

*Thames-Sydenham and Region  
Watershed Characterization Summary Report*

**Thames Watershed & Region**  
(Upper Thames River & Lower Thames Valley Source Protection Areas)

**December 2008**

Prepared by --



**UPPER THAMES RIVER  
CONSERVATION AUTHORITY**

-- in cooperation with --



**Ontario**

Made possible through the support  
of the Government of Ontario



## Table of Contents

*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 2.7-2, 2.7-3, 3.1-1, 4.1-10 and 4.1-11, which were created for the summary only and are not included in the full report.*

Table of Contents .....	i
List of Tables .....	i
List of Figures .....	ii
List of Maps .....	ii
1.0 Introduction .....	1
2.0 Watershed Description .....	3
2.1 Source Protection Region .....	3
2.2 Physical Description .....	4
2.3 Hydrology (and Climate) .....	7
2.4 Naturally Vegetated Areas .....	12
2.5 Aquatic Ecology .....	13
2.6 Human Characterization .....	15
2.7 Water Uses .....	17
3.0 Water Quality .....	21
3.1 Selecting Indicator Parameters .....	21
3.2 Raw Water Characterization for Inland Surface Water .....	22
3.3 Groundwater Quality .....	25
3.4 Raw Water Characterization for Drinking Water Intakes .....	32
4.0 Water Quantity .....	37
5.0 Description of Vulnerable Areas .....	41
6.0 Existing Drinking Water Threats Inventories .....	43
6.1 Threats to Water Quality .....	43
6.2 Known Water Quality Issues .....	44
7.0 Summary of Identified Issues and Concerns .....	45
7.1 Identified Issues .....	45
7.2 Identified Concerns .....	45
Maps	

### List of Tables

Table 2.2.4-6	Percentages of Soils in the Thames Watershed & Region .....	5
Table 2.3.1.2-3	Thames Region Annual Precipitation 1950-2005 in mm .....	8
Table 2.4.3-3	LTVCA Subwatersheds with greater than 30% Woodland/ Forest Cover .	13
Table 2.7-1	Number of Water Taking Permits by Sector - Thames Watershed & Region .....	17
Table 2.7-2	Municipal Groundwater Systems .....	18
Table 2.7-3	Intakes Servicing the Thames Watershed & Region .....	19
Table 3.1-1	Water Quality Parameter Examples .....	21
Table 3.3-1	Range of Parameters in Thames PGMN Wells for 2002-2006 .....	27
Table 4.1-1	Number of Water Taking Permits by Sector - Thames Watershed & Region .....	38
Table 4.1-10	Water Treatment Plant Capacities .....	39
Table 4.1-11	Municipal Groundwater Systems & Wells .....	39
Table 7.2-1	Threats to Drinking Water Quality .....	45

# Watershed Characterization Summary Report

## Thames Watershed & Region

### List of Figures

Figure 2.2.1-1	Structural Elements .....	4
Figure 2.2.5-1	Thames River Profile .....	6
Figure 2.3.1.2-8	Thames Watershed & Region Average Annual Temperature 1950-2005 ..	7
Figure 2.3.1.2-3	Thames Watershed & Region Annual Precipitation 1950-2005 .....	8
Figure 2.3.3-1	Potential Evapotranspiration, Precipitation and Discharge for the Thames River above Thamesville .....	10
Figure 3.2.4-1	Box and Whisker Plot .....	22
Figure 3.3.4.1-1	Coliform Bacteria Subgroups .....	30

### List of Maps

Map 1:	Thames-Sydenham & Region Source Protection Region .....	49
Map 2:	Major Subwatershed Delineations .....	50
Map 3:	Bedrock Topography .....	51
Map 4:	Bedrock Geology .....	52
Map 5:	Overburden Thickness .....	53
Map 6:	Surficial Geology .....	54
Map 7:	Physiography .....	55
Map 8:	Soils Information .....	56
Map 9:	Ground Surface Elevation .....	57
Map 10:	Environment Canada Climate Monitoring Stations .....	58
Map 11:	Climate Monitoring Network .....	59
Map 12:	Bedrock Water Table .....	60
Map 13:	Water Table Elevation .....	61
Map 14:	Areas of Potential Groundwater Discharge .....	62
Map 15:	Provincial Groundwater Monitoring Network .....	63
Map 16:	Permit to Take Water by Location .....	64
Map 17:	Permit to Take Water General Purpose of Taking .....	65
Map 18:	Intrinsic Susceptibility Index .....	66
Map 19:	Agricultural Tile Drains .....	67
Map 20:	Watercourse Classification (UTRCA) .....	68
Map 21:	Stream Flow and Water Level Monitoring Stations .....	69
Map 22:	Watercourse Dams and Barriers .....	70
Map 23a:	Percent Wetland Cover (UTRCA) .....	71
Map 23b:	Percent Wetland Cover (LTVCA) .....	72
Map 24:	Percent Riparian Woodland Cover (UTRCA) .....	73
Map 25a:	Percent Woodland Cover (UTRCA) .....	74
Map 25b:	Percent Woodland Cover (LTVCA) .....	75
Map 26:	Fish Sampling Locations .....	76
Map 27:	Mussel Sampling Locations .....	77
Map 28:	Benthic Monitoring Sampling Sites .....	78
Map 29:	Species At Risk (SAR) .....	79
Map 30:	Generalized Land Cover .....	80
Map 31:	Oil and Gas Wells .....	81
Map 32:	Transportation .....	82
Map 33:	Land Capability for Agriculture .....	83
Map 34:	Water Well Record Locations .....	84
Map 35:	Municipal Wellhead Protection Areas .....	85
Map 36:	Wastewater Treatment .....	86
Map 37:	Surface Water Quality Sampling Sites .....	87
Map 38:	Drinking Water Supplies/Intakes .....	88

## **1.0 Introduction**

The Thames Watershed & Region includes the Thames River drainage basin and several smaller watercourses that drain directly to Lake Erie or Lake St. Clair.

The Watershed Characterization Report is one of the first steps in the development of Source Protection Plans, as recommended by Justice O'Connor 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.

The Watershed Characterization Report summarizes information on the physical, social and economic characteristics of the Thames Watershed & Region. It also reviews water quality and summarizes known issues and concerns pertaining to drinking water sources. A series of maps have 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, St. Clair River and Lake Huron. The SPR extends out from the shorelines to the international boundary.

The Thames Watershed & Region is the combined watershed area associated with the Upper Thames River Source Protection Area and the Lower Thames Valley Source Protection Area. It stretches from Lake St. Clair in the west, to the headwaters of the Thames River in Oxford and Perth Counties in the east.

In addition to the Thames River drainage, the Thames Watershed & Region includes a small triangle of land north of the mouth of the Thames River that drains to Lake St. Clair, and a long, narrow strip of land south of the Thames River that drains to Lake Erie. **Map 2: Major Subwatershed Delineations** shows the drainage basins for Lake St. Clair, Lake Erie, and the Thames River. On the map, the drainage for the river is divided to show the lands that drain to the main river and the watershed areas that drain to each of the three upper branches.

The Upper Thames River Source Protection Area includes all areas draining into the Thames River above the community of Delaware. This area covers large parts of Oxford, Perth and Middlesex Counties, including most of the City of London. Very small portions of Huron and Elgin Counties also drain into the upper Thames River. The SPA covers approximately 3,423 square kilometres with a total watershed population (2001) of about 472,000.

The Lower Thames Valley Source Protection Area includes those lands draining into the Thames River from the community of Delaware to Lake St. Clair. It also includes the lands that drain into Lake Erie lying south of the lower Thames River watershed and a small triangle of land north of the mouth of the Thames draining directly into Lake St. Clair. This area includes most of the municipality of Chatham-Kent, the western portion of Elgin County, part of southwestern Middlesex County (including some of the City of London) and a portion of eastern Essex County. The area covers approximately 3,274 square kilometres with a total watershed population (2001) of about 107,000.

Five First Nations are located in the Lower Thames Valley Source Protection Area watershed, including Caldwell First Nation, Chippewas of the Thames First Nation, Delaware First Nation, Munsee-Delaware First Nation and Oneida Nation of the Thames.

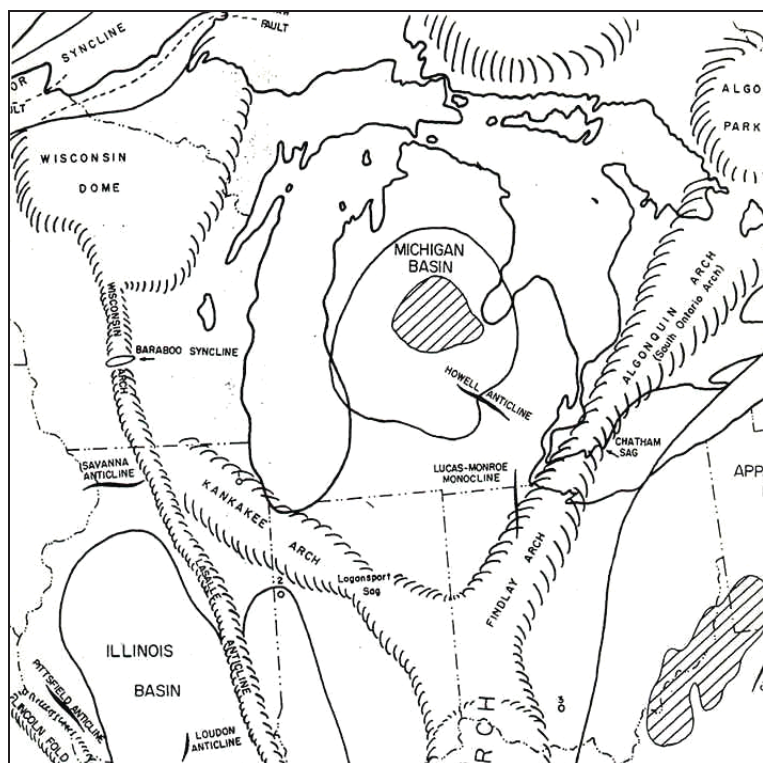
## 2.2 Physical Description

### Bedrock Geology

Most of the region lies on the crest of the broad Algonquin Arch, which is a basement ridge forming the spine of the southwestern Ontario peninsula. As shown in **Figure 2.2.1-1: Structural Elements**, the Findlay-Algonquin Arch separates the Michigan Basin and the Appalachian Basin.

These basins served as catchment areas for sediments and, over time, the sediments became bedrock layers that cover the arches. Thus, the Canadian Shield is buried deep beneath Paleozoic sedimentary rocks in southwestern Ontario. Several of these geologic formations thin as they cover the Algonquin Arch. On the eastern edge of the Michigan Basin, the bedrock units exhibit a regional dip (slope) of 0.2% to the southwest. In the southeastern portion of the region, the bedrock units near Lake Erie exhibit a regional dip of 0.5% to the south.

The bedrock topography of the area is shown in **Map 3: Bedrock Topography**. The region's highest elevations are in the northeast in Perth County. The lowest bedrock surface elevations correlate with the shorelines of Lake St. Clair and Lake Erie. There is a bedrock valley in the Mount Brydges/Strathroy area that runs from Lake Huron south to Lake Erie. The bedrock topography is also slightly depressed in the Chatham area between Lake St. Clair and Lake Erie.



**Figure 2.2.1-1: Structural Elements**

As a result of the sloping nature of the bedrock units, there are several different types of bedrock in the region. **Map 4: Bedrock Geology** provides an overview of the different types of bedrock formations across the region. These include the Salina Formation, Bass Island Formation, Bois Blanc Formation, Detroit River Group, Dundee Formation, Hamilton Group, Kettle

Point Formation, and Marcellus Formation. The bedrock is covered with overburden material consisting mainly of deposits that were associated with geologically recent glacial activity.

### Surficial Geology

The depth of the local overburden covering the bedrock is shown in **Map 5: Overburden Thickness**. The type and amount of overburden covering the bedrock 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 the lakes. Clay and silt plains were formed in the deeper, quiet water basins of 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.

### Soil Characteristics

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 the decay of leaves and wood associated with the growth of hardwood trees. **Map 8: Soils Information** shows the soil types across the region. There are some recent (post glacial) deposits of organic overburden (peat, muck and marl) 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.

**Table 2.2.4-6: Percentages of Soils in the Thames Watershed & Region** provides a comparison of the soil types in the total watershed and the individual CA areas. There is a distinct difference between the two Conservation Authority watershed areas, with much higher percentages of silt and clay type soils in the LTVCA area. The high percentage of “Not Mapped” reflects the larger urban communities in the region.

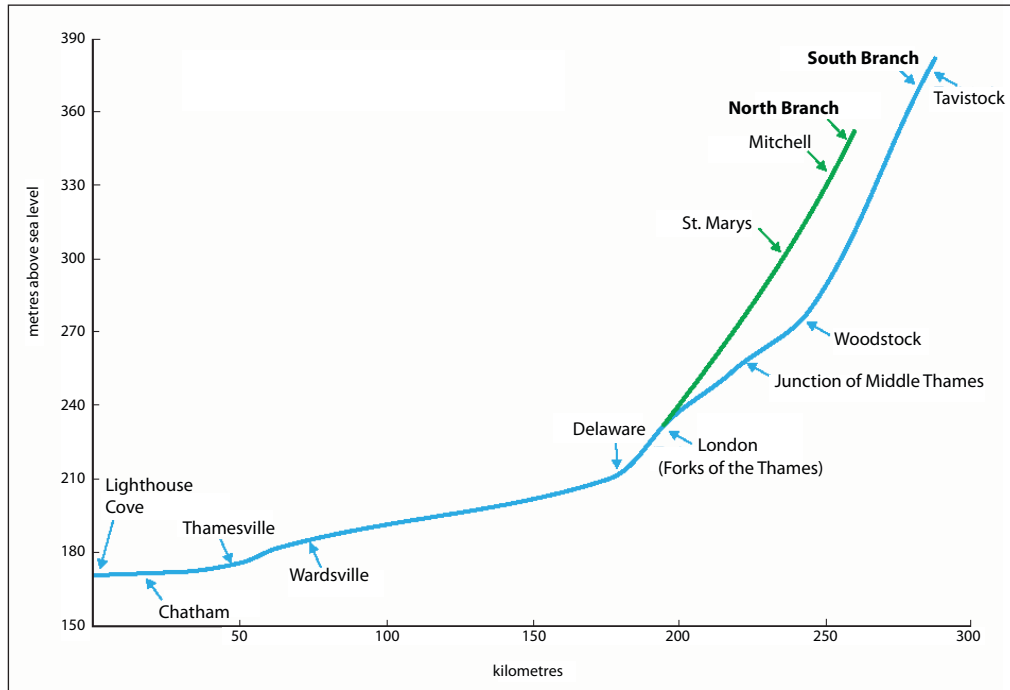
**Table 2.2.4-6: Percentages of Soils in the Thames Watershed & Region**

General Soil Grouping	Percentage (%)		
	Thames Region	LTVCA	UTRCA
Silt & Clay	39	51	26
Sand Loams	16	24	7
Silt & Clay Loams	25	12	39
Loams	9	4	15
Bottom Land & Beach	3	4	3
Organic	1	0	2
Not Mapped & Other	7	5	8
Total	100	100	100

### Topography

The topography of the land was formed by the retreat of the Wisconsin Glacier, about 14,000 years ago. **Map 9: Ground Surface Elevation** provides an overview of the Thames Watershed & Region topography.

The Thames River rises at three distinct points near Mitchell (North Thames), Hickson (Middle Thames) and Tavistock (South Thames). The Middle Branch is approximately 26 km long. It joins the South Branch, which is 86 km long, east of the City of London. The South Branch continues west to meet the North Branch, which is 77 km long, at the Forks in London. From there, the river flows 187 km southwest before it empties into Lake St. Clair at Lighthouse Cove. **Figure 2.2.5-1: Thames River Profile** shows the difference in elevation across the Thames River basin.



**Figure 2.2.5-1: Thames River Profile**

The upper Thames drainage pattern is a random network of tributaries reaching out like the branches of a tree. The smaller tributaries collect into three branches (North, Middle and South) that join together to form the main river. The upper branches of the river flow through ancient glacial spillways. Today they are termed *misfit* or *underfit* streams, which means the modern watercourses are too small to have cut the valleys they currently occupy. The river beds are rocky and the valley slopes are steep.

In contrast, the lower Thames River has carved its own channel into flat plains of clay and sand. Here, the river bed is soft and the water flow is gentle. Due to the long, narrow shape of the lower Thames watershed, most of the tributaries that enter it are short and steep with relatively mature tributary valleys carved into the sand and clay plains. Downstream of Chatham, the river is shallowly entrenched below the old lake plain and dykes have been constructed to control flooding of the adjacent lands.

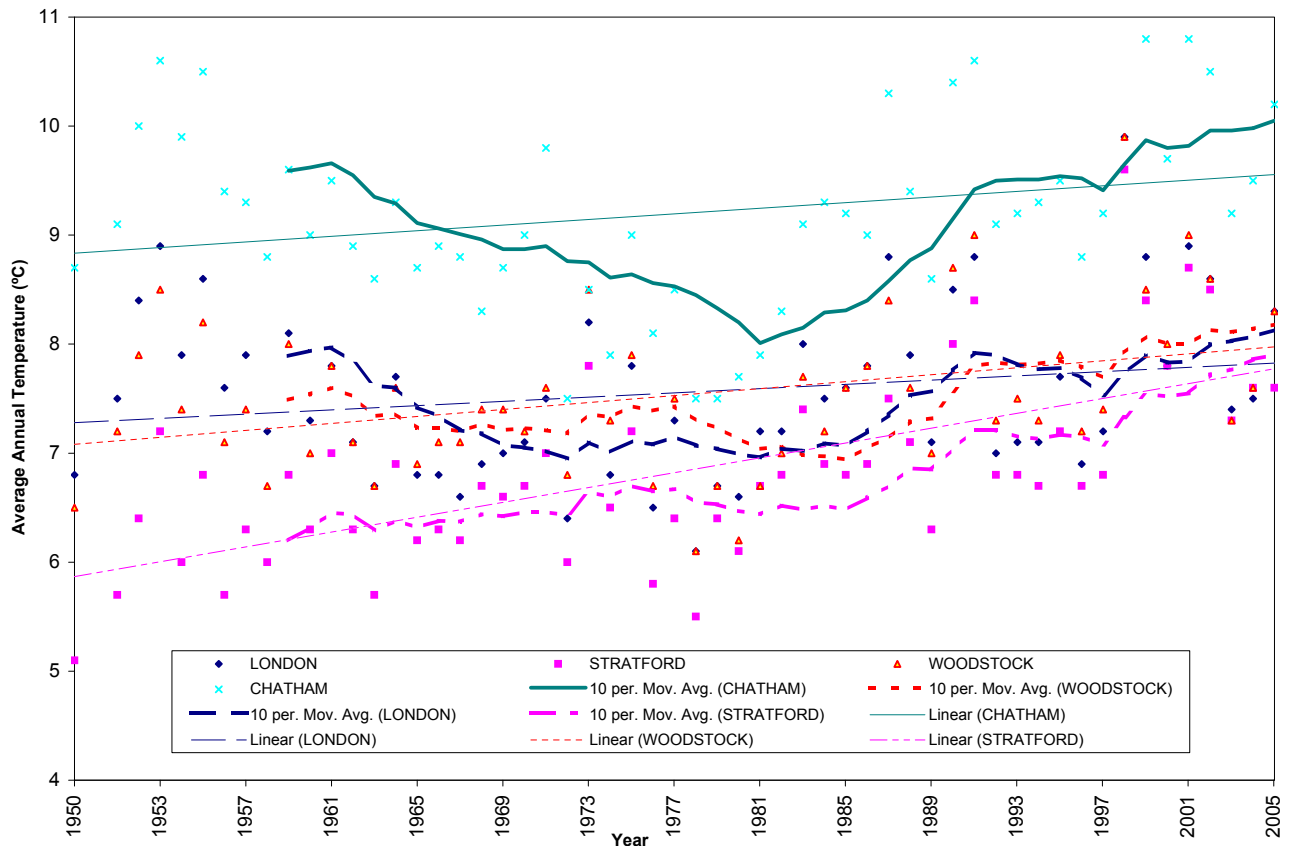
A height of land divides the lower Thames River and Lake Erie watersheds. The distance from the height of land to the lake is up to 12 kilometres in the eastern part of the LTVCA watershed and as little as 100 metres at points in the western portion. In the east, this narrow watershed is drained into the lake by numerous short watercourses with deep valleys cut into sand and clay plains. In the west, the Rondeau Bay watershed is somewhat different. This land falls relatively evenly to the Bay and the streams have a much shallower profile.

North of the mouth of the Thames, the land beside Lake St. Clair has little relief and is drained via numerous small creeks or drains constructed under the Drainage Act. All of the drains are pumped into Lake St. Clair.

## 2.3 Hydrology (and Climate)

Water levels vary from season to season and from year to year because of the combined effects of precipitation, runoff and evaporation. Hydrology and climatic conditions are monitored locally by a combination of Environment Canada monitoring stations shown in **Map 10: Environment Canada Climate Monitoring Stations** and Conservation Authority monitoring stations shown in **Map 11: Climate Monitoring Network**.

The average annual temperatures for the Stratford, Woodstock, London, and Chatham climate stations have been plotted and are shown in **Figure 2.3.1.2-8: Thames Watershed & Region Average Annual Temperature 1950-2005**. (Individual station plots are presented in the report.)



**Figure 2.3.1.2-8: Thames Watershed & Region Average Annual Temperature 1950-2005**

The 10 year running averages and linear lines of best fit are shown to try to smooth out year to year fluctuations and capture possible trends. Both the linear trend line and the 10 year running averages show increasing temperature trends for all of the stations. The most southerly station, Chatham, has higher 10-year averages and linear trend lines than the other stations. The London and Woodstock stations have relatively similar temperature values. The 10 year running average and linear trend line for Stratford is similar to London and Woodstock but shows slightly lower annual temperatures.

**Table 2.3.1.2-3: Thames Region Annual Precipitation** illustrates the variation in annual precipitation over the years from 1950 to 2005. Within the region, annual precipitation can vary by almost 2.5 times from year to year and station to station, which means that there can be a significant difference in the water available to recharge groundwater aquifers or maintain stream flow.

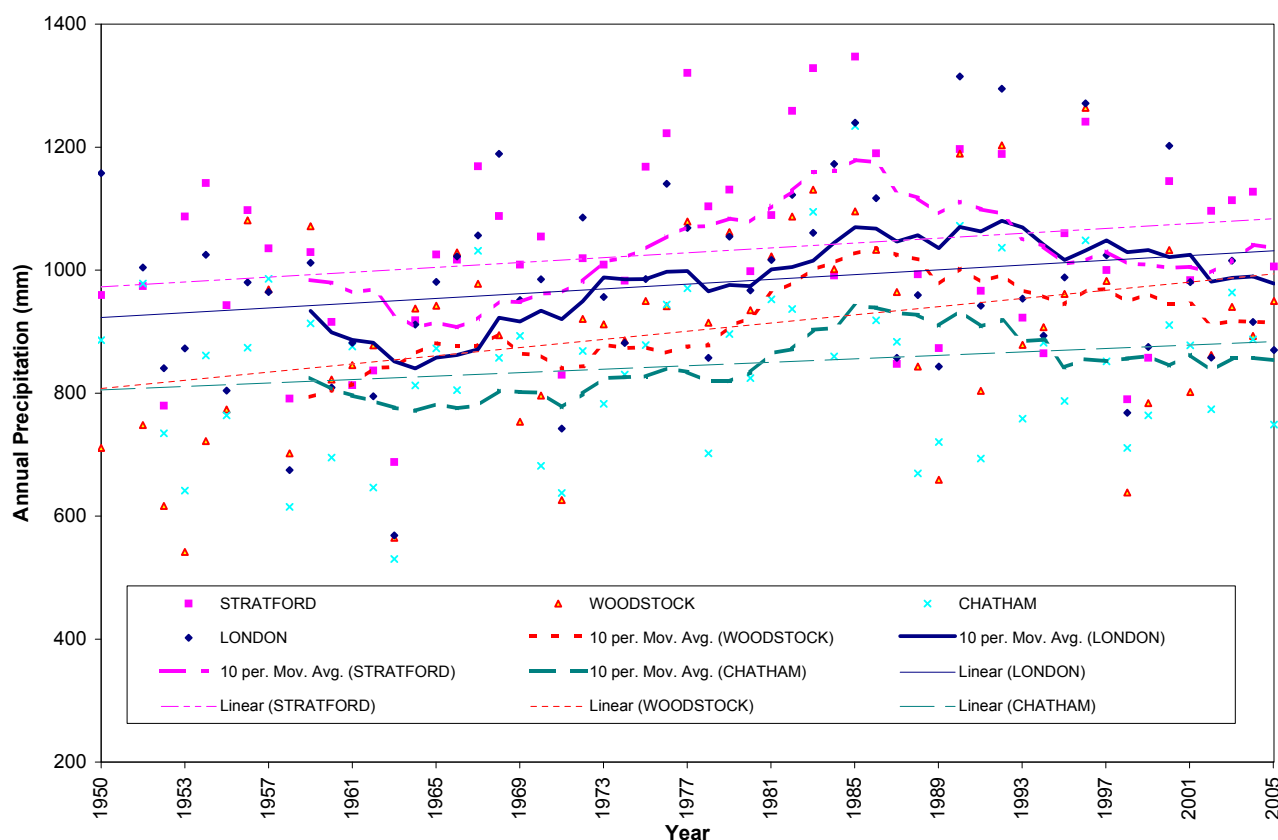
# Watershed Characterization Summary Report

## Thames Watershed & Region

**Table 2.3.1.2-3: Thames Region Annual Precipitation 1950-2005 in mm**

Location	Average	Max (year)	Min (year)
Chatham	845	1234 (1985)	530 (1963)
London	978	1315 (1990)	569 (1963)
Woodstock	902	1264 (1996)	542 (1953)
Stratford	1029	1347 (1985)	688 (1963)

Environment Canada data from 1950 to 2005 has also been used to plot graphs of the total annual precipitation for the Stratford, Woodstock, London, and Chatham climate stations. These plots are shown in **Figure 2.3.1.2-3: Thames Watershed & Region Annual Precipitation 1950-2005**. (Individual plots for each station are presented in the full report.)



**Figure 2.3.1.2-3: Thames Watershed & Region Annual Precipitation 1950-2005**

As a way to smooth out the year to year fluctuations while trying to capture trends, 10 year running averages have been calculated and plotted on the graphs. In general, the 10 year running averages appear to show an increasing level of precipitation in the 1970s and early 1980s, with decreases more recently. The linear trend lines are also shown for each station. All stations (Chatham, London, Stratford and Woodstock) have increasing linear trend lines.

### Groundwater Hydrogeology

Precipitation is the primary source of groundwater recharge. Groundwater recharge is determined by three factors: the amount of precipitation that is not lost by evapotranspiration and runoff; the vertical hydraulic conductivity of the surficial deposits (the ability of 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) that vary greatly in spatial extent and thickness. The 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, 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 region. **Map 13: Water Table Elevation** also provides information on groundwater elevations. The bedrock water table elevation across the combined watersheds of the Thames-Sydenham & Region ranges from 355 to 170 metres above sea level (masl).

### Groundwater Monitoring

Historically, the Ministry of the Environment monitored groundwater levels at about 450 observation wells throughout the province. The original monitoring network existed between 1946 and 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 Upper Thames River Conservation Authority has 22 wells in the PGMN system and the Lower Thames Valley Conservation Authority has 12 wells. The locations of the wells are shown in **Map 15: Provincial Groundwater Monitoring Network**. Wells in the monitoring network vary in depth, elevation and geology between bedrock and overburden wells.

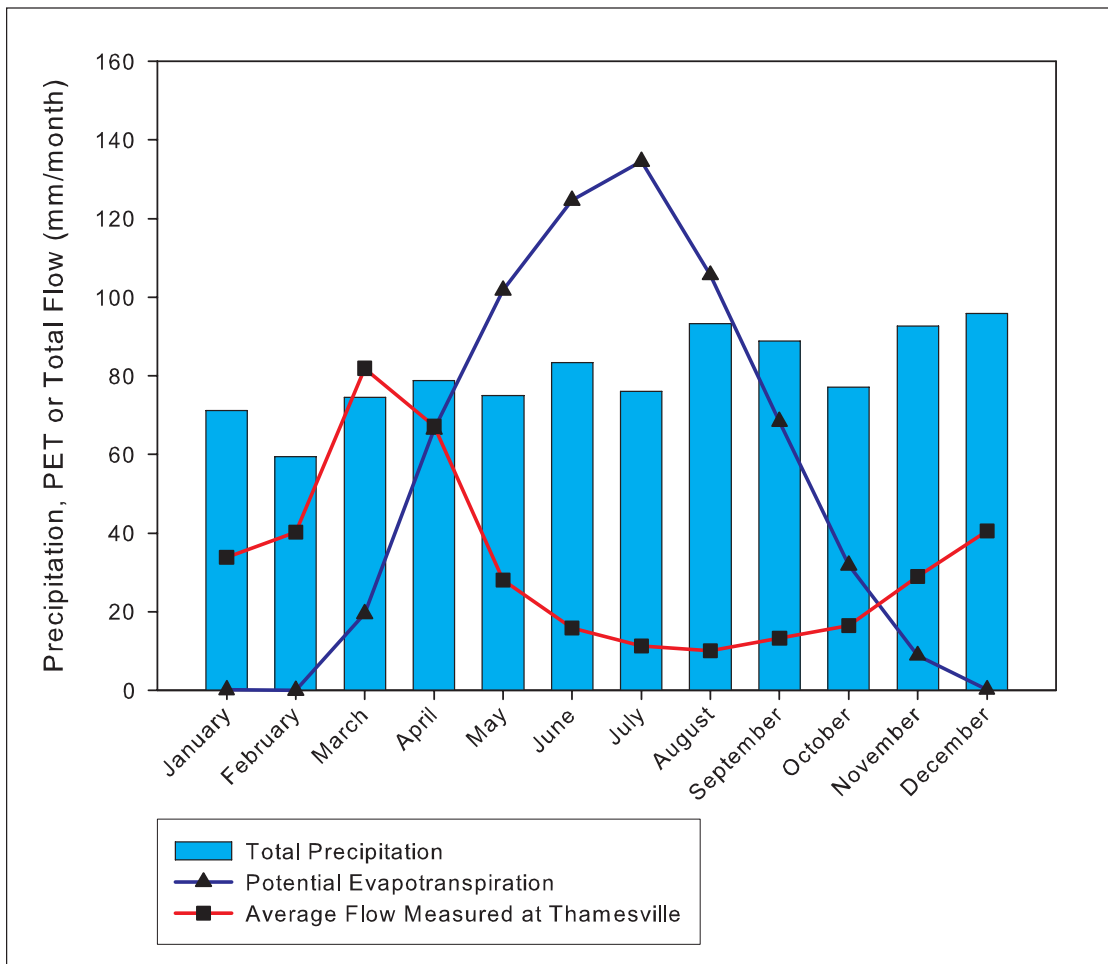
### Surface Water - Groundwater Interactions

In rivers and subwatersheds, stream flow measured during low flow (base 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 14: Areas of Potential Groundwater Discharge** shows zones of potential discharge within the watershed.

### Surface Water Hydrology

On average, approximately 60% of precipitation that falls on the Thames basin infiltrates into the ground, evaporates or is evapotranspired by plants. The remaining 40% ends up as flow in the river. In the upper Thames basin, flow in the river is comprised of approximately 40% surface water runoff and 60% base flow. In the lower portion of the Thames River, the flow is 60% surface runoff and 40% base flow. In addition to groundwater, base flow includes contributions from tile drains, flow augmentation from reservoirs and treated sewage effluent discharge.

**Figure 2.3.3-1: Potential Evapotranspiration, Precipitation and Discharge for the Thames River above Thamesville** plots monthly precipitation, potential evapotranspiration, and stream flow measured at the Thamesville stream gauge.



**Figure 2.3.3-1: Potential Evapotranspiration, Precipitation and Discharge for the Thames River above Thamesville**

During the spring, peak flows occur as a result of the combination of spring rains and snow melt. There is very little evapotranspiration and most available water shows up as flow at Thamesville. During the summer when the potential evapotranspiration losses exceed precipitation, flows in the river decrease. In the fall, as evapotranspiration decreases, flows in the river begin to increase.

### Watercourse Classification

Agricultural land use practices have significantly modified the natural surface water drainage patterns in the Thames River watershed. Agricultural ditches have been an integral part of Southwestern Ontario’s watercourses since the 1800s. **Map 19: Agricultural Tile Drains** provides an overview of drainage in the watershed. The agricultural drains provide significant fish habitat and make a substantial contribution towards sustainable fisheries. Drain maintenance activities can alter essential fish habitat components by changing riparian vegetation, substrate composition and width to depth ratios. The resiliency of drains can be categorized according to flow, temperature, fish species present, and stability.

Due to the demand for the maintenance of municipal drains and the requirement for Fisheries Act approval, several agencies have developed a Fisheries Act Class Authorization Process. Aquatic biologists assessed the sensitivity of fish habitat in open municipal drains based on stream flow (permanent or intermittent), water temperature (warm or cool/cold water), habitat, and indicator fish species (baitfish, trout, pike, bass, etc.).

**Map 20: Watercourse Classification (UTRCA)** illustrates the classifications that differentiate between municipal drains, natural watercourses (non-municipal drains) and tiled (closed surface) watercourses. There are approximately 47% open municipal drains, 28% natural or non-municipal drains, and 25% tiled watercourses in the UTRCA watershed.

In the UTRCA watershed, most (about 61%) of the watercourses are permanent warm water systems, almost equally divided between natural watercourses (31%) and municipal drains (30%). About 30% of the watercourses are intermittent watercourses that are dry for most of the year. Only 2% of the intermittent systems are considered natural, while 28% are municipal drains. Approximately 10% of the watercourses are permanent cold/cool water streams with less than half considered to be natural.

In the LTVCA portion of the region, 852 habitat assessments were completed throughout the watershed to gather information and help classify the local watercourses. There were 328 warm water, one cold water and 513 intermittent habitat classifications. There were 36 assessments that suggested that further information regarding fisheries was required. At 19 of the 36 sites, sampling for fish found suitable habitat and water quality for sensitive species.

The location of the many stream gauges operated within the Thames River watershed is provided on **Map 21: Stream Flow and Water Level Monitoring Stations**. Dams and barriers in the region are shown in **Map 22: Watercourse Dams and Barriers**.

### **Floodway Area**

The Upper Thames River Conservation Authority is responsible for the regulation of approximately 500 km<sup>2</sup> of river valley lands, which is predominantly the flood plain of the Thames River and its major tributaries. The major flood prone areas in the upper Thames River basin are generally all on the main branches of the river. These include the communities of Mitchell, St. Marys, Ingersoll, London, Woodstock and, to a lesser extent, Stratford. There are some additional smaller flood prone areas along tributary watercourses.

Fanshawe Dam is a large flood control structure in the upper Thames watershed located near the outlet of the North Thames River. Wildwood Dam upstream of St. Marys and Pittock Dam in Woodstock are both large structures that have the dual purposes of flood control and flow augmentation.

The Lower Thames Valley Conservation Authority is responsible for the regulation of the flood prone areas in the lower Thames River watershed. From just above Thamesville downstream to Chatham, the river definitely leaves its banks under Regulatory Flood conditions. Both Thamesville and Chatham are urban centres that require special flood plain policies to remain socially and economically viable. The largely rural area below Chatham to the mouth of the Thames also requires flood protection and development controls.

The Indian/McGregor Creek Dam located in Chatham is designed to protect the south part of the community from cresting flood waters in the Thames River. It does not act as a “true” dam since flows from the upstream watershed normally pass through the structure. The gates for the dam are closed when flood level flows come down from the upper Thames watershed.

Significant areas within the LTVCA are flood prone due to flooding along the Lake Erie and Lake St. Clair shorelines. Shorelines along large inland lakes are subject to flooding, erosion and dynamic beach hazards. A shoreline classification system has been developed to determine the factors and processes that influence the severity of potential hazards. Flooding on the Great Lakes can be caused by weather systems with sustained high winds from critical directions. These conditions are worsened if the lakes are also at high lake levels.

## 2.4 Naturally Vegetated Areas

Environment Canada (2004) recommends over 10% of each major watershed and 6% of subwatersheds be in wetland habitat. It is also recommended that wetlands be restored to the original percentage in the watershed if possible.

The original amount of wetland cover in the UTRCA watershed is unknown. The vast majority of the remaining wetlands in the Upper Thames River Conservation Authority are classified as deciduous swamps or mixed deciduous-coniferous swamps that are dominated by trees and shrubs such as silver maple, ash, willow, dogwood and cedar. The total area of wetland cover (evaluated wetlands) is about 57 sq. km and is less than 2% of the conservation authority's watershed area. **Map 23a: Percent Wetland Cover (UTRCA)** shows the location of the 81 evaluated wetlands within the watershed and the percentage of wetland coverage for each of the subwatersheds.

Within the Lower Thames Valley Conservation Authority watershed, a total of 50 known wetlands have been identified. Elgin and Middlesex Counties have a majority of upland treed swamps, while Chatham-Kent and Essex have marsh habitats due to the low lying nature of the lands adjacent to Lakes Erie and St. Clair. **Map 23b: Percent Wetland Cover (LTVCA)** provides an overview of the wetlands for each subwatershed. Wetlands make up 49.7 sq. km or 1.5% of the LTVCA watershed area.

### Riparian Zone

The area of land adjacent to streams is often called the riparian zone or buffer zone. Natural or permanent vegetation adjacent to streams and rivers improves conditions for aquatic health. Environment Canada (2004) recommends that streams have at least a 30 metre wide naturally vegetated area on both sides. It also recommends that 75% of stream length be naturally vegetated.

**Map 24: Percent Riparian Woodland Cover (UTRCA)** shows the estimated cover for each subwatershed. The values ranged from a low of 6.1% to a high of 31.8% with an overall average of 21.14%. The lowest riparian woodland/forest cover occurs in the headwaters area of the North Branch of the Thames River in rural Perth County (North Mitchell and Whirl Creek subwatersheds). The highest cover is in the Dorchester watershed east of London and the River Bend and Oxbow Creek watersheds west of London.

There is a wide variation in the amount of riparian cover in the Lower Thames Valley Conservation Authority watershed. In the eastern part of the area, there are many incised watercourses that cut through the more elevated surrounding lands. These result in extensive riparian cover as these ravines are unsuited for urban or rural development. In the western part (from approximately Thamesville to the mouth of the Thames River at Lake St. Clair), the low gradient has resulted in minimal buffers adjacent to stream systems as the land adjacent to the watercourses is more accessible. Channels that used to meander have been straightened to allow for straighter row-cropping and for urban development, with little if any riparian cover.

### Woodlands/Forest

Forests provide numerous functions including protecting and building the soil, giving off oxygen and absorbing air pollutants, moderating local climate, protecting groundwater and providing habitat for wildlife. Environment Canada (2004) recommends at least 30% of a given watershed be in forest cover, primarily to support wildlife species.

Hardwood forests covered the majority of the upper Thames River watershed prior to European settlement with smaller pockets of grassland and savanna habitat. Today, the woodland/forest cover is highly fragmented, existing as small woodlots separated by agricultural fields, urban development and other land uses.

**Map 25a: Percent Woodland Cover (UTRCA)** illustrates the distribution of woodlots across the upper Thames watersheds. The subwatersheds are colour-coded according to the range of percent woodland/forest cover they possess. The overall percent woodland/forest cover in the upper Thames watershed is approximately 12% and the individual subwatersheds have values ranging from 5 to 21%. The subwatershed with the highest amount of woodland/forest cover is Dorchester, owing to the presence of the large Dorchester Swamp and North Dorchester Swamp complexes. The lowest amount of woodland/forest cover (4.9%) is in the North Mitchell watershed which is the headwaters of the North Branch of the Thames in Perth County.

**Map 25b: Percent Woodland Cover (LTVCA)** illustrates the distribution of woodlots across the watershed. There are approximately 426 sq. km of woodland/forest cover within the entire LTVCA watershed, equating to 13% of the total watershed. In the LTVCA watershed, there is a dramatic difference between the counties of Elgin and Middlesex in the east, and Essex and Chatham-Kent in the west. Woodland/forest cover ranges from 18% in Elgin County and 12% in Middlesex, to 7% in Essex and less than 3% in Chatham-Kent.

Several LTVCA subwatersheds not only meet the 30% recommendation of Environment Canada, but well exceed it as shown in **Table 2.4.3-3: LTVCA Subwatersheds with greater than 30% Woodland/Forest Cover**.

**Table 2.4.3-3: LTVCA Subwatersheds with greater than 30% Woodland/Forest Cover**

Subwatershed	Forest Cover (%)	Municipality
Brock Creek	49.5	West Elgin
Skunk's Misery area	39.7	Southwest Middlesex
Hookaway Drain & watershed	38.1	West Elgin
Millstream & watershed	34.6	Strathroy-Caradoc
Clear Creek	32.5	Chatham-Kent
Ashton Drain	30.0	Chatham-Kent

The emerald ash borer is a serious invasive species that has been found in several areas of southwestern and southern Ontario. 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 inhabit the waters of this region. There are records of 94 species of fish, 34 species of freshwater mussels, and 30 species of reptiles and amphibians. Twenty-seven of these aquatic species have been federally designated as Species At Risk (SAR).

### Fish

**Map 26: Fish Sampling Locations** illustrates locations of both recent (1997 - 2004) fish sampling efforts and historic work recorded in the Royal Ontario Museum (ROM) database from various sources.

The Thames River and its tributaries support one of the most diverse fish communities in Canada and the 94 recorded species represent more than half of all of Ontario's 165 species. Currently, 13 of the 94 species found throughout the Thames River watershed are considered Species At Risk. There have been 39 fish species found in the Lake St. Clair tributaries and 57 species in the Lake Erie tributaries of the LTVCA watershed.

## Mussels

Recent monitoring efforts indicate that the Thames River can still be characterized as a good freshwater mussel river. To date, 33 native species and 1 non-native species of freshwater mussels have been recorded in the Thames River watershed. **Map 27: Mussel Sampling Locations** shows the locations of recent (1990-2004) and historic (prior to 1990) sampling throughout the watershed.

Downstream of London to Chatham, the Thames River has a high diversity of mussels with abundant numbers. However, previous research indicated declines of 15-31% in the freshwater mussel species for the Thames River watershed and researchers have confirmed that five species of mussels are believed to no longer occur within the Thames River watershed.

At one point in time, mussel shells were harvested from the Thames River in large quantities. Even though they seem to no longer have an apparent economic significance, freshwater mussels are significant ecosystem monitors. Due to their sedentary nature, their filter-feeding, and their ability to accumulate substances, mussels have a significant role as biological indicators of ecosystem health. Habitat conditions (quality and quantity) determine the type of aquatic community that will occupy a given aquatic ecosystem.

## Aquatic Macroinvertebrates

Aquatic invertebrates, especially benthic macroinvertebrates (BMI) are abundant in all Thames reaches and tributaries. BMI are also 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 numerous 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 would indicate that chronic contamination, a spill or major habitat disturbance has removed the pollution-intolerant species. **Map 28: Benthic Monitoring Sampling Sites** shows the locations sampled between 1997 and 2004.

UTRCA has been monitoring the BMI community and conducting habitat assessments since 1994 at over 300 sites throughout the upper Thames watershed to capture data on the diverse habitat and water quality conditions. In the UTRCA watershed, the subwatershed benthic data indicates a moderate level of water quality impairment with most sites occurring in the “fair” or “fairly poor” categories. Of the BMI sampled, 72% are considered tolerant, 25% mid-tolerant and only 3% sensitive. A preliminary evaluation of the raw benthic data indicated that a correlation likely exists between groundwater discharge and the proportion of a site’s sample that consists of sensitive BMI.

In recent years, about 50 benthic samples have also been conducted at 40 sites on the portions of the lower Thames River that can be waded and its tributaries. However, the information collected for the LTVCA watershed has not been summarized.

## Species at Risk

The Thames Watershed & Region has a number of aquatic species that are listed as Extirpated, Endangered, Threatened or Special Concern. **Map 29: Species At Risk (SAR)** provides an overview of the number of species in the local subwatersheds. In the Thames River watershed, 27 aquatic species found have been identified as having Species at Risk (SAR) status. Lake Erie and the many tributaries that flow into it have approximately 19 species of fish, six species of freshwater mussels and 13 species of reptiles and amphibians listed.

Human migration has long served as a source of species introductions. Over 160 non-native species have been introduced to the Great Lakes watershed, either naturally, intentionally or accidentally, since the 1800s. 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 Thames include the common carp, goldfish, round goby and sea lamprey. Carp can have a direct impact on water quality by disturbing the sediment and creating a very turbid environment. Carp can also severely modify nearshore habitats and increase turbidity through their spawning behaviour.

In the Great Lakes, native freshwater mussel populations have been decimated by zebra mussels (*Dreissena polymorpha*), which are native to the Black and Caspian Sea region of Asia. Zebra mussels have been known to block pipes used for water intakes. Zebra mussels have been found in the Fanshawe Reservoir and have colonized the Thames River downstream of the Fanshawe Reservoir.

Most non-native invasive plant species that invade wetlands and other wet areas displace the diverse native plant populations with very dense monocultures. Common reed/giant reed (*Phragmites australis*) is probably the most aggressive wetland species in this region. Purple loosestrife (*Lythrum salicaria*) is another readily identifiable perennial that can rapidly degrade wetlands.

## 2.6 Human Characterization

Based on the 2001 Census, the population in the Thames Watershed & Region is over 550,000. Most of the population is located in urban centres that have more concentrated housing densities as shown on **Map 30: Generalized Land Cover**. The largest urban centre within the LTVCA watershed is the former City of Chatham, with an approximate population of 44,000, now a part of the Municipality of Chatham-Kent. In the UTRCA watershed, the largest urban centre is the City of London with a population of 336,539.

The Ontario Ministry of Finance indicates that the population of Southwestern Ontario is projected to grow by about 18% from 1,579,400 in 2006 to 1,857,700 in 2031. The Ministry predictions indicate that there will be significant differences in the growth rates across the region over the next 25 years. The Essex (23%), Middlesex (22%) and Elgin (20%) Census Divisions are expected to equal or exceed the provincial average. Oxford (17%) and Perth (16%) will have growth close to the provincial average of 18%. Huron (11%) and Lambton (4%) will have some growth. Chatham-Kent is expected to continue to see a population decline (-1%).

Some municipalities have indicated that their planning projects higher growth rates than that predicted by the Ministry of Finance. The Oxford County Official Plan predicts a higher growth rate of about 35% based on their projections. The Chatham-Kent Official Plan also predicts a growth rate of about 6% based on a proactive development strategy.

In the UTRCA portion of the watershed, the majority of the residential development is in the fully serviced urban cities, towns and large villages. In the LTVCA area, there are currently few areas of urban growth within the watershed other than Tilbury and the Lighthouse Cove area in the Town of Lakeshore. All other municipalities within the LTVCA's jurisdiction have projections of low, steady growth rates within the urban landscape over the next 20 year time span. **Map 36: Wastewater Treatment** shows the location of municipal sewage treatment facilities in the Thames Watershed & Region.

## Agriculture

Agriculture has a long history in the Thames Watershed & Region. This is one of the most productive agricultural regions in Canada, supporting a broad range of both specialized and intensive farming operations. As shown on **Map 33: 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. As shown on **Map 30: Generalized Land Cover**, agriculture accounts for more than 80% of the current land use. Over the last 40 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 land use. More recently, the size of individual farm operations has increased substantially.

## Industrial/ Commercial/ Transportation Land Use

While agriculture is the dominant land use, a wide variety of industrial, commercial and institutional land uses provide employment for most of the population. The City of London has a large, growing industrial sector that employs roughly 54,000 people between automotive and manufacturing jobs. Chatham-Kent has developed a strong industrial land base due to its proximity to Highway 401 and other major urban centres in Ontario and the United States. The new Toyota manufacturing facility currently being constructed in Woodstock is projected to employ 2,500 workers and this will increase the automotive sector component. Southwestern Ontario also has a long history related to the oil and gas industry. **Map 31: Oil and Gas Wells** shows the concentration of wells across the area.

Southwestern Ontario has an excellent transportation network with travel and transportation connections across Canada, North America and the world. Much of the development, urban and industrial, can be traced to the availability of water, rail and road transportation, and the availability of good transportation continues to be a major factor in industrial and commercial development activities across the region. **Map 32: Transportation** provides an overview of the transportation network for the Thames Watershed & Region.

## Significant Protected Areas

Specific areas are protected from developmental changes that could alter their natural character. This protection is designated through federal, provincial and local initiatives. Depending on the degree of protection, “protected areas” are not likely to change over time and will encounter minimal human disturbance.

In the LTVCA watershed, Rondeau Provincial Park and the St. Clair National Wildlife Area are two large protected areas.

There are several significant areas in the UTRCA watershed. The Ellice Swamp covers approximately 856 hectares and is the largest woodlot in Perth County. Golspie Swamp covers 295 hectares and represents the third largest forested area remaining in Oxford County. The Dorchester Swamp is a 548 hectare site that is recognized as a Class 1 Significant Wetland, a Carolinian Canada Site and an Area of Natural and Scientific Interest (ANSI). The Sifton Bog in the City of London is a Class 2 provincially significant wetland and the most southerly large acidic bog in Canada. Also in London, Westminster Ponds/Pond Mills Conservation Area covers approximately 300 hectares with six major ponds over an area 3 kilometres long and 1.5 kilometres wide.

## 2.7 Water Uses

Numerous human activities and ecosystems within the Thames Watershed & Region benefit from an essential supply of water. The abundance of local watercourses and the Great Lakes provides bountiful recreational opportunities to people in the region. Over one-third of the boundary of the LTVCA is comprised of Lake Erie or Lake St. Clair shoreline. The Thames River affords multiple recreational prospects to the residents due to its large size and length.

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 16: Permit to Take Water by Location** shows the locations of water takers that have water taking permits in the Thames Watershed & Region. **Map 17: Permit to Take Water General Purpose of Taking** shows the various types of water takers.

The number of permits for various water taking purposes (as listed in the MOE database) in the Thames Watershed & Region is summarized in **Table 2.7-1: Number of Water Taking Permits by Sector - Thames Watershed & Region**. The total number of PTTWs listed in the database for the area is 905. However, many of the permits still listed in the database have expired dates listed beside them and it is unclear if these permits have been updated or renewed. A more detailed review of water usage will be undertaken as part of the Water Budget Report.

**Table 2.7-1: 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, sod farm, tender fruit, tobacco	300	33%
Commercial	Aquaculture, bottled water, golf course irrigation, mall/ business, snowmaking	158	17%
Construction	Construction, road building	10	1%
Dewatering	Construction, pits and quarries	52	6%
Industrial	Aggregate washing, cooling water, food processing, pipeline testing, power production	92	10%
Institutional	Hospitals	1	0%
Miscellaneous	Dams and reservoirs, heat pumps, other – miscellaneous, pumping test, wildlife conservation	57	6%
Recreational	Aesthetics, other – recreational, wetlands	12	1%
Remediation	Groundwater, other – remediation	6	1%
Water Supply	Campgrounds, communal, municipal, water supply	217	24%

Groundwater is an important source of drinking water for rural residents throughout the region and for many urban communities, especially in Perth and Oxford Counties.

**Map 34: Water Well Record Locations** 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.

The locations of the municipal drinking water supply systems that use groundwater in the Thames Watershed & Region are shown on **Map 38: Drinking Water Supplies/Intakes**. Of the 25 municipal systems in the region, six are in Perth, 10 are in Oxford, seven in Middlesex/London and two are in Chatham-Kent. There are from one to 11 wells in each system. **Table 2.7-2: Municipal Groundwater Systems** gives the names of the systems and the number of wells in operation.

# Watershed Characterization Summary Report

## Thames Watershed & Region

The majority of the population in the Thames Watershed & Region is supplied with treated surface water from Lake Huron, Lake Erie and Lake St. Clair. **Table 2.7-3: Intakes Servicing the Thames Watershed & Region** provides a list of intakes and the water source. The treated water is transmitted through pipelines to residents across the region.

**Map 38** also shows the locations of the intakes for surface water sources and the communities using treated surface water. Three surface water intakes are located within the region, and four intakes are located outside the Thames Watershed & Region.

**Table 2.7-2: Municipal Groundwater Systems**

	System Name	Number of Wells	Source *
<b>Perth – systems are operated by individual municipality</b>			
1	Mitchell	3	Bedrock
2	Sebringville	1	Bedrock
3	Shakespeare	1	Bedrock
4	St. Marys	2	Bedrock
5	St. Pauls	1	Bedrock
6	Stratford	11	Bedrock
<b>Oxford – systems are operated by County of Oxford</b>			
1	Beachville-Loweville	1	Bedrock
2	Embro	2	Bedrock
3	Hickson-King	1	Bedrock
4	Ingersoll	7	Bedrock
5	Innerkip	2	Bedrock
6	Lakeside	1	Bedrock
7	Mount Elgin	1	Overburden
8	Tavistock	3	Overburden, Bedrock
9	Thamesford	3	Overburden, Bedrock
10	Woodstock	10	Overburden
<b>Middlesex – systems are operated by individual municipality</b>			
1	Birr	1	Overburden
2	Dorchester	8	Overburden, Bedrock
3	Melrose	2	Overburden
4	Kilworth Heights	3	Overburden
5	Mount Brydges	2	Overburden
6	Thorndale	2	Bedrock
7	City of London Back Up Wells*	7	Overburden
<b>Chatham-Kent – systems are operated by Municipality of Chatham-Kent</b>			
1	Highgate	2	Overburden
2	Ridgetown	6	Overburden

\* Note: Based on available information.

**Table 2.7-3: Intakes Servicing the Thames Watershed & Region**

System	Intake Source
Chatham Water Treatment Plant*	Lake Erie
South Chatham-Kent Water Treatment Plant*	
West Elgin Water Treatment Plant	
Wheatley Water Treatment Plant	
Union Water Supply System**	
Elgin Primary Area Water Supply**	
Lake Huron Primary Area Water Supply**	Lake Huron
Stoney Point Water Treatment Plant**	Lake St. Clair

\* Shared intake

\*\* Located outside of the Source Protection Region

The South Chatham-Kent Water Treatment Plant (WTP) and Chatham WTP share one intake at Erie Beach in Lake Erie and together supply many of the communities in Chatham-Kent. The Wheatley WTP derives its surface water from Lake Erie south of Wheatley. The West Elgin Water Treatment Plant has a Lake Erie intake south of West Lorne at Eagle. The Lake Huron Primary Water Supply System (LHPWSS) located north of the community of Grand Bend on Lake Huron supplies water to the City of London and several other communities. The City of London also receives water from the Elgin Area Primary Water Supply System (EAPWSS) located east of the village of Port Stanley in Central Elgin on Lake Erie. The Stoney Point Water Treatment Plant is located in the Town of Lakeshore in Essex County. It takes surface water from Lake St. Clair and serves the northeastern portion of the Town of Lakeshore. The Union Water Treatment Plant is located west of Leamington in Essex County. It takes surface water from Lake Erie and serves the Town of Leamington and parts of the Town of Lakeshore.

In addition to municipal systems, there are a number of small water systems serving facilities that have non-residential or seasonal uses. Ontario Regulation 252/05 came into effect on June 30, 2005 and applies to these systems. Exact information on the number and location of Reg. 252/05 facilities in the Thames Watershed & Region was not available at the time this report was being prepared. It is estimated that there may be approximately 1200 Reg. 252/05 systems in the Thames Watershed & Region. This estimate is based on information obtained from discussions with local health units and the percentage of each municipality in the region.



## 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	Fluoride	Pesticides	Total coliform
Turbidity	Metals	Benzene	<i>Escherichia coli</i>
Temperature	Nitrate	Trichloroethylene	
Colour	Phosphate		

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, for example phosphorus, there is no drinking water quality standard since phosphorus does not pose a direct threat to human health. It is an essential component of all cells, bones and teeth. When there is no readily available drinking water standard, an alternative such as the Provincial Water Quality Objectives (PWQO) that provides general guidelines for healthy aquatic life was used to evaluate water quality. For some parameters the drinking water standards are very different from the healthy aquatic life levels. Aquatic life protection has 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 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 or aquatic protection guidelines in order to assess surface water and groundwater sources. The comparison is only intended to provide a means of quality assessment by using an established value and is not intended to judge conformance of raw water to the standards or guidelines.

## 3.2 Raw Water Characterization for Inland Surface Water

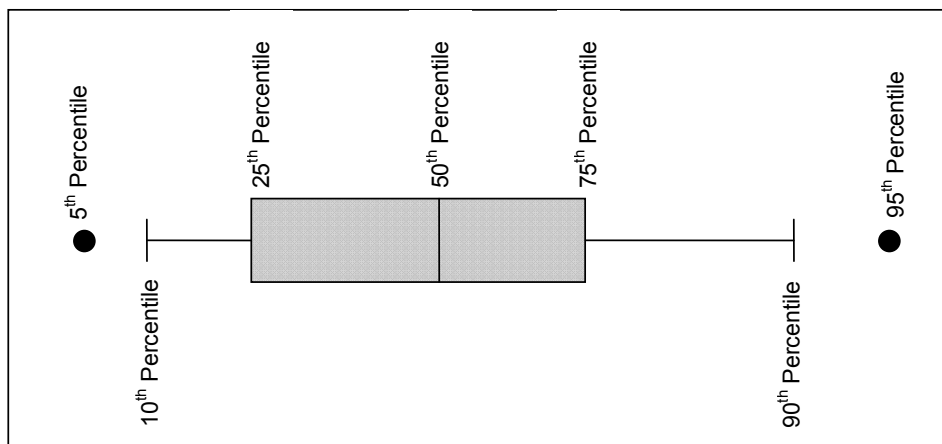
Water quality has been examined in the LTVCA and UTRCA watersheds since the 1960s when the Provincial Water Quality Monitoring Network (PWQMN) was first established. The sampling locations and the subwatershed areas are shown on **Map 37: Surface Water Quality Sampling Sites**.

In the UTRCA watershed, the PWQMN monitoring program historically consisted of up to 23 stations monitored monthly up to 12 times per year. In the mid-1990s, changes in provincial funding reduced the program to 15 sites. In 2002, UTRCA and OMOE redesigned the monitoring program for the upper Thames to better reflect the UTRCA's subwatershed management approach. Currently there are 24 sample locations with nine sites monitored eight times per year, and 15 sites monitored four times per year.

In the LTVCA watershed, the PWQMN program involved monitoring up to 10 stations until 1996 when changes in provincial funding reduced the program to one site on the Thames River at Jacob Road. In 2002, the monitoring program was re-designed by LTVCA and OMOE, resulting in eight PWQMN sites monitored eight times per year. Sampling sites for current monitoring programs were selected to reflect conditions in each of the main subwatersheds (Thames River, Lake St. Clair and Lake Erie) in the LTVCA watershed.

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.

Where possible, the 75<sup>th</sup> percentiles were used to evaluate the data to reduce sampling bias and help reflect pollutants more appropriately than using average values. As shown in **Figure 3.2.4-1: Box and Whisker Plot**, the 75<sup>th</sup> percentile (‘upper quartile’) is the value below which 75% of the values fall.



**Figure 3.2.4-1: Box and Whisker Plot**

For the stations in the UTRCA watershed, the 75<sup>th</sup> percentile values were used to evaluate parameter levels. The 75<sup>th</sup> percentile values could also be used to evaluate LTVCA historic data up to 1996. However, only one LTVCA station (Thames River at Jacob Road) had enough samples to evaluate the current conditions statically using 75<sup>th</sup> percentile values. For the other stations in the LTVCA watershed, there is a limited amount of current data; therefore, current

conditions for these LTVCA stations were evaluated using average, minimum and maximum values for each parameter.

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 staff. 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.

The evaluation of inland surface water quality for the eight parameters is summarized below with some examples of the figures that were prepared to illustrate the information.

### Phosphorus

As noted previously, there is no Ontario Drinking Water Standard (ODWS) for phosphorus. The Interim Provincial Water Quality Objective (IPWQO) of 0.03 mg/L was used as an alternative to evaluate water quality.

At all stations in the UTRCA subwatersheds, the current 75<sup>th</sup> percentile levels are above the IPWQO of 0.03 mg/L. Most sites are less than 0.15 mg/L but two stations, Thames Woodstock and Thames Byron, are over 0.2 mg/L. The historic values are generally between two and eight times the IPWQO.

At all LTVCA stations, the average current phosphorus levels are three to six times higher than the IPWQO of 0.03 mg/L. The historic 75<sup>th</sup> percentile concentrations of total phosphorus also exceed the IPWQO throughout the study period at all stations in the LTVCA subwatersheds.

### Nitrates

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

Seven of 30 UTRCA stations have current 75<sup>th</sup> percentile values that are higher than the ODWS of 10 mg/L. For the LTVCA subwatersheds, all current average nitrate values are less than the ODWS of 10 mg/L but some stations have maximums that are higher than 10 mg/L.

Since 1965, the historic 75<sup>th</sup> percentile values of nitrate appear to have increased at both UTRCA and LTVCA monitoring sites. However, different analytical tests used over the last 40 years may make it difficult to determine if a change in total nitrates over time is due to an absolute change in total nitrates or due to changing test methods.

To evaluate water quality for aquatic life, a value of 2.93 mg/L has been used. Only two UTRCA stations have current 75<sup>th</sup> percentile values that are less than 2.93 mg/L. The current average nitrate levels for all LTVCA stations except one (Big Creek) are higher than 2.93 mg/L. Historically, the levels at all UTRCA and LTVCA stations were above 2.93 mg/L with the exception of Dorchester Swamp Creek which has been consistently below 2.93 mg/L.

### Chloride

The ODWS aesthetic objective for chloride is 250 mg/L. The current 75<sup>th</sup> percentile chloride concentrations at all UTRCA sites are below the ODWS. Both the average and maximum current chloride concentrations at all LTVCA sites are below the ODWS.

Historically, most UTRCA and LTVCA sites have concentrations that are below 100 mg/L. However, the concentrations at the Avon River have shown a significant increase since 1990-1994 from approximately 100 mg/L to over 200 mg/L.

The Environment Canada aquatic health guideline for chloride is 210 mg/L. The current 75<sup>th</sup> percentile chloride concentration at the Avon River station in the UTRCA watershed is close to this and 25% of the samples are above 210 mg/L. All other UTRCA and LTVCA stations have concentrations below 210 mg/L.

## Suspended Solids

While there are no established standards for suspended solids, turbid water is undesirable for water supplies, healthy aquatic life, recreation and aesthetics.

For the UTRCA stations, the current 75<sup>th</sup> percentile levels are generally less than 30 mg/L, with the exception of Stoney Creek which has a current level of about 80 mg/L. Over the 40 year study period, historic data indicates that most UTRCA sites have the same suspended solids levels in 2000-2004 as they had in 1965-1969. However, Dingman Creek has shown a decrease from a high of about 60 mg/L to a current level of approximately 30 mg/L.

## 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 UTRCA stations. There is no current data for the LTVCA stations but historic results indicate that *E. coli* was present at all of the LTVCA stations.

The PWQO (recreational guideline) for exposure to surface water (e.g. swimming) is 100 counts/100 mL as a geometric mean. At UTRCA stations, the current geometric means are all over 110 counts/100 mL with the exception of the Thames at Woodstock with 96 counts/100 mL. The highest levels are at Reynolds Creek and Stoney Creek at 829 and 754 counts/100 mL respectively. Historically, most of the UTRCA and LTVCA stations have geometric means between 100 and 1,000 counts/100 mL.

## Copper

The ODWS for copper is 1 mg/L (1,000 µg/L) for aesthetic water quality. All of the current and historic levels at both the UTRCA and LTVCA stations are well below the ODWS.

While copper is an essential element, it can be toxic to aquatic life and the PWQO is 5 µg/L. At the UTRCA stations, all current 75<sup>th</sup> percentile concentrations are routinely below the PWQO. At the LTVCA stations, the current 75<sup>th</sup> percentile concentration at the Thames River at Jacob Road station is over the PWQO at about 6.5 µg/L. The average concentrations at the other LTVCA stations are below the PWQO.

## Zinc

The ODWS for zinc is 5 mg/L (5,000 µg/L) for aesthetic objectives. All current and historic data for UTRCA and LTVCA stations have concentrations that are well below the ODWS.

While zinc is an essential element, it can be toxic to aquatic life and the PWQO is 20 µg/L. At the UTRCA stations, all current 75<sup>th</sup> percentile concentrations are routinely below the PWQO. The highest is about 18 µg/L at Avon River and the lowest is approximately 1 µg/L at Gregory Creek. At the LTVCA stations, all the average concentrations of zinc are below the PWQO. The highest average is 14.3 µg/L at Big Creek and the lowest is 3.8 µg/L at McGregor Creek.

## 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 exceeding the limits.

At the UTRCA stations for the period from 2000-2004, 14 of 25 stations had lead levels less than the ODWS and the other 11 stations all had only one sample with lead levels less than the ODWS. At the LTVCA stations, seven of eight stations had all their sample lead levels less than the ODWS. For the stations that have historic data available, there has been a general decrease in the lead concentrations.

At the UTRCA stations in 1980-84, all stations had samples above the ODWS of 10 µg/L and the percentage of samples above the ODWS ranged from 21% to 51%. By 2000-04, five of the six stations with historic data had all sample results below the ODWS and the other station only had 2% of the samples above the ODWS.

At the LTVCA stations in 1980-84, all stations had samples with lead levels above the ODWS of 10 µg/L and the percentage of samples with lead above the ODWS ranged from 33% to 47%. By 2000-04, all stations' lead levels were below ODWS.

### 3.3 Groundwater Quality

The Watershed Characterization Report provides a summary of existing groundwater monitoring programs, an overview of groundwater quality based on available data sets, and a brief synopsis of known groundwater quality issues.

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

#### Background Monitoring Data - Chemical Parameters

In general, groundwater characteristics are considered to be relatively consistent and the chemical parameter monitoring is not as extensive as that of surface water sources, in terms of monitoring frequency and long-term data collection. Thus, groundwater monitoring water quality data for chemical parameters is limited when compared to the data used to review surface water sources in Section 3.2 Raw Water Characterization for Inland Surface Water and Section 3.4 Raw Water Characterization for Drinking Water Intakes.

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) to address the need to collect a baseline database on water quality (and quantity).

As of May 2007, there are a total of 35 PGMN monitoring wells in the Thames Watershed & Region. Some of the wells have been monitoring water levels since 2001, but most were brought into the system between 2002 and 2004.

UTRCA has 23 monitoring wells in 19 locations. Multiple wells at Embro, Shakespeare and Fish Creek are used to monitor aquifers at different depths. In the UTRCA watershed, two wells are awaiting installation of instrumentation (level loggers). LTVCA has 12 monitoring wells, all in different locations.

Based on the PGMN monitoring, the UTRCA overburden and bedrock wells are dominated by calcium-magnesium-bicarbonate water. The carbonate, magnesium (and sulphate) ions in the groundwater primarily originate from the carbonate rock at depth (bedrock: dolostones, limestones and evaporites) and the carbonate material incorporated in overburden sediments.

The primary difference between the LTVCA and the UTRCA areas is the predominance of sodium and chloride in the LTVCA watershed groundwater, where the sodium and chloride content is significantly higher.

The PGMN monitoring provides information on numerous parameters that may be of concern for health, aesthetic or water treatment plant operational reasons. There is a wide range of results across the region and some wells had parameters that were above an Ontario drinking water standard, guideline, or objective. A summary of information is shown in **Table 3.3-1: Range of Parameters in Thames PGMN Wells 2002-2006**. Only those parameters that were above a limit in at least one well are included in this table.

There are a few chemical parameters that are above health related limits set out by the Ontario Drinking Water Standards (ODWS).

Fluoride levels were above 1.5 mg/L in seven UTRCA wells and three LTVCA wells. High fluoride levels affect dental health by causing dental fluorosis in children. Fluoride can occur naturally in groundwater at levels that are above the drinking water standard.

In addition to fluoride, some high levels of health related parameters were found in some wells. In the UTRCA watershed, two wells had nitrate + nitrite or nitrate results above 10 mg/L, one well had arsenic above 0.025, and one well had cadmium above 0.005 mg/L. In the LTVCA watershed, one well had lead above 10 µg/L and one well had barium above 1 mg/L.

Ontario Drinking Water Aesthetic Objectives are established for parameters that may interfere with good water quality control practices or may impair the taste, odour or colour of water.

Two of the most frequent parameters found were iron and manganese. In the UTRCA, 13 wells had iron above the aesthetic objective of 0.3 mg/L and six wells had manganese above 0.05 mg/L. In the LTVCA, six wells had iron above 0.3 mg/L and four wells had manganese above 0.05 mg/L. If present in water in excessive amounts, iron can be an objectionable impurity and it forms red precipitates that stain laundry and plumbing fixtures. The chemistry of manganese is somewhat like that of iron. Iron and manganese in groundwater are usually due to the natural weathering of rocks and minerals.

In addition to iron and manganese, some high levels of aesthetic parameters were found in several PGMN wells across the region. In the UTRCA watershed, dissolved solids (five wells), dissolved organic carbon (three wells) and chloride (one well) were found above Ontario Drinking Water Aesthetic Objectives. One well had trihalomethanes above 0.1 mg/L but this is attributed to sampling too soon after chlorination of the well. In the LTVCA watershed, total dissolved solids (five wells), chloride (five wells), sodium (five wells) and zinc (one well) were found above Ontario Drinking Water Aesthetic Objectives.

Sodium values above 20 mg/L can be of concern for individuals that are on a sodium restricted diet and the local Medical Officer of Health is notified. Sodium above 20 mg/L (but below 200 mg/L) was found in nine UTRCA wells and four LTVCA wells.

The Ontario Drinking Water Operational Guidelines are established for parameters that may negatively affect efficient and effective water treatment.

Hardness was the most recurring operational issue found in the PGMN wells and the monitoring wells commonly showed hardness levels that were above the ODWS Operating Guideline of 80-100 mg/L. There were 19 UTRCA wells and seven LTVCA wells that had hardness levels that were not within the range. Hardness is the sum of the calcium and magnesium carbonate concentrations expressed in terms of mg/L of calcium carbonate. High levels of hardness

# Watershed Characterization Summary Report

## Thames Watershed & Region

cause taste issues in drinking water, scaling problems in plumbing fixtures and heaters, and hinder the lathering of soap.

In addition to hardness, four UTRCA wells had high aluminum, one UTRCA well had high pH, and one LTVCA well had high alkalinity.

While there is no ODWS for phosphorus, a review of PGMN data was done since groundwater can be a source of surface water and provide a significant base flow to local streams. Phosphorus was above the Interim Provincial Water Quality Objective (IPWQO) of 0.03 mg/L (for the prevention of nuisance algae growth) at two LTVCA wells and nine UTRCA wells.

Several parameters that do not have limits under the Ontario Drinking Water Standards were detected as part of the PGMN sampling program. It is important to note that these parameters are detected using low levels of detection and, at those levels, may not pose human health concerns. In the UTRCA watershed, nickel (nine wells), vanadium (five wells), cobalt (one well), and thallium (four wells) were detected. In the LTVCA watershed, nickel (one well), vanadium (six wells) and cobalt (three wells) were detected.

**Table 3.3-1: Range of Parameters in Thames PGMN Wells for 2002-2006**

Parameter (ODWS Limit)	UTRCA (23 wells)			LTVCA (12 wells)					
	Min. (mg/L)	Max. (mg/L)	Number of Wells above Limit	Min. (mg/L)	Max. (mg/L)	Number of Wells above Limit			
Fluoride (1.5 mg/L)	0.1	3	7	0	2.5	3			
Sodium (200 mg/L)	2.7	140	0	9.2	489	5			
Hardness (80-100 mg/L)	5.5	660	19	30	548	7			
Manganese (0.05 mg/L)	0.0005	0.17	6	0.00076	0.279	4			
Total Dissolved Solids (500 mg/L)	98	924	5	268	1450	5			
Chloride (250 mg/L)	0.5	265	1	16	790	5			
Iron (0.3 mg/L)	0	3	13	-0.003*	2.1	6			
pH (6.5- 8.5)	7.58	10.1	1	None above the ODWS					
Aluminum (0.1 mg/L)	0	0.48	4						
Nitrate (10 mg/L)	0.05	10.6	1						
Nitrate+Nitrite (10 mg/L)	0.05	10.6	1						
Arsenic (0.025 mg/L)	0	0.03	1						
Dissolved Organic Carbon (5 mg/L)	0.1	16.1	3						
Trihalomethanes (0.1 mg/L)	0	0.274	1						
Cadmium (0.005 mg/L)	-0.00003*	0.012	1						
Zinc (5 mg/L)	None above the ODWS						0	12.3	1
Lead (0.01 mg/L)							0	0.0134	1
Alkalinity (30-500 mg/L)				130	723	1			
Barium (1 mg/L)				0.0239	2.18	1			

\* Laboratory reporting method can result in negative values being reported

### Municipal Groundwater Supply Systems

Data that has been collected as part of the monitoring of municipal well supplies provides an opportunity to review water quality from several groundwater sources. This report reviews the raw (untreated) source water quality data of municipal wells, supplemented by a review of treated water data.

Since water treatment processes are designed to remove or reduce contaminant levels before the treated water enters the distribution system, the information in this report should not be considered an evaluation of overall water quality in a municipal water supply system.

# Watershed Characterization Summary Report

## Thames Watershed & Region

Ontario's Drinking Water Systems Regulation (O. Reg. 170/03) made under the Safe Drinking Water Act, 2002 requires that the owner of a system prepare an annual report on the system and the quality of its water. To obtain an overall evaluation of a system including treated water quality, these annual reports should be consulted. Reports for systems serving more than 10,000 people are posted on the municipality's web site. Hard copies of reports for smaller systems must be available from the municipality.

Of the 25 municipal well supply systems in the Thames Watershed & Region, 23 are located in the UTRCA.

In Perth, the six well supply systems in the UTRCA watershed are Mitchell, Sebringville (Black Creek Estates), Shakespeare (Miller Ave.), St. Marys, St. Paul's and Stratford.

In Oxford, the 10 municipal well supply systems in the UTRCA watershed are Beachville-Loweville Subdivision, Embro, Hickson-King Subdivision, Ingersoll, Innerkip, Lakeside, Mount Elgin, Tavistock, Thamesford and Woodstock.

In Middlesex, there are six active municipal well supply systems serving populations within the UTRCA watershed including Birr, Dorchester, Melrose, Kilworth Heights Subdivision, Mount Brydges and Thorndale. The Mount Brydges well supply system also supplies residents living in the St. Clair Region watershed.

The City of London system wells are for emergency back up only and are not active. The primary sources of drinking water to the City of London are the Elgin Area Primary Water Supply System (Lake Erie water) and the Lake Huron Primary Water Supply System (Lake Huron water). Several other communities in Middlesex are also supplied with piped lake water.

In Chatham-Kent, the Highgate and Ridgetown well supplies are the only municipal systems using groundwater located in the LTVCA watershed. The primary source of municipal water for Chatham-Kent communities is treated water from Lake Erie.

### **Chemical Parameters - Municipal Monitoring**

The sources of water chemistry data available to assess water quality for municipal groundwater well supplies in the Thames Watershed & Region include:

- Drinking Water Information System (DWIS)
- Drinking Water Surveillance Program (DWSP)
- Annual Drinking Water System (DWS) Reports
- MOE Inspection Reports

The DWIS information covers most (up to 23 of 25) of the active systems in the region. The DWSP is a voluntary program and there is information for only four of the 25 systems. The DWS and MOE annual reports typically provide a single treated water sample data per year. Hence, they are reviewed in the report for information purposes only and are not considered to be a conclusive evaluation.

The groundwater quality data was reviewed and compared against Ontario Drinking Water Standards, Guidelines or Objectives, and the results were presented in the form of tables. In general, most groundwater sources had raw water quality that met treated drinking water standards, with a few exceptions as discussed below. The DWIS data, which was the largest data set, only identified three chemical parameters that might be of concern.

**Fluoride** is a chemical parameter that can occur naturally in groundwater. Fluoride is often associated with sodium bicarbonate groundwater. It is very common in the wells in the region. Based on the DWIS data set from 2003 to 2006, the 22 systems that had data available had some fluoride present. The concentration ranged from as low as 0.07 mg/L to as high as 2.6 mg/L.

More than half (12 of 22) of the systems had some samples with fluoride concentrations above the ODWS of 1.5 mg/L. For seven of the 12 well systems, the minimum concentrations were above 1.5 mg/L.

**Sodium** concentrations are below the ODWS value of 200 mg/L across the region based on the 2003-06 DWIS data set. Concentrations ranged from as low as 1.01 mg/L to as high as 120 mg/L. The highest sodium levels were found in the Chatham-Kent well supply systems. Most of the systems (16 of 23 systems with data) had some samples that were above the 20 mg/L level which is of concern for low sodium diets and requires notification to local Health Units.

**Nitrate** was identified as being present at a concentration above 10 mg/L in one well field in Oxford County based on the information available in the 2003-06 DWIS data set.

From Annual Drinking Water System reports, parameters with ODWS aesthetic objectives (AO) and operational guidelines (OG) were also reviewed. In most wells, hardness and total dissolved solids were found to be above the AO or OG. In some wells, iron, manganese and other parameters of aesthetic or plant operational concern were above the respective AO or OG level.

### **Ambient Water Quality Study**

Waterloo Hydrogeologic, Inc. (WHI), A Schlumberger Company, has a contract to complete a local study to characterize and understand the state of the water quality within the Thames-Sydenham & Region. This work is focused on chemical water quality parameters and does not include a review of microbiological data.

Only a draft of the WHI Report for the Thames-Sydenham & Region was available at the time the Watershed Characterization Report was prepared. However, some of the findings in the draft report have been used to provide information on ambient groundwater quality.

*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 UTRCA, both the bedrock and overburden water is predominately calcium sulphate (Ca-SO<sub>4</sub>) type water. Calcium chloride (Ca-Cl) and sodium-bicarbonate (Na-HCO<sub>3</sub>) are the other significant water types present in both bedrock and overburden.

In the LTVCA, calcium chloride (Ca-Cl) and sodium chloride (Na-Cl) type waters make up 60% of the water facies in both bedrock and overburden. Calcium sulphate (Ca-SO<sub>4</sub>) and calcium carbonate (Ca-HCO<sub>3</sub>) are the other significant water types present.

Ca-SO<sub>4</sub> waters may achieve their mineralization from an anhydrite layer in the Lucas formation. Alternatively, they may indicate ascending waters from the underlying Salina formation, with its well-documented presence of evaporites. The overburden sampling points characterized by calcium sulphate water are located close to the bedrock surface, and are strongly imprinted by bedrock groundwater composition. Ca-SO<sub>4</sub> type water is considered poor in quality due to its typically high salinity and hardness.

Na-Cl water facies indicate aquifers of low permeability and/or long residence time. Na-Cl type waters are mainly located in the LTVCA watershed. This location coincides with the proximity of evaporates in the Salina formation and likely indicates ascending fluids from this formation.

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

Sodium-bicarbonate ( $\text{Na-HCO}_3$ ) is another significant groundwater type that is found in both bedrock and overburden wells. This water type indicates a mixing or intrusion of saline groundwater into a freshwater aquifer, or freshwater into an aquifer containing saline groundwater. The Hamilton Group and Kettle Point Formation are the most probable origin of these waters, as these formations have high organic carbon content that provides excellent ion exchange capabilities.  $\text{Na-HCO}_3$  type waters are vulnerable to certain water quality issues due to the high pH that frequently accompanies these waters.

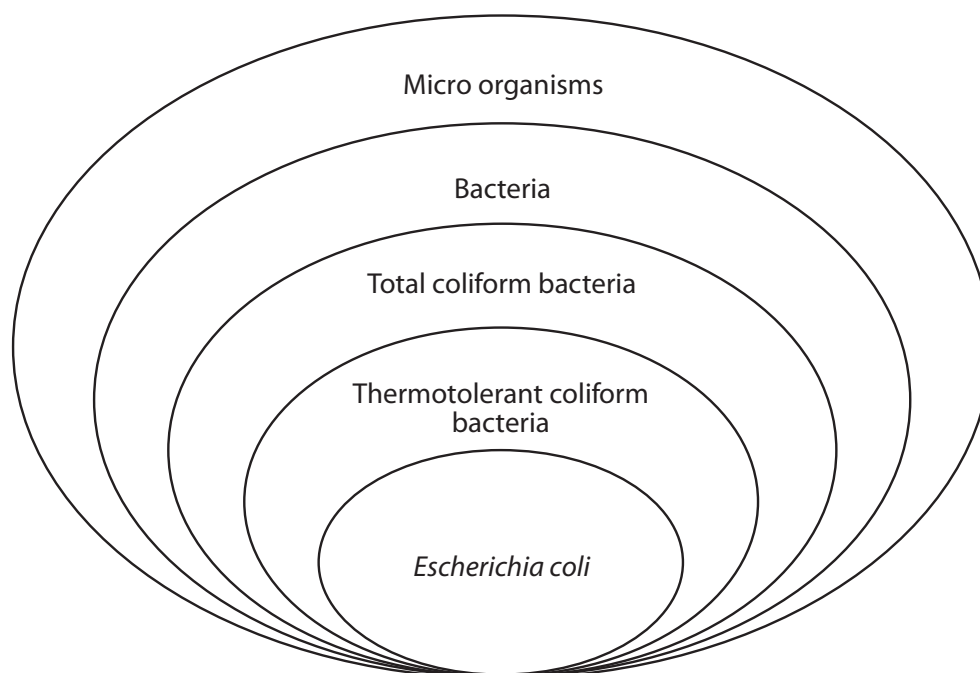
Over 25% of samples from bedrock wells are higher than the ODWS of 1.5 mg/L for fluoride, and about 20% of samples in overburden wells. It is believed that fluoride is natural in origin. Fluorite dissolution and ion exchange of sorbed fluoride in the Kettle Point formation are the most likely processes leading to the observed elevated concentrations.

Waters with high sodium values are concentrated in the area with  $\text{Na-Cl}$  and  $\text{Na-HCO}_3$  type waters in the southernmost part of the study area. The combined effect of low calcium with high sodium in  $\text{Na-HCO}_3$  type waters leads to sodium adsorption ratios (SAR) of up to 28, which makes this water unsuitable for the irrigation of sodium sensitive crops. The sodium hazard may be intensified by the high boron levels encountered in many of the sodium rich waters. All waters with low sodium levels are encountered in bedrock wells in the northeastern portion of the area.

Overburden wells have higher nitrate values and are above the Ontario Drinking Water Standard (ODWS) of 10 mg/L more frequently than bedrock wells.

### 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* (*E. coli*) and total coliform are the two microbiological indicator parameters used to assess groundwater well (raw water) quality. **Figure 3.3.4.1-1: Coliform Bacteria Subgroups** provides an overview of the relationship between groups of micro-organisms, and the types of coliforms relevant to the current report.



**Figure 3.3.4.1-1: Coliform Bacteria Subgroups**

Total coliform are widespread in nature being present in soil as well as in the intestines of warm blooded hosts. Total coliform is an indication of potential concern. *E. coli* are a subgroup of total coliform bacteria and are an indicator of potentially dangerous recent fecal contamination of water.

### **Municipal Monitoring – Active Systems and Wells**

The source of microbiological data to characterize groundwater quality for most of the municipal groundwater wells in the Thames Watershed & Region is the Drinking Water Information System (DWIS). This database provides total coliform and *E. coli* data on a weekly basis. The data provided for this report contains raw (untreated) water data from May 2003 to September 2006 for most groundwater wells.

DWIS data was available for 23 of the 25 municipal well water systems. For the two well supply systems where DWIS data was unavailable (Mount Brydges and Mount Elgin), equivalent data was obtained from well monitoring reports and used to evaluate the systems.

A total of 92 wells were analyzed using *E. coli* and total coliform raw water data from 2003 to 2006. Of these wells, 83 are actively in use. Nine wells are ‘extra’ wells that were decommissioned, sealed, abandoned, or used for monitoring purposes only (not considered to be a source of municipal drinking water in recent years). However, these extra wells have partial data available for analysis.

Since the Ontario Drinking Water Standards (ODWS) for *E. coli* and total coliform is “not detectable,” exceedences are taken as any detects, or any coliform counts greater than zero (occurrences).

The data for each well supply 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 a scatter plots.

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

A specific type of *E. coli* bacteria was a primary cause of the deaths at Walkerton in 2000, which led to the development of Source Protection Planning. For the active municipal well supply systems, the review of the DWIS and equivalent data shows that there are a few incidents of *E. coli* being present. While the overall number of *E. coli* positive samples was relatively low, the results show the need to maintain proper disinfection and monitoring procedures.

Only five of the 25 active systems had some samples with *E. coli* present. There were a combined total of 36 wells in the five systems. Each case involved only one well in each system. For three wells, there was a single sample with *E. coli* present. For the other two wells, one had three positive samples out of 174 samples and the second had four positive samples out of 165 samples.

Total coliform bacteria are widespread and the number of samples having a positive result was higher than those with *E. coli* present. Only 18 of the 83 active wells did not have at least one sample that had a positive result for the presence of total coliform bacteria. Overall, 21 of the 25 active municipal systems had some samples with positive total coliform results. Most of the samples had less than 10 counts/100 mL but results as high as 630 counts/100 mL were reported.

## Municipal Monitoring – Extra Wells

There was some limited data available for municipal wells that are no longer in use. None of the wells had *E. coli* present. Four of the nine wells did not have total coliform present. The other wells had from 1 count/100 mL to as high as 252 counts/100 mL.

## Background Monitoring Data – PGMN Wells

None of the 12 PGMN wells in the LTVCA watershed are analyzed for *E. coli* or total coliform. The 23 PGMN wells in the UTRCA watershed have been sampled and tested for *E. coli*. However, samples are taken infrequently (less than once a year) and the laboratory detection limit used for non-drinking water groundwater samples is 10 counts/100 mL. While all results were reported as less than 10 counts/100 mL, this data set provides a very limited characterization for the PGMN well microbiological water quality.

## 3.4 Raw Water Characterization for Drinking Water Intakes

Lake Erie and Lake Huron are the two major surface water sources of drinking water for residents living in the Thames Watershed & Region. Some residents also receive treated Lake St. Clair water. Background information on the seven intakes (including one intake that supplies two treatment plants) is summarized in Section 2.7 Water Uses.

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

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 Annual 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 undertaken 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 source 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 (according to the Lake Erie Lakewide Management Plan) and in Lake Huron (according to the 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.

No data was available for the West Elgin plant. Prior to 1998, the Lake Huron Primary Water Supply System (PWSS) intake had some maximum and average phosphorus values above 0.02 mg/L. Since 1998, the maximum values have been below 0.01 mg/L. All reviewed Lake Erie intakes except Wheatley had phosphorus in the raw water. The maximum phosphorus levels at both the Union Lake Erie intake and the Stoney Point intake in Lake St. Clair were above the IPWQO based on information from the Essex Region Conservation Authority's Watershed Characterization Report. For the other Lake Erie intakes, the maximum phosphorus levels frequently rise to levels above the IPWQO and averages also can be above 0.02 mg/L. As recently as 2003, the minimum, average and maximum levels were all above the IPWQO.

### Nitrates

The 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.

The average and maximum nitrate levels for all intakes were also well below both the ODWS of 10 mg/L and the modified CCME guideline of 2.93 mg/L. Very few results were above 1.0 mg/L.

### Chloride

The ODWS is 250 mg/L for aesthetic objectives. 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.

The maximum chloride levels at all intakes were less than 30 mg/L.

### Turbidity

An 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 on turbidity for the Lake Erie Union intake and the Lake St. Clair Stoney Point intake was not available at the time this report was prepared. For the Lake Huron PWSS intake, most maximum and average values were above the ODWS between 1990 and 1999. In recent years, all values were lower than ODWS of 5 NTU. For the Lake Erie intakes, the average turbidity levels ranged between 2.2 and 60.4 FTU. Maximum turbidity levels as high as 450 NTU were recorded but maximum levels had also been as low as 3.2 FTU.

## pH

An 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 minimum, maximum and annual average pH levels at all plants were within the operational guideline of 6.5 to 8.5, with the following exceptions. 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 extremely 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 books allowed the validated exclusion of the extremely high and low pH values. From 2001 to (September) 2004, the operator log books provided possible causes for the high and low pH values but the incidents could not be conclusively linked due to the lack of trending analysis.

## Temperature

An ODWS aesthetic objective of 15°C has been established for temperature. Low temperatures help to maintain free chlorine residual by reducing the rates of decay of the chlorine. Also, a temperature below 15°C will tend to reduce the growth of nuisance organisms and minimize taste, colour, odour and corrosion problems. Information was available for seven plant intakes.

The analysis of temperature data for the Lake St. Clair Stoney Point Intake and the Lake Erie Union intake were not done at the time of writing of this report. During the summer months, the maximum temperatures for all plants had water temperatures that were above the aesthetic objective of 15°C. The maximum temperatures range between 22°C and 31°C. In the winter, minimum temperatures drop as low as 0.1°C. Between 2002 and 2004, Chatham average intake water temperatures were above the aesthetic objective of 15°C.

## Coliform Bacteria

The 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.

For the Lake Huron PWSS intake, total coliform levels ranged from 0 to 9,600 counts/100 mL and *E. coli* counts ranged from 0 to 150 counts/100 mL from 2003 to 2006. For the Lake Erie intakes, total coliform levels ranged from 0 to as high as 91,000 counts/100 mL and *E. coli* counts ranged from 0 to over 2,000 counts/100 mL.

## Other Parameters

Using DWSP data sets from 2000 to 2005, a total of 88 parameters were analyzed for the intake raw water to the Chatham WTP, Elgin Primary Area WSS and Lake Huron Primary WSS.

Water treatment plant laboratory monitoring data was used to analyse ‘other parameters’ for raw water to the West Elgin WTP (data for 2001 to 2003) and Wheatley WTP (data from 2000 to 2002). The hardness and aluminum data for the Wheatley WTP raw water was obtained from Municipality of Chatham-Kent Water Quality Laboratory Reports for 2000 to 2002.

The data sets were reviewed to determine how many samples had test results that were 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 were above the health related ODWS or half standard values.

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 ODWS Operational Guideline range 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 Microsoft Access cross tab query analysis, when Mirex is detected in a sample, it is automatically considered to be above the objective although that may not be the case. Mirex was reported to be detected at LHPWSS, EAPWSS 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 levels.



## 4.0 Water Quantity

Within the Thames Watershed & Region, many human activities 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 that is being prepared in parallel to the Watershed Characterization Report will provide 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 16: Permit to Take Water by Location** shows the locations of water taking permit holders in the Thames Watershed & Region watershed. The locations shown on the map are colour coded to indicate groundwater, surface water or combined sources. Permit holders draw water for a variety of applications. **Map 17: Permit to Take Water General Purpose of Taking** shows the various types of water takers.

In the upper portion of the watershed, permit holders mainly use groundwater as their source. In the lower portion of the watershed, permit holders mainly draw from surface water sources.

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 – Thames Watershed & Region**. A total of 905 PTTWs are listed in the database for the Region. However, many of these permits have expired dates listed beside them. It is unclear if these permits have been updated or renewed.

As part of the review of water use done in the Draft Conceptual Water Budget, an estimate of maximum permitted water use was made by multiplying the maximum permitted amount by the maximum number of permitted days.

**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	Total Annual Maximum Permitted Volume (m <sup>3</sup> x10 <sup>6</sup> )	Percent of Total Maximum Volume Permitted
Agricultural	Field and pasture crops, fruit orchards, market gardens / flowers, nursery, sod farm, tender fruit, tobacco	300	33%	36,043	5%
Commercial	Aquaculture, bottled water, golf course irrigation, mall / business, snowmaking	158	17%	32,116	4%
Construction	Construction, road building	10	1%	947	0.1%
Dewatering	Construction, pits and quarries	52	6%	241,193	33%
Industrial	Aggregate washing, cooling water, food processing, pipeline testing, power production	92	10%	222,480	30%
Institutional	Hospitals	1	0%	183	0.0%
Miscellaneous	Dams and reservoirs, heat pumps, other – miscellaneous, pumping test, wildlife conservation	57	6%	59,081	8%
Recreational	Aesthetics, other – recreational, wetlands	12	1%	539	0.1%
Remediation	Groundwater, other – remediation	6	1%	51	0.0%
Water Supply	Campgrounds, communal, municipal, water supply	217	24%	148,510	20%
<b>Total</b>		<b>905</b>		<b>741,142</b>	

Note: Data from MOE Permit to Take Water Database

While the agricultural sector has 33% of the total permits in **Table 4.1-1**, the percent of total maximum volume permitted is only 5%. This difference probably reflects the seasonal nature of the water taking associated with crop irrigation. Specialized crops such as tobacco, ginseng and market crops including potatoes, beets, carrots and tomatoes are irrigated on a regular basis to maintain yield and quality. In general, irrigation of cash crops, such as corn and soybeans, is not practiced in the region.

In **Table 4.1-1**, the dewatering sector has 6% of the number of permits but appears to account for 33% of volume. The difference probably reflects the need for continuous water taking associated with dewatering activities.

As outlined in Section 2.7 Water Uses, most of the population that has municipal piped water supplies receives treated surface water from Lakes St. Clair, Huron and Erie. A summary of the water treatment plants and the rated capacity is provided in **Table 4.1-10: Water Treatment Plant Capacities**. These plants supply urban and rural areas in Chatham-Kent, Elgin and Middlesex. Groundwater is the source for municipal water supply systems in Perth and Oxford. Some municipal supply systems in Middlesex and Chatham-Kent also use groundwater. **Table 4.1-11: Municipal Groundwater Systems & Wells** provides an overview of the municipal systems using groundwater.

**Table 4.1-10: Water Treatment Plant Capacities**

Water Treatment Plant	Capacity m <sup>3</sup> /day	Source
<b><i>Plants taking water in the Thames Watershed &amp; Region</i></b>		
Chatham	60,000	Lake Erie
South Chatham-Kent		Lake Erie
Wheatley	10,200	Lake Erie
West Elgin	6,829	Lake Erie
<b><i>Plants taking water outside the Thames Watershed &amp; Region for supply to Region</i></b>		
Lake Huron Primary	340,000	Lake Huron
Stoney Point	4,600	Lake St. Clair
Union	124,589	Lake Erie
Elgin Area Primary	90,000	Lake Erie

**Table 4.1-11: Municipal Groundwater Systems & Wells**

County	Systems	Number of Wells
Oxford	10	31
Perth	6	19
Middlesex	7	25
Chatham-Kent	2	8
Total	25	85

Private wells are an important source of water for domestic supply and other uses in rural areas, especially Oxford and Perth Counties. The Thames-Sydenham & Region Draft Conceptual Water Budget has attempted to estimate the private (unserved domestic water use) based on a number of assumptions. Unserved populations were determined from county groundwater studies and multiplied by a water use factor. The estimated annual water use by private groundwater users was calculated to be approximately 1,575,000 cubic metres per year (4,315 m<sup>3</sup>/day).



## 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 water quality and/or quantity perspective.

### Groundwater

The general groundwater aquifer vulnerability for the watershed is shown in **Map 18: Intrinsic Susceptibility Index**. The areas of highest susceptibility are in the sand plains and moraines across the Thames Watershed & Region. The areas of low susceptibility are in the silt and clay plains.

A number of groundwater and hydrogeologic studies have been completed for municipalities in southwestern Ontario. Based on the studies, Wellhead Protection Areas are available for all operating municipal systems and the back-up wells in the City of London. **Map 35: Municipal Wellhead Protection Areas** shows the areas of most concern based on the estimated time of travel from two to 25 years.

Overburden aquifers especially had limitations on their usefulness for drinking water sources. 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). The Oxford County Study also indicated that the shallow aquifer was highly vulnerable. The Perth County Groundwater Study indicated that overburden aquifers are sparse and limited to alluvial sands and gravels deposited along rivers and streams. The Essex Region/Chatham-Kent Region Groundwater Study did not identify any significant potential groundwater aquifers.

There are three First Nation systems that utilize groundwater sources in Middlesex County. It is unknown if ISI or other vulnerability analysis has been done for the First Nation systems.

### 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 seven municipal surface water intakes supplying communities in the Thames Watershed & Region. **Map 38: 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 was used for the delineation of an initial Intake Protection Zone (IPZ-1). A second, larger Intake Protection Zone (IPZ-2) will be delineated based on the two 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 current, wave action, stream flow and drift.

Work on the Intake Protection Zone Studies is ongoing. It is expected that the studies for all of the municipal water treatment plants will be completed in 2009.



## 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.

### 6.1 Threats to Water Quality

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.

- Essex Region/Chatham-Kent Region Groundwater Study
- Middlesex-Elgin Groundwater Study
- Strathroy-Caradoc Groundwater Management Study
- Phase II Groundwater Protection Study, County of Oxford
- Vulnerability (SWAT) Pilot Study, County of Oxford
- Perth County Groundwater 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 Thames Watershed & Region. Information on the locations of potential threats was provided in several maps and tables that were prepared as part of the Groundwater Study Reports.

As noted in Section 5.0 Description of Vulnerable Areas, there are several Intake Protection Zone studies currently underway for surface water intakes supplying drinking water to communities in the Thames Watershed & Region. These studies will provide details on local threats for the areas around the intakes.

## 6.2 Known Water Quality Issues

Issues regarding the quality of drinking water sources in the Thames Watershed & Region are summarized below, based on existing reports and information sources.

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 Perth District Health Unit completed a rural water quality study in 1991/1992 examining the bacterial, nitrate and fluoride levels in private wells in Perth County. 38% of the 142 wells sampled in the study were found to contain some form of contamination in the water, with the majority of the contamination being bacterial in nature. A regional groundwater study completed by the UTRCA, ABCA and MVCA in 2001 identified naturally-occurring fluoride in high concentrations as a concern. This study also found several other parameters including hardness, iron, colour and total dissolved solids to be above aesthetic objectives.

The Oxford County Groundwater Study assessed general groundwater quality by sampling 84 shallow overburden wells and 83 bedrock aquifer wells. The groundwater quality was mapped for nitrate, total dissolved solids and sodium. Bacteriological results showed a higher incidence of total coliform and *E. coli* presence in the shallow wells. Moderate levels of nitrate were found with some wells having levels over 10 mg/L.

## 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:

- nitrates in overburden source groundwater
- bacteria in groundwater and surface water sources
- chemical parameters, for example fluoride in groundwater

### 7.2 Identified Concerns

Some concerns may also be identified by a review of previous public discussions. **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

It is expected that concerns will be identified as part of public consultation and stakeholder involvement in the source protection process.

