Updated Assessment Report

Sault Ste. Marie Region

Source Protection Area

CHAPTER 2a

CONCEPTUAL WATER BUDGET

With Support Provided by

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ASSESSMENT REPORT
CONCEPTUAL WATER BUDGET

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List of Acronyms

cm	**centimetre**
d	**day**
GIS	**Geographic Information System**
GW	**Groundwater**
IPZ	**Intake Protection Zone**

km	**kilometre**
km^2	**square kilometre**
m	**metre**
mm	**millimetre**
m^3/s	**cubic metres per second**
m^3/d	**cubic metres per day**
MNR	**Ministry of Natural Resources**
MODFLOW	**A Three-Dimensional Finite-Difference Ground-Water Flow Model**
MOE	**Ministry of the Environment**
DEM	**Digital Elevation Model**
OMNR	**Ontario Ministry of Natural Resources**
PTTW	**Permit To Take Water**
SPA	**Source Protection Authority**
SPC	**Source Protection Committee**
SSMR SPA	**Sault Ste. Marie Region Source Protection Area**
SSMRCA	**Sault Ste. Marie Region Conservation Authority**
SWP	**Source Water Protection**
WWTP	**Wastewater Treatment Plant**

EXECUTIVE SUMMARY

OBJECTIVE

To address the initiatives of the Clean Water Act, the Sault Ste. Marie Region Conservation Authority has initiated the development of the Water Budget for the Sault Ste. Marie Region Source Protection Area (SSMR SPA). The objectives of this report are to meet the requirements of the Conceptual Understanding for the Water Budget.

The Conceptual Understanding involves baseline data collection, mapping, and an analysis of the information compiled in order to produce an initial overview of the function of the flow system in the study area (both groundwater and surface water). The main objective of this assessment is to answer the following basic questions:

- Where is the water?
- How does the water move between reservoirs?
- What and where are the stresses on the water?
- What are the trends?

DATA

Data from numerous historical surface water studies and groundwater studies have been incorporated. The Groundwater Management and Protection Study prepared by R.J. Burnside & Associates in 2003 has contributed significantly to our current understanding of the hydrogeologic system. Rather than reinterpreting information already assessed, the information provided will be used as the basis for further analysis and any data gaps will be identified.

The SSMR Source Protection Area depends on surface water from Lake Superior and groundwater wells within the St. Marys River watershed for water supply. As a result, the development of the water budget will require an integrated approach of both systems.

The assessment report was originally developed under the 2008, 2009 and 2013 versions of the Technical Rules and where updates were made, they were carried out under amendments to the 2017 Rules and 2018 addition of pipelines circumstances to the Table of Drinking Water Threats.

SURFACE WATER SYSTEM

The SSMR Source Protection Area consists of a number of smaller subwatersheds each independently draining into both the St. Marys River and Lake Superior. These 12 subwatersheds are associated with 10 major creek systems; one system which discharges directly into Lake Superior and another that is an unnamed river, south of the confluence of the Root River and Crystal Creek and discharges directly to St. Marys River. The land-based area of the planning region is 522 km^2. The City of Sault Ste. Marie obtains surface water from Lake Superior at Gros Cap. Both Lake Superior and the St. Marys River are shared resources of Canada and the United States.

GROUNDWATER SYSTEM

The study area consists of two distinct landforms. The northern portion is referred to as “Precambrian uplands”. The Precambrian granites have very little inherent or primary porosity and are considered practically impermeable. In general, groundwater in the uplands is limited to the shallow sand and gravel glaciofluvial deposits overlying the granite that are mostly centralized around the valley hosting the ACR railway and the Hwy 17 North corridor.

The second major landform is located in an area referred to as the “lowlands”, south of the Precambrian uplands. The major overburden aquifers in this region are within the “west, central, and east basins”. The lowlands area is covered by relatively thick clay-rich overburden unit consisting of glaciolacustrine clays. A layer of coarse grained glaciolacustrine overburden deposits overlie the Jacobsville Formation, a regional sandstone bedrock aquifer. The Jacobsville Formation and the overlying sand and gravel materials are generally considered as one unit. Each of the basins are considered confined aquifers and are known to be artesian at the southern extents near the St. Marys River and each basin is separated by bedrock highs, such that each basin is apparently a separate and hydraulically isolated regional groundwater flow system.

Regional groundwater flow is generally from the higher Precambrian uplands in the north to the St. Marys River in the south, corresponding with the surface topography. Thick sand and gravel beach deposits located along the southern edge of the Precambrian uplands have been identified as the main “recharge area” for the central and east basins identified in the lowlands. The east and central basins are higher yielding aquifers than the west basin. The stratigraphy of the west basin has shown finer materials and a less extensive aquifer unit.

Groundwater recharge in the northern sand and gravel deposits occurs through direct infiltration of precipitation, and recharge from surface streams and wetlands and are the main source of water for the three basins. The shallow sand and gravel deposits are also local groundwater discharge areas, producing headwaters of some local surface drainage features. The Jacobsville Formation, bedrock aquifer is recharged indirectly by the infiltration of water through the permeable overburden materials in the basins.

Groundwater continues to flow downgradient in a southerly direction and crosses the Source Protection Area boundaries at the St. Marys River. The discharge may continue to flow south beneath the St. Marys River to the US or as St. Marys River is the regional topographic low, may discharge to the river. Further investigation is required to determine the discharge rate and pathway.

WATER TAKINGS

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 include the central and east basins. The Lorna and Shannon Wells are located in the east basin and the Steelton and Goulais Wells are located in the central basin. Surface water is obtained at the Gros Cap intake from Lake Superior.

WATER BALANCE

Comparison of the estimated recharge to east basin to the permitted water taking shows that in the east basin, the total permitted pumping rate of 18,188 m^3/day is less than the estimated recharge which likely ranges between 28,600 m^3/day to 30,000 m^3/day (IWS, 1978). In the central basin, the total permitted pumping rate is 21,000 m^3/day, which is greater than the estimated recharge rate which likely ranges between 15,900 to 20,000

m^3/day. However, the actual pumped volume during the year is about half of the permitted volume as indicated by the Public Utilities Commission (PUC).

The permitted rate of surface water taking at Gros Cap is 75,000 m^3/day from Lake Superior. Since this water taking is from a Great Lake and not from the St. Mary's watershed, this water is considered an import into the water balance system. The surface water system in the subwatersheds of the Source Protection Area does not otherwise have significant water takings; however, is an integral source of recharge for the groundwater system and should be included in the overall hydrologic balance as recharge for each basin.

The central and east basins both provide municipal groundwater supply. Based on our current understanding, this resource is finite and its main source of recharge is through infiltration of the coarse granular materials that have been identified on the southern slopes of the Precambrian uplands. From this perspective, a good understanding of the surface water system and its inputs to the groundwater system are necessary to conduct an integrated water-budget assessment.

The volume of water taking from the groundwater system can be estimated based on population data, land-use information and permitted water takings. Based on our current understanding, the groundwater takings are high in comparison to the estimated recharge (recharge values obtained by IWS, 1978 vs. PTTW, 2006). Further assessment of the recharge rate to the groundwater system is recommended to better assess the groundwater balance.

DATA GAPS

Data gaps have been identified in various areas; however, in most cases, estimates for values can be used to develop a reasonable understanding of the water budget. In order to obtain a more accurate understanding of the inputs and outputs to the system, some monitoring is recommended. The following provides a summary of some of the major data gaps identified during this stage of the study:

- Incorporate finalized delineation of sub-watershed boundaries.
- The lack of physical data to calibrate surface water inflow into the system (Sw_i) and surface water outflow from the system (Sw_o) for the water budget. Additional stream gauging stations will be required. Estimates can be achieved using infiltration and runoff values based on land cover data.
- The lack of physical data to calibrate stream flow losses. In order to measure the rate of stream flow loss, or contribution to the groundwater system, it will be necessary to monitor the stream flow prior to passing the recharge zone and comparing it to stream flow downstream of the recharge zone. Estimates can be achieved using infiltration and runoff values based on land cover data.
- The lack of physical data to calibrate the amount of recharge to the groundwater basins. Estimates of the groundwater inflow into the system (Gw_i) can be obtained by summing the infiltration in the sub-watersheds upgradient of each aquifer basin.
- Potentially outdated land cover information.
- The lack of physical data to determine whether groundwater discharges to the US or to St. Marys River and the rate of groundwater outflow from the system (Gw_o). To assist

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

- The lack of geological data and bathometric data for St. Marys River.

RECOMMENDATIONS

As a result of the recommendations above, the Tier 1 assessment was completed and the results are contained within Chapter 2b.

1.0 INTRODUCTION

1.1 SOURCE WATER PROTECTION

One of the prime recommendations of the Walkerton Inquiry was to establish legislation that covers the protection of the drinking water supply through a "source to tap" policy. This policy is expected to provide necessary protection of drinking water resources through a multi-barrier approach that includes protection of the source water prior to its intake into the drinking water system via a surface water intake or groundwater wells.

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 Lake Superior. The planning area encompasses the Municipality of Sault Ste. Marie and the Township of Prince and includes portions of the Townships of Dennis, Pennefather, Aweres, Jarvis and Duncan as well as areas of the Garden River and Batchewana First Nation Reservations. Both Lake Superior and the St. Marys River are shared resources of Canada and the United States. The boundary of the planning region extends out to the international border to the south. The land-based area of the planning region is 522 km^2.

The City of Sault Ste. Marie and the rural residences outlying the city limits depend on surface water from Lake Superior and groundwater wells within the St. Marys River watershed for water supply. Based on this goal, the SSMR was delineated to encompass the St. Marys River watershed as well as a number of smaller watersheds draining the northern shore of Lake Superior above the mouth of St. Marys River.

1.2 IDENTIFICATION OF TECHNICAL OBJECTIVES

The water budget analysis is the first step to quantify and characterize the contributions of each component of the hydrologic system to develop technically sound methodologies for the management of existing and future sources of drinking water.

For the Sault Ste. Marie area this includes the protection of both surface water and groundwater resources.

The primary step in a water budget analysis is the development of a Conceptual Understanding that involves baseline data collection, mapping, and an analysis of the information compiled, to produce an initial overview of the function of the flow system in the study area (both groundwater and surface water). The main objective of this assessment is to answer the following basic questions:

- Where is the water?
- How does the water move between reservoirs?
- What and where are the stresses on the water? and
- What are the trends?

This report describes the Conceptual Understanding developed for the Sault Ste. Marie Source Protection Planning Region and provides a summary of the available baseline information. As part of the analysis, surface water and groundwater systems are assessed with a focus on the development of an understanding of the various components of the watersheds and the interactions between the groundwater and surface water systems.

Upon evaluation of the available information, data gaps are identified and data availability is assessed to determine what level of investigation is possible with the existing data.

Once the systems are characterized, an Integrated Conceptual Understanding is developed that describes how the various elements of the systems relate to each other. In this part, the important linkages between the climate, geology/physiography, land cover, groundwater, surface water and water usage are interlinked to form the basis of the water budget analysis.

1.3 THE HYDROLOGIC CYCLE AND WATER BALANCE

The hydrologic cycle is a continuous process by which water is transferred from the oceans, to the atmosphere, to the land and back to the sea. Understanding the mechanisms of this process is the key to understanding the water balance at a watershed scale. Figure 1-2 illustrates this theory.

Many subcycles exist within this process; however, in all hydrologic budgets, precipitation is the primary input. Some of the precipitation may be intercepted by vegetation or structural objects and will eventually return to the atmosphere by evaporation. Some precipitation that reaches the ground may penetrate the ground (infiltration) to replenish soil moisture and groundwater reservoirs whereas the rest may become surface runoff.

The total quantity of water on earth is finite; therefore, the hydrologic system can be considered a closed system. For most analytical purposes, a water budget can be developed to account for the hydrologic components, based on some general assumptions. The watershed is the basic hydrologic unit within which all measurements, calculations, and predictions are made. A watershed is defined as an area that drains to one outlet, such that any precipitation that falls within the watershed will run-off and either travel overland or in a creek or stream until it discharges to one point. In general, watershed boundaries are based on topographic highs.

In most cases, the watershed boundaries seldom match aquifer boundaries; therefore, when assessing the water budget, it may be necessary to consider the extents of both watershed boundaries and aquifer boundaries. The SSMR Source Protection Area has watershed boundaries that do not match aquifer boundaries and an adaptation of the water budget has been developed to account for this discrepancy and is described in the following sections.

Infiltration is the key component of the hydrologic cycle that describes the relationship between water considered a part of the surface water system and the groundwater system. Some of the water, which infiltrates the ground surface remains at shallow depth (interflow) and its flow eventually contributes to shallow surface water systems including creeks, streams and wetlands. Most of the remaining water is available to recharge the underlying aquifer or aquifers.

As a part of this assessment, the conceptual framework of the surface water and groundwater systems and their interrelationship will be developed. This understanding will be used to assess any stresses or long-term trends in the SSMR Source Protection Area.

2.0 ELEMENTS OF CONCEPTUAL UNDERSTANDING

The elements of a water balance determine the dominant watershed characteristics, features or factors that influence the water balance in a given watershed. This section identifies the elements within the Sault Ste. Marie Source Protection Area and provides a brief description on each as a precursor to the development of the integrated conceptual model. To develop the conceptual understanding for the SSMR Source Protection Area, the following elements were taken in to consideration as available data:

- Climate;
- Physiography;
- Geology;
- Land Cover;
- Land Use;
- Surface Water;
- Groundwater; and
- Water Use.

2.1 CLIMATE

Precipitation, evaporation, and temperature, have a direct effect on the amount of surface runoff and the amount of water available to recharge the aquifers. Hence, understanding precipitation, evaporation, and temperature and their patterns plays a key role in the water budget analysis. The climate of the Sault Ste. Marie source water protection area is affected temporally and spatially by seasonal variations and the physical proximity to Lake Superior. The area is subject to warm summers and cold snowy winters. Lake-effect snow is a common feature of Sault Ste. Marie winters making it a recognized snow-belt area.

The seasonal influences and climate patterns significantly affect the hydrologic cycle of this area in terms of precipitation, snowmelt, depth and extent of frost and infiltration.

Climate data are available from several sources for the Sault Ste. Marie source water protection region. Environment Canada has had weather stations located at several sites in the Sault Ste. Marie area. Table 2.1 presents a summary of Environment Canada's weather station history in the Sault Ste. Marie region.

Table 2.1: Environment Canada Weather Station Recording History

Station Name	Station ID	Latitude	Longitude	Elevation	Years of Data
Sault Ste. Marie Forestry	6057595	46°30'N	84°22'W	193 m	1889-1933
Sault Ste. Marie Insectary	6057597	46°28'N	84°28'W	191 m	1951-1954
Sault Ste. Marie Shingwauk	6057605	46°30'N	84°17'W	183 m	1954-1955
Sault Ste. Marie	6057589	46°32'N	84°30'W	206 m	1949-1959
Sault Ste. Marie #2	6057590	46°32'N	84°20'W	212 m	1957-2002
Sault Ste. Marie A	6057592	46°29'N	84°31'W	192 m	1945-2004

However, currently there are only two weather stations in operation in the Sault Ste. Marie region recording both temperature and precipitation data within the study area: Sault Ste. Marie Airport Station and Sault Ste. Marie Station #2, as shown in Figure 1-1. Although the periods of record date back to 1945 for the Airport Station and 1957 for Station #2, it was found that the earlier part of the data was incomplete with missing records. In order to analyze continuous data records, it was decided to include the period from 1962-2004 for the Sault Ste. Marie Airport Station and 1971-2002 for Sault Ste. Marie Station #2. Tables 2.2 and 2.3 summarize the available climate data for the Sault Ste. Marie Region Watershed.

Table 2.2: Summary of Climate Data for the Period 1962-2004 Recorded at Sault Ste. Marie Airport Station ID=6057592.

Latitude= 46°29'N Longitude= 84°31'W Elevation=192 m

Month	Temperature (°C)	Average		
		Rainfall (mm)	Snowfall (cm)	Precipitation (mm)
January	-10.5	7.2	85.5	72.9
February	-10.1	5.3	51.0	47.2
March	-4.6	26.2	37.1	59.1
April	3.1	50.7	15.7	66.9
May	9.8	69.5	1.1	70.6
June	14.6	78.1	0.0	78.1
July	17.7	73.3	0.0	73.3
August	17.1	85.3	0.0	85.3
September	13.0	96.8	0.2	97.0
October	7.2	83.9	5.7	89.7
November	0.7	53.4	39.4	89.6
December	-6.2	15.6	80.7	78.3
Average	4.3			
Total		645.4	316.4	908.1

Table 2.3: Summary of Climate Data for the Period 1971-2002 Recorded at Sault Ste. Marie #2 Station ID=6057590.

Latitude= 46°32'N Longitude= 84°21'W Elevation=212 m

Month	Temperature (°C)	Average		
		Rainfall (mm)	Snowfall (cm)	Precipitation (mm)
January	-9.9	7.9	92.4	100.3
February	-8.6	5.9	49.5	55.4
March	-3.2	26.4	36.6	63.0
April	3.9	50.5	16.5	66.9
May	11.5	67.3	0.4	67.8
June	15.5	80.8	0.0	80.8
July	18.3	76.2	0.0	76.2
August	17.9	85.0	0.0	85.0
September	13.0	101.7	0.1	101.8
October	7.2	91.3	9.0	100.4
November	0.6	54.9	41.2	96.1
December	-6.2	15.0	95.9	110.8
Average	5.0			
Total		662.9	341.5	1004.4

2.2 PRECIPITATION

Tables 2.4 and 2.5 show that the average snowfall for December, January, February and March are 80.7 cm, 85.5 cm, 51.0 cm, and 37.1 cm annually for the Sault Ste. Marie Airport Station and 95.9 cm, 92.4 cm, 49.5 cm, and 36.6 cm annually for the Sault Ste. Marie Station #2, respectively. Furthermore, the snowfall maxima and minima demonstrate the immense climate variability from year to year in this area. Note that the December 1995 maximum of 207.2 cm was preceded by the 1994 record low of 10.9 cm for the Sault Ste. Marie Airport Station. Similarly, the December 1995 maximum of 244.4 cm was preceded by the 1994 record low of 16.6 cm for the Sault Ste. Marie Station #2.

Table 2.4: Environment Canada Data from Sault Ste. Marie Airport Station 6057592

Month	Average	Maximum	Year of	Minimum	Year of
	Snowfall (cm)	Snowfall (cm)	Maximum	Snowfall (cm)	Minimum
December	80.7	207.2	1995	10.9	1994
January	85.5	146.9	1982	26.5	1981
February	51.0	133.9	1968	9.2	1993
March	37.1	162.8	2002	4.6	1968

Table 2.5: Environment Canada Data from Sault Ste. Marie #2 Station 6057590

Month	Average	Maximum	Year of	Minimum	Year of
	Snowfall (cm)	Snowfall (cm)	Maximum	Snowfall (cm)	Minimum
December	95.9	244.4	1995	16.6	1994
January	92.4	142.3	1972	43.5	1981
February	49.5	95.0	2001	7.6	1998
March	36.6	82.4	1997	7.9	1977

A review of Tables 2.2 and 2.3 shows that for the period of records shown, the average annual rainfall and snowfall are in close agreement. For the Sault Ste Marie Airport, the average annual rainfall is 645.4 mm and the average snowfall is 316.4 cm. Similarly for the Sault Ste. Marie Station #2, the average annual rainfall is 662.9 mm and the average snowfall is 314.5 cm. However, according to the Groundwater Management & Protection Study Report (Burnside, 2003), the inland location of the Sault Ste. Marie Station #2 provides a better representation of the climate conditions in the Sault Ste. Marie area. For this reason, the information from this station was used in the conceptual understanding of the water budget.

For the Sault Ste. Marie Station #2, it was determined that the daily mean minimum temperature ranges from -14.1 °C in January to a mean maximum of 24.1 °C in July with an annual mean daily temperature of 5 °C.

2.3 PHYSIOGRAPHY

The planning area comprises two eco-regions, the Chapleau Plains and the Nipissing eco-region (Environment Canada et al., 1987). The Chapleau Plains comprise the northern uplands portion of the planning area and the Nipissing eco-region comprises of the southern lowland area.

The Chapleau Plains area in the uplands consists of moderately broken terrain with bedrock exposure. There are pockets of till within this northern region which generally surround lakes and wetland areas. Along the north-western edge of the planning area lies a strip of Wartburg till. Through the heart of this Wartburg till runs a significant escarpment which follows the Lake Superior shoreline. The other significant feature in the uplands area is a band of gravel deposits running north-south roughly following the Highway 17 North corridor.

The lowland and upland areas are roughly divided by escarpments running in a southwest to northeast direction. Moderate to strongly broken sandy loam till plains are characteristic in the Nipissing eco-region area of the lowlands. The majority of the till in the area is Mornington Till with a number of the watercourses being associated with Dunkfeld Till.

There are two notable beach head areas in the lowlands. The first follows the shoreline between Sunnyside and Pointe des Chênes. There are a number of beach heads identified along the stretch of Lake Superior shoreline. Further inland from the beach heads lies a terrace following the shoreline running in a northwest to southeast direction. This terrace curves around 180 degrees very roughly following the shape of the shoreline around Pointe des Chênes, Pointe Louise and Pointe aux Pins. The other area of beach heads is at the eastern edge of this terrace just west of the Big Carp River near the shore of the St. Marys River.

A third beach head is a nearly continuous terrace which encircles the City of Sault Ste. Marie to the north and also follows the general shape of the present day shoreline of the St. Marys River. This escarpment dips south moving closer to the river just east of the city's downtown and extends eastward for approximately three kilometres and then curves north. This curve in the terrace forms a plateau within the city that is locally known as "the top of the hill". Map CWB Map 1 shows the general physiography of the area.

2.4 GEOLOGY

The study area consists of two distinct landforms. The northern portion represents the topographic high forming a relatively rugged terrain of Precambrian granites (Figure 2-1). This region is referred to as "Precambrian uplands". South of this region is the relatively flat lying area adjacent to the St. Marys River. This area is referred to as the lowlands. This lowlands area is covered by relatively thick clay-rich overburden unit consisting of glaciolacustrine clays. Few shallow deposits of sand and gravel are present in this area.

The overburden geological formations observed in the Sault Ste. Marie area originated during the last stage of the Pleistocene glaciations known as Wisconsinan glaciations. The advance and retreat of glaciers resulted in the formation of various overburden formations. The lacustrine surficial soils are believed to have been deposited in the glacial Lake Algonquin that occupied the area during Wisconsinan glaciations. The terraced sand and gravel deposits on the southern slopes of the Precambrian uplands have been identified as Lake Algonquin beach deposits. In the Precambrian uplands area, the glaciers have scraped out the majority of the surficial material exposing the bedrock (Burnside, 2003). Conceptual cross section as shown in Figure 2-2 and Figure 2-3 illustrates the general stratigraphy in the area.

The generalized stratigraphy present in the Sault Ste. Marie area consists of seven major units: two bedrock units and five overburden units. Precambrian granite underlies the entire area, which is overlain by Jacobsville Sandstone formation in the lowlands. The geology of the northern part of the State of Michigan, USA is similar to the Sault Ste. Marie area geology. As evidenced from a number of water well records from Sault Ste. Marie, Michigan (downloaded from the USGS website), the overburden formations are similar to those identified in the study area (Burnside, 2003).

2.4.1 Bedrock

The majority of the study area is underlain by Precambrian rock as illustrated in Figure 2-4. The Precambrian unit consist of granitic and magmatic rocks, as well as quartzite, basalts and limestones. As a result of their resilient composition, these rocks have endured years of weathering and glaciation and persist as the Precambrian uplands. South of the Precambrian uplands are sandstones of the Jacobsville Formation of Cambrian age. The Precambrian rock is present everywhere beneath the sandstone.

Three elongated bedrock highs, which run in a southerly orientation originating from the uplands towards the St. Marys River act as boundaries for the three major groundwater basins, the “west, central and the east basins” within the SSMR Source Protection Area. Figure 2-5 illustrates the bedrock topography.

2.4.2 Surficial Geology

The most recent glaciation occurred during the Wisconsinan Substage of the Pleistocene Epoch approximately between 23,000 years to 10,000 years before present resulted in a highly varied surficial geology as shown in the Geologic map Figure 2-6.

Glaciolacustrine beach sands and gravels occur immediately adjacent to the Precambrian uplands and consist of a series of glacial age lakes beaches and terraces, mainly along the southern edges of the uplands. These sand and gravel deposits appear as ridges, increasing in elevation to the north, and directly overlying the bedrock for the most part.

Further to the south is a thick overburden unit consisting of glaciolacustrine clays, deposited by glacial stages of Lake Superior, forming the major confining unit for the area. Figure 2-7 and WC Map 02E – Overburden Thickness illustrates the geologic features and thickness of the overburden materials.

2.5 LAND USE

The SSMR Source Protection Area is situated within the District of Algoma, along the north shore of the St. Marys River and Lake Superior. The planning area encompasses the Municipality of Sault Ste. Marie and the Township of Prince and includes portions of the Townships of Dennis, Pennefather, Aweres, Jarvis and Duncan as well as areas of the Garden River and Batchewana First Nation Reservations.

The land use of the SSMR Source Protection Area is presented in Figure 2-8. Most development and the majority of the population is in the City of Sault Ste. Marie, along the north shore of St. Marys River on the lowlands. Other small communities are found along the northern shore of Lake Superior and on the Precambrian uplands, along the Hwy 17 North corridor. The Census data taken from Statistics Canada shows that the population in the Sault Ste. Marie Region in 1996 was 83,619 and in 2001 was 78,908; the decline in population suggests that future changes to the present land use will be limited. It is estimate that the urbanized area accounts for approximately 9.8% of the overall planning region. This includes residential, industrial, commercial and institutional uses. The remainder of the area is mainly composed of rural, sparsely wooded, or scrub.

2.6 LAND COVER

The boundary of the SSMR Source Protection Area extends out to the international border along its entire width. The land-based area of the planning region is 522 km^2. The City of Sault Ste. Marie and the rural residences outlying the city limits located north of the shore of St. Marys River on the lowlands is the main urban area. The urbanized area accounts for approximately 9.8% of the overall planning region.

Land cover for the SSMR Source Protection Area is shown in Figure 2-9 (WC Map 01 – Source Protection Area). The remainder of the Source Protection Area is comprised of a combination of water bodies, vegetation in the form of woodlands and scrub and land suitable for agricultural (Land Use – Canada Land Inventory, 1966). The estimated area of woodland was 71.5% (productive woodland), the area for scrub was 6% (non-productive woodland) and the area suitable for agriculture was 9% of the overall planning region.

Land cover is one of the factors that influences the distribution of surface runoff and infiltration to the subsurface. In the SSMR Source Protection Area, the local land use, land cover, and surficial geology will be considered in conjunction when assessing the potential infiltration since each may affect infiltration differently. For example, the woodland area would typically receive a moderate amount of infiltration; however, since it is located in the Precambrian uplands where overburden material is limited and the area is underlain by bedrock material, limited infiltration would occur in this area. Rather, flow may occur in the shallow overburden materials and the weathered portion of the bedrock to some degree, otherwise, the majority of the water would likely travel as interflow, or as runoff prior to reinfiltration to the aquifer systems found in the lowlands. The major land uses within the planning area also shown on the CWB Map 8 and CWB Map 8A.

2.7 SURFACE WATER

The St. Marys River is the outlet from Lake Superior where water exits the lake from Whitefish Bay flowing in a south-easterly direction. The river is the connecting channel between Lake Superior and Lake Huron. The entirety of the St. Marys drainage basin includes the Lake Superior watershed as the lake drains directly into the river as shown in Figure 2-10. The immediate watershed consists of a number of smaller subwatersheds in both Canada and the United States, which collectively include 2,600 km^2 of land and 230 km^2 of water (MOE & DNR, 1992). The Source Protection Planning Region includes the Canadian component of the St. Marys watershed consisting of 12 subwatersheds with each independently draining into both the St. Marys River and Lake Superior. These 12 subwatersheds are associated to 10 major creek systems, one system which discharges directly into Lake Superior and another that is an unnamed river, south of the confluence of the Root River and Crystal Creek and discharges directly to St. Marys River. The subwatersheds are illustrated in Figure 2-10. In addition, the CWB Map 3 shows the surface water control structures within the watershed areas.

A description of the major subwatersheds draining to the St. Marys River is presented in the following sections. A summary of relevant information for these major subwatersheds is presented on Table 2.6.

2.7.1 Big Carp River

This river is the first major watercourse east of Lake Superior. The Big Carp originates at Walls Lake at an elevation of 312 masl (metres above sea level) in heavily forested terrain in the Precambrian Shield. Walls Lake is a small inland lake rimmed with wetland areas approximately four kilometres in length. From the lake, the river flows south-easterly where it is joined by a 8 km long easterly tributary. This confluence is approximately 2.4 km south of Second Line. The river flows to the St. Marys just east of Carpin Beach (SSMRCA, 1969).

Surrounding the mouth of both the Big Carp and the Little Carp Rivers is a provincially significant wetland area known as the Carp River wetland. The wetland extends along approximately 3 km of the St. Marys shore (Cooke, 2005). This wetland area is subject to flooding in times of elevated water on the St. Marys River and high surface runoff. Burnside (2003) determined that future development within this watershed would increase flooding at the mouth of the river.

The latest analysis of flood flows by Dillon (1997) utilized the Natural Resources Soil Conservation Service (SCS) Curve Number (CN) method. The characteristic CN for the Big Carp River watershed was found to be 70, resulting in a peak flow of 164 m^3/s. The peak flow was calculated using the Timmins Regional storm (Burnside, 2003).

2.7.2 Little Carp River

The Little Carp River runs approximately 12 km from its headwaters to its mouth just east of the Big Carp River along the St. Marys River. It originates in the Precambrian Shield in Prince Township at a small lake (1.8 ha) north of Third Line. From this point, it flows through a steep valley south to Second Line. After this point, it meanders through the lowlands of the Algonquin and Nipissing Terraces and approaches the Big Carp River before meeting the St. Marys (SSMRCA, 1969, Dingwall, 1982). Similar to the Big Carp River, land use within this watershed is mainly undeveloped with some sparse residential and agricultural development.

In the floodplain management report prepared by Dillon (1977), the Regional Storm flow at the mouth of the Little Carp River was calculated to be 64 m^3/s. The 100-yr return flood flow at the same location was calculated to be 39 m^3/s by the SSMRCA (1969).

Flooding at the mouth of the Little Carp River occurs similar to the flooding at the Big Carp because of the close proximity of the mouths of these two rivers. Remedial measures to alleviate this problem could include channel excavation and improvements as suggested by Dillon (1977). As with the Big Carp, the report notes that development within this watershed should take into account the impacts on downstream flooding and include flood control measures to mitigate its effects (Burnside, 2003).

Table 2.6 : Peak Flood Flows for Major Drainage Basins

		Drainage Area	Slope	1966 Proctor & Redfern*	1969 SSMRCA*	1977 Dillon Ltd**	1987 Wm. R. Walker	1988 Proctor & Redfern
Watercourse	**Location**	**(km^2)**	**(m/km)**	**(m^3/s)**				
Big Carp River	at St. Marys River	58	28.7		82	164		
Little Carp River	at St. Marys River	21	26.8		39	64		
Leigh Bay Creek	at Leigh Bay	7	18.5		23	43		
W & E Davignon Creek	at St. Marys River	66	38 & 36			223		
Central Creek	at E. Davignon	3	13.9	22	15	22		
Bennett Creek	at confluence w/ W. Davignon	22	41.3		37	72		
Fort Creek	at St. Marys River	7	20.0			38		27/37
Clark Creek	at St. Marys River	6	8.5	19				
Root River	at West boundary of Indian Reserve	114	20.4			174	97/159	
West Root River	at confluence w/ Root River				35			
Coldwater Creek	at confluence w/ Root River	3				12		
Crystal Creek	at West boundary of Indian Reserve	21				67		

* 1 in 100 year flood
** Timmins Regional Storm
#/# - 1 in 100 year flood/Timmins Regional Storm
Table taken from Sault Ste. Marie Area Groundwater Management & Protection Study, R.J. Burnside, 2003

2.7.3 Leigh Bay Creek

Leigh Bay Creek borders the western edge of the urban area of the city. Its headwaters do not extend to the uplands area but originate in the flat lowland area just north of Second Line. The creek flows south easterly across Second Line and Leigh's Bay Road. It then crosses Baseline and discharges to St. Marys River. A diversion channel from the Bennett and West Davignon Creeks joins these two systems with the Leigh Bay Creek just north of the Base Line Road crossing. This diversion was built in 1979 (CRA, 2005) in order to minimize flooding west of Goulais Avenue between Third Line and St. Marys River. The outfall of the city's west end wastewater treatment plant (WWTP) is in the vicinity of the discharge point of Leigh Bay Creek to St. Marys River approximately 1.2 km offshore (Griffith, 2005).

Dillon (1977) estimated a peak flow of 43 m^3/s based on the Regional Storm and the SSMRCA (1969) reported a peak flow of 23 m^3/s based on the 100-year return storm (Burnside, 2003). Historically, flooding has not been an issue within the Leigh Bay Creek watershed.

2.7.4 Bennett Creek

The Bennett Creek drainage basin originates in a vast marshy area in the Precambrian Shield. It flows south easterly from its headwaters for approximately 14.5 km to its confluence with the West Davignon Creek just south of Wallace Terrace (SSMRCA, 1969). Initially, the creek's slope is gentle and it increases as the watercourse drops into the terraced lowlands area within the city. Flow of the creek is restricted within the urban area of the city due to road crossings prior to its confluence with the West Davignon. The Bennett-West Davignon diversion channel reduces the creek's flow just north of Wallace Terrace east of the Allan's Side Road intersection. The Bennett Creek discharges to the St. Marys River via a constructed channel that terminates at a boat slip on the Essar Steel Algoma Inc. property.

The Dillon (1977) report estimated that the Regional Storm flow for Bennett Creek upstream of the confluence with the West Davignon Creek was 72.20 m^3/s prior to the diversion and would be reduced to 1.42 m^3/s after the diversion was to be built.

2.7.5 West Davignon Creek

The main channel of the West Davignon Creek is approximately 11 km long. Similar to the Bennett system, the West Davignon headwaters are located high up within the Precambrian Shield. The main source for this system is Allard Lake, a lake edged by wetlands. Other wetland areas in the vicinity also contribute to the flow of this creek. Flow of the creek is generally south until it reaches Second Line at which point it swings southeast. Just north of Second Line, a portion of the flow is diverted south to join Bennett Creek. The remaining flow meanders southeast until it crosses Wallace Terrace. From this point, the natural creek bed has been channelled west and then south to its confluence point with Bennett Creek. As previously mentioned, the discharge point of the Bennett and the West Davignon creeks is at the top of the Essar Steel Algoma Inc. boat slip.

The Dillon (1977) report estimated that the Regional Storm flow for the West Davignon Creek upstream of the confluence with the Bennett Creek was 71.35 m^3/s prior to the diversion and would be reduced to 12.17 m^3/s after the diversion was to be built.

2.7.6 Central Creek

This small watercourse contributes flow to the East Davignon Creek and is almost entirely within the urban area of Sault Ste. Marie (SSMRCA, 1969). The creek begins near the intersection of Moss Road and Third Line. It flows south to a continuous concrete aqueduct at Wallace Terrace. Through the aqueduct, it is discharged to the East Davignon Creek on Essar Steel Algoma Inc. property approximately 1 km upstream of the East Davignon's discharge point to the St. Marys River. Central Creek collect residential and industrial run off from the west end of the city.

The Dillon (1977) report estimates that the Regional Storm flow for Central Creek upstream of the confluence with West Davignon Creek is 21.94 m^3/s.

2.7.7 East Davignon Creek

The East Davignon headwaters are located north of the city limits high within the Precambrian Shield. Nettleton Lake is a small lake (12 ha) located along the main branch of the creek at Fifth Line. The East Davignon flows south through a steep ravine to Rossmore Road. South of Rossmore Road the urban development is very close to the creek. South of Second Line, the creek is channelled into a continuous concrete aqueduct that carries the creek across Wallace Terrace and then south-westerly through the Essar Steel Algoma Inc. property to the St. Marys River. Along this channel, discharges from Tenaris Algoma Tubes and Essar Steel Algoma Inc. contribute to the creek flow as well as the aqueduct carrying Central Creek.

Proctor and Redfern (1996) projected the 10-yr and 100-yr flood flows within the East Davignon Creek at the St. Marys River to be 27.5 m^3/s and 40 m^3/s, respectively.

2.7.8 Fort Creek

Fort Creek originates at the northern limit of the Algonquin Terrace and flows through the heart of the urban district, located on the Nipissing Terrace. The Fort Creek dam was constructed in the 1970's upstream of the Second Line crossing, to alleviate flood damage to the urban core. The upper two thirds of the watershed (i.e., upstream of the dam) is steeply sloped and has a number of steep sided ravines. Downstream of the dam at Second Line, the topography gently slopes south towards the St. Marys River.

Below the dam, Fort Creek is conveyed by a concrete aqueduct from Hudson Street to Queen Street. Below this point, Fort Creek flows along an open channel to the St. Marys River.

Both Dillon (1997) and Proctor & Redfern (1988) have presented peak flood flows along Fort Creek at the St. Marys River. Dillon (1977) estimated the peak flood flow of 38 m^3/s for the Regional Storm. In 1988, Proctor & Redfern estimated the peak flow of 37 m^3/s for the same storm event and also calculated the 100-year peak flow to be 27 m^3/s.

In the same report, Proctor and Redfern also concluded that several potential flooding issues still existed within this area. Their recommendations included several natural channel improvements and culvert replacements to alleviate flooding problems upstream of Wellington Street and at the creek's outlet at St. Marys River (Burnside, 2003).

2.7.9 Clark Creek

Clark Creek is an engineered drainage channel that conveys storm water runoff from the east end of the city to the St. Marys River. The creek discharges into St. Marys River south of Drake Street and Queen Street East intersection (Walker, 1998). From the Drake/Queen Street intersection to the discharge point on St. Marys River, the creek flows through a concrete box culvert. Upstream of this culvert the creek is an open channel, which extends northeast for approximately 750 metres through the Gravelle Subdivision and the Sault Ste. Marie Golf Club and then north for approximately 900 metres to the southwest corner of Bennett Boulevard and Boundary Road (Walker, 1998).

The drainage area of Clark Creek extends significantly further north than the intersection of Bennett Boulevard and Boundary Road, due to the municipal storm sewer system in this area. There are two significant storm sewer discharges to Clark Creek at the Bennett Boulevard and Boundary Road intersection. The creek's watershed is located in the terraced lowland area. Land use within the catchment is primarily residential resulting in high surface runoff. Development in the east end of the city has led to increased flows to Clark Creek. In the mid-1990s, a capacity review study was carried out by Wm. R. Walker Engineering (1994) as a result of near flood conditions during storm events at the time. The study determined that the capacity of Clark Creek was only sufficient to contain a 1 in 10-year flood without overtopping its banks. This issue has not been resolved and continues to be a potential problem.

2.7.10 Root River

The Root River watershed, which also includes the West Root River, is the largest catchment in the planning area. The basin originates in the northern uplands where a number of swamps, bogs and lakes, including Upper and Lower Island, Aweres and Trout Lakes, feed into the three main tributaries of the river; the Root, the West Root and Crystal Creek. The West Root drains the western portion of the basin and joins the main river west of Highway 17 North near the Root River Golf Course. The Crystal Creek headwaters are in the north-eastern region of the basin. Crystal Creek joins the main river north of Highway 17 East, close to the eastern boundary of the Batchewana First Nation Rankin Reserve. Root River discharges to St. Marys River at Bell's Point on Little Lake George.

Flooding issues have not been reported within the Root River watershed although seasonal flow variation of the river is substantial. Dillon (1977) did however identify that the Algoma Central Railroad culvert on the Root River at Highway 17 North is insufficient. Flood peaks have historically occurred in month of April, May and November. Land use within the area is largely undeveloped with some rural residential and industrial activity (SSMRCA, 1969 Burnside, 2003).

Peak flows for the Root River based on the Regional Storm were calculated at the point where the river enters the western boundary of the Batchewana First Nation Rankin Reserve. Dillon (1977) reported the peak flood flow to be 174 m^3/s using the SCS method and Walker (1987) calculated it as 159 m^3/s using a 3-parameter lognormal distribution analysis. Walker (1987) calculated the 100-year return flow to be 97 m^3/s.

2.7.10.1 Coldwater Creek

Coldwater Creek adjoins the Root River but is very small in comparison. At the confluence with the Root River, it has a drainage area of approximately 3 km^2.

It has similar hydrological characteristics as the Root River since in the Dillon (1977) report it has similar runoff potential. Dillon estimated the Region Storm flow to be 11.75 m^3/s at the confluence with the Root River.

2.7.11 Crystal Creek

Crystal Creek is located at the north-eastern corner of the SSMRCA jurisdictional boundary and flows to the western boundary of the Indian reserve. Prior to discharging to the St. Marys River, it joins with the Root River.

Crystal Creek traverses primarily the Uplands area but at the downstream area passes through the Algonquin and Nipissing Terraces. The sub-watershed is marked by several inland lakes and fairly extensive drainage system. The area is largely undisturbed.

Dillon (1977) calculated that under the Regional Storm, the peak flow would be 66.54 m^3/s. No evidence of flooding was reported in the document.

2.8 GROUNDWATER

The study area consists of two distinct landforms. The northern portion represents the topographic high forming a relatively rugged terrain of Precambrian granites. Figure 2-1 shows the topography for the study area. This region is referred to as "Precambrian uplands". Intact Precambrian granites have very little inherent or primary porosity and are considered practically impermeable. Freeze and Cherry, 1979, have identified an estimated hydraulic conductivity in the range of 10^{-13} to 10^{-10} m/s for unfractured igneous rock. Groundwater flow in the Precambrian granites occurs only in the weathered and fractured portions of the rock. In general, groundwater in the uplands is limited to the shallow sand and gravel glaciofluvial deposits overlying the granite that are mostly centralized around the valley hosting the Algoma Central Railway (ACR) and the Hwy 17 North corridor. Various alluvial and glaciomarine deposits have also been identified in the uplands; however, shallow Precambrian granite is predominant in this area. Figure 2-4 and WC Map 02A – Bedrock Geology illustrates the bedrock geology in the study area.

South of this region is the relatively flat lying area adjacent to the St. Marys River, with most of the commercial and residential development within the City. This area is referred to as the lowlands. This lowlands area is covered by relatively thick clay-rich overburden unit consisting of glaciolacustrine clays. Few shallow deposits of sand and gravel are present in this area. These deposits are a source for shallow domestic wells. The major overburden aquifers in this region are within the "west, central, and east basins" as illustrated in Figure 2-11 and CWB Map 4.

The glaciolacustrine overburden deposits overlie the Jacobsville Formation, a regional bedrock aquifer. In the study area, the Jacobsville Formation is present south of the Precambrian uplands. The sandstone of Jacobsville Formation and the overlying sand and gravel materials act almost as one aquifer unit. A conceptual cross section illustrates the general stratigraphy in the area (see Figure 2-2 and Figure 2-3).

2.8.1 Regional Hydrogeology

Regional groundwater flow is generally from the higher Precambrian uplands in the north to the St. Marys River in the south, corresponding with the surface topography. Figure 2-12 shows the water table elevation contours as prepared by Burnside, 2003. The contours were derived from water levels observed in MOE WWR installed to a maximum depth of 20 m. Thick sand and gravel beach deposits located along the southern edge of the Precambrian uplands have been identified as the main "recharge area" for the three basins identified in the lowlands. A conceptual diagram of the stratigraphy is shown in Figure 2-2, Figure 2-3 and WC Map 02B - Bedrock Topography (DEM).

Groundwater recharge in the northern sand and gravel deposits occurs through direct infiltration of precipitation and recharge from surface streams and wetlands and are the main source of water for the three basins. The shallow sand and gravel deposits are also local groundwater discharge areas, producing headwaters of some local surface drainage features.

The Jacobsville Formation, bedrock aquifer is recharged indirectly by the infiltration of water through the permeable overburden materials in the basins. Each groundwater basin as described in the following sections is separated by bedrock highs, such that each basin is a separate and likely a hydraulically isolated regional groundwater flow system. Figure 2-13 shows the potentiometric surface contours. The potentiometric contours were derived from water levels observed in MOE WWRs installed at depths greater than 20 m.

St. Marys River is the regional topographic low and is most likely the discharge boundary for the groundwater within the Sault Ste. Marie area. Limited information is available at this point to determine the extent of the interconnectivity between the aquifers and the river. Due to the location of the municipal wells near the shore of St. Marys River, further investigation into the relationship of the groundwater and surface water is recommended.

2.8.2 Precambrian Uplands

The available groundwater in the Precambrian uplands is fairly limited since the granitic bedrock material is considered not water-bearing. However, there is a bedrock valley filled with sand and gravel materials. This represents the only recharge zone located within the Precambrian uplands. Groundwater discharge zones within the uplands occur along surface watercourses, as well as the area of sand and gravel located along the northern contact for the uplands. Burnside, 2003 developed a map of groundwater recharge and discharge areas based on geologic formations (see Figure 2-14 and CWB Map 6).

Two groundwater recharge areas occur within the municipal city limits; one in the area of Gros Cap along the shore of Lake Superior in the west (approximately 3.12 km^2), and a major area at the bedrock/overburden interface along the southern contact of the Precambrian uplands in the north portion of the City (approximately 37.5 km^2). The latter of the two is recognized as the main recharge zone having connection with the capture zones of all six municipal groundwater wells. This valley is providing recharge to both confined and unconfined aquifers. Approximately 124 mm of total precipitation (1010 mm) is infiltrate per year, which is approximately 87.12 % (> 55%) greater than the whole of the related groundwater recharge area (Burnside, 2003).

2.8.3 East Basin

In plan view, the east basin is narrow on the upgradient side and widens towards the St. Marys River. The regional aquifer consists of a sand and gravel layer of varying thickness and permeability and the upper portion of the underlying Jacobsville sandstone. The aquifer is mainly recharged through glaciolacustrine sands and gravels adjacent to the Precambrian uplands to the north.

An upper aquifer is located along the north shore of the river, which receives seasonal recharge from the river. Piezometric levels observed in the aquifer near the shoreline of St. Marys River are generally artesian in nature, suggesting the potential for upward flow from the confined aquifer to St. Mary's River under natural conditions. However, water-taking activities may temporarily lower the piezometric level that may induce a reversal in flow. The long-term influence of this stress will be dependent on the degree of pumping and the thickness of the overlying unit separating the river and the aquifer. Some borehole information from wells installed along St. Marys River shows that the depth of the overburden in this area ranges from 5 m to 20 m below ground surface (bgs). Further information is required to evaluate this scenario and/or the potential rate of flow beneath St. Marys River to the US.

Two municipal wells, the Lorna and Shannon wells are located within the East Basin. Approximate natural groundwater recharge in this basin is estimated to ranges from 15,900 to 20,000 m^3/day (5,800,000 to 7,300,000 m^3/yr) (IWS, 1978).

2.8.4 Central Basin

The aquifer of the central basin is defined by the north-south trending, pre-glacial valley. It also consists of a combination of the sand and gravel overburden material and the upper portion of the underlying Jacobsville Sandstone.

The central basin appears to be directly connected to the "recharge area" adjacent to the Precambrian uplands to the north, with a number of streams from the uplands draining into this basin. Piezometric levels observed in the aquifer near the shoreline of St. Marys River are generally artesian in nature, suggesting the potential for upward flow from the confined aquifer to St. Mary's River under natural conditions. However, water-taking activities may temporarily lower the piezometric level, which may induce a reversal in flow. The long-term influence of this stress will be dependent on the degree of pumping and the thickness of the overlying unit separating the river and the aquifer. Some borehole information from wells installed along St. Marys River shows that the depth of the overburden in this area ranges from 5 m to 12 m below ground surface (bgs). Further information is required to evaluate this scenario and/or the potential rate of flow beneath St. Marys River to the US.

Approximate natural groundwater recharge is estimated to range from 28,600 to 30,000 m^3/d (10,439,000 to 10,950,000 m^3/yr) (IWS, 1978).

Although, the overburden thickness appears to be relatively thin, wells in this area (Goulais and Steelton) were found to be very productive and artesian conditions exist over a large part of this basin (Burnside, 2003). Overburden is about 60 m thick near St. Marys River and consists of 40 m of clay and silt and 18 m of fine sand.

2.8.5 West Basin

An upper sand formation in the shoreline area of the west basin was identified in the Burnside Study. The major aquifer comprised of a combination of the sand and gravel overburden material and the upper portion of the underlying Jacobsville sandstone is overlain by a significant thickness of silt and clay in some areas (greater than 140 m). In other areas, the aquifer contained significant quantities of silt and clay, making it less suitable for groundwater development.

Recharge from the Precambrian uplands to the west basin appears limited as only a small number of streams drain into the upper reaches of this basin. Another recharge area was identified, as the barrier-bar deltaic complex fronting the Gros Cap Highland near Gros Cap along the shores of Lake Superior in the west. The estimated natural groundwater recharge for the basin ranges from 9,090 to 13,640 m^3/day (IWS, 1978). There is currently no development of the groundwater resource for municipal purposes within this basin (Burnside, 2003).

2.9 WATER USE

2.9.1 Existing Surface Water Use

The largest surface water user in the study area is the municipal / public supply system that is primarily located in the Urban Service Line of the City of Sault Ste. Marie. The source comprises of surface and groundwater with each contributing an approximately equal portion to the municipal system. This system is used to meet the needs of both the public and the commercial/industrial sectors. CWB Map 5 shows the location of surface water intake at Gros Cap, Lake Superior.

The main source of surface water is from Gros Cap intake west of the Lake Superior shoreline. The other half of the water need was contributed from groundwater sources. The current permitted pumping rates is 75,000 m^3/d. Table 2.7 provides a summary of rates from Gros Cap.

Table 2.7: Pumping Rates from Gros Cap

Year	Average Pumpage	
	m^3/day	m^3/year
1999	19,000	7,100,000
2004	20,000	7,400,000
2005	21,000	7,700,000

Based on MOE Permit to Take Water records, eight (8) additional surface water users for commercial/industrial purposes were identified. Table 2.8 lists the number of most recent surface water permit holders. The main use for surface water takings includes hydroelectric power generation and their permitted rate is approximately 85,076,300 m^3/day. Other uses include irrigation, process water and cooling. The permitted rates are illustrated in Figure 2-15. Permitted pumping rates for a few of the water takers was not provided in the information available; however, based on available information the estimated total permitted volume of annual water taking for commercial industrial purposes (not including hydroelectric power or municipal supply) is approximately 2,300,000 m^3/annum.

2.9.2 Existing Groundwater Use

The Sault Ste. Marie Source Protection Planning Area (SSMR Source Protection Area) is comprised of a variety of land uses serviced by groundwater:

- Individual/Domestic;
- Municipal/Public;
- Commercial/Industrial;
- Agricultural; and
- Ecosystem/Recreational.

Table 2.9 lists the groundwater permit holders in the Source Protection Area.

2.9.2.1 Individual/Domestic

Areas outside of the City of Sault Ste Marie's urban area including Prince Township, Rankin Reserve, as well as the Sault North planning area are primarily serviced by individual domestic wells. Shallow dug wells are common where groundwater is present but limited to the shallow surficial sand and gravel lenses. The locations of wells identified in a MOE water well records search is shown in Figure 2-16 and CWB Map 7. Water demands of such areas are estimated based on 350 litres per capita per day (l/c/d) (Best Management Practices Water Wells, 1997). 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 2-15 illustrates the location of current PTTWs.

Based on the assumption that the population is 9,426 (see Table 2.10), the individual/domestic water demand within the study area is estimated at approximately 1,204,170 m^3 per annum.

Table 2.8: 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

Table 2.9: 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

2.9.2.2 Municipal/Public

The majority of the City of Sault Ste Marie is serviced by municipal supply. A number of private wells exist within the City of Sault Ste Marie; however, it is assumed that the primary source of potable water is the municipal supply. As indicated by the PUC, it is estimated that about 50% of the municipal supply is obtained from groundwater and the remaining 50% is obtained from a lake-based source. CWB Map 5 shows the location of surface water intake and six groundwater wells within SSMR Source Protection Area.

The residents from 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 this 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 this basin is 18,188 m^3/day or 6,639,000 m^3/annum.

According to the Sault Ste Marie Public Utilities Commission, the amount of water pumped from the wells is shown in Figure 2-15 and averaged approximately 17,000 m^3/day in 2004 and 15,000 m^3/day in 2005, which is well below the permitted limit.

2.9.2.3 Commercial/Industrial

The commercial/industrial system is primarily serviced through the municipal network. Approximately 3,200,000 m^3/annum are accounted for in the municipal category. Based on current available data, there are no existing PTTW records for groundwater taking; however, as indicated previously, there are a few surface water PTTWs identified for commercial and industrial purposes. Other than municipal water supply, the only other major groundwater taking is associated with remediation programs, one of which is owned by the Sault Ste. Marie Municipal landfill.

2.9.2.4 Agricultural

There are no major groundwater takings associated with agriculture.

2.9.2.5 Ecosystem/Recreational

The interaction between groundwater and surface water has not been quantified in terms of extensive baseflow studies; however, areas of recharge and discharge have been identified through groundwater elevations and topographic maps. Upwelling areas, wetlands and headwaters are known to exist south of the Precambrian uplands as a result of local scale discharge of groundwater through the coarse permeable materials. The shallow system provides groundwater flux to the streams and is an essential component to preserving the natural function of the ecosystem.

The extensive rivers and creeks present in the study area are habitat for a multitude of fish species that depend on upwellings for spawning and sustained health throughout the seasons. Figure 2-17 and CWBMap09 identifies the natural features in the study area. Similarly, within the planning region, wetlands are habitat for numerous amphibians, flora and fauna. Figure 2-17 illustrates the wetlands within the planning area. The wetlands comprise 3.9 % of the study area. There are number of small wetland areas in the northern uplands of the planning region associated with headwater areas of the rivers and creeks, which flow south towards the St. Marys River. Along the shore of the St. Marys River, a number of larger wetland areas are found at the outlet of rivers such as the Big and Little Carp and the Root River.

As a part of this water balance, the water used by these features will be discussed qualitatively since no monitoring data are available at this stage to provide quantitative estimates. The objective of including these features in the assessment is to ensure that they are considered as a part of the system and that necessary flows to support natural function of these features is not altered or affected severely as a result of an imbalance of the water budget.

2.9.2.6 Permits to Take Water (PTTW) for Non-Municipal Supply

Permits to Take Water (PTTWs) are issued for water supply wells that draw more than 50,000L/day. Figure 2-15 provides a summary of all the existing PTTW showing the permitted rates of usage. The type of use of each of the PTTW is also shown on Figure 2-15. PTTWs on file at the MOE for the City of Sault Ste Marie include permits for groundwater remediation, and communal water supply. In total, the maximum permitted volume of annual water taking for these purposes is approximately 540,200 m^3/annum. This accounts for approximately 4% of the permitted municipal takings.

2.9.2.7 Estimated Groundwater Water Taking

The data sources for the assessment of the amount of water used by residents and businesses within the study area included: Sault Ste Marie Public Utilities Commission pumping records, Ministry of the Environment water well records, permits to take water, and typical water consumption estimates based on type of use. Table 2.10 provides a summary of groundwater users in the City of Sault Ste Marie and surrounding area.

Table 2.10: Groundwater Use Summary

Water Use Area/Category	Total Annual Volume (m^3/annum)	Comments	Source
Prince Township	128,000	Based on a population of 977 and 350 L/c/d	1
Batchewana Indian Reserve of Ojibways	19,000	Based on a population of 150 and 350 L/c/d	1
Sparse rural population	1,060,197	Based on a population of 8,299 and 350 L/c/d	1
Sault Ste Marie PUC - Municipal Supply (groundwater)	7,850,000	Based on PUC annual pumpage summary	2
Sault Ste Marie PTTW (groundwater)	540,200	Based on PTTW maximum daily water taking	3
Total Volume of Taking	9,597,397		

1 Best Management Practices, *Irrigation Management*, Agriculture and Agri-Food Canada, Ontario Ministry of Agriculture, Food and Rural Affairs, 1995.
2 Sault Ste Marie Public Utilities Commission, Annual Pumpage Summary, 2000.
3 Ministry of Environment, Permits to Take Water (PTTW).

3.0 INTEGRATED CONCEPTUAL UNDERSTANDING

In the SSMR Source Protection Area, both surface water and groundwater resources play an important role in the water budget. The surface water system is the main input to the groundwater system and therefore establishes an integrated relationship. As discussed previously, precipitation is the primary driver of the hydrologic cycle. In order to quantify the volume of water available for groundwater recharge, or that is diverted to the streams as run-off, a good understanding of the land cover, land-use, and underlying soil type is necessary.

The SSMR Source Protection Area consists of two distinct landforms. The northern portion is referred to as "Precambrian uplands". South of this region is the relatively flat lying area referred to as the lowlands that is covered by relatively thick clay-rich overburden unit. The granite in the Precambrian uplands is non-permeable; however, there is limited groundwater found in shallow weathered bedrock and fractures and there is a valley of coarse overburden material described as shallow sand and gravel glaciofluvial deposits overlying the granite that are mostly centralized around the valley hosting the Algoma Central Railway and the Hwy 17 North corridor. Several wells have been identified in this area and some supply communal systems.

As shown previously, the watershed boundaries are not reflective of the groundwater divides, nor are they reflective of the surficial soil characterization. The Precambrian granite spans several of the watersheds including the ones that discharge directly to Lake Superior, Big Carp River, Little Carp River, Bennett Creek, West Davignon Creek, East Davignon Creek, Root River and Crystal River. Due to the low infiltration anticipated in the Precambrian uplands, a large amount of the precipitation is contributed to the streams and as a result the headwaters for all these creeks occur in this area.

Even though significant areas of outcropping of the Precambrian Granites are present in the north, shallow cover 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 infiltrate into the groundwater system at the thick sand and gravel beach deposits located along the southern edge of the Precambrian uplands. This is the main source of recharge for the central and east basins.

Groundwater upwellings just south of the contact are the headwaters for several streams and creeks. Water that does not contribute to the surface water system infiltrates through the porous material and flows downgradient into the central and the east basins. Limited recharge from the contact area enters the western basin. The volume of water recharging the groundwater system can be estimated by estimating the amount of runoff from the Precambrian uplands minus the amount of surface water remaining after passing the highly permeable materials found south of the Precambrian uplands, evaporation and other losses.

The lowlands are covered by a relatively thick clay-rich overburden unit consisting of glaciolacustrine clays. Few shallow deposits of sand and gravel are present in this area. In addition, a significant portion of the lowlands in the central and east basin has been urbanized. As a result, the amount of infiltration is expected to be lower due to the paved surfaces and the amount of runoff and contribution to the surface water system will increase.

The aquifer units 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 to the US. Piezometric levels observed in the aquifer near the shoreline of St. Marys River are generally artesian in nature, suggesting the potential for upward flow from the confined aquifer to St. Mary's River under natural conditions. Burnside, 2003 suggest that the groundwater flow passes the Source Protection Area boundary flowing south to the US. At this stage, the details of how much groundwater discharges to either St. Marys River or the US is uncertain. Further analysis of existing stratigraphy and measured piezometric levels from the Canadian side, the American side and stage/elevations of the river are needed.

Quantification of the water budget based on the Conceptual Understanding will be the next step. In the following sections, the methods used to estimate the key component of the water budget in the SSMR Source Protection Area are discussed.

3.1 WATER BUDGET

As indicated previously, the situation for the SSMR Source Protection Area, although not unique, requires some slight variances in the typical water budget equation because the watershed boundaries and the groundwater basins are not the same. To account for this characteristic the water budget equation has been modified to suit the SSMR Source Protection Area specifically. For this region, the groundwater system experiences the greatest stresses due to the water takings for municipal supply. Not many stresses to the surface water system in the watershed are known; therefore, instead of considering the watershed as the hydrologic unit, the extents of the groundwater basins will be considered the boundaries of the hydrologic unit. The conceptual understanding of the water budget is illustrated in Figure 3-1.

For the purposes of this water budget, each groundwater basin will be considered as a separate unit for which inputs and outputs will be assessed. 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 on an annual basis in 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 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. 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.

The conceptual understanding of the water budget is illustrated in Figure 3-1. Inputs to the basin can be accounted for with Sw_i and Gw_i. These are representative of runoff and infiltration, which occurs on the Precambrian uplands. Runoff and infiltration, which occurs over the basin area, are not shown in the water budget equation as they are internal flows and are only descriptors of where the precipitation is distributed.

3.1.1 Evapotranspiration

For a water budget analysis over the whole watershed, an important component is the total evaporation from all free-water surfaces, plus transpiration, the loss of vapour through small openings in plant tissues. For most plants, transpiration occurs only during daylight hours during photosynthesis, which can lead to diurnal variations in the shallow ground water table in heavily vegetated areas. The combined evaporation and transpiration loss is called evapotranspiration (ET) and is a maximum if the water supply to both the plant and soil surface is unlimited.

The loss of water from the earth to the atmosphere by transpiration from vegetation and by direct evaporation constitutes an important part of the water budget analysis. However, direct measurement of these factors has proved to be extremely difficult, and this inherent difficulty has led to the development of a number of formulas designed to estimate water loss directly from meteorological data. The Thornthwaite method (1948) was developed from rainfall and runoff data for several drainage basins and takes into account average monthly temperature and hours of daylight. The result is basically an empirical relationship between potential evapotranspiration and air temperature. The Thornthwaite's empirical formula can be used for any location at which daily maximum and minimum temperatures are recorded. In this study, to estimate the evapotranspiration losses the Thornthwaite method was chosen due to its simplicity and the ability to use available data.

Table 3.1 summarizes the estimated average annual evapotranspiration based on the data analyzed for the period 1971-2001 for the Sault Ste. Marie Station #2.

Table 3.1: Summary of Estimated Annual Evapotranspiration

Month	P	ET	Surplus
	(mm)	(mm)	(mm)
January	100.3	0.0	100.3
February	55.4	0.0	55.4
March	63.0	0.5	62.5

Month	P	ET	Surplus
	(mm)	(mm)	(mm)
April	66.9	23.2	43.7
May	67.8	75.1	(-7.3)
June	80.8	106.3	(-25.5)
July	76.2	118.6	(-42.4)
August	85.0	106.3	(-21.3)
September	101.8	68.2	33.6
October	100.4	35.3	65.0
November	96.1	4.3	91.8
December	110.8	0.0	110.8
Total	1004.4	537.9	466.5

The surplus represents the water available for surface runoff in the watershed and potential infiltration into the subsurface for any given time period. Based on the results of the analysis during the summer months there is a net deficit in the amount of precipitation that falls and the amount lost through evapotranspiration. The potential evapotranspiration amounts are higher than the total precipitation for the period May through August and are shown as negative values in Table 3.1 to reflect a deficit in moisture.

Figures 3-2, 3-3, 3-4 show plots of the average, maximum and minimum monthly precipitation, evapotranspiration and surplus water, respectively, available for surface runoff and potential infiltration based on the data analyzed during the period 1971-2001 for the Sault Ste Marie Station #2.

3.1.2 Runoff

There are two active Environment Canada HYDAT gauging stations monitoring flow of the watercourses within the planning area. One is located on the Big Carp River and the other on the Root River. There are two additional gauging stations, which have historically been used to monitor flow. Table 3.2 summarizes the data recorded at each station and the date range for which validated data are available. The location of the Big Carp River and Root River stations is shown in Figure 1-1 and CWB Map 10.

Table 3.2: Summary of Environment Canada HYDAT Data

Station Name	Station ID	Latitude	Longitude	Area (km^2)	Years of Data
Big Carp River	02BF004	46°30'57"N	84°27'54"N	51.5	1979-2003
Root River	02CA002	46°33'46"N	84°16'55"N	108	1971-2003
Bennett Creek	02BF003	46°31'53"N	84°23'51"N	18.6	1971-1978
St Marys River	02CA001	46°30'34"N	84°21'42"N	210000	1860-1993

Surface water runoff into watercourses or other bodies of water is composed of direct runoff and baseflow. In order to estimate the direct runoff component, it is required to separate the hydrograph. There are several methods that are available to separate the hydrographs. Since the period of flow record is very long, it is difficult to separate the hydrograph for each separate event. To simplify the method, the flows recorded during the inter-event (dry) periods were used to represent the base flow conditions in the respective watercourses. Initially rainfall records were reviewed to determine periods of no rain (dry days). Thereafter, the stream flow records for the corresponding dry periods were reviewed to identify and establish baseflow contributions in the creek/river. During the no rain periods, the stream flow records showed little variation in flow values. On the other hand, following a rainfall event, there was a significant variation in the recorded stream flow values indicating the runoff contribution resulting from the rainfall event on the subcatchment.

Using the observed flow records, hydrograph separation was carried out to determine the direct runoff depths. Tables 3.3 and 3.4 summarize the depths of baseflow and direct runoff values for the Big Carp River and Root River. Figures 3-5 and 3-6 show the depth of direct runoff and baseflow for the Big Carp River and Root River, respectively. Sample baseflow and direct runoff calculations are provided in Appendix A.

Table 3.3: Summary of Baseflow and Direct Runoff Depth for the Big Carp River

Year	Runoff	Baseflow	Direct Runoff
	(mm)	(mm)	(mm)
1980	403.8	148.7	255.1
1981	469.3	124.1	345.1
1982	584.9	157.2	427.7
1983	416.5	145.5	271.0
1984	442.8	141.5	301.3
1985	638.6	222.2	416.4
1986	528.8	126.4	402.5
1987	520.7	174.3	346.3
1988	793.9	256.0	537.9
1989	366.9	179.5	187.4
1990	508.2	135.8	372.5
1991	428.2	127.4	300.8
1992	521.5	148.4	373.1
1993	462.5	215.0	247.5
1994	371.5	129.1	242.4
1995	546.0	195.5	350.6
1996	722.2	207.4	514.8
1997	513.1	243.8	269.3
1998	294.4	66.3	228.1
1999	369.5	99.6	269.9
2000	213.0	93.5	119.5
2001	534.5	120.6	413.9

Table 3.4: Summary of Baseflow and Direct Runoff Depth for the Root River

Year	Runoff	Baseflow	Direct Runoff
	(mm)	(mm)	(mm)
1971	515.4	136.0	379.4
1972	480.9	124.0	356.9
1973	610.5	181.8	428.8
1974	534.4	155.7	378.7
1975	545.5	120.9	424.6
1976	351.8	85.3	266.5

Year	Runoff (mm)	Baseflow (mm)	Direct Runoff (mm)
1977	683.1	168.7	514.4
1978	537.5	142.4	395.2
1979	829.7	201.0	628.7
1980	452.6	172.5	280.1
1981	478.2	151.4	326.8
1982	686.2	183.0	503.2
1983	550.1	168.5	381.7
1984	654.9	231.5	423.4
1985	700.0	178.1	521.9
1986	539.6	170.4	369.2
1987	505.0	189.0	316.0
1988	787.1	300.8	486.4
1989	443.6	173.3	270.3
1990	611.8	168.8	443.0
1991	598.9	214.4	384.5
1992	578.4	138.9	439.5
1993	681.1	257.0	424.1
1994	471.4	151.7	319.7
1995	646.4	238.9	407.5
1996	762.5	215.3	547.3
1997	525.3	238.8	286.5
1998	401.8	80.6	321.2
1999	468.4	133.3	335.1
2000	297.5	101.6	196.0
2001	746.8	210.1	536.7

The average depth of direct runoff and baseflow for the Big Carp River based on data available for the period 1980-2001 is 327 mm and 157 mm, respectively. Similarly, for the Root River based on the data available for the period 1971-2001, the depth of direct runoff is 397 mm and the baseflow is 174 mm, respectively.

For the remaining subwatersheds the Soil Conservation Service (SCS) method was used to estimate the direct runoff depths. The most commonly used method of estimating losses and determining the direct runoff is the “Hydrologic Soil Complex Method” of the United States Department of Agriculture, Soil Conservation Service. In this method, direct runoff is estimated by the use of runoff curve numbers (CN) which are related to land use and land cover and hydrologic soil groups. The higher the curve number, the higher the runoff.

Runoff curve numbers based on the land use for four different hydrologic soil groups are readily available in the literature. Hydrologic soil Group A represents sandy and well drained soils, Group B represents sandy loam, Group C represents clay loam or shallow sandy loam and Group D has a poorly drained, heavy plastic clay that swells when wet. Group A has the highest infiltration capacity and Group D has the lowest.

Prior to the start of overland flow, a small portion of the initial rainfall is stored and permanently extracted from surface runoff by interception and surface or depression storage. The interception evaporates and depression storage either evaporates or infiltrates after the rainfall. The interception is subtracted from the beginning of the rainfall, whereas depression storage accumulates only after the rain intensity exceeds the infiltration capacity.

The amount of direct runoff from a storm depends largely on the losses, or abstractions, caused by infiltration, depression storage and evaporation. These losses depend upon soil type, type of vegetation and amount of impervious cover. In this study, the direct runoff is estimated based on factors such as land use and land cover (pasture, woodland, cultivated or urban) and soil texture. The land use within the study area is estimated to comprise of 25% urban and 75% woodland. The topography is rolling to hilly in the north portion of the study area, whereas very gentle slopes define the southern portion that includes the City of Sault Marie. Figure 2-8 and Figure 2-9 shows the land use and land cover for the subwatersheds in the study area.

Using the SCS method, the average direct runoff depths were determined for ungauged subwatersheds based on data available for the period 1971-2001. Table 3.5 summarizes the results of the analysis. The direct runoff depth for these subwatersheds varies from 137.7 mm to 538.6 mm, and the average direct runoff is 313 mm for the period 1971-2001. Sample calculations for CN values are shown in Appendix B and that for the direct runoff are shown in Appendix C.

Table 3.5: Summary of Direct Runoff Depths for the Ungauged Subwatersheds Using the SCS Method

Subwatershed Name	Subwatershed No.	Area (km^2)	Average CN	Direct Runoff (mm)
Lake Superior	1	3.3	64.4	332.1
	8	31.8	44.0	137.7
	29	10.5	53.9	222
	30	41.5	61.3	297.1
	31	15.2	59.4	276.7
	32	3.1	56.9	251.1
Little Carp River	12	20.1	56.0	242.2
Leigh Creek	6	15.9	65.3	342.6
Bennett Creek	18	23.0	59.4	276.7
	3	2.4	76.9	499.1
West Davignon Creek	14	20.3	65.3	342.6
Central Creek	7	2.7	69.9	399.9
East Davignon Creek	15	22.7	62.7	312.6
Fort Creek	2	1.7	79.4	538.6
	27	29.8	74.8	467.6
Crystal Creek	16	26.1	53.0	213.6
	20	6.9	49.6	183.2
	25	18.6	57.5	257.1
Unnamed Creek	4	42.7	59.8	280.9
	28	7.6	68.8	385.7

3.1.3 Infiltration

In the study area, the surplus water is available for direct runoff and infiltration for the months January to April and September to December. However, unless a winter thaw occurs due to above freezing temperatures to melt the accumulated snow and /or the occurrence of rainfall, the direct runoff and infiltration will not occur during the winter months and the water content will be held in storage until the spring runoff.

The depths of direct runoff for each of the subwatersheds are estimated as described in Section 2.3.4. The remainder of the water infiltrates into the subsurface and contributes to groundwater recharge. Table 3.6 presents a summary of the results for the precipitation, evapotranspiration, runoff and infiltration for the study area based on the climate data for the period 1971-2001 for the Sault Ste. Marie Station #2.

Table 3.6: Summary of Precipitation, Evapotranspiration, Runoff and Infiltration for Each Subwatershed

Subwatershed Name	Subwatershed No.	Area (km^2)	Average CN	P (mm)	ET (mm)	Surplus (mm)	Runoff (mm)	Infiltration (mm)
Lake Superior	1	3.3	64.4	1004	538	466	333	133
	8	31.8	44.0	1004	538	466	139	327
	29	10.5	53.9	1004	538	466	221	245
	30	41.5	61.3	1004	538	466	297	169
	31	15.2	59.4	1004	538	466	277	189
	32	3.1	56.9	1004	538	466	251	215
Big Carp River	5	4.0	65.4	1004	538	466	345	121
	10	27.8	57.0	1004	538	466	252	214
	11	20.0	62.8	1004	538	466	314	152
Little Carp River	12	20.1	56.0	1004	538	466	242	224
Leigh Creek	6	15.9	65.3	1004	538	466	344	122
Bennett Creek	3	2.4	76.9	1004	538	466	466	0
	18	23.0	59.4	1004	538	466	277	189
West Davignon Creek	14	20.3	65.3	1004	538	466	344	122
Central Creek	7	2.7	69.9	1004	538	466	402	64
East Davignon Creek	15	22.7	62.7	1004	538	466	313	153
Fort Creek	2	1.7	79.4	1004	538	466	466	0
	27	29.8	74.8	1004	538	466	466	0
Root River	9	22.3	68.4	1004	538	466	382	84
	13	4.2	64.5	1004	538	466	334	132
	17	3.2	62.3	1004	538	466	309	157
	19	22.5	61.9	1004	538	466	304	162
	21	13.5	66.0	1004	538	466	352	114
	22	5.7	64.0	1004	538	466	328	138
	23	18.3	63.8	1004	538	466	326	140
	24	6.7	65.2	1004	538	466	344	122
	26	27.1	57.8	1004	538	466	260	206
Crystal Creek	16	26.1	53.0	1004	538	466	213	253
	20	6.9	49.6	1004	538	466	183	283
	25	18.6	57.5	1004	538	466	257	209
Un-named Creek	4	42.7	59.8	1004	538	466	281	185
	28	7.6	68.8	1004	538	466	387	79

Figure 3-7 shows a plot of the water budget for the study area. The figure shows that the infiltration is greatest during the spring and fall seasons with the summer period showing a soil moisture deficit. Based on the results of the analysis for the period 1971-2001, the average annual precipitation is 1004 mm, of which the evapotranspiration is 538 mm, and the direct runoff is 316 mm. The potential average infiltration into the subsurface for groundwater recharge is estimated to be about 150 mm per year, which is equivalent to 78 million m^3/yr. However, as shown in Figure 3-7, there is great monthly variation, which will affect the infiltration into the ground. Figure 3-8 illustrates the estimated rates of infiltration and runoff.

3.2 DELINEATION OF WATERSHED AND GROUNDWATER BOUNDARIES

Although the various subwatershed systems were delineated based on topography and surface drainage mapping, the boundaries of these systems do not correlate with the groundwater basins boundaries. Previous studies including Burnside 2003 and IWS 1978 suggest the deep overburden aquifers, the three basins are not hydraulically connected. The watersheds, which provide infiltration and recharge to the basins will be influenced by:

- Surface area;
- Geology of the basins;
- Thickness and permeability of the overburden units; and
- Contribution of recharge from the coarse grained recharge area identified adjacent to the Precambrian upland formation.

During the next stage (Tier 1), an iterative process needs to be initiated to assess the different possible scenarios of balance between the watersheds and groundwater basins. Analytical estimates will be compared with the available historical data.

3.3 RECHARGE AND DISCHARGE AREAS

The previous groundwater investigation conducted by Burnside (2003) has identified key areas of recharge to the deep overburden/shallow bedrock aquifer formation and areas of discharge where upward movement of groundwater is anticipated based on observed water levels and potentiometric levels.

Areas of groundwater upwelling contribute to headwater, stream baseflow and wetlands. Most of these areas, which have been previously identified, are found south of the recharge area that is located south of the Precambrian upland. The amount of infiltration can be estimated by considering the amount of runoff and infiltration in the Precambrian uplands and the infiltration anticipated in the recharge area minus the amount, that is contributed to the baseflow of the creeks.

Discharge areas can also include the arbitrary boundary of our study area, the St. Marys River. Two possible scenarios of flow can be considered at this boundary:

1) Groundwater flow continues south towards the US; and

2) Groundwater flow discharges to the St. Marys River.

These two possibilities should be examined during the water budget analysis. For the shallow water table system, comparison of the shallow water levels with the regional topography can show local areas of upwelling.

Although no monitoring has been conducted in the past, based on the conceptual understanding, strategic areas can be identified for future monitoring both in the shallow and deep groundwater flow systems.

3.4 WATER BALANCE

The SSMR Source Protection Area relies on both groundwater and surface water resources. As suggested by current PTTWs, the main use of groundwater is for municipal, or communal water supply followed by water taken for remedial purposes.

In the central basin, the total permitted groundwater water taking is 18,188 m^3/day, compared to the estimated recharge, which likely ranges between 28,600 m^3/day to 30,000 m^3/day (IWS, 1978). In the east basin, the total permitted pumping rate is 21,000 m^3/day, compared with an estimated recharge rate that likely ranges between 15,900 to 20,000 m^3/day (IWS, 1978). However, the actual pumped volume during the year is about half of the permitted volume as indicated by the PUC. During the next phase of this water budget, the estimated recharge rates will be reassessed and compared with the estimated rate of groundwater use.

Table 3.7: Summary of Major Permitted Groundwater Takings vs. Estimated Recharge

Basin	Water Taking Location	Permitted Pumping Rate (m^3/day)	Estimated Pumping Rate (m^3/day)	Recharge (m^3/day)
Central Basin	2 Goulais Wells	9,988	5,000	28,600-30,000
	1 Steelton Well	8,200	6,000	
	Total	**18,188**	**11,000**	
East Basin	1 Shannon Well	7,000	3,500	15,900-20,000
	2 Lorna Wells	14,000	7,000	
	Total	**21,000**	**10,500**	

Comparison of the volume of surface water taking to the amount of available surface water can be misleading since the surface water source at Gros Cap (permitted rate: 75,000 m^3/day) is from Lake Superior and the majority of the watersheds in this study area drain towards the St. Marys River; therefore, the water balance will have to account for the import of surface water for consumption and similarly any water exports.

4.0 IDENTIFICATION OF STRESS TO THE SYSTEM AND CORRESPONDING LEVEL OF INVESTIGATION

Through the development of the Conceptual Understanding for the Sault Ste. Marie Source Protection Planning Region, available data have been compiled to determine a basic understanding of the hydrologic and hydrogeologic systems. This screening process is intended to identify the level of detail the water budget should meet.

4.1 AVAILABLE DATA AND DATA GAPS

In some cases, the stresses to the system are qualitatively described due to the lack of physical data. This exercise has allowed us to identify data gaps where concentration in future steps are recommended and are outlined below:

- The conceptual understanding is currently based on the delineation of 32 sub-watersheds, (watershed boundaries based on mapping provided by the SSMRCA) associated to 10 major creek systems; however, the finalized sub-watershed boundaries are yet to be determined. Although, minor changes in the demarcation of these boundaries is unlikely to change the outcome of the analysis, it is recommended that upon determining new sub-watershed boundaries, the estimates for runoff and infiltration in each sub-watershed be revisited.

- Baseflow trends for many of the major streams are also unknown as limited monitoring was historically conducted. The only rivers with gauging stations are the Root River and the Big Carp River which each have one gauging station. Gauging stations at other major creeks will improve the understanding of stream flow in other major subwatersheds. Estimates of baseflow can be achieved using infiltration and runoff values based on land cover data; however, due to the limited number of gauging stations on each stream, it is difficult to determine if the calculated amount of stream flow contribution for each basin is representative of natural conditions.

The lack of physical data will require calculated estimates of Sw_i, Sw_o for the water budget. Sw_i can be estimated by summing the runoff in sub-watersheds upgradient of each aquifer basin. Sw_o can be estimated by adding the anticipated additional runoff likely to contribute in the basins. Data can be calibrated by comparing results with the stream gauging data from Big Carp River and Root River; however there is a lack of physical data to calibrate Sw_i, Sw_o for the other creeks in the water budget.

- Areas of recharge for the groundwater system have been identified based on regional geologic and hydrogeologic information; however, the specific rates are unknown and it will be difficult to account for stream flow losses. In order to estimate the rate of stream flow loss, or contribution to the groundwater system, it will be necessary to monitor the stream flow prior to passing the recharge zone and comparing it to stream flow downstream of the recharge zone.

- Introduction of groundwater to the basins will also be difficult to measure. Estimates of the Gw_i will be obtained by summing the infiltration in the sub-watersheds upgradient of each aquifer basin. Increased groundwater infiltration in the recharge area will also be accounted for; however, as mentioned previously, it will be difficult to determine if the calculated contribution of surface water to groundwater values are representative of the natural environment without physical monitoring.

The amount of groundwater leaving the basin Gw_o, will also be difficult to measure. Estimated rates of flow leaving the basin will be based on equipotentials measured in water wells near the basin boundary. Based on the assessment of several geotechnical reports along the riverbank of St. Marys River, it appears the bedrock formation is continuous beneath the St. Marys River; however, some areas exhibit a thinner clay overburden layer between the bedrock and the river.

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 US is unknown; however will be estimated using 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.

- Furthermore, there is a lack of geological data and bathometric data for St. Marys River which is critical in better understanding the relationship between the confined aquifer and the river.

- Estimations for the amount of infiltration and runoff in the subwatersheds are mainly based on the land cover and land use data; however, the land cover data may be out-dated. The land cover information was obtained from the Canada Land Use Inventory from 1966. This information should be evaluated to determine its validity.

- There is also limited data regarding the aquifer units in the Precambrian uplands, although the majority of this area is not water bearing nor are there significant populations in this area to stress the water resources, there is a valley of coarse grained material near the ACR which is not well defined.

4.2 SUMMARY

The objective of the conceptual understanding was to address the following key questions regarding water resources in the watershed:

- Where is the water?
- How does the water move between reservoirs?
- What and where are the stresses on the water?
- What are the trends?

The criteria used to determine the appropriate level of investigation for a particular area is based on the following points:

Sources of Water – The main groundwater source in Sault Ste. Marie is from the overburden and bedrock formations found in the east and central basin. Assessment of both the central and east basin is recommended to ensure the sustainable quantity and quality of available water. It is also recommended that the surface water features such as streams and the watersheds be included in the assessment as they are the main method for recharging the groundwater system.

The main surface water source is from Lake Superior of the western coast of Gros Cap. Lake Superior is a part of the Great Lakes system and is not a part of the watershed.

Movement Between Reservoirs – A large proportion of the groundwater is introduced to the basins at the highly permeable contact zone between the Precambrian uplands and the lowlands. Areas of upwelling in the area are also the headwaters for numerous creek systems. All groundwater flows in a southerly direction and discharges to the south.

All surface water systems either discharge to Lake Superior or to the St. Marys River. The sub-watersheds that discharge to Lake Superior are not considered as a part of this assessment.

Stress – The central and east basins cover most of the developed lands of Sault Ste. Marie. Consequently, with development, the need for water is greater within these areas. Comparison of the recharge volume to the permitted rate of water taking suggests that there may be a stress in the east and central basins. A Tier 1 assessment is necessary to quantify the extent of stress. As part of the Tier 1 assessment analytical methods will be used to perform the water balance and assess the stress on a watershed scale.

In terms of water quality, no major stress was identified; however, chloride and nitrate concentrations observed from previous studies suggest an anthropogenic influence. An historical landfill identified north of the City has also been identified as a potential stress to the groundwater resources. In all cases, the location of the source is near the permeable recharge zone between the Precambrian uplands and the lowlands. The lowland area is covered by a thick clayey overburden layer, which reduces the potential for the introduction of contaminants.

Vulnerable Areas – Areas that are critical to the health of the water resources include the recharge and discharge areas. Major recharge areas for the groundwater source includes the sand and gravel beach deposits located on the southern side of the Precambrian uplands and the recharge area located in the west basin along the shore of Lake Superior near Gros Cap. Numerous quarries have been identified that mine the coarse granular material.

4.3 SCREENING DECISION

The Conceptual Understanding describes the general setting of the Sault Ste. Marie Source Protection Planning Region, providing information on the surface water and groundwater environments. The purpose of this was to determine whether a sufficient understanding of the elements has been achieved to begin numerical modelling, furthermore to assess the need for more complex analysis of the water budget process, and what extent of investigation would be required.

Four key screening questions were developed to guide in this decision making process and are addressed below:

Is the water supply from an international or inter-provincial waterway or from a large inland water body only?

The SSMR Source Protection Area relies on both groundwater and surface water takings equally for municipal supply. The groundwater sources are obtained from municipal wells installed in the water bearing porous material just overlying the Jacobsville Formation and the Jacobsville Formation in the central and the east basin. The Goulais Wells and Steelton Well have a maximum permitted pumping rate of up to 18,188 m^3/day and their groundwater source is the central basin. The Shannon Well and Lorna Wells have a maximum permitted pumping rate of up to 21,000 m^3/day and their groundwater source is the east basin.

The surface water is obtained from Lake Superior at Gros Cap and the permitted pumping rate at this location is 75,000 m^3/day. Lake Superior is one of the Great Lakes and is an international water body separating the U.S. and Canada. Both the U.S. and Canada use Lake Superior as a water source and as a result will require MOE review.

Are both groundwater and surface water models needed?

Municipal water supply is obtained from both surface water and groundwater sources. As surface water is obtained from Lake Superior, which is not the receiving water body for the majority of the subwatersheds in the Source Protection Area, modelling of the surface water system is not needed. However, the surface water system in the subwatersheds of the Source Protection Area is the integral source of recharge for the groundwater system and should be included in the overall hydrologic balance as recharge for each basin.

The central and east basin both provides municipal groundwater supply. Based on our current understanding, this resource is finite and its main source of recharge is through infiltration of the coarse granular materials that have been identified on the southern slopes of the Precambrian uplands. From this perspective, a good understanding of the surface water system and its inputs to the groundwater system is necessary to conduct a Tier 1 assessment.

The volume of water taking from the groundwater system can be estimated based on population data, land-use information and permitted water takings; however, since this volume can be fairly significant, further assessment of the recharge to the groundwater system is recommended. The following table summarizes the current understanding of rate of recharge to the groundwater system compared to the major permitted water takings from the groundwater system. This balance will be further assessed during the Tier 1 assessment.

Table 4.1: Summary of Major Permitted Groundwater Takings vs. Estimated Recharge

Basin	Water Taking Location	Permitted Pumping Rate (m^3/day)	Estimated Pumping Rate (m^3/day)	Recharge (m^3/day)
Central Basin	2 Goulais Wells	9,988	5,000	28,600-30,000
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	2 Lorna Wells	14,000	7,000	
	Total	**21,000**	**10,500**	

What is the required level of numeric modelling?

At this stage of the water budget, Tier 1 analytical techniques can be applied such that a good estimate of the water budget can be achieved through water balance by conducting scenario analysis for recharge and discharge boundaries. The amount of evapotranspiration, runoff and infiltration characteristic of each watershed can be calculated and compared with existing monitoring data to obtain a rough estimate of the inputs and outputs to the system.

Are there sub-watershed-wide water quality threats and issues that require complex modelling to assist with their resolution?

Water quality issues identified in the Source Protection Area include slightly elevated chloride, nitrate and iron concentrations. Historical water quality issues associated with the landfill have also been raised and investigated. It is believed the slightly elevated chloride levels are associated with historic road salting practices. Elevated nitrate levels have been identified near the contact of the overburden sediments and the Precambrian uplands and are believed to be associated to the septic systems (Burnside, 2003). The observed iron concentrations are believed to be naturally occurring within the Precambrian rock.

Since no water quality issues have been identified, further complex modelling to assess threats and issues is not recommended as a part of the water budget analysis; however, these issues should be revisited as a part of the Watershed Characterization, the Groundwater Vulnerability Analysis and the Water Quality Risk Assessment.

Water quality issues associated to the surface water intake at Gros Cap should be addressed as a part of the Surface Water Vulnerability Analysis.

Recommendations

Based on the factors presented above, a Tier 1 assessment was conducted for the central and east basins. The results of the Tier 1 assessment are within Chapter 2b.

Due to the large supply of both surface water and groundwater in those areas and the few water taking permits there is likely to be no potential threat to drinking water sources in those areas. The uncertainty related to assigning low hydrologic subwatershed stress to those areas should be designated as low.