Approved

Chapter 3

WATER QUANTITY STRESS ASSESSMENT

APPROVED ASSESSMENT REPORT
for the
Saugeen Valley Source Protection Area

October 15, 2015

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3.0 Water Quantity Stress Assessment

3.1 Summary of Conceptual Water Budget Results

The goal of any water budget is to characterize, as accurately as possible, the fluxes of water through the hydrologic system one is attempting to define. In order to do this, a basic understanding of the processes and components within the area and the flow between specific components of that cycle must be understood. This process of developing a basic understanding of the processes and components of the hydrologic cycle and developing a methodology for quantifying and correcting these fluxes is referred to as a conceptual water budget. Such a conceptual water budget was completed for the Saugeen, Grey Sauble, Northern Bruce Peninsula Source Protection Region (2007a) and the summary of the pertinent aspects of that report are presented below for the Saugeen Valley Source Protection Area (SPA).

3.2 Description of Region

The Watershed Characterization Report (SGSNBP SPR, 2008) provides an overview of how physiography, topography and soils generally influence the surface hydrology of the planning region and the SPA. The overview material presented is organized by major watershed/drainage system present in the study area, specifically:

- Saugeen River
- Pine River
- Penetangore River
- Lake Huron shoreline Streams and Gullies

The conceptual water budget document provides a more detailed description of the character of each of these main surface systems by presenting the historical observations and summarizing the findings and outcomes from earlier hydrologic modelling exercises that focused on these surface water systems.

3.2.1 Climate of the Saugeen Valley Source Protection Area

The climate of a region is a significant factor affecting its overall water budget. Precipitation, either in the form of rain or snow, provides the major input to a region's water cycle. Air temperatures influence the form of precipitation, runoff patterns, evapotranspiration rates, and soil and ground cover conditions, all affecting water balance. Wind patterns at a macro level affect air moisture and precipitation patterns, particularly as they are influenced by Lake Huron to the west of the study area. At the local level, winds affect evapotranspiration in the growing season and the drifting and accumulation of snow across the landscape.

Map 3.2 shows the location of the main active or recently active gauges located within or in close proximity to the Saugeen Valley Source Protection Area, including those that have been developed through the years by the local conservation authorities, primarily for flood forecasting purposes. Tables 3.2.1 and 3.2.2 list the gauge stations in or near the Saugeen Valley SPA, along with the period of record for the stations.

TABLE 3.2.1 – Climate and Streamflow Monitoring Stations in the Saugeen Valley SPA Operated by Water Survey of Canada (WSC)

Station Name	*WSC_ID*	*Drainage Area*	*Data Collected*	*Years of Flow Data*	*Status*
Saugeen River above Durham	02FC016	329	Flow, Levels, Precipitation, Temperature	1976-1998	Active
North Penetangore River at Kincardine	02FD003	154	Flow, Levels, Precipitation, Temperature	2002-2003	Active
Beatty Saugeen River near Holstein	02FC017	130	Flow	1985-1994	Active
Pine River at Lurgan Beach	02FD001	163	Flow, Levels, Precipitation, Temperature	1974-2003	Active
Teeswater River near Paisley	02FC015	663	Flow, Levels	1972-2003	Active
Carrick Creek near Carlsruhe	02FC011	163	Flow, Levels, Precipitation	1953-2003	Active
Saugeen River near Walkerton	02FC002	2150	Flow, Levels	1914-2003	Active
Saugeen River near Port Elgin	02FC001	3960	Flow, Levels	1914-2003	Active
South Saugeen River near Neustadt	02FC012	635	Levels		Active
Rocky Saugeen River near Traverston	02FC004	249	Flow	1915-1940	Inactive
Rocky Saugeen River near Markdale	02FC005	109	Flow	1920-1924	Inactive
Armstrong Creek at Markdale	02FC009	9.32	Flow	1920-1920	Inactive
North Saugeen River near Paisley	02FC013	262	Flow	1972-1986	Inactive
Saugeen River near Durham	02FC014	381	Flow	1972-1977	Inactive
Hamilton Creek near Holland Centre	02FC019	59.8	Flow	1993-1994	Inactive
Teeswater River at Teeswater	02FC020		Flow, Levels		New

TABLE 3.2.2 – Active Gauge Stations Operated by the Saugeen Valley Conservation Authority

Station Name	*SVCA_ID*	*Drainage Area*	*Data Collected*	*Years of Flow Data*
Teeswater River at Bruce Rd. 20	SVCA_10	499	Levels, Precipitation, Temperature	1986-2005
Rocky Saugeen at Aberdeen	SVCA_11	273	Levels	1988-2004
North Saugeen River above Chesley	SVCA_12	216	Flow, Precipitation, Temperature	1989-2005
South Saugeen River at Cedarville	SVCA_13	195	Levels, Precipitation, Temperature	1995-2005
Pine River above Ripley	SVCA_17	60	Levels, Precipitation	1993-2005
Saugeen River above Priceville	SVCA_18	216	Levels, Precipitation, Temperature	1993-2005
Saugeen River near Hanover	SVCA_2	904	Flow, Levels	1984-2005
Camp Creek at Allan Park	SVCA_20	112	Levels	
South Saugeen River below Mount Forest	SVCA_6	419	Levels, Precipitation	1985-2005
Beatty Saugeen River near Hanover	SVCA_2	249	Levels	1984-2005
Saugeen River above Paisley	SVCA_9	2480	Levels, Precipitation, Temperature, Radiation, Wind Speed	1984-2005

3.2.1.1 Precipitation

Precipitation data was acquired from the Environment Canada National Climate Archive (http://climate.weatheroffice.ec.gc.ca/). A total of 27 stations were used to characterize average precipitation inputs across the planning region. At each station, 30-year average annual precipitation values were calculated from 1971 to 2000 (inclusive) to create a weighted average of precipitation inputs into each subwatershed. The locations of climate stations used for the data analysis are shown in Map 3.2.

Missing precipitation data were interpolated in order to create a continuous time series using the Inverse Weighted Distance (IWD) method. With IWD, data points are weighted during interpolation so that the influence of one data point, relative to another, declines with distances from the interpolation points. Data from each active gauge (see Tables 3.2.1 and 3.2.2) were compiled and screened for gaps in the record. These gaps were then filled according to the methodology described above in order to develop a continuous data set. Precipitation data was generated and summarized for each subwatershed on an annual basis. These data are presented in Table 3.10.1 for the period of 1971-2000 (inclusive).

Precipitation amounts vary from approximately 746-1,138 mm per year, and are highest in the areas that are in the lee of Lake Huron, largely as a result of lake-effect precipitation during the winter months. The seasonal distribution of rainfall for four stations is shown in Figure 3.2.1 below.

As mentioned, the sites were chosen primarily on the completeness of the data record.

Kincardine is considered representative of the southwestern portion of the SPR, and Hanover is considered representative of the eastern portion. Based on the available data, there is a large amount of precipitation that falls over the region from November through January. Snowfall may represent as much as 40-50% of the annual precipitation, highlighting the importance of the spring freshet to runoff conditions in the region.

In addition, total precipitation is higher in the winter months (i.e. November-March), although this trend is more pronounced in the northern portion of the region. Monthly precipitation amounts typically decrease from January to April and gradually increase from May to December. These trends are typical at the four stations. The highest mean annual precipitation amounts were found at the Wiarton station (1,169 mm), followed by Chatsworth (1,054 mm), Hanover (1,044 mm) and Kincardine (941 mm) climate stations.

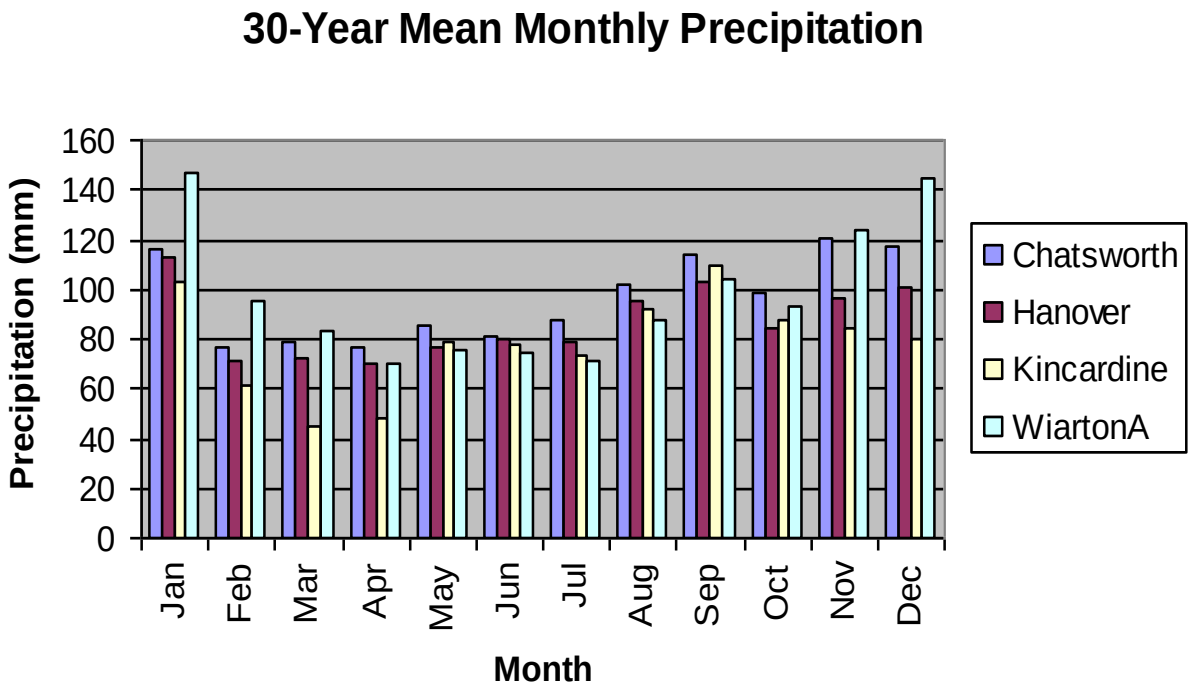

FIGURE 3.2.1 – Seasonal distribution of monthly precipitation for selected sites in the Saugeen, Grey Sauble, Northern Bruce Peninsula Source Protection Region

3.2.1.2 Air Temperature

In total, data from 27 climate stations, operated by conservation authorities and Environment Canada, were analyzed for the area (Map 3.2). Data from all of the stations are uploaded to Environment Canada and are stored in a centralized database in a common data format, facilitating analysis of these data.

Ecodistricts, reflecting the overall suitability of land of specific agricultural activities, were developed based on temperature and soils data for the study area by Agriculture and Agri-Food Canada. Temperature is a key measured variable used in the definition of ecodistricts and relies on minimum 30-year climatic normals derived for each area (Agriculture and Agri-Food Canada, 1997). Therefore, variations in ecodistricts are largely reflective of the differences in temperature within the study area and are the most reliable means for graphically representing this variation, due to the widely spaced nature of temperature data available from other sources.

Ecodistrict data suggests that temperatures in the Owen Sound area, as well as in the southwestern portion of the SPR along the shore of Lake Huron, are relatively warmer than the remaining areas, largely as a result of their physical setting in a confined valley and/or proximal to large water bodies, respectively. The coldest zones seem to be located along the western slope of the Niagara Escarpment and the northern portion of the Bruce Peninsula.

3.2.1.3 Evaporation and Transpiration

Evaporation and transpiration (collectively referred to as ET) can only be derived for the study area, as they are not directly measured. In the development of ecodistricts for the study area, Agriculture and Agri-Food Canada derived ET values based on 30-year climate normals available for the area. The ecodistrict ET data was then intersected with the subwatershed boundaries to produce average ET values. It is understood that these values represent modelled and/or calculated values based on 30-year climate normals and significant variation may occur on an annual basis. Estimated ET values for the study area are shown in Table 3.10.1.

ET is inherently tied to variables such as heat, sunlight, length of growing season, and average wind. As a result, southern areas, which are warmer and have longer growing seasons, and those areas along the Lake Huron shoreline known to have high consistent winds, exhibit higher ET values. Low ET values in the eastern portion of the study area are likely a reflection of the elevation of the area and the resultant shorter growing season.

3.2.2 Land Use and Land Cover

The primary sources of land use data for the SPA are the Canada Land Inventory (1966-1988) and municipal official plans and zoning by-laws. For the purpose of water budgeting, the Canada Land Use Inventory is the most useful data source, as it provides uniform data across the entire region and is readily available in a geo-referenced format. Map 3.1 shows land cover separated into three broad categories: agriculture; woodland; and built-up/transportation/extraction.

Official plan information is available for the area and categorizes lands according to their present or anticipated land uses. These data commonly separate information into broad categories of agricultural, natural environment, and urban/developed lands and are defined for municipal

purposes. Map 2.13 shows the land uses as derived from the official plans for Bruce County and Grey County. Although official plans may be useful for predicting the areas that will undergo substantial land use changes in the immediate future (i.e. the next 5 years), they do not provide enough accurate information on whether to develop a water budget model, as they often include existing and planned land use. They also do not discern between forms of agriculture, a critical exercise in estimating the proportions of runoff from different contributing areas to surface water bodies.

Historical Trends in Land Use

The Saugeen Valley Source Protection Area is not considered to have undergone, nor is expected to undergo, significant changes in land use. The development pressure of the area is primarily focused on the waterfront areas, especially along the shores of Lake Huron, where adult lifestyle-type housing is growing in popularity. The existing urban areas, with the exception of Saugeen Shores and Kincardine, in the very west of the region, are not anticipating significant growth. The growth that is anticipated will not likely exceed over 2% of the existing land area, will likely still remain restricted to the waterfront areas, and is not considered significant.

3.2.3 Soils

Soils mapping is available for the entire Saugeen Valley SPA based on county-scale soils surveys completed in the 1950-1955 period, with some minor updates completed in the 1980's. These surveys have been digitized and attributed and are available in a GIS format from the Ministry of Natural Resources and Forestry (2002).

A compilation of the soils textures from county soil reports within the study is shown in Map 2.8. One of the main objectives of the water budget exercise is to account for the amount of infiltration at the surface interface to the ground. In order to develop an estimation of infiltration, accurate and detailed descriptions of the soil series are required.

3.3 Runoff and Streamflow

This section provides a characterization of the surface water resources of the source protection area, including the contributing watersheds for the following four (4) rivers:

- Penetangore River
- Pine River
- Saugeen River
- Teeswater River

The surface water characterization is based on the surface water drainage areas contributing to streamflow gauges located in the above rivers as shown on Map 3.2. These assessment areas have been altered from those originally defined for water budgeting analysis in order to accommodate the best quality data available to perform these analyses. Due to its size, the Saugeen River has been further delineated into the Lower Saugeen, Upper Saugeen and South Saugeen areas.

This section provides a summary of the data sources used to carry out the surface water characterization. The characterization is based on a discussion of the land cover, physiography, and hydrology of the Saugeen Valley SPA. Where possible, hydrological response is discussed with relevance to the land cover and physiography of the drainage area.

Streamflow monitoring is carried out within the SVCA by a collection of gauges operated under a federal/provincial cost share agreement, and gauges owned and operated by SVCA. Water Survey of Canada (WSC) maintains gauges under the federal/provincial cost share agreement under the HYDAT program (Hydroclimatological Data Retrieval Program). As listed in Table 3.1 and 3.2, there are a total of 27 existing and historic streamflow gauging stations in the region (16 HYDAT and 11 SVCA operated gauges).

HYDAT Gauges

WSC currently maintains 9 active stations, and recently installed an additional gauge in 2005. Historical data for 6 inactive WSC gauges is also available. Gauged data collected by WSC undergoes an extensive quality assurance/quality control process to correct observed problems with the data including:

- Backwater effects due to ice and aquatic plant effect, which artificially raises the water level resulting in falsely high calculated streamflow; and
- Equipment malfunctions, sensor drift or estimates data lost due to equipment failure.

A rating curve is prepared by gauge operators to relate measured streamflow to water depth. This curve is generated by physically measuring river discharge and relating it to a river stage. Multiple measurements of flow and stage are combined to develop a rating curve for a particular station. Errors in streamflow records can arise when considering infrequent flows, such as extreme low flows or high flows that are on the high and low ends of the rating curve. This is particularly an issue with extreme low flows, as changes in channel morphology can significantly impact the stage/discharge relationship. The effects of ice and vegetation on streamflow measurements are similar. This limitation needs to be kept in mind when analyzing low flows.

SVCA Gauges

SVCA operates 11 gauge stations independent of the federal/provincial cost share agreement (Table 3.2.2). Data from these stations are considered provisional, with little or no quality assurance/control processes carried out. The gauges are maintained primarily for higher flow and flood monitoring, and are not corrected for backwater due to ice or aquatic plant growth. As a result, low streamflow estimates in the winter and summer are likely to be overestimated at these gauges.

Mapping

Several sources of GIS mapping were used when completing the surface water characterization as summarized below:

- Digital Elevation Model (DEM) and enhanced flow direction grid provided by the Ministry of Natural Resources and Forestry (MNRF); (see Map 2.4)
- Drainage catchment boundaries delineation. Drainage catchment boundaries were based on the DEM and flow direction grid (See Map 2.3);
- Evaluated Wetlands, Natural Resources Values Information System (NRVIS), MNRF (See Map 2.9);
- Hummocky Topography dataset from the Ministry of Northern Development, Mines and Forestry (MNDMF). A supplementary dataset included with the Quaternary Geology of Ontario Seamless Coverage;
- Land use layer from the Canada Land Inventory (CLI) - Natural Resources Canada (NRCan). Based on land use classifications from 1966-1988 (See Map 2.13); and
- Quaternary Geology, dataset produced by the Ontario Geological Survey, MNDMF (See Map 2.6)

3.3.1 Streamflow Analysis

To describe the hydrologic response of the catchment areas within this SPA, daily average flow data from 17 stations, for both WSC and SVCA gauges, was imported into a relational database (Microsoft Access) and analyzed to produce reports summarizing the data for each gauge. The stations selected for the analysis must be currently active with a relatively long period of record. In addition, stations that exhibited questionable results were not considered. The Penetangore River was omitted for this analysis, as the period of record is insufficient for any meaningful analysis.

Table 3.3.1 lists gauges that were used in this analysis, as well as some of the hydrologically important physical characteristics of each of the gauged catchments. These physical characteristics were calculated for the contributing drainage area of each gauge using GIS analysis of the datasets presented in the previous section. The physical characteristics are summarized as follows:

- Quaternary Geology: Quaternary geology was simplified to seven groupings as shown, including six primary groupings and one left blank for areas without quaternary geology mapping coverage. Quaternary geology classifications were selected instead of soil classifications, primarily due to the simplified mapping. As soil types are typically a reflection of quaternary geology, the groupings shown are expected to be reflective of their influence on hydrological response. Wetlands are included within these groupings.
- Percentage of hummocky topography and karst deposits are also included; and
- Percentage of forest cover.

TABLE 3.3.1 – Gauged Catchment Characteristics

Station Name	Station	Drainage Area (ha)	Physiography		Soil / Surficial Classification							Forest
			Hummocky	Karst	Unclassified	Impervious / Bedrock	Clay / Clayey Tills	Silty Tills	Sandy Tills	Sand / Gravel	Wetland Deposits	
Saugeen River above Paisley	SVCA_9	251,264	13%	0%	0%	0%	10%	47%	1%	35%	7%	30%
Saugeen River near Port Elgin	02FC001	373,148	9%	0%	0%	0%	14%	47%	1%	32%	6%	30%
North Saugeen River above Chesley	SVCA_12	21,823	0%	1%	0%	0%	2%	43%	0%	37%	17%	44%
Beatty Saugeen River near Holstein	02FC017	5,190	47%	0%	0%	0%	7%	52%	4%	31%	5%	20%
Beatty Saugeen River near Hanover	SVCA_8	26,702	24%	0%	0%	0%	7%	51%	1%	34%	6%	28%
Saugeen River near Hanover	SVCA_2	26,702	13%	1%	0%	1%	4%	52%	1%	32%	10%	35%
Saugeen River above Priceville	SVCA_18	21,803	5%	0%	0%	1%	8%	62%	1%	11%	17%	41%
Rocky Saugeen at Aberdeen	SVCA_11	27,011	10%	2%	0%	2%	3%	53%	1%	31%	10%	36%
Saugeen River above Durham	02FC016	31,071	16%	0%	0%	1%	8%	60%	1%	16%	14%	36%
Saugeen River near Walkerton	02FC002	213,469	12%	0%	0%	0%	9%	49%	1%	34%	7%	30%
Carrick Creek near Carlsruhe	02FC011	15,631	23%	0%	0%	1%	10%	54%	2%	28%	4%	22%
South Saugeen River below Mount Forest	SVCA_6	42,021	1%	0%	0%	0%	0%	64%	0%	28%	7%	31%
South Saugeen River at Cedarville	SVCA_13	21,354	0%	0%	0%	0%	0%	71%	0%	18%	11%	34%
South Saugeen River near Neustadt	02FC012	61,796	7%	0%	0%	0%	3%	59%	0%	31%	6%	29%
Teeswater River at Bruce Rd. 20	SVCA_10	50,113	16%	0%	0%	2%	9%	43%	2%	39%	5%	28%
Teeswater River near Paisley	02FC015	66,940	13%	0%	0%	2%	16%	37%	1%	38%	6%	28%
Pine River at Lurgan Beach	02FD001	15,570	0%	0%	0%	0%	7%	87%	0%	6%	0%	16%

3.3.1.1 Streamflow

All available flow data from WSC and SVCA stream gauges was organized within a relational database for ease of analysis. The selected time period for analyzing the data was from 1980-2003. Where the full time period was not available for a gauge, any available data in the 1980-2003 period was used. In order to describe the hydrology of the catchments, the following parametrics were calculated:

- Mean Monthly Streamflow: Mean monthly streamflow volumes were calculated to represent the average volume of water seen at each gauge, and illustrate how that changes seasonally.

- Ranked Duration: Similar to calculating percentiles, ranked duration plots were also constructed for the 17 gauging stations. This allows one to determine if the percent of time flows are above a certain threshold.

- Median Monthly, 10th and 90th Percentile Monthly Streamflow: As streamflow data do not obey normal (Gaussian) distributions, mean flow values were not considered appropriate for this analysis. Median monthly flows, defined by the flow observed 50% of the time, is a better indicator of typical conditions. Additionally, the 10th percentile flow is an indicator of typical high flows and represents streamflow that is exceeded only 10% of the time, while the 90th percentile streamflow is an indicator of typical low flows and represents low flows that are exceeded 90% of the time. The median, 10th and 90th percentile flows are referred to as parametric statistics and are calculated monthly.

- Flashiness. The amount of flashiness, or how quickly a catchment responds to a precipitation event, and returns to pre-event flow conditions, can be quantified by calculating the 10:90 ratio. The 10:90 ratio refers to the ratio of the flow rate equalled or exceeded 10% of the time to the flow rate equalled or exceeded 90% of the time. A high 10:90 ratio would indicate a watershed with highly variable flow, usually characterized by a well-defined drainage network, and low permeability surficial materials, with little to no sustained flow during non-runoff periods. A low 10:90 ratio would be indicative of a steady, well-buffered catchment, with poorly defined drainage networks, large storage elements, such as wetlands or lakes, permeable surficial materials, and sustained dry weather flows. This ratio was calculated for all gauged catchments.

Tabulated results of the analysis are presented for all 17 streamflow gauges in Table 3.3.2; discussion of the streamflow characteristics is limited to the 10 largest catchment areas identified in Table 3.3.2.

Table 3.3.2 includes the mean annual streamflow and baseflow, both in m^3/s as well as mm over the upstream area. Calculated runoff and base flows expressed as equivalent precipitation in millimetres are shown for the study area in Table 3.3.2, Baseflow Index (BFI) for each gauge station has been calculated and is included as well. BFI is the ratio of baseflow to total streamflow, and is used to characterize the proportion of total streamflow that is baseflow. Annual median, 10th percentile and 90th percentile flows are included, as is the 10:90 ratio.

TABLE 3.3.2 – Flow Characteristics for Gauged Catchments

Station Name	*Station Number*	*Mean Annual Streamflow (m^3/s)*	*Streamflow Depth (mm)*	*Mean Annual Baseflow (m^3/s)*	*Baseflow Depth (mm)*	*BFI**	*Annual Median Flow (m^3/s)*	*10% Flow Exceed-ance (m^3/s)*	*90% Flow Exceed-ance (m^3/s)*	*90:10 Ratio*
Saugeen River above Paisley	SVCA_9	49.9	627	27.5	345	0.55	34.8	98.2	11.3	9
Saugeen River near Port Elgin	02FC001	56.7	480	30.7	259	0.54	37.1	128.0	13.8	9
North Saugeen River above Chesley	SVCA_12	4.4	641	2.9	417	0.65	3.6	8.6	1.2	7
Beatty Saugeen River near Holstein	02FC017	0.6	371	0.3	171	0.46	0.4	1.4	0.1	15
Beatty Saugeen River Near Hanover	SVCA_8	5.8	691	3.3	394	0.57	4.00	12.0	1.1	10
Saugeen River near Hanover	SVCA_2	22.2	722	12.4	404	0.56	15.9	47.0	5.0	9
Saugeen River above Priceville	SVCA_18	3.8	555	1.2	167	0.3	1.4	9.6	0.2	60
Rocky Saugeen at Aberdeen	SVCA_11	5.1	593	3.4	397	0.67	4.1	9.0	1.9	5
Saugeen River above Durham	02FC016	4.7	481	2.0	207	0.43	2.5	10.6	0.7	15
Saugeen River near Walkerton	02FC002	30.5	451	16.5	244	0.54	21.2	65.0	8.3	8
Carrick Creek near Carlsruhe	02FC011	2.1	429	1.00	193	0.45	1.2	4.9	0.3	15
South Saugeen River below Mount Forest	SVCA_6	6.9	521	3.0	224	0.43	3.8	15.2	0.5	32
South Saugeen River at Cedarville	SVCA_13	4.3	632	1.1	164	0.26	1.7	10.5	0.2	53
South Saugeen River near Neustadt	02FC012	9.4	480	3.6	183	0.38	4.3	22.4	1.2	19
Teeswater River at Bruce Rd. 20	SVCA_10	9.8	616	5.3	332	0.54	7.0	23.5	1.3	18
Teeswater River near Paisley	02FC015	11.0	517	5.5	258	0.5	6.2	27.0	1.8	15
Pine River at Lurgan Beach	02FD001	2.3	463	0.5	107	0.23	0.7	5.3	0.03	177

** BFI (Baseflow Index)*

3.3.1.2 Baseflow

Baseflow typically refers to the component of streamflow that would be observed in the absence of direct runoff from a precipitation event. Although baseflow is generally thought of as a result of groundwater discharge to streams, it can also be supported by the release of water from natural and controlled reservoirs and lakes as well as wetlands.

A baseflow separation exercise was carried out on selected stream gauges to isolate the streamflow hydrograph into runoff and baseflow components. Although there are a wide variety of baseflow separation techniques, the baseflow separation routine used in this analysis is the Baseflow Separation Program. This program simulates a daily record of estimated baseflow, coinciding with streamflow records. It also calculates a Base Flow Index (BFI) that represents the fraction of mean annual flow that is a result of a baseflow contribution.

It is very important to note that baseflow should not be considered to be entirely due to groundwater discharge. Baseflow is a result of the slow release of water from storage contained within a contributing upstream drainage area. This water released from storage could originate in groundwater, and hence be termed groundwater discharge, but also could originate from wetlands or reservoirs. Other anthropogenic impacts such as sewage treatment plant discharges may constitute a portion of baseflow as well. Within the study area, significant wetland complexes (e.g. Greenock Swamp) are a major contributing factor to baseflows. However, for the purposes of this exercise, it was necessary to assume that most baseflow originates from groundwater discharge. Table 3.3.2 presents the Baseflow Index (BFI) at each of the selected gauges.

3.3.2 Topography and Watercourses

The primary source of data for the topography in the region is available as a digital elevation model, provided by the MNRF (2002). These data are based on existing Ontario base mapping completed during the 1980s. Map 2.4 shows the surface elevation (topography) of the Saugeen Valley SPA. Watercourses are available from existing Conservation Authority datasets, which are commonly attributed to include cold and warm water fisheries present in the watercourses. Map 2.11 includes the known cold and warm watercourses and existing stream network information.

3.3.3 Inland Lakes, Reservoirs and Wetlands

Inland lakes, reservoirs and waterways provide critical storage of water and are important for development of an overall water budget. These features are shown in Map 2.11 for the Saugeen Valley SPA. These features are important sources of baseflow for the region.

3.4 Groundwater Recharge Estimates

Recharge values were initially estimated using a physical based approach that considers the geology, topography, land use, and land cover of the SPA. Recharge values were further refined during the Tier I water budget and in the delineation of significant groundwater recharge areas (SGRAs), details of which are shown in section 3.14.

3.5 Surface Water Characterization

3.5.1 Saugeen River

The Saugeen River watershed represents a total drainage area of approximately 3,900 km^2 which discharges into Lake Huron in the Town of Saugeen Shores. The watershed is comprised of a number of large tributaries that are grouped into a number of different areas for this assessment as shown on Map 3.6. These areas include:

- Lower Saugeen: includes the North Saugeen River, and the Saugeen River downstream of Walkerton.
- Upper Saugeen: includes the Saugeen River upstream of Walkerton in addition to the Beatty Saugeen and Rocky Saugeen subwatersheds.
- South Saugeen: includes the Carrick Creek subwatershed along the boundary of the Grand River Watershed.
- Teeswater: The Teeswater River is a large tributary that joins the Saugeen River in Paisley.

There are a relatively large number of dams located throughout the Saugeen watershed (see Map 2.3) that may have an impact on hydrological response. There are currently 52 dams in the watershed that are greater than 3 metres in height. The majority of these structures are former mill dams that supplied power to mill operations.

Today, eight of these dams produce hydroelectric power while others provide recreational and transportation benefits. None of the 52 dams were designed to prevent or control flooding; however, a small number of dams in the watershed do provide minimal assistance in preventing floods by breaking up ice or by controlling ice movement and thereby prevent the formation of ice jams (Smith, 2002). Since these dams are not actively controlled, it can be assumed that baseflow along major tributaries can be generally attributed to natural conditions, but that some buffering effects from the dams are expected. Baseflow calculations in smaller tributaries containing higher proportions of wetlands and larger dams and inline ponds may be affected to a greater extent by those features.

In addition to HYDAT gauges, SVCA maintains a separate set of 11 stream gauges at various locations throughout the watershed. Although these gauges may provide suitable records for flood events, they have not been corrected for damming due to ice conditions, and therefore the gauges are not used to support this generic hydrologic characterization.

The hydrological characterization for each of the above four areas is summarized in the following sections.

3.5.1.1 Lower Saugeen

The Lower Saugeen includes a drainage area of approximately 930 km^2 downstream of the Saugeen River at Walkerton, and excludes the Teeswater River. Three gauges are included in this area, including the Saugeen River at Port Elgin (02FC001) and two SVCA gauges: North Saugeen River above Chesley (SVCA_12); and Saugeen River above Paisley (SVCA_9).
The surficial materials in the drainage area contributing to the Port Elgin gauge are primarily silty tills, and also include extensive deposits of sand/gravel, which account for approximately 30-35% of the area. Hummocky topography makes up approximately 10% of the drainage area, which may provide precipitation additional time to infiltrate. Note that these distributions of surficial materials are aggregated over the entire upstream catchment area.

There are no significantly large wetland complexes in the Lower Saugeen area that would have a significant effect on flows within the Saugeen River.

The Port Elgin gauge indicates approximately 480 mm/yr of streamflow from the upstream catchment. Baseflow is estimated to be 259 mm/yr resulting in a BFI of 0.54. Because of the very large drainage area associated with the lower reaches of the Saugeen River, the flow regime is very buffered and constant. Flashiness is low, as indicated by the low 10:90 ratio of 9. The two SVCA gauges in this area also exhibit a low 10:90 ratio, however it is unknown how impacted this metric is, due to inaccurate winter flows.

3.5.1.2 Upper Saugeen

The Upper Saugeen area includes the area upstream of the Walkerton gauge, with the exception of the South Saugeen and Carrick Creek tributaries. This area includes a number of smaller tributaries, such as the Rocky Saugeen and Beatty Saugeen Rivers. There are 8 gauges within this area, as follows:

- Beatty Saugeen River near Holstein (WSC)
- Beatty Saugeen River near Hanover (SVCA)
- Saugeen River near Hanover (SVCA)
- Saugeen River above Priceville (SVCA)
- Rocky Saugeen River at Aberdeen (SVCA)
- Saugeen River above Durham (WSC)
- Saugeen River near Walkerton (WSC)

Silty tills predominate the surficial geology, with some catchments having deposits of sand and gravel in excess of 30%. This area has approximately 30% or more forest cover. Hummocky topography has been extensively mapped over this area, with typical catchments having between 10% and 20% hummocky topography, and up to 47% for the Beatty Saugeen River near Holstein.

Although there are wetlands located throughout the Upper Saugeen area, some of the wetland complexes that may have the most hydrological effect include:

- the Welbeck Wetland and Dornoch Swamp in the headwaters of the Saugeen River;
- Topcliff, Yeovil and Dromore Swamp wetland complexes in the headwaters of the Beatty Saugeen River (note that this is also an area of significant hummocky topography); and
- Turner-Gillies-Wilcox Lake, Maxwell Swamp, Hatherton Wetland, and Proton Station wetland in the Saugeen River above Priceville headwaters catchment.

The HYDAT stations report average annual streamflow ranging from 370 to 480 mm/yr. The relatively low annual streamflow in the Beatty Saugeen River near Holstein (370 mm/yr) may be due to higher evapotranspiration rates associated with the swamp wetland complexes and hummocky topography in the area.

The BFI values for smaller catchments including the Beatty Saugeen River near Holstein and the Saugeen River above Durham are 0.46 and 0.43, respectively, indicating that baseflow is a smaller component of total flow in these headwaters catchments. This is expected, given that some of the groundwater recharged in the headwaters areas is expected to discharge in downstream reaches. The estimated baseflows at the Saugeen River near Walkerton is 244 mm/year, which results in a BFI of 0.54. This value is higher than those for the headwaters areas, and is equal to the BFI for the Saugeen River at Port Elgin. BFI for other catchments in the Upper Saugeen area cannot be reliably calculated due to the potential errors associated with the SVCA gauges.

The 10:90 ratio also shows a similar comparison between the hydrological responses in the headwaters versus the main river. The smaller drainage areas having WSC gauges each have 10:90 ratios of 15, signifying a moderate level of flashiness. Primarily because of the size of the Walkerton drainage area, this gauge exhibits a less variable flow rate with a 10:90 ratio of 8. Monthly hydrologic trends at all HYDAT gauges show expected results, with peaks during the snowmelt period and low flows in August and September.

3.5.1.3 South Saugeen

The South Saugeen drains an area of approximately 618 km^2, and abuts the Grand River watershed. The Carrick Creek catchment area is included within the South Saugeen catchment area due to geographic proximity. There are two HYDAT gauges located in the area including South Saugeen River near Neustadt (02FC012) and Carrick Creek near Carlsruhe (02FC011). There are two SVCA gauges located in this area including; South Saugeen River below Mount Forest (SVCA_6) and South Saugeen River at Cedarville (SVCA_13).

Much like other areas in the Saugeen River watershed, the surficial materials are mainly comprised of silty tills (60-70%) and deposits of sand and gravel (20-30%). Forest cover throughout the Saugeen watershed is relatively consistent at approximately 30%. Hummocky topography is not as common as in the Upper Saugeen area.

Wetland complexes with a larger hydrologic significance include:

- North Lakelet complex in the headwaters of Carrick Creek;
- Clifford-Harriston wetland complex in the headwaters of Carrick Creek and the adjoining South Saugeen River;
- South Saugeen River complex; and
- Gildale Wetland, Ventry Swamp and Keldon Swamp wetlands in the South Saugeen River headwaters.

The South Saugeen near Neustadt HYDAT gauge indicates that the mean annual streamflow for the Saugeen River is approximately 480 mm/yr. Baseflow is estimated to be 180 mm/yr, which results in a BFI equal to 0.38. Although the SVCA gauges are less reliable and would tend to over-estimate BFI, they are also indicative of low BFI values for the South Saugeen River. Given that the estimated groundwater recharge into the South Saugeen Catchment is approximately 280 mm/year, approximately 100 mm/year, or 36% of this recharge, is not being seen as baseflow to the river.

The 10:90 flow ratios calculated for Carrick Creek and South Saugeen Rivers are 15 and 19, respectively. The South Saugeen River is relatively flashy when compared to other rivers with similar catchment areas. The flashiness may be due, in part, to the relatively low baseflow.

It is noted that the catchments with SVCA gauges also exhibit high 10:90 ratios, which would support the South Saugeen being a runoff driven system. However, due to the ice effect on the flow data, this cannot be accurately confirmed.

As with the other SVCA stream gauges, both the Mount Forest and Cedarville gauges exhibit evidence of ice-influenced flows. For both gauges, monthly median and high decile winter flows are very similar to spring flows.

3.5.2 Teeswater River

The Teeswater River drains an area of 669 km^2 adjacent to the Maitland River watershed. The Teeswater River joins with the Saugeen River near Paisley. The catchment area is primarily comprised of silty tills with sand/gravel deposits; however, a higher proportion of clay/clayey tills also start to appear in this area. Hummocky topography makes up approximately 15% of the area and forest cover is just under 30%.

The Greenock Swamp is a very significant wetland complex covering a large portion of the catchment area. In addition, the Teeswater Complex is a significant wetland feature in the headwaters of the Teeswater River.

There are two gauges within this area; Teeswater River at Bruce Rd. 20 (SVCA_10); and Teeswater River near Paisley (02FC015). The Paisley gauge reports an estimate of 515 mm/yr of streamflow. Estimated baseflow is 260 mm/yr, which results in a BFI of 0.50 that is similar to the average for all analyzed stream gauges.

The 10:90 ratio of 15 indicates a moderate level of flashiness that is consistent with other similarly sized catchments in this area. Low flows appear to be relatively stable, with the low deciles for summer months being relatively stable. The Greenock Swamp wetland complex present in this basin may also be moderating the flow regime.

3.5.3 Pine River

The Pine River has a catchment area of 156 km^2 and drains directly into Lake Huron. This catchment is primarily comprised of silty tills, with some clay/clayey tills and little sand/gravel deposits. There is no mapped hummocky topography or karst, and forest cover is the lowest of all analyzed catchments at 18%. The gauge investigated for this area is the Pine River at Lurgan Beach (02FD001).

Mean annual streamflow is estimated to be 463 mm/yr. Baseflow is estimated to be 107 mm/yr, which results in very low BFI of 0.28. This low baseflow can likely be explained by the fact that a component of groundwater that recharges into the catchment area will discharge directly into Lake Huron, as opposed to the Pine River.

The 10:90 ratio is calculated to be 177, which is the highest of all analyzed catchments. This is an extremely flashy watercourse, which quickly responds to precipitation events and quickly returns to dry weather conditions. Low decile flows for summer months shows that flows can drop to as low as 0.001 m^3/s for the month of August.

3.6 Groundwater System

3.6.1 Geology

3.6.1.1 Precambrian Basement Rocks

Underlying all of the study area and a large majority of the North American continent are the metamorphic rocks associated with the large physiographic feature called the Canadian Shield. These rocks are not exposed in the study area and what is known of them is only from oil and gas exploration wells, which were terminated in the Precambrian rocks. From this drilling data, the rocks that underlie the study area have been correlated with rocks of the Grenville Province, understood to be between 1.7 and 2.5 billion years ago. East and north of the study area, these rocks are exposed to the surface. In these areas, metamorphosed plutonic rocks with thin bands of meta-volcanic and meta-sedimentary sequences dominate the rocks. These rocks form the foundation upon which the later carbonate rocks were deposited.

Although the Precambrian geology of the area is not considered to have a significant influence on the hydrogeology of the area, it has played a significant role as a regional control on the deposition of later rocks. Two major features that have acted as regional-scale controls on the deposition and are attributed to these rocks are the development of the Michigan Basin and the Algonquin Arch.

The Michigan Basin is composed of younger carbonate rocks but is centered along a failed rift zone (the North American rift) that unsuccessfully began to open approximately 1.1 billion years ago. The basin that formed as a result provided the initial depression into which the younger

carbonate rocks were deposited, beginning approximately 545 million years ago. The basin is centered in the middle of the main peninsula (the "thumb") of Michigan and is the regional structure with which the carbonate rocks of the study area are associated.

The second major Precambrian feature that has controlled the deposition of the younger carbonate rocks in our area is the Algonquin Arch. The Algonquin Arch is a linear uplift of the Precambrian rocks that extends roughly from the Algonquin Park in central Ontario southwest through to the Windsor area. The Algonquin Arch is poorly understood, but may have formed during an early phase of orogeny in the Appalachians. The arch likely acted as a barrier between waters circulating between the Michigan Basin and those associated with the fore-arch basinal waters of the Appalachians. As such it has had a profound effect on the depositional facies of similar aged rocks on either of its flanks. It is of particular note to our study area that the Algonquin Arch, during deposition of the Lucas formation, likely restricted flow in the western portion of the Michigan Basin leading to development of Sabkha sequences in these rocks with which modern-day karst features have developed. In fact, the Algonquin Arch has had such a significant influence on the topography of the area through time that, even today, the boundaries between the Lake Huron and Lake Erie and Ontario basins still can be roughly traced along the crest of the arch.

Some smaller Precambrian features may have also had an effect on present-day topography, as it has been noted that major bedrock valleys in the younger carbonate rocks (i.e., the "Dundas Bedrock valley") and even modern river valleys have similar orientations as some of the larger Precambrian faults (see Johnson et al., 1992 and references therein).

3.6.1.2 Paleozoic Carbonate Rocks

After a non-conformity spanning approximately 600 million years, deposition of the sedimentary rocks of the Michigan Basin commenced. The Michigan Basin was the dominant regional structure controlling deposition of rocks in central North America during this time. The Michigan Basin is a roughly circular depression centered within the present day State of Michigan and on the failed North American paleo-rift. The entire sequence of rocks within the Michigan Basin was deposited in warm seas analogous to modern-day deposition in tropical regions. Periodic climatic and sea level changes led to the slight differences in the lithologies that were deposited. As an example of this, during periods of relatively high sea level, deeper water sediments, such as shales and mudstones were deposited, while during lower stands, shallow water limestone, Sabkha and reefal facies dominated. Indeed, there are several points during the deposition of these rocks that evidence exists suggesting that they were aerially exposed and eroded (Liberty and Bolton, 1971; Johnson et al., 1992). In addition, differences in water chemistry led to slightly different chemical compositions of the rocks themselves.

The rocks of this area dip slightly towards the interior of the Michigan Basin (southwest of the study area) and as such, the oldest rocks are exposed in the far northeastern portion of the study area. Map 2.5 shows the major bedrock units in the study area. For the purposes of this document, only bedrock units that subcrop or outcrop in the study area will be discussed, from oldest to youngest beginning with the Amabel formation. These formations are used as domestic and municipal sources of drinking water throughout the study area, which will be dealt with in section 3.7.1 of this report.

3.6.1.3 Amabel Formation

The thick sequence of dolomitic rocks that overlie the Cabot Head formation have been historically considered very difficult to subdivide, but have recently been identified as being a separate formation, named the Amabel. In the planning area, particularly along a narrow band just south and west of the Niagara Escarpment, these rocks have been targeted for extraction as building stone. The generally accepted terminology for these rocks within the study area is to split them into the Amabel and overlying Guelph formations.

The Amabel is the primary target for extraction of building stone and is also a host to good quality and quantity aquifers. It is composed of thinly to massively bedded, grey to bluish-grey dolostones.

3.6.1.4 Guelph Formation

Overlying the Amabel formation is the Guelph formation. The Guelph formation is well known from areas outside of the planning region, yet subcrops along a wide band through the region. Outcrops of the Guelph formation can be found along the valley walls of the Rocky Saugeen River, and in an almost continuous band along the Lake Huron shore from Tobermory to Oliphant.

The Guelph formation is composed of buff-brown, crystalline dolostones that represent a true reefal sequence, with large biohermal “pinnacle” reefs surrounded by more massive, fine-grained and crystalline inter-reefal facies.

The Guelph formation is a host to good quality and quantity aquifers.

3.6.1.5 Salina Formation

The Salina formation subcrops through a northwest oriented band of the central portion of the study area and underlies at depth a large section of the study area to the west of a line from approximately Walkerton to Southampton. The Salina formation, deposited during the Silurian Era approximately 410 to 440 million years ago, is composed of between 50 and 200 metres (true thickness) of interbedded shales, dolostones and evaporates. The Salina is well known throughout the study area for its ample deposits of evaporites, particularly that of halite (rock salt) from which it gets its name. Historic mining of these deposits has occurred in the study area and continues today just south of the study area, with the large salt extraction facilities (both a mine and a brine well/evaporation system) at Goderich. A major feature of the Salina is a large dissolution front from which the salt deposits are absent (likely dissolved during diagenesis) which extends on a roughly north-south line situated just east of Kincardine. The effect of this dissolution front on the deposition of younger rocks is unknown, but it is speculated to have a relationship to the development of karstic features in overlying formations.

Through the study area and extending both north and south of the study area right to Lake Huron and Lake Erie, the easily erodible Salina formation has led to the development of a large bedrock valley. This valley extends from Walkerton in the south part of the study area to Southampton in the west, as it is followed by the Saugeen River on its course to Lake Huron (see Map 3.3).

This bedrock valley is an important bedrock topographical feature that has a profound effect on the regional flow of groundwater (see Map 3.3). The bedrock valleys tend to have been filled with coarse-grained gravels and sands that preferentially concentrate flow into the valleys. In the study area the predominant west-southwest direction of regional groundwater flow is reversed in the Salina, discharging into the bedrock valley and eventually Lake Huron, either via the Saugeen River or through preferential subterranean flow in the valley itself (WHI, 2003).

The Salina formation is an important source of drinking water in the planning region, however it is often associated with water quality problems, particularly high sulphate content, associated with the abundant sulphate minerals gypsum and anhydrite. Several municipal wells penetrate and are drawing water from the Salina formation as well as numerous private domestic supplies.

3.6.1.6 Bass Islands Formation

Deposited on top of the Salina formation is the Upper Silurian Bass Islands formation. This formation forms a relatively thin band of rocks in the southwestern section of the study area due to the relative thin section of rocks of which it is composed (approximately 30 m true thickness). A brown, oolitic limestone with minor interbeds of relatively resistant dolomitic shales dominates the Bass Islands formation.

Based on the limited area of subcrop within the study area, the Bass Islands formation is not considered to be a major source of drinking water. However, several municipal wells penetrate and are drawing water from the Bass Islands formation as well as numerous private domestic supplies. Where it is encountered, the Bass Islands can be considered a reliable, good quality aquifer.

3.6.1.7 Bois Blanc Formation

Overlying the Bass Islands formation is the Bois Blanc formation. This relatively thin formation (~50 m true thickness) is composed of fossiliferous limestones interbedded with siliceous shales and cherts.

The top of the Bois Blanc formation is delineated by an unconformity at which time the rocks were exposed sub-aerially and eroded. The resultant weathering and fracturing of these rocks along its upper and lower contacts makes the Bass Islands formation's contacts layers of high permeability that may have a disproportionately important role in the flow of groundwater in the area.

The Bois Blanc formation's high permeability contact zones have also led to its extensive exploitation as a source of groundwater in the study area. Although it is relatively thin and not an areally extensive formation, drillers have targeted the Bois Blanc for water supplies due to its high yields (Singer et al., 2003).

3.6.1.8 Detroit River Group

Overlying the Bois Blanc formation is the areally extensive Detroit River Group. The Detroit River Group is a 60 to 90 mm thick sequence of limestones and dolostones that are be separated into two distinct formations in the study area, the Amherstburg and Lucas formations. Due to the

relative importance of the Detroit River Group, the two formations will be dealt with independently.

3.6.1.9 Amherstburg Formation

The Amherstburg formation is composed of brown limestones, and is further separated into reefal and non-reefal facies. The reefal facies, named the Formosa Reef member, is composed of biohermal reefs that outcrop in the south of the study area in the village of Formosa. These reefal facies are located at all stratigraphic levels suggesting a prolonged period of reef development, coincident with deposition of the less fossiliferous, non-reefal Amherstburg facies.

The Amherstburg is used extensively for municipal and private water supplies and is considered to be a high quality, high yield aquifer for the area. It is not uncommon to encounter high yields and artesian conditions associated with the Amherstburg.

3.6.1.10 Lucas Formation

The Lucas formation, overlying the Amherstburg formation, is composed of non-fossiliferous, microcrystalline limestones and dolostones. The Lucas formation subcrops in a large area in the southwestern portion of the planning region. The Lucas outcrops within the study area along the shore of Lake Huron north of Kincardine as well as within the beds of the Pine and Penetangore Rivers.

The Lucas was deposited in extremely warm waters during a prolonged period of restricted flow within the Michigan Basin. These conditions led to the development of typical Sabkha sequences in the Lucas, which may also be responsible for the characteristic chemistry of the Lucas and groundwater within the Lucas.

Near the upper contact of the Lucas, it has been associated with karst development. Within the study area, at least two sinkholes are developed along this contact, south of Ripley. Several studies have been conducted and are continuing, which are investigating the relationship between the Lucas and karst development south of the study area (e.g. WHI, 2002, 2004). Further karst inventory work is also ongoing as part of regional geological mapping efforts (Brunton et al., 2006).

The Lucas formation is considered a high quality, high yielding aquifer in the study area and as such is used extensively as a source of drinking water. Numerous municipal wells have been completed into the Lucas formation for this purpose. The water has notoriously high levels of fluoride and, in fact, the pioneering study on tooth decay that led to the use of fluoride in toothpaste was initiated in a community within the study area that was exploiting the Lucas for its groundwater, and where a dentist noticed a dramatic decrease in the instance of tooth decay.

3.6.2 Pleistocene Glacial Deposits

3.6.2.1 Paleozoic-Pleistocene Non-Conformity

Following deposition of the Paleozoic carbonate rocks, a long non-conformity of approximately 300 million years ensued (Barnett, 1992; Chapman and Putnam, 1984; Karrow and Occheitti, 1989). During this period the bedrock was exposed aerially and was eroded extensively. Erosion during this period was a major factor in the development of bedrock valleys in the study area, while weathering and fracturing of the upper surface of the rocks produced zones of high permeability that are important hydrogeological features for the study area.

3.6.2.2 Wisconsinan Glaciation

Numerous cycles of glacial advance (stades) and retreat (interstades) covered the study area, further eroding the bedrock and depositing unconsolidated materials. The latest glacial sheets of ice, which reached their furthest extents during the late Wisconsinan Glaciation approximately 10,000 to 12,000 years ago, are responsible for all of the unconsolidated overburden in the study area. During this period, major lobes of the Wisconsinan ice sheet covered the area, eroding pre-existing glacial deposits as well as the bedrock surface. In particular, the deposits of the planning region can be associated with two separate advances of the Wisconsinan Glaciation, the Port Bruce Stade and the Port Huron Stade, as well as the correspondent Mackinaw and Twocreeken interstades.

The dominant features associated with Port Bruce Stade are the deposition of tills. During the subsequent retreat of the ice sheets during the Mackinaw Interstade, glacial Lake Arkona was formed leaving behind paleoshoreline deposits and scarps. The re-advance of the ice sheets during the Port Huron Stade led to the deposition of the St. Joseph’s till in the study area, as well as the formation of many of the physiographic features that dominate the landscape today, such as the Wyoming and horseshoe moraines as well as many of the glacial outwash features. During the latest retreat of the glaciers during the Twocreeken Interstade, Lake Warren was formed leading to the deposition of a shoreline deposit at the base of the Wyoming moraine. Subsequent melting and recession led to the establishment of Lakes Algonquin and Nipissing.

Map 2.6 shows the surficial geology of the study area and Map 3.4 shows, at a crude scale, the distribution and thickness of glacial deposits. The most prominent feature in the southern part of the area is the prevalence of till deposits that exist through the study area and underlie a significant portion of the watershed. Perched atop these till deposits, particularly in the northern portion of the area, are numerous moraines, spillways, eskers, and syn-glacial and post-glacial lake deposits. These deposits are extremely important features as they tend to include coarser grained gravels and sands, which serve as valuable sources of aggregate, and also tend to host many surficial aquifers. These deposits will be dealt with in more detail in the section 3.7.2.

3.6.2.3 Post Glacial Lakes

During and immediately following the recession of the glaciers, large lakes were formed. The shoreline deposits from these lakes, and the deltaic deposits from the rivers that had outlet in them, form important deposits of sand and gravel material for the watersheds. Shorelines tended to leave cuestas behind, which have become important topographical features. In the study area, four major postglacial lakes are documented, in order of development, Lakes Warren (the

oldest), Nipissing, Algonquin, and present day Lake Huron (which includes Georgian Bay). The lakes formed extensive, largely flat clay plains offshore of the shoreline deposits. These clay plains are a key element in the hydrology of the shoreline streams of the southwestern portion of the study area.

3.6.3 Holocene Erosion and Deposition

Erosion and deposition of sediment continues today. The major rivers of the SPA continue to erode and transport sediment, which is eventually deposited into Lake Huron, and shape their respective valleys. Lake Huron is a major erosional force and continues to erode the glacial sediments along its shoreline, in the process mining and transporting sediment in cells along the shore. Along large beaches in the study area, large deposits of this sediment have been and continue to be altered by wind, forming large sand dunes that migrate inland from the shore of Lake Huron.

3.7 Hydrogeology

Major aquifers in the planning region can be divided grossly into two major types – bedrock and overburden. Bedrock aquifers are by far the most important source of drinking water for the region. Municipal supplies located away from the shore of Lake Huron rely almost exclusively on groundwater from the bedrock aquifers for their drinking water. A large majority of documented private wells also rely on the bedrock aquifers for their water supplies.

3.7.1 Bedrock Aquifers

The bedrock aquifers are composed of an aggregate of the bedrock formations discussed in section 3.6.1. Within each specific bedrock formation, water quality and quantity can differ dramatically, which is largely a consequence of the chemical and physical characteristics of the rocks themselves.

Throughout the majority of the study area, an overlying layer of clay and silt till confines the bedrock aquifer. The bedrock aquifer itself is exposed at the surface in only in the northeastern portion of the planning region near the Niagara Escarpment, (see Map 3.4) and is known to have a potentiometric surface well above its contact with the overlying glacial deposits (Map 3.5). Groundwater extraction from these aquifers is typically confined to the upper portion of the bedrock, near the contact with the overlying glacial sediments. Large water takings and municipal wells often extend deeper into the bedrock, accessing multiple water bearing horizons.

3.7.1.1 Regional Groundwater Flow

Groundwater flow within the bedrock aquifers radiates away from the Dundalk area and follows a generally west to southwesterly flow path towards Lake Huron and north towards Georgian Bay. It should be noted that groundwater levels indicate that most of the groundwater inside the study area originates from within the study area, of which a significant portion flows through and is eventually discharged outside the study area, particularly to the south into the Maitland Valley Conservation Authority area. Map 3.5 shows the regional potentiometric surface for the bedrock aquifer system.

3.7.1.2 Groundwater-Surface Water Interactions

With existing data it is difficult to delineate recharge areas for the study area. Through the southern portion of the watershed region the bedrock aquifer is not exposed at the surface so any recharge must be transient through the overburden deposits. However, an approximation of the location of any recharge areas has been developed and is discussed in section 3.14.

Karst features, formed by the dissolution of bedrock by infiltrating waters, are well documented within the northern portion of the planning region and is manifested by numerous sinkholes and disappearing streams (WHI, 2005; Brunton at al., 2006). These features represent areas where surface waters are directly accessing bedrock groundwater, with little to no infiltration through overburden materials. Preliminary investigations (WHI, 2005; Brunton et al., 2006) have focused predominantly at locating the known karst features. The impacts these features have on the regional groundwater flow system is poorly understood.

Water quality issues are a major concern in areas with karst development. Specific to the study area, two municipal systems are reliant on groundwater (spring-fed) in karst areas. These systems have significant water quality issues as a result (Ford and Williams, 1989).

Similarly, little is known about the discharge of water from the bedrock aquifer. Based on piezometric surfaces for the bedrock aquifer, it is thought that the bedrock aquifer likely discharges into the overlying overburden aquifers in the area, but the extent of such an interaction is unknown. In the lower reaches of the major rivers, bedrock is exposed in the river beds and it is assumed that the bedrock aquifers in these areas are discharging directly into the area's rivers. Ultimately the bedrock aquifers are thought to discharge directly into Lake Huron in the offshore.

3.7.2 Overburden Aquifers

Located within the unconsolidated glacial deposits overlying the bedrock aquifers are numerous overburden aquifers. Locally, these aquifers are important sources of drinking water and are essential for their contribution to surface water and recharge of the bedrock aquifers. For the most part, these aquifers are unconfined and are generally much more susceptible to contamination from surface waters than the bedrock aquifers.

Unfortunately, little information exists on the overburden aquifers for the watershed region. Due to the preference of local drillers for the bedrock aquifers, few well records exist for the overburden aquifers. As such, little information exists for these aquifers and flow directions, water quality and quantity are poorly understood.

3.7.2.1 Flesherton Aquifer

Located south of the village of Flesherton. It consists of gravel and sand deposits that range in thickness from several metres to 23.0 m and is covered by ice-contact sand and gravel, outwash, and till deposits. Where the aquifer is exposed at the surface, it is under water table condition, but otherwise it is confined.

This aquifer is considered of good quality and quantity, with some wells yielding up to 225 L/min. The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area.

3.7.2.2 Arthur-Mount Forest Aquifer

Located between Arthur and Mount Forest, this aquifer consists of sand and gravel deposits that occur at the surface or are overlain by till or clay deposits up to 47 m in thickness. The thickness of sand and gravel deposits range from 20-45 m. Where the deposits are at the surface, the aquifer is unconfined.

This aquifer is considered of good quality and quantity, with some wells yielding up to 130 L/min. The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface, which may have an impact on the placement of septic systems and foundations.

3.7.2.3 Chesley Aquifer

Occurs in proximity and north of Chesley, this aquifer consists of gravel and sand deposits that range in thickness from 10-44 m. These deposits are overlain by clay and till up to a depth of 21 m. Where the sand and gravel deposits are at the surface, the aquifer is unconfined.

This aquifer is considered of good quality and quantity, with some wells yielding up to 50 L/min. The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations.

3.7.2.4 Dundalk Aquifer

Centred near Dundalk, this composite aquifer consists of gravel and sand deposits that range in thickness of 7-15 m. It is overlain by 18 m of a till-like deposit where the sand and gravel deposits are at the surface. The aquifer has both unconfined and confined portions.

The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 120 L/min.

3.7.2.5 Durham Aquifer

Located near Durham, this aquifer consists mainly of sand and gravel deposits occurring at the surface. This unconfined aquifer ranges in thickness from 13-42 m.

The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 120 L/min.

3.7.2.6 Port Elgin – Southampton Aquifer

Located within the lower part of the Saugeen River and in the vicinity of Port Elgin and Southampton. It consists of sand and gravel deposits that range in thickness from 6-20 m. In some places it is partially confined, overlain by up to 13 m of clay deposits. Elsewhere, and more typically, it is situated in sand and gravel deposits that are exposed at the surface.

The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 120 L/min.

3.7.2.7 Hanover Aquifer

Located in proximity to Hanover, this aquifer consists of sand and gravel deposits of which the thickness ranges from a few metres to 33 m. The aquifer is confined by clay and till deposits of 35 m. At places where the sand and gravel deposits are at the surface, the aquifer is unconfined. This aquifer acts as a source for the municipality, as it discharges into Ruhl Lake, from which water is extracted.

Outside of the Ruhl Lake area, the extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 120 L/min.

3.7.2.8 Holstein Aquifer

This aquifer occurs between Durham and Mount Forest and mainly consists of gravel and sand deposits with thickness ranging from 14-68 m. It is a predominantly unconfined aquifer. In some places it is overlain by sand and gravel deposits up to 35 m of till and clay deposits.

The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 50 L/min.

3.7.2.9 Priceville Aquifer

Located near Priceville, this aquifer is situated within gravel and sand deposits with thicknesses of 21-71 m. In some places these deposits are overlain by 30 m of a till-like deposit. It is mainly unconfined within gravel and sand deposits that are exposed at the surface.

The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 50 L/min.

3.7.2.10 Walkerton Aquifer

This aquifer occurs in the vicinity of Walkerton and consists of gravel and sand deposits from 1-12 m thick. In certain places, it is overlain by clay and till deposits up to 15 m deep.

The extent to which this aquifer is utilized is not known at present, due to the lack of reliable well records for this area. This aquifer has static water levels that are very close to ground surface that may have an impact on the placement of septic systems and foundations. This aquifer is considered of good quality and quantity, with some wells yielding up to 225 L/min.

3.7.2.11 Lake Warren Shoreline Aquifer

Forming a narrow, north-south oriented band along the south of the entire watershed region is the former Lake Warren shoreline. These former beaches and dunes have formed well-sorted, well-rounded sand deposits that are ideal potential aquifers. This aquifer is an important source of cold water for the numerous lakeshore streams and wetlands. In addition, several documented private wells are located within this aquifer, in particular in the Municipality of Kincardine and the Township of Huron-Kinloss. This is an unconfined aquifer and is likely recharged *in situ*; otherwise, very little is known about this aquifer.

3.7.2.12 Lake Huron Beach Aquifer

Located within the beach deposits along the present day shoreline of Lake Huron, this aquifer is used sporadically as a source of drinking water by various cottagers. This aquifer is an aggregate aquifer composed of a number of unconfined aquifers that are likely recharged *in situ* with some contribution from surface runoff from nearby bluffs, where they exist. Flow within this aquifer is likely towards Lake Huron.

3.7.2.13 Wawanosh Kame Moraine Aquifer

The Wawanosh moraine, located along the very southern portion of the area, is composed of large kame deposits and is an ideal location for potential surficial aquifers. The Wawanosh moraine forms a distinct topographic high within the southern portion of the Teeswater River watershed and is often characterized by hummocky terrain. This preponderance for hummocky terrain makes the Wawanosh moraine an area of high infiltration and groundwater recharge for the study area. The extent to which the moraine contributes water to bedrock aquifers is unknown, but it does directly overlie bedrock in a number of locations and may be an important source of “inline” recharge for the bedrock aquifers.

The Wawanosh moraine is the major source of water for the coldwater Teeswater River system and the Nine Mile River system to the south (part of the Maitland River watershed). Within this aquifer, significant amounts of water are exchanged between the Teeswater and Nine Mile River systems, as shown by groundwater flow directions determined in the Grey Bruce Groundwater Study (WHI, 2003). Usage by private wells is poorly documented in water well records, but the aquifer was used historically for water extensively.

Information about usage, groundwater flow and groundwater quality are lacking for this aquifer.

3.7.2.14 Howick Aquifer

The Howick aquifer is located in the southern part of the study area and is located within and along the northern boundary of Howick Township. This composite aquifer is situated within a large outwash deposit and glacial spillways that form the rolling topography of this area. In addition, there are numerous drumlins associated with the Teeswater Drumlin Field and smaller eskers and spillways, which are included in this aquifer.

This aquifer is likely recharged *in situ*. It is an important source of water for the Teeswater River system as well as the North Maitland River, Lakelet Lake, Lakelet Creek, and Blind Lake Bog to the south (part of the Maitland River watershed). Within this aquifer significant amounts of water are exchanged between the Teeswater River and the North Maitland River systems, as shown by groundwater flow directions determined in the Grey Bruce Groundwater Study (WHI, 2003). This aquifer is also likely an important source of "inline" recharge for the bedrock aquifer, as it has incised the underlying tills and lies directly on bedrock. The extent of this interaction is poorly understood.

Of particular interest for this aquifer is the concentration of Mennonite and Amish communities in the aquifer. These communities tend to rely on shallow aquifers for drinking water, which are considered to be more vulnerable to contamination than bedrock sources.

This aquifer is poorly understood, with little to no information about groundwater flow, water quantity and water quality.

3.7.3 Groundwater/Surface Water Interactions

Shallow overburden aquifers are important sources of baseflow for many surface water streams. These aquifers help to moderate flow and provide cold water, which is valuable for specific fisheries. Shallow overburden aquifers, particularly unconfined aquifers, are areas of increased infiltration due to their coarse-grained composition and topography.

3.7.4 Cold-Water Fisheries

Map 2.11 shows the cold-water fisheries throughout the SPA. Cold-water fisheries are indicative of areas where significant discharge from shallow overburden aquifers is occurring. In fact, a large portion of flows in the surface water systems can be attributed to groundwater discharge. This component of surface water flow is critical for maintaining baseflow and ecological health of the surface water system. Cold-water fisheries, as a general rule, tend also to have a higher quality of water as well as quantity due to the dilution of overland runoff from groundwater discharge. This is an example of how the issues of water quantity and quality cannot be considered discretely, yet should be viewed as a single component within the framework of a water budget.

3.7.5 Hummocky Terrain

Hummocky terrain is described as areas with broad, gently sloping swales, within which there is increased depressional storage and increased flow lengths for overland flow. These factors lead to slower runoff to surface waters and a coincident increase in infiltration. Indeed, hummocky terrain tends to predominate within very coarse-grained materials where overland flow is not

likely to occur. Hummocky terrain is important, as it may produce a disproportionately high volume of recharge to underlying aquifers.

Section 3.14.1.3 has additional discussion on hummocky terrain.

3.8 Water Use

3.8.1 Data Sources

A number of sources of data for water usage are available for the Saugeen Valley SPA. These data include the Provincial Permit to Take Water (PTTW) database, the Water Well Information System, agricultural water usage and census data, municipal well annual reports and Certificates of Approval, and existing groundwater studies. These data are useful for approximating the amount of water being extracted in the region. Takings from surface and groundwater sources are represented graphically in Maps 3.7 and 3.8. Takings are represented both by permitted takings at locations, as well as expressed as depth of equivalent precipitation over each subwatershed.

3.8.2 Municipal Water Takings

Water takings for municipal drinking water supplies comprise a high volume of water takings within the SPA. A large portion of these takings is exploiting bedrock aquifers with only a few supplies reliant on overburden aquifers. Surface water is exploited extensively along the Lake Huron shoreline, as well as one inland lake, with no municipal water takings from rivers.

As part of the Grey and Bruce Counties Groundwater Study (WHI, 2003), municipal water takings were quantified based on Permit to Take Water values. It was recognized in this study that these values represent daily maximums and therefore could be misleading. These permitted values were then reduced by examining the water system annual reports as well as any other inflow data provided by municipalities that have been required to install flow meters and report annual water consumption since 2001.

Table 3.8.1 lists these municipal water takings by municipality for Grey and Bruce Counties. According to the data, the amount of water taken from the Saugeen Valley SPA is approximately 16,176 m^3/day.

Two municipal water supply systems in the Saugeen Valley SPA exploit Lake Huron as a water source. Each of these systems has an outlet into Lake Huron directly or via river systems and small lakeshore gullies. Surface water takings were estimated based on the maximum daily amounts as defined by the PTTW for each supply.

TABLE 3.8.1 – Groundwater Use by Municipality and Sector for Grey and Bruce Counties*, from Grey and Bruce Counties Groundwater Study (WHI, 2003)

Municipality	*Municipal Groundwater Takings (m^3/day)*	*Agricultural Groundwater Takings (m^3/day)*	*Private Well Groundwater Takings (m^3/day)*	*Other Takings** (m^3/day)*
Georgian Bluffs	208	719.7	1,660	8,769
Chatsworth	170	1,128.6	985	32,869
West Grey	1,463	2,065.5	1,627	53,818
Southgate	660	1,578.8	864	1,014
Hanover	1,753	0	47	0
Grey Highlands	3,490	1,280.5	1,260	9,157
Owen Sound	0	0	0	1,650
Meaford	0	2,083.5	1,025	0
Blue Mountains	0	3,649.4	760	2,781
Arran-Elderslie	1,262	1,680.9	512	197
South Bruce Peninsula	198	550.2	858	464
Brockton	5,756	1,757.6	801	546
Huron-Kinloss*	2,030	1,271.7	137	267
South Bruce	1,047	2,333.9	676	25,911
Kincardine	579	1,549.4	667	67,534
Saugeen Shores	0	244.6	327	5,245
Northern Bruce Peninsula	0	478.5	542	0
Native Reserves	0	0	221	0
Total (m^3/day)	**18,615**	**22,373**	**12,696**	**210,588**

** includes some takings that are part of the Ausable Bayfield Maitland Valley Source Protection Region*
*** includes industrial, commercial, recreational, and some communal water system takings, both consumptive and non-consumptive*

3.8.3 Agricultural Water Takings

Agriculture, including livestock feeding operations and irrigation, represents the largest land use within the SPA. As a result, it is also expected that the highest water takings will also be associated with these operations.

Agricultural operations rely heavily on the bedrock aquifers as a water supply, with relatively few takings from surface water. As part of the Grey and Bruce Counties Groundwater Study (WHI, 2003), municipal water takings were first quantified based on Permit to Take Water values. However, most livestock facilities are not required to obtain a PTTW and, as such,

estimations of usage are best approximated from the distribution and estimated usage of different agricultural sectors.

Several previous studies have been completed in order to estimate the usage of water for the SPA and were summarized in the Grey and Bruce Counties Groundwater Study (WHI, 2003). Based on 2001 Statistics Canada agricultural census data, water takings were estimated on a township scale and are summarized in Table 3.8.1 above. Total consumption for the Saugeen Valley SPA is estimated at 12,040 m^3/day.

3.8.4 Consumptive Commercial Water Takings

Consumptive water takings are those takings in which water is directly exported outside of the watershed, and includes such activities as water bottling, food processing, and beer and beverage production. These takings are important as they represent the only net removal of water from the hydrologic system within the planning region.

As part of the Grey and Bruce Counties Groundwater Study (WHI, 2003), consumptive groundwater takings were quantified and summarized by municipality, and are included as part of the "other takings" shown above in Table 3.8.1. Estimated total consumptive groundwater takings for Grey and Bruce County are approximately 84,690 m^3/day.

There are no known consumptive surface water takings in the SPA.

3.8.5 Non-Consumptive Commercial Water Takings

Non-consumptive commercial water takings are those takings in which water is returned to the natural water system after use, and includes activities such as golf course irrigation, aggregate washing, quarry dewatering, aquaculture, and takings for dams and reservoirs.

In the SPA these takings represent large and important takings from the system, and commonly result in removal of water from one component of the hydrologic system (in this case, often the bedrock aquifer) and artificially directing it to another component (surface waters). This redistribution may have both positive impacts, such as augmenting streamflow in periods of drought, and negative impacts, such as releasing contaminated water, on the natural water system.

As part of the Grey and Bruce Counties Groundwater Study (WHI, 2003), non-consumptive groundwater takings were quantified and summarized by municipality, and are included as part of the "other takings" shown in Table 3.8.1. Estimated total non-consumptive takings for Grey and Bruce County are approximately 157,004 m^3/day.

3.8.6 Private Domestic Water Takings

Private consumption within the SPA almost exclusively exploits overburden and bedrock aquifers. The typical taking utilizes a drilled or, less commonly, a bored well, which is then redirected into shallow overburden aquifers via a septic system.

Estimates of private usage of groundwater was developed on a municipal scale using population data, water well records and estimated usage per capita in the Grey and Bruce Counties Groundwater Study (WHI, 2003). The summary of this estimated water usage is included within Table 3.8.1, above. Total estimated usage for the Saugeen Valley SPA is estimated at 6,197 m^3/day.

There are no known private surface water takings in the region, although the possibility exists that some rural residents may be exploiting surface water for domestic water supplies.

3.8.7 Recreational Water Usage

Recreational water use is a large economic driver within the Saugeen Valley Source Protection Area. These uses include outdoor recreation, hobby fishing, canoeing, and tourism and are focused on the major river systems, Lake Huron and Georgian Bay. Recreational usage of water within the region tends to be generally non-consumptive and is not generally considered to impact the quantity of water in the system; however, adequate availability of water is required for the continued recreational use of these resources.

3.9 Conceptualization of the Hydrologic System

3.9.1 Key Components and Processes

For the Saugeen Valley Source Protection Area, the key components and processes considered for water budgeting are shown in Figure 3.9.1. This schematic strives to explain the pathways and fluxes of water between the key reservoirs. In order to complete a successful numeric water budget, these fluxes will have to be quantified, whether empirically or through modelling.

3.9.1.1 Ground Surface

The initial inputs into the system as a whole are in the form of precipitation. Precipitation falling to the ground is initially partitioned into surface runoff, which moves directly to surface systems or into infiltration. Storage on or within the ground surface occurs as soil field capacity and depressional storage. From this point, a portion of the water on or in the ground surface is released back into the atmosphere via evapotranspiration (referred to as ET on Figure 3.9.1). Evapotranspiration occurs throughout the system whenever water is exposed to the atmosphere or within the root zone of plant life. During dry periods, precipitation is augmented from the river systems, overburden aquifers and bedrock aquifers via irrigation.

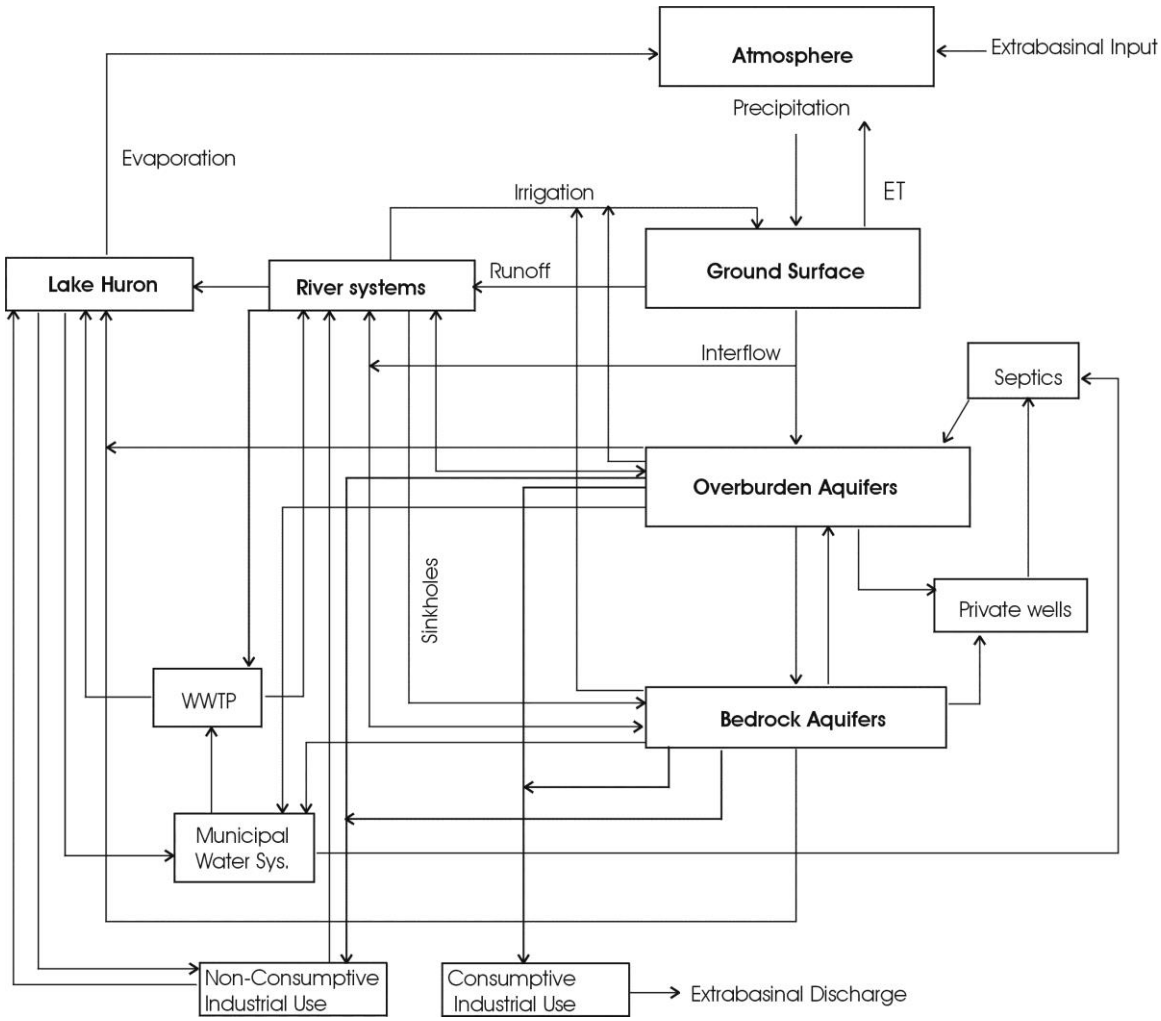

FIGURE 3.9.1 – Components and flux of water in the Saugeen Valley Source Protection Area

3.9.1.2 River Systems

River systems receive direct runoff from the ground surface as well as groundwater discharge from both the overburden and bedrock aquifers. Interflow from infiltrating water is also diverted to river systems. Runoff into the riverine surface water systems eventually makes its way to Lake Huron. River systems are not heavily exploited as sources of water in the planning region but an unknown amount of irrigation is documented, removing water from the river systems and placing it on the ground surface.

3.9.1.3 Interflow

A portion of infiltrating water is redirected to surface water systems before entering the saturated zone via interflow. Tile drainage acts as a conduit that may accelerate interflow throughout the planning region.

3.9.1.4 Overburden Aquifers

The remainder of infiltrating water reaches the saturated zone within either the overburden or bedrock aquifers as recharge. The overburden aquifers also receive inputs of water from river systems via losing streams, septic systems and potential discharge from the underlying bedrock aquifers. These overburden aquifers discharge water to the bedrock aquifers, private wells and, most importantly, to the surficial river systems where they represent high quality sources of groundwater discharge for cold-water streams. Water extracted for domestic consumption into private wells is subsequently discharged back into the overburden aquifers via septic systems.

3.9.1.5 Bedrock Aquifers

Inputs into the bedrock aquifers include recharge originating from the ground surface where the bedrock is exposed, recharge from overlying overburden aquifers, and recharge from river systems via losing streams and via sinkholes, which act as direct conduits for runoff into the bedrock aquifers. The vast majority of input into the bedrock aquifers is derived from within the Saugeen Valley Source Protection Area itself. Water from the bedrock aquifers naturally discharges into Lake Huron and, in certain areas, into river systems. In addition, large volumes of water are extracted from the bedrock aquifers for commercial and municipal water uses. The majority of this water is treated in municipal wastewater treatment facilities (referred to as WWTP in Figure 3.9.1) and released into the river systems. However, an unknown portion of this water is diverted to the overburden aquifers via private wells or municipal wells and septic systems.

3.9.1.6 Lake Huron

Lake Huron is the ultimate destination for water within the system. Lake Huron receives water from all the components shown in Figure 3.9.1. River systems, overburden aquifers and bedrock aquifers all naturally discharge toward the Great Lakes. Water from WWTP is also outlet directly into Lake Huron. The key process for Lake Huron is the extraction of water from the Lake for drinking water purposes. The Lake Huron shoreline within the Saugeen Valley Source Protection Area is host to two large municipal water systems. In addition, the single largest user of water within the area is for the production of electricity at Bruce Power. These systems form a closed loop, as water from them is treated and subsequently released back into Lake Huron.

3.10 Summary of Tier I Water Budget

A Tier I water budgeting exercise is intended to estimate the hydrologic stress of subwatersheds for the purpose of screening out areas from further, more detailed assessment. This is to be done using the best available data for the major hydrologic components and processes of these subwatersheds (“watershed elements”). The data is then compared to the amount of consumptive water demand within a given subwatershed to determine the degree of stress in the hydrologic system due to human water usage.

This section is a summary of the Saugeen, Grey Sauble, Northern Bruce Peninsula Source Protection Region Tier I Water Budget Reports (AquaResource, 2008a; 2008b), which have been completed in compliance with the Technical Rules: Assessment Reports, issued by the Ministry of the Environment and Climate Change (MOECC, 2009).

TABLE 3.10.1 – Tier I Water Budget Values for the Saugeen Valley SPA (all values expressed as mm/year of equivalent precipitation)

Subwatershed	*Precipitation* (mm/year)	*ET* (mm/year)	*Runoff* (mm/year)	*Recharge* (mm/year)	*Water Takings* (mm/year)
Underwood/Tiverton	759	391	244	124	53
North Penetangore River/Kincardine	759	394	272	92	2
Pine River/Lurgan Beach	759	394	271	94	1
Sauble Falls/Huron Shore	1,060	495	205	360	143
Saugeen River/Priceville	1,008	580	209	219	1
Rocky Saugeen River/Traverston	1,057	558	212	287	2
Rocky Saugeen/Aberdeen	1,057	561	202	295	1
Saugeen River/Allan Park	1,057	555	154	348	164
Saugeen River/Dornoch	1,047	554	226	266	0
South Saugeen/Mount Forest	1,007	627	173	207	3
Beatty Saugeen River/Holstein	1,034	580	205	249	1
Beatty Saugeen River/Hanover	1,010	572	153	285	1
South Saugeen River/Neustadt	983	575	229	179	1
Carrick Creek/Carlshrue	983	550	202	231	4
South Saugeen/Hanover	983	505	179	299	51
Otter Creek/Walkerton	983	505	153	325	2
Saugeen River/Walkerton	983	521	239	222	1
Pearl and Dear Creek	1,090	541	341	207	11
Hamilton Creek/Holland Centre	1,092	519	269	304	1
North Saugeen River/Chesley East	1,092	515	228	350	1
North Saugeen River/Chesley West	1,090	532	420	138	1
Upper Teeswater	1,028	581	169	279	9
Greenock Swamp/Lower Teeswater	1,043	582	280	182	5
Willow Creek	1,090	541	406	143	1
Mill Creek	1,090	542	440	108	5
Snake and Burgoyne Creeks	1,090	542	407	141	1
Lower Saugeen	1,060	505	336	219	4

3.10.1 Subwatersheds for Tier I Water Quantity Stress Assessments

For the Tier I water budget, new subwatersheds were proposed for the purposes of performing subwatershed stress assessments. These subwatersheds were delineated according to a hierarchy of factors, developed with the assistance of the Peer Review Committee, including: total water contributing area for municipal water supplies; limits of existing subwatersheds used for modelling purposes; areas of concentrated water usage; and physiographic and hydrologic characteristics. Tier I subwatersheds were developed separately for surface and groundwater analyses, and are shown in Maps 3.8 and 3.9, respectively. A detailed rationale for the

delineation of Tier I subwatersheds can be found in the Tier I water budget reports (AquaResource, 2008a; 2008b). A total of thirty (30) subwatersheds were identified for the Tier I water budget analysis in the Saugeen Valley SPA.

3.10.2 Modelling

Quantitative estimates of the flow of water between the watershed elements for these subwatersheds were derived from existing surface and groundwater models.

3.10.2.1 Surface Water Modelling

Surface water modelling was carried out for the entire Saugeen Valley Source Protection Area using the Guelph All Weather Sequential Event Runoff (GAWSER) model. This tool was used to simulate long-term evapotranspiration, streamflow and deep drainage for all the major river systems located within the Saugeen Valley Source Protection Area including the Saugeen River, Pine River, Penetangore River, and the extensive set of lakeshore gullies and streams situated along the SPA's Lake Huron shoreline. A report outlining the steps required to complete the modelling was developed by AquaResource, Inc. (2008b). The simulated quantification of these watershed elements is essential in determining the Tier I subwatershed stress assessments for the region.

3.10.2.2 Groundwater Modelling

A fully calibrated 3D groundwater flow model was developed for the region using FEFLOW groundwater modelling software. Details on this model, including information on development and calibration of the conceptual and groundwater flow models, is available in the Tier I water budget report (AquaResource, 2008a).

The groundwater flow within the model was calibrated against static water levels from MOECC Water Well records, Provincial Groundwater Monitoring Network wells throughout the region and to 4th order or greater streams. Water Well records were screened based on confidence in locations, and elevations from these Water Well records were adjusted using the digital elevation model (DEM) for the area.

For the purposes of that project, each of the Tier I subwatersheds were separated and refined from the regional scale model. In order to extract models, the regional scale model was overlain with a layer outlining the Tier I subwatersheds. As the individual elements within the model were of a coarse scale, some elements traversed subwatershed boundaries. Boundary conditions, including groundwater flow between subwatersheds, for each Tier I subwatershed were developed using FEFLOW from the fully calibrated, regional-scale model and are shown in Table 3.10.4.

Tier I subwatershed models were simulated for the period from 1985 to 2005. Groundwater fluxes were developed using the continuous boundary flux methodology within the FEFLOW water budgeting module and are shown for the entire SPA in Table 3.10.4.

TABLE 3.10.2 – Monthly Median Flow (L/s) per Subwatershed (Surface Water Supply)

Subwatershed	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Underwood/Tiverton	951	714	3,642	2,090	883	328	54	27	53	285	1,225	1,295
North Penetangore River/Kincardine	821	617	3,146	1,805	762	283	47	23	46	247	1,059	1,119
Pine River/Lurgan Beach	840	631	3,218	1,846	780	290	48	23	47	252	1,083	1,144
Saugeen River/Priceville	2,454	1,861	5,588	7,889	2,803	2,280	1,237	838	698	1,801	3,197	3,260
Rocky Saugeen River/Traverston	2,264	1,750	4,373	4,198	2,451	2,183	1,455	1,041	1,026	2,367	3,051	2,943
Rocky Saugeen/Aberdeen	2,827	2,177	5,196	5,016	3,104	2,756	1,822	1,286	1,275	2,873	3,740	3,582
Saugeen River/Allan Park	9,988	7,733	19,851	22,635	10,895	9,370	6,204	4,416	4,006	8,991	12,643	12,594
Saugeen River/Dornoch	1,458	1,133	2,507	2,360	1,572	1,410	901	598	559	1,224	1,810	1,807
South Saugeen/Mount Forest	4,521	3,628	10,112	10,469	5,314	4,222	1,979	1,318	915	1,556	3,818	5,190
Beatty Saugeen River/Holstein	920	708	2,269	2,046	955	827	437	324	273	591	1,251	1,198
Beatty Saugeen River/Hanover	2,619	1,989	5,707	5,734	2,714	2,167	1,225	949	748	1,538	2,961	3,015
South Saugeen River/Neustadt	5,181	4,173	11,713	11,861	5,920	4,564	2,241	1,534	1,117	1,810	4,184	6,070
Carrick Creek/Carlsruhe	1,500	1,232	3,158	2,396	1,339	1,106	642	488	406	925	1,578	1,483
South Saugeen/Hanover	21,232	16,575	44,290	45,900	22,942	18,882	11,424	8,949	7,370	14,295	23,920	25,062
Otter Creek/Walkerton	22,861	17,742	46,668	48,568	24,312	20,130	12,292	9,598	8,094	15,521	26,256	26,715
Saugeen River/Walkerton	23,317	18,156	47,736	49,617	24,866	20,516	12,563	9,760	8,195	15,897	26,777	27,329
Pearl and Deer Creek	1,541	1,386	4,104	4,203	1,607	1,263	753	501	512	774	1,654	1,831
Hamilton Creek/Holland Centre	1,135	875	2,386	2,185	1,282	1,239	851	588	682	1,508	1,854	1,541
North Saugeen River/Chesley West	2,514	1,955	4,460	4,311	2,847	2,669	1,872	1,324	1,406	2,971	3,765	3,279
North Saugeen River/Chesley East	2,912	2,312	5,906	6,445	3,175	2,971	2,033	1,456	1,587	3,208	4,354	3,811
Upper Teeswater	3,043	2,287	5,996	8,604	3,363	2,194	1,112	621	617	2,375	3,813	4,013
Greenock Swamp/Lower Teeswater	6,544	4,940	14,962	20,037	7,091	4,630	2,579	1,782	1,686	4,404	7,346	8,399
Willow Creek	524	440	1,630	2,278	532	372	163	95	114	312	600	679
Mill Creek	1,243	1,112	4,526	6,715	1,159	727	310	168	273	695	1,374	1,748
Snake and Burgoyne Creeks	1,574	1,399	5,194	7,795	1,499	999	487	286	381	855	1,661	2,076
Lower Saugeen	41,710	33,563	95,792	113,051	43,935	35,237	21,413	17,369	15,488	29,626	50,902	52,305
Sauble Falls/Huron Shores	22,826	18,368	52,423	61,868	24,044	19,284	11,718	9,506	8,476	16,213	27,857	28,625

3.10.3 Surface Water Supply Estimate

At any given time, the available drinking water supply in a river or stream is limited to the instantaneous flow rate. Surface water supply is a method for determining the amount of flow available based on streamflow data for the Saugeen Valley Source Protection Area. The prescribed approach for determining the surface water quantity stress takes into consideration seasonal variability and is evaluated using an estimate of expected monthly flow values.

For each subwatershed within the study area, median flows were calculated to provide an estimate of surface water supply. Fiftieth percentile flows were derived from the daily GAWSER analyses for each month and are shown in Table 3.10.2. These values represent the surface water supply values for use in the surface water stress assessment.

3.10.4 Surface Water Reserve Estimate

The water reserve estimate for a surface water system in Tier I is based on the maximum of a statistical measure of low flow or a known anthropogenic need (i.e., wastewater assimilation). The water reserve estimate is the means by which a portion of water may be protected from being considered within the stress calculations. The concept behind its use is to support other uses of water within the watershed, including both ecosystem requirements (in-stream flow needs) as well as other human uses (primarily permitted uses). The reserve quantity is subtracted from the total water source supply prior to evaluating percent water demand.

For the scale of this Tier I assessment, surface water reserve is not complicated by the need for assimilative capacity and is; therefore, most simply expressed as the 90th percentile flows for each subwatershed. Ninetieth percentile flows were derived from the daily GAWSER analyses for each month and are shown in Table 3.10.3. In order to be consistent with MOECC guidance, for the Tier I surface water stress assessment, reserve values are used for the months with the lowest monthly water supply estimates, rather than the lowest monthly water reserve estimates.

3.10.5 Groundwater Supply Estimate

An estimation of the amount of groundwater available to supply a subwatershed's groundwater users is determined as a summation of groundwater recharge and lateral groundwater flow into the subwatershed. The percent water demand can then be calculated as both average annual and average monthly conditions for current and future scenarios. For this Tier I analysis, aquifer storage is not considered and as such, the water supply terms for the subwatersheds are assumed to be consistent on an average annual basis.

Groundwater flux through the system was developed from the FEFLOW model. Tier I subwatersheds were refined and extracted and flux values determined using continuous boundary flux within the FEFLOW water budgeting module.

TABLE 3.10.3 – Monthly 90th Percentile Flow (L/s) per Subwatershed (Water Reserve)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Underwood/Tiverton	713	565	729	797	245	39	15	12	9	35	65	630
North Penetangore River/Kincardine	616	488	630	688	211	33	13	10	8	30	56	544
Pine River/Lurgan Beach	630	499	644	704	216	34	13	10	8	31	57	556
Saugeen River/Priceville	557	939	1,482	3,012	1,960	1,042	461	324	275	467	756	894
Rocky Saugeen River/Traverston	911	927	1,304	2,368	1,817	1,109	692	520	393	444	1,019	1,320
Rocky Saugeen/Aberdeen	1,104	1,147	1,584	2,938	2,307	1,396	859	650	494	567	1,197	1,628
Saugeen River/Allan Park	3,619	4,122	5,709	10,833	8,010	4,903	2,953	2,213	1,635	1,959	4,783	5,728
Saugeen River/Dornoch	530	491	766	1,452	1,201	738	456	349	242	246	455	790
South Saugeen/Mount Forest	1,239	1,670	2,804	5,606	3,559	1,623	932	700	523	618	1,027	1,580
Beatty Saugeen River/Holstein	244	342	547	1,011	652	334	164	105	90	154	227	419
Beatty Saugeen River/Hanover	646	970	1,606	2,857	1,895	1,056	584	385	261	430	686	1,165
South Saugeen River/Neustadt	1,335	1,979	3,197	6,152	4,117	1,965	1,115	827	578	701	1,159	1,864
Carrick Creek/Carlsruhe	470	711	1,007	1,181	868	475	250	171	125	189	283	549
South Saugeen/Hanover	6,798	8,732	12,342	23,279	16,940	10,312	5,855	4,452	3,249	4,599	7,571	10,546
Otter Creek/Walkerton	7,613	9,511	13,400	24,670	17,993	10,894	6,295	4,711	3,395	5,001	7,953	11,700
Saugeen River/Walkerton	7,895	9,721	13,757	25,176	18,367	11,111	6,420	4,765	3,455	5,136	8,064	12,076
Pearl and Deer Creek	706	784	1,129	1,602	1,190	688	431	280	218	201	278	792
Hamilton Creek/Holland Centre	485	493	752	1,123	933	663	348	281	235	275	491	622
North Saugeen River/Chesley West	1,063	1,099	1,589	2,411	2,063	1,466	841	668	561	620	1,035	1,295
North Saugeen River/Chesley East	1,337	1,349	1,858	2,944	2,302	1,601	932	747	616	701	1,150	1,667
Upper Teeswater	1,188	1,112	1,811	3,750	1,943	822	373	267	186	191	513	1,875
Greenock Swamp/Lower Teeswater	2,654	2,489	4,025	8,016	4,137	1,929	1,115	883	667	637	1,147	3,771
Willow Creek	261	289	406	566	354	141	75	50	41	43	56	300
Mill Creek	621	640	906	1,638	687	238	128	87	67	73	92	755
Snake and Burgoyne Creeks	758	802	1,174	2,032	942	400	243	159	121	121	166	907
Lower Saugeen	15,454	18,411	26,416	48,446	31,117	18,648	10,687	8,987	6,406	7,224	13,496	22,325
Sauble Falls/Huron Shore	8,457	10,076	14,456	26,512	17,029	10,205	5,848	4,918	3,506	3,953	7,386	12,217

TABLE 3.10.4 – Groundwater Budget Expressed in Equivalent mm/year Precipitation

Subwatershed		Area (km²)	Recharge (mm/yr)	External Boundary Flux (mm/yr)	Discharge to Great Lakes (mm/yr)	Discharge to Lakes and Streams (mm/yr)	Interbasin Transfer (mm/yr)	Water Taking (mm/yr)
Huron Shore	Underwood/Tiverton	220.84	136	0	-74	-10	-50	-4
	North Penetangore/Kincardine	193.16	250	0	-90	-106	-49	-7
	Pine River/Lurgan Beach	206.8	204	0	-51	-84	-67	-3
	Upper Lucknow River	110.99	257	0	0	-194	-61	-3
Saugeen River	South Saugeen River/Hanover	59.43	305	0	0	-358	54	-2
	Lake Rosalind	10.72	184	0	0	-447	335	-69
	Maple Hill	22.45	343	0	0	-14	-329	-1
	Snake and Burgoyne Creeks	177.8	214	0	0	-112	-102	-1
	Mill Creek	154.53	176	0	0	-95	-80	-1
	South Saugeen River/Dornoch	127.33	191	0	0	-104	-87	-1
	Willow Creek	63.22	161	0	0	-142	-19	-1
	Pearl and Deer Creek	148.03	162	0	0	-254	91	-1
	Greenock Swamp/Lower Teeswater	373.36	163	0	0	-149	-12	-2
	Upper Teeswater	304	238	0	0	-220	-13	-6
	Beatty Saugeen River/Hanover	131.58	275	0	0	-338	63	-1
	Beatty Saugeen River/Holstein	134.39	309	0	0	-83	-225	-1
	Carrick Creek/Carlsruhe	158.44	211	0	0	-205	-6	-12
	Maitland River Tributary	239.28	173	-50	0	-74	-50	-9
	Saugeen River/Walkerton	46.79	204	0	0	-230	28	-10
	Otter Creek/Walkerton	137.65	224	0	0	-225	6	-6
	South Saugeen River/Neustadt	131.62	185	0	0	-443	258	-1
	South Saugeen/Mount Forest	508.47	203	0	0	-140	-62	-9
	South Saugeen River/Allan Park	264.33	250	0	0	-322	75	-6
	Saugeen River/Priceville	282	203	0	0	-162	-38	-4
	Rocky Saugeen/Aberdeen	66.16	281	0	0	-451	169	-1
	Rocky Saugeen River/Traverston	223.28	205	0	0	-144	-52	-10
	Lower Saugeen	263.28	211	0	-42	-295	129	-4
	North Saugeen River/Chesley West	26.01	210	0	0	-114	-81	-15
	North Saugeen River/Chesley East	105.34	263	0	0	-264	2	-1
	Hamilton Creek/Holland Centre	99.43	196	0	0	-122	-74	-1

For the study area, two sources of recharge data are available: estimates derived from the groundwater model (annual only); and from the GAWSER analysis (monthly and annual). Table 3.10.4 summarizes groundwater flux through the Tier I subwatersheds derived from FEFLOW. These recharge values derived from FEFLOW for the groundwater model will be used for the Tier I assessment. These data are considered to be the more conservative value, which is consistent with expectations for a Tier I water budget.

Groundwater supply is the sum of the groundwater flow in and the recharge for each subwatershed, and does not take into account groundwater flow out of the subwatershed.

3.10.6 Groundwater Reserve Estimate

The groundwater reserve for Tier I analysis is determined by estimating the reserve quantity as 10% of the existing groundwater supply.

3.10.7 Consumptive Groundwater Usage Estimate

3.10.7.1 Permitted Usage

Permitted groundwater usage is primarily documented through the PTTW database, as well as through municipal drinking water supply records. Similar to the permitted surface water takings, the best available water taking data (actual, estimated average, maximum permitted) was used to estimate permitted amounts, which were subsequently adjusted using the consumptive factor outlined in MOECC guidance. Groundwater use by Tier I subwatershed is included in Table 3.10.5.

3.10.7.2 Non-Permitted Agricultural Usage

Agricultural usage, particularly those not related to crop irrigation, is exempt from requiring a Permit to Take Water. As a result, no documentation of this usage is available for analysis. Estimates of agricultural usage were developed based on agricultural data and projected watering requirements from the 2001 census data as part of De Loë (2002). This information is broken into watersheds for all of southern Ontario and was incorporated into the consumptive usage estimates. Estimated takings were then adjusted according to consumptive use factors provided by the MOECC's Technical Rules. Groundwater use by Tier I subwatershed is included in Table 3.10.5.

3.10.7.3 Private-Domestic Usage

Private domestic usage is not considered within the MOECC guidance document (MOECC, 2006b). It was felt, due to the high reliance on groundwater for private potable water sources, that this taking should be incorporated into this Tier 1 water budgeting exercise.

Private well records for each subwatershed, available in the Ministry of the Environment and Climate Change's Water Well Information System (WWIS) were assigned a minimum taking value of 450 L/day (0.45 m^3/day), based on usage requirements set out in MOECC best practice documents for the sizing and evaluation of septic systems. These values were then adjusted according to consumptive use factors for domestic water takings provided by the MOECC's Technical Rules. Groundwater use by Tier I subwatershed is included in Table 3.10.5.

TABLE 3.10.5 – Groundwater Use by Tier I Subwatershed

Subwatershed	*Municipal Demand (avg) (m^3/day)*	*Agricultural Demand (m^3/day)*	*Private Wells (m^3/day)*	*Permitted Use (m^3/day)*
Underwood/Tiverton	949.5	600.1	272.3	6,947.2
North Penetangore River/Kincardine	808.9	548.4	126.0	8,172.1
Pine River/Lurgan Beach	1,279.2	578.6	121.5	6,605.3
Upper Lucknow River	418.0	331.3	56.3	2,347.5
Sauble Falls/Huron Shore	372.6	54.5	102.6	1,120.6
South Saugeen River/Hanover	0	148.6	79.2	127.3
Lake Rosiland	1,784.9	27.0	29.3	9,766.1
Maple Hill	0	56.5	22.5	0
Snake and Burgoyne Creeks	0	583.0	85.1	0
Mill Creek	0	355.7	54.9	0
South Saugeen River/Dornock	0	296.5	111.6	239.8
Willow Creek	0	184.4	27.5	0
Pearl and Dear Creek	0	432.0	93.6	0
Greenock Swamp/Lower Teeswater	16.8	1,487.7	255.6	4,382.8
Upper Teeswater	1,921.8	1,219.2	183.2	12,307.9
Beatty Saugeen River/Hanover	0	328.8	87.3	0
Beatty Saugeen River/Holstein	0	328.8	91.8	0
Carrick Creek/Carlshrue	4,450.5	644.1	164.7	6,040.8
Maitland River Trib	4,681.0	1,081.0	149.0	4,681.0
Saugeen River/Walkerton	1,000.0	119.6	55.8	15,096.7
Otter Creek/Walkerton	722.0	342.1	126.9	4,311.5
South Saugeen River/Neustadt	0	375.4	127.8	0
South Saugeen/Mount Forest	10,537.5	1,437.1	359.1	11,963.4
South Saugeen River/Allan Park	2,696.6	660.3	339.3	6,761.9
Saugeen River/Priceville	658.0	710.8	227.3	5,164.9
Rocky Saugeen/Aberdeen	0	131.3	61.7	0
Rocky Saugeen River/Traverston	5,294.0	440.4	249.8	8,462.4
Lower Saugeen	249.0	660.4	173.3	9,157.0
North Saugeen River/Chesley West	995.6	66.3	25.7	9,329.5
North Saugeen River/Chesley East	0	262.6	153.5	314.2
Hamilton Creek/Holland Centre	0	243.9	120.2	0

3.10.8 Consumptive Surface Water Usage Estimate

3.10.8.1 Permitted Surface Water Usage

Permitted users are the only reliable source for surface water takings for the area. Surface water takings are generally confined to irrigation activities, with the exception of the Lake Huron based municipal (and private) water supply systems, which are excluded from the Tier I water budgeting exercise. The best available water taking data (actual, estimated average, maximum permitted) was used to estimate permitted amounts, which were subsequently adjusted using the consumptive factor outlined in the MOECC's Technical Rules. Surface water use by Tier I subwatershed is included in Table 3.10.6.

TABLE 3.10.6 – Surface Water Use by Tier 1 Subwatershed

Subwatershed	*Permitted Takings (m^3/day)**	*Non-Permitted Agricultural Demand (m^3/day)**
Underwood/Tiverton	31622.4	604.8
North Penetangore River/Kincardine	1641.6	518.4
Pine River/Lurgan Beach	518.4	604.8
Sauble Falls/Huron Shore	39484.8	172.8
Saugeen River/Priceville	0	777.6
Rocky Saugeen River/Traverston	691.2	432
Rocky Saugeen/Aberdeen	0	86.4
Saugeen River/Allan Park	64108.8	691.2
Saugeen River/Dornoch	0	345.6
South Saugeen/Mount Forest	2937.6	1728
Beatty Saugeen River/Holstein	0	259.2
Beatty Saugeen River/Hanover	0	345.6
South Saugeen River/Neustadt	0	172.8
Carrick Creek/Carlshrue	0	1555.2
South Saugeen/Hanover	19094.4	345.6
Otter Creek/Walkerton	2678.4	345.6
Saugeen River/Walkerton	0	172.8
Pearl and Dear Creek	4147.2	432
Hamilton Creek/Holland Centre	0	259.2
North Saugeen River/Chesley East	0	259.2
North Saugeen River/Chesley West	0	86.4
Upper Teeswater	8208	1382.4
Greenock Swamp/Lower Teeswater	3715.2	1641.6
Willow Creek	0	172.8
Mill Creek	4147.2	345.6
Snake and Burgoyne Creeks	0	604.8
Lower Saugeen	10540.8	432

** Values converted by DWSP staff from L/s in Tables 3.3 and 3.4 (AquaResource, 2008b) to m^3/day.*

3.10.9 Future Usage Projections

Future increases in the usage of both (non-Lake Huron) surface water and groundwater are not considered significant for the study area. The study area is considered to be "fully developed" in that it has very little natural area that will likely be converted to either agricultural or residential land uses.

Population growth is projected to be minimal in the immediate future, with growth centered along the shore of Lake Huron and in existing towns and villages. Given the low consumptive water uses in the area it seems unlikely that future usage, based on today's projections, will lead to any additional stress on the natural system. Caution should be added that not all future uses can be accounted for or anticipated, and that no additional stresses are anticipated for the subwatersheds at the scale being investigated; however, large takings within specific areas may still lead to significant problems.

3.11 Tier I Surface Water Stress Assessment

The Tier I surface water stress assessment is designed to screen and flag those subwatersheds where the degree of stress is considered moderate or significant for further study. The stress assessment evaluates the ratio of the consumptive demand for permitted and non-permitted users to water supplies, minus water reserves within a given subwatershed.

Within the study area, for each subwatershed, the monthly water reserve (10th percentile flows) was subtracted from the monthly water supply (median flows) for the month with the lowest monthly water supply in order to determine water availability. The percentage water demand was then calculated as a percentage of the consumptive demand versus this water availability, where:

$$\% \text{ water demand} = \frac{\text{consumptive demand}}{(\text{water supply} - \text{water reserve})} \times 100$$

Table 3.11.1 shows the percent water demand by subwatershed on a monthly basis.

Subwatershed stress levels are defined as:

- less than 20% - low
- between 20 and 50% - moderate
- more than 50% - significant

Table 3.12.1 outlines the water supplies, reserves, availability, consumptive demand, percentage water demand, and surface water quantity stress levels for each subwatershed in the study area.

TABLE 3.11.1 – Monthly Percent Water Demand by Tier I Subwatershed

Subwatershed	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Underwood/Tiverton	3.7	5.9	0.3	0.7	1.4	3.0	22.3	60.2	19.9	3.5	0.8	1.3
North Penetangore River/Kincardine	3.1	4.9	0.3	0.6	1.1	10.1	74.1	199.9	66.0	2.9	0.6	1.1
Pine River/Lurgan Beach	3.4	5.4	0.3	0.6	1.3	2.8	28.5	76.8	18.1	3.2	0.7	1.2
Saugeen River/Priceville	0.5	1.0	0.2	0.2	1.1	0.7	1.2	1.8	2.2	0.7	0.4	0.4
Rocky Saugeen River/Traverston	0.6	1.0	0.3	0.5	1.3	0.8	1.1	1.6	1.3	0.4	0.4	0.5
Rocky Saugeen/Aberdeen	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.1
Saugeen River/Allan Park	0.9	1.6	0.4	0.5	2.3	1.8	2.5	3.6	3.4	1.0	0.9	0.9
Saugeen River/Dornoch	0.4	0.6	0.2	0.4	1.0	0.5	0.8	1.4	1.1	0.4	0.3	0.3
South Saugeen/Mount Forest	0.7	1.2	0.3	0.5	1.3	0.9	2.2	3.7	5.8	2.4	0.8	0.6
Beatty Saugeen River/Holstein	0.5	0.8	0.2	0.3	1.0	0.6	1.1	1.4	1.7	0.7	0.3	0.4
Beatty Saugeen River/Hanover	0.2	0.4	0.1	0.2	0.5	0.4	0.7	0.8	0.9	0.4	0.2	0.2
South Saugeen River/Neustadt	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.2	0.1	0.1
Carrick Creek/Carlsruhe	1.7	3.4	0.8	1.5	3.8	2.8	4.5	5.6	6.3	2.4	1.4	1.9
South Saugeen/Hanover	0.1	0.1	0.0	0.1	0.2	0.3	0.5	0.6	0.6	0.1	0.1	0.1
Otter Creek/Walkerton	0.0	0.1	0.0	0.0	0.1	0.0	0.3	0.4	0.1	0.0	0.0	0.0
Saugeen River/Walkerton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pearl and Deer Creek	0.7	0.9	0.2	0.2	1.3	0.9	1.7	2.5	1.9	1.0	0.4	0.5
Hamilton Creek/Holland Centre	0.4	0.8	0.2	0.3	0.8	0.5	0.6	0.9	0.7	0.2	0.2	0.3
North Saugeen River/Chesley West	0.2	0.3	0.1	0.2	0.4	0.2	0.3	0.4	0.3	0.1	0.1	0.1
North Saugeen River/Chesley East	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.1
Upper Teeswater	1.0	1.5	0.4	0.4	1.6	1.7	3.2	6.6	5.4	1.1	0.7	0.8
Greenock Swamp/Lower Teeswater	0.6	1.0	0.2	0.2	0.8	0.9	1.7	2.7	2.4	0.6	0.4	0.5
Willow Creek	0.8	1.4	0.2	0.1	1.2	0.9	2.4	4.7	2.9	0.8	0.4	0.6
Mill Creek	0.7	0.9	0.1	0.1	2.5	4.2	11.3	25.5	9.9	1.9	0.9	0.4
Snake and Burgoyne Creeks	0.8	1.1	0.2	0.1	1.2	1.1	2.8	5.3	2.6	0.9	0.5	0.6
Lower Saugeen	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.9	0.4	0.0	0.0	0.0
Sauble Falls/Huron Shore	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0

TABLE 3.11.2 – Summary of Potential for Surface Water Stress per Subwatershed

Watershed	***Subwatershed Name***	***Potential for Stress***
Huron Shore	Underwood/Tiverton	Significant
Huron Shore	North Penetangore River/Kincardine	Significant
Huron Shore	Pine River/Lurgan Beach	Significant
Upper Saugeen	Saugeen River/Priceville	Low
Upper Saugeen	Rocky Saugeen River/Traverston	Low
Upper Saugeen	Rocky Saugeen/Aberdeen	Low
Upper Saugeen	Saugeen River/Allan Park	Low
Upper Saugeen	Saugeen River/Dornoch	Low
South Saugeen	South Saugeen/Mount Forest	Low
South Saugeen	Beatty Saugeen River/Holstein	Low
South Saugeen	Beatty Saugeen River/Hanover	Low
South Saugeen	South Saugeen River/Neustadt	Low
South Saugeen	Carrick Creek/Carlsruhe	Low
Lower Saugeen	South Saugeen/Hanover	Low
Lower Saugeen	Otter Creek/Walkerton	Low
Lower Saugeen	Saugeen River/Walkerton	Low
Lower Saugeen	Pearl and Deer Creek	Low
Lower Saugeen	Hamilton Creek/Holland Centre	Low
Lower Saugeen	North Saugeen River/Chesley West	Low
Lower Saugeen	North Saugeen River/Chesley East	Low
Lower Saugeen	Upper Teeswater	Low
Lower Saugeen	Greenock Swamp/Lower Teeswater	Low
Lower Saugeen	Willow Creek	Low
Lower Saugeen	Mill Creek	Moderate
Lower Saugeen	Snake and Burgoyne Creeks	Low
Lower Saugeen	Lower Saugeen	Low
Huron Shore	Sauble Falls/Huron Shore	Low

3.11.1 Surface Water Stress Assessment Uncertainty

To increase confidence in the surface water stress assessment presented above, the percent water demand equation was repeated for four different scenarios. Each scenario represents uncertainties associated with the water supply and consumptive demand estimates used in the stress assessment calculation and determines if variation in those terms can cause a change in the final stress classification. Should the stress classification remain the same with all four scenarios, one can be confident that the uncertainties inherent in estimating water supply and water demand terms are not impacting the final stress assessment.

Both the water supply and water demand estimates were varied by ±25%, independent of one another. These variations resulted in the four scenarios summarized in Table 3.11.3. Subwatersheds where the stress classification remained the same for all four scenarios and the best estimate are considered to have low uncertainty. Those subwatersheds that vary between low and moderate/significant are considered uncertain. As the outcome is the same for subwatersheds classified as having a moderate or significant potential for stress, fluctuations between these stress classifications does not result in an uncertain stress assessment.

TABLE 3.11.3 – Sensitivity of Surface Water Stress Classification

Subwatershed Name	***Surface Water Stress Classification***				
	Best Estimate	***+25% Water Supply***	***-25% Water Supply***	***+25% Water Demand***	***-25% Water Demand***
Underwood/Tiverton	Significant	Moderate	Significant	Significant	Moderate
North Penetangore River/Kincardine	Significant	Significant	Significant	Significant	Significant
Pine River/Lurgan Beach	Significant	Significant	Significant	Significant	Significant
Lower Sauble River	Low	Low	Low	Low	Low
Saugeen River/Priceville	Low	Low	Low	Low	Low
Rocky Saugeen River/Traverston	Low	Low	Low	Low	Low
Rocky Saugeen/Aberdeen	Low	Low	Low	Low	Low
Saugeen River/Allan Park	Low	Low	Low	Low	Low
Saugeen River/Dornoch	Low	Low	Low	Low	Low
South Saugeen/Mount Forest	Low	Low	Low	Low	Low
Beatty Saugeen River/Holstein	Low	Low	Low	Low	Low
Beatty Saugeen River/Hanover	Low	Low	Low	Low	Low
South Saugeen River/Neustadt	Low	Low	Low	Low	Low
Carrick Creek/Carlsruhe	Low	Low	Low	Low	Low
South Saugeen/Hanover	Low	Low	Low	Low	Low
Otter Creek/Walkerton	Low	Low	Low	Low	Low
Saugeen River/Walkerton	Low	Low	Low	Low	Low
Pearl and Deer Creek	Low	Low	Low	Low	Low

Subwatershed Name	Surface Water Stress Classification				
	Best Estimate	+25% Water Supply	-25% Water Supply	+25% Water Demand	-25% Water Demand
Hamilton Creek/Holland Centre	Low	Low	Low	Low	Low
North Saugeen River/Chesley West	Low	Low	Low	Low	Low
North Saugeen River/Chesley East	Low	Low	Low	Low	Low
Upper Teeswater	Low	Low	Low	Low	Low
Greenock Swamp/Lower Teeswater	Low	Low	Low	Low	Low
Willow Creek	Low	Low	Low	Low	Low
Mill Creek	Moderate	Moderate	Moderate	Moderate	Low
Snake and Burgoyne Creeks	Low	Low	Low	Low	Low
Lower Saugeen	Low	Low	Low	Low	Low

3.12 Tier I Groundwater Stress Assessment

Similar to the Tier I surface water stress assessment, the Tier I stress assessment for groundwater is designed to determine the degree of stress within each subwatershed. The stress assessment evaluates the ratio of the consumptive demand for permitted and non-permitted users to water supplies, minus water reserves within a subwatershed.

Within the Saugeen Valley Source Protection Area, the groundwater reserve (10% of supply) was subtracted from the groundwater supply (recharge plus groundwater influx) in order to determine groundwater availability. The percentage water demand was then calculated as a percentage of the consumptive demand versus this water availability, where:

$$\% \text{ water demand} = \frac{\text{consumptive demand}}{(\text{water supply} - \text{water reserve})} \times 100$$

Subwatershed stress levels are defined for average annual fluxes, as:

·less than 10% - low ·between 10 and 25% - moderate ·more than 25% - significant

For monthly (maximum demand) fluxes, the stress levels are defined as:

·less than 25% - low ·between 25 and 50% - moderate ·more than 50% - significant

Table 3.12.1 outlines the water supplies, reserves, availability, consumptive demand, percentage water demand and groundwater quantity stress levels for both average (annual) and monthly (maximum) basis for each subwatershed in the study area.

The stress levels are presented graphically in Map 3.9 and summarized in Table 3.12.2.

The following sections summarize the subwatersheds classified as having a potential for stress relating to groundwater takings above, at or close to the moderate or significant threshold**,** under average annual and/or maximum monthly demand conditions. The hydrologic factors influencing the classification are discussed, and municipal supplies located within the subwatershed are identified.

TABLE 3.12.1 – Groundwater Stress Assessment

Subwatersheds		Area (km^2)	swsID	Supply and Demand (m^3/day)					% Water Demand	
				Recharge	Q Reserve	Flow In	Q_{Avg} Demand	Q_{Max} Demand	% Avg.	% Max.
Huron Shore	Underwood/Tiverton	220.8	21	82,548	5,039	-	2371	3697	3%	5%
	North Penetangore/Kincardine	193.2	27	132,291	10,363	-	3444	8745	3%	7%
	Pine River/Lurgan Beach	206.8	30	115,627	7,622	-	1882	4507	2%	4%
	Upper Lucknow River	111.0	32	78,086	5,900	-	766	1063	1%	1%
Saugeen River	South Saugeen River/Hanover	59.4	16	49,740	5,835	8,733	292	292	1%	1%
	Lake Rosalind	10.7	17	5,413	1,312	9,827	2040	9529	**15%**	**68%**
	Maple Hill	22.5	18	21,112	89	-	61	61	0%	0%
	Snake and Burgoyne Creeks	177.8	19	104,426	5,457	-	600	600	1%	1%
	Mill Creek	154.5	20	74,547	4,041	-	367	367	1%	1%
	South Saugeen River/Dornoch	127.3	22	66,532	3,631	-	320	320	1%	1%
	Willow Creek	63.2	23	27,936	2,459	-	190	190	1%	1%
	Pearl and Deer Creek	148.0	24	65,878	10,287	36,992	451	451	0%	0%
	Greenock Swamp/Lower Teeswater	373.4	25	166,262	15,233	-	2097	3112	1%	2%
	Upper Teeswater	304.0	26	198,522	18,347	-	5023	5042	3%	3%
	Beatty Saugeen River/Hanover	131.6	28	99,205	12,198	22,779	346	346	0%	0%
	Beatty Saugeen River/Holstein	134.4	29	113,632	3,059	-	347	347	0%	0%
	Carrick Creek/Carlsruhe	158.4	31	91,778	8,896	2,283	5128	6717	6%	8%
	Maitland River Tributary	239.3	33	113,709	4,843	0	5792	5792	5%	5%
	Saugeen River/Walkerton	46.8	37	26,199	2,949	4,507	1221	6401	4%	**23%**
	Otter Creek/Walkerton	137.6	38	84,369	8,469	1,343	2126	3041	3%	4%
	South Saugeen River/Neustadt	131.6	39	66,589	15,965	87,002	401	401	0%	0%
	South Saugeen/Mount Forest	508.5	40	282,736	19,444	0	13134	13235	5%	5%
	South Saugeen River/Allan Park	264.3	41	181,314	23,302	64,189	4334	5532	2%	2%
	Saugeen River/Priceville	282.0	42	156,905	12,552	0	2727	3913	2%	3%
	Rocky Saugeen/Aberdeen	66.2	43	51,010	8,170	20,662	144	144	0%	0%
	Rocky Saugeen River/Traverston	223.3	44	125,528	8,830	0	5873	8525	5%	7%
	Lower Saugeen	263.3	45	152,133	24,353	111,808	3186	4249	1%	2%
	North Saugeen River/Chesley West	26.0	46	14,936	813	0	1070	8587	**8%**	**61%**
	North Saugeen River/Chesley East	105.3	47	75,793	7,620	1,874	372	372	1%	1%
	Hamilton Creek/Holland Centre	99.4	48	53,334	3,327	0	268	268	1%	1%
Other	Maitland River Tributary	239.3	33	113,709	4,843	0	5792	5792	5%	5%
	Upper Lucknow River	111.0	32	78,086	5,900	-	766	1063	1%	1%

Notes: **61%** *Shaded cells denote subwatersheds with Moderate or Significant Potential Hydrologic Stress*

8% *Striped cells denote subwatersheds close to a Stress Threshold*

TABLE 3.12.2 – Subwatershed Groundwater Stress Classification

Watershed		***Area (km^2)***	***Potential Stress (Avg Demand)***	***Potential Stress (Monthly Max Demand)***
Huron Shore	Underwood/Tiverton	220.8	Low	Low
	North Penetangore/Kincardine	193.2	Low	Low
	Pine River/Lurgan Beach	206.8	Low	Low
	Upper Lucknow River	111.0	Low	Low
Saugeen River	South Saugeen River/Hanover	59.4	Low	Low
	Lake Rosalind	10.7	Moderate	Significant
	Maple Hill	22.5	Low	Low
	Snake and Burgoyne Creeks	177.8	Low	Low
	Mill Creek	154.5	Low	Low
	South Saugeen River/Dornoch	127.3	Low	Low
	Willow Creek	63.2	Low	Low
	Pearl and Deer Creek	148.0	Low	Low
	Greenock Swamp/Lower Teeswater	373.4	Low	Low
	Upper Teeswater	304.0	Low	Low
	Beatty Saugeen River/Hanover	131.6	Low	Low
	Beatty Saugeen River/Holstein	134.4	Low	Low
	Carrick Creek/Carlsruhe	158.4	Low	Low
	Maitland River Tributary	239.3	Low	Low
	Saugeen River/Walkerton	46.8	Low	Low
	Otter Creek/Walkerton	137.6	Low	Low
	South Saugeen River/Neustadt	131.6	Low	Low
	South Saugeen/Mount Forest	508.5	Low	Low
	South Saugeen River/Allan Park	264.3	Low	Low
	Saugeen River/Priceville	282.0	Low	Low
	Rocky Saugeen/Aberdeen	66.2	Low	Low
	Rocky Saugeen River/Traverston	223.3	Low	Low
	Lower Saugeen	263.3	Low	Low
	North Saugeen River/Chesley West	26.0	Low	Significant
	North Saugeen River/Chesley East	105.3	Low	Low
	Hamilton Creek/Holland Centre	99.4	Low	Low
Other	Maitland River Tributary	239.3	Low	Low
	Upper Lucknow River	111.0	Low	Low

3.12.1 Lake Rosalind/Hanover

The Lake Rosalind subwatershed, which is immediately west of the Town of Hanover, is used as the drinking water supply source area for the Town of Hanover. As delineated for this study, the subwatershed is only 10 km^2 and is the smallest subwatershed in the region. Based on the calculations, this subwatershed was assigned a moderate potential for stress under average annual pumping and a significant potential for stress under monthly (maximum) pumping conditions. The percent water demand for this area is 15% under average annual demand conditions and 68% under maximum monthly demand conditions. An analysis of the water budget values presented in Table 3.12.1 shows that the peak demand within the subwatershed exceeds the local recharge and approaches the amount of water flowing into the subwatershed from the adjacent subwatershed (Maple Hill).

3.12.2 Saugeen River/Walkerton

The Saugeen River/Walkerton subwatershed was calculated to have a low potential for stress under average (annual) demand conditions, as well as under monthly (maximum) demand conditions. However, the percent water demand calculations for this subwatershed warrant some discussion as the percent demand under maximum demand conditions was very near the threshold value. A review of the water budget values presented in Table 3.12.1 indicates that the monthly (maximum) demand is considerably higher than the average annual demand. A conservative estimate of the percent water demand can be obtained by neglecting, in the equation, the groundwater flow in term; if this calculation is performed for the Walkerton subwatershed, the percent water demand under the monthly (maximum) demand condition would exceed the moderate threshold (28% water demand). Given the locality of this subwatershed, and the proximity of municipal well fields, this area may warrant a Tier II assessment, subject to the uncertainty assessment.

3.12.3 North Saugeen River/Chesley

The percent water demand for the subwatershed designed to evaluate the potential for stress at Chesley was calculated to have a low potential for stress for annual (average) demand conditions (8% water demand); however, this result is considered to be close to the threshold value. Further, this subwatershed was calculated to have a significant potential for stress for monthly (maximum) demand conditions (61% water demand).

The subwatershed designed to evaluate the potential for stress at Chesley is smaller than recommended in the guidance; however, it originated from the natural topographic divides that flank this branch of the North Saugeen tributary. The impact of the area being smaller than advised in the guidance is that it could provide an inflated estimate of the potential for stress, particularly under maximum pumping conditions. The stress assessment performed assumes that the flow field would remain unchanged for average and maximum monthly conditions (cross-boundary flows would remain unchanged). However, in smaller subwatersheds cross-boundary flows are likely to be induced during maximum pumping conditions. This is expected to be the case for the Chesley area; under maximum pumping conditions a significant volume of water would likely be drawn across the subwatershed boundary. As a result, the predicted percent water demand calculated for the maximum water demand scenario is considered suspect as the

water budget terms applied in the calculation do not encompass the area that would contribute to the municipal system for the maximum pumping scenario.

A review of the water budget values presented in Table 3.12.1 for both this subwatershed and the adjacent subwatershed indicate that there is an ample volume of recharge available to supply the municipal demand at Chesley between the two subwatersheds. Further, there are no permitted water takers that would be impacted under such a scenario. Consequently, it is expected that recharge available may offset the stresses induced under the maximum pumping scenario and result in a lower degree of stress than predicted.

Based on the potential for stress identified for this subwatershed, this area may warrant a Tier II assessment. However, given the uncertainty in the calculation as discussed above, the approach to a Tier II assessment at this location should be tailored to specifically address the uncertainty by evaluating the stress under different stress assessment areas, rather than applying the subwatershed boundary.

3.12.4 Groundwater Stress Assessment Uncertainty

This section describes the sensitivity analysis carried out to determine the level to which the uncertainty associated with the underlying components of the stress assessment may affect the potential stress classifications.

To be conservative, consumptive factors and water demand numbers were chosen to be the highest range possible. For example, unpermitted agricultural use was considered to have a 100% consumptive factor. The assumptions used to estimate demand are based on both average and maximum conditions and were verified with reported information (percentage of permitted rate pumped), feedback from the governing facilities and model simulations.

Despite the validation of the assumptions associated with the estimates of water demand, a level of uncertainty remains. One focus of this uncertainty analysis is on municipal and domestic use and testing the sensitivity of the final stress classifications to population changes within the study area. This was completed by increasing water demand by 25%, which reflects a marginal growth rate of < 1% per year, for the next 25 years.

In addition, calculations were carried out by varying the water supply terms upwards and downwards by 25%. This is seen as a large range, as it would be unlikely that water supply volumes, at the scale of the subwatersheds, would vary by more than 25% (this range is equal to >+/-100 mm of recharge for pervious subwatersheds).

Table 3.12.3 summarizes the results of the sensitivity analysis. The sensitivity analysis presented above has confirmed that all but four subwatersheds can be confidently classified as having a low potential for stress.

With regard to the North Saugeen/Chesley subwatershed, the subwatershed delineation applied in this sensitivity analysis was the same as that applied for the base case scenarios.

The results of this analysis indicate that the stress assessment is largely insensitive to significant changes in the primary stress assessment terms, agricultural water demand and water supply. This suggests that uncertainties associated with these terms would not significantly alter the stress assessment identification.

TABLE 3.12.3 – Summary of Sensitivity Analysis

Subwatershed		***Potential for Groundwater Stress (Either Avg or Peak Demand)***
Huron Shore	Underwood/Tiverton	Low Potential for Stress (Certain)
	North Penetangore/Kincardine	Low Potential for Stress (Certain)
	Pine River/Lurgan Beach	Low Potential for Stress (Certain)
	Upper Lucknow River	Low Potential for Stress (Certain)
Saugeen River	South Saugeen River/Hanover	Low Potential for Stress (Certain)
	Lake Rosalind	**Potential for Stress under Peak Demand (*Uncertain*)**
	Maple Hill	Low Potential for Stress (Certain)
	Snake and Burgoyne Creeks	Low Potential for Stress (Certain)
	Mill Creek	Low Potential for Stress (Certain)
	South Saugeen River/Dornoch	Low Potential for Stress (Certain)
	Willow Creek	Low Potential for Stress (Certain)
	Pearl and Deer Creek	Low Potential for Stress (Certain)
	Greenock Swamp/Lower Teeswater	Low Potential for Stress (Certain)
	Upper Teeswater	Low Potential for Stress (Certain)
	Beatty Saugeen River/Hanover	Low Potential for Stress (Certain)
	Beatty Saugeen River/Holstein	Low Potential for Stress (Certain)
	Carrick Creek/Carlsruhe	Low Potential for Stress (Certain)
	Maitland River Tributary	Low Potential for Stress (Certain)
	Saugeen River/Walkerton	**Potential for Stress under Peak Demand (*Uncertain*)**
	Otter Creek/Walkerton	Low Potential for Stress (Certain)
	South Saugeen River/Neustadt	Low Potential for Stress (Certain)
	South Saugeen/Mount Forest	Low Potential for Stress (Certain)
	South Saugeen River/Allan Park	Low Potential for Stress (Certain)
	Saugeen River/Priceville	Low Potential for Stress (Certain)
	Rocky Saugeen/Aberdeen	Low Potential for Stress (Certain)
	Rocky Saugeen River/Traverston	Low Potential for Stress (Certain)
	Lower Saugeen	Low Potential for Stress (Certain)
	North Saugeen River/Chesley West	**Potential for Stress (Certain)**
	North Saugeen River/Chesley East	Low Potential for Stress (Certain)
	Hamilton Creek/Holland Centre	Low Potential for Stress (Certain)
Other	Maitland River Tributary	Low Potential for Stress (Certain)
	Upper Lucknow River	Low Potential for Stress (Certain)

3.13 Summary of Tier II Water Budget

The Tier II subwatershed stress assessment used more refined water demand estimates and a more advanced water budget model than those used for the Tier I assessment. The percent water demand calculations were the same as those used in the Tier I assessment and the same threshold values for stress assessment were used. Tier II subwatershed stress assessments were developed at the subwatershed scale (similar to the Tier I) using a continuous surface water model and, where necessary, a groundwater flow model.

Municipal water supplies located within subwatersheds that are confirmed to have a moderate or significant potential for stress, proceed to a locally focused, Tier III water quantity risk assessment.

The Tier I groundwater stress assessment (AquaResource, 2008a) concluded that a number of areas within the SPR had a moderate or significant potential for stress. The goal of the current Tier II investigation is to refine and potentially confirm the Tier I results through a more detailed analysis. This analysis included:

- Updating the geologic conceptual understanding within the potentially stressed areas.
- Updating the groundwater flow model with the refined geologic understanding and recharge rates estimated using the continuous surface water model.
- Refining the consumptive groundwater use estimates.
- Performing a Tier II water quantity stress assessment for identified areas.

Through this sensitivity analysis, it has been identified that the subwatershed stress classification is uncertain for two subwatersheds: the Lake Rosalind subwatershed and the Walkerton subwatershed.

3.13.1 Tier II Subwatershed Delineation

Under the requirements of the Technical Rules (MOECC, 2009), the water quantity stress assessment is carried out on a subwatershed basis. Tier I subwatershed boundaries were updated (see description below) as part of the Tier II assessment to better capture the local groundwater flow system(s) in areas previously identified as potentially stressed in the Tier I assessment (AquaResource, 2008a).

Map 3.10 illustrates a modified set of Tier II subwatershed areas delineated to better represent aquifer systems. Table 3.13.1 lists the Tier II assessment areas. There are a total of four (4) Tier II assessment areas (subwatersheds) identified in the Saugeen Valley SPA. The following sections describe the revisions to each of the assessment areas.

TABLE 3.13.1 – Tier II Subwatershed Area Summary

Tier II Subwatershed	***Area (km^2)***	***Municipal Supplies***
Lake Rosalind/Hanover	27	Hanover (Wells #1 and #2) Hanover (Ruhl Lake) Lake Rosalind (Wells #1 & #3)
Walkerton	53	Walkerton (Wells #7 & #9)
Otter Creek (Mildmay)	151	Mildmay (Wells #1 & #2)
Chesley	70	Chesley (Wells CPW #1,2 & 3)

3.13.1.1 Lake Rosalind/Hanover

The Tier I groundwater stress assessment included two small subwatersheds that isolated the Hanover and Lake Rosalind water supplies. These subwatersheds were combined into a single Tier II assessment area, with land located to the south of the Saugeen River grouped with the Otter Creek (Mildmay) assessment area.

3.13.1.2 Walkerton

The Tier I Saugeen River subwatershed, which encompassed Walkerton, was split along the Saugeen River for the Tier II assessment: the western portion extended further westward to encompass an additional 25.5 km^2 and formed the Saugeen River (Walkerton) assessment area, whereas the eastern portion was joined to the Otter Creek assessment area (Mildmay). The revised assessment area includes the Walkerton municipal wells.

3.13.1.3 Otter Creek (Mildmay)

The revised assessment area for Otter Creek (Mildmay) includes land area previously within the Tier I Saugeen River (Walkerton) and Lake Rosalind (Hanover) subwatersheds. While not identified as having a moderate or significant potential for stress within the Tier I groundwater stress assessment (AquaResource, 2008a), the revised assessment area delineation includes areas of the Tier I Walkerton and Lake Rosalind subwatersheds, thus necessitating a Tier II stress assessment analysis for this area. The revised assessment area includes municipal wells for the Mildmay urban area.

3.13.1.4 Chesley

The North Saugeen (Chesley) assessment area was extended eastward to encompass an additional 44.5 km^2 of land area that was thought to provide recharge to production aquifers. This assessment area includes the municipal wells for Chesley. The Tier I subwatershed was considered too narrow to encompass the entire capture zone for the Chesley water supply.

3.13.2 Model Updates

Models developed as part of the Tier I water budget were refined in order to assess groundwater quantity stress for the Saugeen Valley SPA. Details of these updates are outlined in the section below.

3.13.2.1 Groundwater Model Updates

The FEFLOW steady-state groundwater-flow model was developed as a tool to assess groundwater flow at the regional scale as part of the Tier I water budget exercise. The hydrogeological characterization reflected by the model includes regional-scale groundwater aquifers and aquitards. As a result, the model's predicted water levels and groundwater discharge rates are consistent with groundwater flow conceptual models at the larger (i.e., subwatershed) scale.

The Tier II assessment represents a refinement of the Tier I assessment and includes a more detailed review of data on a subwatershed basis. The conceptual hydrostratigraphic layer structure for the Tier II assessment areas were revisited as part of the Tier II assessment. Specifically, the hydrostratigraphic layer elevations were refined locally to improve on the hydrogeologic characterization developed in the Tier I Conceptual Geologic and Water Budget Assessment (AquaResource, 2008a).

The hydrostratigraphic layer structure within the Tier II subwatershed areas was updated as part of this study. Based upon interpreted cross-sections, the elevations of the hydrostratigraphic layer structure was modified within the Tier II subwatershed areas. The focus of this refinement was on significant hydrogeologic features within Tier II subwatershed areas, or on areas not previously characterized as part of the Tier I stress assessment. This refinement has led to better characterization than was included within the Tier I assessment.

The three-dimensional groundwater flow model developed as part of the Tier I groundwater stress assessment (AquaResource, 2008a), has been updated and refined for use within the current Tier II stress assessment. Most notably, this refinement included modifying groundwater recharge rates to those estimated from the calibrated GAWSER model, developed as part of the Tier I surface water stress assessment (AquaResource, 2008b). Other refinements included modifications to the hydrostratigraphic layer elevations as described in Section 2.1. Based on the consumptive demand estimates, pumping wells were updated. The hydrostratigraphic layer structure, or the finite element mesh used within the FEFLOW model, was not modified as part of the Tier II stress assessment.

Following the refinements made to the FEFLOW model, a calibration exercise was carried out to ensure the model was able to reasonably estimate groundwater inflows to the Tier II subwatershed areas. Calibration metrics for the entire model domain, as well as for individual Tier II assessment areas, indicate that the major flow processes are well represented at the subwatershed scale, and that the model is able to support the Tier II stress assessment.

3.13.2.2 Surface Water Model Updates

No major updates of the existing Tier I surface water (GAWSER) models were undertaken as part of the Tier II assessment. The existing models were considered sufficient for the purposes of completing the Tier II assessment. Recharge values derived from the GAWSER models were used to update the FEFFLOW groundwater model within the Tier II subwatershed areas.

3.13.3 Consumptive Water Use Update

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

The following sections determine total consumptive water demand by quantifying municipal water demand, permitted water demand and non-permitted water demand. Reported pumping rates were utilized to generate municipal water demand estimates. Estimated pumping rates were generated by combining the permitted rate with the months of expected active pumping. Pumping rates for non-permitted takings were area-prorated from the Tier I stress assessments (AquaResource, 2008a). Consumptive factors were then applied to determine the amount of pumped water that is not returned to the original source in a reasonable amount of time.

While this section documents estimated consumptive water demand, it is recognized that there are a number of non-consumptive water uses (i.e. water for waste assimilation or for sustaining ecological health) that are not included. These water needs do not remove water from its source and, as such, are not considered to be water takings in this assessment.

3.13.3.1 Municipal Water Takings

Municipal water use is a predominant water use sector within the assessment areas; it accounts for approximately half of the total extracted groundwater. Municipal pumping rates reported in the Tier I groundwater stress assessment were utilized for this analysis. Following the methodology of the Tier I groundwater stress assessment, the Ruhl Lake supply for the Town of Hanover was considered to be a groundwater taking. All municipal taking were assumed to be 100% consumptive, as wastewater discharges are discharged to the surface water system and not returned to the groundwater system.

3.13.3.2 Permits to Take Water

The Ministry of the Environment and Climate Change’s Permit to Take Water (PTTW) Program began in the early 1960s. It requires any person (or organization) taking more than 50,000 L/day of water to have an active PTTW. Exceptions are granted for domestic water use, livestock watering and water taken for firefighting purposes. Ontario’s PTTW database stores information on permits, including the location, the maximum permitted rates, and the general and specific purpose of the water taking.

Originally designed to manage the fair sharing of water, data collected in support of the PTTW program can be used to estimate current water demands. Although the program is currently adapting to collect records of actual water takings, the datasets provided by the MOECC only include maximum permitted water takings, and must be manipulated to estimate realistic water demands. The PTTW program is now requiring PTTW holders to report their actual pumping rates; however, this new information was not available for this assessment.

When using the PTTW database to estimate actual water demands, the following considerations are made:

- When specifying the amount of water required for their specific use, permit holders often request a volume of water that exceeds their requirements. This may be done to ensure compliance in dry years or to secure sufficient water for possible future expansion of the operation.
- Permitted volume is often derived from the capacity of the pumping equipment rather than the requirements of the user, often significantly over-estimating the user's demand.
- The database does not maintain a record of seasonal water demand requirements.
- Multiple wells or sources may be included on a particular permit, and the permitted rate refers to the total for all sources associated with that permit. As an example, two nearby municipal wells may operate under one permit but the wells may never operate simultaneously. In this case, each well source could pump at the maximum permitted rate, but not at the same time. To estimate total demand, the total permitted rate should be logically divided amongst the active source locations.
- The spatial location of water taking sources is not always accurate.
- The PTTW database is not current with respect to the MOECC's actual permitting activities (recent permit numbers may not be included within the database).
- Historic water takings may be "grandfathered" and do not require a permit. As a result, there may be some significant water takings not reflected by the PTTW database.

A copy of the PTTW database current to January 2009 was used in this assessment. Only active permits, or permits representing sustained water taking, were included in this analysis. To aid in the proper characterization of water taking permits, the Environmental Bulletin Registry was used. Searching the Environmental Bulletin Registry allowed the permit application details and the granted paper permit to be viewed for many water takings. Temporary permits, such as pipeline testing, pumping tests or temporary construction permits, were not included. Additionally, groundwater takings, where the water source was identified as a spring, were assumed to be surface water takings and removed from the groundwater stress assessment.

Estimating consumptive demand from information contained within the PTTW database was completed by following the methodology included in the Technical Rules: Assessment Report (MOECC, 2009). This procedure is summarized below:

- Maximum permitted rates were combined with the number of days each source is permitted to pump. The resultant volume was then evenly distributed through months in which it was assumed the PTTW would be active (e.g. snowmaking permit was assumed to be active Dec-Feb).
- The pumping rate was adjusted using a consumptive use factor. Consumptive use refers to the amount of water that is pumped but not returned back to the original water source.

Monthly estimates of water use are required to accurately quantify the annual volume of water withdrawn, as well as to represent the seasonal changes in total water use within the assessment

area. The months where a water taking is expected to be active, based on the purpose of that water taking, were evaluated to facilitate estimates of actual water used in a Tier II subwatershed area, recognizing that many types of water taking operations only take water during a specific time period each year (e.g., snow making generally is active December, January and February). Monthly demand adjustments were combined with the maximum permitted days per year, and the maximum permitted withdrawal, both specified in the PTTW database, to obtain monthly water use estimates.

As discussed in Part I.1 – Definitions of the Technical Rules: Assessment Report (MOECC, 2009), "consumptive use" refers to the amount of water removed from a hydrological system and not returned back to the same system in a reasonable time period. To assess the portion of pumped water that is being removed from the hydrologic system, estimates of water demand must consider the consumptive use.

The percent water demand calculation requires the estimate of water that is consumed and not returned to the original source within a reasonable amount of time. Therefore, for a groundwater assessment, if water is removed from the groundwater system and not returned to the groundwater system, the taking is assumed to be 100% consumptive. Groundwater takings are typically 100% consumptive, since wastewater is seldom returned to the groundwater system, but rather discharged to surface water systems. Exceptions would include irrigation, where a portion of the applied irrigation water would saturate surficial soils and percolate beneath the evaporative root zone, returning to the groundwater system.

Consumptive water demand was estimated for each permitted water taking. These rates, when combined with the municipal rates represent the majority of water extraction from each Tier II subwatershed area.

3.13.3.3 Non-Permitted Water Takings

In addition to permitted water use, there are various types of non-permitted water uses, such as livestock watering and unserviced domestic use (typically rural residents). Non-permitted agricultural and unserviced domestic water were estimated as part of the Tier I water budget and stress assessment (AquaResource, 2008a). These estimates were utilized to quantify non-permitted water use for the current Tier II stress assessment.

Non-permitted agricultural water use includes livestock watering, equipment washing, pesticide/herbicide application, or any other minor use of water. The Tier I study (AquaResource, 2008a) quantified the water demands for this particular water use sector by combining agricultural water use coefficients with Census of Agriculture data. This study adapted this data and proportioned it based on the area of the assessment area.

There is currently no information regarding the water source that is used to supply water for the non-permitted agricultural users; water may be obtained from shallow or deep groundwater sources, online ponds, or nearby creeks or rivers. In the absence of this information, it is assumed that half of the demand is serviced through groundwater sources, and half is serviced through surface water sources.

Unserviced domestic use is any household water use that is not supplied by a municipal water supply system. Typically, these are households in rural areas, and almost exclusively are supplied from groundwater. This water demand was previously estimated within the Tier I groundwater stress assessment by combining a per capita rate to the serviced population.

3.13.3.4 Tier II Consumptive Water Use

Table 3.13.2 summarizes estimated total consumptive demands for each Tier II subwatershed area by month; maximum monthly demand and annual average demand are also provided. On an average annual basis 20,600 m^3/day of water is estimated to be removed from groundwater aquifers within the Tier II assessment areas and not returned to the original aquifer.

TABLE 3.13.2 – Tier II Consumptive Water Demand Summary (m^3/day)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
Hanover	2,983	2,983	2,983	2,983	3,555	3,555	3,555	3,555	3,555	2,983	2,983	2,983	3,221	3,555
Walkerton	954	954	954	954	954	954	954	954	954	954	954	954	954	954
Otter Cr.	1,034	1,034	1,034	1,034	1,116	1,116	1,116	1,116	1,116	1,116	1,116	1,034	1,082	1,116
Chesley	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369

Consumptive use estimates tend to be lower than the reported maximum permitted pumping rates documented in the PTTW database**,** representing more realistic estimates than what would be estimated by simply summing the permitted volumes. This highlights the need for effective understanding and assessment of demand volumes.

Included in Table 3.13.3 is the consumptive water use for each assessment area, broken down by major sector.

Despite the relatively low consumptive rates associated with livestock and rural domestic demand (200-600 m^3/d), these uses comprise a significant portion of the consumptive water demand for the Walkerton, Otter Creek and Chesley subwatershed areas (15-35%). This is due to the overall low consumptive water demands present in these areas.

TABLE 3.13.3 – Consumptive Water Use Breakdown by Sector (Percent of Total)

Subwatershed	Commercial	Industrial (Permitted)	Recreational	Private Wells	Municipal	Agricultural
Hanover	n/a	n/a	n/a	1	98	1
Walkerton	7	22	n/a	0	53	18
Otter Cr.	0	n/a	0	0	65	35
Chesley	n/a	4	n/a	0	76	20

3.13.4 Tier II Groundwater Quantity Stress Assessment

The approach for conducting a Tier II stress assessment is outlined in Part III.4 of the Technical Rules (MOECC, 2009). The Technical Rules prescribe an approach for estimating subwatershed stress based on estimates for water supply, water reserve and water demand in each assessment area. The estimated values for water supply and water reserve are calculated using the groundwater model and the surface water model (AquaResource, 2008a; 2008b).

Tier II stress assessment was evaluated for each assessment area that was identified at the Tier I level (AquaResource, 2008a; 2008b) as having a moderate or significant potential for stress, and which contained a municipal groundwater supply. The purpose of the Tier II stress assessment is to confirm the results of the Tier I and to identify municipal water supply systems where a Tier III water quantity risk assessment is required. Although the Tier I surface water stress assessment did identify certain subwatersheds as having a moderate or significant potential for stress, there are no inland surface water drinking sources. As such, the Tier II stress assessment is solely focused on evaluating the groundwater system.

3.13.4.1 Groundwater Consumptive Use

The procedure used to estimate consumptive groundwater demands under current conditions is documented in Section 3.13. The consumptive groundwater demand refers to all groundwater that is removed from the groundwater system and not returned to the same system within a reasonable amount of time. Consumptive demand estimates included in Section 3.13 include both permitted and non-permitted groundwater takings. These estimates are used to compute the percent water demand for current conditions.

3.13.4.2 Groundwater Supply and Reserve

Groundwater supply is calculated as the average annual groundwater recharge plus the amount of groundwater flowing laterally into each assessment area. The GAWSER model developed by the Tier I surface water budget and stress assessment (AquaResource, 2008b) predicted groundwater recharge over the study area. The FEFLOW model refined as part of the current study estimated the groundwater flowing laterally into each assessment area. The groundwater flow in for each assessment area is calculated from the model results as the sum of all positive flow vectors into each area.

Groundwater reserve is calculated as 10% of the estimated groundwater discharge to surface water streams within each assessment area. Groundwater discharge to streams was estimated by the FEFLOW groundwater flow model.

3.13.4.3 Percent Water Demand

Percent water demand for groundwater is calculated for each assessment area using estimates of groundwater supply, groundwater reserve and consumptive demand described above. The results of the stress assessment for existing conditions are shown in Table 3.13.4. The rows shaded in yellow identify those percent water demand values that are above the threshold for a moderate potential for stress.

TABLE 3.13.4 – Percent Water Demand under Existing Conditions

Subwatershed	Groundwater Supply (m^3/day)			Groundwater Reserve (m^3/day)	Demand (m^3/day)		Percent Water Demand (%)	
	Recharge	Flow In	Supply		Avg	Max	Avg Water Demand	Max Water Demand
Hanover	23,800	0	23,800	300	4,369	4,369	**19**	**19**
Walkerton	29,900	26,700	56,700	5,400	3,221	3,555	6	7
Otter Cr.	136,800	22,200	158,900	10,000	954	954	1	1
Chesley	51,700	12,200	63,900	4,00	1,082	1,116	2	2

The only assessment area with a percent water demand that is above the provincial thresholds (Table 3.13.4**)** is the Lake Rosalind/Hanover assessment area. At 19%, the percent water demand for this assessment area is well above the moderate threshold of 10% and is classified as having a moderate potential for stress.

3.13.5 Tier II Future Use Assessment

The Technical Rules require that any assessment area not already identified as having a moderate or significant potential for stress, undergo an additional scenario where future municipal pumping and future land use be considered. As the Lake Rosalind subwatershed area (Hanover and Lake Rosalind municipal supply) has already been identified as having a moderate potential for stress, there is no need to assess the future conditions of this assessment area.

To evaluate the percent water demand under future conditions, the population projections contained within each municipality's official plan were summarized. This summary is included in Table 3.13.5.

Population increases were combined with current per capita water use rates to estimate the increase in municipal water demand. Future non-municipal water demand was assumed to be equal to current non-municipal water demand.

TABLE 3.13.5 – Future Population Summary

System	Current Population	Future Population (2026)	Percentage Increase
Walkerton	4,900	5,800	19%
Otter Cr.	1,000	1,205	21%
Chesley	2,010	2,423	21%

Changes in land cover due to population growth are typically associated with increased urbanization, with resulting reductions in recharge. To consider how changes in land use may affect the future percent water demand, the urban area associated with each assessment area was increased by the population growth rate. This increase in urban area was conservatively assumed to be 100% impervious, thereby reducing the total recharge for the assessment area.

TABLE 3.13.6 – Percent Water Demand under Future Conditions

Subwatershed	Groundwater Supply (m^3/day)			Groundwater Reserve (m^3/day)	Demand (m^3/day)		Percent Water Demand (%)	
	Recharge	Flow In	Supply		Avg	Max	Avg Water Demand	Max Water Demand
Walkerton	29,600	26,700	56,300	5,400	3,536	3,870	7	8
Otter Cr.	136,700	22,200	158,900	10,000	1,082	1,082	1	1
Chesley	51,500	12,200	63,700	4,00	1,251	1,285	2	2

The increased municipal pumping and the revised assessment area recharge was combined with the groundwater flow in and groundwater reserve calculated for the current condition scenario to calculate the future percent water demand, and is shown in Table 3.13.6. This assessment assumes that neither the groundwater flow in, nor the groundwater discharge, would be modified significantly given the expected increases in urban area (0.1-1.1%). As shown in Table 3.13.6, all Tier II subwatershed areas remain well below the thresholds for moderate potential for stress. As a result, all assessment areas are classified as having a low potential for stress under future conditions.

3.13.6 Tier II Drought Assessment

According to the Technical Rules, groundwater assessment areas can also be classified as having a potential for moderate stress if either of the following circumstances occurs within the assessment area during observed or simulated drought conditions:

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

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

This study proceeded with running the entire 1950-2005 period through the groundwater flow model. By investigating the range of precipitation/recharge fluctuations that might be expected to occur throughout the historic 55-year period, this approach captures two-year and ten-year periods of drought.

The FEFLOW steady-state groundwater flow model was configured to use the time series of monthly recharge adjustment factors for the complete 1950-2005 simulation based on variations in recharge derived from the GAWSER model. Water levels resulting from the steady-state

groundwater flow simulation were set as initial conditions for the 1950-2005 transient simulation.

The groundwater flow model was configured to export groundwater levels at each municipal well during the simulation. Should the simulated water level fluctuations at a specific well be greater than what can be accommodated by that well (i.e. greater fluctuation than the average depth of water over the intake), the well would be deemed to be sensitive to drought conditions, and a classification of a moderate potential for stress would be assigned to the assessment area. As the goal of this scenario is to investigate whether current pumping regimes could be sustained throughout historical drought conditions, the simulation also assumes constant pumping from each of the wells.

The results of the drought assessment are shown in Table 3.13.7. In this table, the maximum water level decline over the 1950-2005 period is shown for each municipal well. The maximum decline for each well is compared to the depth of water that is above the well intake elevation. Should the maximum water level decline be greater than the depth of water above the intake, it would indicate that the water level in the well would drop below the intake, and normal operations would cease. The assessment area would then be classified as having a moderate potential for stress.

TABLE 3.13.7 – Drought Results Summary

Municipal System	***Well***	***Simulated Maximum Water Decline (m)***	***Water Depth above Intake (m)***
Chesley	CPW 1	<1	>2
	CPW 2	<1	>2
	CPW 3	<1	>2
Walkerton	Well # 7	3.3	61
	Well #9	9.5	62
Mildmay	Well #1	<1	>2
	Well #2	<1	>2

The depth of water above the well intake elevation for each municipal well was assumed to be at least two metres. This value was considered an initial, conservative assumption. For those wells that were simulated to experience more than two metres, specific information related to the depth of water above the well intake was requested of the municipal water supply managers to more accurately evaluate the significance of the simulated drawdown impact.

As seen in Table 3.13.7, there are no municipal wells susceptible to drought conditions; no wells are predicted to experience drawdown that would exceed their estimated available drawdown.

3.13.7 Tier II Uncertainty Assessment

While the stress classification is based on best estimates of consumptive water demand, water supply and water reserve, there is uncertainty with these estimates that may affect the classification. The Technical Rules require that each assessment be assigned an uncertainty classification of low or high uncertainty in regards to the stress assessment classification assigned to each assessment area.

This section describes a sensitivity analysis designed to evaluate whether the uncertainty associated with the water demand or supply components is sufficient to modify the stress assessment classification. Where the sensitivity analysis indicates that the classification may change from moderate to low potential, or low to moderate potential, an uncertainty classification of high is assigned. For subwatershed areas that do not change stress levels within the sensitivity analysis, an uncertainty classification of low is assigned.

Table 3.13.8 summarizes the results of four sensitivity scenarios; the percent water demand is re-calculated with the estimated portion of both water demand and the groundwater recharge increased and decreased by a factor of 20%. Each sensitivity scenario is completed independent to one another.

TABLE 3.13.8 – Sensitivity Analysis Summary

Subwatershed	***120% Water Demand***		***80% water Demand***		***120% Recharge***		***80% Recharge***		***Uncertainty***
	Avg	***Max***	***Avg***	***Max***	***Avg***	***Max***	***Avg***	***Max***	
Hanover	22	22	15	15	15	15	23	23	Low
Walkerton	8	8	5	6	6	6	7	8	Low
Mildmay	1	1	1	1	1	1	1	1	Low
Chesley	2	2	1	1	2	2	2	2	Low

For each assessment area, the stress classification under the four sensitivity analysis scenarios did not differ from the stress classification under current conditions. The sensitivity analysis shows that the stress assessment results are not sensitive to uncertainty ranges of 20% applied to water demand and groundwater recharge estimates. As such, the uncertainty classification assigned to all assessment areas is low. This confirmation of the stress classification provides additional confidence in the Tier II stress assessment.

3.13.8 Summary of Tier II Stress Assessment Results

Based on historical conditions, current percent water demand, future percent water demand, the drought assessment, and the uncertainty consideration, the Tier II groundwater stress assessment classifications for each assessment area is summarized in Table 3.13.9 and displayed in Map 3.10.

Assessment areas identified as having a moderate or significant potential for stress are discussed below.

TABLE 3.13.9 – Summary of Tier II Stress Assessment Results

Tier II Subwatershed	***Municipal Supplies***	***Tier 2 Stress***	***Uncertainty***
Lake Rosalind/Hanover	Hanover (Wells #1 and #2) Hanover (Ruhl Lake) Lake Rosalind (Wells #2 & #3)	Moderate	Low
Walkerton	Walkerton (Wells #7 & #9)	Low	Low
Otter Creek (Mildmay)	Mildmay (Wells #1 & #2)	Low	Low
Chesley	Chesley (Wells CPW #1,2 & 3)	Low	Low

The Lake Rosalind assessment area is classified as having a moderate potential for stress under the current percent water demand calculation. The percent water demand is estimated to be 19%, well above the threshold for moderate potential for stress (10%). By far the majority of consumptive water demand is related to municipal demand (98%), with a campground water supply, livestock water use and rural domestic comprising the remaining 2%. Furthermore, all scenarios evaluated under the stress assessment sensitivity all suggest that the potential for stress within this assessment area is moderate.

The Lake Rosalind assessment area, while receiving large amounts of recharge (320 mm/yr), is simulated not to receive any groundwater inflow from adjacent assessment areas. There are groundwater flow divides in both the observed and simulated water levels that correspond with the assessment area boundaries to the west, north and east. The Saugeen River to the south of the assessment area acts as a similar flow divide. In essence, the water demand within the Hanover area is capturing a significant portion of the local recharge, which results in the moderate stress level calculation.

The Lake Rosalind assessment area contains the municipal supplies for the town of Hanover, and the Lake Rosalind settlement. As per the Technical Rules (MOECC, 2009), these municipal supplies require a Tier III water quantity risk assessment. A detailed work plan for the Tier III water budget is included in Chapter 7 (Addressing Limitations) of this report.

3.13.9 Tier II Significant Groundwater Recharge Area Update

Tier II recharge estimates utilized existing Tier I GAWSER modelling results, which were deemed sufficient for the purposes of the Tier II water quantity stress assessment. As a result, Significant Groundwater Recharge Areas were not updated as a result of the Tier II work (Map 3.11).

3.14 Significant Groundwater Recharge Areas

Under the *Clean Water Act, 2006,* Technical Rules for development of an Assessment Report have been established. These rules outline the delineation of four types of vulnerable areas within which policies will be developed and implemented to protect water, namely: wellhead protection areas, intake protection zones, highly vulnerable aquifers, and significant groundwater recharge areas.

Significant groundwater recharge areas are to be developed using existing models and data from Tier I water budgets, and the Technical Rules allow for the use of professional judgment in the form of a technical Peer Review Committee. Specifically, the rules state:

> 44. Subject to rule 45, an area is a significant groundwater recharge area if,
>
> (1) the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or
>
> (2) the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.
>
> 45. Despite rule 44, an area shall not be delineated as a significant groundwater recharge area unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system.
>
> 46. The areas described in rule 44 shall be delineated using the models developed for the purposes of Part III of these rules and with consideration of the topography, surficial geology, and how land cover affects groundwater and surface water.
>
> (Technical Rules: Assessment Report, November 2009)
> *Clean Water Act, 2006*

Further guidance was provided by the Ministry of Natural Resources and Forestry on the development of significant groundwater recharge areas (SGRAs) in the form of a Technical Bulletin (MNRF and MOECC, 2009). This bulletin highlighted what aspects of the methodology require professional judgment. Specifically, key decisions that require professional judgment are:

- Which methodology is to be used in order to determine SGRAs (i.e. Technical Rule 44 (1) or (2)).
- The scale at which these methodologies will be applied.
- Incorporation of local geological and hydrological knowledge into the SGRA delineation process.

3.14.1 Hydrologic Response Units

In order to determine SGRAs, an approach was selected that incorporated results from the Tier I and II surface water modelling efforts, incorporating hydrologic response units. This approach

was designed to account for the geology, soils, land cover, and topography of the Region. In order to do this, a series of unique hydrologic response units (HRUs) were created using available geology, land cover and topographical mapping. HRUs were developed as part of the Saugeen, Grey Sauble, Northern Bruce Peninsula Source Protection Region. Once HRUs have been developed, they are used as key inputs in to the GAWSER modelling process and are adjusted as part of the calibration process.

Hydrologic response units were created by reclassifying and intersecting a number of datasets, the details of which are described below.

3.14.1.1 Surficial Geology

Surficial geological units were reclassified according to the texture of the materials of which they are composed. It should be noted that the surficial geological classifications also account, to a large extent, for the soil texture distribution and topography of the region and are, therefore, considered redundant with respect to determining SGRAs. The reclassification of the surficial geological units are listed below in Table 3.14.1.

TABLE 3.14.1 – Surficial Geology Reclassification for HRU Derivation

Geologic Grouping	***Quaternary Geology Description***
Impervious	Open Water, Alluvium
Clay Tills	St. Joseph Till, Glaciolacustrine Deep Water Deposits, Lacustrine Clay and Silt, Man-Made Deposits, Tavistock Till Fluvial Deposits, Modern Fluvial Deposits, Flood Plain Deposits[1]
Silt Tills	Bruce Till, Dunkeld Till, Elma Till, Rannoch Till, Newmarket Till, Tavistock Till
Sand Tills	Catfish Creek, Wentworth Till
Sand and Gravels	Eolian Deposits, Fan or Cone Deposits, Aeolian Deposits, Glacial-outwash Sand, Glaciofluvial ice-contact Deposits, Glaciofluvial Outwash Deposits, Glaciolacustrine Deposits Beach Bar, Glaciolacustrine Deposits Shallow Water, Glaciolacustrine Shoreline Deposits, Modern Beach Deposits, Ice-contact deposits
Bedrock	Exposed Bedrock or Bedrock with Thin Drift.

3.14.1.2 Land Cover

Land cover datasets were created by overlaying the following existing datasets: forested areas (Ministry of Natural Resources and Forestry (MNRF) Forest Resource Inventory); wetland areas (MNRF wetlands); and urban areas identified on the municipal parcel fabric. Land areas that did not fall into one of the three categories (forest, wetland or urban) are assigned as agricultural.

3.14.1.3 Hummocky Topography

Hummocky topography is those areas typified by highly variable, gentle slopes that have high depressional storage and closed depressions with no outlets. They are commonly associated with

moraines in the region. These areas typically have enhanced recharge rates due to the lack of outlet and increase depressional storage. Areas of hummocky topography were identified in the Grey Bruce Groundwater Study (WHI, 2003). These areas were then overlain on the land cover data set to create unique HRUs. All areas of identified hummocky topography were given the hummocky land cover designation. Final land cover categories are listed below in Table 3.14.2.

TABLE 3.14.2 – Land Cover Reclassification for HRU Development

Land Cover Reclassification
Wetland
Forested
Urban
Agricultural
Hummocky

3.14.2 Hydrologic Response Unit Creation

Hydrologic response units (HRUs) were then created by combining all four reclassified datasets – quaternary geology, land cover, karst, and hummocky topography – into 16 HRUs, as shown in Table 3.14.3.

TABLE 3.14.3 – HRU Classifications

HRU	***Description***
1	Impervious
2	Wetland
3	Clay / Clay Till Agricultural
4	Silt Till Agricultural
5	Sand Till Agricultural
6	Sand & Gravel Agricultural
7	Low Permeability Forest
8	High Permeability Forest
9	Low Permeability Hummocky
10	High Permeability Hummocky Vegetation
11	Clay / Clay Till Urban
12	Silt Till Urban
13	Sand Till Urban
14	Sand & Gravel Urban
15	Bedrock
16	Karst

It should be noted that clay till and silt till were grouped together into the “low permeability” category, while sand till and sand and gravel were grouped into the “high permeability” category for forested and hummocky land cover groups. This was done to be consistent with HRU development methodologies in abutting Source Protection Regions.

3.14.2.1 Assigning Recharge Values to HRUs

Recharge values for individual HRUs were derived from a surface water model calibration exercise using the GAWSER modelling package.

3.14.2.2 Determination of Groundwater Recharge Areas

In order to determine which HRUs would be considered significant groundwater recharge areas, the Peer Review Committee recommended the approach outlined in Technical Rule 44 (1); whereby any HRU with an annual recharge rate more than 1.15 times the average for the SPA would be considered an SGRA.

Accordingly, mean annual adjusted recharge values for all HRUs in the Saugeen Valley Source Protection Area was developed, and all HRUs with values more than 1.15 times this mean were identified as potential SGRAs. The mean recharge in the Saugeen SPA was 283 mm/year, and the corresponding threshold for identifying potential SGRAs was set at (283 mm/year X 1.15) 326 mm/year. Therefore, all HRUs with modelled recharge values greater than 326 mm/year were identified as potential SGRAs.

3.14.2.3 Determination of Significance

In order to determine significance under Technical Rule 45, the identified SGRA must have a drinking water system located within it. In order to assess this, the HRUs identified as having annual adjusted recharge rates greater than 1.15 times the SPA mean were assembled into new, larger polygons. These polygons were then screened, and any areas less than 1 ha were removed. Due to the prevalence of wells throughout the area, an assumption was made that all remaining recharge areas reasonably have the potential to be hydraulically connected to a drinking water system, consistent with Technical Rule 45. Significant groundwater recharge areas are shown in Map 3.11.

3.14.3 Data Limitations and Uncertainty

The data used for the development of the SGRAs is based on existing climate data, Tier I surface water modelling outputs and existing geological and land cover data. These datasets were not developed for the explicit purposes of delineating SGRAs, and have certain limitations that can be attributed to them, specifically:

- Climate data has been filled and corrected to try and account for missing data for discrete time intervals and locations where no monitoring stations exist.
- Surface water modelling has been completed for the entire source protection area, yet has not been calibrated in certain regions due to a lack of monitoring data. In such cases models were calibrated to similar subwatersheds.

- Land cover data is valid only at the time it was collected, and has not been altered or corrected for changes in land use since the time of collection.

The SGRAs have not been evaluated with respect to their hydrologic connection to specific aquifers themselves. Rather, they have been calculated to the nearest surficial aquifer. Recharge areas for confined regional aquifers may lie outside areas. Future use of this delineation, specifically at local scales, should consider the aquifer of interest before employing this methodology.

Uncertainty for SGRAs is a measure of the reliability of the delineations with respect to providing protection to the overall groundwater system, rather than specific aquifers. In this light, the methodology for calculating SGRAs is highly reliant on the surficial geology of the area and can be considered reliable for the overall groundwater system. The uncertainty for the SGRAs is considered low for the source protection area.

3.15 Peer Review

The water budget process was completed in consultation and with the approval of a peer review committee. This committee was formed at commencement of the water budgeting exercise and met regularly throughout the process. The following were part of the peer review committee:

Brad Benson, P.Geo, *hydrogeologist*, Genivar Consultants
Stan den Hoed, P.Eng, *hydrogeologist* , Harden Environmental
Miln Harvey, P.Eng, *hydrogeologist*, Schlumberger Water Services
Alge Merry, P.Eng, *hydrogeologist*, Schlumberger Water Services
Lynne Milford, *water budget analyst*, Ministry of Natural Resources and Forestry

3.16 Tier III Water Budget

Based on the outcome of the Tier II water quantity stress assessment, it was determined that a Tier III analysis was required for the subwatershed in the vicinity of Lake Rosalind in the Municipality of Brockton to the west of Hanover. The Town of Hanover operates a municipal drinking water system that is supplied by two wells near Marl Lake and a surface water intake at Ruhl Lake. The Municipality of Brockton operates a small municipal drinking water system that is supplied by two wells on the west side of Lake Rosalind.

3.16.1 Tier III Methodology

According to the *Technical Rules* (MOECC, 2009), Tier III Assessments are required to complete the following steps:

- Develop conceptual and numerical Tier III Assessment models with detailed hydrogeologic and/or hydrologic characterization surrounding municipal wells and intakes
- Characterize the municipal wells and intakes and identify the low water operating constraints of those wells and intakes

- Estimate the allocated and planned quantity of water by compiling and describing the existing, committed, and planned rates for each municipal well and intake
- Identify and characterize drinking water quantity threats
- Evaluate the potential impact of future land use changes on drinking water sources
- Characterize and identify other water uses that might be influenced by municipal pumping
- Delineate vulnerable areas (WHPA Q1, WHPA Q2, and IPZ-Q) using the models
- Define the Local Area based on the delineation of the WHPA Q1, WHPA Q2, and IPZ-Q areas
- Evaluate the risk assessment scenarios, using the models to simulate the conditions at each well and intake during average and drought conditions, and under varied municipal pumping and recharge conditions
- Assign a Risk Level (Low, Moderate, or Significant) to the Local Areas based on the results of the risk assessment scenarios. An uncertainty level (i.e., high and low) will accompany each risk level
- Identify drinking water quantity threats for Local Areas where the risk level is significant and moderate

3.16.2 Water Budget Modelling Tools

The Tier II Assessment completed for the Saugeen, Grey Sauble, Northern Bruce Peninsula Source Protection Region (AquaResource, 2010) identified the Lake Rosalind Groundwater Assessment Area as having a moderate potential for groundwater stress. This identification of stress potential led to the requirement of a Tier III Assessment for the municipal supply wells of the Town of Hanover and Community of Lake Rosalind. As Ruhl Lake supplies a significant proportion (45%) of Hanover's water supply, and because it is considered hydraulically connected to the shallow groundwater system, the intake at Ruhl Lake was included in this Tier III Assessment (Matrix, 2016).

The Tier III Assessment involved a detailed review and representation of the physical system within the area of the Hanover and Lake Rosalind municipal water supplies in Bruce County. The conceptual model used within the Tier III Assessment was refined and enhanced from an earlier conceptualization from the Tier II Assessment (Matrix, 2016).

A regional FEFLOW groundwater flow model developed for the Tier I Assessment (AquaResource, 2008a) was updated and refined in the Tier II Assessment (AquaResource, 2010) and further refined in this Tier III Assessment. The areas of refinement were focused around the four Tier III municipal wells and the Ruhl Lake area to assess groundwater flow and the potentiometric surface impacts at a well field scale. The groundwater flow model was calibrated to observed water levels at both a local (municipal well field scale) and regional (regional groundwater model domain) scale. The Tier III Assessment groundwater flow model was calibrated at the municipal well field-scale to steady-state (long-term average) conditions. A transient calibration was not completed due to a lack of observed pumping and water level data and hydraulic conductivity and storage estimates were noted as a data gap (Matrix, 2016).

The GAWSER watershed-based flow generation model was developed, peer-reviewed, and applied for the Tier I (AquaResource, 2008b) and Tier II Assessments (AquaResource, 2010)

and was applied to determine a water budget for the Marl Creek subwatershed area (Figure 3.1). GAWSER outputs were also used to develop a spreadsheet-based, water budget model to estimate water level and discharge from Ruhl Lake. The spreadsheet model was linked to the groundwater model through the groundwater discharge component. As the FEFLOW and GAWSER models were calibrated to observed steady-state water levels and transient stream flows, they were considered reliable tools for water budget estimation (Matrix, 2016).

3.16.3 WHPA-Q1 Delineation

The WHPA-Q1 was delineated as the combined area that is the cone of influence of a well and the whole of the cones of influence of all other wells that intersect that area (MOE 2009).

Two WHPA-Q1 areas lie within the study area (Figure 3.16.1). The largest (WHPA-Q1-A) is circular in shape, encompasses the municipal wells of the Town of Hanover and extends radially outward from those wells southeast to the Saugeen River, and north to the Lake Rosalind Wells. The water level elevations in the production aquifer at Hanover Wells 1 and 2 were simulated in the model to be lower than observed. As such, the drawdown associated with municipal pumping at the allocated rates, and the delineated WHPA-Q1, may be larger than reality. Therefore, the extent of the WHPA-Q1-A for the Hanover wells is conservative (Matrix, 2016).

In Lake Rosalind, the maximum drawdown was predicted to be less than 2 m at each of the Lake Rosalind wells and extend in the vicinity immediately surrounding each well. As such, the WHPA-Q1 surrounding the Lake Rosalind Wells is represented by a single 100 m buffer zone (WHPA-Q1-B) that surrounds each well (Figure 3.16.1). The size and shape of the area were chosen because, due to a lack of operational pumping rates, it was determined that any further modelling would not produce improved results. Therefore the WHPA-Q1-B was aligned to the current WHPA-A for Lake Rosalind, as it represents a small area constrained to the immediate vicinity around the wells, which were determined to be significant drinking water threats. There are no permitted non-municipal consumptive water users located within the WHPA-Q1 areas (Matrix, 2016).

While the WHPA-Q1-A and WHPA-Q1-B areas overlap, they remain separate due to the demonstrated hydraulic separation between the two aquifers. The two Town of Hanover wells are completed within a deep confined overburden aquifer, while the two Lake Rosalind Wells are completed in a shallow unconfined aquifer. Previous characterization and field studies in the demonstrated that the two flow systems are separate. The deeper aquifer has a high yield, is of good quality, and is not influenced by surface water of the shallow aquifer. Field work included drilling shallow and deep wells roughly 2 m apart near Ruhl Lake 1 km west of the Lake Rosalind Wells. The observed water level in the shallow aquifer was 5 m higher than the water level in the lower aquifer, suggesting hydraulic isolation between the two units in the area. Due to the small magnitude of pumping by the Lake Rosalind system (27 m3/day) and the demonstrated hydraulic separation, each WHPA-Q1 area (and subsequent Local Areas) remain as separate areas and therefore any elevated (i.e., moderate or significant) risk level assigned to one area will not automatically be assigned to the other area (Matrix, 2016).

3.16.4 WHPA-Q2 Delineation

The WHPA-Q2 is defined by the *Technical Rules* as the WHPA-Q1 area plus any area where a future reduction in recharge may have a measurable effect on the wells inside the WHPA-Q1. Due to the fact that the land use and associated recharge rates are not expected to change, the WHPA-Q2 area is identical to the WHPA-Q1 for both Local Areas A and B, the Hanover and Lake Rosalind areas respectively.

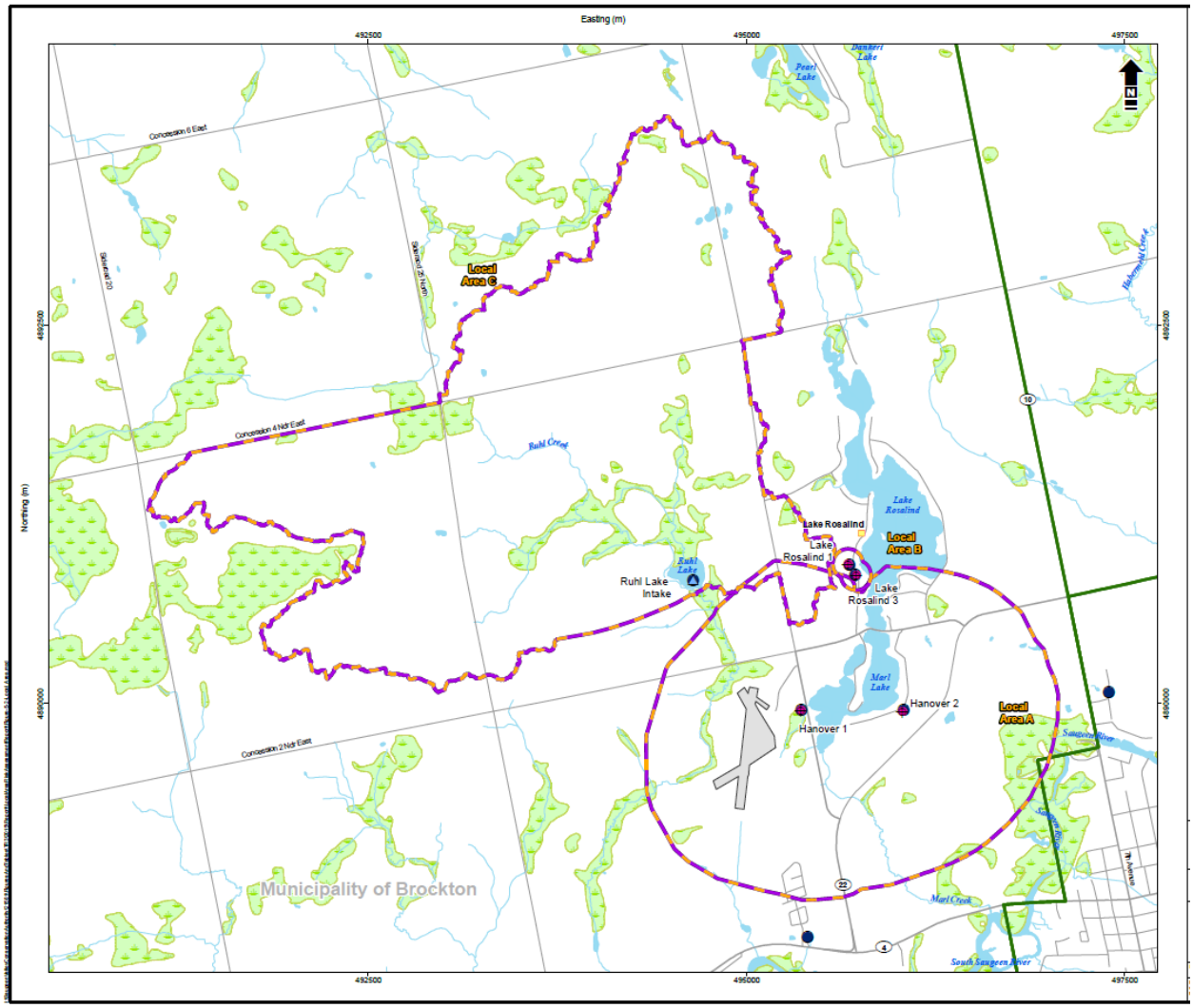

Figure 3.16.1 Local Areas Delineated for the Study Area Risk Assessment

3.16.5 IPZ-Q Delineation

IPZ-Q, corresponds to the drainage area that contributes surface water to an intake, and the area that provides recharge to an aquifer that contributes groundwater discharge to the drainage area. Part VI.7 of the *Technical Rules* specifies the rules with respect to the delineation of IPZ-Q (Matrix, 2016).

3.16.6 Local Area Delineation

"Three Local Areas (Local Areas A, B, and C) were delineated surrounding the municipal intake and supply wells in the Study Area (Figures 3.16.1). The areas were delineated following the Technical Rules (MOECC, 2009) based on a combination of the cone of influence of each municipal well (WHPA-Q1) and the surficial drainage area, which may contribute water to" surface water intake and associated area that provides recharge to an aquifer that discharges to the drainage area (IPZ-Q) (Matrix, 2016).

3.16.7 Local Area Risk Assessment

A set of risk assessment scenarios (Table 3.16.1) were developed to represent the municipal existing and allocated rates (existing plus committed pumping rates) and current land uses. The calibrated groundwater and spreadsheet-based water budget models were used to estimate water level decline in Ruhl Lake and drawdown in the Town of Hanover municipal wells under average and drought conditions. Impacts to other water uses under average climate conditions were evaluated with the groundwater model through the assessment of impacts to groundwater discharge to coldwater features. The estimates of drawdown in all scenarios were based on the assumption that wells are maintained in their current conditions (Matrix, 2016).

The risk assessment scenarios predicted that there was a low risk level associated with the operation of the intake (Local Area C) and wells (Local Area A) for Hanover. Risk assessment scenarios were not completed for the Lake Rosalind Wells due to the historical observation that the municipal system has had difficulty meeting demand in the past and the recognition that a significant risk level would automatically apply to Local Area B, surrounding the Lake Rosalind wells (Matrix, 2016).

Table 3.16.1 Surface Water and Groundwater Risk Assessment Model Scenarios

Scenario	Time Period	Model Scenario Details		
		Land Cover	Municipal Water Demand	Model Simulation
Surface Water Risk Scenarios				
A	Full Climate Record (1950 to 2005), Including Drought Periods	Existing	Existing	Simulate transient water levels using hourly climate and monthly pumping. Assess using average water levels.
B	Full Climate Record (1950 to 2005), Including Drought Periods	Existing	Existing	Simulate transient water levels using hourly climate and monthly pumping. Assess using minimum water levels.
E(2)	Full Climate Record (1950 to 2005), Including Drought Periods	Existing	Allocated	Simulate transient water levels using hourly climate and monthly pumping. Assess using average water levels.
F(2)	Full Climate Record (1950 to 2005), Including Drought Periods	Existing	Allocated	Simulate transient water levels using hourly climate and monthly pumping. Assess using minimum water levels.
Groundwater Risk Scenarios				
C	Average of Climate Record (1950 to 2005)	Existing	Existing	Steady-state, simulate water levels using average annual recharge and average annual pumping
D	Full Climate Record (1950 to 2005), Including Drought Periods	Existing	Existing	Transient, simulating water levels using monthly recharge and monthly pumping
G(2)	Average of Climate Record (1950 to 2005)	Existing	Allocated	Steady-state, simulate water levels using average annual recharge and average annual pumping
H(2)	Full Climate Record (1950 to 2005), Including Drought Periods	Existing	Allocated	Transient, simulating water levels using monthly recharge and monthly pumping

3.16.8 Significant Water Quantity Threats Enumeration

Due to the low risk level of Local Areas for Ruhl Lake and the Hanover wells, no significant threats were assigned to Local Areas A and C. The Lake Rosalind area was determined to be of a significant risk level, therefore threats were assigned to Local Area B; the two permitted municipal water takings and a non-permitted private groundwater taking (see Table 3.16.2).

Table 3.16.2 Count of Significant Water Quantity Threats by Threat Group

Threat Group	Local Area	Source Protection Area	Municipal Area
	Local Area B	Saugeen Valley Source Protection Area	Municipality of Brockton
Municipal	2	2	2
Non-municipal Permitted	0	0	0
Non-Municipal, Non-Permitted	1	1	1
Recharge Reduction[1]	0 km^2 (0% of Local Area B)	0 km^2 (0% of the Saugeen Valley Source Protection Area)	0 km^2 (0% of the Municipality of Brockton Area)
Total	Total # of Significant threats within all Local Areas of the Tier Three Assessment 3	Total # of Significant threats within all Source Protection Areas of the Tier Three Assessment 3	Total # of Significant threats within all Municipalities of the Tier Three Assessment 3

3.16.9 Peer Review of Tier III Water Budget

The Tier III water budget process was completed in consultation and with the approval of a peer review committee. The following were part of the peer review committee:

Kathryn Baker, M.S.c, P.Geo., *hydrogeologist*, Ministry of the Environment and Climate Change
Ron Cooper, *director of Public Works*, Town of Hanover
Stan den Hoed, P.Eng., *hydrogeologist*, Harden Environmental
Lynne Milford, *water budget analyst*, Ministry of Natural Resources and Forestry
Hugh R. Whiteley, PhD. School of Engineering, *hydrologist*, University of Guelph

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