WATER QUANTITY RISK ASSESSMENT

March 2015

Essex Region Source Protection Area

Updated Assessment Report

APPROVED

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MAPS: Please see separate file and/or binder

***Note:** The information contained in this section of the Essex Region Assessment Report was approved in 2011. Updates in this version have been restricted to grammatical corrections.

3.0 Water Quantity Risk Assessment

3.1 Introduction

One of the requirements of the Clean Water Act of the Province of Ontario is to perform water quantity risk assessments for drinking water sources. To this end, as per the Provincial guidelines, each Source Protection Area is required to generate various levels (Conceptual, Tier 1, and where applicable Tier 2 and Tier 3) of water budget estimates. The complexity in methodologies increases for each of the water budget levels. At a minimum, each region is required to generate Conceptual and Tier 1 water budget estimates. The Essex Region Source Protection Area (SPA) has developed the water budgets at two levels – Conceptual water budget and Tier 1 water budget.

The objective of these water budget analyses is to estimate the quantities of water within the various reservoirs of the hydrologic cycle as applicable to the subwatersheds of the region, including precipitation, evapotranspiration, runoff, groundwater inflow and outflow, surface water inflow and outflow, change in storage, water withdrawals and water returns. All water sources are placed into the context of the subwatershed region, such that the cumulative water takings and in-stream needs are taken into account. In order to achieve this, the water budget studies made an effort to describe the groundwater and surface water flow pathways and develop temporal, seasonal and annual estimates and changes in water quantities within each reservoir (i.e. surface water streams and groundwater). The studies focussed on identifying areas of key hydrologic processes (e.g., recharge and discharge areas) and the availability of potential water sources (aquifers and unused surface water sources), and water use by different sectors in each of the subwatersheds. Based on the methodology provided in the guidelines, the stresses on the hydrological regime were evaluated.

The Conceptual water budget and substantial parts of the Tier 1 water budget studies were peer-reviewed by a committee consisting of representatives from the academia, consulting, government and Conservation Authorities. In order to bring in the knowledge generated from the neighbouring source protection region, the Essex Region SPA and the Thames-Sydenham and Region Source Protection Region (TSRSPR) shared the same peer-review committee to review the reports of the water budget studies. This has benefited both regions in transferring the knowledge between the two regions.

Based on the locations of municipal drinking water sources, and stress conditions evaluated in the Tier 1 water budget, Tier 2 and Tier 3 levels of water budgets are normally performed. Because there are no inland water intakes or wells for municipal drinking water systems in the Essex Region SPA, Tier 2 and Tier 3 levels of water budget studies will not be performed under the source protection program at this time. However, the findings from the Tier 1 water budget studies will aid water resources management decisions for purposes other than drinking water supplies. There might be other opportunities to perform these water budget studies under other programs.

3.2 Data and Information Sources

The Conceptual and Tier 1 water budget studies such as the ones reported in this chapter require compiling datasets from a wide variety of sources and obtaining information from the reports completed through various studies in the past. The following table shows the data, their sources and purpose for which they are used:

Table 3.1: Data Sources – Water Quantity Risk Assessment

	Data Type	Data Source	Data Source Purpose
1.	*Physical data*		
	Topography, Drainage	Provincial Digital Elevation Model (DEM) database	Delineating of the subwatersheds, establishing the drainage patterns
	Soils	LIO*	Determining the infiltration characteristics, excess runoff, recharge potential
	Land Use	LIO*	Determining of evapotranspiration, runoff characteristics
	Geology	LIO*, Ontario Geological Survey Maps	Delineation of hydrostatigraphic units (hydrogeology)
	Hydrogeology	Water well database, groundwater studies, landfill studies, LIO*	Establish the hydrogeological cross-sections, establishment of groundwater recharge, discharge areas, groundwater flow pattern, etc. Assessment of groundwater potential and flow directions
2.	*Climate data*		
	Precipitation, temperature, wind velocity, solar radiation and humidity	Climate database of Environment Canada, Provincial database on corrected climate data	Summary of climate parameters and their trends, estimating evapotranspiration
3.	*Streamflow*		
	Streamflow	Environment Canada's HYDAT data	Establishing the runoff characteristics, estimating the base flows, recharge rates
	Baseflows	Field measurements	Developing knowledge about low flows and dry streams
4.	*Water use*		
	Permitted water uses	MOE PTTW** database	Estimate the permitted water demand in different subwatersheds
	Field surveys	Surveys completed by representative water users with assistance from the Source Protection Committee members	Compare water use rates specified in water use permits and estimate actual water usages

* LIO: Land Information Ontario
**PTTW: Permit To Take Water

The references of the previously completed studies used for the purpose of water budget assessment are provided at the end of the subwatershed description report, Conceptual and Tier 1 water budget reports. Some of the important ones include:

Balakrishna, T., Strynatka, S., and G. Harvey. 2004. Groundwater Resources Inventory Paper, Windsor-Essex Region – Draft Report, Essex Region Conservation Authority.

Dillon Consulting. 2004. Essex/Chatham-Kent Regional Groundwater Study: Volume I Geologic/Hydro-geologic Evaluation

Dillon Limited, M.M. 1988. Essex County Landfill No.3 Application for continued use, Hydro-geological Analysis, 171p.

Morris, T. F. 1994. Quaternary Geology of the Essex Region – Ontario Geological Survey, Open File Report 5886, 130p.

Singer, S.N., Cheng, C.K., and M.G. Scafe. 1997. The Hydrogeology of Southern Ontario; Ministry of Environment and Energy, Report 1, 80p.

Waterloo Hydrologic Inc. 2006. Six Conservation Authorities FEFLOW Groundwater Modeling Project, Waterloo.

3.3 Conceptual Water Budget

The Conceptual Water Budget Report as completed by Dr. Bolisetti (2008) is found in **Appendix III**. To develop the conceptual understanding, all the available data and maps were examined to locate all climate stations, groundwater monitoring wells, and surface water flow gauges in the area. The report includes an initial understanding of the various reservoirs and fluxes in the study area (precipitation, recharge, runoff, evapotranspiration, etc.). An understanding of the geologic system and consideration of surficial features and a preliminary inventory of all water uses and withdrawals is summarised in this report. An effort was made to identify and prioritize data gaps. At the end, the report presents a discussion on the screening decisions for moving forward on the Tier 1 Water Budget.

3.3.1 Physical Description

The Essex Region consists of about 28 drainage areas, as shown in **Map 2.1** and as discussed in **Section 2 (Watershed characterization)**. The subwatersheds may be broadly delineated into three major drainage areas in the mainland consisting of the areas that drain to Lake St. Clair, Detroit River and Lake Erie (**Table 3.2**). The Conceptual water budget estimates were generated at the level of these major drainage areas. On the time scale, the water budgets were analysed at both annual and seasonal scales.

Table: 3.2: Major Drainage Areas in Essex Region SPA

Drainage Basin	Area (km^2)
Lake Erie	239.7
Detroit River	218.0
Lake St. Clair	425.8

The Essex Region is predominately made up of flat, productive land with relatively small areas of forest and wetland habitat. **Map 2.9** presents the topography of the region. The Essex Region is a part of the Essex Clay Plain, which itself is a sub-division of the St. Clair Plain physiographic region. The soils (**Map 3.1**) found in the Essex Region are the end result of glacial lake action (Ontario Ministry of Natural Resources, 1975). The overburden stratigraphy in the Essex Region, as shown in **Map 3.2**, consists of several distinct types of material, which include tills, clays, fine to coarse-grained glaciolacustrine deposit and lacustrine sediments. The overburden in most of the study area is less than 40 meters in thickness (**Map 2.13**). The bedrock, as shown in **Map 2.10**, is underlain by a thick succession of Paleozoic sedimentary rocks which are a part of the Michigan Basin sedimentary deposits. The oldest formations are found in the south part of the region, generally along the Lake Erie shoreline, while the youngest formations are found primarily in the north part of the Region.

As discussed in **Section 2.1.3**, more than three-quarters of the area is used for agriculture, with cash-crop farms, specialty crops, orchards and greenhouse farming being the most prevalent agricultural uses. The remainder of the area is roughly 18 percent urban land use and 7.5 percent natural heritage such as forests and wetlands. The agricultural fields in the region are extensively drained by tile drains and other artificial drainage.

3.3.2 Surface Water Conditions

As mentioned in the previous section, the Essex Region consists of about 28 drainage areas which may broadly be divided into three major drainage areas on the mainland consisting of the areas that drain to Lake St. Clair, Detroit River and Lake Erie. Pelee Island, in Lake Erie, was studied as an additional separate drainage area. Most of the streams/rivers/creeks in the Essex Region flow through flat terrains of clay or sand plains. The flat terrain of the study area poses problems in delineating the drainage areas. Surface drainage in much of the region is influenced by a ridge, extending roughly from the south part of Windsor, in a south-easterly direction through the central part of the Region. This ridge defines a drainage divide, north of which water flows into Lake St. Clair and Detroit River, while south of the divide streams empty into the Detroit River and Lake Erie.

Another smaller ridge trending southeast to northwest about 5 km north of the Lake Erie shoreline is evident in the southwest part of the region. Many of the streams in the Essex Region have extensive marsh areas at the mouth which fluctuate in size with the lake levels. Many have headwaters which periodically dry up in the summer due to extensive artificial drainage and historical clearing/removal of wetlands. Throughout most of the Essex Region, ditches have been excavated, and tile drains have been installed, in order to improve the drainage and provide satisfactory conditions for crop growth and tillage (Chapman and Putnam, 1984). The natural drainage patterns of many of the subwatersheds have been extensively artificially realigned, primarily for agricultural purposes. Cedar Creek, Big Creek, Turkey Creek, Little River, Canard River and its Long Marsh Drain tributary, have been substantially altered by major diversions in parts of their subwatershed areas, as shown in **Map 3.3**. There are no major flow control structures such as large dams in the Region, although there are several major dyke systems.

At the time this report was prepared, there were four active stream gauging stations (on Canard River, Ruscom River, Little River and Turkey Creek) and one inactive stream gauging station in the Region (on Sturgeon Creek). There were two other gauging stations (2^{nd} Concession drain and 5^{th} Concession drain) in the SPA region. However, these two stations were test sites with very limited periods of operation. The streamflow characteristics and further information on surface water conditions are summarized in the Tier 1 Water Budget analysis **(Section 3.4** of this Assessment Report).

A brief summary of aquatic habitat is presented in the Watershed Characterisation of this Assessment Report **(Section 2.6).**

3.3.3 Surface Water Intakes

There are seven municipal water treatment plants (WTPs) in the Essex Region. Municipal water use includes domestic, commercial and institutional uses which depend on the municipal water distribution systems for their water requirements. **Table 3.3** lists all the WTPs in the Essex Region and their rated capacities. All of the municipal water treatment plants obtain water from surface water sources of the Great Lakes system. There are two intakes each in Lake St. Clair (Stoney Point WTP and Belle River WTP), Detroit River (Windsor WTP and Amherstburg WTP) and three in Lake Erie (Union WTP, Colchester WTP and Township of Pelee-West Shore).

Domestic use consists of the largest proportion of the municipal water supply in most areas. The municipal water distribution systems serve more than 95% of the population in the region. As further discussed in **Section 3.4.2.3**, a population of about 2700 (about 900 households) in the rural areas are not yet serviced by municipal distribution systems.

The quantities given in **Table 3.3** may not affect the water budget directly as the water for these municipal treatment plants is pumped out of the Great Lakes system. However, these quantities give an idea, in some cases, as to how much of this water supply is likely to return to the streams, in the form of sewer outflows. In most cases, wastewaters are discharged directly into the Great Lakes system. However, some urban areas discharge into the inland streams.

Table 3.3: Water Treatment Plant Capacity

Water Treatment Plants (WTPs)	Water Source	Rated Capacity of WTP (m^3/day)
Stoney Point	Lake St. Clair	4,546
Belle River	Lake St. Clair	36,400
Windsor	Detroit River	349,000
Amherstburg	Detroit River	18,184
Harrow-Colchester	Lake Erie	10,227
Union	Lake Erie	124,588
Pelee Island-West Shore	Lake Erie	153

3.3.4 Assessment of Surface Water Use

As discussed in the previous section, the water for municipal drinking water purposes is obtained from the Great Lakes system. However, there are other *permitted* and *non-permitted* water demands. The permits issued by the Ministry of Environment under the 'Permit to Take Water' (PTTW) program are classified according to their purpose and type of source water and are shown in **Map 3.4**. Based on the data available during the Conceptual water budget study, very rough estimates of rates of surface water use were developed. However, these estimates of the maximum and actual demands of water use were further improved during the Tier 1 water budget study, as presented in **Section 3.4.2** of this Report.

3.3.5 Groundwater Assessment

A conceptual understanding of groundwater and hydrogeological conditions was developed mainly with information from previous studies, largely based on water well drilling records. Various aquifers in this area may be classified into overburden aquifers, contact aquifer and bedrock aquifer (Dillon, 2004). The water table surface (**Map 3.5**) closely reflects the surface topography. The map shows that the principal direction of shallow groundwater flow is away from the two topographic ridges that are aligned southeast to northwest, and therefore is generally to the northeast or southwest. Groundwater flows toward the major surface water bodies i.e., Lake St. Clair, Detroit River and Lake Erie, which surround most of the study area. As shown in the potentiometric surface map (**Map 3.6**), the groundwater within the contact aquifer generally flows in a radial pattern away from the high area in Leamington. Most of the near surface bedrock units consist of interbedded limestones, dolostones, and shales. The bedrock aquifers appear to be confined to the limestone and dolomite formations within the region. The morainic areas around Leamington and parts of the sandy formations near Harrow are the significant recharge areas as discussed further in **Section 3.4.3.**

There are no groundwater wells that pump water for municipal drinking water systems in this region. Most of the groundwater is used for various non-municipal purposes, such as agriculture, dewatering of quarries, commercial and recreational uses and domestic use in un-serviced areas. The estimates of permitted and non-permitted water use (both maximum and actual) for the present period are developed during the Tier 1 water budget study and are discussed in **Section 3.4.2.**

3.3.6 Surface and Groundwater Interaction

A brief discussion on the surface and groundwater interaction is presented as part of the Tier 1 Water Budget study, **Section 3.4.3** in this report. In order to understand the groundwater inflow and outflow dynamics, recharge and discharge areas are presented in **Map 3.7**.

3.3.7 Climate Assessment

The climate data on meteorological parameters and streamflow used in the water budget studies were obtained from Environment Canada’s website. The Ontario Ministry of Natural Resources ensured that the precipitation and temperature datasets were filled in, since there were significant gaps in Environment Canada’s database. The annual means of daily temperatures at different stations in the Essex Region were found to lie just above 9^{o}C and are the highest in southern Ontario. The mean temperatures were found to range from less than -19^{o}C in winter, to higher than 34^{o}C in summer. The mean values of annual maximum temperature vary between 31.7^{o}C and 34.2^{o}C, and the mean values of annual minimum temperatures range between -16.8^{o}C and -19.6^{o}C for different stations in the study area. A summary of mean maximum and minimum temperature for the region is shown in **Table 3.4**. The highest temperature usually occurs in the month of July while the lowest temperature occurs in January.

The mean monthly precipitation values for six climate stations are also shown in **Table 3.4**. The mean annual rainfall amounts in the mainland portion of the study area ranged between 686 mm and 849 mm. Almost 47% of annual precipitation occurs between the months of May to September. The highest and the lowest annual rainfalls recorded on the mainland were 1152 mm and 569 mm, respectively. The highest and lowest annual rainfall amounts recorded at the Pelee Island station are 1402 mm and 509 mm, respectively, in 1892 and 1987. The Essex Region receives most of its snow during the months of December to February.

As part of the Tier 1 Water Budget study, the actual evapotranspiration (ET) rates were estimated using Penman-Monteith method for various stations. They ranged between 500-546 mm (**Table 3.4**). This is equivalent to 60-65% of the precipitation. In general, the southern part of the Region has lower evapotranspiration rates.

Table 3.4: Summary of Climate Data (1950-2005)

Station Name	Annual Precipitation (mm)	Mean Monthly Maximum Temperature (^oC)	Mean monthly Minimum Temperature (^oC)	Annual Evapotranspiration (ET) (mm)
Amherst-burg	867	9.3 – 34.2	-17.6 – 11.0	563
Harrow	845	9.0 – 33.0	-18.5 – 10.1	520
Kingsville-MOE	835	8.6 – 31.7	-18.1 – 11.2	500
Windsor Airport	887	9.3 – 33.9	-18.2 – 11.4	546
Windsor Riverside	848	9.8 – 34.2	-16.8 – 10.8	548
Woodslee CDA	827	9.1 – 33.4	-19.6 – 9.2	531

Climate Change

At the time this report was prepared, no detailed studies on climate change had been carried out for the Essex Region. An overview of climate change research, and potential implications, is provided in **Section 6 (State of Climate Change Research in the Great Lakes Region)** of this Assessment Report.

3.4 Tier 1 Water Budget

3.4.1 Introduction

The Tier 1 Water Budget Report completed by Dr. Bolisetti (2011) is found in **Appendix IV.** Please refer to the full report in the appendix for more complete details. The Tier 1 water budget study is aimed at developing the water budget estimates at a relatively finer scales compared to the Conceptual water budget. There are more than 20 drainage areas in the Essex Region. However, due to the paucity of data at this level, it was decided to develop Tier 1 level water budgets at the quaternary watershed scale. To remain consistent with Provincial requirements, a quaternary watershed will be referred to as a subwatershed in this report. The subwatersheds are shown in **Map 3.8** and have their respective drainage areas listed in **Table 3.5**. There are a total of eleven subwatersheds within the Essex Region SPA, eight subwatersheds and two partial subwatersheds (shared with the Thames-Sydenham Region SPR) on the mainland, and one subwatershed for Pelee Island. Monthly time scales were adopted for estimating the water budget components and assessing stress conditions.

The Province recommends that the Tier 1 water budget analysis be performed using simple spreadsheet based calculations. However, if an implemented model is already available, the model may be used. Hence, the water budget estimates were developed through a combination of hydrological modeling and desktop calculations. The water budget analysis in two gauged subwatersheds (Canard River and Ruscom River) was performed using the Soil and Water Assessment Tool (SWAT). Water budgets were developed for two other gauged subwatersheds (Little River and Turkey Creek) based on simple spreadsheet calculations. The water budget estimates for the other (ungauged) subwatersheds were generated by extrapolating findings from gauged subwatersheds.

Table 3.5: Subwatershed Drainage Areas

Sub-watershed ID	Subwatershed Name	Drainage Area (Km^2)
2GE-01	Little Creek	42.3
2GH-01	Little River, Pike Creek, Puce River, etc.	271.3
2GH-02	Ruscom River	198.2
2GH-03	Belle River	151.0
2GH-04	Turkey Creek and other nearby drainage areas	114.5
2GH-05	Canard River	348.6
2GH-06	Big Creek	113.8
2GH-07	Cedar, Wigle, and Mill Creeks, etc.	229.2
2GH-08	Sturgeon Creek and other areas around Point Pelee	79.2
2GH-09	Hillman and Muddy Creeks, etc.	92.7
2GH-10	Pelee Island	41.2
	Total:	1682.0

3.4.2 Water Use

The water use in the Essex Region includes *permitted* water use and *non-permitted* water uses. Through MOE's Permit To Take Water (PTTW) program, those who want to pump more than 50,000 litres/day, are required to obtain a permit. The water demand under these permits is referred to as *permitted* demand. The water use for purposes such as livestock, or pumping rates less than 50,000 litres per day do not require permits. These water demand rates are referred to as *non-permitted* demand. The Tier 1 Water Budget study has identified the following sectors under *permitted* water use: Municipal water supply, Agriculture, Dewatering (Pits and Quarries), other Commercial, Industrial, Construction, and Miscellaneous.

3.4.2.1 Municipal Water Use

The supply for municipal drinking water systems is from the Great Lakes System and hence, the permits for municipal drinking water systems' supply were excluded from the water use estimation, as per the Provincial guidelines.

3.4.2.2 Permitted Water Demand

The estimates of annual consumptive water use from surface water and groundwater sources in various subwatersheds are presented in **Table 3.6a**. The estimated rates of pumping include water taking rates permitted by the MOE under its PTTW program. Efforts were made to supplement these data with some representative information on actual water use in different categories of agriculture (vegetable crops, fruit and orchards, etc.) and dewatering from quarries and golf courses, provided by some members of the Source Protection Committee. The areal extents of various categories of the agricultural crops were obtained from Statistics Canada and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). The study estimated that groundwater consumption (69% of total annual water use) is higher than the consumption from surface water streams. Further details, including monthly values in applicable seasons, are provided in the Tier 1 Water Budget Report (**Appendix IV**).

Table 3.6a: Estimated Annual Consumptive Water Use (m^3/year)

Sub-watershed ID	Subwatershed Name	Groundwater	Surface Water
2GE-01	Little Creek	0	0
2GH-01	Little R., Pike Cr., Puce R, etc.	0	111,713
2GH-02	Ruscom River	367,417	603,796
2GH-03	Belle River	92,034	23,276
2GH-04	Turkey Creek	671,891	0
2GH-05	Canard River	1,387,829	41,376
2GH-06	Big Creek	454,861	649,037
2GH-07	Cedar, Wigle, Mill Creeks, etc.	1,289,810	495,820
2GH-08	Sturgeon Creek, etc.	567,199	66,156
2GH-09	Hillman, Muddy Creeks, etc.	258,097	3,410,079
2GH-10	Pelee Island	18,922	0
	Total:	5,108,060	5,401,252

These annual estimates were obtained by aggregating various monthly values during applicable seasons, as detailed in the Tier 1 Water Budget Report **(Appendix IV**). Additional details on the maximum permitted water use by source for each subwatershed is provided in **Table 3.6b**, while the consumption use factors implemented are found in **Table 3.6c**.

Table 3.6b: Total Number of Permits and Maximum Permitted Water Uses by Source

Subwatershed		No. of Permits			Annual Maximum Permitted Water Use			Surface	Ground -
ID	Name	Surface Water	Ground-water	Total	Surface Water (m^3)	Ground-water (m^3)	Total (m^3)	Water %	Water %
2GE-01	Little Creek	0	0	0	0	0	0	-	-
2GH-01	Little River, Pike Creek, Puce River and others	2	0	2	265,982	0	265,982	100	0
2GH-02	Ruscom River	6	27	33	1,083,778	537,845	1,621,623	67	33
2GH-03	Belle River	1	4	5	55,418	115,043	170,461	33	67
2GH-04	Turkey Creek and other drainage areas in the vicinity of City of Windsor	0	5	5	0	1,599,740	1,599,740	0	100
2GH-05	Canard River	8	15	23	305,440	6,450,803	7,056,470	5	95
2GH-06	Big Creek	2	4	6	6,490,373	2,181,406	8,671,779	75	25
2GH-07	Cedar Creek, Wigle Creek, Mill Creek and others	14	30	44	872,951	1,723,229	2,596,180	34	66
2GH-08	Sturgeon Creek and other areas around Point Pelee	5	7	12	155,014	572,124	727,138	21	79
2GH-09	Hillman Creek, Muddy Creek, Lebo Creek and others	36	20	56	5,010,285	383,395	5,393,680	93	7
2GH-10	Pelee Island	0	2	2	0	94,608	94,608	0	100
	Total:	**74**	**114**	**188**	**14,239,241**	**13,658,193**	**27,897,434**	**51**	**49**

Table 3.6c: Consumptive Use Factors

Category	Specific Purpose	Consumptive Factor for	
		Surface Water	**Groundwater**
Agricultural	Field and pasture crops	0.8	0.8
	Fruit orchards	0.8	0.8
	Tobacco	0.9	0.9
	Tender fruit	0.8	0.8
	Market gardens/flowers	0.9	0.9
	Other-agricultural	0.8	0.8
Commercial	Golf course irrigation	0.7	0.7
Industrial	Aggregate washing	0.25	0.25
Industrial	Other-industrial	0.25	0.25
Dewatering	Construction	0.25	1.0
Dewatering	Pits and quarries	0.25	1.0
Water supply	Municipal	0.2	1.0
Miscellaneous	Wildlife conservation	0.1	0.1

Source: MOE, 2006, any changes to these factors were based on the professional judgement of the technical team with support from the Peer Review Committee.

3.4.2.3 Non-Permitted Water Demand

Un-serviced Area Domestic Water Demand:

The un-serviced water use includes water use from private wells by the population not serviced by municipal water supply. These areas are delineated based on the water distribution network maps and limited field checks (**Map 3.9**). The domestic consumptive water use per day was estimated by multiplying the total population in non-serviced areas by estimated daily water consumption per capita. There exists no database for un-serviced populations. A methodology was developed to estimate total population in un-serviced areas. Based on the approximate estimate of 900 houses located in the un-serviced areas, the population is estimated to be about 2,700. As shown in **Table 3.7**, the estimated annual un-serviced domestic water use is about 173,000 m^3.

Table 3.7: Estimated Annual Non-serviced Domestic Water Consumption

Sub-watershed ID	Subwatershed Name	House-holds	Annual Water Consumption (m^3)	Groundwater Pumping Rate (m^3/day)
2GE-01	Little Creek	9	1,700	4.6
2GH-01	Little R., Pike Cr., Puce R.	165	31,600	86.6
2GH-02	Ruscom River	77	14,800	40.4
2GH-03	Belle River	48	9,200	25.2
2GH-04	Turkey Creek	0	0	0.0
2GH-05	Canard River	175	33,500	91.9
2GH-06	Big Creek	115	22,000	60.4
2GH-07	Cedar, Wigle, Mill Creeks	197	37,800	103.4
2GH-08	Sturgeon Creek, etc.	75	14,400	39.4
2GH-09	Hillman, Muddy Creeks	2	400	1.0
2GH-10	Pelee Island	40	7,600	20.8
	Total:	903	173,000	474.0

Other Domestic Water Demand:

There are some serviced areas located outside the urban areas, where people sometimes use groundwater for watering lawns, car washing, gardening, livestock, recreation purposes etc., particularly during the summer, in addition to the municipal water supply. According to the Census of Population (2006), 124,766 people live outside of the City of Windsor, Town of LaSalle and Town of Tecumseh. Most of these people are being serviced by municipal water supply. Based on anecdotal information, it has been suggested that about 15% of this serviced population uses groundwater for gardening, livestock, and recreation purposes. Assuming that the groundwater use for the above purposes is about 25% of domestic water uses during the six month period May to October in this area, the groundwater pumping rate was estimated for each subwatershed using the estimated population size and typical average water consumption (175 litres/capita/day), as shown in **Table 3.8**.

Table 3.8: Estimated Groundwater Pumping Rates in Serviced Areas

Sub-watershed ID	Subwatershed Name	Annual Groundwater Consumption (m^3)	Groundwater Pumping Rate (m^3/day)*
2GE-01	Little Creek	8,100	44
2GH-01	Little R., Pike Cr., Puce R., etc.	8,100	44
2GH-02	Ruscom River	14,400	78
2GH-03	Belle River	14,400	78
2GH-04	Turkey Creek, etc.	0	0
2GH-05	Canard River	25,200	137
2GH-06	Big Creek	13,000	71
2GH-07	Cedar, Wigle, Mill Creeks, etc.	18,400	100
2GH-08	Sturgeon Creek, etc	17,400	95
2GH-09	Hillman, Muddy Creeks, etc.	17,400	95
2GH-10	Pelee Island	0	0
	Total:	136,400	742

*Based on 6 month period May to October only

Other Non-Permitted Water Demand:

There may be other *non-permitted* water uses, such as agriculture and other purposes. However, these water uses are assumed to have been considered under *permitted* water demand. Hence, additional quantities were not considered in the total water demand.

3.4.2.4 Total Water Use

The total water use for different purposes discussed above are summarised in **Table 3.9**. **These estimates do not include the water pumped out of the Great Lakes system for both municipal and non-municipal purposes**.

Table 3.9: Total Annual Water Use

Water Use Category	Annual Surface Water Use (m^3)	Annual Groundwater Use (m^3)	Total Water Use (m^3)
Permitted - PTTW (consumptive)	5,401,252	5,108,060	10,509,312
Unserviced - domestic	0	173,000	173,000
Unserviced - agricultural (considered in PTTW agricultural use)	0	0	0
Serviced - other water uses	0	136,400	136,400
Total:	5,401,252	5,417,460	10,818,712

Further details, including monthly values in applicable seasons, are provided in the Tier 1 Water Budget Report (**Appendix IV**).

3.4.3 Surface Water and Groundwater Interaction

3.4.3.1 Streamflows and Baseflows

The portion of the precipitation that falls on the ground which doesn't either evaporate or infiltrate into the soil is referred to as runoff. The sum of runoff and the groundwater outflows (commonly referred to as baseflows), is the total streamflow. At present, there are four active stream gauging stations (on the Canard River, Ruscom River, Little River and Turkey Creek) and one inactive station (on Sturgeon Creek) in the region. Streamflows observed in various gauging stations range between 33% and 47% of annual rainfall, as shown in **Table 3.10**. The baseflow components of streamflows were estimated using BFLOW software (Arnold, 1999). Mean annual baseflows typically range between 12% and 14% of precipitation, except for Sturgeon Creek where baseflow is about 26% of annual precipitation. Further details on the data, methodology and results (including monthly flows, etc.) may be found in the Tier 1 Water Budget Report in **Appendix IV.**

Table 3.10: Mean Annual Streamflow in Gauged Subwatersheds

Subwatershed	Precipitation (mm)	Stream-flow (mm)	Baseflow (mm)	Evapo-transpiration (mm)
Sturgeon Creek (1972-1991)	834	391	223	500
Ruscom River (1972-2003)	827	274	108	531
Canard River (1977-2003)	862	313	118	544
Turkey Creek (1983-2003)	887	370	-	546
Little River (1983-2003)	887	300	105	546

The streamflow data from the gauged subwatersheds were translated to the ungauged subwatersheds, as listed in **Table 3.11**. For example, the Canard River streamflow data were used for Big Creek and Belle River.

Table 3.11: Translation of Streamflow Data to Ungauged Subwatersheds

Sub-watershed ID	Subwatershed Name	Gauged Subwatershed Used
2GE-01	Little Creek	Ruscom River
2GH-01	Little R., Pike Cr., Puce R., etc	Little River
2GH-02	Ruscom River	Ruscom River
2GH-03	Belle River	Canard River
2GH-04	Turkey Creek etc.	Little River
2GH-05	Canard River	Canard River
2GH-06	Big Creek	Canard River
2GH-07	Cedar, Wigle, Mill Creeks, etc.	Sturgeon Creek
2GH-08	Sturgeon Creek etc.	Sturgeon Creek
2GH-09	Hillman and Muddy Creeks, etc.	Sturgeon Creek
2GH-10	Pelee Island	Canard River

3.4.3.2 Recharge Estimation

Recharge is the amount of water reaching the groundwater from the surface. Most of the recharge occurs due to precipitation, while small amounts may occur during irrigation. Recharge was estimated using several methods as described in the Tier 1 Water Budget Report. These methods make use of streamflow data as described in the previous section. In addition, recharge is estimated by integrating various GIS layers (land slope, land use, soils, precipitation and evapotranspiration). After analysing the recharge results from various methods, recharge estimates considered most reasonable for the Tier 1 water budget were from the method using the GIS layers (see **Table 3.12)**. Further details of recharge estimation procedures are presented in the Tier 1 Water Budget Report in **Appendix IV.** The spatial distribution of the recharge is presented in **Map 3.11**. The estimates are presented in millimetres (mm). This indicates the amount of water that is entering the groundwater system through the soil throughout the subwatershed. In order to estimate the total volume of water recharged, the recharge rate in mm is multiplied by the subwatershed area.

Table 3.12: Subwatershed Recharge Rates

Sub-watershed ID	Subwatershed Name	Average Recharge (mm)
2GE01	Little Creek	61
2GH01	Little R., Pike Cr., Puce R., etc.	57
2GH02	Ruscom River	61
2GH03	Belle River	60
2GH04	Turkey Creek, etc.	57
2GH05	Canard River	60
2GH06	Big Creek	60
2GH07	Cedar, Wigle, Mill Creeks, etc.	61
2GH08	Sturgeon Creek etc.	61
2GH09	Hillman, Muddy Creeks, etc.	61
2GH10	Pelee Island	60

3.4.3.3 Significant Recharge Areas

Based on the amounts of recharge occurring in the subwatersheds, some parts of the Region are identified as Significant Groundwater Recharge Areas (SGRAs). The Clean Water Act requires that SGRAs be delineated in order to assess the vulnerable areas. Rules 44 and 45 under Part V.2 of the Technical Rules describe the methodology for delineating the SGRAs. Rule 44 states that, subject to rule 45, an area is a significant groundwater recharge area if,

> *44(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*
>
> *44(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.*

These two methods are described in further detail in **Section 4.1.3.1**. From further analysis, based on the final Tier 1 Water Budget resulting from the Peer Review process, the method described in Rule 44(1) provides the better results for this region. The resulting SGRAs were filtered out to exclude smaller isolated areas and areas without wells, to cover total areas of about 195 km^2. Most of the SGRAs are located in the sandy soil areas in the southern part of the Essex Region, such as the Harrow area, and parts of Kingsville and Leamington. Further details of the delineation procedures are presented in **Section 4.1.3**.

3.4.4 Water Budget Assessment

As described earlier, the surface water budget was assessed using hydrological modeling tools for the Canard River and Ruscom River subwatersheds, and using simple desktop methods for the remaining subwatersheds. A physically-based distributed model, Soil and Water Assessment Tool (SWAT), was used to develop the water budget estimates in the

Canard River subwatershed, since the SWAT model was calibrated and validated for this subwatershed. In order to understand the transferability of the calibrated parameters to another subwatershed and assess the performance of the model in another gauged subwatershed, the model was implemented in the Ruscom River subwatershed. For the other subwatersheds, water budget estimates were developed based on spreadsheet calculations. In the spreadsheet calculation method, water budget components were estimated using observed precipitation and streamflow data as well as estimated actual evapotranspiration, baseflow and surface water use data.

The results of the surface water budget analysis for each subwatershed are presented in **Table 3.13**. It was found that on average, about 35% of the average annual precipitation contributed to the streamflow while the majority (60 to 70%) of precipitation is lost to evapotranspiration. Significant seasonal and monthly variations in the water yield were observed. Most of the annual water yield occurred during winter and spring months, whereas summer months yielded a lower amount of water due mainly to the higher rates of evapotranspiration.

The groundwater budget components are presented in **Tables 3.16** and **3.17**, in volume rates per year (m^3/year) and depth units (mm), respectively. Further details of the water budget assessment, including monthly values, are presented in the Tier 1 Water Budget Report in **Appendix IV.**

Regarding water quantity trends, there are no specific trends observed in the streamflow patterns at all the gauging stations, except at the Canard River gauging station. The mean monthly flows at the Canard River gauging station seem to be on the rise between January to March of the last 4 to 5 years. No explanation for this is evident at this time. In addition, it is not possible to provide any interpretation regarding trends in groundwater quantity due to insufficient data.

Table 3.13: Annual Surface Water Budget for Subwatersheds

Sub-watershed	Precip-itation (mm)	Evapo-transpi-ration (mm)	Direct Runoff (mm)	Baseflow (mm)	Average Recharge (mm)	Surface Water Use (mm)
Little Creek	827	531	213	61	61	0.0
Little R., Pike Cr., Puce R.	887	547	243	57	57	0.4
Ruscom River	827	531	213	61	61	3.1
Belle River	827	531	253	60	60	0.15
Turkey Creek	887	547	243	57	57	0.0
Canard River	862	544	253	60	60	0.12
Big Creek	858	542	253	60	60	5.8
Cedar, Wigle, Mill Cr.	848	520	213	61	61	2.2
Sturgeon Creek	835	500	213	61	61	0.8
Hillman, Muddy Creeks	835	500	213	61	61	36.9
Pelee Island	862	544	253	60	60	0.0

Note: The average recharge values are not added to the other values in this table

3.5 Stress Assessment

The Tier 1 water budget analysis includes stress assessment that is designed to efficiently screen the subwatersheds and highlight the areas where the degree of stress warrants further refinement provided there are municipal drinking water sources located in the subwatersheds. The municipal drinking water systems in this region obtain their water from the Great Lakes system and hence, the stress conditions would not affect the municipal drinking water supplies.

The stress assessment, as required by the Technical Rules, evaluates the ratio of the consumptive water demand or use to the available water supplies in the aquifers and streams. While consumptive use may affect stress conditions, many of the subwatersheds experience stress due to hydrological conditions where there is no evidence of consumptive water use.

Both existing and future conditions were considered for this analysis. Since there are generally few situations involving new developments for agriculture and other activities requiring significant surface water use in this area, the future surface water demand is not likely to be significantly different from the present rates. However, there is a high degree of fairly recent greenhouse development in some of the southern areas of the region. While these operations mainly use water from the municipal distribution systems, anecdotal evidence suggests that there may be some interest in the use of groundwater for the purpose of greenhouse operations. However, there are no data available on the potential future groundwater consumption use by the greenhouse operators at this time. As a result, an analysis of potential future changes in stress conditions is not feasible at this time.

The summary estimates of stress assessments are presented in this Report. However further details are presented in the Tier 1 Water Budget Report in **Appendix IV.**

3.5.1 Surface Water Stress Assessment

Surface water quantity stress was assessed on a monthly basis for the subwatersheds of the region following the guidance provided by the Province. Monthly water supply, water reserve and consumptive water demand estimation were used for assessing surface water quantity stress in each subwatershed. Water reserve is the quantity of water that is required for ecosystems to maintain in-stream flows as well as other human uses. Water supply and water reserve quantities were estimated from long-term daily streamflow data for the subwatershed where available.

The surface water demand is the ratio of water demand to the difference between the supply and reserve (expressed as a percentage) for the present water demand conditions.

$$\%\,WaterDemand = \frac{Q_{demand}}{Q_{\sup ply} - Q_{reserve}}\ x\,100\%$$

For each of the subwatersheds, stress levels are determined based on the criteria provided by the Province (i.e., threshold values of maximum monthly percent demand), as shown in **Table 3.14**.

Table 3.14: Surface Water Potential Stress Thresholds

Stress Level	Criteria
Significant	Maximum monthly demand is greater than 50%
Moderate	Maximum monthly demand is 20% to 50%
Low	Maximum monthly demand is less than 20%

The surface water demand rates were reported in **Section 3.4.2** and are further detailed in the Tier 1 Water Budget Report in **Appendix IV**, including monthly demand estimates. The areas showing the stress levels in different subwatersheds are presented in **Table 3.15** and **Map 3.11**.

Six subwatersheds were found to have potential **significant stress** conditions from the surface water point of view. The remaining subwatersheds were categorized as having low stress. Since there are no permits for the Little Creek and Pelee Island subwatersheds, they are required to be categorised as low stress conditions. It should be noted that this particular method only evaluates potential stress **based on water demand as indicated by estimated usage.** This is the method prescribed by the Technical Rules (MOE, 2009) for the purpose of the Water Budget work under the Clean Water Act. The anecdotal evidence and the limited field observations conducted during the baseflow monitoring program demonstrate that substantial portions of many streams often dry up during summer periods. These dry conditions may be attributed to historical land clearing and drainage improvements completed as the area was settled, which accelerates the runoff and leads to reduced baseflows during summer periods.

Table 3.15: Surface Water Quantity Stress Levels Based on Water Demand

Sub-watershed ID	Subwatershed Name	Maximum Monthly % Demand	Water Quantity Stress Level
2GE01	Little Creek	0	Low**
2GH01	Little R., Pike Cr., Puce R.	100	Significant
2GH02	Ruscom River	500	Significant
2GH03	Belle River	12	Low*
2GH04	Turkey Creek	0	Low*
2GH05	Canard River	10	Low*
2GH06	Big Creek	212	Significant
2GH07	Cedar, Wigle, Mill Creeks	218	Significant
2GH08	Sturgeon Creek	79	Significant
2GH09	Hillman, Muddy Creeks	4,180	Significant
2GH10	Pelee Island	0	Low**

* Please see the discussion in the paragraph below
** These subwatersheds are categorized as low as there is no known consumptive demand

For example, Canard River and Belle River subwatersheds are categorized as low stress conditions because the water demand is very low. The anecdotal evidence (**Map 3.16**) and the limited field observations made during the baseflow monitoring program show that substantial portions of these streams often dry up during the summer periods. **Maps 3.13** to **3.15** show the baseflow conditions observed during the summers of 2006 to 2008, respectively, which show that most streams were either dry or have discontinuous stagnant pools of water. The water budget results for the summer months also indicate very low flow conditions of these watercourses. Thus, there is a need for further investigations regarding the conditions in these subwatersheds and others.

For reasons described in **Section 3.5**, the future demand and stress conditions are not evaluated, as no significant changes are anticipated.

3.5.2 Groundwater Stress Assessment

As discussed in the Director's Rules of the Clean Water Act, those locations with an annual percent water demand for groundwater of greater than 10% but less than 25% were considered moderately stressed, while locations with greater than 25% annual water demand were considered significantly stressed. The equation used to calculate these stress factors is as follows:

$$\% \text{ Water Demand (Groundwater)} = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} * 100$$

Where:

Q_{Demand} = Groundwater consumptive demand

Q_{Supply} =

Recharge + Groundwater inflow

$Q_{Reserve}$

= 0.1 x (Discharge to streams)

= 10% of the groundwater discharge if known, otherwise 10% of groundwater inputs

Groundwater consumptive demand was considered to be represented by pumping rates in each subwatershed during this study. All groundwater pumping was considered to be 100% consumptive as it is unlikely that the water returned to the same aquifer following extraction.

Tables 3.16a, 3.16b, 3.17a and **3.17b** present the stress calculations in flow units (m^3/year) and depth units (mm/year) based on the maximum monthly and average annual groundwater supply. As can be seen in these tables, the groundwater stress conditions in all the subwatersheds lie below 25% except for three subwatersheds, where two are between 25% and 50%, and one is above 50%. From the average annual analysis, all subwatersheds are below 10% except for three, which are between 10% and 25%. The overall result with respect to groundwater stress is that all subwatersheds are considered to have a low stress except for the Turkey Creek, Sturgeon Creek and Hillman Creek subwatersheds (moderate stress), as well as the Cedar Creek subwatershed (significant stress). **Map 3.17** depicts groundwater stress levels in the various subwatersheds.

Sensitivity analysis studies were performed to investigate the stress conditions if there are changes in either recharge and demand conditions, or if there are any errors in the estimation of various quantities that would lead to a different stress assignment due to uncertainty in any of the data obtained. Various scenarios were considered, and most subwatersheds were not affected. If the water budget components are estimated correctly, all inflows should be equal to the outflows. However, the differences between inflows and outflows for the Cedar Creek, Hillman Creek and Sturgeon Creek subwatersheds were found to be significantly large. These differences may be contributing to the lower stress conditions. The only resulting change following the sensitivity analysis is the change from a low to moderate stress level for the Canard River subwatershed. This is also reflected in the results shown on **Map 3.17.**

For reasons described in the last paragraph of **Section 3.5**, the future demand and groundwater stress conditions were not evaluated.

Table 3.16a: Maximum Monthly Groundwater Supply and Stress Calculations (Flow Units)

	Little Creek	Little R., Pike Cr. and Puce R.	Ruscom River	Belle River	Turkey Cr. and others	Canard River	Big Creek	Cedar Creek	Sturgeon Cr. and others	Hillman and Muddy Creek	Pelee Island
Supply (m^3/day)											
Recharge	7,069	42,367	33,124	24,822	17,881	57,304	18,707	38305	13236	15492	6,773
Demand (m^3/day)											
Consumptive Use – Max. Monthly	-49	-131	-5,490	-1,588	-5,507	-5,398	-1,709	-18,612	-1,952	-3,780	-52
Max. Monthly Groundwater Demand	1%	0.3%	18%	7%	34%	10%	10%	54%	16%	27%	1%

Table 3.16b: Maximum Monthly Groundwater Supply and Stress Calculations (Depth Units)

	Little Creek	Little R., Pike Cr. and Puce R.	Ruscom River	Belle River	Turkey Cr. and others	Canard River	Big Creek	Cedar Creek	Sturgeon Cr. and others	Hillman and Muddy Creek	Pelee Island
Supply (mm/yr)											
Recharge	61	57	61	60	57	60	60	61	61	61	60
Demand (mm/yr)											
Consumptive Use – Max. Monthly	-0.4	-0.2	-10	-4	-18	-6	-5	-30	-9	-15	-0.5
Max. Monthly Groundwater Demand	1%	0.3%	18%	7%	34%	10%	10%	54%	16%	27%	1%

Table 3.17a: Average Annual Groundwater Supply and Stress Calculations (Flow Units)

	Little Creek	**Little R. Pike Cr. and Puce R.**	**Ruscom River**	**Belle River**	**Turkey Cr. and others**	**Canard River**	**Big Creek**	**Cedar, Wigle and Mill Creeks**	**Sturgeon Cr. and others**	**Hillman and Muddy Creek**	**Pelee Island**
Supply (m^3/day)											
Recharge	7,069	42,367	33,124	24,822	17,881	57,304	18,707	38305	13236	15492	6,773
Demand (m^3/day)											
Consumptive Use – Average Annual	-27	-109	-1,086	-317	-1,841	-3,963	-1,342	-3,688	-1,641	-756	-52
Average Annual Percent Groundwater Demand	0.4%	0.3%	4%	1%	11%	8%	8%	11%	14%	5%	1%

Table 3.17b: Average Annual Groundwater Supply and Stress Calculations (Depth Units)

	Little Creek	**Little R. Pike Cr. and Puce R.**	**Ruscom River**	**Belle River**	**Turkey Cr. and others**	**Canard River**	**Big Creek**	**Cedar, Wigle and Mill Creeks**	**Sturgeon Cr. and others**	**Hillman and Muddy Creek**	**Pelee Island**
Supply (mm/yr)											
Recharge	61	57	61	60	57	60	60	61	61	61	60
Demand (mm/yr)											
Consumptive Use – Average Annual	-0.2	-0.1	-2	-1	-6	-4	-4	-6	-8	-3	-0.5
Average Annual Percent Groundwater Demand	0.4%	0.3%	4%	1%	11%	8%	8%	11%	14%	5%	1%

3.6 Summary

The Conceptual and Tier 1 water budget involves compilation, collation and analysis of data obtained from various sources on climate, streamflow, water demand, groundwater system, etc., to estimate the water budget components and stress conditions for surface water and groundwater. The work was done in accordance with the Provincial Guidance based on available data.

There are approximately 28 drainage areas in the Essex Region. However, based on data availability and guidance from the Province, it was decided to perform the water budget and stress calculations on a quaternary watershed (referred to as a subwatershed in this document) scale (11 drainage area groupings) and on a monthly time step. A combination of modeling and spreadsheet calculation approaches were used for the Tier 1 Water Budget study.

Since the municipal drinking water systems in the subwatershed are supplied from the Great Lakes System, the stress conditions do not affect the municipal drinking water needs. However, information regarding stress conditions would affect the water management decisions for other sectors.

It should be pointed out that this particular method only evaluates potential stress based on water demand as indicated by actual usage. This is the method prescribed by the Technical Rules for the purpose of the Water Budget work under the Clean Water Act. However, it is not the only indicator of whether a subwatershed or aquifer is actually "stressed". In much of the Essex Region, hydrological stress (i.e. drying up of many streams) is often observed in summer months.

Some of the key findings are:

Surface water:

- On average, 827 mm to 887 mm precipitation has occurred annually in the subwatersheds of the Essex Region. Of this, about 500 mm to 546 mm contributes towards evapotranspiration (an average of about 65% of precipitation). The mean annual flows in gauged subwatersheds range from 274 mm to 391mm (33% to 46% of precipitation).

- The water budget estimates were performed using hydrological modeling tools in two subwatersheds (Canard River and Ruscom River), and simple spreadsheet based tools were employed to estimate the water budget components in the remaining nine subwatersheds.

- Water budget and water use demand estimates were used to determine the water quantity stress levels in different subwatersheds. Based on the available data and knowledge generated, six subwatersheds in the Essex Region were categorized to be significantly or moderately stressed in terms of surface water quantity, according to the guidelines provided. These inferences are confirmed through field data and anecdotal evidence provided by the staff of ERCA and from on-site monitoring during dry periods.

- It is interesting to note that the Canard River and Belle River subwatersheds are calculated to have low stress conditions. As observed in the Canard River and Belle River subwatersheds (as with many other subwatersheds in the region), significant portions of these streams are often dry during the summer time. They are showing up as “low stress” due to the very limited water takings, based on the methodology prescribed by the Technical Rules. Similar situations exist in other subwatersheds to varying degrees. These dry conditions may be attributed to historical clearing and drainage which accelerates the runoff from the watersheds and leads to reduced baseflows during the summer period. Thus, the stress analyses for these and other subwatersheds need revisiting.

Limitations:

- There are limited data available in the Essex Region. For example, there are only six climate stations and four stream gauging stations with available data. Also, there are no streamflow gauging stations available in the southern region where soil conditions are different from other parts of the region. Based on the knowledge available, the information was extrapolated from gauged watersheds to the ungauged watersheds. These approaches have inherent limitations and hence additional data on streamflows and water demands are needed to improve the reliability.

- Most of the analysis for Pelee Island was performed by extrapolating the estimates from the mainland. Given the unique characteristics of the island, the estimates generated for Pelee Island are likely to have higher uncertainty. These estimates could be improved with additional field monitoring of such parameters as streamflows, baseflows and water use patterns.

Groundwater:

- The consumptive groundwater demand was represented by the pumping rates in each subwatershed. The results from the water budget were used to evaluate the groundwater quantity stress level of each subwatershed.

- Since there was no information available on groundwater inflows from adjacent watersheds, this inflow component was set as zero. This will lead to conservative estimates of the stress conditions. Based on the best available datasets and the local knowledge of the groundwater system in the Essex Region SPA, Cedar Creek subwatershed is the only one to be categorized as having potential for significantly stressed conditions under maximum monthly pumping rates. Turkey Creek and Hillman Creek subwatersheds fall under moderately stressed conditions under maximum monthly pumping rates. Turkey Creek, Cedar Creek and Sturgeon Creek subwatersheds are categorized as moderate stress conditions under average annual pumping conditions. When sensitivity analysis is considered, the Canard River and Big Creek subwatersheds are found to have a moderate stress condition. All other subwatersheds fall under low stress conditions under both average annual and maximum monthly pumping conditions.

- Given the limitations discussed below, some subwatersheds in the Essex Region are categorized as low stress. It may be noted that the low stress conditions arise due to relatively lower water use conditions in the respective subwatersheds, based on the methodology prescribed by the Province. This does not necessarily indicate that groundwater resources are sufficient and sustainable. Traditionally, water users are aware of low groundwater availability and hence do not depend fully on groundwater. Further study is recommended in this regard.

Limitations

- The groundwater supply term consists of recharge plus groundwater inflow. Even though significant effort was put on estimating recharge, there remains uncertainty in its estimation. This is largely due to the limited monitoring data for climate and streamflow. Also, there is only limited understanding about the groundwater inflow and outflow quantities. This may affect the estimation of available water supply.

Water Use Estimation

- Water use or demand was estimated for various sectors (e.g. agriculture, pits and quarries (dewatering), commercial, industrial, domestic and other miscellaneous categories). Monthly and annual surface water and groundwater demand in each of the subwatersheds was estimated using the MOE's 'Permit to Take Water' database, which specifies the maximum allowable pumping rates. An attempt was also made to more realistically estimate water demand using the information obtained through limited sample surveys, assisted by the Source Protection Committee.

Limitations

- The available information on water demand is rather limited. There would be benefit in further study to better estimate water demands and needs, both in terms of human and ecological uses. Also, potential increased demand for water use (due to climate change or other factors) was not considered in this analysis. Potential increased demand for groundwater use associated with greenhouse operations in the south part of the Region, may reinforce the need for further study. Thus, any further studies on groundwater availability and use should consider water requirements associated with greenhouses.

Next Steps

- Since the Essex Region SPA relies on the Great Lakes System to supply all of its municipal drinking water, further levels of evaluation, such as Tier 2 or Tier 3 evaluation are not required. Further levels of detailed water budget analyses to address the limitations highlighted in terms of data and knowledge gaps may be carried out under other programs. Such a study would provide better quantification and confirmation of water quantity stress levels and contributing factors developed through this study.

3.7 Uncertainty

Given the scope of the Conceptual and Tier 1 water budget analysis, the water budget estimates were generated based on the existing data with minimal field data. There are several identified data and knowledge gaps. However, the best professional judgement was employed in extrapolating the results from gauged watersheds to ungauged watersheds. These results need verification, and some of the conclusions may change as a result. Efforts may be made to fill these gaps and revise the water budget estimates during further levels of water budgets.

There are considerable limitations with respect to various aspects of the Tier 1 water budget analysis, as discussed throughout the preceding sections. It is recognized that further study will not be carried out under the Source Water Protection Program for this particular region since municipal drinking water systems are not directly affected. However, serious efforts should be made to carry out the necessary further studies through other means.