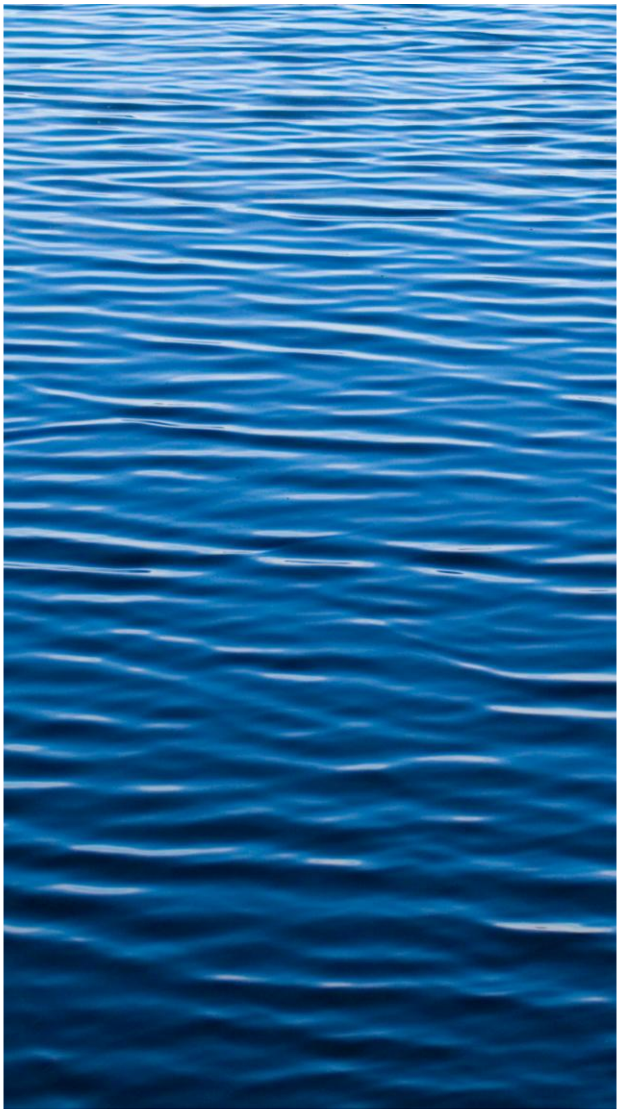


Part Two

The Greater Sudbury Source Protection Area

Meandering through
one of Canada's largest
mining centres and
covering 9,150 km^2
are three large river
systems: the Vermilion, the
Wanapitei and the
Whitefish.

Approved on September 2, 2014
Minor revisions on March 1, 2017
Amendments on March 16, 2021

Table of Contents

Chapter 4 - The Greater Sudbury Source Protection Area: A Tale of Three Rivers

Meandering through one of Canada's largest mining centres and covering 9,150 km^2 are three large river systems: the Vermilion, the Wanapitei and the Whitefish. Beginning at the Arctic Divide, the Vermilion and Wanapitei Rivers wind their way through the vast expanse of the Canadian Shield, boreal forest, and numerous wetlands and lakes before reaching the boundary of the City of Greater Sudbury. The City itself spans more than 3,600 km^2 and contains more than 330 lakes, earning it the nickname the "City of Lakes." Map 2.1 illustrates the boundaries of these watersheds.

The Wanapitei River begins as two main branches in the upper reaches of the watershed. The western limb begins by flowing to the northeast before turning south and joining with the East Wanapitei River. An unending number of lakes that were once part of historical canoe routes for First Nation peoples and fur traders scatter this heavily forested terrain. After travelling 117 km, the Wanapitei reaches the sandy shores of Lake Wanapitei, the largest and most notable lake within the Source Protection Area. Covering an area of 132.5 km^2, Lake Wanapitei is thought to be a relic from a meteor impact approximately 37 million years ago. Few people live on the shores, with the exception of the Wahnapitae First Nation on the western shore and the community of Skead on the southern shore. The Lake Wanapitei Dam regulates the water and marks the beginning of the Wanapitei River as it continues its way south. The Wanapitei River travels through three more dams before becoming the water source for approximately 90,000 residents of the City of Sudbury and passing through the town of Wahnapitae. The Wanapitei continues until it meets the French River and finally makes its way into Georgian Bay.

Like the Wanapitei, the Vermilion River begins almost 70 km north of the City boundary. In an odd strike in the topography, the Vermilion system straddles the Wanapitei River on either side with two subwatersheds: The Onaping River and the Upper Vermilion. The Onaping River strings together a number of long lakes beginning at Onaping Lake. As it enters Lower Onaping Lake, a large portion of the river is diverted through the Bannerman Dam to join the Spanish River watershed. The other portion is allowed to continue moving towards the towns of Levack and Onaping and, ultimately, through large tracts of mining territory before reaching the Vermilion River. The Upper Vermilion, bordering the eastern side of the Wanapitei, also flows through large expanses of relatively uninhabited land before reaching the town of Capreol. Here, the Vermilion River passes through the flattest part of the region and offers precious wetland habitat identified as a Provincially Significant Wetland.

The pace changes as the Vermilion joins with the Onaping and journeys through Vermilion Lake. The Whitson River, which passes through the only available agricultural land in the area, meets the Vermilion and continues the journey south. The Vermilion once again enters relatively undisturbed land and passes over Cascade Falls where it becomes the drinking water source for many of the smaller communities in the western part of the City of Greater Sudbury. The last major subwatershed to join forces with the Vermilion drains most of the City itself and the historical footprint of Sudbury's mining legacy. The Junction Creek subwatershed drains the town of Garson and the City of Sudbury including countless mine and tailings sites, sewage lagoons and outfalls, urban drainage and other industrial land uses. It also includes a third drinking water source for the City, Ramsey Lake. The Vermilion River then dumps into the Spanish River system where it continues to the North Channel of Lake Huron.

The Whitefish River watershed has more humble beginnings in the southern section of the City, flowing through more populated terrain. The long string of lakes joining the watershed is home to a number of cottagers and lake residents and includes the Atikamksheng Anishnawbek (Whitefish Lake) First Nation. It flows through Lake Panache, the largest recreational lake in the area, before entering the North Channel.

Chapter 5 - Drinking Water Systems

Drinking Water Systems are covered under a number of different regulations in the Province of Ontario. This chapter lists the drinking water systems that fall within O. Reg. 170/03.

5.1 Large Municipal Residential Drinking Water Systems

The City of Greater Sudbury municipal water supplies include three surface water intakes and 24 municipal wells under O. Reg. 170/03 and are classified as Large Municipal Residential.

Table 2.1- Municipal groundwater wells within the City of Greater Sudbury

Name	Owner	Community Serviced	Name of Wells	Number of Users	Watershed
Garson wells	City of Greater Sudbury	Garson	Garson 1, 2 and 3	4,890	Vermilion
Falconbridge wells	City of Greater Sudbury	Falconbridge	Well 5, 6 and 7	750	Wanapitei
Onaping wells	City of Greater Sudbury	Onaping and Levack	Hardy Wells 3, 4 and 5	2,150	Vermilion
Valley wells	City of Greater Sudbury	Capreol, Valley East, Azilda, Chelmsford	Wells M, J and I Linden Notre Dame Pharand Frost Michelle Deschene Kenneth Phillipe Well Q Well R	35,000	Vermilion
Dowling wells	City of Greater Sudbury	Dowling	Riverside Lionel	1,850	Vermilion

Table 2.2 - Municipal surface water intakes within the City of Greater Sudbury

Name of Water Treatment Plant	Owner	Source of Water	Community Serviced	Number of Users	Watershed
Wanapitei WTP	City of Greater Sudbury	Wanapitei River	Sudbury, Garson, Coniston, Wanapitei, Markstay	These systems are combined by the Ellis Reservoir and serve approximately 90,000 residents.	Wanapitei
David Street WTP	City of Greater Sudbury	Ramsey Lake	Sudbury		Vermilion
Vermilion River WTP	Vale	Vermilion River	Lively, Naughton, Whitefish, and Copper Cliff	13,000	Vermilion

5.2 Small Non-municipal, Non-residential

Table 2.3 – Registered small non-municipal, non-residential systems

Name of System	Owner	Source of Water	Community Served
Long Lake Public School Well Supply	Rainbow District School Board	Groundwater	Long Lake Public School
Wanup Public School Well Supply	Rainbow District School Board	Groundwater	Wanup Public School
Hannah Lake Bible Centre Well Supply	Canadian Finnish Evangelization Society Inc.	Groundwater	Hannah Lake Bible Centre
Camp Solelim Water Treatment Plant	Camp Solelim	Surface Water	Camp Solelim
YMCA Camp Falcona Water Treatment Plant	YMCA Sudbury	Surface Water	Camp Falcona
Goodfellow Home Well Supply	---	Groundwater	Unknown

5.3 Non-municipal, Year Round Residential

Table 2.4 – Registered non-municipal, year round residential systems

Name of system	Owner	Source of Water	Community Serviced
Eagle Valley Investment Limited Well Supply	Kona Management	Groundwater	Pine Grove Mobile Home Park
Skead Well Supply	Skead Heritage Homes Inc.	Groundwater	Skead
Southlane Trailer Park Well Supply	---	Groundwater	Southlane Trailer Park
Mobile Homes Court Hwy 69 Ltd. Well Supply	---	Groundwater	Mobile Homes Court Hwy 69 Ltd.
Humarcin Residents Organization Well Supply	Humarcin Residents Organization	Groundwater	Humarcin Residents
Hamersveld Trailer Park Well Supply	---	Groundwater	Hamersveld Trailer Park
Chuck’s Mobile Home Village Well Supply	Chuck’s Mobile Home Village	Groundwater	Chuck’s Mobile Home Village
Rintala Mobile Home Park Well Supply	Rintala Construction Company	Groundwater	Rintala Mobile Home Park
Peace Valley Trailer Haven Well Supply	Peace Valley Trailer Haven	Groundwater	Peace Valley Trailer Haven
Kingwell Trailer Park Well Supply	Kingwell Trailer Park	Groundwater	Kingwell Trailer Park

Chapter 6 - Physical Geography

The Greater Sudbury Source Protection Planning Area comprises part of the Abitibi Uplands to the north and west, the Cobalt Plain to the east, and the Laurentian Highlands and Penokean Hills to the southeast and southwest, respectively (Bostock, 1970; Chapman and Putnam, 1984).

The dominant feature in the Sudbury area is the Sudbury Igneous Complex (SIC) and the Sudbury Basin known as the “Valley.” The formation of these geographical landmarks and the theories behind their existence are described in Chapter 8. Chapter 7 explains the strong relationship between Sudbury’s geography, patterns of settlement and economic development.

6.1 Topography

The topography of this region is rugged, with elevations above mean sea level (AMSL) ranging from a maximum of 579 m in Leask Township in the north to a minimum of 174 m in Curtain Township to the south. The maximum topographic relief within the planning area is between 410 to 427 m AMSL.

Within the southern reaches of the planning area the topography is generally lower and undulating. Elevations increase abruptly towards the north rim of the Sudbury Basin, reaching 460 m AMSL and then dropping off slightly in a northward direction.

Bedrock ridges along the east rim generally have elevations between 335 and 385 m AMSL. Elevations along the south rim are generally in the order of 305 m to 335 m AMSL (Bajc and Barnett, 1999). Elevations within the valley are generally in the order of 290 m AMSL.

6.2 Soil Characteristics

Soil characteristics are greatly influenced by parent material composition and weathering and erosion processes. Soils in the Sudbury area belong to five orders of the Canadian Soil Classification System including Luvisolic, Gleysolic, Podzolic, Brunisolic and Organic.

Luvisols develop on glaciolacustrine sediments in well to imperfectly drained sites on sandy loam to clay parent material. Luvisols of the Sudbury area belong to the Gray Luvisol Great Group, due primarily to the effect of climate and parent material on soil development.

Gleysols are characterized by poorly drained sites and long periods of water saturation and reducing conditions. Gleysols in the Sudbury area belong to two groups, Humic Gleysols and the Gleysol Great Group. These soils develop most commonly on glaciolacustrine, glaciofluvial or fluvial sediments.

Podzols develop in coarse to medium textured parent materials or strongly leached calcareous materials under forest or heath vegetation in cool to very cold humid to prehumid climates.

Brunisols in the Sudbury area include Melanic and Sombric Brunisols. These soils develop on coarser textured morainal and outwash parent materials and exhibit a lack of horizon development.

Three groups of organics soils are located in the Sudbury area and include Fibrisols, Mesisols, and Humisols. Organic soils are commonly found in enclosed basins, or on margins of lake basins.

6.3 Land Cover

Land cover is one of the main factors which determines the amount of evapotranspiration, infiltration and surface runoff. Land development through urbanization plays a significant role in changing the hydrologic balance in a watershed. The land cover change not only affects the water quantity but adversely affects the water quality in terms of sediment and the nutrients attached to the sediment particles. According to the province of Ontario's Provincial Land Cover 2000 database, the planning area is 77% forest and 12% water as tabulated below. The remaining 11% of the area consists of wetlands, bedrock, urban and rural areas and aggregate areas and mine tailings. Map 2.2 and Table 2.5 illustrate the land cover of the planning area.

Table 2.5- Land Cover within the Greater Sudbury Source Protection Planning Area

Land cover	Hectares	GSSPA	Wanapitei	Vermilion	Whitefish
Agriculture	9,646	1.1%	0.0%	2.2%	0.0%
Settlement	20,585	2.3%	1.0%	3.6%	0.7%
Forest	706,744	77.2%	80.3%	76.8%	66.9%
Wetland	21,612	2.4%	3.2%	1.5%	3.1%
Bedrock	38,792	4.2%	4.7%	3.5%	6.0%
Sand / Gravel / Mine Tailings	9,688	1.1%	0.4%	1.8%	0.0%
Water	108,033	11.8%	10.4%	10.6%	23.3%
Total Area (ha)	915,100	100%	377,960	442,937	94,204

6.4 Forest Cover

The Greater Sudbury Source Protection Area spans the transition forest from the Great Lakes-St. Lawrence Forest in the south to the Boreal Forest in the north. The Great Lakes-St. Lawrence forest type dominates the central and southern parts of the planning area with even-aged mixed stands of white pine, red pine, white spruce, poplar and white birch. Concentrations of tolerant hardwoods, particularly hard maple and yellow birch, occur in these areas. The distribution of jack pine stands exhibits a somewhat scattered pattern along with lowland pockets of black spruce.

Boreal forest types dominate in the northern parts of the planning area. Pure to mixed stands of jack pine, poplar, white birch and black spruce predominate but these stands are also interspersed with sections of white pine and red pine. Tolerant hardwood stands of hard maple and yellow birch have a scattered occurrence. Black spruce predominates on the lowland peat bogs.

Statistics from the 2005 to 2010 Sudbury Forest Management Plan show that white birch, jack pine and poplar are the most common tree species in the area. White pine is also found throughout the area and black spruce is common in wetter areas. Other tree species include balsam fir, red pine, soft maple, white spruce, red oak, hard maple, cedar, hemlock, yellow birch, ash and larch.

Mining and smelting activities from the early to mid-1900's caused severe damage to forest vegetation in the Sudbury area. Logging and repeated fires were also significant factors in deforestation. About 80,000 hectares were disturbed or damaged by smelting (VFM Co, 2005). A land reclamation program sponsored by municipal, provincial and federal governments, industry and academia began in the mid-1960's. The program began with research trials, proceeded to liming and grassing and, eventually, to tree planting by the mid-1970's. Over 10 million trees have been planted since 1979 (VFM Co, 2005). The planting focus has been on conifer species - jack pine, red pine, white spruce, white pine, cedar and larch but some deciduous species have been planted as well; these include red oak, silver maple and ash. Natural regeneration of poplar and white birch is also occurring as a result of the liming process and artificial regeneration efforts. Poplar, birch and the tree species planted by the program are believed to be the major components of the original forests in the Sudbury area (VETAC, 2006).

The woodland cover is illustrated in Map 2.3.

6.5 Wetlands

Wetlands in the boreal landscape are numerous and scattered, tucked between bedrock outcroppings and hugging the edges of a number of lakes and streams. According to the Ministry of Natural Resources and Forestry's Forest Resource Inventory (FRI), 5% of the Sudbury source protection planning area is classified as wetland. Wetlands are also mapped as part of the Provincial Land Cover program. Many of the wetlands on this part of the Canadian Shield are small and only 2.4% of the planning area shows as wetland at this coarser resolution. Map 2.4 illustrates wetlands in the planning area.

The Ministry of Natural Resources and Forestry's Values Information System (NRVIS) lists one provincially significant wetland in the planning area, the Vermilion River Delta Wetlands. This wetland complex is also a Canada Life Science Area of Natural and Scientific Interest. The Vermilion River Delta Wetlands are a series of abandoned channels and remnant levees located where the Vermilion River empties into Vermilion Lake, approximately 16 km upstream of the water intake. Marsh and, in a few instances, fen types, occupy the wettest areas and willow and alder thicket swamps serve as transitional communities between the wettest areas and the silver maple deciduous swamps on the periphery. Both permanently and seasonally wet moisture conditions are associated with these silver maple forests. These latter forests are "spring" swamps in the sense that they are inundated by flooding during the spring season. Silver maple also dominates the levee ridges but as an upland forest type. The levee ridges, which are dry during the summer, also support some bur oak (OMNR, 2005).

6.6 Water Features

The Sudbury area is not only characterized for its mining footprint and legacy. As its nickname, "the City of Lakes" suggests, lakes, rivers and streams, along with associated riparian areas are abundant throughout the planning area. Approximately 12% of the area is covered by water bodies. There are approximately 3,000 lakes that are greater than 2 hectares[1] and 997 lakes that are 10 hectares or greater. These lakes are predominantly deep, nutrient poor lakes. There are more than 1,200 km of rivers, tributaries and subtributaries, and more than 10,000 km (10,383 km) when streams and intermittent streams are counted. Riparian areas are typically defined as an area of wet soils and distinctive vegetation immediately adjacent to streams, rivers and lakes, and are a transition zone between a water body and upland vegetation communities.

The amount of area classified as riparian was calculated using the same buffer widths as specified in the Conservation Authority Generic Regulations. A 30 metre buffer was placed on lakes and wetlands less than 2 hectares and on streams that are less than 20 metres wide. A 120 metre buffer was placed on lakes and wetlands greater than 2 hectares and on rivers that are consistently wider than 20 metres. Riparian areas are illustrated on Map 2.3.

Water bodies and associated riparian areas comprise 64% of the planning area or 518,669 hectares. There are 331,207 hectares of riparian areas in the planning area; this represents 36% of the total planning area.

Chapter 10 describes the hydrologic features of the main watersheds in the Source Protection Area in greater detail.

Consideration of Great Lakes Agreements

The *Clean Water Act, 2006,* requires Source Protection Areas that drain directly into the Great Lakes or the St. Lawrence River to consider the following documents:

- Canada-United States Great Lakes Water Quality Agreement
- Canada Ontario Agreement Respecting the Great Lakes Basin Ecosystem
- Great Lakes Charter
- Great Lakes St. Lawrence River Basin Sustainable Water Resources Agreement
- Any other Agreement to which the Government of Ontario or Canada is a party

These documents deal with water quality and quantity concerns and principles for joint water management of the Great Lakes Basin. The Great Lakes do not provide drinking water for any municipal systems in the Greater Sudbury Source Protection Area. The Whitefish River watershed does flow into the North Channel of Lake Huron at Whitefish Falls, but there are no municipal drinking water systems in this watershed.

---

[1] There are 3,430 water bodies which are greater than 2 ha in the Greater Sudbury Source Protection area. However, out of the 3,430 water bodies, some of them may be segments of rivers that are not labeled as such. Therefore, it is estimated that there are approximately 3,000 lakes that are greater than 2 ha in the planning area.

Water from the Vermilion River watershed enters the Great Lakes via the Spanish River, which is outside of the Greater Sudbury Source Protection Area. The Spanish River flows into the North Channel in the community of Spanish, west of Sudbury. The Wanapitei River flows into the French River, which is also outside of the source protection area. The French River flows into Georgian Bay south of the town of Killarney. Since neither of the watersheds with municipal drinking water systems flow directly into the Great Lakes or the St. Lawrence River, the Great Lakes Agreements were not considered in the assessment report.

Chapter 7 - Human Geography

In the late 1800s, the town of Sudbury was in its infancy and was beginning to make a name for itself in the forestry business. A major fire in Chicago became the impetus for increased logging and the creation of transportation corridors. Then, in 1895, the discovery of large deposits of nickel ore changed the course of history for Sudbury. The region quickly became one of the world's largest producers of nickel, copper and other metals.

The population distribution in the Sudbury area has been largely influenced by its geography and mining history. During World War I, mining camps and company towns dispersed along the Sudbury Igneous Complex and the flat, fertile land of the Valley was developed into agricultural lands and rural villages. Houses in company towns were often scattered due to solid rock outcrops preventing organized development. The development of Sudbury from a village to a town, and later a city, was moulded by physical constraints that had few parallels elsewhere in Canada.

During the 1950s and '60s the pattern of dispersed urban sprawl continued to flat glacial deposits in the Valley and along highways. Company towns scattered along the Sudbury Igneous Complex contributed to the low density population distribution. Today, this pattern of development has continued and has resulted in the sprawling nature of the City of Greater Sudbury. The broad pattern of development of the City has been determined by the location of ore bodies, the history of human settlement, the technology of transportation and the geography of the land. The dispersed pattern of growth poses challenges for the efficient provision of services and infrastructure. Map 2.5 and Table 2.6 illustrate the pattern of dispersal throughout the planning area.

The source protection planning area consists of virtually all of the City of Greater Sudbury and the entirety of the three major watersheds from which residents obtain their drinking water. Greater Sudbury with a population of approximately 160,274 (Stats Can, 2011) consists of a large central urban area surrounded by more than 20 smaller communities. Over half of the total population of the city lives in the former City of Sudbury. The communities of Whitefish Falls and Estaire are outside of the City of Greater Sudbury border, but within the planning area and make up less than 1% of the total population in the Source Protection Area.

Table 2.6 – Major population centres within the Greater Sudbury Source Protection Area

Area	Population (2011)
Capreol	3,286
Garson, Coniston, Wahnapitae, Falconbridge, Skead	13,232
Onaping Falls (Dowling, Onaping, Levack)	4,874
Rayside Balfour (Azilda, Chelmsford)	14,557
Sudbury	88,503
Valley East (Val Thérèse, Blezard Valley, Hanmer, Val Caron)	23,978
Walden (Lively, Naughton, Whitefish)	10,564
City of Greater Sudbury	160,274
Wahnapitei First Nation	320 members
Atikamksheng Anishnawbek (Whitefish Lake) First Nation	1,092 members

7.1 Population and Settlement Areas

Historically a resource-based settlement, Sudbury has evolved from a railway village to a frontier mining town and a regional capitol. Since the 1970s, the City has strengthened its role as a regional center. As the primary industrial activity, mining still plays an important role in the community, but the economy has diversified to include education, health care, government, retail and tourism services. The shift to a service-based economy is reflected by the City's changing work profile, as more than 80% of Greater Sudbury's labour force now work in the service-producing sector (CGS 2008b).

The Greater Sudbury population has fluctuated over the years due to the large influence of the typical boom and bust cycle of resource based industries. Population scenarios were developed as part of the Infrastructure Background Study to the 2006 Official Plan in order to assess the long-term viability of the water and wastewater infrastructure systems and their ability to service future growth. The population projections were developed by City of Greater Sudbury staff. The base population for the projections and basis for the Background Study was 155,225 people, taken from the 2001 Statistics Canada Census data.

7.2 Industry

As described in the previous sections, the Sudbury area is a major mining centre for nickel and other metals. Mining and associated mineral processing activities in Sudbury are primarily concentrated in Copper Cliff in the south-central area, Onaping Falls/Levack in the northwest, the

Creighton Mine Complex in the west, and Falconbridge in the east. Additional mines are also located in Garson, Fairbanks (in the southwestern portion), and north of Valley East.

Numerous abandoned and closed mine sites are also present throughout the planning area. Closed mines are owned by Vale, Xstrata Limited or junior companies such as KGHM International (formerly Quadra FNX) or other companies and are not considered to be abandoned. Some of the abandoned sites may simply consist of small abandoned adits from which no ore was ever removed, to larger sites where some production has occurred. Currently, the Ministry of Northern Development and Mines is undertaking a study to assess the environmental hazards of these abandoned mines.

The Official Plan, Section 4.6.1 and Schedule 1a, has designated a large section of the Sudbury Igneous Complex as Mining/Mineral Reserve. The reserve is approximately 40% of the City of Greater Sudbury and 1,450 km^2. The reserve may be used for a variety of purposes related to the extraction of minerals and include mining and mining related uses, mineral aggregate uses, smelting and refining uses, pits and quarries and related uses, and accessory uses and structures associated with mining. Other development may occur within the reserve; however, it must not interfere with possible mining related activity. Mining activity is legislated under the *Mining Act* and administered by the Ministry of Northern Development and Mines.

The Official Plan also designates an Aggregate Reserve to be protected for pits and quarry operations. Other uses that do not preclude the possibility of future extraction may also be permitted. Lands designated as Aggregate Reserve are to be protected from uses and/or activities that may hinder the extraction of aggregates in the future. Aggregate Reserve is located in patches across the City of Greater Sudbury area and represents approximately 5% of the City of Greater Sudbury or 178 km^2.

Forestry is done on a small scale in the planning area and is conducted mainly by the Vermilion Forest Management Company Ltd. In addition to the Sudbury Forest, small parts of the planning area in the west are located in the Northshore Forest and the Spanish Forest and, in the northeast, the Timiskaming Forest. The Ontario Ministry of Natural Resources and Forestry oversees legislation and compliance for forest management activities on Crown land.

7.3 Agriculture

The majority of farms in the planning area are located in the Valley, which is located in the Vermilion River watershed. Agriculture has played a central role in the historical development of the Valley and continues to be an important part of the local economy. During the development of the mining industry, the Valley attracted people from the French speaking community to develop family farms. In recent times, agriculture activity has decreased, though it still plays an important part in the Valley community and the local economy.

According to the 2011 Census, there were 141 reported farms in the District of Sudbury. Approximately 60% of the farms are between 10 and 129 hectares. The majority of these farms are animal production, including beef and diary cattle, poultry and egg production or crop farming. Field crops produced in the area include mainly hay and clover with some oat and barley production.

A variety of other agriculture activities in the area include floriculture, nurseries, and fruits and vegetables. A number of farms produce berries, potatoes and other vegetables, but they do not represent a significant portion of agricultural activities in the area.

The Agricultural Background Study for the Official Plan investigated the state of agricultural lands within the City of Greater Sudbury and provided an overview of trends in the community. Using aerial photographs, it was clear that large areas under cultivation in the mid-50's are no longer used for agriculture today. Some farms may not have been viable and were abandoned; however, some lands are highly productive and no longer in use. Many farms were abandoned in the 1960's when the mines attracted farmers looking for better wages and better hours. Today, the agricultural lands in the region are faced with two significant pressures: lot creation and topsoil removal. Lot creation in agricultural areas is increasing rapidly due to high demand for rural residential housing. These developments are typically located in areas with prime agriculture potential. Topsoil removal will downgrade the agricultural productivity of the land and hinder the ability to grow crops. Removal of topsoil has a short term financial benefit to land owners but will adversely affect the ability to grow food in the long term. Subsequently, land where top soil has been removed may be converted into non-agricultural use where it may not have been permitted before.

Section 6.0 of the Official Plan describes overall agricultural objectives and an Agriculture Reserve to be preserved for growing crops, raising livestock for food, fur or fibre, aquaculture, apiaries, agroforestry and maple syrup production (See Schedule 1a of the Official Plan). The reserve is less than 1% of the City of Greater Sudbury total area and is approximately 29 km^2. The objective of the reserve is to retain prime agricultural land and minimize the non-farm use of productive agricultural land.

7.4 Recreation

The City of Greater Sudbury and the surrounding area offer a wide variety of opportunity for recreational pursuits and activities. The surrounding area provides an abundance of outdoor recreational activities including cottaging, snowmobiling, skiing, golfing, canoeing, hiking and fishing. Within the City, there are a number of community centres, arenas, swimming pools and athletic fields available for the community to use.

7.5 Protected Areas

Protected areas are generally kept from developmental changes that could alter their natural character. Protection can be designated by the federal government (National Parks), the provincial government (Provincial Parks, Crown land), and local initiatives such as Conservation Areas.

There are four provincial parks, seven Conservation Reserves and six Forest Reserves in the planning area. There are no national parks, nor any other federal lands in the source protection area other than the two First Nation communities described in the next section.

In addition to the provincial protected lands described above, the Nickel District Conservation Authority has control over one Conservation Area, which is in the vicinity of the urban area of Sudbury.

Within the City of Greater Sudbury, publicly-owned lands designated as parks and open space include a variety of lands used for active and passive recreational uses. According to the Official Plan, the City provides a ratio of approximately 4.18 hectares of developed parkland per 1,000 population, or 3.83 hectares when parks are included and facilities are excluded.

7.6 First Nation Perspectives

The First Nation communities within close proximity to the City of Greater Sudbury include the Wahnapitae First Nation and the Whitefish Lake First Nation. Wahnapitae First Nation and Whitefish Lake First Nation are progressive communities proactively participating within the drinking water source protection planning process for the City of Greater Sudbury. There are many other First Nation communities which have close connection with the Sudbury area. First Nation communities located on Manitoulin Island, the North Shore of Lake Huron and Georgian Bay consistently visit the Sudbury area. First Nation communities within this area are considered Anishinaabe people.

Historically, the First Nations in the area utilized the territory for traditional activities such as hunting, fishing, trapping and harvesting. The area was particularly significant for trade routes utilizing the Wahnapitae and Vermillion River to gain access to the Great Lakes and other major waterways. The route included the establishment of the Hudson’s Bay Trading Post located at the North River on Lake Wahnapitae in 1821 and in the mid-1870s on Post Creek.

It is commonly recognized that Indigenous people around the world have a close spiritual connection with Mother Earth and are often viewed as the stewards of the earth. In the Anishinaabe culture, women are considered to be the guardians of water, it is their responsibility to ensure the health of Shkagamik-kwe (Mother Earth) and keep the water clean for future generations as water is the life blood of Mother Earth. Grandmother Josephine Mandamin has pledged her life to the environment and love for water and has walked around the five great lakes in hopes of raising awareness for the protection of water sources. Josephine Mandamin said “water is precious and sacred; it is one of the basic elements needed for life to exist.”

In Sudbury, the Anishnaabe-Kweg Water Journey was initiated in order to raise awareness of the sacredness of water and the need to respect, protect and rehabilitate it. The water journey is a relay walk of Anishinaabe women who carry a bucket of water around Ramsey Lake to raise awareness of the sacredness of water and the importance of keeping the water clean. The Anishinaabe-Kweg Water Journey is held annually in September.

Wahnapitae First Nation

The Wahnapitae First Nation (WFN) is a signatory to the Robinson-Huron Treaty of 1850. It is listed as #11 on the Schedule of Reserves. The First Nation is an Ojibway Band and is part of the Anishinabek Nation. The First Nation Reserve is located approximately 50 km north of Sudbury and is accessible by all season gravel roads from the town of Capreol. The reserve land base is 3.2 km by 3.2 km on the north shore of Lake Wanapitei and covers approximately 1,036 hectares of land. A pending land claim settlement may increase this land base. The Wahnapitae First Nation elects its Chief and Council under Band Custom. There is one chief and 4 councillors.

The WFN is a developing community with a growing population and expanding land base. There are approximately 320 members with approximately 60 living on reserve. There are several tourism related businesses owned by individual members. These include a licensed restaurant and four camp/ trailer/cottage grounds. Band members residing on reserve are employed in Band administration, public works and in other areas of the reserve. Limited development has occurred on reserve, primarily along the north shore of Lake Wanapitei. There are more than 70 surveyed residential lots. The community is surrounded by mining (nickel exploration/mining, and gold exploration activity), forestry (pine and spruce harvesting) and tourist operators. The Band participates in some of these activities, and the community has developed a Community Development Plan. This Plan is based on the priority needs of the community as follows: Economic Development, Watershed Management and Infrastructure.

Atikameksheng Anishnawbek (Whitefish Lake) First Nation

Atikameksheng Anishnawbek are descendants of the Ojibway, Algonquin and Odawa Nations. In 1850, Chief Shawenekezhik, on behalf of the Whitefish Lake First Nation, signed the Robinson-Huron Treaty granting the Canadian Government much of the First Nation’s land. The First Nation is located approximately 19 km west of the City of Greater Sudbury. The current land base is 43,747 acres, much of it being deciduous and coniferous forests, surrounded by eight lakes, with eighteen lakes within its boundaries. As of January 2013, the total population is 1,092 members. The community has grown significantly throughout the years. Currently, there are 120 houses located in the community and 30 cottages owned by residents on various lakes throughout the First Nation. Along the northern shores of Lake Penage, 43.5 acres of land was surrendered for cottage leasing purposes. Currently, there are 97 lots that have road access to the cottages. Not only is it road accessible, but electricity and telephone services are available for the cottagers.

Band Government falls under section 74 of the Indian Act. Elections are held every two years. The number of councillors is based on the amount of registered Band members; for every 100 people, one councillor is elected. Band meetings are held bi-weekly. Each council member holds a portfolio based upon the organizational structure of the First Nation. The First Nation Government belongs to a variety of political organizations such as the Assembly of First Nations, Chiefs of Ontario, Anishinabek Nation and North Shore Tribal Council.

Chapter 8 – Geology

The geology of the area is directly responsible for hydrological characteristics such as gradients, flow rates, and the direction and type of drainage network. The bedrock deposits within the planning area record a complex geologic history spanning approximately 3 billion years of Earth history. Bedrock in the northern portions of the Vermilion and Wanapitei watersheds include some of the oldest crustal rocks in Ontario. Rocks in the southern portions of the City record the opening and closing of an ancient ocean basin, and a subsequent billion-year-old continent-continent collision resulting in the creation and erosion of a mountain range comparable to the present-day Himalaya of Indo-China.

8.1 Bedrock Geology

The primary geological feature in the planning area is referred to as the Sudbury Structure. The Sudbury Structure comprises: the Sudbury Igneous Complex (SIC), the surrounding brecciated footwall rocks and the Sudbury Basin, which is located within the SIC. In plan view, the SIC is elliptical in shape with its long axis oriented SW-NE, and is approximately 60 km long by 27 km wide.

There are several theories about how the Sudbury Basin was formed, but no single one is totally accepted. The opinion is that this feature was either formed by Meteor Impact (Deitz, 1960) or the Volcanic Collapse Theory (McDonald, 1987). The basin has an oval shape, with high relief bedrock ridges along the north, east and south rims. The central portion of the basin is commonly referred to as the “Valley,” an area of regionally low topographic relief (Bajc and Barnett, 1999). Within the central valley, the bedrock is overlain by Quaternary sediments. Much of the terrain within the planning area consists of either exposed bedrock or shallow overburden deposits that were deposited during the past 25,000 years (Barnett and Bajc, 2002).

The Sudbury Basin comprises an extremely thick package of metasedimentary and exhalative rocks of Paleoproterozoic age, called the Whitewater Group. The more commonly known formational terms for this succession, from base to top, include: the Onaping, Onwatin and Chelmsford formations. These rocks both overlie the SIC and appear to be confined to its interior.

The rocks that make up the Archean assemblage to the north of the SIC include mainly granitic plutonic rocks (2.6 Ga – billion years) and gneissic rocks (at least 2.7 to more than 3 billion years old). A small greenstone belt has also been mapped to the northwest of the Sudbury Basin.

The Proterozoic-age rocks of the Southern Geologic Province, which outcrop predominantly to the south of the SIC, include gabbro-peridotite intrusive complexes such as the East Bull Lake complex (situated to the west of the SIC; Peck et al., 1993), Shakespeare-Dunlop complex in the Archean rocks (see Vogel et al., 1998) and the metavolocanic-metasedimentary rocks that make up part of the Huronian Supergroup of the Southern Geologic Province (more specifically the Elliot Lake and Hough Lake Groups). The Huronian Supergroup comprises an extremely thick succession of volcanic and metasedimentary rocks that formed between approximately 2.5 to 2.2 billion years ago (2490 Ma to 2200 Ma). These rocks have been subsequently intruded by porphyritic granitic rock bodies known as the Creighton Granite dated at 2333 Ma (Frarey *et al.*, 1982) and Murray Granite dated at approximately 2388 Ma, and slightly later by Nipissing diabase sills or dykes that have been dated at 2150 and 2220 Ma (Golder, 2005). Map 2.6 illustrates the bedrock geology for the City of Greater Sudbury, however, data at this scale is not available for the entire watershed area.

8.2 Surficial Geology

The Quaternary geology of significant portions of the planning area has been described in detail by Bajc and Barnett (1999). The following summary is based in large part upon this field guide. Several Quaternary geology maps have also been prepared by Bajc (1997) and include Ontario Geological Survey Maps 2519, 2520, 2521 and 2522. Map 2.7 illustrates the surficial geology of the area based primarily upon these maps. In areas not covered by these maps, information from the Ontario Geological Survey Northern Ontario Engineering Geology Terrain Study (NOEGTS) Data Base Maps was used.

Overburden deposits in the area are generally located along bedrock depressions or former erosional features (Richards, 2002). Much of this ancient bedrock is largely impermeable, making it a very poor source of any significant quantities of potable groundwater for the scattered communities located within the planning area. Therefore, most of the drinking water resources are derived from either surface waters and/or shallow groundwaters within glacially-derived, Quaternary sands and gravels.

In general, the Quaternary deposits in the Sudbury region are of Wisconsinan age and are a result of glaciation and deglaciation associated with the Laurentide ice sheet which covered all of Ontario and some of the northern US states approximately 20,000 years ago (Bajc and Barnett, 1999). Various types of glacial deposits have been mapped in the planning area and include two distinct till facies, ice-contact deposits, outwash deposits, glaciolacustrine deposits of clays, silts and sands, and fluvial deposits. From a groundwater perspective, the ice-contact deposits, outwash deposits and fluvial deposits have the highest groundwater supply potential.

The glaciofluvial ice-contact stratified deposits have been subdivided into four units by Bajc and Barnett (1999) and include lee-side cavity fills, isolated esker ridges and/or esker systems consisting of glaciofluvial complexes, spatially associated with ice-marginal positions and large areas of ice stagnation, and ice marginal subaquatic fans and deltas. The sediments in these deposits are highly variable and can include various mixtures of boulder gravel to very fine sand and silt.

One of the largest of these deposits is located in the eastern section of the planning area and extends from the southern tip of Lake Wanapitei, past the Sudbury Airport and through the former Town of Garson towards the former City of Sudbury. This esker deposit also extends upwards of 22 km along a north-south axis on the northern side of Lake Wanapitei. These linear features on both the north and south sides of Lake Wanapitei are locally referred to as the Wanapitei Esker, but the feature actually comprises a complex mixture of glaciofluvial, deltaic and glaciolacustrine deposits.

Another significant ice-contact deposit is located in the northwestern portion of Valley East, and consists of esker and kame deposits (Bajc and Barnett, 1999).

Terraced glaciofluvial outwash deposits have been mapped within all of the significant structurally-controlled river valleys that enter the Sudbury Basin from the north and east rims (Bajc and

Barnett, 1999), including the Vermilion River, the Rapid River, the Nelson River, Sandcherry Creek and Onaping River valleys.

A large delta deposit associated with the Wanapitei Esker is also present to the south of Lake Wanapitei, in the Sudbury Airport area. This delta is associated with a re-entrant that formed along the ice margin at a structural zone of weakness. It should be noted that thickness of overburden deposits along this stretch of deltaic outwash deposits in the Sudbury Airport area are in excess of 100 m. Other deltaic / outwash deposits are present in the northern portion of the Valley and in Dowling. The outwash deposits in the planning area generally consist of gravel and sand, with some boulder gravel zones. These coarse grained deposits generally have high groundwater supply potential.

Glaciolacustrine deposits in the Sudbury area are associated with Glacial Lake Algonquin and consist largely of massive to laminated deposits of pebbly sand to silt with minor clay. These deposits are generally only found in low-lying areas of the Valley (Bajc and Barnett, 1999) and have generally been observed to fine laterally away from the sediment input sources along the north and east rims. Most of the glaciolacustrine deposits in the planning area are sandy facies, whereas finer textured sediments, such as silts and clays, are generally limited to the southeastern parts of the Valley region. These deposits generally have poor groundwater supply potential.

Across the entire planning area, overburden comprises approximately 24.6% of the land area. This 24.6% can be further subdivided into approximately 7% eolian deposits, 8.6% glaciofluvial, 1.2% glaciolacustrine, 3.3% morainal, 3.4% organic and less than 1% alluvial. Over the entire planning area, approximately 0.37% of the land mass is covered by manmade features, including mine tailings and waste rock piles.

Chapter 9 - Climate and Climatic Trends

The planning area is located in two climatic regions with some minor variations: the southern part is associated with the Laurentian Plateau while the northern area is located in the Boreal climatic zone (NDCA, 1980). The area is traversed alternately by:

- Cool, dry polar air from the north;
- Pacific air that has become warmed and somewhat moister over the western portion of the continent;
- Continental polar air, returning from the south; and
- Sub-tropical air, carrying by far the most water vapour and generally warm temperatures.

Changes to the above mentioned air masses generally occur approximately every three days throughout the area, with precipitation occurring at the margins of the moving air masses (NDCA, 1980).

9.1 Climate Stations

The network of climatic gauges in the Sudbury area to record temperature and precipitation data has varied throughout time. Most of the gauges are concentrated in the southern part of the watershed while the north has had a few gauge stations in the past, which have since been abandoned (i.e. data is no longer being collected). The Biscotasing, Turbine, Sudbury Airport, Massey and Monetville gauges contain the most continuous data records. The Biscotasing gauge station has data from 1914 to 2000. The Turbine gauge has data from 1914 to 1990. The Sudbury Airport location is the only currently operating gauge and has data from 1954. Unfortunately, there are currently no active gauges in the northern part of the watershed and the historical records have many missing values.

9.2 Temperature

The planning area is subjected to temperate summers and moderately severe winters. In the southern part of the area, mean monthly minimum temperature taken at the Sudbury Airport between 1963 and 1990 for January and February ranges from -19ºC to -17ºC. Colder temperatures were observed in the north at Biscotasing during the same time period and ranged from -23ºC to -21ºC. Drastic variations in temperature are observed during summer months. Occasional extreme hot days can be expected during June, July and August with mean monthly maximum temperature ranging from 22ºC to 25ºC at the Sudbury Airport in the south and 22ºC to 23ºC in the north at Biscotasing.

9.3 Precipitation

The average annual precipitation from 1963 – 1990 ranged from 817 mm in the north at Biscotasing to 940 mm in Monetville in the south and varied from location to location.

For gauges where complete records are available, the northern part of the watershed showed less precipitation compared to the southern part of the watershed, and a general trend of increased precipitation from southwest to southeast.

9.4 Climatic Trends and Climate Change

Variations in average temperature and average precipitation for the Sudbury Airport from one decade to another during the data duration of 1955-2004 are indicative of the minor climatic fluctuations for the region. Although the specific climatic values in the northern and southern portions of the planning area would be expected to vary, the overall climatic trends should generally be the same. As such, only the decadal temperature, precipitation and potential evapotranspiration (PET) data from the Sudbury Airport have been used for trend analyses. The resultant trend graph is shown in Figure 2.1, which indicates overall increases in temperature and precipitation since 1955. The trend lines were added using linear regression with Microsoft Excel. However, as can be seen in the graphical depictions, trends can change from decade to decade, and are not necessarily good predictors of future decades. Figure 2.2 shows the overall upward trend in precipitation, temperature and evapotranspiration from 1955-2004 at the Sudbury Airport. Figures 2.3 and 2.4 further depict the departure of temperature and precipitation from 1971-2000 climatic normals at the Sudbury Airport.

9.5 Local Initiatives for Climate Change Adaptation

Climate change is being experienced in Greater Sudbury watersheds. Adapting to the changed climate is of utmost importance and it is a collective responsibility for the community to act. In order to move forward in the community, the Nickel District Conservation Authority spearheaded the formation of the Greater Sudbury Climate Change Consortium. The consortium is a collaboration of many partners from the community, including the municipality, health sector, education sector, business/industry and NGO/ENGO sectors, among others. The vision of the consortium is to:

- Facilitate and coordinate the work of community agencies and organizations to develop sound climate change adaptation strategies for the community and for residents.
- Engage the community in dialogue on climate change adaptation.
- Champion locally, provincially and nationally, the work being done in Greater Sudbury in terms of developing climate change adaptation strategies.
- Seek opportunities for joint projects and partnership collaborations.
- Support and encourage local research, projects and activities.
- Feed into regional, provincial and national processes as appropriate.
- Report back to the partners and the community on a regular basis.

The Greater Sudbury Climate Change Consortium is an example of a community based initiative that will work proactively to deal with our changing climate and the future impacts of climate change.

As part of a climate change adaptation project led by the Ministry of the Environment, Conservation and Parks , eight climate change monitoring stations were installed across the province. One of the locations is on the Whitson River in the Vermilion watershed. These climate change stations measure water level, rainfall, soil moisture, groundwater levels and wind speed. All of this information is being uploaded to a central database for interpretation and analysis.

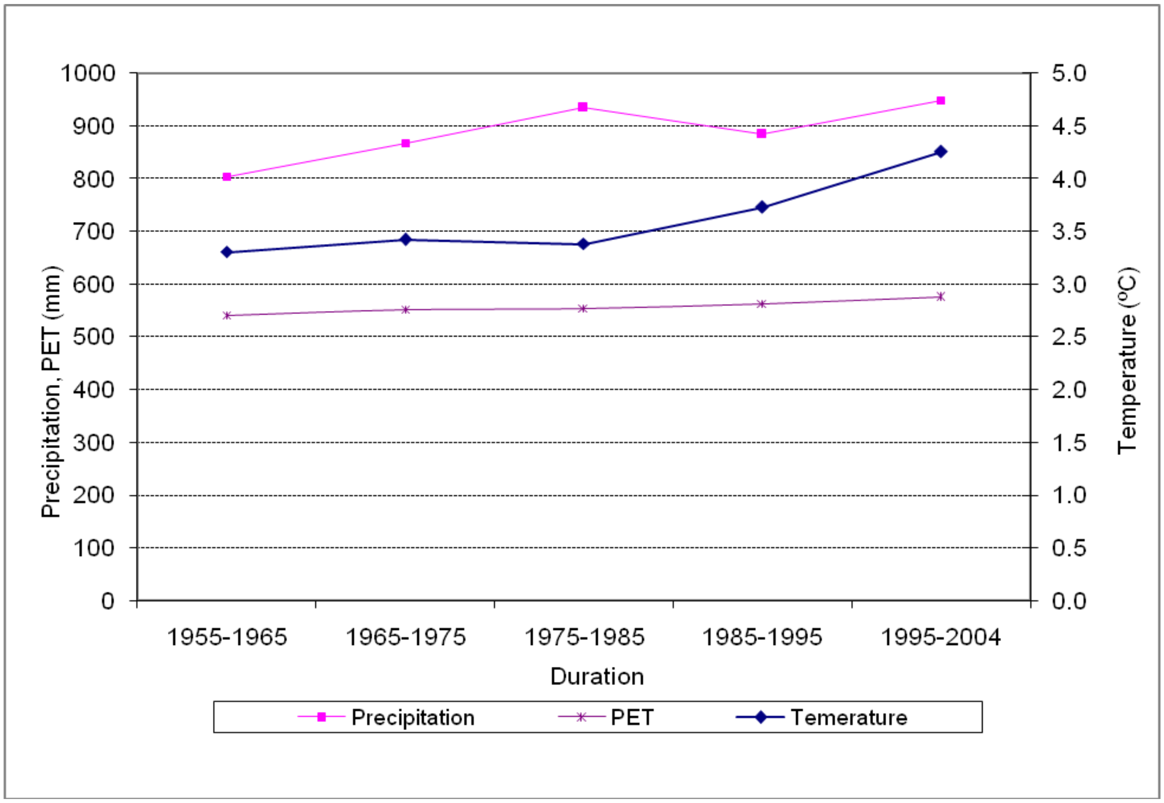


Figure 2.1– Decadal climatic trends at Sudbury Airport (EC, 2002)

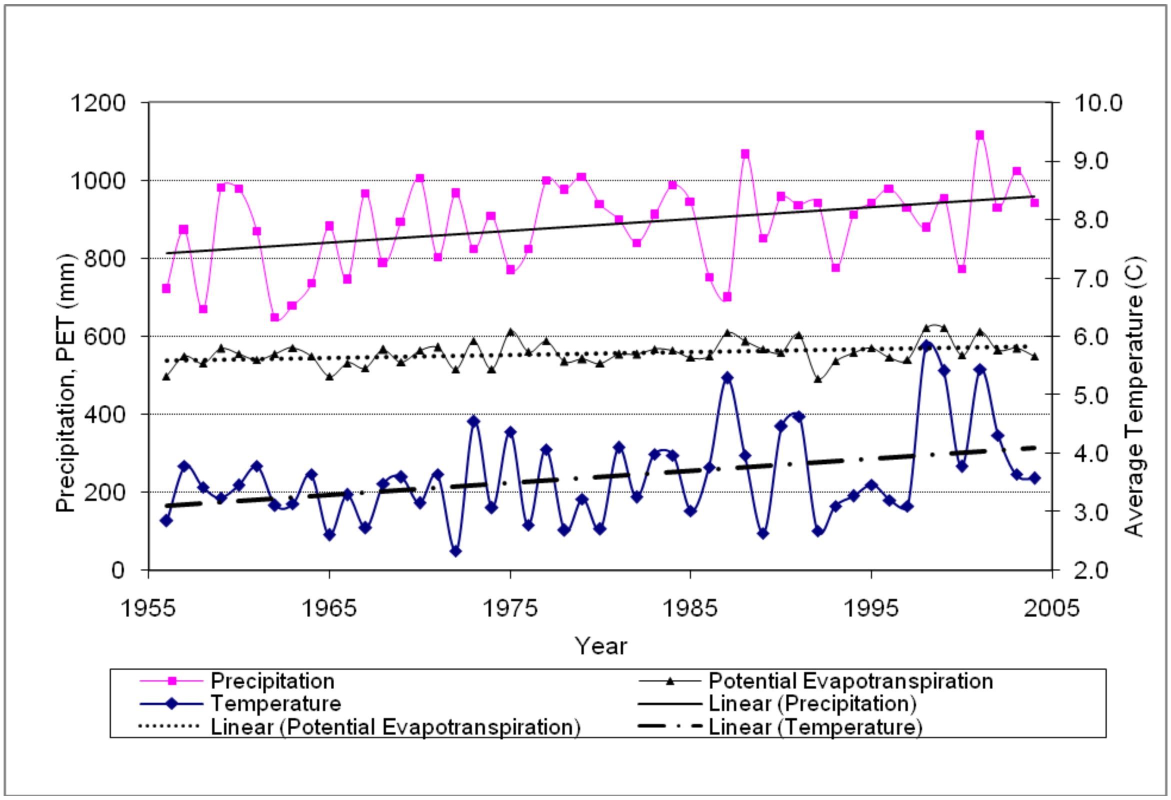


Figure 2.2 – Long term climatic trends at Sudbury Airport (EC, 2002)

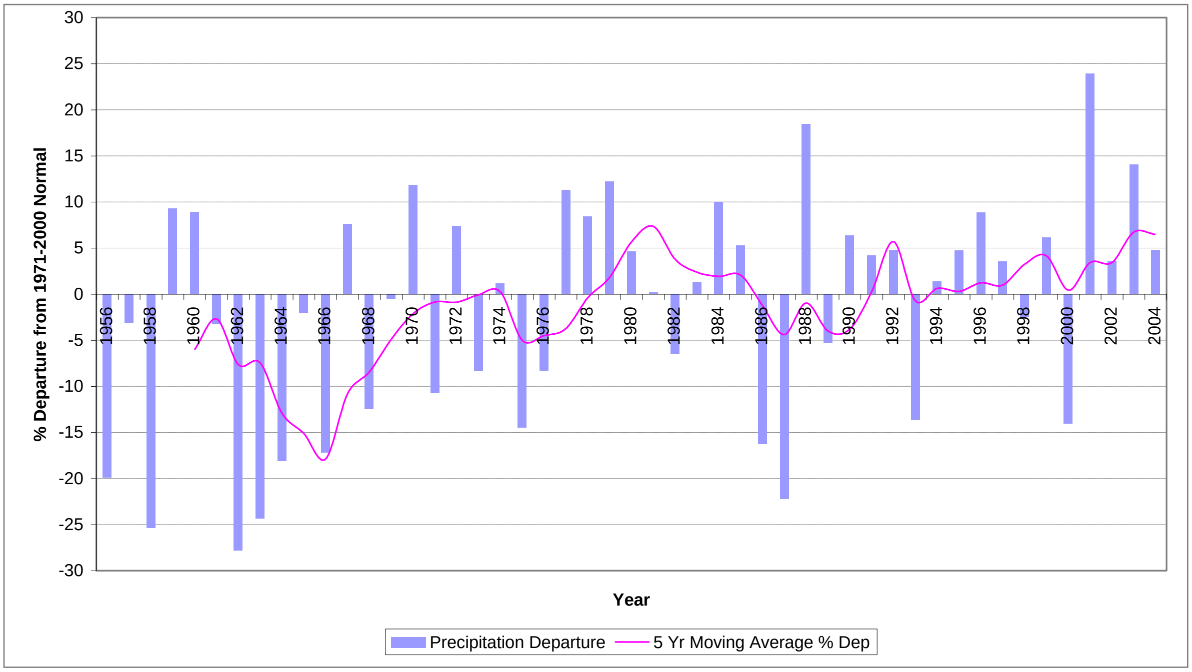


Figure 2.3 – Annual precipitation departure from 1971-2000 normal at Sudbury Airport (EC, 2002)

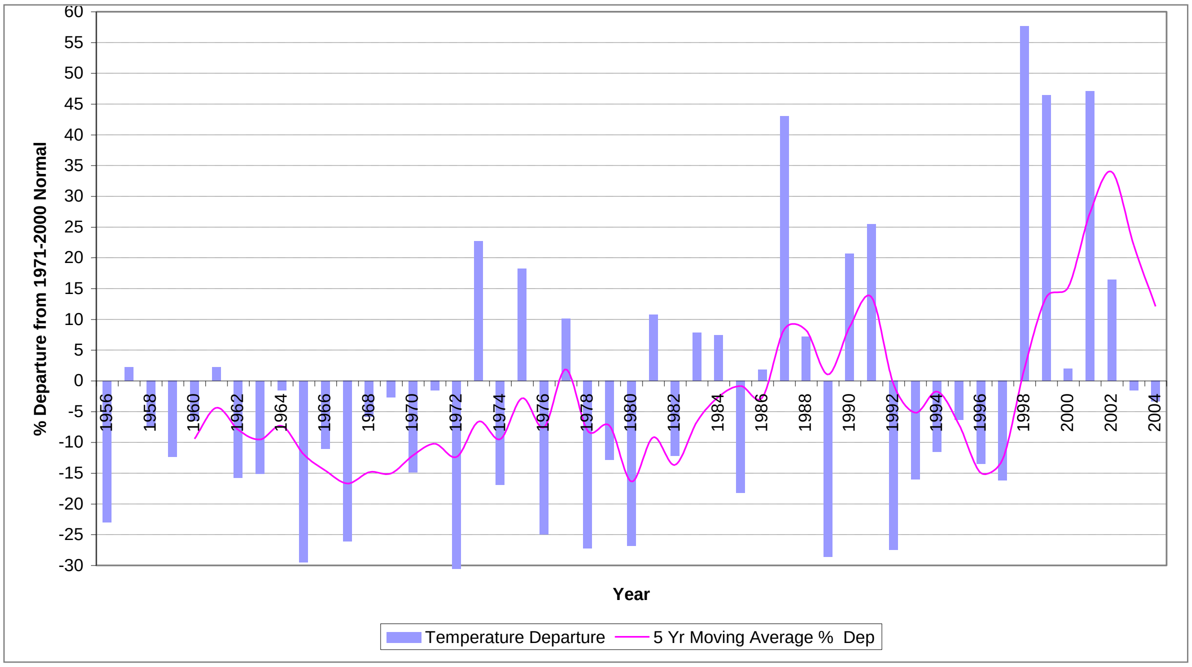


Figure 2.4 – Annual temperature departure from 1971-2000 normal at Sudbury Airport (EC, 2002)

Chapter 10 – Hydrology

10.1 Wanapitei River Watershed

The Wanapitei River, a main tributary of the French River, drains an area of approximately 3,780 km^2, starting from the north at Scotia Lake and flowing towards the south. The watershed area is mostly forested and consists of approximately 268 km^2 of lakes. Lake Wanapitei, the largest inner-city lake in the world, has an area of 132 km^2 and is the main feature of the watershed.

The river is approximately 257 km long with an approximate elevation change of 230 m. The operating level of the lake is shown in Table 2.16. The river is fed by various tributaries and sub-tributaries along the flow as tabulated in Table 2.7. The river above Lake Wanapitei has two main tributaries, the west and the east. The eastern tributary drains an area of 193 km^2 (OMNR, 2005) while the western tributary, which is the main river, drains an area of 1,794 km^2. The western branch drains a number of large tributaries including Scotia Lake, and Meteor, Raven, Rosie, Silvester, Unwin, Barnet and Demott Creeks in the northernmost reaches of the watershed.

The river downstream of Lake Wanapitei is regulated by the Lake Wanapitei Dam and several other hydropower generating stations. Main dams on the river include Lake Wanapitei Dam, Moose Rapids, Stinson Dam, Coniston Dam and McVittie Dam. Four generating stations are installed at Moose Rapids, Stinson, Coniston and McVittie Dams.

A network of streamflow gauges exists on the system and historical flow records are available from the Water Survey of Canada and Ontario Power Generation. The flow records from 1955-2003 show a mean annual flow of 29.8 m^3/s at Lake Wanapitei Dam, 32.4 m^3/s at Stinson GS, 32.6 m^3/s at Coniston GS, 36.6 m^3/s at Wanup GS and 38.3 m^3/s at McVittie GS. The mean annual flow (1955-2003) at the outlet of the watershed is 44.6 m^3/s, which was pro-rated on the basis of flow recorded at McVittie generating station.

The watershed hydrology is illustrated on Map 2.8.

Table 2.7 - Wanapitei River watershed tributaries and sub-tributaries

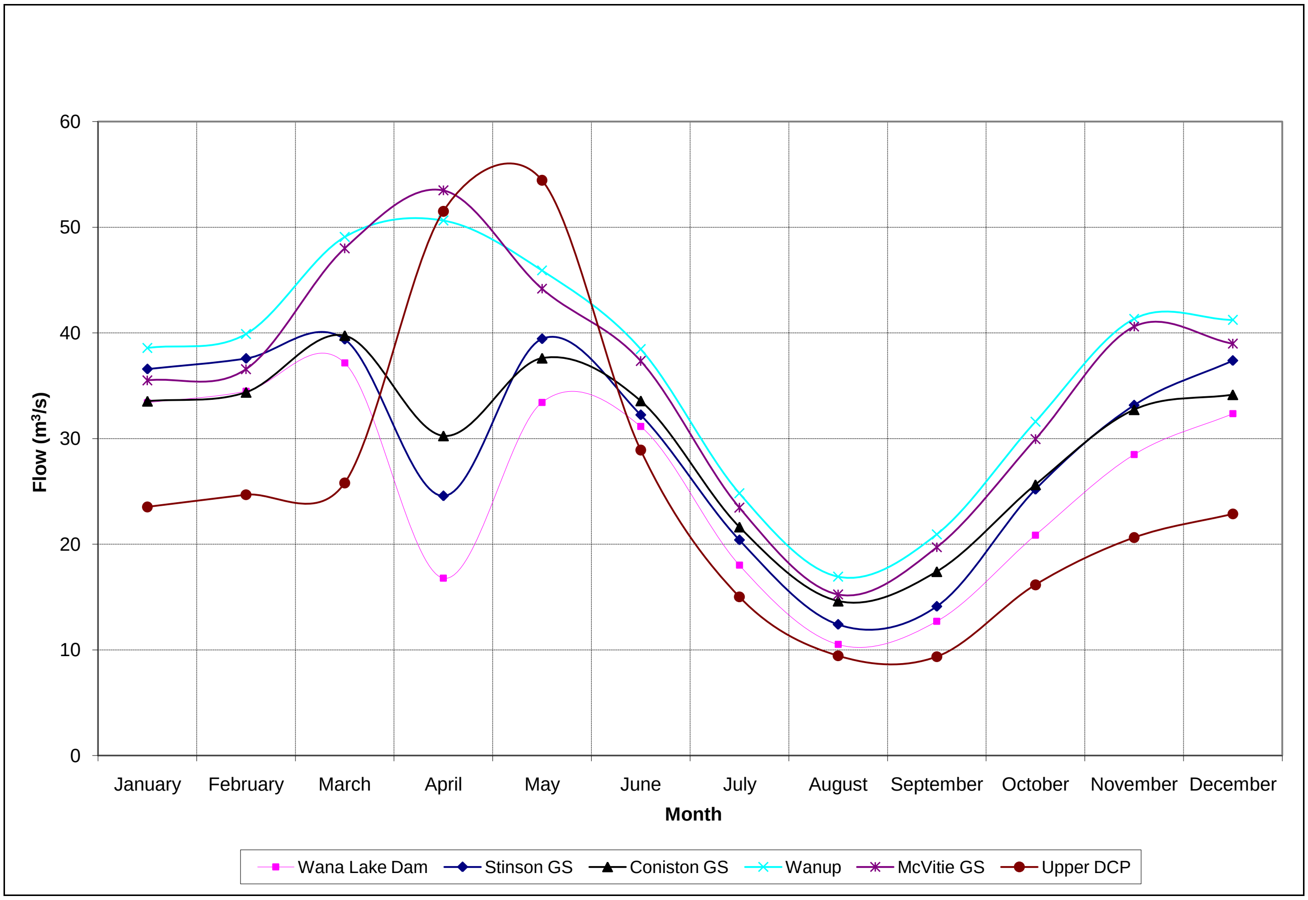
River	Length (km)	Drainage area (km^2)	Drop (m)	Average gradient (m/km)
Barnet Creek	18	128.94	50	2.78
Meteor Creek	44	287.82	42	0.95
Silvester Creek	32	161.04	33	1.03
Burwash Creek	31	184.01	121	3.90
East Wanapitei River	25	193.61	48	1.92
Parkin Creek	27	192.74	121	4.48

Table 2.8 - Stream flow gauge data gaps

Stream Gauge	Status	Data Record
Wanapitei-Wanup	Active	1955-2013
Coniston-Coniston	Active	1980-2013
Upper DCP Gauge	Active	1986-2013
Wanapitei Lake Dam	Active	1955-2013
Stinson	Active	1955-1961 & 1975-2013
Coniston	Active	1955-2013
McVittie	Active	1955-2013

Table 2.9 - Wanapitei River watershed dams and diversion structures

Dam Structure	Owner/Operator	Purpose	Description of Operational Plan
Wanapitei Lake Dam	Ontario Power Generation	Impound lake water for power generation and attenuate peak flows.	Dam has 15 sluiceways, capable of passing 100 year return flood. Stores water during spring freshet and flow is released for power generation.
Moose Rapids Dam	Canadian Hydro Developers	Power generation	Consists of diversion weir and a dam. Plant operates year around through computer control system that automatically starts and stops turbines to keep the water level at the diversion weir at 261.4 m.
Stinson Dam	Ontario Power Generation	Power generation	The dam receives water from various streams and a controlled runoff from Wanapitei Lake Dam. The flow is regulated through the operation of stop logs and gates.
Coniston Dam	Ontario Power Generation	Power generation	The flow is regulated through the operation of sluice gates and stop logs. A minimum flow of 3m^3/sec is maintained for environmental reasons at the request of MNR.
McVittie Dam	Ontario Power Generation	Power generation	The facility is composed of a side dam, main dam and head works. Flow is regulated through sluice gates. A minimum flow of 10 m^3/sec is maintained during the pickerel spawn as per directions of MNR.
Burnt Lake Weir Dam	Ministry of Natural Resources and Forestry	Facilitate the landing of float planes. Also acts as an access for cottagers on Horseshoe Lake.	



Wanapitei Figure 2.5 – Mean monthly flows for the River 1955-2003

10.2 Vermilion River Watershed

The Vermilion River is the main tributary of the Spanish River and its head waters originate in Frechette Township in the rugged northern Precambrian ridges of the watershed. It flows in a southerly direction and follows a winding path. The watershed area is mostly forested, with approximately 302 km^2 of lakes. The watershed hydrology is illustrated on Map 2.8. The operating level of several lakes in the watershed is shown in Table 2.16.

The Vermilion River has an approximate length of 248 km with an approximate elevation drop of 251 m and drains an area of 4,429 km^2. The flow in the Vermilion River comes from a number of tributaries and sub-tributaries as tabulated in Table 2.10.

Onaping Lake, which is a head water reservoir for the Onaping River, eventually discharges in three directions: southerly to the Vermilion River, westerly to the Spanish River and northerly to the Mattagami River. The northern flow has been blocked and the water is mainly diverted towards the Spanish River through regulation of the Bannerman Dam. The Onaping River is the main outlet of the lake and a main tributary of the Vermilion River. It drains an area of 1,378 km^2 which includes Onaping Lake with a surface area of 66 km^2.

The Whitson River, another main tributary of the watershed, flows in a south-westerly direction and enters the Vermilion River in Creighton Township in the City of Greater Sudbury. The Whitson River drains an approximate area of 313 km^2. This river passes through the urban towns of Val Caron and Chelmsford and has been a source of a number of flooding events in the past.

Junction Creek, another urbanized watershed, includes significant mining activity. It drains an area of 324 km^2 passing through the City of Greater Sudbury and eventually joins the Vermilion River at McCharles Lake. Nolin Creek and Copper Cliff Creek are the sub-watersheds which join Junction Creek in downtown Sudbury.

The water level and flow is measured at various locations by the Water Survey of Canada, NDCA, Domtar and Vale. The river has a mean annual flow of 45.7 m^3/s at Lorne Falls and 46.6 m^3/s (pro-rated on the basis of recorded flows at Lorne Falls) at the outlet to the Spanish River.

Table 2.10 - Vermilion River watershed tributaries and sub-tributaries

River	Length (km)	Drainage area (km^2)	Drop (m)	Average gradient (m/km)
Michaud River	19	145.86	38	2.00
Rapid Creek	34	82.66	146	4.29
Roberts River	28	187.67	108	3.86
Onaping River	71	1377.56	141	1.99
Sancherry Creek	24	139.82	148	6.17
Windy Creek	19	90.64	102	5.37
Junction Creek	49	324.19	55	1.12
Levey Creek	17	148.14	13	0.76
Whitson River	44	312.88	43	0.98
Cameron Creek	34		103	3.03
Fairbank Creek	23	72.47	68	2.96
Nelson River	16	193.35	74	4.63

Table 2.11 - Stream flow gauge data gaps

Stream Gauge	Status	Data Record
Bannerman Dam		N/A
Onaping Lake Dam		N/A
Stobie Dam		N/A
Windy Lake Dam		N/A
Moose Creek	Active	1981-2013
Onaping-Levack	Active	1976-1997 / 2002-2013
Vermilion-Capreol/Milnet	Active	1970-1977 / 2006-2013
Vermilion-Val Caron	Active	1970-1994 / 2006- 2013
Whitson-Val Caron	Active	1962-2013
Whitson-Chelmsford	Active	1960-2013
Nolin Creek-Sudbury	Discontinued	1959-1994
Junction-Sudbury	Active	1958-1996 / 2006-2013
Junction-Kelley Lake	Active	1977-2013
Vermilion-Lorne Falls	Discontinued	1955-1993

Table 2.12 - Vermilion River dams and diversion structures

Dam Structure	Owner/ Operator	Purpose	Description of Operational Plan
Bannerman Dam	Domtar	Onaping Lake serves as a reservoir.	The reinforced concrete dam has a single log sluiceway, which contains stop logs. The dam also has east and west weir.
Onaping Lake Dam	Domtar	In conjunction with the Bannerman Dam, regulates the lake level.	The reinforced concrete dam has three log sluiceways, which contain many stop logs.
Strathcona Creek Dam	Xstrata	Is a final effluent polishing pond dam. The purpose of the control station is to control water quantity and quality.	A 61 cm diameter pipe is installed in the roadway beside the existing 1.83 m diameter culverts (culverts remain for contingency purposes). A separate 31 cm pipe is installed to provide extra discharge. The 61 cm pipe flow is measured by an ultrasonic flow meter which is controlled by a butterfly valve.
Stobie Dam	Domtar	Water management	The reinforced concrete dam has five log sluiceways, four of which have double stop logs. The dam also has an east and west weir.
Windy Lake Dam	Ministry of Natural Resources and Forestry	The dam is used to regulate the water level.	The dam discharges in to the Windy Creek, which finally discharges in to the Onaping River near Dowling. The dam consists of a log sluiceway and an Ogee Spillway.
Whitewater Lake Dam	Ministry of Natural Resources and Forestry	Regulate water level for recreational purposes. Dam controls the level of Whitewater Lake.	The reinforced concrete dam has two log sluiceways which contain stop logs. The sluiceways are 8.5 m in width, the height of the dam is 3.96 m with maximum head of 2.7 m and a total dam length of 24.4 m.
Maley Dam	NDCA	Flood control	Dam discharges through sluiceway and steel gates.
Nickeldale Dam	NDCA	Flood control	Controls a discharge area of 9 km^2. The dam is 381 m long and 9 m high with a core of impervious clay covered with earth fill and protected by a layer of rock fill.
Lake Laurentian Dam	NDCA	Controls lake level	The structure is a concrete box culvert with six 4 inch logs installed. Controls a drainage area of approximately 8 km^2.
Nepawhin Dam	NDCA	Water level control	The dam has three bays, each approximately 0.9 m wide, with a 10 cm log in each bay.
Kelly Lake Dam	NDCA	Manage water level in Kelly Lake	The concrete weir is about 18.3 m wide and 1.22 m high.
Robinson Lake Dam	City of Greater Sudbury	Used for recreation and to prevent a back flow from Kelley lake.	The concrete weir has one stop log and covers a drainage area of 25.4 km^2.
Ramsey Lake Dam	City of Greater Sudbury	Used for flood control, recreation and water level control for the municipal water supply intake.	The reinforced concrete dam has two sluiceways and contains up to seven stop logs in each sluiceway. The dam covers a drainage area of 12.7 km^2.
Wabageshik Dam	Vale	Power generation	The run on the river facility consists of a concrete gravity type dam structure. The dam is 221 m in length. The spillway consists of a single motorized gate, which is 12.2 m in length and 7.3 m in height.

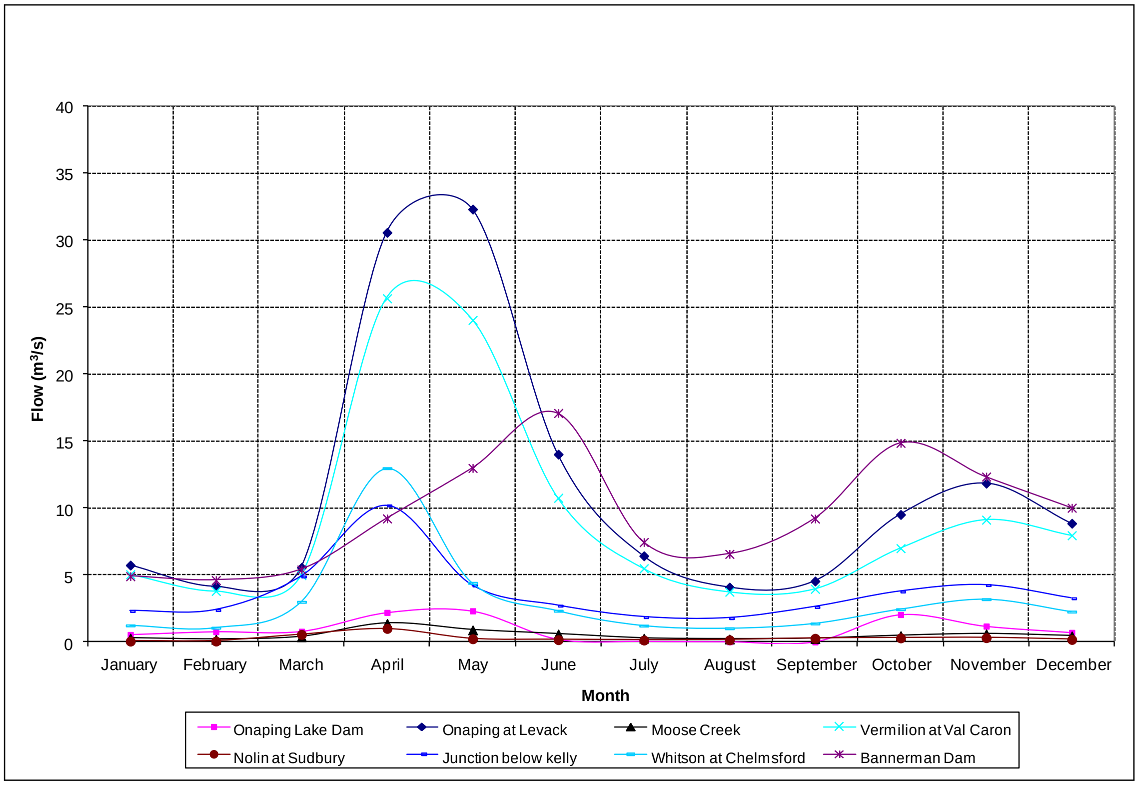


Figure 2.6 – Mean monthly flows for the Vermilion River 1955-2003

10.3 Whitefish River Watershed

The Whitefish River, which ultimately drains into the Lake Huron system, is bounded to the north by the Vermilion River system, to the south by the South La Cloche Range drainage basins and to the southeast by the Wanapitei River system. The watershed hydrology is illustrated on Map 2.8.

The river flow originates at Daisy Lake and flows southwest through Richard, McFarlane, Long, Round, La Vase, Panache, Walker, Little Bear, Lang, Cross, Charlton and Frood Lakes before discharging into the Bay of Islands in the North Channel of Lake Huron at Whitefish Falls.

Blackwater Creek, which flows into Round Lake, is also connected to the Vermilion River, which enters the Whitefish System through Round Lake during high flows. Observation indicates that Blackwater Lake is the headwaters of the watercourses leading to the Vermilion River and Round Lake. Blackwater Lake has been reported to be higher in elevation than Round Lake and the Vermilion River (EGA Consultants, 2000). The degree to which inter-basin transfer is occurring during high flows has not been quantified by studies undertaken to date.

The Whitefish River has a length of 90 km, an elevation drop of 58 m and drains an area of 942 km^2. The area is mostly forested and approximately 20% of the surface area consists of lakes. Three dams are constructed on the river to regulate water levels and flow, and are located on Lake Panache, Lang Lake, and Frood Lake. MNR operates and records the water levels at Lake Panache

Dam, Lang Lake Dam and Frood Lake Dam. Mean annual flow at the Frood Lake Dam is 11.0 m³/s. The operating level for Lake Panache is shown in Table 2.16.

The main contributing tributaries are West River, Howry Creek and Bevin Creek as tabulated in Table 2.13.

Table 2.13 – Whitefish River watershed tributaries and sub-tributaries

River	Length (km)	Drainage area (km^2)	Drop (m)	Average gradient (m/km)
West River	25	80.64	13	0.52
Howry Creek	28	112.06	32	1.12
Bevin Creek	14	62.22	62	4.55
Wavy Creek	6	25.67	45	7.59

Table 2.14 - Stream flow gauge data gaps

Stream Gauge	Status	Data Record
Panache Dam	Active	1999-2013
Lang Lake Dam	Active	1999-2013
Frood Lake-Whitefish Falls	Active	1999-2013
Frood Lake - Automatic	Active	2005-present
Panache Lake @ Jackson's Point	Active	2005-2013

Table 2.15 – Whitefish River watershed dams and diversion structures

Dam Structure	Owner/Operator	Purpose	Description of Operational Plan
Panache Lake Dam	Ministry of Natural Resources and Forestry	Maintain lake water level within regulated ranges	The concrete gravity dam consists of three stop log control bays and an overflow Ogee weir. The stop log bays have a sill elevation of 220.1 m and a bay width of 4.27 m. The crest of the overflow ogee weir is 8 m long and 1.95 m high.
Lang Lake Dam	Ministry of Natural Resources and Forestry	Water level	The concrete dam consists of four stop log control bays and overflow weir. The west two stop log bays have a width of 4.2 m. The two stop logs bays have a bay width of 4.3 m. The overflow weir is 9.96 m long and 1.7 m high.
Frood Lake Dam	Ministry of Natural Resources and Forestry	Control Frood and Charlton Lake water levels	The concrete dam consists of two adjoining control sections and overflow weir. The north control section has three stop log control bays and the south section of the dam consists of two stop log bays and an overflow weir.

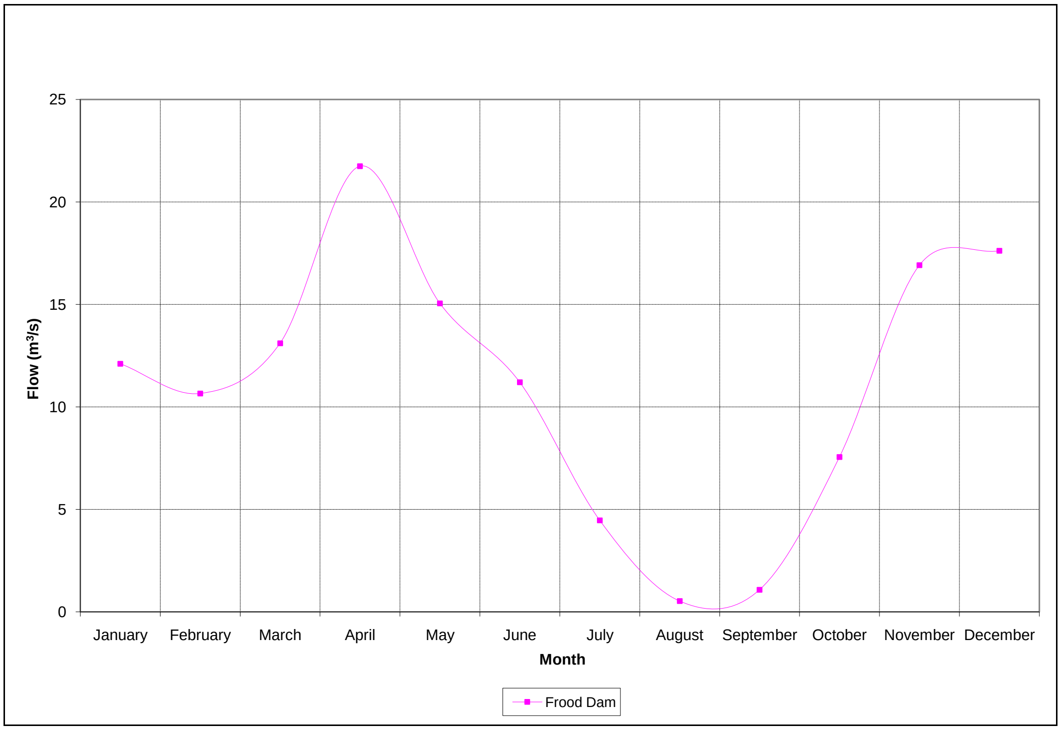


Figure 2.7 – Mean monthly flows for the Whitefish River 1955-2003

Table 2.16 – Operating levels of the lakes

Surface Water Bodies	Operating Ranges/Target Elevation (m)
Ramsey Lake	249.35 – 249.48
Robinson Lake	246.92
Vermilion Lake	256.49
Whitewater Lake	265.17 – 265.48
Whitson Lake	290.56
Windy Lake	0.5 drawdown
Onaping Lake (Onaping Dam)	2.74 above sill
Ella Lake Outlet (Wabageshik Dam)	225.4 – 225.73
Wanapitei Lake	265.05 – 267.95
Panache Lake	221.45

Chapter 11 – Hydrogeology

Groundwater is defined as subsurface water that occurs beneath the water table in soils and geological formations, such as aquifers and aquitards that are fully saturated. Hydrogeology is the study of the movement and interactions of groundwater in geological materials. This chapter will characterize the aquifers within the watershed in the planning area.

The MECP Water Well Information System (WWIS) contains information on the subsurface geology, aquifer properties and groundwater use in the province. This database provided the majority of the information to produce the recharge/discharge, depth to water table, sediment thickness and bedrock topography maps. In addition, this database is used to determine the specific capacity values of the wells in order to have an estimate of the physical hydrogeologic properties of the aquifer in the vicinity of that particular well.

There are 4,108 wells listed in the MECP WWIS for the planning area with most wells concentrated along the major roads and in the most heavily settled areas. Approximately 73% of the wells in the planning area are located within the Vermilion watershed. Very few wells are located to the north and northwest of Lake Wanapitei; therefore, very little information is available for the northern portions of the Wanapitei and Vermilion watersheds.

11.1 Overview of Aquifers

The hydrogeology of the planning area can be separated into two distinct groundwater systems, namely:

- The bedrock groundwater system: flow within this system occurs in relatively small, localized fractures. This system is considered to have limited groundwater supply potential and is generally considered to be a regional aquitard; and
- A series of overburden aquifer systems whose distribution and three-dimensional geometry is complex. Overburden aquifers are generally surrounded by bedrock outcrop and vary from small restricted aquifers in local bedrock valleys, to the extensive aquifers beneath the Valley and within the prominent, north-south trending Wanapitei Esker.

The planning area can be divided on the basis of geology into areas of exposed bedrock or thin overburden cover, and areas of thick overburden deposits. The bedrock areas are considered to be a limited groundwater resource, sufficient only for domestic private water supply. Transmissivity values of the bedrock in the planning area have been found to be generally less than 5 m^2/day (Richards, 2002). As a comparison, transmissivity values less than 12 m^2/day are generally considered to be only sufficient for domestic wells or low yield uses.

The more extensive aquifers are found in areas of thick overburden, including former glacial meltwater channels (Levack and Onaping areas), large glaciofluvial and deltaic deposits around the margin of a former glacial lake that occupied the Sudbury Valley (Dowling, Valley East and Capreol) and the Wanapitei Esker, a major subglacial tunnel and delta feature extending from Lake Wanapitei to the downtown Sudbury area (through Falconbridge and Garson). This esker also extends along the north side of Lake Wanapitei. Several morainal features are located in the northern portions of the Wanapitei and Vermilion watersheds as well as along the eastern limit of the Wanapitei watershed. In many cases, these thick overburden deposits fill deep valleys eroded into the bedrock surface.

A more extensive discussion of the hydrostratigraphy of each groundwater system can be found in the Groundwater Vulnerability Assessment Report, dated January 2010 in Appendix 2.

11.2 Groundwater Flow

The regional groundwater flow in the planning area generally appears to be a result of topographic features, and parallels the surface drainage patterns, with discharge generally being towards the Vermilion, Wanapitei and Whitefish Rivers (Richards, 2002).

In the areas around Levack, Onaping and the Valley, groundwater is found relatively close to the surface and the direction of groundwater flow generally follows surface water flow and overall topography. Within the Valley, groundwater generally flows towards the southwest, exiting the Valley as surface water flow in the Vermillion River.

Groundwater flow directions are more complex within the Wanapitei Esker. North of Falconbridge, groundwater flows towards the north, discharging into Lake Wanapitei, and the water table is up to 40 m below ground surface. Between Falconbridge and Garson, groundwater flow directions are complex and not well mapped. Southwest of Garson, where the esker is confined on both sides by higher bedrock topography, groundwater flow is generally towards the southwest, with some discharge supporting flow in Junction Creek.

11.3 Highly Vulnerable Aquifers

The interaction of surface water and groundwater not only replenishes the quantity of water but can also transport contaminants. The type and thickness of the overlying substrate can determine the vulnerability of the aquifer to contamination from surface activities. To assess groundwater vulnerability in the Greater Sudbury Source Protection Area, an intrinsic susceptibility index (or ISI method) was used. This method generates an overall vulnerability score on the scale of 1 to 100. For more information regarding the ISI method, please refer to Chapter 2 or Appendix 2. The results of this assessment demonstrate the groundwater vulnerability as high, medium or low for the entire source protection area and can be seen on Map 2.9.

To calculate ISI scores, well records were used where the density of wells provided some confidence in the results and surficial geology maps were used in areas that had sparse well records.

The Technical Rules (2009) categorize aquifers into high, medium or low vulnerability (Rule 38). Using the ISI scores:

- Areas with **high** vulnerability are those with ISI scores that are **less than 30,**
- Areas with **medium** vulnerability are those with ISI scores that are **greater than or equal to 30 and less than or equal to 80,** and
- Areas with **low** vulnerability are those areas with ISI scores that are **greater than 80.**

A highly vulnerable aquifer as defined in the Technical Rules (2009) is an area that has been identified with high vulnerability (Rule 43). A vulnerability score of 6 is given to this area (Rule 79). Map 2.10 shows the extent of the highly vulnerable aquifer and its vulnerability score.

11.4 Drinking Water Quality Threats Activities

The assessment of potential threats to drinking water quality followed the methodology outlined in Chapter 2. The list of prescribed drinking water threats is located in Table 1.7 in Part 1 of this report.

Identification of areas where threats can occur

The areas where a potential threat is or would be moderate or low are illustrated on Map 2.10. The highly vulnerable aquifer areas have a vulnerability score of 6, which means that they have the potential for a moderate or low threat to occur.

The MECP has established an online tool that incorporates the Provincial Table of Drinking Water Threatsinto an interactive mapping tool, accessible via http://swpip.ca/. With the address search function, this tool lets you identify what vulnerable area(s) a property is located in and what the vulnerability score is at that location. It also identifies a list of circumstances of all is or would be significant, moderate or low drinking water threats. For more detailed instructions on how to use the above mentioned website refer to Appendix 5.

Managed Lands, Impervious Surfaces and Nutrient Units

Areas within the highly vulnerable aquifer which had a vulnerability score of 4 and above were assessed for percentage of managed lands, impervious surfaces and nutrient units. These results were used to evaluate non-point source threats. The methodology used to calculate these is described in Chapter 2.

The storage, handling and application of agricultural source material, non-agricultural source material, pesticides and fertilizers can result in potential contamination of municipal water supplies. The percentage of managed lands in the area was assessed to be under 40% (low) and is illustrated on Map 2.11. The exception is the Whitson River Sub-watershed which had between 40 and 80% managed land (moderate).

Impervious surfaces are measured as an indicator of the amount of area where road salt can be applied. The percentage of surface area within a vulnerable area which will not allow surface water or precipitation to be absorbed into the soil is measured. According to these calculations, most of the highly vulnerable aquifers are in the <1% range, but the 1-<8% range dominates in the Sudbury Basin, and the 8-<80% range occurs in built-up areas and along some of the major road corridors. The percentage of impervious area is illustrated on Map 2.12. The outcome of the impervious surface calculations resulted in the application of road salt being designated as a low threat.

The calculation of livestock density is based on the calculation of nutrient units per acre of agricultural managed lands. Overall, there is very little agricultural land in the highly vulnerable aquifers resulting in a score of under 0.5 nutrient units per acre, as illustrated on Map 2.13. The result of the managed land and livestock density calculations lead to the application of commercial fertilizer to land and the application of agricultural source material to land both being designated as a low threat for the highly vulnerable aquifer area.

Enumeration of Threats

Table 2.17 lists an estimate of the current number of moderate and low drinking water quality threats in the highly vulnerable aquifer in accordance with the Drinking Water Threats Tables.

Table 2.17 - Drinking water quality threats for the highly vulnerable aquifers

Drinking Water Threat Category	Number of Occurrences with Threat Classification		
	Significant	Moderate	Low
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.		5	21
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			48
The application of agricultural source material to land			1
The storage of agricultural source material.			325
The application of commercial fertilizer to land.			1
The application of pesticide to land.			12
The handling and storage of commercial fertilizer.			7
The handling and storage of pesticide.			3
The application of road salt.			1
The handling and storage of road salt.			6
The storage of snow.			12
The handling and storage of fuel.			45
The handling and storage of a dense non-aqueous phase liquid.			13
The handling and storage of an organic solvent.			14
The management of runoff that contains chemicals used in the de-icing of aircraft.			1
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.			325

Chapter 12 - Surface Water and Groundwater Interactions

The identification of areas of groundwater recharge and discharge is important from the perspective of surface water and groundwater management and protection. Groundwater recharge areas act to replenish the aquifer and are susceptible to impacts from near surface contaminants, which can migrate with groundwater flow into the sub-surface and affect potable aquifers. Contamination in recharge areas can also affect surface water quality where impacted groundwater discharges into receiving streams and wetlands. Groundwater discharge areas also provide cold water habitat for aquatic life and can maintain stream flow in times of drought conditions.

Unconfined groundwater aquifers are a principle source of drinking water and also typically network with surface water streams. These streams receive their baseflow from the aquifer. Surface water feeds groundwater through precipitation, which infiltrates into the ground and percolates into the aquifer.

As previously indicated, the bedrock in the planning area is generally considered to be a regional aquitard, with low infiltration potential and high runoff potential. As such, in areas where bedrock outcrops are at surface or at shallow depth, most of the precipitation runs off the bedrock and often flows directly into nearby surface water bodies.

With the exception of the glaciolacustrine deposits, the overburden deposits in the planning area are considered to be local unconfined aquifers, often of limited extent and bounded by bedrock outcropping. The overburden is considered to have low runoff potential and, in turn, high infiltration potential. Significant groundwater and surface water interaction is likely limited to overburden aquifer areas, which consists of approximately 24% of the planning area.

The overburden and shallow bedrock systems interact to some extent, with recharge to the bedrock being supplied primarily from the overburden in areas of downward vertical gradients. Groundwater also likely flows from the shallow bedrock into the overburden in areas of upward hydraulic gradients. However, the quantity of groundwater contribution from the underlying bedrock into overburden is likely minimal in most parts of the planning area.

12.1 Significant Groundwater Recharge Areas

Groundwater recharge is the process in which precipitation or surface water replenishes an aquifer. A *significant* groundwater recharge area is defined in the Technical Rules (2009) as an area that (Rule 44):

a) annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or,

b) annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the groundwater recharge area.

Additionally, the significant groundwater recharge area must be hydrologically connected to a surface water body or aquifer that is a source of drinking water for a drinking water system (Rule 45).

The average annual water surplus for the source protection area was estimated to be 400 mm. The estimation was based on a series of calculations involving surficial geology, precipitation, potential evapotranspiration, actual evapotranspiration, streamflow, baseflow and surface runoff.

Using criteria b) as described above, 55% of the average annual water surplus (i.e. 55% of 400 mm) is 220 mm. Therefore, a significant groundwater recharge area for the Greater Sudbury Source Protection Area is an area that can achieve a water surplus of greater than 220 mm. Soils that fall into this category include coarse till, silt, silty sand and sand (Golder, 2009).

In the planning area, the dominant surficial geology includes bedrock, wetlands, glaciofluvial and glaciolacustrine deposits (See Map 2.7 and refer to Chapter 8). The principal groundwater recharge areas occur in the glaciofluvial and glaciolacustrine deposits which consist of silt and sand. The MECP Water Well Records were used to determine the location of drinking water systems in the GSSPA. The resulting significant groundwater recharge areas are located in the Valley East area, Dowling, Onaping and the length of the Wanapitei Esker. An isolated recharge area is also located in the northern reach of the Wanapitei River watershed. Map 2.14 delineates the SGRAs in the Source Protection Area.

Managed Lands, Impervious Surfaces and Nutrient Units

The storage, handling and application of agricultural source material, non-agricultural source material, pesticides and fertilizers can result in potential contamination of municipal water supplies. The percentage of managed lands in the significant groundwater recharge areas was assessed to be under 40% and is illustrated on Map 2.15. The exception is the Whitson River Sub-watershed which had between 40 and 80% managed land.

Impervious surfaces are measured as an indicator of the amount of area where road salt can be applied. The percentage of surface area within a vulnerable area which will not allow surface water or precipitation to be absorbed into the soil is measured. According to these calculations, most of the significant groundwater recharge area is in the <1% range and 1-<8% range, with a fairly even amount in each range. Impervious areas in the 8-<80% range occur in built-up areas and along some of the major road corridors. The percentage of impervious area is illustrated on Map 2.16.

The calculation of livestock density is based on the calculation of nutrient units per acre of agricultural managed lands. The amount of agricultural land in the significant groundwater recharge areas is very limited, therefore there is a score of under 0.5 nutrient units per acre. The results are illustrated on Map 2.17.

12.3 Groundwater Discharge Areas

To identify areas of potential groundwater discharge, the vertical hydraulic gradients were calculated by comparing the shallow water table elevation with the potentiometric surface. Where the potentiometric surface is greater than 2 m below the water table surface, vertical gradients are downwards and the deeper aquifer systems are likely receiving groundwater from the shallow system. Likewise, when the potentiometric surface is more than 2 m above the shallow water table, vertical gradients are upwards and the deeper aquifer systems are potentially discharging to the shallow system.

In the Sudbury Basin, areas of upward hydraulic gradient and potential groundwater discharge are seen along the southern margin of the basin and north of Vermilion Lake and east of Dowling. These areas have also been identified as groundwater discharge areas through the groundwater modelling efforts undertaken as part of the Municipal Groundwater Study for the City of Greater Sudbury.

Along the Wanapitei Esker, groundwater discharge patterns are more complex. North of Garson, groundwater discharges northwards to Lake Wanapitei. South of Garson, groundwater discharge is primarily along Junction Creek and associated tributaries. Water bodies that likely receive a significant portion of groundwater discharge within the planning area include the Vermilion, Whitson and Onaping Rivers, Lake Wanapitei and Junction Creek.

Baseflow is the contribution to streamflow that originates from delayed sources, such as groundwater or surface depression storage (Smakhtin, 2001). During dry periods, these delayed releases help to maintain streamflow and, therefore, baseflow is an important contributor to water quantity and quality. A number of manual and automatic methods have been developed to separate baseflow from streamflow records (see Tallaksen, 1995 for review).

In southern Ontario, deep glacial deposits allow for the calculation of baseflow to be an estimate of groundwater discharge to streams (Piggott et al., 2005). However, conventional baseflow separation techniques in the lake-dominated, shallow soil and relatively impermeable bedrock areas of northern Ontario predict >50% annual contribution from baseflow to streamflow (Conceptual Water Budget Report). This predicted baseflow is too high to represent groundwater inputs to streams, but may realistically reflect slow inputs from the numerous wetlands, lakes and reservoirs in the region. Wang and Chin (1978) suggested that for northern Ontario, the 95% flow exceedance value on a flow-duration curve appropriately estimated groundwater contributions to streamflow (i.e. the groundwater component of baseflow), while government reports (MNR, 1984; Singer and Chang, 2002) calculated approximately 20% - 30% of annual streamflow in Northern Ontario was contributed by groundwater.

A recent USGS report (Neff *et al*., 2005) investigated baseflow in the Great Lakes Basin, including parts of the Canadian Shield near Sudbury. Their model incorporated functions for surface water attenuation and soil classification. Using this method, annual groundwater contributions to streamflow in the source protection planning area were calculated to be 35%. It should be noted that groundwater contributions may be higher in areas of thicker/deeper overburden and considerably less in areas dominated by bedrock.

Chapter 13 - Water Quantity

13.1 Wanapitei River Watershed

In the Wanapitei Watershed there are 38 Permits to Take Water: 21 are for surface water, 13 are for groundwater and 4 are for both groundwater and surface water. The actual water use estimates for each sector is detailed in Table 2.24 and Figure 2.8 represents water use by sector in the watershed. The groundwater withdrawal is estimated to be 10% while 90% usage is surface water. The City of Greater Sudbury takes surface water from the Wanapitei River for the Wanapitei Water Treatment Plant which provides 60% of the water for the former City of Sudbury (CGS, 2004). The treated water from this plant is delivered to New Sudbury, Coniston, Wahnapitae, Markstay, and parts of downtown. The water diverted to New Sudbury and parts of downtown constitutes an inter-basin transfer to the Junction Creek (sub-watershed of the Vermilion River) because the sewage system of the area is discharged into Junction Creek at Kelly Lake. The City of Greater Sudbury's groundwater wells in Falconbridge are also located in the Wanapitei River watershed.

As noted in Chapter 3, a Tier 1 water budget was done for this watershed, and the results showed a low stress level, so Tier 2 and Tier 3 analyses were not required. A summary of the results of the Tier 1 analysis are provided in this section and the complete report is provided in Appendix 2. Monthly and annual water budget analyses were carried out to evaluate water quantity stress within the Wanapitei Watershed. The water budget results are detailed in Table 2.19. Stress assessments were performed for surface water and ground water systems in the watershed separately. Tables 2.20 and 2.21 summarize the stress assessment results for surface water and groundwater systems. Maps 2.18 and 2.19 illustrate the stress level of surface water and groundwater systems for the Wanapitei River watershed.

A Tier 1 water budget was also done for each of the drinking water systems within this watershed. The results of these analyses are in Part Four, Wanapitei River Drinking Water System and Part Eight, Falconbridge Drinking Water System.

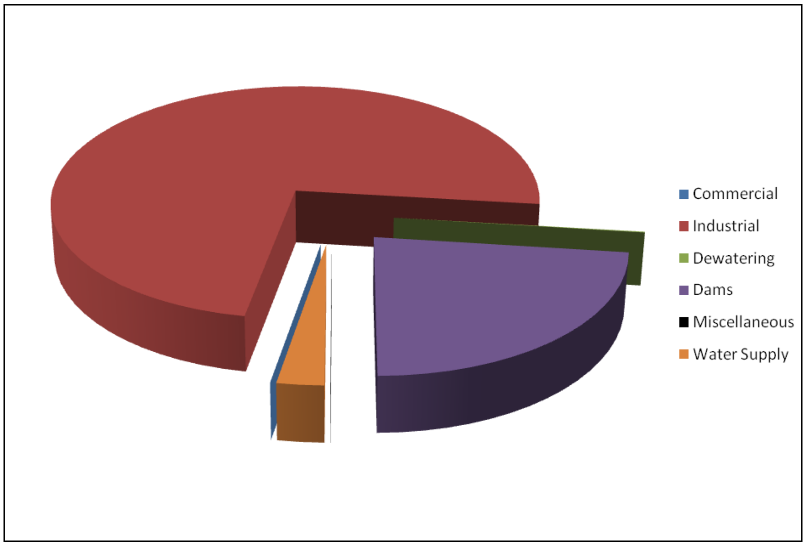


Figure 2.8 –Summary of Wanapitei River watershed water use by sector

Table 2.18- Wanapitei River watershed water budget

Water Balance Element (mm)											
Month	Rainfall	Snowfall	Snow-melt	Total Input	PET*	AET*	Stream-flow	Base-flow	Runoff	Water Surplus	Water Deficit
January	2.3	61.2	5.8	8.1	0	0	32.4	8.0	24.4	0	-24.3
February	2.9	48.5	13.5	16.4	0	0	33.5	7.0	26.5	0	-12.2
March	20	46.7	67.2	87.2	0	0	40.9	12.0	28.9	46.3	0
April	52	13.4	129.2	181.2	19.2	19.2	42.5	20.0	22.5	119.5	0
May	80.8	1	8.8	89.6	74.5	74.5	41.3	25.0	16.3	0	-26.2
June	77.1	0	0	77.1	110.5	107.4	34.0	18.0	16.0	0	-64.3
July	78	0	0	78	130.3	114.7	19.3	14.0	5.3	0	-56
August	84.9	0	0	84.9	112.7	100.2	12.8	8.0	4.8	0	-28.1
September	106.4	0	0	106.4	69	69.0	14.8	6.0	8.8	22.6	0
October	82.3	2.5	2.5	84.8	30.2	30.2	24.8	12.0	12.8	29.8	0
November	45.4	33.3	19	64.4	0.7	0.7	34.0	14.0	20.0	29.7	0
December	9.3	55.5	15.2	24.5	0	0	34.9	25.0	9.9	0	-5.3
Annual Total	**641.4**	**262.1**	**261.2**	**902.6**	**547.1**	**515.8**	**365.3**	**169.0**	**196.3**	**247.9**	**-216.4**
Annual Recharge											31.5

*PET – Potential Evapotranspiration
**AET – Actual Evapotranspiration

Table 2.19 – Wanapitei River watershed surface water stress assessment

Month	Supply (m^3/s)		Demand (m^3/s)				Stress (%)	
	Median	Reserve	Municipal	PTTW	Total	Forecast	Present	Forecast
January	47.31	36.57	0.29	0.44	0.73	0.75	6.79	7.03
February	48.9	35.53	0.28	0.43	0.71	0.74	5.31	5.5
March	59.61	47.47	0.29	0.43	0.72	0.75	5.95	6.017
April	62.0	32.23	0.29	0.43	0.72	0.75	2.42	2.51
May	60.25	16.23	0.29	0.43	0.72	0.75	1.64	1.7
June	49.64	13.66	0.32	0.46	0.78	0.81	2.16	2.24
July	28.13	13.28	0.32	0.46	0.77	0.80	5.22	5.41
August	18.68	9.49	0.31	0.45	0.76	0.79	8.3	8.61
September	21.59	8.97	0.30	0.45	0.75	0.78	5.93	6.15
October	36.2	12.41	0.29	0.43	0.71	0.74	3.0	3.1
November	49.55	24.29	0.29	0.43	0.71	0.74	2.84	2.94
December	50.88	33.09	0.30	0.44	0.73	0.76	4.13	4.28

Table 2.20 – Wanapitei River watershed groundwater stress assessment

Month	Supply (m^3/s)		Demand (m^3/s)					Stress (%)	
	Median	Reserve	Municipal	PTTW	Agriculture	Total	Forecast	Present	Forecast
January	3.78	0.38	0.003	0.05	0	0.05	0.02	1.53	0.94
February	3.78	0.38	0.003	0.04	0	0.05	0.02	1.50	0.94
March	3.78	0.38	0.003	0.04	0	0.05	0.02	1.47	0.94
April	3.78	0.38	0.003	0.05	0	0.05	0.02	1.63	0.94
May	3.78	0.38	0.004	0.04	0	0.05	0.03	1.42	0.97
June	3.78	0.38	0.005	0.05	0.01	0.07	0.03	2.07	1.28
July	3.78	0.38	0.006	0.05	0.02	0.07	0.04	2.25	1.61
August	3.78	0.38	0.004	0.05	0.02	0.07	0.04	2.28	1.50
Sept.	3.78	0.38	0.003	0.05	0.01	0.06	0.03	2.0	1.23
October	3.78	0.38	0.003	0.05	0	0.05	0.02	1.62	0.94
Nov.	3.78	0.38	0.003	0.05	0	0.05	0.02	1.53	0.94
Dec.	3.78	0.38	0.003	0.05	0	0.06	0.02	1.78	0.94
Annual	3.78	0.38	0.004	0.05	0	0.06	0.03	1.76	1.10

Table 2.21 – Summary of Permits to Take Water by Sector in the Wanapitei Watershed

Type	Surface Water	Groundwater	Both	Total	Percentage
	(Thousands of cubic meters)				
Commercial	49			49	0.004
Industrial	812,578	2,782	995	816,355	74
Water Supply	22,201	7,412	332	29,936	2.715
Dewatering		1,195		1,195	0.108
Dams	254,880			254,880	23
Miscellaneous	42			42	0.004
Total				1,102,456	

13.2 Vermilion River Watershed

In the Vermilion River watershed there are 80 Permits to Take Water: 39 are for surface water, 36 are for groundwater and 5 for both groundwater and surface water together. The actual water use estimates for each sector is detailed in Table 2.23 and Figure 2.9 represents water use by sector in the watershed. The groundwater withdrawal is estimated to be 13% while 77% usage is surface water. Surface water-groundwater combined contributes about 10%. Municipal supply removals from this watershed include the Vale owned surface water removal from the Vermilion River, the City of Greater Sudbury's surface water removal from Ramsey Lake, and groundwater removals in the Valley, Capreol, Dowling, Onaping and Garson.

A summary of the results of the Tier 1 analysis for this watershed are provided in this section and the complete report is provided in Appendix 2. Monthly and annual water budget analyses were carried out for the period 1970-2005, to evaluate water quantity stress within the Vermilion River watershed. The water budget results are shown in Table 2.24. Stress assessments were performed for surface water and ground water systems in the watershed separately. Tables 2.25 and 2.26 summarize the stress assessment results for surface water and groundwater systems.

Maps 2.18 and 2.19 illustrate the Tier 1 stress level for the Vermilion River watershed and for the Ramsey Lake and Valley subwatersheds, and Maps 2.20 and 2.21 show the Tier 2 stress levels.

Tier 1 water budgets and stress assessments were also completed for each municipal drinking water system within this watershed. The results of these analyses are in Part Five (the Vermilion system upstream of the intake), Part Six (Valley), Part Seven (Garson), Part Eight (Falconbridge), Part Nine (Onaping), and Part Ten (Dowling). Further analyses were required for the Ramsey Lake system where a combined Tier 1/2 was completed as well as a Tier 3 (Part Three), and for the Valley system where Tier 2 and Tier 3 analyses were completed (Part Six).

Table 2.22 – Summary of Permits to Take Water by Sector in the Vermilion Watershed

Type	Surface Water	Groundwater	Both	Total	Percentage
	(Thousands of cubic meters)				
Commercial	605			605	0.04
Industrial	118,215	1,386		119,601	7.15
Water Supply	18,579	8,892		27,471	1.64
Dewatering	1,207	13,638	16,883	31,727	1.90
Dams	1,492,067			1,492,067	89.25
Miscellaneous	7	316		322	0.02
Total				1,671,794	

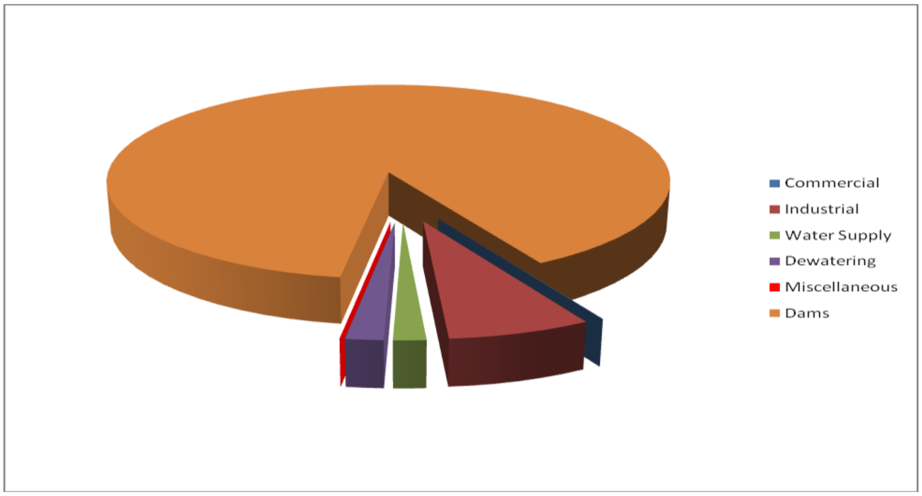


Figure 2.9 – Vermilion River watershed water use by sector

Table 2.23 – Vermilion River watershed water budget

Water Balance Element (mm)										
Month	Rainfall	Snowfall	Snow-melt	Total Input	PET*	AET*	Stream-flow	Base-flow	Runoff	Water Surplus	Water Deficit
January	2.3	61.2	5.8	8.1	0	0	13.4	8.0	5.4	0	-5.3
February	2.9	48.5	13.5	16.4	0	0	11	7.0	4.0	5.4	0
March	20	46.7	67.2	87.2	0	0	20.3	12.0	8.3	66.9	0
April	52	13.4	129.2	181.2	19.2	19.2	87.2	50.0	37.2	74.8	0
May	80.8	1	8.8	89.6	74.5	74.5	64.9	30.0	34.9	0	-49.8
June	77.1	0	0	77.1	110.5	108.2	30.7	20.0	10.7	0	-61.8
July	78	0	0	78	130.3	118.7	16.3	15.0	1.3	0	-56.9
August	84.9	0	0	84.9	112.7	103.1	9.3	8.0	1.3	0	-27.5
September	106.4	0	0	106.4	69	69	9.9	8.0	1.9	27.5	0
October	82.3	2.5	2.5	84.8	30.2	30.2	17.7	18.0	2.7	36.9	0
November	45.4	33.3	19	64.4	0.7	0.7	27.3	14.0	13.3	36.4	0
December	9.3	55.5	15.2	24.5	0	0	21.7	2.0	19.7	2.8	0
Annual Total	**641.4**	**262.1**	**262.1**	**902.6**	**547.1**	**523.6**	**329.6**	**189.0**	**140.6**	**250.7**	**-201.4**
Annual Recharge											49.3

*PET – Potential Evapotranspiration
**AET – Actual Evapotranspiration

Table 2.24 – Vermilion River watershed surface water stress assessment

	Supply (m^3/s)		Demand (m^3/s)				Stress (%)	
Month	Median	Reserve	Municipal	PTTW	Total	Forecast	Present	Forecast
January	21.89	11.71	0.02	0.19	0.22	0.22	2.14	2.16
February	18.67	11.03	0.02	0.19	0.22	0.22	2.87	2.90
March	25.9	16.02	0.02	0.19	0.22	0.22	2.19	2.21
April	147.14	90.47	0.02	0.19	0.22	0.22	0.38	0.38
May	103.94	48.81	0.02	0.19	0.22	0.22	0.4	0.40
June	41.16	24.79	0.02	0.23	0.25	0.25	1.54	1.55
July	22.24	10.19	0.02	0.23	0.25	0.25	2.10	2.12
August	14.53	7.38	0.02	0.23	0.25	0.26	3.57	3.60
September	13.62	6.74	0.02	0.23	0.25	0.26	3.70	3.73
October	22.05	6.67	0.02	0.19	0.22	0.22	1.41	1.42
November	37.41	13.38	0.02	0.19	0.22	0.22	0.90	0.91
December	34.94	14.94	0.02	0.19	0.22	0.22	1.08	1.09

Table 2.25 – Vermilion River watershed groundwater stress assessment

	Supply (m^3/s)		Demand (m^3/s)					Stress (%)	
Month	Median	Reserve	Municipal	PTTW	Agriculture	Total	Forecast	Present	Forecast
January	24.44	2.44	0.14	0.26	0	0.39	0.4	1.79	1.84
February	24.44	2.44	0.13	0.26	0	0.38	0.39	1.74	1.79
March	24.44	2.44	0.13	0.26	0	0.38	0.4	1.75	1.80
April	24.44	2.44	0.13	0.26	0	0.38	0.4	1.76	1.80
May	24.44	2.44	0.13	0.26	0	0.39	0.4	2.36	1.81
June	24.44	2.44	0.14	0.37	0.01	0.52	0.4	2.36	2.42
July	24.44	2.44	0.13	0.37	0.03	0.52	0.53	2.38	2.43
August	24.44	2.44	0.13	0.37	0.03	0.52	0.53	2.37	2.43
September	24.44	2.44	0.14	0.37	0.01	0.52	0.53	2.36	2.42
October	24.44	2.44	0.13	0.26	0	0.38	0.39	1.74	1.79
November	24.44	2.44	0.12	0.26	0	0.38	0.39	1.72	1.77
December	24.44	2.44	0.12	0.26	0	0.38	0.39	1.72	1.77
Annual	24.44	2.44	0.13	0.29	0.01	0.43	0.44	1.95	2.01

13.3 Whitefish River Watershed

The Whitefish River drains an area of approximately 940 km^2, and is bounded to the north by the Vermilion River system, to the south by the La Cloche Range drainage basins and to the southeast by the Wanapitei River system. According to the most recent Permit to Take Water database, there are no current permits in the Whitefish River watershed. There remains the possibility of older removals that precede Permit to Take Water regulation. There are no municipal removals from this watershed. Where municipal water is provided, it is transported from the Vermilion River water treatment plant, which is owned and operated by Vale. According to the MECP Water Well Information System (WWIS), there are 683 recorded wells in the watershed. The majority of these wells (83%) were designated as domestic use.

As noted in Chapter 3, a Tier 1 water budget was done for this watershed, and the results showed a low stress level, so Tier 2 and Tier 3 analyses were not required. A summary of the results of the Tier 1 analysis are provided in this section and the complete report is provided in Appendix 2. Monthly and annual water budget analyses were carried out to evaluate water quantity stress within the watershed. The water budget results are detailed in Table 2.27. Stress assessments were performed for surface water and ground water systems in the watershed separately. Maps 2.18 and 2.19 illustrate the stress level of surface water and groundwater systems for the Whitefish River watershed.

Table 2.26 – Whitefish River watershed water budget

Water Balance Element (mm)											
Month	Rainfall	Snowfall	Snow-melt	Total Input	PET*	AET*	Stream-flow	Base-flow	Runoff	Water Surplus	Water Deficit
January	2.3	61.2	5.8	8.1	0	0	32.8	8.3	24.5	0	-24.7
February	2.9	48.5	13.5	16.4	0	0	26.0	5.5	20.4	0	-9.6
March	20.0	46.7	67.2	87.2	0	0	35.5	9.06	25.9	51.7	0
April	52.0	13.4	129.2	181.2	19.2	19.2	59.3	13.8	45.5	102.7	0
May	80.8	1.0	8.8	89.6	74.5	74.5	40.9	12.4	28.5	0	-25.8
June	77.1	0	0	77.1	110.5	107.6	30.3	9.6	20.6	0	-60.7
July	78.0	0	0	78.0	130.3	115.6	11.7	4.1	7.6	0	-49.4
August	84.9	0	0	84.9	112.7	100.9	0.9	0.6	0.3	0	-16.8
September	106.4	0	0	106.4	69.0	69.0	2.4	1.4	1.0	35.0	0
October	82.3	2.5	2.5	84.8	30.2	30.2	20.2	5.5	14.7	34.4	0
November	45.4	33.3	19	64.4	0.7	0.7	46.0	6.9	39.1	17.7	0
December	9.3	55.5	15.2	24.5	0	0	47.9	8.3	39.7	0	-23.4
Annual Total	641.4	262.1	261.2	902.6	547.1	517.7	353.8	85.8	268.0	241.5	-210.3
Annual Recharge											**31.1**

*PET – Potential Evapotranspiration
**AET – Actual Evapotranspiration

Chapter 14 - Water Quality

The quality of water has become one of the most important political and environmental topics of our time. As water makes its way through the water cycle, it picks up minerals and compounds from the natural and human environment which inevitably impacts its chemical makeup. Generally, the quality of water can determine the safety and palatability of drinking water as well as impact the habitat of aquatic organisms.

This chapter provides a general overview of surface water and groundwater quality in the planning area. Sudbury's history of mining and smelting has created great interest from scientists and academics who study the recovery and reclamation of mining impacted environments. Since reclamation efforts began in the 1970s, there has been a wide range of water quality data collected in the area. The Provincial Water Quality Monitoring Network (PWQMN), the Lake Water Quality Group with the City of Greater Sudbury and the Freshwater Ecology Unit at Laurentian University have collected and stored a large amount of surface water quality data. Preliminary trends in water quality can be determined from their work.

14.1 Sampling Programs

The Provincial Water Quality Monitoring Network (PWQMN) collects surface water quality information from streams at locations across Ontario. The purpose of the PWQMN network is to assess water quality, determine the location and causes of water quality problems and measure the effectiveness of pollution control and water management programs. Information is used by the Ministry of the Environment, Conservation and Parks to evaluate applications for certificates of approval, permits to take water and to develop water quality standards.

The standard set of water quality indicators monitored at each PWQMN station includes chloride, nutrients, suspended solids, trace metals and other general chemistry parameters. Other substances such as pesticides and other contaminants are monitored in detailed water quality surveys in priority watersheds.

A total of 84 stations have historically been monitored within the planning area. Of these 84 stations, two stations are currently monitored. These stations are located along Junction Creek and the Wanapitei River. The data from these two locations were used for both water quality trends over time as well as current water quality of the watershed. The other 82 stations were sampled anywhere from 1 to 31 years, from 1968 to 1999.

Groundwater quality sampling in the Sudbury area has been irregular and there is limited available data for long term trend analysis. Historical groundwater data collection was conducted in the late 70's by the MECP as part of a water resources assessment program. Various wells in the Sudbury area were monitored for parameters relating to drinking water at one point in time.

More recently, the Provincial Groundwater Monitoring Network (PGMN) has been established by the MECP to build a comprehensive groundwater database for Ontario. The NDCA has been operating the PGMN program since 2003 and sampling occurs in the late summer/fall season. Physical, chemical and biological parameters and water levels are measured in each sampling period and results are compiled in a database administered by the MECP. Any exceedances in the

Ontario Drinking Water Standard (ODWS) for health related parameters are reported to the Conservation Authorities and designated authorities. As part of this program, five new monitoring wells have been installed in the planning area.

In 2012, the City of Greater Sudbury initiated a groundwater monitoring program for the Valley drinking water system. Twelve wells that had been drilled for various purposes were re-commissioned and two new wells were drilled in 2013. Samples were collected in the 2012 field season and the program is on-going for 2013. The NDCA designed the sampling program with input from various local and provincial groundwater experts and the City of Greater Sudbury. The NDCA is currently managing and delivering this sampling program for the City.

14.2 Indicator Parameters

The planning area intakes and wells are subject to a variety of activities that may have an impact on water quality. Preliminary findings indicate that road salting, urban runoff and mining are the major contributors to changes in local water quality. Three categories of potential contaminants were identified as indicator parameters for the area. These include: 1) sodium and chloride; 2) nutrients and microbial abundance; and 3) metals related to the mining industry and natural deposits.

Sodium and chloride concentrations have been selected to evaluate the impact of road salting to surface water and groundwater quality. Sodium is a common component of road salt and therefore is useful to indicate impacts from road salting. Although the ODWS for sodium is 200 mg/L, the regulations also require that the local Medical Officer of Health be notified when sodium in drinking water exceeds 20 mg/L due to concerns for people on sodium-restricted diets. Chloride is also often used as an indicator parameter for road salt impact as well as municipal landfill leachate impact, as it is a common constituent of municipal landfill leachate and road de-icing agents. In the Canadian Shield region, natural chloride levels are relatively low and therefore elevated chloride levels signal impacts from human activity. High chloride levels in freshwater can also severely impact natural lake cycles and ecosystem dynamics.

Phosphate, nitrate and nitrites are used as indicator parameters to evaluate nutrient loadings from sources such as lawn fertilizers, detergents, domestic sewage or treated wastewater contamination, and decay of plant or animal material. Nitrogen and phosphorus are essential nutrients required for the growth of plants, however in excess can be deleterious to ecosystem health. For example, excess phosphorus in freshwater lakes can cause algae blooms which can lead to poor water clarity and low dissolved oxygen levels.

Several metals have been selected as indicator parameters due to the prevalence of mining activity and natural mineral features in the Sudbury area. The presence of trace metals in the aquatic system is necessary for plant and organism growth, however in excess, some metals have an associated aesthetic or health related concern. Arsenic, nickel, cobalt, copper, and zinc have been selected as indicators for contamination and all have ODWS with the exception of nickel. Because there is no ODWS for nickel, municipal water supplies are not routinely analyzed for nickel. The World Health Organization (WHO) Guidelines for Drinking-water Quality is 0.07 mg/L. The Provincial Drinking Water Quality Objectives (PWQO) for nickel is 0.025mg/L.

The analytical methods used to determine water quality have improved significantly over the past several decades, consequently reducing method detection limits. As such, during the evaluation of water quality trends over time, in particular for the PWQMN stations, this information must be considered. It is possible that some of the apparent decreases in water quality over time may be attributed to improvements in analytical method detection limits.

14.3 Surface Water Quality

Nitrate and nitrite concentrations at both stations were generally low, and below their respective ODWS. Total phosphorus concentrations were often measured at concentrations in excess of the PWQO for the Junction Creek station. Total phosphorus concentrations ranged between 0.002 and 0.098 mg/L at both surface water monitoring stations. Data for the Junction Creek station from 2003 to 2012 ranged from 0.007 to 0.243 mg/L. Sodium and chloride concentrations at the Junction Creek monitoring station ranged from 70 to 119 mg/L and 9.1 to 165 mg/L respectively.

Metals

Metal concentrations have generally been decreasing at most surface water monitoring stations since the 1970s, following the reduction in smelter emissions. Many of the metal parameter concentrations, including nickel, copper and zinc exceeded their respective PWQOs at several of the historical sampling locations. Many of these parameter concentrations were decreasing, and were often measured at concentrations below or approaching their respective PWQO when sampling was discontinued in the 1990's.

Copper concentrations at four of the surface water stations (Ramsey Lake, 2 stations along the Wanapitei River and Junction Creek) generally exceeded their respective PWQO of 0.005 mg/L. Copper concentrations in the Wanapitei River are measured above the PWQO. The highest copper concentrations were measured along Junction Creek, at Kelly Lake. Junction Creek receives runoff from several mine sites as well as urban runoff.

Nickel from the two active PWQMN stations has generally been measured at concentrations above the PWQO, but below the WHO drinking water standard. Concentrations at the Wanapitei station have been in the order of 0.006 mg/L to 0.06 mg/L from 2003 to 2012.

Concentrations of iron exceeding the PWQO occur frequently at many PWQMN sites. Very high concentrations of iron is observed in Emery Creek between 2007 and 2012, concentrations ranging from 331 mg/L to 4270 mg/L were reported. Iron is extremely prevalent in rock forming minerals and elevated iron concentrations are typically associated with elevated suspended solids.

Even though some of the water quality parameters at many sites have exceeded the guidelines, with the limited data available it is very difficult to access the issues and identify their source of contamination. At present there are ten active PWQMN stations within the Vermilion and the Wanapitei River watersheds. In 2007 seven new stations were introduced two old stations on Junction Creek and Wanapitei River were reinstated. A new station on Whitson River was established in 2012. Summary statistics for the nine PWQMN stations are given in Table 2.30.

The Freshwater Ecology Unit has prepared a summary report, entitled the Recovery of Acid and Metal Damaged Lakes near Sudbury, Ontario: Trends and Status (Keller *et al*, 2004). This summary report was prepared for the Sudbury Area Risk Assessment (SARA) Group, as a supporting report for the Ecological Risk Assessment, Sudbury Soils Study that was undertaken in the Sudbury area. This report examines recent trends in the chemistry of Sudbury lakes, providing considerable evidence of continuing chemical and biological recovery as a result of smelter emission reductions. The following is based in large part on this summary report.

Over 7,000 lakes within a 17,000 km^2 area surrounding the Sudbury area have been acidified to pH 6.0 or lower and have elevated concentrations of potentially toxic trace metals as a result of over one hundred years of metal mining and smelting in the Sudbury area. Some lakes within 20 to 30 km of the smelters have been reported as among the most atmospherically-contaminated lakes in the world. However, since emissions of SO_2 and metals were dramatically reduced in the 1970's, and further reduced in the 1990's due to the implementation of the Countdown Acid Rain Program, large improvements in lake water quality have been observed in the Sudbury area.

Dominant trends in the data from annual monitoring of 44 lakes within about 100 km of Sudbury conducted from 1990 to 2002 included increased pH (66% of the lakes), and decreased concentrations of sulphate, calcium and magnesium (98, 95, and 89% of the lakes, respectively). Reductions in metal concentrations were also observed during the 1990's. Copper and nickel concentrations exceeding Ontario's Provincial Water Quality Objectives (PWQOs) are restricted to lakes within about 20 km of Sudbury. Recent lake sediment data showed continuing relationships between metal concentrations in surface sediments and distance from the smelters. Surface sediments were contaminated with copper and nickel in lakes up to 50 km from Sudbury, with concentrations in lakes closest to the smelters far exceeding Ontario sediment quality guidelines of 110 µg/g for copper and 75 µg/g for nickel. Lead concentrations in lake sediments often approached, and in one case exceeded, provincial guidelines. Cobalt and arsenic concentrations exceeded provincial guidelines in several lakes within 20 km of Sudbury.

There have been some remarkable pH recoveries in many of Sudbury's historically acidified lakes, particularly in some lakes closest to the smelters. Although the reasons for these declines in acidity are not clear, it has been suggested that the natural buffering capacity of many Sudbury lakes was relatively high, and was simply overcome by the magnitude of the historical acid load rather than totally exhausted. If this were the case, a rapid rebound might be expected under reduced acid loads. Another possible contributor to the dramatic pH recovery is the stimulation of internal alkalinity-generating processes by abundant nutrient inputs from changing watershed conditions. For example, land liming and tree planting programs have had noticeable effects on the water quality of some lakes.

Overall, there is considerable evidence of chemical recovery in Sudbury's aquatic ecosystems. However, in order to fully understand the direct effects of the most recent emission reductions and develop a more complete understanding of the recovery process, continued monitoring will be essential.

Nutrients

The Lake Water Quality Group with the City of Greater Sudbury has been active in measuring phosphorus concentrations in several area lakes for a number of years. A Lake Water Quality report is released annually, which details the results from the sampling season in select lakes (approximately 45 lakes per year. Annual reports for 2001 through to 2012 show that Bethel, Minnow, Mud and Simon Lakes had phosphorous concentrations in excess of the PWQO of 20 µg/L each year they were sampled. Little Beaver Lake exceeded 20 µg/L seven out of the eight years it was sampled; McCharles seven out of 11 years sampled and Robinson Lake eight out of 11 years sampled.

Phosphorous concentrations in Ramsey Lake were measured at 15.2 µg/L in 2005. Since 1978, a total of 14 water samples have been analyzed for phosphorous in Ramsey Lake. Concentrations have ranged from 7.5 µg/L in 1982 and 1985 to 16.8 µg/L in 2002. Phosphorous concentrations appear to be increasing slightly in Ramsey Lake.

Phosphorous concentrations in Lake Wanapitei have been sampled on 4 occasions from 1981 to 2002. Concentrations have ranged from 3.0 µg/L (1981) to 5.8 µg/L (2002). Although only limited data is available for Lake Wanapitei, total phosphorous concentrations appear to be increasing in Lake Wanapitei, but are below the PWQO of 20 µg/L.

14.4 Groundwater Quality

The PGMN wells were brought online in 2003, however the water quality sampling did not begin until 2006. Water quality samples from these wells are sampled once a year in late summer or early fall. Data trends could not be analyzed due to the lack of long term data. However, the results to date indicate elevated sodium levels in two of the PGMN wells. One well is located in the vicinity of Ramsey Lake, while the other is in the south-west end of the City near Municipal Rd 55. Elevated levels of iron and manganese are also present in these wells, though do not pose a health risk.

Though statistical analysis cannot be performed on this data, some general observations can be made. In several of the wells sampled, elevated sodium levels were observed and ranged from 3-105 mg/L. As well, select wells indicated elevated iron and manganese levels which would not be unusual due to the geology of the region.

Table 2.27- Summary of Provincial Water Quality Monitoring Network Sampling, page 1 of 2

Para-meter	Statistic	Onaping River	Whitson River	Levey Creek	Vermilion River	Junction Creek	Lily Creek	Wanapitei River	Emery Creek	East Wanapitei	PWQO	ODWS
Chloride (mg/L)	Number	40	40	40	40	60	39	59	35	39	250	250
	Minimum	0.5	0.5	14.7	5	9.1	77.3	1.6	0.6	0.2		
	Maximum	39.6	60.6	379.	122	165	233	17.7	3	1.7		
	25th Percentile	0.9	35.2	17.4	8.5	100	85.6	2	1.1	0.4		
	Median	1.2	41.4	18.2	9.5	118.5	87.9	3	1.6	0.5		
	75th Percentile	1.5	52.7	19.3	11.1	130	92	4.6	2.6	0.8		
	Std. Deviation	6.1	11.6	3.5	17.9	25.8	28.4	2.8	0.8	0.3		
TKN (mg/L)	Number	40	40	40	40	60	39	59	35	39	N/A	N/A
	Minimum	0.17	0.22	0.18	0.24	0.18	0.24	0.21	0.34	0.21		
	Maximum	1.38	2.95	0.73	1.38	5.32	0.97	0.43	1.01	0.56		
	25th Percentile	0.23	0.46	0.34	0.29	0.84	0.29	0.24	0.51	0.3		
	Median	0.27	0.54	0.37	0.32	1.59	0.30	0.26	0.67	0.33		
	75th Percentile	0.29	0.6	0.40	0.34	2.82	0.37	0.30	0.88	0.41		
	Std. Deviation	0.19	0.4	0.10	0.18	1.22	0.16	0.05	0.21	0.08		
Total Phosphorus (mg/L)	Number	40	40	40	40	61	40	59	35	39	0.03	N/A
	Minimum	0.003	0.002	0.005	0.005	0.007	0.002	0.002	0.006	0.002		
	Maximum	0.29	0.8	0.033	0.069	0.243	0.098	0.031	0.056	0.013		
	25th Percentile	0.005	0.016	0.011	0.008	0.03	0.010	0.007	0.016	0.006		
	Median	0.006	0.019	0.014	0.010	0.042	0.012	0.008	0.025	0.008		
	75th Percentile	0.011	0.025	0.018	0.012	0.059	0.023	0.01	0.036	0.011		
	Std. Deviation	0.045	0.124	0.007	0.01	0.038	0.019	0.005	0.012	0.003		

Table 2.27- Summary of Provincial Water Quality Monitoring Network Sampling, page 2 of 2

Para-meter	Statistic	Onaping River	Whitson River	Levey Creek	Vermilion River	Junction Creek	Lily Creek	Wanapitei	Emery Creek	East Wanapitei	PWQO	ODWS
Iron (mg/L)	Number	39	40	40	40	60	40	57	35	38	300	0.3
	Minimum	140	76.2	31.7	34.3	54.7	13.6	96	331	82.1		
	Maximum	788	1010	327	399	3160	1420	455	4270	526		
	25th Percentile	245	246	58	95	107	32	127	1010	204		
	Median	348	181	123	165	130	138	199	433	250		
	75th Percentile	424	687	153	245	206	249	187	2380	347		
	Std. Deviation	138	258	69	86	407	287	58	1023	109		
Copper (ug/L)	Number	40	40	40	40	60	40	57	35	39	5	1,000
	Minimum	-4.76	-0.597	3.11	-3.53	3.59	1.51	0.43	-1.61	-2.7		
	Maximum	9.55	13.3	15.4	10.9	80.7	32.3	13.8	28	3.65		
	25th Percentile	0.81	3.29	6.37	2.91	13.8	9.4	3.66	10.36	0.56		
	Median	1.21	4.40	7.57	3.28	19.40	11	4.06	14	1.05		
	75th Percentile	1.57	6.69	9.24	3.67	27.85	11.98	5.33	16.85	1.30		
	Std. Deviation	1.85	2.77	2.52	1.87	13.72	4.92	2.52	6.54	0.96		
Nickel (ug/L)	Number	39	39	39	39	59	39	56	34	38	25	N/A
	Minimum	-3.6	0.86	35.9	3.83	11.2	19.2	6.38	22	-3.53		
	Maximum	21.3	34.1	197	412	477	60.2	59.7	140	2.15		
	25th Percentile	1.1	8.05	49.15	8.29	246	38.70	12.65	50.08	0.26		
	Median	3.94	35.0	36.55	231.5	229	26.10	25.20	1.92	0.92		
	75th Percentile	2.33	20.95	99.40	12.8	338	48.85	24.95	81.08	1.32		
	Std. Deviation	3.48	8.0	40.89	64.38	78.73	8.39	12.07	26.03	1.29		

14.5 Potential Threat Considerations

A number of potential threats to water quality exist that are not listed in the prescribed threats tables developed by MECP and are of concern in the Greater Sudbury Source Protection Area. The Greater Sudbury Source Protection Committee acknowledges the concern that the public may have regarding the following activities.

Motorized Boats, Vehicles and Planes on Ramsey Lake

Ramsey Lake is used for a number of motorized recreational pursuits including boating, fishing and ice-fishing, and supports several private float plane users. For many years, there has been debate over the potential banning of these vehicles on the lake. Today, concern regarding potential spills and waste generation from these activities and how they may impact drinking water quality still exists.

Pet Waste

The shores of Ramsey Lake offer a number of walking trails and beaches where residents can enjoy access to the lake and bring their pets for exercise. People also walk, skate and snowshoe on the lake in the winter with their dogs. Although not listed as a prescribed drinking water threat, pet waste was brought to the attention of the source protection committee by local residents during the completion of this report. Concerns were raised regarding the addition of nutrients and bacteria to the lake as a possible drinking water threat. At this time, there is no information to determine the magnitude of this threat and, therefore, it cannot be properly assessed.

Bird Waste

Ramsey Lake's shores and islands are residence to a variety of geese and gull populations. Droppings from large numbers of birds, potentially causing nutrient enrichment and addition of bacteria to the lake, has been noted as a concern in the community, however it is not included in the prescribed list of threats. Currently, there is no information to suggest that the bird populations in the Ramsey Lake watershed are causing any water quality issues that would threaten the drinking water source.

Mining Related Activities

The Greater Sudbury Source Protection Area has been shaped and transformed by the mining industry over the last century. Mining related activities affect all the drinking water systems in the Greater Sudbury Source Protection Area; however, primarily influence the Ramsey Lake watershed, the Wanapitei River watershed and the Vermilion River watershed. The Ramsey Lake watershed does not contain any direct mining activities within its boundaries; however, the area has historically been impacted by the deposition of air pollutants. The Wanapitei River watershed contains numerous mining related activities throughout the watershed. The Vermilion River watershed has a number of mining related activities within its boundaries, however they are not deemed to be a significant threat under the Technical Rules (2009). Although air emissions and related pollutant releases from the mining industry have improved in recent years, long term effects remain a concern within the community.

Urban/Residential Drainage

Many drinking water systems and associated vulnerable areas are located in urban or residential neighbourhoods. While not identified as a prescribed threat, there are cumulative and various non-point sources of contaminants that could impact the quality of the drinking water at the wells and intakes.

Abandoned Wells, Improperly Constructed Wells and Boreholes

An abandoned well, an improperly constructed well or boreholes can increase the vulnerability of the groundwater resource to contamination. As the Valley drinking water system already has a high vulnerability ranking, a higher ranking cannot be given to reflect the presence of these wells and boreholes. It is known that a number of abandoned, improperly constructed wells and boreholes are present in the Valley, which increases the vulnerability of the groundwater resource to contamination. The presence of abandoned and improperly constructed wells and boreholes pose a concern in the Greater Sudbury Source Protection Area.

Removal of Top Soil

The Valley area consists of relatively deep deposits of soil compared to other areas within the Greater Sudbury Source Protection Area. This deposit of soil provides one of the few potential opportunities for agricultural activity in the region. Top soil removal has become a relatively common practice in the Valley to provide surrounding urban landscapes with adequate soil for lawns and gardens. The removal of soil is not considered a threat in the prescribed list of threats; however, it does increase the vulnerability of groundwater resources to contamination.

Transportation Corridors

A number of transportation corridors, including rail lines and major road arteries, exist within close proximity to many drinking water sources. These corridors do not fall within the MECP prescribed list of drinking water threats. However, the Greater Sudbury Source Protection Committee had concerns with these transportation corridors and requested, under technical rule 114, to have the transportation of specific hazardous substances (sulfuric acid, diesel fuel, and hauled sewage) added as a local threat. More details about the addition of this local threat to the Greater Sudbury Source Protection Area Assessment Report can be found in section 2.3 and within each relevant drinking water section in the tables of drinking water threats.

Contaminants of Emerging Concern

Public interest and concern is increasing regarding the environmental and health-related effects of substances which, historically, have not been monitored or assessed. These contaminants of emerging concern include pharmaceuticals, personal care products, endocrine disruptors, antibiotics and antibacterial agents. The public has expressed concern regarding the implications of these trace contaminants in finished drinking water and the issue has been highlighted in many publications. Justice O’Connor’s recommendations in Part Two of the Walkerton Report (2002) include a statement that “water providers must keep up with scientific research on endocrine disrupting substances and disseminate the information.”

Pharmaceuticals and personal care products are found where people or animals are treated with medications and where people use personal care products. These contaminants are often found in rivers, streams, lakes and groundwater influenced by wastewater treatment plants.

The Ministry of the Environment, Conservation and Parks completed a survey of emerging contaminants in source water and drinking water directly from treatment systems across Ontario. The samples were collected in 2005 and 2006 from six lake-based water systems and were analyzed for 25 antibiotics, nine hormones, 11 pharmaceuticals and one emerging contaminant. The survey results showed that 15 antibiotics, seven pharmaceuticals and the one emerging contaminant (Bisphenol A) were detected in at least one sample of source water at trace levels (Ministry of the Environment, Conservation and Parks , 2010).

The concentrations measured were below therapeutic level and the estimated, maximum acceptable daily intake for drinking water. The report suggests that an individual would have to drink thousands of glasses of water in a day to reach the maximum daily level for any of the compounds detected. The Ministry of the Environment, Conservation and Parks also showed that five of the compounds were removed with the existing treatment processes.

Chapter 15 - Aquatic Ecology

15.1 Aquatic Habitat

Aquatic ecosystems in the Sudbury region are especially significant given the vast number of lakes, rivers and wetlands that are present in the area. The ecology of lakes, rivers and wetlands determine the biological and chemical dynamics within the watershed and will, in turn, impact the water quality and storage capacity for drinking water sources.

A significant portion of lakes in the planning area have been impacted by mining and smelting activities. Many lakes have been acidified to pH < 6.0, which is the apparent threshold for significant biological damage. Smelter emissions were greatly reduced in the 1970s and dramatic water quality improvements have occurred, but some lakes are still acidic and continue to retain elevated levels of metals ultimately impacting the ecology of aquatic resources (Keller *et al*, 2004).

There has not been a complete inventory of all water bodies in the source protection planning area yet, but within the boundaries of the NDCA jurisdictional area, there are 1,206 identified cold water lakes, 745 warm water lakes, and 71 lakes designated as cool water bodies (GIS database, NDCA). Map 2.22 illustrates the location of cold and warm water habitat with critical spawning areas for brook trout, lake trout and walleye.

15.2 Fish Species

The planning area supports a diverse range of fish communities. At least 38 species have been characterized within the area, although the focus of these studies has been primarily on lake environments. The most recent broad survey of fish was conducted during the summers of 2000 to 2006 when the Co-operative Freshwater Ecology Unit of Laurentian University assessed 35 lakes within the City of Greater Sudbury (CGS, 2006a). A listing of the species commonly encountered during this study that are expected to be found within the wider area is provided in Table 2.29.

Table 2.28 - List of fish species

Blacknose dace (Rhinichthys atralus)	Lake whitefish (Coregonus culpeaformis)
Blacknose shiner (Notropis heterolepis)	Largemouth bass (Micropterus salmoides)
Bluegill (Lepomis macrochirus)	Log perch (Percina caprodes)
Brook stickleback (*Inculea inconstans*)	Mottled sculpin (*Cottus bairdi*)
Bluntnose minnow (*Pimephales notatus*)	Ninespine stickleback (*Pungitius pungitius*)
Brown bullhead (Ameiurus nebulosus)	Northern pike (*Esox lucius*)
Burbot (Lota lota)	Pearl dace (Margariscus margarita)
Central mudminnow (*Umbra limi*)	Pumpkinseed (Lepomis gibbosus)
Lake herring (Coregonus artedi)	Rainbow smelt (*Osmerus mordax*)
Common shiner (*Luxilus cornutus*)	Rock bass (Ambloplites rupestris)
Creek chub (Semotilus atromaculatus)	Slimy sculpin (*Cottus cognatus*)
Emerald shiner (Notropis athernoides)	Smallmouth bass (Micropterus dolomieui)
Fathead minnow (Pimephales promelas)	Splake (brook trout/lake trout hybrid cross)
Finescale dace (Chrosomus neogaeus)	Spoonhead sculpin (*Cottus ricei*)
Golden shiner (Notemigonus ctysoleucas)	Spottail shiner (Notropis hudsonicus)
Iowa darter (Etheostoma exile)	Trout-perch (Percopsis omiscomaycus)
Johnny darter (Etheostoma nigrum)	Walleye (Sander vitreus)
Lake chub (Couesius plumbeus)	White sucker (Catostomus commersoni)
Lake trout (Salvelinus namycush)	Yellow perch (Perca flavescens)

15.3 Macroinvertebrates

Aquatic macroinvertebrates are used as bio-indicators in the scientific community to aid in the assessment of water quality. As a result of their narrow tolerance range for specific environmental characteristics, the prevalence and type of macroinvertebrate indicator species is indicative of certain water quality conditions.

The Ontario Benthos Biomonitoring Network (OBBN), of which the NDCA is not currently a member, has been established to build partnerships and provide information on aquatic ecosystem conditions and evaluate management performance for local decision makers. The OBBN uses a reference-condition approach (RCA) to bioassessment in which samples from reference or minimally impacted sites are used to define the normal range of variation for a variety of indices that summarize biological community composition. Sites where biological health is in question or where there is particular need to address environmental conditions (*i.e.* water quality) can be evaluated by determining whether test site indices fall within the normal range established for minimally impacted sites.

Recent RCA work by the Co-operative Freshwater Ecology Unit at Laurentian University in Sudbury has been initiated within two of the three watersheds (Vermilion River and Wanapitei River). Available data is restricted to a limited number of sites, primarily on Broder Lake (Wanapitei River watershed) and the upper Vermilion River, but is insufficient to draw conclusions from in terms of overall water quality within the planning area.

In general, there are encouraging signs of biological recovery in Sudbury lakes affected by the smelter emissions. A number of acid and/or metal sensitive invertebrate species have recolonized some Sudbury lakes, which appears to be correlated to decreasing metal concentrations. However, despite these signs of recovery, low species richness appears to still be a general characteristic of many Sudbury area lakes, which suggests greater sensitivity of certain species to metals. Even at near-neutral pH, some lakes are lacking several ubiquitous organisms, such as molluscs, amphipods, mayflies and crayfish, that would be expected to thrive in such lakes. Their absence or scarcity may greatly affect the nutrient cycling in Sudbury lakes, which in turn may affect many other indigenous species and lake water quality. The two general factors that appear to be causing the continuing absence of key aquatic organisms from some Sudbury lakes are: inability of these species to reach uninhabited lakes to permit colonization and unsuccessful colonization due to continuing inhospitable conditions (Pearson *et al*, 2002).