DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Thames-Sydenham and Region Watershed Characterization Summary Report

St. Clair Region Source Protection Area

December 2008

Prepared by --

ST. CLAIR CONSERVATION

-- in cooperation with --

LOWER THAMES VALLEY CONSERVATION AUTHORITY

UPPER THAMES RIVER CONSERVATION AUTHORITY

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Note: *The numbering system used in this summary for the various sections, tables, figures and maps is identical to that used in the full Watershed Characterization Report, to enable anyone reading the summary report to easily locate the relevant information in the full report. The exceptions to this are tables 3.1-1 and 4.1-7, which were created for the summary only and are not included in the full report.*

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1.0 Introduction

The St. Clair Region Source Protection Area includes the Sydenham River drainage basin and several smaller watersheds that drain to Lake Huron, the St. Clair River or Lake St. Clair. It is part of the Thames-Sydenham & Region Source Protection Region.

The Watershed Characterization Report is one of the first steps in the development of Source Protection Plans, as recommended by Justice O'Conner following the Walkerton Inquiry. The inquiry investigated the May 2000 bacterial contamination of the Town of Walkerton's water supply, which resulted in seven deaths. Source Protection Plans will be required across Ontario by regulations made under the Ontario Clean Water Act (2006).

The Watershed Characterization Report summarizes information on the physical, social and economic characteristics of the St. Clair Region Source Protection Area. It also reviews existing information on water quality and summarizes known issues and concerns pertaining to drinking water sources. A series of maps has been prepared to help illustrate the information presented in the report.

A Water Budget, which deals with water use and demand, is also being prepared. This report will be used to develop the Watershed Assessment Report that will form the foundation for the Source Protection Plan, as required by Rules and Regulations made under the Ontario Clean Water Act (2006).

2.0 Watershed Description

2.1 Source Protection Region

In 2005, the St. Clair Region Conservation Authority (SCRCA), Lower Thames Valley Conservation Authority (LTVCA), and Upper Thames River Conservation Authority (UTRCA) formed a partnership to pool resources when working on watershed based Source Protection Planning.

In 2007, Ontario Regulation 284/07 under the Clean Water Act established the Thames-Sydenham and Region Source Protection Region (SPR). The Region has three Source Protection Areas (SPAs) corresponding to the watersheds of the three Conservation Authorities. **Map 1: Thames-Sydenham & Region Source Protection Region** shows the boundaries of the Source Protection Region and the three Source Protection Areas. The boundaries of the LTVCA and SCRCA include the shorelines of Lake Erie, Lake St. Clair, the St. Clair River and Lake Huron. The SPR extends out from the shorelines to the international boundary.

The St. Clair Region Source Protection Area covers over 4,100 square kilometres. It includes most of the County of Lambton, part of the Municipality of Chatham-Kent, and part of the County of Middlesex. **Map 2: Drainage Areas** provides an overview of the boundaries of the major subwatersheds, municipalities and First Nations in the St. Clair Region SPA.

2.2 Physical Description

The bedrock topography of the area is shown in **Map 3: Bedrock Topography**. There is an area of higher bedrock on the eastern side of the St. Clair Region SPA in the Warwick area. In general, the lowest bedrock surface elevations correlate with the shorelines of Lake Huron, Lake St. Clair and the St. Clair River. There is also a bedrock valley in the Strathroy area that runs from Lake Huron south to Lake Erie.

The SPA is located on the eastern edge of the Michigan Basin, which is a large carbonate-dominated sedimentary basin centered in the State of Michigan. Over time, the sediments in the basin became bedrock layers that cover the ancient Canadian Shield rock. In the western portion of the SPA, the sedimentary bedrock units exhibit a regional dip (slope) of 0.2% to the southwest. As a result, several different types of bedrock including Port Lambton Group, Kettle Point Formation, Hamilton Group and Dundee Formation underlie the area, as illustrated in **Map 4: Bedrock Geology**.

The bedrock is covered with overburden material consisting mainly of deposits that were associated with geologically recent glacial activity. The depth of the local overburden is shown in **Map 5: Overburden Thickness**. The type and thickness of the overburden has a significant impact on the nature of the local area.

The overburden characteristics are illustrated in **Map 6: Surficial Geology** and **Map 7: Physiography**. Sand plains were created as early rivers emptied into glacial lakes. Clay and silt plains were formed in the deeper, quiet water basins of the glacial lakes, where fine grained materials were deposited. Sandy shoreline features were deposited as a result of different glacial lakes levels. Receding glaciers also created moraines, which are generally regional topographic highs.

Beginning with the different overburden materials, a combination of climate, drainage and vegetation resulted in various soil types developing over a period of time. Most of the soils in the area fall into the great soil group Grey-Brown Podzolic Soils or Grey-Brown Forest Soils, which were formed from decaying hardwood trees and leaves. **Map 8: Soils Information** shows the soil types across the SPA. Some recent (post glacial) organic overburden deposits of peat, muck and marl have been deposited in localized low-lying marshy or swampy wetland areas. Also, modern alluvial sediments, consisting of sand and gravel, occur along the flood plains of major watercourses and smaller tributaries.

2.3 Hydrology & Climate

The type of overburden and the physiographic features had a significant impact on the development of the surface water drainage. **Map 9: Topography** illustrates how the SPA is divided into the four main subwatersheds shown on **Map 2: Drainage Areas**.

Most (2,751 sq. km) of the SPA is drained by the branches of the Sydenham River. In the northern part of the region, the Wyoming Moraine creates a height of land. As a result, there are several shorter watercourses that drain approximately 645 sq. km of land to Lake Huron. In the west along the St. Clair River, there is a relatively narrow band of land (262 sq. km) that drains to the river. In the southwestern part of the area, approximately 484 sq. km of land are included in the Lake St. Clair drainage. These lands have little relief and are prone to flooding.

The Sydenham River is the largest watercourse in the St. Clair Region Conservation Authority's area of jurisdiction. The East Branch of the river has a total length of 165 kilometres with a fall of 106 metres. The North Branch is 137 kilometres long with a fall of 77 metres. The main Sydenham River is only approximately 5 kilometres long, running from Wallaceburg, where the North and East Branches meet, to its mouth at the Chenal Ecarte. **Figure 2.3.3.2-1: Sydenham River Length and Fall** provides a schematic view of the Sydenham River elevations.

The East and North branches of the Sydenham River are significantly different in nature. The length and fall of the branches, substrate and adjacent soils all contribute to these differences. The tributaries of the North Branch pass through till and clay plains. The East Branch and its tributaries pass through various sand and till plains before joining the North Branch at Wallaceburg.

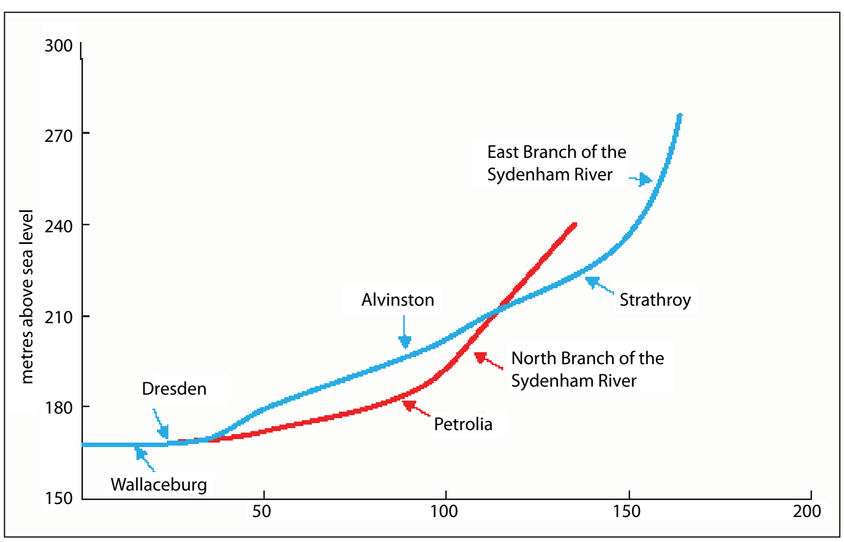

Figure 2.3.3.2-1: Sydenham River Length and Fall

The Wallaceburg area is one of the most flood prone parts of the St. Clair Region due to its location on low ground at the confluence of the East and North branches of the Sydenham River. To protect the community, the W. Darcy McKeough Floodway and flow control dam were built in the early 1980s to divert floodwaters away from Wallaceburg. The flows from the upstream watershed normally pass through the McKeough control dam. The dam gates are closed during flood events to divert water to the floodway. Located approximately 12 km north of Wallaceburg, the floodway is shown on **Map 2: Drainage Areas** as a straight channel cut from the North Sydenham west to the St. Clair River. The floodway and dam control flood water from over 33% of the Sydenham drainage basin. It is the largest flood diversion project in Ontario.

Hydrology and climatic conditions are monitored locally by a combination of Environment Canada monitoring stations shown in **Map 10: Environment Canada Climate Stations** and St. Clair Region Conservation Authority monitoring stations shown in **Map 11: Watershed Hydrologic Conditions Monitoring**. Variations in climate conditions have significant impacts on local watercourses and the recharge of groundwater aquifers. Water levels vary from season to season and from year to year because of the combined effects of precipitation, runoff and evaporation. The average annual temperatures for the three Environment Canada stations have been plotted and are shown in **Figure 2.3.1.2-7: St. Clair Region Average Temperature 1950 - 2005**.

Both the linear trend lines and the 10 year running averages show increasing temperatures for all of the stations. In general, the stations have similar highs and lows in the 10 year running averages. The most southerly station, Wallaceburg, has 10 year averages and linear trend lines that are higher than the other stations. The Sarnia station appears to show a more moderate linear trend line and running average, which may reflect its proximity to a large body of water. (Individual plots for each station are presented in the main report.)

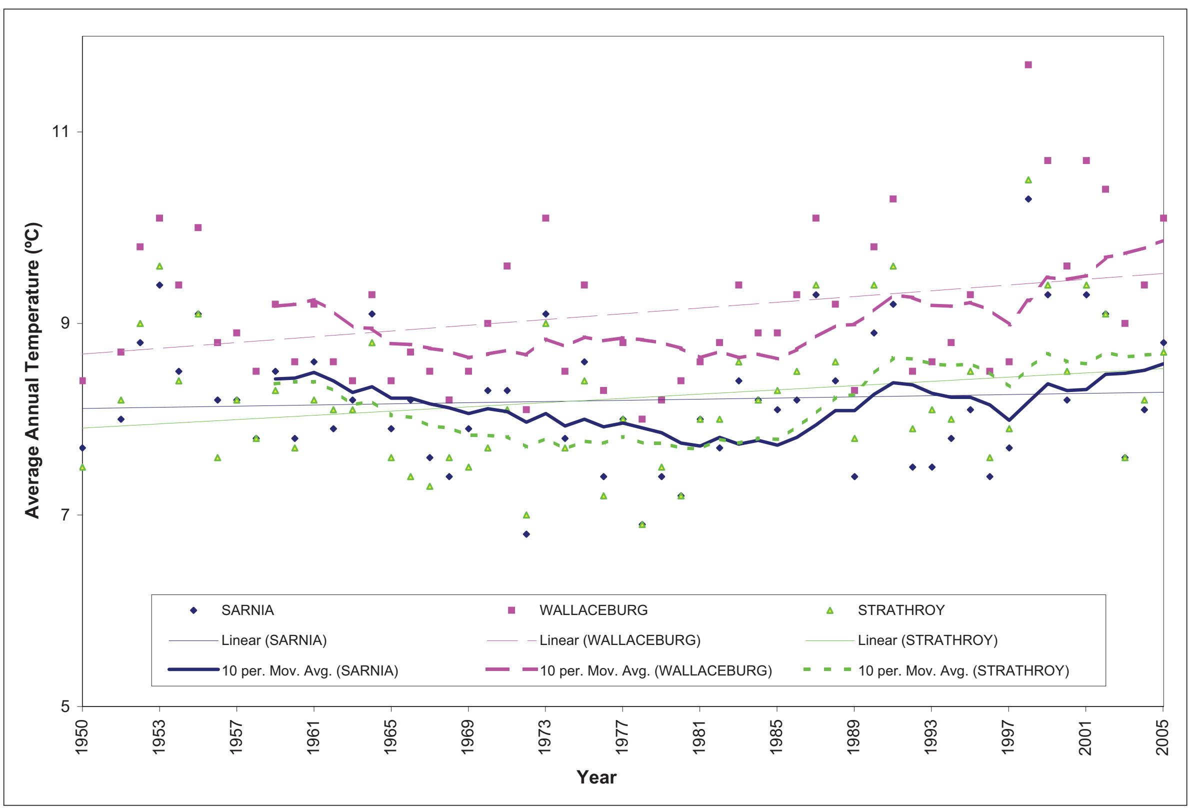

Figure 2.3.1.2-7: St. Clair Region Average Temperature 1950 - 2005

Annual precipitation can vary widely from year to year and from station to station. **Table 2.3.1.2-3: St. Clair Region Annual Precipitation 1950 - 2005** illustrates the variation over the years. Annual precipitation can vary by over two times from year to year. For example, the average annual precipitation at Sarnia between 1950 and 2005 was 819 mm. However, the minimum annual precipitation was as low as 443 mm in 1963, and the maximum precipitation was as high as 1,086 mm in 1984.

Table 2.3.1.2-3: St. Clair Region Annual Precipitation 1950-2005 in mm

Location	Average	Max (year)	Min (year)
Sarnia	819	1086 (1984)	443 (1963)
Wallaceburg	806	1170 (1996)	561 (1963)
Strathroy	914	1162 (1976)	532 (1963)

Climate normals are used to summarize or describe the average climatic conditions of a particular location. The World Meteorological Organization considers 30 years to be an adequate duration to eliminate year-to-year variations. The 30 year (1971-2000) Annual Precipitation Normals published by Environment Canada are shown in **Figure 2.3.1.2-1: Annual Precipitation Normals**, for the Environment Canada stations in the Thames-Sydenham & Region Source Protection Region.

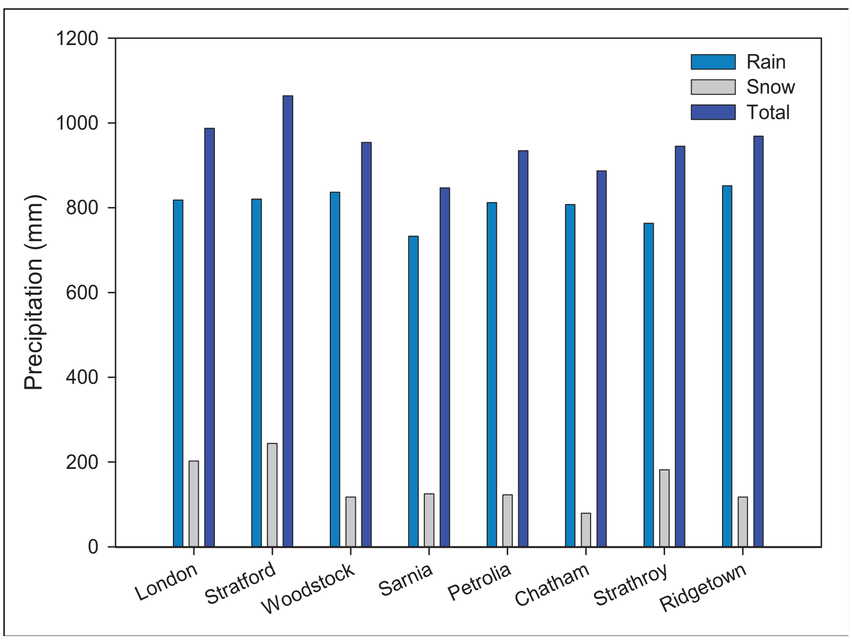

Figure 2.3.1.2-1: Annual Precipitation Normals

Environment Canada data from 1950 to 2005 has also been used to plot graphs of the total annual precipitation for the Sarnia, Wallaceburg and Strathroy climate stations. These plots are shown in **Figure 2.3.1.2-3: St. Clair Region Annual Precipitation 1950 - 2005**. The data for the individual years and stations illustrates the wide range of annual precipitation that can occur.

The 10 year running average helps to show longer term variations in the precipitation. In general, the 10 year running averages were lower during the1960s and increased into the late 1980s or early 1990s. More recently they have decreased. The linear trend lines are also shown for each station. (Individual plots for each station are presented in the main report.)

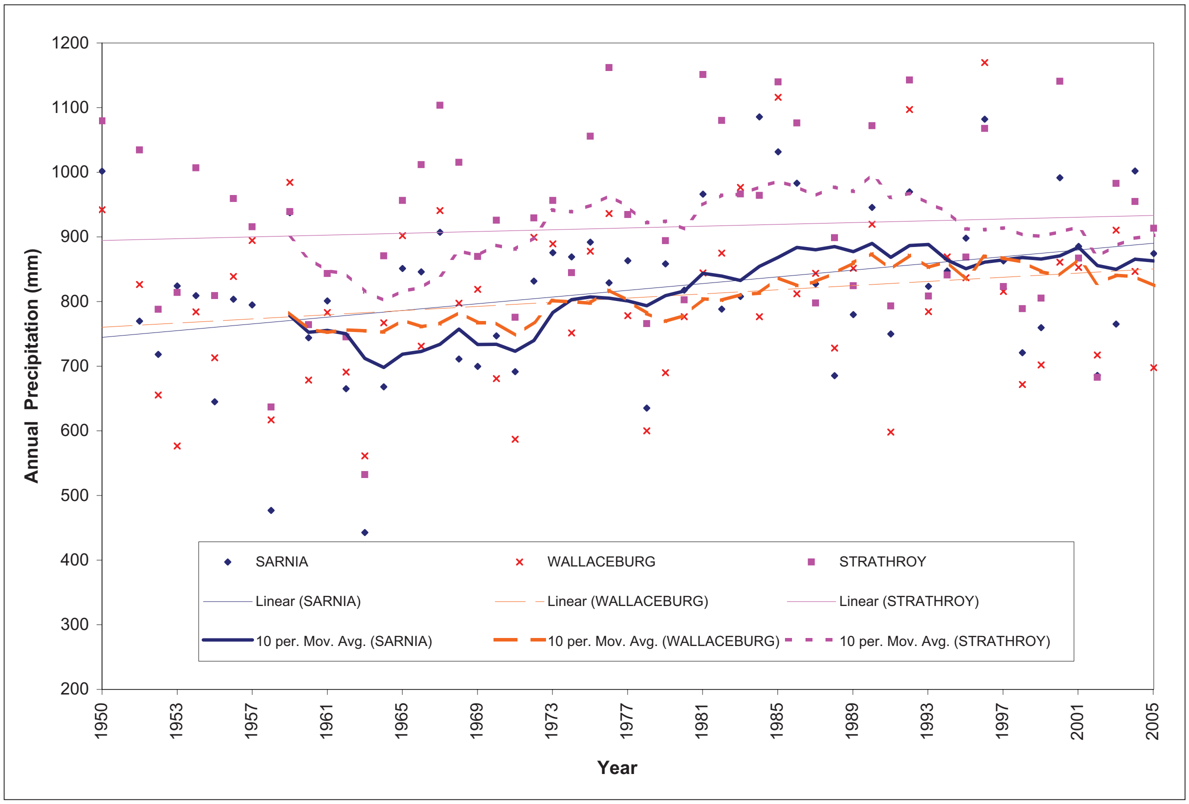

Figure 2.3.1.2-3: St. Clair Region Annual Precipitation 1950 -2005

Hydrogeology

Precipitation is the primary source of groundwater recharge. Groundwater recharge is determined by three factors: the amount of precipitation that is not lost to evapotranspiration and runoff; the vertical hydraulic conductivity of the surficial deposits (the ability for the water to move downwards); and the gradient of the water table (potentiometric surface) which determines how quickly or slowly the water can move away from the recharge area.

Within the region, there are a number of aquifers, which readily transmit water, and aquitards, which prohibit the movement of water. These aquifers and aquitards vary greatly in spatial extent and thickness.

Aquifers are divided into two distinct types: overburden and bedrock. In addition, aquifers are classified as either confined (bounded by two low permeability units) or unconfined (the upper surface is defined by the water table).

Overburden aquifers may be divided into shallow, intermediate and deep overburden aquifers. Overburden aquifers in the region include the coarse-grained sands and gravels of the various sand plains, kame moraines and coarse-grained interstadial sediments that lie between till sheets.

Bedrock aquifers can usually be subdivided into contact and deeper bedrock aquifers. The upper three to five metres of the bedrock surface is more weathered and fractured, forming a more transmissive contact aquifer than the underlying deeper competent bedrock units. **Map 12: Bedrock Water Table** presents a generalized groundwater level (potentiometric surface) map for the bedrock units in the area. In the St. Clair Region SPA, the bedrock water table is highest in the eastern parts of the watershed.

In rivers and subwatersheds, stream flow rates measured during base flow (low flow) periods can be used to identify areas of significant groundwater discharge. The base flow is assumed to be equal to the quantity of groundwater that discharges to the upstream reach of the river and its tributaries. **Map 13: Potential Groundwater Discharge Areas** shows zones of potential discharge within the watershed.

Groundwater Monitoring

Historically, the Ministry of the Environment monitored groundwater levels at about 450 observation wells throughout the province. The original network was in place from 1946 to 1979. The monitoring wells were used to monitor groundwater levels for detailed hydrogeologic studies, water supply forecasting, and resolution of interference complaints. This monitoring was substantially reduced in the 1980s and virtually eliminated in the Thames-Sydenham & Region Source Protection Region.

In 2001, a Provincial Groundwater Monitoring Network (PGMN) was re-established. The St. Clair Region Conservation Authority has nine wells in the network, as shown on **Map 14: Provincial Groundwater Monitoring Network**. Wells in the monitoring network vary in depth, elevation and geology between bedrock and overburden wells.

Surface Water Hydrology

There are over 6000 km of watercourses in the St. Clair Region Source Protection Area watershed. From 1999 to 2004, the St. Clair Region Conservation Authority carried out field work to analyze local watercourses. Most of the work was done at road crossings that provided easy access. Watercourses were classified as N (natural or not municipal drain), T (tiled or closed surface), U (unclassified) and open Municipal Drains (Type A, B, C, D, E or F). The open municipal drains are categorized as based on stream flow, thermal regime and fish species.

Approximately 4500 km of watercourses have been classified. One-quarter of the watercourses (1500 km) have not been classified since they begin between public roads and were not accessible without obtaining landowner permission.

The classified municipal drains are shown on **Map 18: Municipal Drain Classifications**. **Map 19: Watercourse Classifications** shows the natural watercourses, municipal drains and tiled/closed drains.

Intermittent municipal drains (Type F) are the largest category of classified watercourses with over 2000 km mapped. Warm water municipal drains, which provide habitat for common baitfish species (Type C), are the second most common category with 1100 km mapped. Natural watercourses (Type N) are the third most common category with 900 km mapped. Approximately 500 km of closed or tiled watercourses have been mapped to date in the SCRCA watershed.

2.4 Naturally Vegetated Areas

A review of the original surveyors' land cover records from the early 1800s for the Sydenham watershed reveals that approximately 30% of the watershed was wetland swamps and 67% was forest.

Dredging and straightening of watercourses for agricultural, residential and industrial development has had a significant impact over the past 150 years. Drainage works have reduced the wetland cover to less than 1% in the St. Clair Region. The diversity of wetlands has also been affected, as there are no bogs or extensive cedar coniferous swamps remaining. **Map 20: Percent Wetland Cover by Subwatershed** shows the values for 10 subwatersheds and illustrates the lack of wetlands across the region.

Environment Canada has provided guidelines indicating that greater than 10% of each major watershed should be in wetland habitat; greater than 6% of each subwatershed should be in wetland habitat; or the original percentage of wetlands in the watershed should be restored.

Currently, the largest evaluated wetland complex in the region is the East Sydenham-South Strathroy Creek swamp complex in the Upper East Sydenham, which results in 2.8% wetland cover for this subwatershed. The Lake St. Clair Marsh complex is also over 1200 hectares, and the Lake St. Clair Tributaries watershed area averages 2.8% wetland cover. The other subwatershed areas in the region have less than 0.8% wetland cover.

The area of land adjacent to the watercourse is often called the riparian zone or buffer zone. Natural or permanent vegetation adjacent to streams and rivers provides many benefits to the watercourse. Environment Canada's riparian habitat guidelines recommend 75% of stream length be naturally vegetated, ideally with 30 metre wide buffers of natural vegetation.

The Sydenham River is the only area in the St. Clair Region with an analysis of riparian zones. Analysis of 30 metre buffer composition indicated that the main tributaries had between 61% and 91% natural vegetation buffers. Low order tributaries had less (18% to 35%) coverage in natural vegetation. The least riparian cover occurs in the lower reaches of the Sydenham River. The highest cover is in the Middle East Sydenham and Black Creek watershed areas.

Environment Canada has also provided guidelines on forest habitats specifically indicating that at least 30% of the watershed should be in forest cover in order to support viable fish and wildlife populations.

Agricultural, residential and industrial development have reduced the extensive deciduous woodlands that once existed in southwestern Ontario. At present, approximately 12% of the St. Clair Region is wooded. **Map 21: Percent Woodland Cover by Subwatershed** shows the woodland cover. The areas with the highest woodland cover are the Chippewas of Kettle and Stony Point, Aamjiwnaang, and Bkejwanong Territory (Walpole Island) First Nation lands. The largest contiguous forest outside of the First Nations lands is Bickford Oak Woods in St. Clair Township.

Most of the remaining woodland is in relatively small parcels. The linear east-west pattern of most woodlots in Lambton County is due to the practice of clearing the acreage closest to the concession road for farming. The remaining woodlots are at the back of the farms and run parallel to the roads. In south Lambton, the concessions of Dawn-Euphemia Township were surveyed to run north-south, rather than east-west, and the difference in the woodlot distribution is obvious. Similarly, the Middlesex County portion of the area has a pattern of southeast-northwest woodlots running parallel to the roads.

The area is classified as Great Lakes Deciduous Forest, which includes sugar maple, American beech, red oak, basswood and white ash. There are also many less common, southerly "Carolinian" species including black cherry, black walnut, sycamore, white oak, swamp white oak, chinquapin oak, and shagbark hickory. Several rarities such as tulip tree, blue ash, Kentucky coffee tree, hoptree, shumard oak, big shellbark hickory and pawpaw are also found in the region.

In addition to trees being removed to clear the land, the native woods have been affected by diseases and invasive species introduced from across the world. The American chestnut was decimated in eastern North America by chestnut blight between 1904 and 1939. Dutch elm disease had a similar impact on American elm between 1959 and 1969. More recently, the emerald ash borer is a serious invasive species that has been found in Chatham-Kent and Lambton County. Its significance for woodlands in the region is not yet known but ash trees form a substantial part of the local tree cover.

2.5 Aquatic Ecology

A great diversity of aquatic species currently inhabits the waters of this region. Forty-five aquatic species of mussels, fish and reptiles have been designated by the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered, Threatened or of Special Concern, or are candidate species for assessment.

During the last 30 years, 82 species of fish have been recorded in the St. Clair Region. This represents almost half of the 165 fish species known from Ontario. Information on the fish communities has been collected in the field by using seine netting, minnow trapping, backpack electro-fishing and boat electro-fishing. The recent (1995-2004) fish sampling sites are shown on **Map 22: Electro-fishing Sites**.

The Sydenham River supports the richest freshwater mussel community of any river in Canada. Freshwater mussels are valuable indicators of environmental degradation because they are affected by many kinds of habitat alteration and pollution. Historically, 33 native mussel species were recorded for the Sydenham. Extensive sampling from 1997 to 1999 found 30 live species, including the Threehorn Wartyback which was a new species of record for the river. However, the work in the late 1990s indicated that conditions were deteriorating. Four species (wavy-rayed lampmussel, slippershell, paper pondshell and lilliput) were represented only by empty shells.

Habitat conditions (quality and quantity) determine the type of aquatic community that will occupy a given aquatic ecosystem. Benthic macroinvertebrates are an important part of the aquatic ecology and provide an excellent tool for water quality assessment since different species have different tolerances to pollution.

Benthic, or bottom-dwelling, macroinvertebrates live on or in the substrate of water bodies and include organisms such as mayflies, stoneflies, aquatic worms and snails. If there are many pollution-intolerant species, such as caddisflies and mayflies, in a certain reach of a stream, it indicates good quality water with no major disturbances in recent years. If pollution-tolerant species such as aquatic worms and midge larvae dominate the substrate, the water quality is poor. This example would indicate that chronic contamination, a spill or major habitat disturbance has removed the pollution-intolerant species.

Some benthic sampling was done as early as 1994. Beginning in 1999 when 20 sites were sampled, the SCRCA established an annual program to monitor the benthic macroinvertebrate community. Since then, between 34 and 68 sites are sampled per year at locations distributed across the region. Samples are collected in spring or early summer and preserved for analysis over the winter. This program has been carried out in cooperation with the biology department of the University of Western Ontario. **Map 23: Benthic Sampling Sites** shows the sampling locations.

The results of the benthic sampling are presented figuratively on **Map 24: Benthic Sampling Analysis Results by Subwatershed**. Based on benthic monitoring between 1999 and 2004, all of the subwatersheds in the St. Clair Region SPW have "poor" to "fairly poor" aquatic health.

Invasive Species

Invasive species have had a significant negative impact on local ecosystems by out-competing native species, carrying pathogens, disrupting communities, causing extinction, altering the food chain, disturbing habitat, affecting environmental/ecosystem health, and impacting water quality.

Introduced fish species found in the SPA include the common carp, goldfish, alewife, round goby and sea lamprey. As the Sydenham River is nationally significant for its native mussel fauna, one of the most serious invasive species for this region is the zebra mussel (*Dreissena polymorpha*). Although it has only been reported at one site in the lower North Sydenham, this European species has already decimated the native mussels of the Great Lakes.

Common reed/giant reed (*Phragmites australis*) is probably the most aggressive wetland species in this region. This invasive plant forms dense monocultures that displace native fish and wildlife habitat.

2.6 Human Characterization

The total population in the St. Clair Region Source Protection Area is about 167,000, based on the 2001 census. Most of the population is concentrated in urban communities surrounded by agricultural land as shown on **Map 25: Generalized Land Cover**. Agricultural land use is over 80% while urban/industrial land use is approximately 4%. The City of Sarnia is the largest urban centre.

Population growth varies across the SPA. Both Lambton County and the Municipality of Chatham-Kent experienced a decline in population over the five year period from 1996 to 2001, while Middlesex County experienced a population increase of over 4%. As shown in **Table 2.6.2-2: Population Projections Census Divisions - Ontario Ministry of Finance**, this difference in population growth will continue.

For the period from 2006 to 2031, the Ministry projections indicate that there will be limited growth (4%) in Lambton County and a continuing population decline in Chatham-Kent (-1%). However, Middlesex is projected to have growth of about 22%, which is slightly above the provincial projection of 21.4% for southwestern Ontario.

Table 2.6.2-2: Population Projections Census Divisions - Ontario Ministry of Finance

Census Division	2001	2006	2011	2016	2021	2026	2031
Chatham-Kent*	111,900	111,000	108,600	108,300	108,300	108,600	108,700
Lambton	131,800	133,300	133,200	133,100	134,400	135,900	137,000
Middlesex	422,000	436,200	453,700	473,800	493,700	512,800	530,100

It should be noted that the Municipality of Chatham-Kent feels that the Ministry of Finance population projections do not take into account the proactive development strategy being implemented by Chatham-Kent. The Chatham-Kent Official Plan (January 2005) projects a higher growth rate of approximately 6% and a population of 122,600 in 2021, based on a medium growth scenario.

Under the County of Middlesex Official Plan, Strathroy is designated as a settlement area in the Township of Strathroy-Caradoc. The growth management strategy for the Township is designed to direct the majority of future growth to the Strathroy settlement area, which has both municipal water supply and sanitary sewage system. The Lambton Official Plan indicates that the majority of growth will be directed to urban centres and urban settlements on full municipal sewage and water services. The Chatham-Kent Official Plan projects a higher growth rate than the Ministry of Finance projections and states that primary urban centres with full municipal services are the focal points for growth.

There are three (Lambton, Middlesex and Chatham-Kent) Census Canada regions within the SCRCA watershed. The amount and percentage of farmland for each census region is shown in **Table 2.6.11.1-2: Farmland in SCRCA Census Regions**. Approximately 81% of the land in the SCRCA is farmland.

Table 2.6.11.1-2: Farmland in SCRCA Census Regions

Census Region	Total area in Region (sq. km)	Farmland in Region (sq. km)	% Farmland in Region
Lambton	3,002	2,447	81
Middlesex	3,333	2,510	75
Chatham-Kent	2,490	2,235	90
Total	**8,825**	**7,192**	**81**

As shown on **Map 28: Land Capability for Agriculture**, most of the soils in the region are Class 1, 2 or 3 soils that are suitable for the sustained production of common field crops. The majority of farmland is used for the cultivation of soybeans, corn and wheat. In addition to crop cultivation, a proportion of farmland is allocated to the raising of livestock. The three SCRCA census regions account for over 20% of Ontario's turkey and swine production.

In the last 50 years, a significant trend in the agriculture industry has been the conversion from a mixed land use (livestock pasture and crop cultivation) to crop cultivation only. In more recent years, agricultural land use activity has focused on farm acreage consolidation.

Southwestern Ontario, particularly Lambton County, has a long history related to oil and gas production. **Map 26: Oil and Gas Wells** shows the concentration of wells across the area. The Source Protection Area is considered to be aggregate poor since most of the deposits are small and largely depleted.

Map 27: Transportation provides an overview of the major rail and road transportation network for the SPA together with the significant port or docking facilities located along the St. Clair River.

Water was the most important initial means of transportation, especially for communities along the St. Clair River. The gradual gradient of the Sydenham River also allowed access to Wallaceburg and Dresden. There continue to be active deep water ports and docking facilities along the St. Clair River that provide connections to the Great Lakes and worldwide ports. Ferry services at Sombra and Walpole also provide international crossings.

The strong agricultural nature of the area results in food processing plants and, more recently, plants that produce alcohol for fuel. The largest concentration of petroleum and chemical industry in Ontario stretches along the St. Clair River in the City of Sarnia and St. Clair Township. The automotive industry is another significant part of the industrial base in southwestern Ontario, with a number of parts suppliers located across the area.

The 402 Highway corridor is a focus for industrial and commercial development in the area. Numerous industrial developments are currently being examined that involve alternative energy sources and conversions. Several of these proposals are situated within St. Clair Township south of the City of Sarnia. Wind powered electrical supplies are also being considered along the Lake Huron shoreline.

The City of Sarnia, due to its industrial history, has a large area occupying approximately 2,295 hectares that is identified in the Brownfield Community Improvement Plan. In Chatham-Kent, the Brownfield Strategy and CIP are unique in that the CIP covers the entire municipality, not just older industrial areas since they need to address several communities within the amalgamated community.

There are a number of active and closed landfills in the SPA, including a hazardous waste disposal site. All active landfill sites are located in Lambton County, as shown in **Table 2.6.5-1: Active Landfills in the St. Clair Region Source Protection Area**.

Table 2.6.5-1: Active Landfills in the St. Clair Region Source Protection Area

Landfill Owner/ Operator	Location	Municipality
Dawn (LC) Lambton County	Tramway Road/Langbank Line Lot 21, Conc. 5	Dawn-Euphemia Twp
Moore (LC) Lambton County	Ladysmith Road, Lot 21, Conc. 5 & 6	St. Clair Twp
Moore (OPG) Ontario Power Generation	Greenfield Road, Lot 28, Conc. 3	St. Clair Twp
Warwick (WM) Waste Management	Zion Line, Lot 19-21, Conc. 3	Warwick Twp
Petrolia (WM) Waste Management	Oil Heritage Road, Lot 16-17, Conc. 10	Petrolia
Secure/Hazardous Waste (CH) Clean Harbors	Telfer Road, Lot 8-9, Conc. 10	St. Clair Twp
Inter Recycling		Sarnia

There are also 33 closed landfills in the SPA, based on the Ministry of the Environment Waste Disposal Site Inventory (Waste Management Branch, June 1991), local municipal official plans and zoning bylaws, and other available sources.

There is a wide range of recreational opportunities in the area. In particular, Lake Huron, the St. Clair River and Lake St. Clair together provide a focus for summer activities.

While human development has changed the area, there are a number of nationally, provincially and locally significant environmental areas in the SCRCA watershed including part of the St. Clair National Wildlife Area and the Bickford Oak Woods. The Bkejwanong Territory (Walpole Island First Nation) is home to a rich mosaic of areas with one of the largest wetland systems in the Great Lakes basin.

2.7 Water Uses

The main source of municipal drinking water is treated surface water delivered via pipeline to both urban and rural residents across the watershed. Only the community of Mount Brydges in the Municipality of Strathroy-Caradoc still has a municipal water supply system that uses a groundwater source.

Map 30: Drinking Water Supplies/Intakes shows the locations of surface water intakes for the SPA. Water from Lake Huron, the St. Clair River and Lake Erie feeds six municipal water treatment plants that supply water to communities in the SPA. Three of these plants are located outside the watershed. There are also two water treatment plants in the watershed that supply First Nation residents.

Groundwater serves as an important source for the region's rural residents that use private wells. **Map 29: Water Wells** shows the locations of wells based on Ministry of the Environment water well records. Most of these wells would supply individual homes, farms or rural businesses.

Section 34 of the Ontario Water Resources Act (OWRA) requires anyone taking more than a total of 50,000 litres of water per day to acquire a Permit To Take Water (PTTW). Permit holders draw water for a variety of applications from both groundwater and surface water sources. **Map 15: Permit to Take Water Locations by Type** shows water taking permit locations and type (i.e. groundwater, surface water or both) in the SPA. **Map 16: Permit to Take Water Locations by Usage** shows the various usages for the takings.

On the eastern side of the region, there is a concentration of permits (most of which derive their water from the ground) in the headwaters of the East Sydenham River near Strathroy for a variety of agricultural irrigation uses. The same is true for the North Sydenham River where several groundwater water taking permits are located near the headwaters of Bear Creek.

Along the shores of Lake Huron, Lake St. Clair and the St. Clair River, the permits are mainly for surface water takings, with few groundwater usages. In the lower southwestern portion of the region, water takers draw their water from surface water (rivers and streams). Many agricultural and commercial (golf course) water users store runoff water during the spring in ponds for application later in the summer.

The locations of municipal sewage treatment facilities are shown on **Map 31: Wastewater Treatment**. The boundaries of the areas serviced by these plants approximate the urban/industrial land cover shown on the map. In addition, sanitary sewers have been extended along the Lake Huron shoreline in Plympton-Wyoming and the St. Clair River front in St. Clair Township. The major industrial plants that are located along the St. Clair River in the City of Sarnia and St. Clair Township have their own specialized wastewater treatment facilities to process industrial sewage prior to discharge to the river.

3.0 Water Quality

3.1 Selecting Indicator Parameters

Water quality can be assessed by analyzing physical, chemical and microbial indicator parameters (**Table 3.1-1**). Physical parameters include measurements such as temperature and turbidity. Chemical parameters include nutrients, metals, organic compounds, and many other substances. Microbiological parameters include coliform and other bacteria. In addition to these examples, other parameters such as radioactive and aesthetic qualities (odour and colour) may be analyzed as well.

Table 3.1-1: Water Quality Parameter Examples

Physical	Chemical		Microbiological
	Inorganic	Organic	
pH Turbidity Temperature Colour	Fluoride Metals Nitrate Phosphate	Pesticides Benzene Trichloroethylene	Total coliform *Escherichia coli*

In 2003, the Ontario Ministry of the Environment (MOE) published standards for drinking water, referred to as the Ontario Drinking Water Standards (ODWS). The ODWS are further categorized into:

- Maximum Acceptable Concentration (MAC) for parameters that, when present above a certain concentration, have known or suspected adverse health effects.
- Interim Maximum Acceptable Concentration (IMAC) for parameters either when there are insufficient toxicological data to establish a MAC with reasonable certainty, or when it is not feasible, for practical reasons, to establish a MAC at the desired level.
- Aesthetic Objective (AO) for parameters that may impair the taste, odour or colour of water or that may interfere with good water quality control practices. For certain parameters, both aesthetic objectives and health-related MACs have been derived.
- Operational Guideline (OG) for parameters that, if not controlled, may negatively affect the efficient and effective treatment, disinfection and distribution of the water.

In some cases, there is no drinking water quality standard. For example, phosphorus does not pose a direct threat to human health, and it is an essential component of all cells, bones and teeth. When there is no readily available drinking water standard, water quality was evaluated using an alternative such as the Provincial Water Quality Objectives (PWQO), which provide general guidelines for healthy aquatic life. The drinking water standards can be very different from the objective for healthy aquatic life. Aquatic life protection objectives have also been included in the evaluation of some parameters when the aquatic protection value is much more stringent than the drinking water standard.

Water quality standards, objectives and guidelines have been developed by provincial and federal agencies to protect both aquatic life and human water uses. In this report, the data for raw (untreated) water are compared to the treated drinking water standards in order to assess surface water and groundwater sources. The comparison with these treated water standards is only intended to provide a means of quality assessment using an established reference (the standard) and not to judge conformance of raw water to the standards.

3.2 Raw Water Characterization for Inland Surface Water

Water quality has been monitored in the SCRCA watersheds since the 1960s when the Provincial Water Quality Monitoring Network (PWQMN) was first established. Current water quality sampling locations have been selected to obtain information for 10 subwatersheds. The sampling locations and the subwatershed areas are shown on **Map 32: Surface Water Quality Sampling Sites**.

This report reviews inland surface water quality based on current conditions and historic changes. Current conditions are based on recent data collected since 2002. Historic changes span 30 to 40 years, depending on the data available for each site, and are compared in five year data blocks. The historic changes do not necessarily indicate a trend over time but do help to provide an overview of long-term water quality.

The 75th percentiles were used to evaluate parameter levels. Use of the 75th percentiles reduces sampling bias and helps to reflect pollutants more appropriately than using average values. As shown in **Figure 3.2.4-1: Box and Whisker Plot**, the 75th percentile ('upper quartile') is the value below which 75% of the values fall.

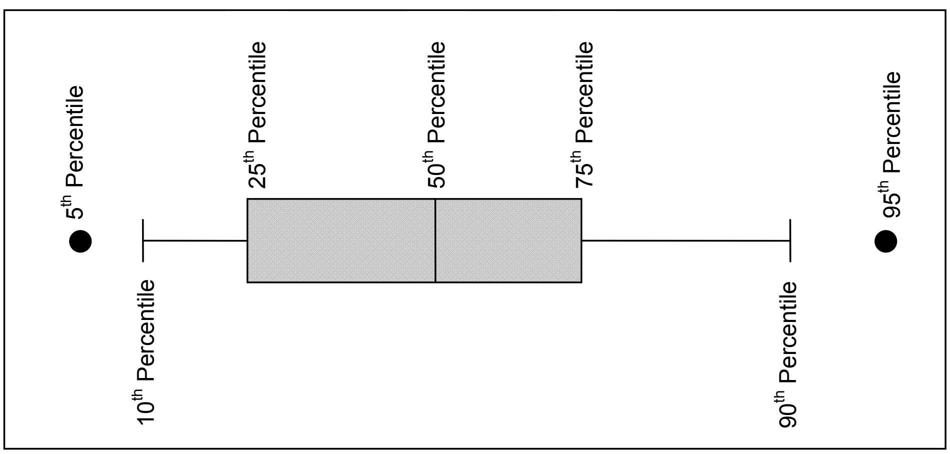

Figure 3.2.4-1: Box and Whisker Plot

To evaluate inland surface water quality, eight parameters were selected for Conservation Authority watershed planning based on extensive discussions between the Ontario Ministry of the Environment and Conservation Ontario. The parameters are total phosphorus, nitrates, suspended solids, chloride, coliform (fecal coliform and *Escherichia coli*), copper, zinc and lead. These parameters reflect nutrient levels, salt loading, solids, fecal bacteria contamination and heavy metal pollution.

Phosphorus

As noted previously, there is no Ontario Drinking Water Standard (ODWS) for phosphorus. The Interim Provincial Water Quality Objective (IPWQO) was used as an alternative to evaluate water quality.

The current 75th percentile phosphorus levels are routinely above the IPWQO of 0.03 mg/L for streams at all sampling locations. The historic five year 75th percentile levels at all stations are also above the IPWQO throughout the 40 year monitoring period.

Nitrates

The Ontario Drinking Water Standard (ODWS) for nitrate is a maximum acceptable concentration of 10 mg/L.

The only station that has a current 75th percentile above the ODWS of 10 mg/L is Little Bear Creek in the Lake St. Clair subwatershed. The historic five year 75th percentile nitrate levels at all stations are below the ODWS.

For the protection of aquatic life, water quality was evaluated using 2.93 mg/L which is based on a Canadian Council of Ministers of Environment (CCME) guideline. The current 75th percentile nitrate levels at all stations are above 2.93 mg/L. The historic levels at all stations have increased over the monitoring period. The lowest 75th percentile nitrate levels were in the 1970s and the nitrate concentrations were lower than 2.93 mg/L at some locations (Strathroy, Oil Springs, Avonry and Wallaceburg).

Chloride

The current 75th percentile chloride concentrations at all sites are within both the ODWS aesthetic objective of 250 mg/L and an Environment Canada aquatic health guideline of 210 mg/L.

Historically, the East Sydenham stations have always been far below both the ODWS aesthetic objective and the EC guideline. On the North Sydenham, the five year 75th percentile chloride levels were extremely high at Oil Springs from 1971-75 to 1986-90. Levels at this location were as high as 694 mg/L. The chloride levels also were above both criteria at Avonry in 1976-80. At Petrolia in 1986-90, chloride concentrations were above the Environment Canada guideline. By 1990-96, levels at Oil Springs, Avonry and Petrolia dropped to below 60 mg/L. Levels in the East and North Branches are now relatively the same.

Suspended Solids

While there are no established standards for suspended solids, turbid water is undesirable for water supplies, healthy aquatic life, recreation and aesthetics. The Petrolia, Avonry and Oil Springs stations have the highest current 75th percentile levels, ranging from 60 to 150 mg/L. The other stations have 75th percentile levels below 50 mg/L. In general, historic suspended solids are highest in the North Sydenham subwatersheds, while the upper reaches of the East Sydenham have lower 75th percentile levels. On the main Sydenham, Wallaceburg has a wide variety of values that range from 20 mg/L to 180 mg/L, with no apparent pattern.

Bacteria

The ODWS for *E. coli* is ‘not detectable’ (zero) in treated drinking water. Both the current and historic data show the presence of *E. coli* at all of the SCRCA stations.

The PWQO (recreational guideline) for exposure to surface water (e.g. swimming) is 100 counts per 100 mL as a geometric mean. All stations except Florence (East Sydenham) and Wallaceburg (Sydenham) have current geometric mean values that are above the PWQO. The current geometric mean values of *E. coli* bacteria range between 84 counts/100 mL at Florence and 297 counts/100 mL at Hickory Drive. Historically, all stations had bacteria present and most of the values were over the PWQO for recreational water usage. All stations have significant decreases in bacteria levels between 1971-75 and 1986-90. However, only Wallaceburg and Petrolia have maintained the reduction in bacteria levels. The other four stations (Alvinston, Strathroy, Avonry and Oil Springs) show increases from 1986-90 to 2002-04.

Copper

The ODWS for copper is 1 mg/L (1,000 µg/L) for aesthetic water quality. At all of the stations, both the current and historic copper concentrations are far below the ODWS of 1 mg/L.

While copper is an essential element, it can be toxic to aquatic life and the PWQO is 5 µg/L. All of the current 75th percentile copper levels are below the PWQO. However, prior to 1985, the 75th percentile levels were above the PWQO at the four stations with historic information. The levels ranged from approximately 10 µg/L to 20 µg/L. By 1991-96, the copper levels had decreased at all sites and appear to have continued to improve to current (2002-04) values below the PWQO of 5 µg/L.

Zinc

The ODWS for zinc is 5 mg/L (5,000 µg/L) for aesthetic objectives. At all of the stations, both the current and historic zinc concentrations are far below the ODWS.

While zinc is an essential element, it can be toxic to aquatic life and the PWQO is 20 µg/L. The current 75th percentile zinc levels at all stations are also well below the PWQO. Historically, three stations (Oil Springs, Petrolia and Wallaceburg) had values that were above or equal to the PWQO for various time blocks prior to 1991-96. Since 1991-96, the 75th percentile zinc values have decreased at all stations and levels are well below the PWQO.

Lead

Laboratory testing for low concentration lead values in surface water is difficult. Lead levels are hard to assess because the laboratory Method Detection Limit for lead is 10 µg/L, which is equal to the ODWS of 10 µg/L and higher than the PWQO of 5 µg/L. Lead was evaluated by the number and percent of samples above the limits.

Only two North Sydenham Branch stations (Petrolia and Oil Springs) have samples with current lead readings that are above the ODWS of 10 µg/L.

Historically, lead levels have decreased at all stations. At Petrolia, the percentage (14%) of samples above the ODWS in 2002-04 has decreased from a high of 32% in 1981-85. At Oil Springs, there has been a similar decrease to 9% in 2002-04 from 33% reported in 1981-85. Wallaceburg (81% in 1975-1980), Alvinston (23% in 1981-85) and Strathroy (31% in 1981-85) have shown similar decreases and these stations had no samples above the ODWS in 2002-04.

3.3 Groundwater Quality

The Watershed Characterization Report provides a summary of existing groundwater monitoring programs and a review of groundwater quality for municipal drinking water supply systems and the Provincial Groundwater Monitoring Network (PGMN) in terms of chemical and microbiological parameters.

In general, the work associated with collecting groundwater quality information can be grouped into three subsections: protecting municipal/public water supply, evaluating private well water and gathering background data.

Background Monitoring Data – Chemical Parameters

In 2001, the Ministry of the Environment and Conservation Ontario together initiated a groundwater quality and quantity network called the Provincial Groundwater Monitoring Network (PGMN). The network supports the development of implementation and monitoring for future source protection plans, by providing background monitoring information on groundwater levels and quality.

The PGMN provides a wide range of information on chemical parameters in the local groundwater. The first round of sampling included a comprehensive analysis by the MOE laboratory and included pesticides, volatiles, metals and basic chemistry (cation/ anion suite: calcium, sodium, magnesium, bicarbonate, sulfate and chloride). The second round of samples included a basic cation/ anion suite, metals, nitrate and fluoride.

As of May 2007, SCRCA had nine monitoring wells. While some have been monitoring water levels since 2002, most were brought into the system in 2006. **Map 14: Provincial Groundwater Monitoring Network** shows the locations of the wells.

Initial monitoring from the PGMN system indicates that the basic water type is dominated by bicarbonate water in both the bedrock and overburden aquifers throughout the region. A strong saline influence was detected in PGMN wells in the SCRCA watershed. This is likely a bedrock source of saline water; however, it could also be anthropogenic (e.g. road salt).

A few chemical parameters are above health related Ontario Drinking Water Standards (ODWS) including fluoride, boron, and selenium. Sodium, iron and manganese levels are also above the ODWS aesthetic objectives. In general, these are considered to be naturally-occurring. The ranges of parameters above the Ontario Drinking Water Standards/Guidelines/Objectives are shown in the **Table 3.3.2.2-2**.

Table 3.3.2.2-2: Range of Parameters Above Ontario Drinking Water Standards/Guidelines/ Objectives in the SCRCA PGMN Wells, for 2002-2006

Parameter & Limit	Minimum (mg/L)	Maximum (mg/L)	Sample Size, n (2002-2006)
Sodium – 200 mg/L	2.6	1470.0	22
Chloride – 250 mg/L	3.0	2430.0	22
Total Dissolved Solids – 500 mg/L	298.0	5428.0	22
Hardness – 80-100 mg/L	8.0	550.0	22
Iron – 0.3 mg/L	0.006	1.68	22
Manganese – 0.05 mg/L	0.0019	0.209	22
Selenium – 0.01 mg/L	-0.001*	0.02	22
Boron – 5 mg/L	0.004	5.86	22
Fluoride – 1.5 mg/L	0.04	2.3	18
pH – 6.5- 8.5	8.0	8.8	19
Dissolved Organic Carbon – 5 mg/L	0.5	20.7	22
Alkalinity – 30-500 mg/L	213.0	640.0	19

* Laboratory reporting method can result in negative values being reported (see discussion on selenium)

Municipal Groundwater Supply Systems

The Mount Brydges system is the only active municipal drinking water supply system that is using a groundwater source, and although it supplies the community of Mount Brydges, the system is located in the Upper Thames River Source Protection Area. Until recently, the community of Strathroy in Strathroy-Caradoc was also using groundwater as the source for the municipal supply of drinking water. The wells are no longer in use since Strathroy is now serviced by the Lake Huron Primary Water Supply System.

A few areas in the SCRCA watershed have documented levels of drinking water constituents that are of concern. Elevated levels of nitrate have been reported in Mount Brydges. Also, Strathroy had high levels of nitrates in the groundwater source it formerly used.

Ambient Water Quality Study

Schlumberger Water Services, formerly Waterloo Hydrogeologic, Inc., has a contract to conduct an Ambient Water Quality Study to gather and consolidate groundwater information over southwestern Ontario. This work is focused on chemical water quality parameters.

A draft of the Schlumberger report is available. Some of the findings in this draft report have been used to provide information on ambient groundwater quality for the St. Clair Region Source Protection Area.

The following discussion is based on the initial information in the draft Schlumberger report and may be subject to change when the final report is completed.

In the SCRCA, the bedrock water type is predominately Na-Cl indicating aquifers of low permeability and/or long residence time. The Na-Cl type bedrock water in the study area has a median Total Dissolved Solids (TDS) of 1000 mg/L and a maximum salinity of 5,500 mg/L.

The overburden wells are also predominately Na-Cl type waters in Lambton County. However, on the southeastern side of the St. Clair Region, overburden groundwater is mainly Ca-HCO_3 indicating young groundwater found in the sand plains. Ca-HCO_3 type waters represent the best water quality.

Ca-Cl type waters are also found in both bedrock and overburden wells. These usually form in deep (bedrock) conditions, such as in oil fields. When Ca-Cl type waters are encountered at the overburden, they may indicate uprising of deep basin waters along fault plains, contamination with oil brines or analysis error.

Sodium-bicarbonate (Na-HCO_3) is another significant groundwater type that is found in both bedrock and overburden wells, indicating a mixing or intrusion of saline groundwater into a freshwater aquifer, or freshwater into an aquifer containing saline groundwater.

Na-HCO_3 type waters have a typical TDS range of 400-600 mg/L and are very soft. Sodium levels are high but normally below the aesthetic objective of 200 mg/L. Hardness is mostly below the aesthetic lower value of 80 mg/L $CaCO_3$. The pH is typically in the alkaline range; however, it is significantly less than waters of the same type further south in the Thames River watershed. The Hamilton Group and Kettle Point Formation are the most probable origin of these waters. These formations have high organic carbon content which provides excellent ion exchange capabilities. Na-HCO_3 type waters are vulnerable to certain water quality issues due to the high pH that frequently accompanies these waters.

Na-SO_4 waters are also found in some wells. They would have been generated in a manner similar to the previous Na-HCO_3 water type, but initiated from Ca-SO_4 type water.

Microbiological Water Quality Characterization

Water can be contaminated by numerous pathogenic (disease-causing) micro-organisms. In order to assess the microbiological quality of drinking water, indicator parameters are used. In this report, *Escherichia coli* and total coliform are the two microbiological indicator parameters used to assess groundwater well (raw water) quality. **Figure 3.3.3.1-1: Coliform Bacteria Subgroups** provides an overview of the relationship between groups of micro-organisms, and the types of coliforms relevant to the current report.

Information for Strathroy's former well system was taken from the Drinking Water Information System (DWIS) database. The database provides total coliform and *E. coli* data on a weekly basis from 2003 to 2006 for most groundwater wells.

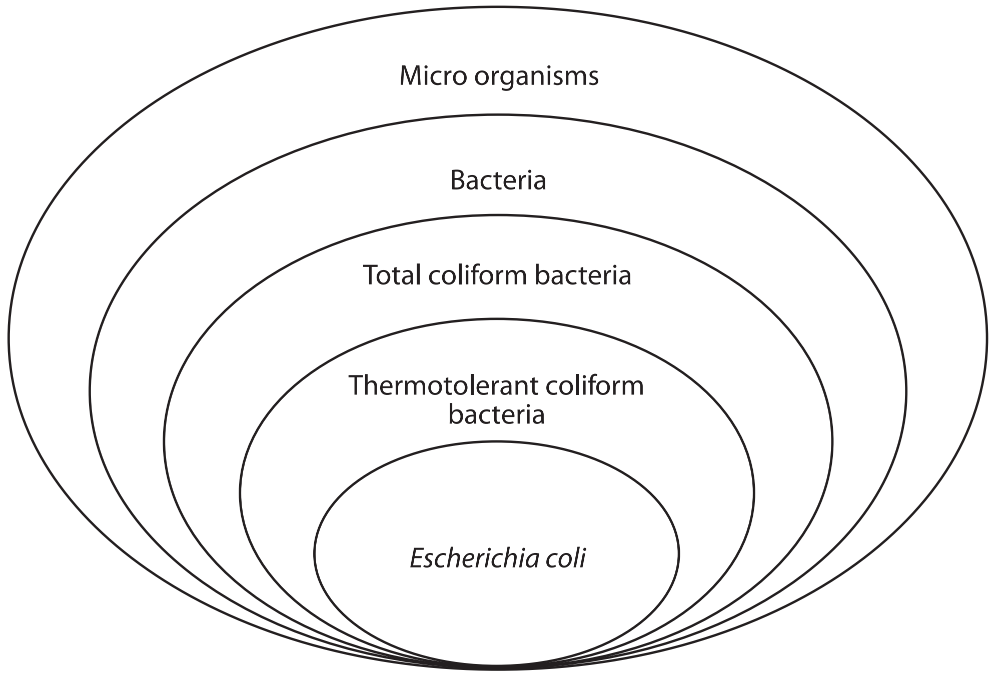

Figure 3.3.3.1-1: Coliform Bacteria Subgroups

DWIS data was unavailable for the Mount Brydges well supply system but equivalent data was obtained in the form of plant operational records from the Environmental Services Department, Municipality of Strathroy-Caradoc.

The Ontario Drinking Water Standards (ODWS) for *E. coli* and total coliform in treated drinking water is "not detectable;" hence, exceedences are taken as any detects, or any coliform counts greater than zero (occurrences).

There were no *E. coli* or total coliform detected in either of the two wells of the Mount Brydges supply well during the time period for which data is available.

Prior to being connected to a pipeline that supplies treated Lake Huron water, the community of Strathroy had a groundwater source with 13 individual wells. For the period data was available, no coliform was detected in eight of the 13 wells. Total coliform was detected from two to seven times in the other five wells. *E. coli* was detected in one (two of 55 samples) of the 13 wells.

The PGMN also provided some *E. coli* data. All results in the PGMN wells are below a count of 10 per 100 mL, which is the laboratory reporting detection limit that has been used for testing non-drinking water samples.

The data for each system was summarized in a table showing the information available for the individual wells. In addition, wells with one or more occurrences of *E. coli* and three or more occurrences of total coliform were graphed as scatter plots.

There were no *E. coli* or total coliform detected in the Mount Brydges wells during the time period for which data is available. *E. coli* was detected twice in one of the 13 Strathroy wells and total coliform was detected from two to seven times in the other five wells. The Strathroy wells are now no longer in use.

Since water treatment processes, particularly disinfection, are designed to remove contamination before the treated water enters the distribution system, the information in this report should not be considered an evaluation of microbiological water quality in a municipal water supply system.

A type of *E. coli* bacteria was a primary cause of the deaths at Walkerton in May 2000, which led to the development of Source Protection Planning. While the overall number of *E. coli* positive samples was relatively low, the results show the need to maintain proper disinfection and monitoring procedures.

3.4 Raw Water Characterization for Drinking Water Intakes

This section of the Watershed Characterization Report provides an evaluation of the surface water intake raw (untreated) water quality in terms of physical, chemical and microbial parameters. It also provides an overview of existing monitoring programs for the surface water sources for these intakes.

Residents within the St. Clair Region Conservation Authority (SCRCA) watershed receive drinking water taken from Lake Huron, the St. Clair River and Lake Erie surface water sources. **Table 3.4.1-1: Intakes Servicing the St. Clair Region Conservation Authority Watershed** identifies the eight water treatment facilities that supply parts of the region and their intake sources. The location of the intakes is shown on **Map 30: Drinking Water Supplies/Intakes**.

Table 3.4.1-1: Intakes Servicing the St. Clair Region Conservation Authority Watershed

System	Intake Source
Bkejwanong Territory (Walpole Island First Nation)	St. Clair River
Wallaceburg	St. Clair River (Chenal Ecarte)
Lambton Area Water Supply System (LAWSS) Town of Petrolia at Bright's Grove Chippewas of Kettle and Stony Point First Nation Lake Huron Primary Water Supply System* (LHPWSS)	Lake Huron
Chatham* West Elgin *	Lake Erie

* Located outside of the SCRCA watershed

There was no information available to evaluate the source water quality for the Chippewas of Kettle and Stony Point First Nation Water Treatment Plant. A summary of the information for the other water treatment facilities is provided below.

The main sources of data used to examine intake raw water quality in this Report are the Drinking Water Surveillance Program (DWSP) database, the Drinking Water Information System (DWIS) database, the Drinking Water System (DWS) Reports and local Plant Operation Records.

To evaluate intake (surface) water for water treatment plants, a 'multi-tier' parameter review was done based on:

- Basic parameters selected by the Ministry of the Environment and Conservation Ontario or routinely used as part of the water treatment process,
- Drinking Water Systems Regulation 170/03 parameters,
- Great Lakes parameters associated with international agreements, and
- Water treatment plant (WTP) or water supply system (WSS) specific parameters.

The Ontario Drinking Water Standards (ODWS) are used to assess the quality of intake water for most of the parameters. Where the ODWS is not available, an alternative assessment standard was established by using:

- The United States Environmental Protection Agency (USEPA) Maximum Concentration Level (MCL) from the USEPA National Primary Drinking Water Regulations, or
- Provincial Water Quality Objectives (for healthy aquatic life) when the USEPA MCLs are not available.

Seven basic parameters have been selected for review. Four of the basic parameters (phosphorus, nitrate, chloride, and fecal coliform bacteria) are among those selected for Conservation Authority watershed planning. Three parameters (turbidity, pH and temperature) are physical parameters measured as part of the treatment plant operation.

Additional parameters reviewed were those identified in Ontario Regulation 170/03; required for State of the Great Lakes Ecosystem Conference (SOLEC); identified by the International Joint Commission (IJC) as pollutants of concern; and plant specific parameters in Drinking Water System (DWS) annual reports. The lists of pollutants of concern in Lake Erie (Lake Erie Lakewide Management Plan) and in Lake Huron (Lake Huron Initiative Action Plan) were reviewed for plants with these sources.

Basic Parameters

Phosphorus

Phosphorus is an essential component of all cells and does not pose a direct threat to human health. There is no Ontario Drinking Water Standard. The Ontario Interim Provincial Water Quality Objective (IPWQO) of 20 µg/L or 0.02 mg/L of total phosphorus to prevent the nuisance growth of algae in lakes was used to evaluate intake water quality. Information was available for five plant intakes. No data was available for the Petrolia and West Elgin plant intakes.

At the Lake Huron Primary Water Supply System (LHPWSS), Lambton Area Water Supply System (LAWSS) and Bkejwanong Territory (Walpole Island FN) Water Treatment Plant, all annual average phosphorus concentrations were lower than the IPWQO of 20 µg/L, except for the 2003 annual average at LAWSS. Each of these plants had maximum concentrations that occasionally were above the IPWQO.

At Wallaceburg, both the average and maximum phosphorus concentrations have been lower than the IPWQO since 1993. Average and maximum concentrations were above the IPWQO in 1990 and 1992.

For the Chatham WTP, nine of 16 years had average levels of total phosphorus in raw water that were above the IPWQO from 1990 to 2005. The maximum phosphorus levels frequently rose to levels above the IPWQO and, as recently as 2003, the minimum, average and maximum levels were all above the IPWQO.

Nitrate

The Ontario Drinking Water Standard (ODWS) for nitrate is a maximum acceptable concentration of 10 mg/L. A value of 2.93 mg/L was used to evaluate water quality for aquatic life based on a Canadian Council of Ministers of the Environment (CCME) guideline to protect aquatic life from direct toxicity. Information was available for six plant intakes. No data was available for the Petrolia WTP intake.

The average levels at all six plants (LHPWSS, LAWSS, Wallaceburg, Bkejwanong Territory, Chatham and West Elgin) were less than 0.7 mg/L. Maximum nitrate levels have also been well below both the ODWS of 10 mg/L and the modified CCME guideline of 2.93 mg/L for all plants, with the exception of two years (1990 and 1992) at the Wallaceburg intake where the maximum concentration was close to 6 mg/L in 1990 and 9.3 mg/L in 1992. Since 1993, the maximum levels in the Wallaceburg intake have been much lower and have ranged from 0.34 to 1.8 mg/L.

Chloride

The Ontario Drinking Water Standard (ODWS) is 250 mg/L for aesthetic objectives. An Environment Canada/Health Canada assessment report documents toxicity for sensitive aquatic species at 210 mg/L and this value was used to assess toxicity to aquatic species. Information was available for six plant intakes. No data was available for the Petrolia WTP intake.

The maximum levels at all six plants (LHPWSS, LAWSS, Wallaceburg, Bkejwanong Territory, Chatham and West Elgin) were less than 30 mg/L, which is well below both the ODWS objective of 250 mg/L and the Environment Canada value of 210 mg/L for toxicity to aquatic species.

Turbidity

An Ontario Drinking Water Standard (ODWS) aesthetic objective of 5 NTU has been established for turbidity. This objective is applicable to all water at the point of consumption. At higher levels the particulate matter in water may cause colour, taste and odour concerns for consumers.

The turbidity levels in the raw water indicate the amount of treatment needed to achieve the treated water quality standard. (Note: The MOE DWSP turbidity data units are in FTU (Formazin Turbidity Units), whereas the ODWS aesthetic objective is in NTU (Nephelometric Turbidity Units. The two measurement units are considered as equal for this report.) Information was available for seven plant intakes.

LHPWSS: Between 1990 and 1999, most maximum and average values are above the ODWS. Maximum levels ranged between 3.8 and 59.7 FTU, and average levels ranged between 2.5 and 20.5 FTU. In recent years (2000 to 2004, with 2003 data missing), all values are considerably lower than ODWS of 5 NTU.

Petrolia: Data sets from 2004 to 2006 show all average (12 to 27 NTU) and maximum levels (172 to 292 NTU) are above the ODWS.

LAWSS: The average turbidity levels from 1990 to 2005 except in the year 1991 are lower than the ODWS aesthetic objective of 5 NTU, with a maximum level of 17.4 FTU.

Wallaceburg: While there are many annual averages that are below or slightly above the ODWS aesthetic objective of 5 NTU, there is an extremely wide range of turbidity values for this intake. The annual average levels range from 3.3 to 215.5 FTU. The maximum turbidity levels range between 4.2 and 839 FTU. From 1990 to 2005 (with the exceptions of 1991 and 1998), all maximum turbidity levels are above the ODWS aesthetic objective.

Bkejwanong Territory: Most of the average turbidity levels are below the ODWS with the exceptions of levels in 1991, 1994, 1997, 1998 and 1999. The maximum turbidity levels are below 50 FTU.

Chatham: The average turbidity levels range between 2.2 and 60.4 FTU and the maximum turbidity levels range between 3.2 and 75.5 FTU. Average turbidity levels were lower than the ODWS in five of 16 years and maximum turbidity levels were lower than the ODWS in the years 1996, 2001 and 2005.

West Elgin: Data sets from 2001 to 2006 show that the average turbidity levels range between 5.7 and 26.6 NTU. The maximum turbidity levels range between 145.2 and 447 NTU.

pH

An Ontario Drinking Water Standard (ODWS) operational guideline of 6.5 to 8.5 has been established for pH. There is a progressive decrease in the efficiency of chlorine disinfection and alum coagulation with pH levels above 8.5. The lower limit of 6.5 is aimed at preventing corrosion in the treatment and distribution system. Information was available for seven plant intakes.

The annual average pH levels at six plants (LHPWSS, Petrolia, LAWSS, Wallaceburg, Bkejwanong Territory and Chatham) were within the operational guideline of 6.5 to 8.5. Minimum and maximum levels were also within the guideline with the following exceptions. In 1996, LAWSS had a maximum pH of 8.52. In 2004, Wallaceburg had a maximum pH of 8.54. In 1997, Bkejwanong Territory had a maximum pH of 8.6. In 2004, Chatham had a maximum pH of 8.7.

At the West Elgin plant, all of the average pH values are within the ODWS range of 6.5 to 8.5 but there are some high and low pH data values that range from over 11.0 to less than 1.0. From 2005 to 2006, trending software and information from the plant log book allowed the validated exclusion of the extremely high and low pH values. With the extreme values removed, all minimum and maximum values for 2005 and 2006 were within the operating range. From 2001 to (September) 2004, the operator log books provided possible causes for the high and low pH values but they could not be conclusively linked due to the lack of trending analysis.

Temperature

An Ontario Drinking Water Standard (ODWS) aesthetic objective of 15ºC has been established for temperature. Low temperature helps to maintain free chlorine residual by reducing the rates of decay of the chlorine. Also, a temperature below 15ºC will tend to reduce the growth of nuisance organisms and minimize taste, colour, odour and corrosion problems. Information was available for seven plant intakes.

During the summer months, the maximum water temperatures for all plants were above the aesthetic objective of 15ºC, ranging from 22ºC to 30ºC. In the winter, minimum temperatures dropped as low as 0.1ºC. In some years, the average annual temperatures at Wallaceburg (2002), LHPWSS (2000, 2001, 2002), and Chatham (2002, 2003, 2004) were above the aesthetic objective of 15ºC.

Coliform Bacteria

The Ontario Drinking Water Standards (ODWS) for total coliform and *E. coli* are Maximum Acceptable Concentrations (MAC) of "not detectable." The bacteria levels in the raw water help to indicate the amount of treatment needed to achieve the drinking water quality standard. Information was available for seven plant intakes.

LHPWSS: From 2003 to 2006, total coliform levels ranged from 0 to 9,600 counts/100 mL and *E. coli* counts ranged from 0 to 150 counts/100 mL.

Petrolia: May 20, 2003 to September 25, 2006, total coliform levels ranged from 0 to 50,000 counts/100 mL and *E. coli* counts ranged from 0 to 1000 counts/100 mL.

LAWSS: From 2003 to 2005, total coliform levels ranged from 0 to 340 counts/100 mL and *E. coli* counts ranged from 0 to 60 counts/100 mL.

Wallaceburg: In most samples coliform was detected. From 2003 to 2006, total coliform levels ranged from 0 to 480,000 counts/100 mL and *E. coli* counts ranged from 0 to 1000 counts/100 mL. In the years 2005 and 2006, there were no raw water samples with zero total coliform counts. From 2003 to 2006, *E. coli* levels greater than 100 counts/100 mL occurred in all years with maximums of 1000. However, there were some samples with zero (non-detect) *E. coli* counts.

Bkejwanong Territory: The only data available is for fecal coliform for 1991, 1993 and 1994 from the DWSP database. Each year had only one sample and the fecal coliform counts were 126, 2100 and 360 counts/100 mL, respectively.

Chatham: From June 2003 to September 2006, total coliform levels ranged from 0 to over 10,000 counts/100 mL and *E. coli* counts ranged from 0 to over 1,000 counts/100 mL.

West Elgin: From 2001 to 2006, the total coliform levels ranged from 0 to over 91,000 counts/100m and *E. coli* counts ranged from 0 to 1,400 counts/100 mL.

Other Parameters

Using DWSP data sets from 2000 to 2005, a total of 83 chemical and physical parameters were reviewed for LAWSS, Wallaceburg WTP, Bkejwanong Territory WTP and Lake Huron Primary WSS raw water. There were 88 parameters reviewed for the Chatham WTP raw water also using DWSP data. Drinking Water System (DWS) annual reports, which contain Schedule 23 data (inorganic, such as metals and phosphorus) and Schedule 24 data (organic, such as dicamba and paraquat) on treated water, were used for the Town of Petrolia WTP and West Elgin WTP.

The data sets were reviewed to determine how many samples had test results above a drinking water standard for a chemical parameter. To provide an additional level of evaluation, the results were also compared to a value of one-half the standard.

No parameters in the raw (untreated) water were above the health related ODWS or half standard values for treated drinking water.

At one plant (Chatham WTP), two parameters (aluminum and hardness) were above the ODWS operational guidelines. For hardness, all minimum, maximum and average levels were above the upper level of the ODWS (operational guideline) of 80 to 100 mg/L from 1990 to 2005. The annual average hardness levels range between 108 to 127 mg/L. For aluminum, half of the annual average aluminum levels are above the ODWS operational guideline of 100 μg/L from 1990 to 2005.

One parameter, Mirex (a pesticide), was found to exceed the Provincial Water Quality Objective for aquatic life. However, the analysis results for Mirex must be interpreted with caution since the detection limit of 5 ng/L is higher than the Provincial Water Quality Objective of 1 ng/L. Hence, in the cross tab query analysis, when Mirex is detected in a sample, it is automatically considered to be above the objective. Mirex was reported to be detected at LHPWSS, LAWSS, Wallaceburg, Bkejwanong Territory and Chatham.

The data sets were also reviewed to determine what parameters had been detected in the plant intake samples. All detected parameters were below the relevant half standard values.

LHPWSS: Three organics, 10 inorganics and dissolved organic carbon were detected in the raw water. All were below the relevant treated drinking water half standard. The organics detected were Malathion (a pesticide), methylene chloride and dichloroethane-1,2. The inorganics were antimony, arsenic, barium, boron, copper, chromium, lead, nickel, uranium and zinc.

Petrolia: Dissolved organic carbon was detected but did not exceed the half standard.

LAWSS: Dissolved organic carbon, 11 inorganics, and three organics were detected in the raw water. All of these detected parameters were below the relevant half standard. The inorganics detected were antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, nickel, uranium and zinc. The organics were Malathion (a pesticide), methylene chloride and dichloroethane-1,2 (volatile organics).

Wallaceburg: Three organics, 11 inorganics and dissolved organic carbon were detected in the raw water. All were below the relevant half standard. The organics were Malathion (a pesticide), methylene chloride and dichloroethane-1,2. The inorganics were antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, nickel, uranium and zinc.

Bkejwanong Territory: Four organics, 11 inorganics and dissolved organic carbon were detected in at least two samples of the raw water. All were below the relevant half standard. The organics detected were Malathion (a pesticide), methylene chloride, dichloroethane-1,2 and lindane (a pesticide). The inorganics were antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, nickel, uranium and zinc.

Chatham: Three organics, 12 inorganics and dissolved organic carbon were detected in the raw water. All were below the relevant half standard. The organics detected were Malathion (a pesticide), methylene chloride and dichloroethane-1,2 (volatile organics). The inorganics were antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, nickel, uranium, zinc and selenium.

West Elgin: Boron and uranium, dissolved organic carbon and Dinoseb (a pesticide) were detected. All were below the respective half standards.

4.0 Water Quantity

Within the St. Clair Region Source Protection Area, there are numerous human activities that benefit from a substantial supply of water. This section of the Watershed Characterization Report provides a brief summary of information on current water usage.

The Water Budget, which is being prepared in parallel to the Watershed Characterization Report, provides a detailed review of water usage and demand.

Water takers have a responsibility to ensure that the amount of water they use does not threaten the environment or existing water users. Section 34 of the Ontario Water Resources Act (OWRA) requires anyone taking more than a total of 50,000 litres of water per day to acquire a Permit To Take Water (PTTW). Some water takings are exempt from the requirement to obtain a permit. These include takings by an individual for ordinary household purposes, and water takings for the direct watering of livestock or poultry, or for firefighting purposes.

Map 15: Permit to Take Water Locations by Type shows the locations of water takers that have water taking permits in the St. Clair Region watershed. The locations shown on the map are colour coded to indicate groundwater, surface water or combined sources. In general, most of the takings are from surface water sources. There is a cluster of groundwater takings in the Strathroy-Caradoc area where the sand plains provide convenient access to overburden aquifers.

Map 16: Permit to Take Water Locations by Usage shows the various uses of the water takings. The number of permits for various water taking purposes (as listed in the MOE database) in the watershed is summarized in **Table 4.1-1: Number of Water Taking Permits by Sector in the St. Clair Region**. (Note: this table is based on inland source locations and does not include permits to take water from Lake Huron, Lake St. Clair and the St. Clair River.)

While the agricultural sector has the largest number of permits, the use is seasonal and the amount of water being used may not be as high as other sectors that have year round operations.

As outlined in Section 2.7 Water Uses, most of the population that has municipal piped water supplies receives treated surface water. A summary of the water treatment plants and the rated capacity is provided in **Table 4.1-7: Water Treatment Plant Capacities**. These plants supply urban and rural areas in Chatham-Kent and Lambton County.

Table 4.1-1: Number of Water Taking Permits by Sector – Thames Watershed & Region

Water Taking Sector	Water Use	Number of Permits	Percent of Total Permits
Agricultural	Field and pasture crops, fruit orchards, market gardens/ flowers, nursery, other – agricultural, sod farm, tender fruit, tobacco	264	57%
Commercial	Aquaculture, bottled water, golf course irrigation, mall/ business, other – commercial, snowmaking	27	6%
Construction	Other – construction, road building	33	7%
Dewatering	Construction, other – dewatering, pits and quarries	16	4%
Industrial	Aggregate washing, cooling water, food processing, other – industrial, pipeline testing, power production	26	6%
Miscellaneous	Dams and reservoirs, heat pumps, other – miscellaneous, pumping test, wildlife conservation	40	9%
Recreational	Aesthetics, other – recreational, wetlands	8	2%
Water Supply	Campgrounds, communal, municipal, other – water supply	47	10%

Note: Data from MOE Permit to Take Water Database

Table 4.1-7: Water Treatment Plant Capacities

Water Treatment Plant	Capacity m^3/day	Source
Plants taking water in the St. Clair Region		
Petrolia	8,000	Lake Huron
Lambton Area	181,844	Lake Huron
Wallaceburg	18,200	St. Clair River
Plants taking water outside the St. Clair Region		
Lake Huron Primary	340,000	Lake Huron
Chatham	60,000	Lake Erie
West Elgin	6,829	Lake Erie
Elgin Area Primary	90,000	Lake Erie

5.0 Description of Vulnerable Areas

This section is intended to provide a preliminary description of watershed areas that may be vulnerable based on information from existing documents. The Watershed Assessment Report will provide a more detailed description and vulnerability analysis.

Wellhead Protection Areas (WHPA) for groundwater sources and Intake Protection Zones (IPZ) for surface water sources identify areas that are considered to be the most immediate concern from a quality and/or quantity perspective.

Groundwater

The general groundwater aquifer vulnerability for the watershed is shown in **Map 17: Intrinsic Susceptibility Index**. The areas of highest susceptibility are in the sand plains and moraines across the St. Clair Region. The areas of low susceptibility are in the silt and clay plains.

The community of Mount Brydges in Middlesex County is the only municipal water system in the St. Clair Region currently utilizing groundwater. Until 2006, the community of Strathroy also used groundwater. The wellhead capture zones for the Mount Brydges wells and the former Strathroy wells are shown on **Map 33: Wellhead Protection Areas**.

Overburden aquifers especially had limitations on their usefulness for drinking water sources. The Lambton County Groundwater Study identified a dominant aquifer at the base of the overburden. However, the report also indicated that existing data for this aquifer shows "approximately 55% of the samples (62 out of 113) contained chloride at a concentration higher than the ODWS aesthetic objective of 250 mg/L." Thus, the aquifer appears to have limited potential for development as a future drinking water source. The Middlesex-Elgin Study indicated that overburden aquifers associated with the Caradoc, Bothwell and Norfolk Sand Plains were identified as being "most vulnerable to impacts" (from contamination).

Surface Water

For surface water sources, Intake Protection Zones will be established as part of the Intake Protection Zone Delineation Studies as the first phase of the Surface Water Threats Studies. Studies are underway for all six municipal surface water intakes supplying communities in the St. Clair Region. **Map 30: Drinking Water Supplies/Intakes** shows the location of these Great Lakes drinking water intakes and the urban areas that receive treated water from them.

As part of the evaluation of surface water threats, a minimum radius of 1 km into the lake (for Great Lakes intakes) with a 120 m or regulatory limit (whichever is greater) setback on land is recommended for an initial Intake Protection Zone (IPZ-1). A second, larger Intake Protection Zone (IPZ-2) will be delineated based on the 2 hour time of travel, taking into consideration the magnitude of the threat delivery vectors and time for intake shutdown. Delivery vectors include factors such as currents, wave action, stream flow and drift.

An example of the preliminary IPZ work is shown in **Figure 5.3.3-1: Town of Petrolia IPZ-1** which shows the initial 1 km radius in the water around the intake. The zone overlaps the immediate shoreline and includes the mouth of Cow Creek. An adjustment was made to expand the IPZ-1 Zone to include storm water sewer drainage. This example is taken from the Draft Phase 1 Report Intake Protection Zone Delineation – Southern Lake Huron Intakes (R.V. Anderson Associates Ltd. and Baird, November 2007).

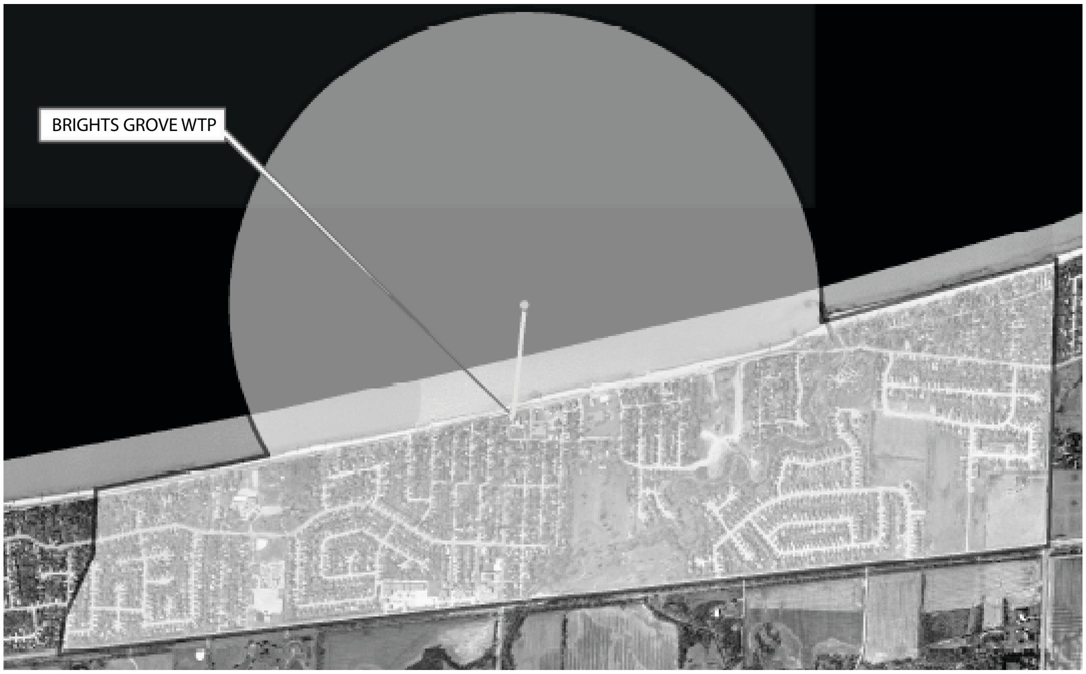

Figure 5.3.3-1: Town of Petrolia IPZ-1s

Work on the IPZ studies is ongoing and will take some time to complete. It is expected that the studies for all of the municipal water treatment plants will be completed in 2009. At this time, there are no IPZ delineation studies underway or planned for the First Nation intakes as part of Source Protection.

6.0 Existing Drinking Water Threats Inventories

A “drinking water threat” can be defined as an activity or condition (existing or future) that affects or has the potential to affect the quality or quantity of a drinking water source. This section of the report is intended to identify existing drinking water quality threats that have been inventoried as part of previous studies, reports and monitoring. The evaluation of these existing threats and the identification of new threats will be done as part of the ongoing work for Source Protection. Water quantity threats will be part of the Water Budget Report.

6.1 Threats to Water Quality

As noted in Section 5.0 Description of Vulnerable Areas, several studies of Intake Protection Zones are being conducted for surface water intakes supplying drinking water to communities in the St. Clair Region Source Protection Area.

The Ontario Ministry of the Environment has provided funding to complete groundwater studies throughout Ontario. The primary goals of these studies were to examine groundwater resources on a regional level, and to identify potential risks and issues related to groundwater resources.

The following groundwater studies provide summaries of the potential threats in the SPA:

- Essex Region/Chatham-Kent Region Groundwater Study
- Lambton County Groundwater Study
- Middlesex-Elgin Groundwater Study
- Strathroy-Caradoc Groundwater Management Study

The reports identified several land uses and human activities that have the potential to impact groundwater quality, including:

- Improperly abandoned water wells
- Oil and gas wells and pipelines
- Private sewage disposal systems (septic tanks)
- Underground storage tanks
- Use of nutrients, land application and storage
- Application of pesticides and herbicides
- Use and storage of road salt
- Spills
- Aggregate extraction and quarry operations
- Landfills
- Stormwater retention/detention facilities
- Industrial facilities and brownfield sites

The distribution of potential threats varies across the SPA. The majority of point source contaminant sources, such as fuel tanks, manufacturing facilities and PCB storage sites, are located in and around urban areas while waste disposal sites and salt storage locations are more broadly distributed. Information on the locations of potential threats was provided in several maps and tables that were prepared as part of the groundwater study reports.

6.2 Known Water Quality Issues

Issues regarding the quality of drinking water sources in the SPA are summarized below based on existing reports and information sources.

- The St. Clair River was listed in 1985 by the International Joint Commission (IJC) as an Area of Concern (AOC). One of the Beneficial Use Impairments (BUI) was "Restrictions on Drinking Water Consumption or Taste and Odour Problems" due to spills from industries. There were no water treatment plant closures between 1994 and 1997, thus meeting the delisting criteria for the drinking water BUI. However, the status of this BUI requires re-assessment due to reports that a number of facilities in the Sarnia industrial sector had allowed potentially harmful chemicals to spill into the St. Clair River since 2000.
- The Sydenham River was a source of drinking water for the communities of Alvinston and Dresden for many years, until the local treatment plants were replaced by a piped water supply from the Lambton Area Water Supply System (Alvinston) and the Chatham Water Treatment Plant (Dresden). The water quality from the Sydenham River and the need to upgrade the treatment plants to meet drinking water standards were among the concerns that led to these changes.
- The Strathroy-Caradoc Groundwater Management Study identified the nitrate content of the groundwater in the Caradoc Aquifer as a significant concern. Nitrates are usually considered to be associated with septic systems or agricultural activities.
- The Provincial Groundwater Monitoring Network (PGMN) has found some parameters that have concentrations above acceptable levels in some monitoring wells in the St. Clair Region. Fluoride (>1.5 mg/L), boron (>5 mg/L), selenium (>.01 mg/L) and sodium (>200 mg/L) are the only parameters that exceed health related standards in the SCRCA watershed. Two other parameters, iron and manganese, are above the aesthetic levels.

7.0 Summary of Identified Issues and Concerns

An "issue" is the realization of a threat within a drinking water source. For water quality, it is represented by exceedences of certain benchmarks such as water quality standards or increasing trends in water quality parameters. For water quantity, the term "stress" can be equated to the term "issue" for water quality.

"Concerns" are different from issues in that they may not be supported by scientific information such as monitoring results. Concerns may represent potential problems for drinking water sources but need further evaluation to determine if they are significant.

7.1 Identified Issues

Issues that have been identified as part of this report include:

- Inland surface water quality in the Sydenham River
- Spills and other discharges to the St. Clair River
- Nitrates in overburden source groundwater
- Bacteria in groundwater and surface water sources
- Chemical parameters, for example fluoride in groundwater
- Temperature of surface water sources in summer
- Phosphorus in surface water sources

7.2 Identified Concerns

Concerns will be identified as part of public consultation and stakeholder involvement in the source protection process. Some concerns may also be identified by a review of previous public discussions. For example, **Table 7.2-1: Threats to Drinking Water Quality** provides a summary of potential threats identified by the National Water Research Institute.

Table 7.2-1: Threats to Drinking Water Quality

1. Waterborne pathogens
2. Algal toxins and taste and odour problems
3. Pesticides
4. Persistent organic pollutants and mercury
5. Endocrine disrupting substances
6. Nutrients - nitrogen and phosphorus
7. Aquatic acidification
8. Ecosystem effects of genetically-modified organisms
9. Municipal wastewater effluents
10. Industrial point source discharges
11. Urban runoff
12. Landfills and waste disposal
13. Agricultural and forestry land use impacts
14. Natural sources of trace element contaminants
15. Impacts of dams/diversions and climate change