.2 whereby when the reserve is greater or equal to the supply, the reserve value of 30% mean monthly discharge is used in place of the Tessmann method. This method greatly increases the stress to levels that should only be accepted with a degree of scrutiny, especially since in no other instances do monthly surface water stress levels exceed any thresholds.

Table 3.2-20: Existing Monthly Groundwater Stress Assessment Summary (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Head River	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Kashe/Gartersnake River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lake Couchiching/St. John	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Severn River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Upper Black River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Upper Talbot River	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

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🟨 ~~-~~ ~~->25% & <50% of available supply being taken~~

Table 3.2-21: Existing Monthly Surface Water Stress Assessment Summary (Earthfx, 2010)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black River	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%
Head River	0%	2%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%
Kashe/Gartersnake River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lake Couchiching/St. John	1%	3%	0%	0%	1%	1%	3%	2%	1%	1%	0%	0%
Severn River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Upper Black River	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Upper Talbot River	3%	5%	1%	1%	2%	6%	14%	22%	7%	5%	2%	2%

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🟨 ~~-~~ ~~->25% & <50% of available supply being taken~~

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Percent Annual Water Demand-Future Conditions

Groundwater

As previously discussed in Section 3.2.3 estimates of future groundwater takings were based on a 35% population increase for domestic consumption and municipal pumping was increased based on projections supplied by the local municipalities. The results of the estimated future demand scenario indicate that no subwatersheds are likely to become moderately stressed (Table 3.2-23). However, the Lake Couchiching/Lake St.John subwatershed is expected to reach a groundwater stress of 9.5% of the available annual supply. Since the stress was close to the moderately stressed threshold of 10%, a sensitivity analysis was required to see if the subwatershed would surpass the threshold. It should be noted that the City of Orillia falls within this subwatershed. The City has a unique water taking situation discussed below.

City of Orillia

The City of Orillia currently obtains 83% of its municipal water supply from a surface water treatment plant located along the western shore of Lake Couchiching within the Lake Couchiching/Lake St.John subwatershed. The remaining 17% is obtained from a groundwater well located in the North River subwatershed of the Severn-Sound watershed. The City also has two additional groundwater wells located near the surface water treatment plant. These wells were not considered in the existing stress assessment, as they are only used when the surface water plant is offline for repairs or when the demand is very high.

The future forecasted demand for the City is estimated to be 35,000 m^3/day. This rate encompasses the maximum permitted rates for all three wells, and the surface water treatment plant. The City is unable to determine how much of the future demand will be supplied from each individual source. Since the proportion of demand from each individual supply cannot be differentiated, the conservative approach of using maximum permitted rates for all sources was taken in the future demand scenario. Due to this conservative approach of including the two standby wells in the future scenario, the potential stress level rise's from 0.6% currently to 9.5%. However, the potential future stress of 9.5% is likely a very conservative assessment as the City plans to keep these wells as standby. But without knowing for certain, the assessment is actually a good indication that the subwatershed, on the whole, cannot tolerate very much more demand from a groundwater source before having to undergo a Tier 2 assessment.

Table 3.2-22: Existing Annual Stress Assessment (Earthfx, 2010).

Subwatershed	Black River	Head River	Kashe/Gartersnake River	Lake Couchiching/St. Johns	Severn River	Upper Black River	Upper Talbot River
Area km^2	509	607	246	102	562	391	285
Precipitation mm/a	1027	989	1059	1005	1025	1057	953
Annual Evapotranspiration mm/a	349	371	357	363	352	363	372
Surplus Water mm/a	678	618	702	642	673	694	581
Annual Mean Flow mm/a	494	462	519	514	499	473	407
Annual Mean Flow m^3/s	8.0	8.9	4.0	1.7	8.9	5.9	3.7
Baseflow mm/a	166.8	189.4	172.9	256.6	139.1	164.6	193.7
Baseflow m^3/s	2.7	3.6	1.3	0.8	2.5	2	1.7
Groundwater Supply (Recharge) mm/a	202	207	206	258	169	180	199
Groundwater Supply (Recharge) m^3/s	3.3	4.0	1.6	0.8	3.0	2.2	1.8
Surface Water Supply (Q_{50}) mm/a	388	369	412	434	406	353	345
Surface Water Supply (Q_{50}) m^3/s	6.3	7.1	3.2	1.4	7.2	4.4	3.1
Groundwater Reserve mm/a	17	19	17	26	14	16	19

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Subwatershed	Black River	Head River	Kashe/Gartersnake River	Lake Couchiching/St. Johns	Severn River	Upper Black River	Upper Talbot River
Groundwater Reserve m^3/s	0.3	0.4	0.1	0.1	0.2	0.2	0.2
Surface Water Reserve mm/a	196	185	208	200	184	175	162
Surface Water Reserve m^3/s	3.2	3.6	1.6	0.6	3.3	2.2	1.5
Groundwater Consumption m^3/a	313,000	1,351,000	130,000	138,000	361,000	122,000	560,000
Groundwater Consumption mm/a	0.6	2.2	0.5	1.3	0.6	0.3	2
Groundwater Stress %	0.3%	1.2%	0.3%	0.6%	0.4%	0.2%	1.1%

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Table 3.2-23: Future Annual Stress Assessment (Earthfx, 2010).

Subwatershed	Black River	Head River	Kashe/Gartersnake River	Lake Couchiching/St. Johns	Severn River	Upper Black River	Upper Talbot River
Area km^2	509	607	246	102	562	391	285
Precipitation mm/a	1,027	989	1,059	1,005	1,025	1,057	953
Annual Evapotranspiration mm/a	349	371	357	363	352	363	372
Surplus Water mm/a	678	618	702	642	673	694	581
Annual Mean Flow mm/a	494	462	519	514	499	473	407
Annual Mean Flow m^3/s	8.0	8.9	4.0	1.7	8.9	5.9	3.7
Baseflow mm/a	166.8	189.4	172.9	256.6	139.1	164.6	193.7
Baseflow m^3/s	2.7	3.6	1.3	0.8	2.5	2	1.7
Groundwater Supply (Recharge) mm/a	202	207	206	258	169	180	199
Groundwater Supply (Recharge) m^3/s	3.3	4.0	1.6	0.8	3.0	2.2	1.8
Surface Water Supply (Q_{50}) mm/a	388	369	412	434	406	353	345
Surface Water Supply (Q_{50}) m^3/s	6.3	7.1	3.2	1.4	7.2	4.4	3.1
Groundwater Reserve mm/a	17	19	17	26	14	16	19

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Subwatershed	Black River	Head River	Kashe/Gartersnake River	Lake Couchiching/St. Johns	Severn River	Upper Black River	Upper Talbot River
Groundwater Reserve m^3/s	0.3	0.4	0.1	0.1	0.2	0.2	0.2
Surface Water Reserve mm/a	196	185	208	200	184	175	162
Surface Water Reserve m^3/s	3.2	3.6	1.6	0.6	3.3	2.2	1.5
Groundwater Consumption m^3/a	382,000	1,465,000	173,000	2,267,130	450,455	159,000	616,390
Groundwater Consumption mm/a	0.8	2.4	0.7	22.2	0.8	0.4	2.2
Groundwater Stress %	0.4%	1.3%	0.4%	9.5%	0.5%	0.2%	1.2%

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Sensitivity Analysis- Lake Couchiching/Lake St.John subwatershed

A sensitivity analysis is required by Technical Rule 33~~2~~(2)(d) (MOE, 2008a) for any subwatersheds assigned a percent water demand bordering the threshold level (i.e., 8 to 10%), and contain a municipal drinking water system. From the future stress levels summarized in (Table 3.2-23), the Lake Couchiching/Lake St. John subwatershed is the only subwatershed within the 8 to 10% threshold. Since this subwatershed contains a municipal system an uncertainty analysis was required.

A means of assessing sensitivity is to increase the conservatism by which these stress levels were calculated. This was accomplished by increasing the percent water demand on all sources of groundwater takings. For the Lake Couchiching/Lake St. John subwatershed, the consumptive factors were increased to 100% for both agricultural and permitted demand, thereby increasing the groundwater demand from 62,000 to 138,000 m^3/a. Since the maximum permitted rates were used in place of actual rates for permitted demand, the increase in the consumptive factor only adds conservatism to these already conservative demand estimates. It is realized that these extra-conservative values are unrealistic and most likely exceed the true uncertainty of the actual demand presented in this report; however, this exaggerated demand can be used to test the likelihood that the subwatershed will exceed the moderately-stressed threshold (Earthfx, 2010).

By increasing the agricultural and permitted groundwater consumptive factors to 100%, the future stress level for the Lake Couchiching/ Lake St. John subwatershed increased from 9.5 to 9.9%. Considering the conservatism implied by this scenario, and the fact that this subwatershed still remains less than moderately stressed, the Lake Couchiching/ Lake St. John subwatershed should not proceed to a Tier 2 analysis (Earthfx, 2010).

Tier One Stress Assessment Summary

Table 3.2-24 summarizes the results of the Tier One Stress Assessment. No subwatersheds exceed to the moderate or significant potential stress with regards to groundwater on an annual basis. The Lake Couchiching/Lake St.John subwatershed was found to bordering the threshold for a moderate potential stress level under the future use scenario at 9.5%. The sensitivity analysis did increase the stress level from 9.5 to 9.9%. No subwatersheds were found to be stressed on a monthly basis with respect to groundwater.

The Lake Couchiching/Lake St. John subwatershed was found to be significantly stressed in the month of June, and the Upper Talbot River was found to be moderately stressed in the month of August, with respect to surface water. It should be noted that although five municipal surface water systems exist within the Black-Severn River watershed all were exempt from being considered within the stress assessments per MOE Technical Rule 4 (MOE, 2008a).

Table 3.2-24: Stress Assessment Summary (Earthfx, 2010).

GW/SW	Subwatershed	Black River	Head River	Kashe/ Gartersnake River	Lake Couchiching/ St. John	Severn River	Upper Black River	Upper Talbot River
Groundwater	**Current Annual Conditions**	0.3%	1.2%	0.3%	0.6%	0.4%	0.2%	1.1%
Groundwater	**Future Annual Conditions**	0.4%	1.3%	0.4%	9.5%	0.5%	0.2%	1.2%
Groundwater	**Current Monthly Conditions**	none	none	none	none	none	none	none
Groundwater	**Future Monthly Conditions**	none	none	none	none	none	none	none
Surface Water	**Current Monthly Conditions**	none	none	none	none	none	none	August
Surface Water	**Future Monthly Conditions**	none	none	none	none	none	none	none
Groundwater	**Municipal System**	No	No	No	Yes	Yes	No	Yes
Surface Water	**Municipal System**	No	No	No	Yes	Yes	No	No
Groundwater	**Tier 2 Recommended**	No	No	No	No	No	No	No
Surface Water	**Tier 2 Recommended**	No	No	No	No	No	No	No

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3.2.5 Uncertainty

The Tier One Water Budget and Water Quantity Stress Assessment is 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.

In applying these methods, attempts have been made to be both consistent and conservative, in order to produce a stress assessment as accurately as possible. In accordance with that, the limitations and assumptions of each data source should be recognized. The assumptions made that reduce the certainty of the estimations include; spatial distribution, use of un-gauged streamflow, water supply estimates, monthly demand adjustments, and consumptive demand factors. The methods used within this study were derived from published literature and considerably refined in some cases. The data produced was also evaluated against previous studies to check the validity of results. The following discusses the uncertainty and rationale for each method used.

Spatial Distribution

Using few gauges over a large land area generalizes the results possibly making them biased. Considering the possible bias, it should be noted that the distribution of precipitation and AET only varies 50 and 30mm/a, respectively, across the study area, which suggests that the climate stations using in PRMS have little spatial variation (Earthfx, 2010).

Ungauged Streamflow

The use of a surface water model such as PRMS is considered the best available in situations where no gauged data or surface water model is available.

Water Supply Estimates

Attempts to verify water use within subwatershed have made the PTTW database more accurate; however, it is known that the maximum permitted taking values, where used, are higher than the actual taking. Non-permitted agricultural demand has been calculated based on coefficients and Statistics Canada census data. As it is a generalized calculation, uncertainty is inherent. Domestic use has been determined based on an average per-capita usage and population data. Variation between households and changes in population introduce uncertainty to this method (Earthfx, 2010).

Monthly Demand Adjustments

Monthly demand adjustments are based on industry averages and could change significantly from year to year based on changes in industry practices and climate conditions (Earthfx, 2010).

Consumptive Demand Factors

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

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 assumptions made in this study will introduce some uncertainty, which would be reduced in a more complex assessment. Some of these refinements could include a more complete understanding of agricultural use based on actual farming practices, involved seasonal water taking estimates for certain land uses, and a detailed collection of actual private domestic wells.

For the purposes of this assessment, quantification of groundwater movement into and out of subwatersheds has been excluded, as has the movement between aquifer units within a subwatershed which is important when considering pumping from deep confined aquifers. To quantify stresses upon confined groundwater supplies, a detailed understanding of groundwater transport and groundwater recharge is required.

3.2.7 Conclusions and Recommendations

The objective of the Tier One was to identify, through a recommended screening process, subwatersheds which require further detailed quantitative analysis of the effects of groundwater consumption. The conservative methods used and data obtained as described in the report are adequate to identify stressed and unstressed subwatersheds.

As a result, of the findings presented in previous sections and summarized in Table 3.2-24, it is recommended that none of the Black-Severn River subwatersheds proceed to a Tier Two analysis.

Figure 3.2-1: Calibration catchments for the reduced parameter PRMS model (Earthfx, 2010)

Figure 3.2-2: Environment Canada climate stations used by the PRMS model

Figure 3.2-3: Annual Precipitation trend for meteorological station 6115525: Muskoka A

Figure 3.2-4: PRMS-simulated annual average evapotranspiration

Figure 3.2-5: Beaver pond contributing areas within the Black-Severn river watershed

Figure 3.2-6: PRMS-predicted annual average recharge in the Black-Severn River basin

Figure 3.2-7: Location of groundwater taking permits within the Black-Severn River watershed

Figure 3.2-8: Location of surface water taking permits within the Black-Severn River watershed.

Figure 3.2-9: Subwatershed GW Stress Levels.

Figure 3.2-10: Subwatershed surface water stress levels.

3.3 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 and that appropriate methodologies are utilized, and 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 3.3-1: Water Budget Peer Reviewers for the Black-Severn River Watershed

Project	Peer Reviewer	Qualification
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., P.Geo. (hydrogeological expert) – CTC SWP Region – Technical Advisor and Senior Hydrogeologist; Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier 1 Water Budget and Stress Assessment Summary	York Region	Tom Bradley, Water Resources Technologist
Tier 1 Water Budget and Stress Assessment Summary	York Region	Tammy Silverstone. M. Eng., P. Eng. – Program Co-Ordinator Water Resources and Environmental Sciences