Approved Assessment Report

Sault Ste. Marie Region
Source Protection Authority

CHAPTER 2b

TIER 1 & TIER 2 WATER BUDGET

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ASSESSMENT REPORT
TIER 1 & TIER 2 WATER BUDGET

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EXECUTIVE SUMMARY

The Sault Ste. Marie Region (SSMR) Source Protection Area is situated within the District of Algoma, along the north shore of the St. Marys River and east shore of Lake Superior. A Water Budget Conceptual Understanding Report for the SSMR Source Protection Area was prepared in accordance with MOE Technical Rules, November, 2009. The Conceptual Understanding provides a basic understanding of the Source Protection Area.

The main objectives of the Tier 1 and Tier 2 Assessments are to estimate and describe the movement of water within the various elements that constitutes the hydrologic cycle to identify areas that may be stressed from a water quantity perspective. This assessment utilizes available data collected during the Conceptual Understanding Phase, to evaluate the cumulative stress within each subwatershed and each groundwater basin. The elements of the Tier 1 and Tier 2 Assessment have been based on those outlined in the updated MOE Technical Rules, November, 2009.

The SSMR Source Protection Area consists of 12 subwatersheds of which 10 are associated with major creek systems, one discharges directly into Lake Superior and one, associated with an unnamed river, discharges directly to St. Marys River. All subwatersheds were included as part of this assessment. For most subwatersheds, with the exception of Big Carp River and Root River, no stream gauging data was available; as such, theoretical data derived from the SCS method was used to estimate the direct run-off which represents the subwatershed surface water supply.

Surface water takings in the SSMR Source Protection Area include domestic, commercial (aquaculture, golf course irrigation), industrial (cooling water) and hydroelectric purposes. Many of these uses have low consumptive factors and therefore, the amount of actual surface water demand in the SSMR Source Protection Area remains low when compared with available supply.

There are two distinct landforms; the northern portion, which is referred to as the “Precambrian uplands”, and an area south of this region, which is relatively flat and referred to as the “lowlands”. The lowlands are covered by a relatively thick clay-rich overburden unit. The east, central and west basins lie within the lowlands and are the three main groundwater units considered in this assessment.

Two methods were used to estimate the amount of groundwater contribution to the groundwater aquifer units: the Desktop Analytical Method and the Numerical Modelling Method. The two main contributors for both methods were in the form of Groundwater Inflow (Q_{IN}) and Groundwater Recharge (Q_R).

The SSMR Source Protection Area has a variety of groundwater users including domestic, commercial and industrial purposes; however, the most significant use of groundwater in the central and east basin is for municipal drinking water supply.

As a part of the Tier 1 Assessment, a water balance on the 12 subwatersheds in the SSMR Source Protection Area was conducted. Water takings from most subwatersheds were found to have a low hydrologic stress level because water supplies vastly exceed water demands. Surface water demands identified in Fort Creek, Root River subwatersheds are less than 9% monthly basis and therefore assigned a low hydrologic stress level.

A Tier 2 assessment was conducted on the three groundwater basins. Results for the current and future scenarios showed that the percent groundwater demand for the West Basin was 2% and 3% respectively, both of which resulted in a low hydrologic stress level assignment. The groundwater percent water demand in the Central and East Basins ranged between 19% and 24.9% under the current and future scenarios resulting in assignment of moderate subwatershed hydrologic stress levels.

All available information was applied during completion of the Tier 2 Assessment to determine the potential stress of the three groundwater basins. The level of uncertainty in the values used to estimate the groundwater supply, Q_R and Q_{IN} are believed to be high because of limited field information. The level of uncertainty associated to the estimated values for groundwater demand are

low as measured water taking information was available. Changes to the amount of groundwater demand in the future are also predetermined.

In moving forward, the uncertainty can be reduced by improving the current understanding of the contribution to the groundwater systems. Development of an integrated groundwater/ surface water monitoring program based on the current understanding can reduce the uncertainty.

1.0 INTRODUCTION

1.1 Conceptual Understanding

The Sault Ste. Marie Region (SSMR) Source Protection Area delineated in Figure 1.1 is situated within the District of Algoma, along the north shore of the St. Marys River and east shore of Lake Superior. The Conceptual Understanding Assessment provides a basic understanding of the Source Protection Area obtained through the compilation and interpretation of all available baseline data, mapping of existing conditions and information regarding historical water use.

The Conceptual Understanding identified 12 subwatersheds of which 10 are associated with major creek systems, one discharges directly into Lake Superior and one, associated with an unnamed river, discharges directly to St. Marys River.

The groundwater system was divided into three major groundwater aquifers, the "west, central, and east basins" which are located in an area referred to as the "lowlands", south of the Precambrian uplands. The stratigraphic sequence in the lowlands area consists of a relatively thick clay-rich overburden unit consisting of glaciolacustrine clays underlain by a layer of coarse grained glaciolacustrine overburden deposits and the Jacobsville Formation, a regional sandstone bedrock aquifer.

Most water use in the SSMR Source Protection Area is associated with the municipal water supply for the City of Sault Ste. Marie and domestic supply in rural areas. Groundwater and surface water sources each provide approximately half of the municipal water supply. The major aquifer units used for municipal supply in the SSMR Source Protection Area are the central and east basins with the Lorna and Shannon Wells being located in the east basin and the Steeleton and Goulais Wells in the central basin. Surface water is obtained at the Gros Cap intake from Lake Superior. No major water takings were identified in the west basin.

SSM water supply is dependant on both groundwater and surface water sources; however, the surface water intake is on Lake Superior and water takings from the great lakes are not to be considered at this time.

The combined Tier 1 and Tier 2 Water Budget Assessment will include an assessment of the stress level from a surface water and groundwater perspective and continue to build on the understanding of the ***groundwater system*** and apply all available tools and actual recorded field data where possible.

1.2 Technical Objectives

The main objectives of the Tier 1 and Tier 2 Assessment are to estimate and describe the movement of water within the various elements that constitutes the hydrologic cycle to identify areas that may be stressed from a water quantity perspective. This assessment utilizes available data collected during the Conceptual Understanding Phase, to evaluate the cumulative stress within each basin. Through this process, additional information was obtained from various sources including existing models and actual water taking rates to confirm the stress level and to refine the estimation of water budget components.

2.0 ELEMENTS OF THE TIER 1 AND TIER 2 ASSESSMENT

The main elements of a Tier 1 and Tier 2 Assessment include:

- Water Supply Estimation;
- Consumptive Demand Estimation;
- Water Reserve Estimation; and
- Water Budget Summary.

In this report, each aspect has been addressed by considering two methods of analysis. First a simple approach in which values obtained in the Conceptual Understanding were applied through a desktop evaluation (Tier 1). Where potential stresses were identified, a more detailed assessment was conducted (Tier 2). The second approach incorporated the numerical model developed by R.J. Burnside as part of a Groundwater Management & Protection Study Report (2003) (Appendix A).

The Tier 1 assessment is to consider both current conditions and the future demand scenario. Based on the census data available from Statistics Canada, significant growth in the SSMR Source Protection Area is not expected and future water uses in this area are expected to be maintained at the current level or potentially decline in the long term. The report entitled “Population, Household and Labour Forecasts for the City of Sault Ste. Marie”, dated May 2006 indicates that the current population of SSM is 73,400 and is expected to increase to 75,700 by year 2026. This is equivalent to less than a 4% increase in the future; however, the potential for increasing the ratio of groundwater takings vs. surface water taking is a possible future demand scenario. Therefore, for the purposes of this assessment, without a current Master Plan for the future of the Sault Ste. Marie water supply, 110% of the current water taking scenario will be considered as the future demand as a worst case scenario.

2.1 Relationship between Watersheds and Groundwater Basins

In the SSMR Source Protection Area both surface water and groundwater resources play an important role in the water budget. The amount of precipitation (P), evapotranspiration (ET), recharge (R), and runoff (RO) were previously estimated for each subwatershed at the conceptual understanding stage. From a surface water perspective, the runoff (RO) represents the amount of water supply in each subwatershed.

From a groundwater perspective, infiltration (I) or recharge (R) represents contributions to groundwater supply. The surface water system is the main input to the groundwater system and therefore there is an integrated relationship. In order to estimate the amount of recharge into each basin, the boundaries for each basin were overlain on the subwatershed maps. At this stage, the estimated recharge value for each subwatershed was used as the input to each respective groundwater basin.

Figure 2.1 overlays the subwatershed boundaries with the groundwater basin divides. Based on this interpretation, Table 2-1outlines the subwatersheds that contribute to each basin.

Table 2-1 Contributing Subwatersheds to Each Basin

Basin	Subwatershed
West Basin	Big Carp River
	Little Carp River
Central Basin	Leigh Bay Creek
	Bennet Creek
	West Davignon Creek
	Central Creek
	East Davignon
	Fort Creek
	Root River

Table 2-1 Contributing Subwatersheds to Each Basin

Basin	Subwatershed
East Basin	Crystal Creek
	Root River
	St. Mary’s River (Un-named Creek)

The relationship between the subwatersheds and the groundwater basins forms the basis for the Tier 1 Assessment from a groundwater perspective.

2.2 Water Budget

For a given time period, a conceptual simple mathematical model of the overall water budget is given by:

$$P+Sw_i+Gw_i=ET+Sw_o+Gw_o+Q_{out}+\Delta S$$

Where:

P = *Precipitation;*
Sw_i = *Surface water inflow into the system;*
Gw_i = *Groundwater inflow into the system;*
ET = *Evapotranspiration losses;*
Sw_o = *Surface water outflow from the system;*
Gw_o = *Groundwater outflow from the system;*
Q_{out} = *Net water taken for consumption or exported from system; and*
ΔS = *Change in storage (both surface and groundwater).*

Given that water budgets are normally estimated to represent a steady state condition, the above equation can be simplified to:

$$P+Sw_i+Gw_i=ET+Sw_o+Gw_o+Q_{out}$$

This form of the equation is usually applied to estimate large-scale water budgets at a conceptual level. The basic component of the hydrologic cycle is the precipitation. Once precipitation is introduced to a system, it is apportioned between the various reservoirs in the system as:

$$P=ET+R+I$$

Where:

P = *Precipitation;*
ET = *Evapotranspiration losses;*
R = *Surface runoff; and*
I = *Infiltration.*

For the surface water budget, each subwatershed was considered as a separate unit for which inputs and outputs were assessed. Monthly averages were estimated to account for seasonal variability.

For the groundwater budget, each groundwater basin was considered as a separate unit for which inputs and outputs were assessed. The movement of water through the various phases of the hydrologic cycle varies greatly in time and space; however, for a groundwater system, seasonal effects have less influence and these variables can be simplified as annual averages. As shown in Figure 2.1, the boundaries of the groundwater basin include several subwatersheds.

To account for this characteristic the water budget equation has been modified to suit the SSMR Source Protection Area specifically. Inputs to the basin can be accounted for in terms of *I* and Gw_i. These are representative of infiltration (*I*) from the recharge areas (later described as Q_R) and groundwater inflow

(Gw_i) into the system (later described as Q_{IN}), which accounts for the infiltration of water in the shallow sediments in the Precambrian uplands, recharging the major aquifers that continue in a southerly direction.

These basic concepts were applied in the desktop analytical method (Tier 1) and the numerical modeling exercise (Tier 2). For both the numerical modeling method, the selection of the infiltration value is an essential step in constraining the distribution of recharge and is one the most important variables as it can significantly influence the outcome of water budget.

3.0 WATER SUPPLY ESTIMATION

In this section, the quantity of water available to supply each surface water subwatershed and each groundwater basin was estimated based on the methods recommended in the Technical Rules and modified to represent the specific characteristics of the SSMR Source Protection Area.

The SSMR Source Protection Area consists of two distinct landforms; the northern portion, which is referred to as the "Precambrian uplands", and an area south of this region, which is relatively flat and referred to as the "lowlands". The lowlands are covered by a relatively thick clay-rich overburden unit. The east, central and west basins lie within the lowlands. The granite in the Precambrian uplands is generally understood to have a low permeability except for the shallow weathered and fractured bedrock and the overlying sand and gravel glaciofluvial deposits.

Even though large areas of outcropping of the Precambrian Granites are present in the north, shallow soil material scattered across this area provides some retention of water during rain events. In these subwatersheds, the run-off flows downgradient through the streams, overland, or through the shallow soils in a southerly direction until the Precambrian uplands end and enter into the groundwater system at the thick sand and gravel beach deposits located along the southern edge of the Precambrian uplands. The flows from runoff are therefore introduced into the groundwater system and removed from the surface water system.

This is the main source of groundwater for the central and east basins and is referred to as lateral groundwater inflow. The amount of groundwater contribution is not fully understood; however, for the purposes of this investigation, it is assumed that the amount of groundwater inflow can range from 0 to 100% of the runoff which falls on the Precambrian uplands above the recharge area. Limited lateral groundwater inflow from the contact area enters the western basin due to the elevated bedrock pinching out the connection to the coarse grained permeable recharge zone.

3.1 Tier 1: Analytical Desktop Method

3.1.1 Recharge Rate Estimation Methods

As part of the analytical desktop method, precipitation is separated into evapotranspiration (ET), infiltration/groundwater recharge (I/R) and runoff (RO). In general, runoff accounts for supply for the surface water system and infiltration accounts for the supply for the groundwater system. Methods used to estimate the groundwater recharge and runoff were calculated using "calibrated soil moisture balance" methods as identified in the Technical Rules. The steps taken to calculate each are provided in the Conceptual Understanding, November 2006.

The Thornthwaite method (1948) was used for each subwatershed and considered the rainfall and runoff data and took into account average monthly temperature and hours of daylight. The result is basically an empirical relationship between potential evapotranspiration and air temperature. The amount of runoff was estimated using baseflow hydrograph separation techniques where possible. For subwatersheds without hydrograph data, the Soil Conservation Service (SCS) method was used to estimate the runoff. The water remaining was considered the available water for infiltration into the groundwater system.

For the surface water budget, RO which falls within the watershed is assumed to contribute to the surface water supply in areas south of the Precambrian uplands.

For the groundwater budget, the infiltration is considered to be the Q_R if it was found to fall on *Significant Recharge Areas* and Q_{IN} if it was found to fall in subwatersheds located in the Precambrian uplands and that might have contributed to lateral groundwater inflow. The Significant Recharge Area (SGRA) is delineated where the average annual recharge rate is greater than the average annual recharge rate for the surrounding watershed by a factor of 1.15 or more (As per Part V.2 of Technical Rules 44.1 and 45). (CWB Map 6). Details regarding the method used to estimate the amount of infiltration to each subwatershed are available in the Conceptual Understanding Assessment.

A second method using groundwater equipotential maps was also used to estimate the lateral groundwater inflow (Q_{IN}). This method is identified in the Technical Rules as a Groundwater Flow In Estimation Method. According to this method, the total amount of groundwater flowing into a subwatershed is calculated using estimates of hydraulic conductivity, aquifer thickness, and hydraulic gradient measured from groundwater level maps. Because there is a high level of uncertainty in these calculations, this method was mainly used for comparison.

3.1.2 Significant Recharge Areas

The Significant Recharge Areas defined as part of this assessment have been delineated as per the Assessment Report: Technical Rules, *Clean Water Act, 2006.* They represent areas with an average annual recharge rate that is greater than the average annual recharge rate for the surrounding watershed by a factor of 1.15 or more (As per Part V.2 of Technical Rules 44.1 and 45).

The significant recharge areas are large sand and gravel deposits identified in quaternary soils maps that are located between the Precambrian Uplands and the lowlands (Figure 3.1). The Precambrian uplands are assumed to have no capacity for infiltration and therefore does not recharge the aquifer in a conventional manner. The lowlands area is covered by relatively thick clay-rich overburden unit consisting of glaciolacustrine clays. The following table compares the typical hydraulic conductivities for the various surficial units within the watershed.

Table 3-1 Summary of Hydraulic Conductivities

Lithology	Typical Hydraulic Conductivities (m/s)	Estimated Hydraulic Conductivities for Watershed (m/s)
Unfractured Bedrock	3 x 10-14 to 2 x 10-10	0
Sand and Gravel	9 x 10-7 to 3 x 10-2	5 x 10-4 to 1 x 10-3
Silt and Clay	1 x 10-11 to 2 x 10-5	1 x 10-7 to 1 x 10-6

The average annual rate of recharge for each of these units is directly related to the hydraulic conductivities, and the comparison of hydraulic conductivities illustrates that the recharge rate within the thick sand and gravel beach deposits located along the southern edge of the Precambrian uplands is greater than 1.15 times that of the surrounding watershed. The sand and gravel deposits have a direct hydrologic connection the central and east aquifer basins that provide drinking water for the City of Sault Ste. Marie. There is limited hydrologic connection between the sand and gravel beach deposits to the west aquifer basin; however, there is an upper sand formation in the shoreline area of the west basin and a barrier-bar deltaic complex fronting the Gros Cap Highland near Gros Cap along the shores of Lake Superior in the west which allow for significant recharge. No municipal water takings occur in the west basin; however, many residents use domestic wells for private water supply.

3.1.3 Groundwater Recharge

For the purposes of estimating the amount of groundwater recharge (Q_R), the amount of infiltration within the previously defined recharge area was used. In the lowlands, the aquifers have been known to exhibit artesian conditions, particularly in the area by St. Marys River. Based on these pressurized conditions and the thick overlying aquitard, infiltration into the deep aquifer for most of the area in the lowlands was assumed to be negligible.

Figure 3.1 outlines the annual rate of recharge through the recharge zone based on surficial infiltration. Table 3-2 summarizes the total estimated annual, monthly and daily rates of recharge for each basin. Table 3-3 shows sample calculations of how the recharge was obtained.

Table 3-2 Summary of Aquifer Recharge (Q_R)

Basin	Annual Recharge (m^3/yr)	Monthly Recharge (m^3/month)	Daily Recharge (m^3/day)
West	1,086,172	90,514	2,974
Central	2,580,039	215,003	7,064
East	2,082,766	173,564	5,702

Table 3-3 Summary Calculations for Aquifer Recharge (Q_R)

Basin	Subwatershed No.	Watershed	Watershed							Area Within Recharge Zone (km^2)	Q_R m^3/year
			Total Area (km^2)	Average CN	P (mm)	ET (mm)	Surplus (mm)	Runoff (mm)	Infiltration (mm)		
Central	6	Leigh Bay Creek	15.9	65.3	1004	538	466	344	122	1.04	126,926
	7	Central Creek	2.7	69.9	1004	538	466	402	64	1.09	69,549
	9	Root River	22.3	68.4	1004	538	466	382	84	0.86	71,966
	11	Big Carp River	20	62.8	1004	538	466	314	152	0.21	32,002
	12	Little Carp River	20.1	56	1004	538	466	242	224	1.67	373,258
	14	West Davignon Creek	20.3	65.3	1004	538	466	344	122	5.11	622,869
	15	East Davignon Creek	22.7	62.7	1004	538	466	313	153	5.41	827,228
	18	Bennet Creek	23	59.4	1004	538	466	277	189	2.08	392,401
	19	Root River	22.5	61.9	1004	538	466	304	162	0.39	63,841
	27	Fort Creek	29.8	74.8	1004	538	466	466	0	2.61	-
										Total	2,580,039
East	4	St Mary's River	42.7	59.8	1004	538	466	281	185	2.62	485,433
	9	Root River	22.3	68.4	1004	538	466	382	84	7.41	622,140
	13	Root River	4.2	64.5	1004	538	466	334	132	0.09	12,289
	16	Crystal Creek	26.1	53	1004	538	466	213	253	3.01	761,836
	19	Root River	22.5	61.9	1004	538	466	304	162	0.59	94,944
	21	Root River	13.5	66	1004	538	466	352	114	0.93	106,123
	27	Fort Creek	29.8	74.8	1004	538	466	466	0	0.19	-
										Total	2,082,766
West	5	Big Carp River	4	65.4	1004	538	466	345	121	0.00	26
	8	Lake Superior	31.8	44	1004	538	466	139	327	2.43	793,068
	10	Big Carp River	27.8	57	1004	538	466	252	214	0.86	183,486
	11	Big Carp River	20	62.8	1004	538	466	314	152	0.66	100,401
	12	Little Carp River	20.1	56	1004	538	466	242	224	0.04	9,192
										Total	1,086,172

3.1.4 Lateral Groundwater Inflow

The volume of lateral groundwater inflow into the groundwater system can be estimated by calculating the contribution in each subwatershed from the Precambrian uplands that flows toward each basin. The exact quantity of contribution from the Precambrian uplands is dependant on the amount of precipitation which enters the groundwater system in the form of infiltration and the hydraulic conductivity of the bedrock.

The remaining run-off contributes to shallow interflow and baseflow which feeds surface water features. Due to the limited amount of overburden in the uplands, there is potential for additional surface water/ groundwater interaction in this environment. In addition, most of the major creeks originating in the uplands cross the coarse grained recharge area and may potentially provide additional recharge contribution to the groundwater system. There is insufficient field data to quantify the component of run-off which eventually infiltrates the groundwater system. Detailed hydrograph separation exercises would be needed in order to gain a more detailed understanding of the surface water/groundwater interaction in the uplands.

Figure 3.2 outlines the maximum and minimum potential annual rate of groundwater inflow from the uplands, based on infiltration and run-off. The amount of inflow to each basin is not uniform and is controlled by the geology. Most of the contribution from the uplands to the basins is through the sandy and gravelly deposits. Table 3-4 summarizes the total estimated annual, monthly and daily rates of lateral groundwater inflow from subwatersheds in the Precambrian uplands that likely contribute to each basin. Table 3-5 shows sample calculations of how the recharge was obtained.

Table 3-4 Summary of Aquifer Lateral Groundwater Inflow (Q_{IN})

Basin	Annual Inflow (m^3/yr)		Monthly Inflow (m^3/month)		Daily Inflow (m^3/day)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
West	5,561,164	14,630,306	463,430	1,219,192	15,236	40,083
Central	11,681,231	31,636,808	973,436	2,636,401	32,003	86,676
East	6,530,296	23,112,725	544,191	1,926,060	17,891	63,323

Table 3-5 Summary Calculations for Aquifer Lateral Groundwater Inflow (Q_{IN})

Basin	Subwatershed No.	Total Area (km^2)	Area Above Recharge Zone (km^2)	Infiltration (mm)	Run Off (mm)	Min Q_{IN} (m^3/year)	Max Q_{IN} (m^3/year)
West	10	27.8	13.1	214	252	2,647,586	6,095,315
	5	4	0.7	121	345	85,548	329,465
	11	20	17.6	152	314	2,676,481	8,205,526
					Total	5,409,614	14,630,306
Central	12	20.1	11.6	224	242	2,596,708	5,402,079
	6	15.9	0.2	122	344	24,470	93,467
	18	23	16.5	189	277	3,120,907	7,694,934
	14	20.3	9.8	122	344	1,199,723	4,582,550
	15	22.7	8.9	153	313	1,362,948	4,151,201
	19	22.5	20.8	162	304	3,376,475	9,712,577
					Total	11,681,231	31,636,808
East	13	4.2	4.0	132	334	530,270	1,872,015
	21	13.5	11.7	114	352	1,331,625	5,443,311
	17	3.2	3.2	157	309	502,400	1,491,200

Table 3-5 Summary Calculations for Aquifer Lateral Groundwater Inflow (Q_{IN})

Basin	Subwatershed No.	Total Area (km^2)	Area Above Recharge Zone (km^2)	Infiltration (mm)	Run Off (mm)	Min Q_{IN} (m^3/year)	Max Q_{IN} (m^3/year)
	22	5.7	5.7	138	328	786,600	2,656,200
	23	18.3	18.3	140	326	2,562,000	8,527,800
	24	6.7	6.7	122	344	817,400	3,122,200
					Total	6,530,296	23,112,725

3.1.5 Equipotential Method

The potentiometric surface developed by Burnside (2003) was included as a part of the Conceptual Understanding (Figure 3.3). Calculations of the groundwater flow into each basin using the equipotential map and estimated hydraulic conductivity, aquifer thickness, and hydraulic gradient were also conducted. Table 3-6 summarizes the estimated hydraulic properties used to calculate the groundwater flow.

As mentioned previously, the amount of inflow to each basin is not uniform and is controlled by the geology. The width parameter accounts for the areas where water from the uplands is likely able to enter the basins based on the location of the sand and gravel deposits.

Table 3-6 Summary of Aquifer Parameters

Basin	Min Hydraulic Conductivity (m/s)	Max Hydraulic Conductivity (m/s)	Min Transmissivity (m^2/day)	Max Transmissivity (m^2/day)	Hydraulic Gradients	Width (m)
West	0.0001	0.001	8.64	86.4	0.059	3725
Central	0.0001	0.001	8.64	86.4	0.065	10000
East	0.0001	0.001	8.64	86.4	0.051	6000

Considering the above range of typical hydraulic conductivities for sand and gravels, Table 3-7 summarizes the range of potential groundwater inflow.

Table 3-7 Summary of Aquifer Lateral Groundwater Inflow (Q_{IN}) – Calculated with Equipotential Map

Basin	Minimum K Scenario			Maximum K Scenario			Average K Scenario		
	Annual Inflow (m^3/yr)	Monthly Inflow (m^3/mon)	Daily Inflow (m^3/day)	Annual Inflow (m^3/yr)	Monthly Inflow (m^3/mon)	Daily Inflow (m^3/day)	Annual Inflow (m^3/yr)	Monthly Inflow (m^3/mon)	Daily Inflow (m^3/day)
West	695,574	57,965	1,904	6,955,743	579,645	19,044	3,825,659	318,805	10,474
Central	2,035,974	169,665	5,574	20,359,742	1,696,645	55,742	11,197,858	933,155	30,658
East	968,520	80,710	2,652	9,685,197	807,100	26,517	5,326,858	443,905	14,584

A comparison of the groundwater inflow values calculated by the two different methods is shown in Table 3-8. In general, the Infiltration Method results in an estimated inflow rate greater than those achieved using the Equipotential Method; however, comparison of the minimum inflow estimate obtained by using the Infitration Method is comparable to the Average inflow estimate obtained by using the Equipotential Method. Additional field information is required in order to further refine the estimate of inflow.

Table 3-8 Comparison of Aquifer Lateral Flow (Q_{IN}) Calculated by Infiltration and by Equipotential Map Data

Basin	Annual Inflow (m^3/yr)					
	Infiltration Method			Equipotential Map Method		
	Min Q_{IN} (m^3/year)	Max Q_{IN} (m^3/year)	Avg Q_{IN} (m^3/year)	Min Q_{IN} (m^3/year)	Max Q_{IN} (m^3/year)	Avg Q_{IN} (m^3/year)
West	5,561,164	14,630,306	10,095,735	695,574	6,955,743	3,825,659
Central	11,681,231	31,636,808	21,659,020	2,035,974	20,359,742	11,197,858
East	6,530,296	23,112,725	14,821,510	968,520	9,685,197	5,326,858

3.1.6 Summary of Total Groundwater

Total water supply into each basin was obtained by summing the amount of groundwater available through lateral inflow and through groundwater recharge from the recharge zone (Table 3-9). A minimum and maximum range of inflow contributed by the Precambrian uplands is included. The actual quantity of contribution likely falls within this range; however, additional field information is required to further refine the estimated total water supply.

Table 3-9 Total Groundwater Supply

Basins	Infiltration			Groundwater Recharge	Total Groundwater Supply		
	Min Q_{IN} (m^3/year)	Max Q_{IN} (m^3/year)	Avg Q_{IN} (m^3/year)	Avg Q_R (m^3/yr)	Min Supply (m^3/yr)	Max Supply (m^3/yr)	Avg Supply (m^3/yr)
West	5,561,164	14,630,306	10,095,735	1,086,172	6,647,337	15,716,479	11,181,908
Central	11,681,231	31,636,808	21,659,020	2,580,039	14,261,270	34,216,848	24,239,059
East	6,530,296	23,112,725	14,821,510	2,082,766	8,613,061	25,195,491	16,904,276

Comparison of the values obtained above with the estimates provided from IWS show that the values presented by IWS are typically lower than those obtained here. The IWS values are closest to the minimum water supply scenario (Table 3-10). The methods used by IWS to estimate the recharge was not available. It is assumed that the use of the terminology “recharge” implied total groundwater contribution to each basin rather than the definition of recharge (Q_R) as used in the Technical Rules.

Table 3-10 Comparison of Previous Groundwater Recharge Estimates and Current Estimated Recharge

Basin	IWS Recharge (m3/yr) (m^3/day)	Minimum Total Water Supply (m^3/yr) (m^3/day)	Maximum Total Water Supply (m^3/yr) (m^3/day)	Average Total Water Supply (m^3/yr) (m^3/day)
Central Basin	10,439,000 – 10,950,000 (28,600-30,000)	14,261,270 (39,072)	34,216,848 (93,745)	24,239,059 (66,408)
East Basin	5,803,500 – 7,300,000 (15,900-20,000)	8,613,061 (23,597)	25,195,491 (69,029)	16,904,276 (46,313)

3.1.7 Summary of Total Surface Water Runoff

The average monthly surface water runoff was calculated for each subwatershed as part of the Conceptual Understanding stage. Estimation of the total surface water supply needs to reflect the same assumptions used in calculating the groundwater supply. The amount of surface water contribution within the watershed can be estimated by summing the potential contribution of runoff from:

- the Precambrian Uplands;
- the Significant Recharge Areas; and

- the Lowlands.

The amount of runoff contribution from the Precambrian uplands can vary from 0 to the calculated runoff. The rationale for the discrepancy is the unknown influence of the significant recharge area on surface water features which cross the highly permeable unit.

The amount of runoff contribution from the Significant Recharge Areas is estimated to be the calculated runoff in this area.

The amount of runoff contribution in the lowlands is assumed to be the total calculated runoff and infiltration in this area as a result of the low permeability overburden material and the significant upward gradients which would inhibit the potential for groundwater infiltration.

The range of total surface water supply is shown in Table 3-11.

Table 3-11 Total Surface Water Supply

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Lake Superior	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	68362	25570	30149	32922	35885	50183	44064	54058	77049	72062	66796	86381
	RO From Significant Recharge Area	1178	352	447	474	562	835	713	915	1397	1302	1152	1626
	RO From Lowlands	18037	5742	7134	7626	8836	12903	11105	14074	21116	19696	17632	24355
	Infiltration From Lowlands	87639	58874	58761	39994	6832	1491	385	653	21777	49179	82338	92445
	Total Min Supply	106854	64968	66342	48093	16231	15229	12203	15641	44290	70177	101121	118425
	Total Max Supply	175216	90538	96491	81015	52116	65412	56267	69700	121339	142239	167917	204806
Big Carp River	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	31736	11861	14402	14703	16541	23151	20143	25522	35328	32974	30331	39773
	RO From Significant Recharge Area	1715	637	775	791	891	1250	1087	1378	1912	1784	1639	2154
	RO From Lowlands	17878	6575	8023	8179	9250	13002	11293	14355	19971	18633	17085	22543
	Infiltration From Lowlands	42513	30351	29634	19024	0	0	0	0	1734	20533	40045	44204
	Total Min Supply	62106	37564	38432	27993	10142	14251	12379	15733	23617	40949	58769	68902
	Total Max Supply	93842	49425	52834	42696	26683	37402	32522	41256	58945	73923	89100	108675
Little Carp River	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	9809	3507	4195	4560	5047	7142	6240	7724	11162	10429	9582	12605
	RO From Significant Recharge Area	1446	517	618	672	744	1053	920	1139	1646	1537	1413	1858
	RO From Lowlands	5742	2053	2456	2669	2954	4180	3652	4521	6534	6105	5609	7378
	Infiltration From Lowlands	16222	11377	11240	7228	793	34	0	0	2689	8216	15168	16897
	Total Min Supply	23409	13947	14314	10569	4491	5267	4572	5660	10868	15857	22190	26133
	Total Max Supply	33218	17454	18509	15129	9538	12408	10812	13384	22031	26286	31772	38739
Leigh Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	237	94	109	120	128	176	156	189	264	247	232	293
	RO From Significant Recharge Area	1234	490	567	623	666	916	810	981	1373	1286	1206	1524
	RO From Lowlands	17390	6905	7994	8776	9382	12915	11413	13834	19351	18127	16999	21486
	Infiltration From Lowlands	30030	22090	21575	12687	633	0	0	0	2045	12838	27860	30926
	Total Min Supply	48654	29485	30136	22086	10680	13831	12223	14815	22769	32251	46065	53936
	Total Max Supply	48891	29579	30245	22205	10808	14007	12378	15004	23033	32498	46297	54229

Table 3-11 Total Surface Water Supply

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Bennet Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	15896	5918	6988	7628	8327	11658	10232	12564	17932	16769	15531	20116
	RO From Significant Recharge Area	2004	746	881	962	1050	1470	1290	1584	2260	2114	1958	2536
	RO From Lowlands	8350	3414	3918	4305	4567	6242	5528	6664	9251	8676	8167	10241
	Infiltration From Lowlands	13710	10075	9838	5720	398	0	0	0	1323	5771	12702	14141
	Total Min Supply	24064	14235	14637	10986	6015	7712	6818	8248	12835	16561	22827	26918
	Total Max Supply	39960	20153	21625	18614	14342	19370	17051	20812	30767	33330	38358	47034
West Davignon Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	11625	4616	5344	5867	6272	8633	7629	9248	12936	12118	11364	14363
	RO From Significant Recharge Area	6062	2407	2787	3059	3270	4502	3978	4822	6745	6319	5925	7489
	RO From Lowlands	6394	2539	2939	3227	3449	4748	4196	5086	7115	6665	6250	7900
	Infiltration From Lowlands	11041	8122	7932	4665	233	0	0	0	752	4720	10243	11370
	Total Min Supply	23497	13067	13658	10950	6952	9250	8174	9908	14612	17703	22419	26759
	Total Max Supply	35122	17683	19002	16817	13224	17884	15804	19156	27547	29821	33782	41122
Central Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	RO From Significant Recharge Area	1502	625	714	786	829	1127	1000	1201	1655	1553	1469	1824
	RO From Lowlands	2219	924	1054	1161	1224	1664	1477	1774	2445	2294	2170	2695
	Infiltration From Lowlands	2989	2261	2193	1208	35	0	0	0	58	1113	2757	3061
	Total Min Supply	6710	3810	3961	3155	2088	2791	2478	2975	4158	4960	6396	7580
	Total Max Supply	6710	3810	3961	3155	2088	2791	2478	2975	4158	4960	6396	7580
East Davignon Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	9657	3730	4354	4769	5143	7132	6285	7660	10808	10117	9437	12053
	RO From Significant Recharge Area	5870	2267	2647	2899	3127	4335	3820	4656	6570	6150	5737	7327
	RO From Lowlands	9103	3516	4105	4496	4849	6723	5924	7221	10189	9537	8896	11363
	Infiltration From Lowlands	18035	13078	12818	7764	522	0	0	0	1743	8169	16777	18633
	Total Min Supply	33009	18861	19569	15159	8498	11059	9745	11877	18501	23856	31410	37322
	Total Max Supply	42665	22591	23924	19928	13641	18191	16029	19537	29310	33973	40847	49375

Table 3-11 Total Surface Water Supply

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Fort Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	RO From Significant Recharge Area	4485	1962	2209	2439	2535	3402	3034	3607	4895	4601	4390	5357
	RO From Lowlands	46370	20352	22885	25275	26244	35198	31402	37300	50578	47547	45385	55320
	Infiltration From Lowlands	46465	36412	35003	17317	268	0	0	0	0	13486	42436	47287
	Total Min Supply	97320	58727	60096	45031	29047	38600	34437	40906	55474	65634	92211	107963
	Total Max Supply	97320	58727	60096	45031	29047	38600	34437	40906	55474	65634	92211	107963
Root River	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	79882	30919	37140	38041	42304	58665	51237	64463	88258	82453	76362	98801
	RO From Significant Recharge Area	13269	5354	6349	6528	7160	9822	8616	10751	14531	13590	12687	16160
	RO From Lowlands	45304	17257	20826	21300	23810	33162	28911	36498	50244	46917	43303	56411
	Infiltration From Lowlands	93236	67455	65562	41104	0	0	0	0	2603	42930	87756	96712
	Total Min Supply	151809	90066	92737	68932	30970	42984	37527	47248	67378	103437	143746	169283
	Total Max Supply	231691	120985	129877	106973	73274	101649	88764	111712	155635	185890	220108	268084
Crystal Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	38377	13464	16204	17571	19584	27852	24281	30171	43863	40966	37490	49696
	RO From Significant Recharge Area	2250	774	938	1014	1139	1628	1416	1766	2583	2411	2198	2935
	RO From Lowlands	0	0	0	0	0	0	0	0	0	0	0	0
	Infiltration From Lowlands	0	0	0	0	0	0	0	0	0	0	0	0
	Total Min Supply	2250	774	938	1014	1139	1628	1416	1766	2583	2411	2198	2935
	Total Max Supply	40627	14238	17141	18586	20723	29480	25696	31937	46446	43378	39688	52631
Un-named Creek	Min RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	Max RO From Precambrian Uplands	0	0	0	0	0	0	0	0	0	0	0	0
	RO From Significant Recharge Area	2562	958	1130	1234	1345	1880	1651	2026	2887	2700	2503	3236
	RO From Lowlands	49301	18820	22050	24122	26119	36332	31971	39063	55332	51778	48178	61838
	Infiltration From Lowlands	104927	75484	74120	45525	3550	0	0	0	11959	48849	97721	108624
	Total Min Supply	156790	95262	97300	70880	31014	38213	33622	41089	70178	103327	148402	173698
	Total Max Supply	156790	95262	97300	70880	31014	38213	33622	41089	70178	103327	148402	173698

3.2 Tier 2: Numerical Modelling Method

3.2.1 Overview of the Groundwater Model

A groundwater flow model was prepared by Waterloo Numerical Modelling Corporation (WNMC) as part of the Sault Ste. Marie Area Groundwater Management and Protection Study (R.J. Burnside & Associates Limited, 2003). The main objective of the modelling exercise was to delineate capture zones of the City of Sault Ste. Marie municipal pumping wells which was done using a steady state solution. The model was used to assist with the water budget estimate and to confirm the results obtained from the Tier 1 Assessment. In applying the model for the purposes of conducting the Tier 2 Assessment, no alterations were made to the model.

The extents of the groundwater model cover 130 km^2 and include most of the Central and East Basins. The uplands are not included in the model and the northern extent of the model is represented by an impermeable boundary. The model extents are smaller than the area considered in the Analytical Desktop Method.

The model is divided into six model layers. The top three layers represent overburden deposits and the bottom two layers represent the bedrock. Layer 4 represents the coarse sand and gravel material, layer 5 represents the sandstone aquifer, and the upper portion of the Precambrian granite is assigned to model layer 6.

3.2.2 Groundwater Budget

For a steady-state groundwater model, the basin scale water balance is written as:

$$GW_{in} + I + GW_{transboundary} + Q_{RIV} = GW_{out} + Q_{out}$$

Where:

GW_{in} = *Groundwater inflow into the basin;*
I = *infiltration of precipitation or recharge to the water table*
$GW_{transboundary}$ = *net groundwater inflow to the basin from other basins;*
Q_{RIV} = *Surface water inflow into the basin;*
GW_{out} = *Groundwater outflow from the basin;*
Q_{out} = *Net water taken for consumption or exported from the basin*

Since the model developed is only capable of calculating flows within the groundwater system, recharge from infiltration of precipitation is a specified boundary condition and is selected and assigned to cells within each basin. The developers of the model have accounted for this by assigning recharge values where inflow is anticipated. The desktop analysis is similar in theory; however, recharge and inflow are estimated based on the amount of precipitation which falls in each subwatershed.

3.2.3 Lateral Groundwater Inflow

The inflow, at a rate of 2,100 mm/yr, contributed by the uplands is represented as a zone of recharge along the northern boundary of the model. This value is an artificially increased value of precipitation in this area to represent the potential flow that would otherwise come from the uplands (Appendix A).

3.2.4 Groundwater Recharge

A recharge rate of 250 mm/yr was also assigned to the 'Significant Recharge Area' to account for the increased contribution as a result of the coarse grained materials.

Recharge rates of 60 and 200 mm/yr were specified in the lowlands (Appendix A).

3.2.5 Summary of Total Groundwater

Total water supply into each basin represented in the model was obtained by summing the recharge contribution from the northern model boundary, which accounts for inflow from the Precambrian uplands, the recharge contribution over the significant recharge area, and additional contribution of recharge in the lowlands (Table 3-10).

Comparison of the total water supply estimated for each basin through the modeling method and through the desktop analysis shows that the amount of water supply estimated by modeling is close to the average total water supply value estimated using the desktop analytical method. One of the major differences between these two approaches is that recharge within the lowlands is not considered in the desktop analytical method.

Table 3-12 Total Groundwater Supply Calculated Using the Numerical Modelling Method

Basin	Q_{IN} (m^3/year)	$Q_R + Q_{lowlands}$ (m^3/yr)	Total Supply (m^3/day)
Central	17,634,609	6,473,641	24,108,250
East	9,208,059	7,613,170	16,821,229

Table 3-13 Groundwater Supply Estimates from the Desktop Analytical Method and the Numerical Modelling Method

Basin	Desktop Analytical Method			Modelling Method
	Minimum Total Water Supply (m^3/yr) (m^3/day)	Maximum Total Water Supply (m^3/yr) (m^3/day)	Average Total Water Supply (m^3/yr) (m^3/day)	Total Supply (m^3/day)
Central Basin	14,261,270 (39,072)	34,216,848 (93,745)	24,239,059 (66,408)	24,108,250
East Basin	8,613,061 (23,597)	25,195,491 (69,029)	16,904,276 (46,313)	16,821,229

4.0 CONSUMPTIVE DEMAND ESTIMATION

4.1 Tier 1: Analytical Desktop Method

4.1.1 Existing Groundwater Use

The SSMR Source Protection Area is comprised of a variety of land uses serviced by groundwater mainly including:

- Individual/Domestic;
- Municipal/Public; and
- Commercial/Industrial.

Residents of the City of Sault Ste. Marie are serviced by six municipal wells that obtain water from the Jacobsville Formation and overlying units of the east and central basins. There are two (2) wells at the Lorna Well Site and one (1) well at the Shannon Well Site within the east basin. The total permitted rate in the east basin is 21,000 m^3/day or 7,665,000 m^3/annum. There are two (2) wells at the Goulais Well Site and one (1) well at the Steelton Well Site located in the central basin. The total permitted rate in the central basin is 18,188 m^3/day or 6,639,000 m^3/annum.

Table 4-1 Summary of Major Permitted Groundwater Takings vs. Estimated Recharge

Basin	Water Taking Location	Permitted Rate (m^3/day)	Permitted Rate (m^3/annum)	Average Pumping Rate (m^3/annum)
Central Basin	2 Goulais Wells	9,988	3,645,620	1,888,000
	1 Steelton Well	8,200	2,993,000	2,239,000
	Total	**18,188**	**6,638,620**	**4,127,000**
East Basin	1 Shannon Well	7,000	2,555,000	1,145,000
	2 Lorna Wells	14,000	5,110,000	1,523,000
	Total	**21,000**	**7,665,000**	**2,668,000**

According to the Sault Ste Marie Public Utilities Commission, the total amount of water pumped from all the wells in 2006 was approximately 18,700 m^3/day and 17,600 m^3/day in 2005, well below the permitted limits. The average annual taking from each basin over the past six years was approximately 4,127,000m^3/yr and 2,668,000 m^3/yr from the central and east basins, respectively.

Table 4-2 summarizes the average monthly taking from each well as observed over the past six years.

Table 4-2 Summary of Average Monthly Groundwater Takings

Month	Goulais (m^3/month)	Steelton (m^3/month)	Central Basin (m^3/month)	Shannon (m^3/month)	Lorna (m^3/month)	East Basin (m^3/month)
January	145,127	199,445	344,572	81,189	144,860	226,049
February	137,650	178,397	316,047	67,158	118,765	185,922
March	155,306	194,747	350,053	58,091	114,500	172,592
April	156,076	160,334	316,410	82,167	127,010	209,177
May	163,760	192,332	356,092	100,266	119,751	220,017
June	156,114	190,360	346,474	108,172	127,120	235,292
July	170,963	196,183	367,146	125,064	135,240	260,304
August	170,798	191,972	362,770	122,072	141,350	263,422
September	170,543	179,319	349,862	105,005	130,396	235,401
October	171,594	181,383	352,977	101,280	127,807	229,087

Table 4-2 Summary of Average Monthly Groundwater Takings

Month	Goulais (m^3/month)	Steelton (m^3/month)	Central Basin (m^3/month)	Shannon (m^3/month)	Lorna (m^3/month)	East Basin (m^3/month)
November	140,793	181,057	321,850	98,457	103,685	202,142
December	144,387	191,604	335,990	101,462	125,119	226,581

Table 4-3 summarizes the average annual taking from each well as observed over the past six years. Appendix A provides a list of the total monthly takings recorded over the past six years.

Table 4-3 Summary of Annual Groundwater Takings

Year	Central Basin (m^3/annum)		East Basin (m^3/annum)	
	Goulais	Steelton	Shannon	Lorna
2000	2,444,631	2,388,434	907,133	1,853,096
2001	2,058,036	2,372,751	1,210,540	1,765,097
2002	1,716,068	2,293,972	1,417,930	1,727,543
2003	1,396,071	1,950,587	1,135,271	1,335,116
2004	1,794,487	2,169,269	1,664,178	734,465
2005	1,873,378	2,219,149	998,152	1,325,750
2006	1,930,187	2,281,572	679,824	1,917,335
Average	4,127,000		2,668,000	

The monthly average municipal water takings between 2000 and 2006 were also assessed, and are presented in Figures 4.3 and 4.4 to determine if there were variations in seasonal pumping. Some variations in use are evident in the Shannon well, which services the east basin.

Areas outside of the City of Sault Ste Marie’s urban area including Prince Township and the Sault North planning area are primarily serviced by individual domestic wells. The locations of wells identified in an MOE water well records search is shown in Figure 4.1. Water demands of such areas are estimated based on 335 litres per capita per day (l/c/d). There are also a number of Permits to Take Water (PTTW) that have been issued for small communal systems, both public and private, using more than 50,000 L per day. Figure 4.2 illustrates the location of current PTTWs and a summary of permits is provided in Table 4-4.

Table 4-4 Groundwater Permits to Take Water

Permit No.	Source Name	General Purpose		Expiry Date	Issued Date	Municipality	Maximum Permitted Rate m^3/day	Maximum Permitted Rate m^3/yr
01-P-6022	Sault Ste. Marie Municipal Landfill	Remediation	Groundwater	6/27/2011	6/27/2001	City of Sault Ste. Marie	720	262,800
01-P-6022	Purge Wells	Remediation	Groundwater	6/27/2011	6/27/2001	City of Sault Ste. Marie	650	237,250
02-P-6005	MOE well #11-937	Water Supply	Campgrounds	5/30/2012	5/31/2002	Parke	-	-
02-P-6005	MOE well # 11-940	Water Supply	Campgrounds	5/30/2012	5/31/2002	Parke	-	-
02-P-5039	Drilled Well	Water Supply	Communal	3/31/2013	5/5/2003	City of Sault Ste. Marie	-	-
98-P-6059	Well	Water Supply	Communal	12/31/2008	7/6/1998	District of Algoma	38	13870
02-P-5045	Upper Well	Water Supply	Communal	6/23/2013	6/24/2003	City of Sault Ste. Marie	-	-
02-P-5045	Lower Well	Water Supply	Communal	6/23/2013	6/24/2003	City of Sault Ste. Marie	-	-
02-P-5033	Steelton Well	Water Supply	Municipal	8/11/2012	8/13/2002	City of Sault Ste. Marie	8,200	2,993,000
02-P-5052	Goulais Well #1 and # 2	Water Supply	Municipal	8/11/2012	12/31/2002	City of Sault Ste. Marie	10,001	3,650,365
78-P-5115	Shannon Well, River Range	Water Supply	Municipal	4/30/2018	3/23/1998	City of Sault Ste. Marie	7,000	2,555,000
92-P-5034	Well #1, Section 20	Water Supply	Municipal	3/31/2013	12/18/1992	District of Algoma	50	18,250
92-P-5034	Well #2, Section 18	Water Supply	Municipal	3/31/2013	12/18/1992	District of Algoma	22	8,030
78-P-5116	Lorna Well #1 and #2	Water Supply	Municipal	8/11/2012	6/16/1978	City of Sault Ste. Marie	13,638	4,977,870

The water demand from individual and domestic systems was divided among the three basins and is summarized in Table 4.5. Demand from Price Township was excluded as the majority of the areas do not contribute to the west basin, rather drain directly to Lake Superior and would not otherwise be included in the balance.

The consumptive demand for each use is summarized on an annual basis for each basin in Table 4-5. Based on the Technical Rules, the consumptive factor for deep wells is 100% consumptive because effluents are not able to return to the deep formation. Shallow wells are considered 20% consumptive because some recharge can be returned from the septic systems. A consumptive factor of 60 % was used for domestic wells because approximately half the wells obtain water from the shallow aquifer and half the wells obtain water from the deep wells are likely screened in the deep aquifer.

Table 4-5 Groundwater Consumptive Demand

Basin	Water Use	Water Use	Demand Rate (m^3/yr)	Consumptive Factor	Consumptive Demand (m^3/yr)
West Basin	Individual Domestic	Sparse Rural Population (MOE WWRs)*	265,050	60%	152,2141
		Prince Township*	128,000	60%	71678
	Municipal Supply	-	-	-	-
	Comm/Industrial	PTTW	unknown	100%	-
				Total	223,892
Central Basin	Individual Domestic	Sparse Rural Population (MOE WWRs)*	530,100	60%	304,428
	Municipal Supply	Estimated Takings**	4,127,000	100%	4,127,000
	Comm/Industrial	PTTW - Landfill	500,000	100%	500,000
				Total	4,931,428
East Basin	Individual Domestic	Communal PTTW	40,150	100%	40,150
		Sparse Rural Population (MOE WWRs)*	265,050	60%	152,214
	Municipal Supply	Estimated Takings**	2,668,000	100%	2,668,000
	Comm/Industrial	-	-	-	-
				Total	2,860,364

* Assume 50% of the wells are shallow and 50% of the wells are deep therefore consumptive factor is an average between 100% and 20% ~ 60%

** Estimated Takings based on measured used between 2000 and 2006

By taking into consideration monthly trends in municipal water takings, the range of monthly consumptive demand is summarized in Table 4-6.

Table 4-6 Groundwater Monthly Consumptive Demands

Basin	Avg Consumptive Demand (m^3/month)	Max Consumptive Demand (m^3/month)
West Basin	18,658	18,658
Central Basin	429,610	452,693
East Basin	238,364	279,030

4.1.2 Existing Surface Water Use

The largest surface water user in the study area is the municipal supply system located within the Urban Service Line of the City of Sault Ste. Marie. The main source of surface water is from the Gross Cap intake west of the Lake Superior shoreline, which has a permitted pumping rate of 75,000 m^3/d.

Since the municipal water taking is from a Great Lake, and most permitted surface water takings are either from Lake Superior or St. Marys River, surface water takings contribute to only a few subwatersheds included in the water budget and are accounted for in surface water PTTWs. Figure 4.2 illustrates the location of current PTTWs and a summary of permits is provided in Table 4-7 presented in the Conceptual Understanding. For the purposes of the water budget, only current surface water taking permits are considered in the water balance.

Table 4-7 Surface Water Permits To Take Water

Permit No.	Source Name	General Purpose		Expiry Date	Issued Date	Municipality	Maximum Permitted Rate m^3/day	Maximum Permitted Rate m^3/yr
74-P-5000	St. Mary's River	Commercial	Golf Course	8/31/2009	4/29/1974	City of Sault Ste. Marie	1,527	557,355
0225-68PS83	Thayer Spring	Commercial	Aquaculture	3/31/2014	9/24/1984	City of Sault Ste. Marie	-	-
96-P-6005	Clergue Generating Station Tailrace	Commercial	Aquaculture	5/6/2006	6/5/1996	City of Sault Ste. Marie	1,384	505,160
92-P-5035	St. Mary's River Power Canal	Industrial	Hydro-Electric	3/30/2008	12/22/1992	City of Sault Ste. Marie	128,000	4,672,000
78-P-5110	St. Mary's River	Industrial	Hydro-Electric	3/31/2028	5/26/1978	City of Sault Ste. Marie	84,948,300	31,006,129,500
97-P-6009	St. Marys River	Industrial	Cooling Water	3/31/2017	3/14/1997	City of Sault Ste. Marie	3,318	1,211,070
2153-6DMMXM	Upper St. Mary's River	Industrial	Pulp and Paper	6/30/2015	6/24/2005	District of Algoma	-	-
0641-6CQJBP	Upper St. Mary's River	Industrial	Cooling Water	6/1/2015	6/14/2005	District of Algoma	-	-
92-P-5951	Gros Cap/Lake Superior	Water Supply	Municipal	7/24/2007	4/23/1992	Township of Prince	75,000	27,375,000

The consumptive demand for each use is summarized on a monthly basis for each subwatershed with a surface water taking in Table 4-8. Based on the Technical Rules, the consumptive factor for aquaculture is 10% consumptive, and industrial water takings used for cooling are 25% consumptive.

Table 4-8 Surface Water Consumptive Demands

Basin	Water Use	Demand Rate (m^3/yr)	Consumptive Factor	Consumptive Demand (m^3/yr)	Avg Demand Rate (m^3/mon)
Root River	Aquaculture	-	0.1	-	-
Fort Creek	Cooling Water	1,211,070	0.25	302,768	25,231

4.2 Tier 2: Numerical Modelling Method

The water taking rate in the model includes assumed pumping rates for the municipal wells estimated at 6,000 m^3/day per well or a total taking of 4,380,000 m^3/yr. Comparison of the assumed rates to the actual rates as calculated in the desktop analysis show that the values are similar in the Central basin; however, the assumed rates are greater than actually taken from the East Basin.

5.0 WATER RESERVE ESTIMATION

The concept of a water reserve was developed to ensure that some water is set aside for purposes other than those that are currently permitted, which may include the natural ecosystem or other human uses. The water reserve quantity is estimated as 10% of the annual existing groundwater flow (Q_{IN} and Q_R) for groundwater systems.

For surface water systems, the water reserve quantity was based on the 10th Percentile method. Streamflow data is available for 2 of the subwatersheds, Big Carp River and Root River. The lower decile for each month was calculated and used as a basis to estimate the reserve for the remainder of the subwatersheds.

Based on the desktop analytical calculations and recharge specified in the model, the water reserves estimated for each scenario are presented in Table 5-1 for the groundwater system and Table 5-2 for the surface water system.

Table 5-1 Groundwater Reserve Estimation

Basin	Total Groundwater Supply				10% of Groundwater Flow				Adjusted Groundwater Supply			
	Minimum Annual Recharge (m^3/yr)	Maximum Annual Recharge (m^3/yr)	Average Annual Recharge (m^3/yr)	Modelling Annual Recharge (m^3/yr)	Minimum Annual Recharge (m^3/r)	Maximum Annual Recharge (m^3/yr)	Average Annual Recharge (m^3/yr)	Modelling Annual Recharge (m^3/yr)	Minimum Annual Recharge (m^3/r)	Maximum Annual Recharge (m^3/yr)	Average Annual Recharge (m^3/yr)	Modelling Annual Recharge (m^3/yr)
West	6,647,337	15,716,479	11,181,908	-	664,734	1,571,648	1,118,191	-	5,982,603	14,144,831	10,063,717	-
Central	14,261,270	34,216,848	24,239,059	24,108,250	1,426,127	3,421,685	2,423,906	2,410,825	12,835,143	30,795,163	21,815,153	21,697,425
East	8,613,061	25,195,491	16,904,276	16,821,229	861,306	2,519,549	1,690,428	1,682,123	7,751,755	22,675,942	15,213,849	15,139,106

Table 5-2 Surface Water Reserve Estimation

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Lake Superior	Min Supply	174038	81459	96044	77944	51554	62494	55553	68785	116073	140937	161385	203181
	Max Supply	175216	90538	96491	81015	52116	65412	56267	69700	121339	142239	167917	204806
	Min Reserve	72763	44715	14884	12470	9461	8843	6198	7513	8383	20196	43214	72533
	Max Reserve	73255	49699	14953	12961	9565	9256	6278	7613	8763	20382	44963	73114
	Min Adjust	101275	36744	81160	65474	42092	53651	49355	61272	107690	120741	118171	130647
	Max Adjusted	101961	40839	81538	68054	42552	56156	49989	62087	112576	121856	122953	131693
Big Carp River	Min Supply	60391	33353	37657	26325	9250	12582	11293	14355	21005	39165	55287	66748
	Max Supply	93842	49425	52834	42696	26683	37402	32522	41256	58945	73923	89100	108675
	Min Reserve	25727	17250	5738	4252	1672	2204	1583	2165	2014	6475	13600	23755
	Max Reserve	39977	25562	8050	6897	4823	6550	4558	6224	5652	12221	21917	38676
	Min Adjust	34664	16103	31920	22073	7578	10379	9710	12190	18991	32690	41687	42993
	Max Adjusted	53865	23862	44784	35799	21860	30852	27965	35032	53293	61703	67183	69999
Little Carp River	Min Supply	21963	12130	13695	9578	3747	4078	3652	4521	8925	14320	20107	24275
	Max Supply	33218	17454	18509	15129	9538	12408	10812	13384	22031	26286	31772	38739
	Min Reserve	9183	6659	2122	1532	688	577	408	494	645	2052	5384	8666
	Max Reserve	13888	9581	2868	2420	1750	1756	1206	1462	1591	3767	8508	13829
	Min Adjust	12781	5471	11573	8046	3060	3501	3245	4027	8281	12268	14723	15609
	Max Adjusted	19330	7873	15641	12709	7788	10653	9606	11922	20440	22520	23264	24909

Table 5-2 Surface Water Reserve Estimation

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Leigh Creek	Min Supply	47420	26189	29569	20771	10015	12498	11413	13834	20706	30965	43412	52411
	Max Supply	48891	29579	30245	22205	10808	14007	12378	15004	23033	32498	46297	54229
	Min Reserve	19826	14376	4582	3323	1838	1769	1273	1511	1495	4437	11624	18710
	Max Reserve	20441	16237	4687	3553	1984	1982	1381	1639	1663	4657	12397	19359
	Min Adjust	27594	11813	24987	17448	8177	10730	10140	12323	19210	26528	31788	33701
	Max Adjusted	28450	13342	25558	18653	8825	12025	10997	13365	21369	27841	33900	34870
Bennet Creek	Min Supply	22060	12184	13756	9701	4966	6041	5528	6664	10233	14448	20196	24382
	Max Supply	39960	20153	21625	18614	14342	19370	17051	20812	30767	33330	38358	47034
	Min Reserve	9223	6688	2132	1552	911	855	617	728	739	2070	5408	8704
	Max Reserve	16707	11063	3351	2978	2632	2741	1902	2273	2222	4776	10271	16791
	Min Adjust	12837	5496	11624	8149	4054	5186	4912	5936	9494	12377	14788	15678
	Max Adjusted	23253	9091	18274	15636	11710	16629	15148	18539	28544	28554	28087	30243
West Davignon Creek	Min Supply	17435	9629	10872	7637	3682	4595	4196	5086	7613	11385	15961	19270
	Max Supply	35122	17683	19002	16817	13224	17884	15804	19156	27547	29821	33782	41122
	Min Reserve	7289	5286	1685	1222	676	650	468	556	550	1631	4274	6879
	Max Reserve	14684	9707	2945	2690	2427	2531	1763	2092	1990	4273	9046	14680
	Min Adjust	10146	4343	9187	6415	3006	3945	3728	4531	7063	9753	11687	12391
	Max Adjusted	20438	7976	16057	14127	10797	15353	14040	17063	25558	25548	24736	26442
Central Creek	Min Supply	5208	2876	3247	2293	1259	1610	1477	1774	2422	3407	4768	5756
	Max Supply	6710	3810	3961	3155	2088	2791	2478	2975	4158	4960	6396	7580
	Min Reserve	2177	1579	503	367	231	228	165	194	175	488	1277	2055
	Max Reserve	2805	2091	614	505	383	395	276	325	300	711	1713	2706
	Min Adjust	3030	1297	2744	1926	1028	1383	1313	1580	2247	2919	3491	3701
	Max Adjusted	3905	1718	3347	2650	1705	2396	2201	2650	3858	4249	4683	4874
East Davignon Creek	Min Supply	27139	14988	16923	11864	5371	6506	5924	7221	11547	17706	24845	29995
	Max Supply	42665	22591	23924	19928	13641	18191	16029	19537	29310	33973	40847	49375
	Min Reserve	11346	8228	2622	1898	986	921	661	789	834	2537	6653	10708
	Max Reserve	17838	12401	3707	3188	2503	2574	1788	2134	2117	4868	10938	17626
	Min Adjust	15792	6761	14300	9966	4385	5586	5263	6432	10713	15169	18192	19287
	Max Adjusted	24828	10190	20216	16740	11138	15617	14241	17403	27193	29104	29909	31749

Table 5-2 Surface Water Reserve Estimation

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Fort Creek	Min Supply	92834	51271	57888	41218	26512	34062	31402	37300	48947	61033	84988	102606
	Max Supply	97320	58727	60096	45031	29047	38600	34437	40906	55474	65634	92211	107963
	Min Reserve	38813	28144	8971	6594	4866	4820	3504	4074	3535	8746	22757	36629
	Max Reserve	40688	32237	9313	7204	5331	5462	3842	4468	4006	9405	24691	38542
	Min Adjust	54022	23127	48917	34623	21646	29242	27899	33226	45412	52287	62231	65977
	Max Adjusted	56632	26490	50783	37826	23716	33138	30595	36438	51467	56229	67520	69421
Root River	Min Supply	138540	76514	86388	60391	23810	32093	28911	36498	51142	89847	126831	153123
	Max Supply	231691	120985	129877	106973	73274	101649	88764	111712	155635	185890	220108	268084
	Min Reserve	56825	44429	13612	9568	4436	3462	2400	2467	2483	10896	36725	54832
	Max Reserve	95032	70252	20465	16949	13651	10965	7368	7551	7557	22544	63734	95999
	Min Adjust	81715	32085	72775	50822	19374	28631	26511	34031	48659	78951	90106	98291
	Max Adjusted	136659	50733	109412	90025	59623	90683	81396	104161	148079	163346	156374	172086
Crystal Creek	Min Supply	38377	12161	16204	17004	19584	26954	24281	30171	42448	40966	36281	49696
	Max Supply	40627	14238	17141	18586	20723	29480	25696	31937	46446	43378	39688	52631
	Min Reserve	16045	6675	2511	2720	3594	3814	2709	3295	3066	5870	9715	17741
	Max Reserve	16986	7816	2656	2973	3803	4172	2867	3488	3354	6216	10627	18789
	Min Adjust	22332	5485	13693	14284	15990	23140	21572	26876	39383	35096	26566	31955
	Max Adjusted	23641	6422	14485	15612	16920	25309	22829	28449	43091	37162	29061	33843
Un-named Creek	Min Supply	154228	85178	96170	67400	29669	35160	31971	39063	65120	100627	141193	170462
	Max Supply	156790	95262	97300	70880	31014	38213	33622	41089	70178	103327	148402	173698
	Min Reserve	64481	46757	14903	10783	5445	4975	3567	4267	4703	14420	37807	60853
	Max Reserve	65552	52292	15078	11340	5692	5407	3751	4488	5068	14806	39738	62008
	Min Adjust	89747	38421	81267	56617	24224	30185	28404	34796	60417	86208	103386	109609
	Max Adjusted	91238	42970	82221	59541	25322	32805	29871	36601	65109	88521	108665	111690

6.0 WATER BUDGET SUMMARY

In the SSMR Source Protection Area both surface water and groundwater resources play an important role in the water budget. The surface water system contributes water in the form of infiltration to the groundwater system and therefore establishes an integrated relationship.

6.1 Groundwater System

The three main groundwater basins, the west, central and east basins, are located in the south of the Source Protection Area in the flat area referred to as the lowlands, that are covered by relatively thick clay-rich overburden unit. To the north, the Precambrian Uplands is the predominant feature. The granite in the Precambrian uplands is generally understood to have a low permeability except for limited water found in shallow weathered and fractured bedrock and overlying glacial fluvial sand and gravel deposits.

There are two main forms of groundwater recharge for the basins:

Q_{IN}: Run-off originating from the Precambrian uplands is able to enter into the groundwater system at the thick sand and gravel beach deposits located along the southern edge of the Precambrian uplands, which is identified as a Significant Recharge Area (SGRA); and

Q_R: Recharge as a result of precipitation directly falling on the SGRA.

The aquifer units within the basins vary in depth; however, they are generally located at 80 m to 100 m below ground surface (bgs). Groundwater flow is in a southerly direction in each respective basin. The overburden aquifer and bedrock aquifer formation extends beneath the St. Marys River into the United States. Piezometric levels observed in the aquifer near the shoreline of the St. Marys River are generally artesian in nature, suggesting the potential for upward flow from the confined aquifer to St. Marys River under natural conditions. Burnside (2003) suggests that the groundwater flow passes the Source Protection Area boundary flowing south to the United States. At this stage, the details of how much groundwater discharges to either the St. Marys River or flows toward the United States is uncertain. Further analysis of existing stratigraphy and measured piezometric levels from the Canadian side, the American side and stage/elevations of the river as well as modeling simulations are needed to address this issue.

Based on our understanding of groundwater use, the groundwater demands in the west basin are small and the majority of the takings are from the central and east basins. Comparison of the amounts of each component of the water budget for each basin is summarized in Table 6-1. The water supply values applied assume an average water supply scenario, which are similar to water supply values used in the numerical modeling method. Figure 6.1 illustrates the current understanding of the water budget for each basin.

Table 6-1 Groundwater Budget Summary

Basin	$Q_{(IN)}$ (m^3/yr)	$Q_{(R)}$ (m^3/yr)	Total Groundwater Supply (m^3/yr)	10% Water Reserve (m^3/yr)	Adjusted Groundwater Supply (m^3/yr)	Water Use (m^3/yr)	
						Current Condition	future Condition
West	10,095,735	1,086,172	11,181,908	1,118,191	10,063,717	235,830	259,413
Central	21,659,020	2,580,039	24,239,059	2,423,906	21,815,153	4,945,060	5,439,566
East	14,821,510	2,082,766	16,904,276	1,690,428	15,213,849	2,867,180	3,153,898

In a drought scenario, it is anticipated that the amount of infiltration and subsequent recharge to the aquifer will be reduced as a result of the reduced precipitation. The groundwater system is naturally buffered to sudden extremes in precipitation; however, if the drought condition is prolonged, it is anticipated that the amount of groundwater recharge would decrease and the amount of groundwater consumption could also increase in order to off-set the effects of the drought. This would result in a greater overall stress to the groundwater system.

6.2 Surface Water System

There are 12 subwatersheds within the Source Protection Area. The average monthly surface water runoff was calculated for each subwatershed by summing the potential contribution to surface water from:

- the Precambrian Uplands;
- the Significant Recharge Areas; and
- the Lowlands.

The amount of runoff contribution from the Precambrian uplands can vary from 0 to the calculated runoff. The rationale for the discrepancy is the unknown influence of the significant recharge area on surface water features which cross the highly permeable unit. The amount of runoff contribution from the Significant Recharge Areas is estimated to be the calculated runoff in this area. The amount of runoff contribution in the lowlands is assumed to be the total calculated runoff and infiltration in this area as a result of the low permeability overburden material and the significant upward gradients which would inhibit the potential for groundwater infiltration.

Based on our understanding of surface water use, the surface water demands are small and the only current, documented surface water takings are in Root River and Fort Creek subwatersheds. Comparison of the amounts of each component of the water budget for each basin is summarized in the following section.

7.0 STRESS ASSESSMENT

7.1 Groundwater Stress

Comparison of the amount of water inputs and water taking in each basin enables the estimation of the amount of stress on each basin. The scale of this stress assessment covers each basin and includes the entire area of influence for water taking. A summary of the stress assessment within the SSMR Source Protection Area is presented in Table 7-1.

Table 7-1 Groundwater Stress Assessment

Time Period	Basin	Average Annual % Water Demand	Highest Monthly % Water Demand
Current Conditions	West	2%	3%
	Central	23%	25%
	East	19%	23%
Future Demand	West	3%	3%
	Central	24.9%	27%
	East	21%	25%

Stress values are interpreted as having a moderate stress if they are greater than 10% and less than 25% on an annual basis. The criteria for groundwater stresses are summarized in Table 7-2 and presented in Figure 7.1.

Table 7-2 Groundwater Stress Threshold

Groundwater Quantity Stress Assignment	Average Annual	Monthly Maximum
Significant	>25%	>50%
Moderate	>10%	>25%
Low	1-10%	0-25%

For the SSMR Source Protection Area, the estimated stress on the west basin is likely to be low; however, the estimated stress on the central and east basins is moderate. Should a drought occur, there would be an increase to the stress on each groundwater basin.

The Local Area Risk Assessment is being conducted to investigate whether the City of Sault Ste. Marie's municipal water supply can meet its existing and planned demands. The water quantity local area risk assessment considers four scenarios when evaluating the level of risk for the municipal supply. They are as follows:

1. Existing Land Use, Existing Pumping, Average Climate Conditions;
2. Existing Land Use, Existing Pumping, Drought Conditions;
3. Planned Land Use, Committed/Future Pumping, Average Climate Conditions; and
4. Planned Land Use, Committed/Future Pumping, Drought Conditions.

Both a two year and a ten year drought scenario will be considered as part of Water Budget Tier-3 study. This study is being carried out. These scenarios are designed to capture probable periods of drought conditions; both short and long term duration droughts.

Since the information for current pumping rates is readily available, the two-year and ten-year scenarios will be evaluated during the same simulation for this Stress Assessment. Information relating to the planned pumping rates for municipal wells is not available and therefore the drought assessment will only be carried out for existing pumping rates for the West Basin groundwater subwatershed. The drought scenarios are not required for the Central and East groundwater subwatersheds since both were assigned a moderate stress level when evaluating the current scenario.

7.2 Surface Water Stress

Comparison of the amount of water inputs and water taking in each subwatershed on a monthly basis enables the estimation of the amount of stress on each subwatershed. The scale of this stress assessment covers each subwatershed and includes the entire area of influence for water taking. A summary of the stress assessment within the SSMR Source Protection Area is presented in Table 7.3.

Table 7-3 Surface Water Stress Assessment

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Lake Superior	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	174038	81459	96044	77944	51554	62494	55553	68785	116073	140937	161385	203181
	Reserve	72763	44715	14884	12470	9461	8843	6198	7513	8383	20196	43214	72533
	S - R	101275	36744	81160	65474	42092	53651	49355	61272	107690	120741	118171	130647
	% WD*	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Big Carp River	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	60391	33353	37657	26325	9250	12582	11293	14355	21005	39165	55287	66748
	Reserve	25727	17250	5738	4252	1672	2204	1583	2165	2014	6475	13600	23755
	S - R	34664	16103	31920	22073	7578	10379	9710	12190	18991	32690	41687	42993
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Little Carp River	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	21963	12130	13695	9578	3747	4078	3652	4521	8925	14320	20107	24275
	Reserve	9183	6659	2122	1532	688	577	408	494	645	2052	5384	8666
	S - R	12781	5471	11573	8046	3060	3501	3245	4027	8281	12268	14723	15609
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Leigh Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	47420	26189	29569	20771	10015	12498	11413	13834	20706	30965	43412	52411
	Reserve	19826	14376	4582	3323	1838	1769	1273	1511	1495	4437	11624	18710
	S - R	27594	11813	24987	17448	8177	10730	10140	12323	19210	26528	31788	33701
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bennet Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	22060	12184	13756	9701	4966	6041	5528	6664	10233	14448	20196	24382
	Reserve	9223	6688	2132	1552	911	855	617	728	739	2070	5408	8704
	S - R	12837	5496	11624	8149	4054	5186	4912	5936	9494	12377	14788	15678
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
West Davignon Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	17435	9629	10872	7637	3682	4595	4196	5086	7613	11385	15961	19270
	Reserve	7289	5286	1685	1222	676	650	468	556	550	1631	4274	6879
	S - R	10146	4343	9187	6415	3006	3945	3728	4531	7063	9753	11687	12391
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

* All % WD row represents Low stress category

Table 7-3 Surface Water Stress Assessment

Subwatershed Name	Parameter (m^3/day)	January	February	March	April	May	June	July	August	September	October	November	December
Central Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	5208	2876	3247	2293	1259	1610	1477	1774	2422	3407	4768	5756
	Reserve	2177	1579	503	367	231	228	165	194	175	488	1277	2055
	S - R	3030	1297	2744	1926	1028	1383	1313	1580	2247	2919	3491	3701
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
East Davignon Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	27139	14988	16923	11864	5371	6506	5924	7221	11547	17706	24845	29995
	Reserve	11346	8228	2622	1898	986	921	661	789	834	2537	6653	10708
	S - R	15792	6761	14300	9966	4385	5586	5263	6432	10713	15169	18192	19287
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fort Creek	Demand	1898	1898	1898	1898	1898	1898	1898	1898	1898	1898	1898	1898
	Supply	92834	51271	57888	41218	26512	34062	31402	37300	48947	61033	84988	102606
	Reserve	38813	28144	8971	6594	4866	4820	3504	4074	3535	8746	22757	36629
	S - R	54022	23127	48917	34623	21646	29242	27899	33226	45412	52287	62231	65977
	% WD	3.51%	8.21%	3.88%	5.48%	8.77%	6.49%	6.80%	5.71%	4.18%	3.63%	3.05%	2.88%
Root River	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	138540	76514	86388	60391	23810	32093	28911	36498	51142	89847	126831	153123
	Reserve	56825	44429	13612	9568	4436	3462	2400	2467	2483	10896	36725	54832
	S - R	81715	32085	72775	50822	19374	28631	26511	34031	48659	78951	90106	98291
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Crystal Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	38377	12161	16204	17004	19584	26954	24281	30171	42448	40966	36281	49696
	Reserve	16045	6675	2511	2720	3594	3814	2709	3295	3066	5870	9715	17741
	S - R	22332	5485	13693	14284	15990	23140	21572	26876	39383	35096	26566	31955
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Un-named Creek	Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Supply	154228	85178	96170	67400	29669	35160	31971	39063	65120	100627	141193	170462
	Reserve	64481	46757	14903	10783	5445	4975	3567	4267	4703	14420	37807	60853
	S - R	89747	38421	81267	56617	24224	30185	28404	34796	60417	86208	103386	109609
	% WD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
* All % WD represents Low stress category													

Surface water stress is based on maximum monthly % water demand and as such takes into consideration seasonal variability. The % water demand is calculated for each month, and the largest monthly stress is selected for comparison against the threshold criteria. The criteria for surface water stresses are summarized in Table 7-4 and Figure 7.1A.

Table 7-4 Surface Water Stress Threshold

Surface Water Quantity Stress Assignment	Maximum Monthly % Water Demand
Significant	>50%
Moderate	20%-50%
Low	<20%

For the SSMR Source Protection Area, there were no recorded surface water takings in the subwatersheds with the exception of the Root River and Fort Creek subwatersheds. The maximum monthly calculated % water demand was 0% and as such, stress is considered low. Should a drought occur, there would be an increase to the stress on each surface water system.

7.3 Uncertainty

All available information was applied during completion of the Tier 1 and Tier 2 Assessment to determine the potential stress of the three groundwater basins. A desktop analytical method was used in addition to the “Burnside Model” developed by WNMC for comparative purposes. Each method incorporated different factors which contribute to the level of uncertainty.

The desktop method was based mostly on the available information collected during completion of the Conceptual Understanding. Through this process, data gaps have been identified. The methods used to estimate groundwater recharge (Q_R) and lateral groundwater inflow (Q_{IN}) are both based mainly on theoretical values estimated from land-use and cover. In addition, the amount of groundwater entering the deep aquifer system in comparison to the shallow aquifer systems, is not known and the amount of groundwater discharge in the form of upwellings has not been estimated. Based on these short comings, the uncertainty associated to the groundwater recharge (Q_R) and lateral groundwater inflow (Q_{IN}) are considered to be moderate to high.

The estimates for consumptive demand are partially based on theoretical indices but are also heavily dependant on metered water taking. The uncertainty associated with metered water taking is low.

The uncertainty associated with use of the numerical modeling method was also high. Use of the model includes the same parameters that had caused uncertainty in the desktop method. Lack of field data during the calibration of the model and assumptions used in the development of the model also contribute to uncertainty. The recharge values used in the numerical model were assigned values and the applicability of these values requires supporting field data. Recharge values were also applied in the lowlands; whereas this value was not included in the desktop analytical method. These recharge values in the lowlands also require supporting field data.

The water taking values used in the model were estimates; however, for the purposes of this exercise, the actual pumping rates were used to reduce the uncertainty.

Finally, the model was calibrated using only MOE water well record water levels which will result in an oversimplification of the overall groundwater condition and should only be used to provide some generalized indications of groundwater levels. It cannot be used to accurately evaluate local conditions.

Comparison of the calculated water levels and targets from the MOE water well records are often used to comment on the calibration of the model and estimate the potential error. The model had a Root-Mean-Square (RMS) error is 10.7 m; in essence, this means that the typical error in water level at a particular location is of the order of ±10.7 m (SSP&A, December 2007).

Estimation of groundwater inflows to the basins was difficult to quantify. Estimates of Q_{IN} were obtained by summing the infiltration in the sub-watersheds upgradient of each aquifer basin. A range of values were estimated and the average value was compared with the estimated flow calculated by using equipotential maps. There is some degree of uncertainty as to whether the calculated contribution of surface water to groundwater values is representative of the natural environment and requires validating through physical monitoring.

The amount of groundwater leaving the basin $Q_{\mathbf{OUT}}$, was also difficult to calculate because of the lack of hydraulic information. At this time, no values are provided. Additional geological information will be needed to better define the variability of the overburden thickness. The amount of groundwater contribution to St. Marys River and to the United States is unknown; however, can be estimated using an iterative process that takes into consideration historical potentiometric levels, local geology, stream gauge level in St. Marys River and the influence of pumping municipal wells on the confined aquifer.

To assist with this evaluation, data from monitoring wells showing historical water level trends and associated pumping rates in the confined aquifer is necessary.

A lack of geological, hydraulic and bathometric data for St. Marys River, which is critical in better understanding the relationship between the confined aquifer and the river, also introduces uncertainty to the assessment.

There is also limited data regarding the aquifer units in the Precambrian uplands, although the majority of this area is not water bearing and there are no significant populations in this area to stress the water resources, there is a valley of coarse grained material near the Algoma Central Railway (ACR) which is not well defined.

In moving forward, the uncertainty can be reduced by improving the current understanding of the contribution to the groundwater systems. Development of an integrated groundwater/ surface water monitoring program based on the current understanding can reduce the uncertainty. As part of the monitoring program, some of the key areas to be considered are discussed below:

- Water level monitoring: To assess the impact of water taking on the groundwater system on a regional scale;
- Streamflow monitoring: Baseflow trends for many of the major streams are unknown as limited monitoring was conducted in the past. Streamflow measurement upstream and downstream of recharge areas could assist in quantifying specific rates for streamflow losses or contribution to the groundwater system; and
- Streambed piezometer monitoring: Streambed hydraulic gradients near recharge areas could assist in quantifying specific rates for streamflow losses or contribution to the groundwater system.

7.3.1 Field Observations

Groundwater taking from the central and the east basin has been fairly consistent throughout recent history. The water levels in the area adjacent to St. Marys River have historically been artesian in nature and locals have noted that water levels in the area remain high. Without consistent water taking for municipal supply, the groundwater levels result in flooding problems in basement structures.

No other unusual changes in either surface water flow or groundwater levels have been noted in the SSMR Source Protection Area.

8.0 CONCLUSIONS AND RECOMMENDATIONS

As a part of the Tier 1 Assessment, a water balance on the 12 subwatersheds in the SSMR Source Protection Area was conducted. Water takings from most subwatersheds had low stress since there was no water takings. Surface water demands identified in Fort Creek, Root River account for less than 9% of water supply on a monthly basis indicating that these areas have low stress.

A Tier 2 assessment was conducted on the three groundwater basins. Results showed that the water takings from the west basin range from 2% to 3% of the water supply, which is a low stress on the groundwater system. The water takings from the central basin and the east basin vary between 19% and 24.9% of the water supply indicating that these areas have moderate stress.

For the west basin, no further assessment is necessary at this time; however, on-going monitoring of the groundwater resource and its consumption should be reviewed periodically.

For the central and east basin, the next step involves the execution of a Tier 3 Assessment. The Tier 3 Assessment will involve refining the estimated values for the water budget elements and conducting a risk assessment to determine whether a risk management plan will be needed.