2.0 Watershed Characterization

Justice O'Connor recommended that watershed-based *Source Protection Plans* be developed. The recommendations were part of the inquiry which investigated the May 2000 bacterial contamination of the Town of Walkerton's water supply. Compiling a summary of information pertinent to drinking water sources is one of the first steps in developing a *Source Protection Plan*.

Under the Clean Water Act (2006), the Assessment Report must identify all subwatersheds in the source protection area and characterize the water quality and quantity across the watershed. The Regulations and *rules* under the Clean Water Act (2006) require that the physical and human geography also be characterized. This information is contained in a watershed characterization report.

2.1 Watershed Characterization Report

The Watershed Characterization Report for the Thames Watershed and Region, completed in 2008, is based on information available at the time. Updated characterization information is included in other sections of the Assessment Report. Some of the water budget related mapping products are available in the Conceptual Water Budget, which is included as an appendix to the Assessment Report.

The Watershed Characterization Report summarizes information on the physical, social and economic characteristics of the Thames Watershed & Region. It reviews surface water and groundwater quality, and summarizes known issues and concerns pertaining to drinking water sources. A series of maps help to illustrate the information presented in the report. Each of the components of the watershed characterization report will be described in the sections that follow.

The summary of the Watershed Characterization Report for the Thames Watershed and Region is included in Appendix 5 in the Lower Thames Valley and Upper Thames River Source Protection Area Assessment Reports; complete with all maps. The entire Watershed Characterization Report is available on compact disk (CD).

2.2 Data Sources

A wide range of data sources have been used as resources to prepare the Watershed Characterization Report and the accompanying maps. Data used to characterize the Thames watershed is provided in the Table 2-1 below.

Table 2-1 Watershed Characterization Report Data Sources

Component	Data Source
Bedrock Geology	Waterloo Hydrogeologic. 2005. Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report.
Surficial Geology	Waterloo Hydrogeologic. 2005. Southwestern Region Edge-Matching Study. Surficial Geology of Southern Ontario. Ontario Geological Survey Miscellaneous Release –Data 128.
Physiography	Chapman, L.J. and D.F. Putnam. 1984. The Physiography of Southern Ontario, 3rd edition.
Soils Information	Ontario Ministry of Agriculture and Food and Agriculture Canada, Soils Ontario Version 1.0. Ontario Soils Surveys
Groundwater Hydrogeology	Waterloo Hydrogeologic. 2005. Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report. Waterloo Hydrogeologic. 2005. Southwestern Region Edge-Matching Study. Municipal Groundwater Studies. MOE.
Surface Water Hydrology	Ontario Ministry of the Environment and Ontario Ministry of Natural Resources. 1975. Thames River Basin Water Management Study. Stream Gauge Data. Ontario Ministry of Agriculture and Food and Agriculture. Municipal Drain Classification (Fisheries and Oceans Canada project) data. UTRCA. 1991. Dam Inventory and Reservoir Assessment.
Naturally Vegetated Areas	Ministry of Natural Resources Aerial Mapping 2001 and 2003.
Aquatic Ecology	Species at Risk Recovery Plan. Fisheries and Oceans Canada. Ontario Ministry of Natural Resources. Royal Ontario Museum. Ontario Ministry of the Environment. COA and COA partners - Thames River Habitat Assessment and Monitoring Program.

Table 2-1 Watershed Characterization Report Data Sources

Component	Data Source
	Thames watershed Species at Risk data from Cudmore, B., C. A MacKinnon and S. E. Madzia. Dec. 2004. Aquatic Species at Risk in the Thames River Watershed, Ontario. Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2707. Thames River Recovery Team. 2004. Recovery strategy for the Thames River Aquatic Ecosystem: 2005-2010. December 2004 Draft. 145 pp. Natural Heritage Information Centre
Human Characterization	Statistics Canada. Censuses of Population, 1901-2001 and 1996-2006. Indian and Northern Affairs Canada website: http://ainc-inac.gc.ca Ontario Ministry of Finance Ontario Population Projections, 2006-2031. Municipality Official Plans. Ministry of Environment. June 1991. Waste Disposal Site Inventory. Census Canada. Ontario Ministry of Agriculture and Food and Agriculture.
Drinking Water Sources	Ministry of Environment Permit To Take Water (PTTW) database. Municipal Groundwater Studies. MOE.
Water Quality	Provincial Water Quality Monitoring Network. Provincial Groundwater Monitoring Network. Drinking Water Surveillance Program. Drinking Water Information System. Annual Drinking Water System Reports. Ministry of Environment Inspection reports. Water treatment plant laboratory data. Ambient Groundwater Chemistry Study of the Thames River and St. Clair Region Watersheds. Waterloo Hydrologic Incorporated, 2008.

2.3 Components of the Watershed Characterization Report

2.3.1. Watersheds and Subwatersheds

The source protection area (*SPA*) watershed boundary within the source protection region (SPR), as well as the subwatersheds within the *SPA*, are identified and described. The Thames watershed and region is comprised of the Lower Thames Valley Source Protection Area (*LTVSPA*) and the Upper Thames River Source Protection Area (*UTRSPA*). Map 1-1 in Appendix 1 illustrates the Thames-Sydenham and Region boundary and the Source Protetcion Area watershed boundaries within the Region.

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 *UTRSPA* covers approximately 3,423 square kilometres with a total watershed population (2001) of about 472,000.

2.3.2. Physical Geography

This component describes the location and types of natural vegetative cover, aquatic habitats, and species habitats within the source protection area that are on the Species at Risk in Ontario List. It also describes the history, structure and composition of the surface, just below the surface, and deep beneath the surface (geology). In addition, this component describes natural landscape features (physiography), soil types, and surface shape and features (topography). Water movement on the surface (surface hydrology), such as rainfall, and water movement below the ground (groundwater hydrogeology), and climate, including air temperature and flooding are also included. A few details are given below but do not provide a complete picture of the characterization. For accurate descriptions, refer to the Thames Watershed and Region Watershed Characterization Report (2008).

Geology, Physiography and Soil Types

Bedrock is the rock formation deep under the ground, over which lies the overburden rock formation. The bedrock geology formations in Upper Thames River Source Protection Area are mainly the Dundee formation (fossiliferous limestone) and Detroit River Group (orthoquartzitic sandstone). The surficial geology is influenced by the type and nature of overburden. In the *UTRSPA*, the primary material of diamicton/till dominates, with silt plain north of St. Marys, and gravel near Komoka. Till is a mixture of clay, silt, sand and pebbles. The *UTRSPA* is mainly till plains without drumlins (streamlined landforms), with the exceptions of Oxford county which is a till plain with drumlins, and a sand plain north of London surrounded by spillways. As described below, till moraines are also important features of the *UTRSPA*. In the *UTRSPA*, 'silt & clay loam' type of soil is predominant (39%), with 'silt & clay' (26%) and 'loams' (15%) following. Maps 4, 5, 6 and 7 in Appendix 5 shows the Thames watershed bedrock geology, overburden thickness, surficial geology and physiography respectively.

Topography, Hydrology and Hydrogeology

In the Upper Thames River Source Protection Area, the bedrock topography is higher than in other parts of the SPR, with the highest elevations occurring in north eastern parts of Perth

County. Moraines are ridges of material that are generally topographic highs. Till moraines are seen across Komoka to Ingersoll and Woodstock, and in Perth County north of St. Marys, while a kame moraine is south of St. Marys. The Thames rises at three distinct points in *UTRSPA*, near Mitchell (North Thames), Hickson (Middle Thames) and Tavistock (South Thames). The river beds are rocky and the valley slopes are steep, in contrast with the lower Thames River in the *LTVSPA* where the plains are flat. In the upper portion of the Thames River, the flow is 40% surface runoff and 60% 'base flow'. Base flow includes contributions from groundwater, tile drains, flow augmentation from reservoirs and treated sewage effluent discharge. An aquifer is a water bearing layer under the surface, which can be tapped by drilling groundwater wells. The depth of the bedrock aquifer to the surface is shown in Map 12 of Appendix 5.

Hydrology and climatic conditions are monitored locally by a combination of Environment Canada and Conservation Authority monitoring stations, including at London, Woodstock and Stratford in the Upper Thames River Source Protection Area. From plotting 10 year running averages over the data years of 1950 to 2005, an increasing level of precipitation in the 1970s and 1980s is seen with decreases recently. An increase in the linear trend line is seen at London, Woodstock and Stratford.

Natural Vegetative Cover

Wetlands are about 57 sq. km and make up less than 2% of the total *UTRSPA* watershed area of 3447 sq. km, as shown in Map 23a of Appendix 5. Overall, wetland cover averages 1.7% with a high of 9.7%. The subwatersheds with the highest wetland cover are Black Creek (north of Stratford), Dorchester (east of London) and Komoka (west of London). All of these areas contain large wetland complexes. The vast majority of the remaining wetlands in the Upper Thames River Conservation Authority (UTRCA) 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. Many swamps contain small pockets of marsh vegetation where emergent plants such as cattails, rushes and sedges dominate, but there are no large marsh sites. Bogs and fens are also very rare. There are a couple of kettle bogs in the London area. In the upper Thames River watershed there are 31 provincially significant and 35 locally significant wetlands.

In the *UTRSPA* watershed, woodland/forest cover varies between 5 and 21% within the subwatersheds (with an average of 12%, or about 413 sq. km), as shown in Map 25a of Appendix 5. 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 largest woodland/forest tract is Ellice Swamp (1014 ha), located north of Stratford. 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.

The area of land adjacent to streams is often called the riparian zone or buffer zone. In the *UTRSPA*, the riparian areas 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.

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. There are several significant protected areas in the *UTRSPA* 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.

Aquatic Ecology and Habitats

In the Thames Watershed & Region, the wide variety of habitats, favourable climate, nutrient-rich waters, and connection with the Great Lakes result in a particularly diverse aquatic community. The Thames River and its tributaries support one of the most diverse fish communities in Canada. Records exist for approximately 94 fish species in the Thames River subwatershed, which represents more than half of all of Ontario's 165 species. Table A5-1 (Appendix 5 Addendum) lists the fish species recorded in the Thames River subwatershed. Table A5-2 (Appendix 5 Addendum) lists the mussel species found in the Thames River.

Aquatic invertebrates, especially the benthic macroinvertebrates (BMI) that inhabit watercourse substrates, are abundant in all Thames reaches and tributaries. BMI communities consist of insect larvae, aquatic worms, crustaceans, and many other species. Most have fairly well known tolerances to pollution and disturbance. Table A5-3 (Appendix 5 Addendum) lists the benthic species commonly found in the Thames River and tributaries.

Introduced fish species found in the Thames such as the common carp and round goby are considered invasive species. In the Great Lakes, native freshwater mussel populations have been decimated by zebra mussels (from certain water bodies in Asia).

Map 20 of Appendix 5 illustrates the UTRCA Watershed Watercourse Classification to differentiate between municipal drains, natural watercourses (non-municipal drains) and some 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. the natural or non-municipal drains represent more than 25% of the length of watercourses in the UTRCA watershed. However, based on a review of Map 20 of Appendix 5, the majority of the natural watercourses are the main rivers including the Thames River, the north, middle and south branches of the Thames and the lower sections of some of the larger tributaries such as the Avon River.

Approximately 24% of watercourses in this watershed provide suitable water quality and habitat conditions for sensitive species. Of those watercourses approximately 6% are municipal drains and 18% are natural watercourses.

Table 2-2 shows the habitat and temperature assessment information for the *UTRSPA*. Approximately 10% of watercourses in UTRCA are permanent cold/cool water streams with less than half considered to be natural. Approximately 61% are permanent warm water while about 30% are intermittent watercourses. Of the 61% that are warm water, there is an almost equal division between natural watercourses (31%) and municipal drains (30%). Of the roughly 30% of watercourses that are intermittent systems, or dry for most of the year, only 2% are considered natural while 28% are municipal drains.

Table 2-2 Habitat and Temperature Assessments in the UTRSPA

Municipality	Permanent Flow	Intermittent Flow	Coldwater	Warmwater
Biddulph	13	3	3	13
Blandford-Blenheim	7	27	0	31
Central Huron	2	0	2	0
East Zorra-Tavistock	44	50	18	78
Ingersoll	2	0	2	0
London	69	93	7	155
Middlesex Centre	71	111	6	176
Mitchell	6	0	0	6
North Dorchester	1	0	1	0
North Perth	0	8	0	8
Norwich	17	1	5	13
Perth East	82	79	18	143
Perth South	126	28	11	143
Sebringville	2	0	0	2
South Huron	16	3	0	19
South West Oxford	25	18	9	34
St. Marys	13	1	0	14

Stratford	22	3	0	25
Strathroy-Caradoc	4	2	2	4
Thames Centre	84	120	20	184
West Perth	99	85	3	181
Zorra	115	145	43	217
Total	**820**	**777**	**150**	**1,446**

Much of the headwaters, particularly intermittent drains, have remnant pools that provide refuge areas for a variety of the more tolerant or hardy aquatic species. However changes such as cobble being removed from the channels and the lack of pool riffles result in aquatic communities limited to hardy warm water species.

In a few isolated headwater locations in the Thames, conditions allow more sensitive cold water communities to persist. Sensitive BMI species, such as stoneflies and some caddisflies, are indicators of a high quality aquatic habitat or ecosystem. Cold water fish species, such as trout and sculpin, that require well-oxygenated cool or cold flows year-round, can be found in these headwater streams. Moving downstream from the headwaters to medium-sized Thames tributaries, overall aquatic habitat generally improves as the stream size increases. In these streams, a diverse aquatic community is generally present, often including many mid-tolerant and the occasional sensitive BMI. In addition, most streams support a diverse fish community that may include top-level predators and Species at Risk (SAR). A few streams that have significant groundwater inputs support native brook trout or introduced brown trout populations.

Further downstream, the larger tributaries and the three main Thames branches generally support aquatic communities of increased complexity and stability. Much of the north Thames, portions of the middle and south Thames, and a few larger tributaries support very diverse and productive aquatic communities. The communities of BMI are largely comprised of mid-tolerant and a few sensitive species. Top-level predators and species that require relatively clear flows and clean substrates to survive are well represented within the fish community. These river and stream reaches also provide habitat for a large proportion of the surviving fish, reptile and

freshwater mussel SAR found in the Thames. From London downstream to the Delaware area, the flow and habitat conditions for the river are much like the upper branches but at a larger scale.

Impact of Human Activities on Aquatic Ecology and Habitats

The Watershed Characterization Report also discusses the impacts human activities have had on aquatic ecology and habitats. The Thames River is situated in a highly developed part of southern Ontario. The aquatic community faces many pressures from urban and rural land uses and human activities. Most of the watercourses have been greatly altered by human influences. On larger watercourses, many of the influences accrue from urban development, including channel alteration, bank hardening, storm water runoff, and sewage effluent input. Rural influences often involve smaller watercourses where habitat changes and alterations such as drains and channelization are aimed at improving agricultural operations. In general, species that prefer clear, fast flowing water are declining (Thames River subwatershed Species at Risk data from Cudmore, B., C. A MacKinnon and S. E. Madzia. Dec. 2004. Aquatic Species at Risk in the Thames River Watershed, Ontario. Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2707).

In 1986, Holm and Crossman completed a study comparing current (1985) information to historic surveys from the 1920s and 1940s. They identified water quality and fish habitat as conditions that had deteriorated significantly in the Thames River. They noted that turbidity and siltation had increased, and that stream flow rates had changed as a result of habitat disruptions such as impoundments. They also indicated a decline of species with a preference for clear, fast water and an increase in abundance of species more tolerant of turbidity.

Intermittent drain systems provide a significant function to the watershed. They provide fish habitat when wet and, in many cases, significant spawning areas during spring flooding. Some drains have pooled refuge areas (as evident in the upper Thames watershed) and support habitat generalist species. These drains still support aquatic communities that primarily consist of tolerant BMI and fish species. These are particularly evident where agricultural best management practices (BMPs) have reduced agricultural impacts. In recent years, many of

these intermittent watercourses have been converted to closed systems. The trend to close drain systems has altered the hydrograph, hydrologic regime and fluvial dynamics of the receiving watercourses and has led to an increase in erosion in downstream watercourses. Changes such as cobble being removed from the channels and the lack of pool riffles result in aquatic communities limited to hardy warm water species.

In a few isolated headwater locations in the Thames, more sensitive cold water communities persist due to the presence of groundwater discharge, riparian vegetation and shading, headwater wetlands, and usually an undisturbed natural channel (although several drains support cold water communities). Moving down from the headwaters, most medium-sized streams have natural channels or, if channelized, their stream power is often more in balance with the channel characteristics. Riffle/pool sequences have redeveloped with a firm (cobble/gravel/sand) substrate similar to that found in most natural watercourses. Most have an evident, well-defined flood plain with varying levels of disruption. A few have relatively undisturbed riparian vegetation and others are pastured or are idle pasture. The areas with idle pasture are now undergoing the slow process of natural succession or regeneration. Influences on these streams are silt, nutrient and pollutant inputs, both from neighbouring land use and from upstream sources. However, the improved habitat allows development of a complex and productive aquatic community with flood plain and hyporheic zone interactions. This enhances nutrient utilization and cycling. A diverse aquatic community is generally present. Further downstream, the larger tributaries and the three main Thames branches generally support aquatic communities of increased complexity and stability. For the most part natural stream morphology and undisturbed flood plain is evident. The less impacted sections include much of the north Thames, portions of the middle and south Thames, and a few larger tributaries which support very diverse and productive aquatic communities. These river and stream reaches also provide habitat for a large proportion of the surviving fish, reptile and freshwater mussel Species At Risk (SAR) found in the Thames. However, many of these larger watercourses are influenced by urban development, including channel alteration, bank hardening, stormwater runoff, and sewage effluent input.

In general, a diverse community of mussels characterizes a healthy aquatic environment. There was once a diverse mussel community in the Thames. Mussel species that have disappeared,

or mussel species that are extremely hard to find, indicate that aquatic conditions may be deteriorating. The primary threats to native freshwater mussel population include turbidity, siltation, habitat loss or degradation, watercourse barriers, invasive species and poor water quality.

Species at Risk

Map 29 of Appendix 5 shows the number and locations of SAR in the Thames watershed. Table A5-4 (Appendix 5 Addendum) lists the aquatic SAR in the Thames River subwatershed.

Currently, 13 of the 94 fish species found throughout the Thames River subwatershed are considered Species At Risk (SAR), under the Species at Risk Act. The gravel chub is the only species considered to be extirpated. The northern madtom is the only species listed as endangered. The eastern sand darter, lake chubsucker, and black redhorse are threatened species. The northern brook lamprey, bigmouth buffalo, black buffalo, silver shiner, pugnose minnow, river redhorse, spotted sucker, and greenside darter are of special concern.

In the Thames River watershed, there are 27 aquatic species with SAR status. Of these, the stinkpot turtle is considered possibly extirpated, the spiny softshell and northern map turtles occur in pockets, the Blanding's turtle is rare and the spotted turtle, queen snake and northern ribbonsnake are very rare.

In the Thames River watershed, seven at risk mussel species have been recorded. All of these mussels are listed as endangered by Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The mudpuppy mussel, round hickorynut and snuffbox are believed to be extirpated from the Thames River (Thames River Recovery Team. 2004. Recovery strategy for the Thames River Aquatic Ecosystem: 2005-2010. December 2004 Draft. 145 pp). The rayed bean and kidneyshell were also believed to be extirpated from the Thames River; however, both species were confirmed alive from different locations in 2004 (Morris, Todd J. 2005. Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada).

2.3.3. Human Geography

The current population and estimated growth rate in each municipality are presented. The Upper Thames River Source Protection Area (*UTRSPA*) includes most of the municipality of City of London, and large parts of Elgin County, Middlesex County, Perth County and Oxford County. It also contains small parts of Huron County and Elgin County. The area covers approximately 3,423 square kilometres with a total watershed population (2001) of about472,000. There are no First Nations in the *UTRSPA*, however there are First Nations in the other two SPAs of the source protection region.

Types of settlements (urban and rural centres) and land use (such as agricultural, residential and industrial) across the watershed are discussed. Map 1-4 of Appendix 1 shows the Areas of Settlement (as per the Places to Grow Act, 2005) in the Upper Thames River Source Protection Area. The largest urban centre within the Upper Thames River Source Protection Area is the City of London, with an approximate population of 336,539 in 2001. Table 2-3 shows the population by municipality, for the years 2006, 2001 and 1996. Map 2-1 in Appendix 1 shows the population density across the Upper Thames River watershed. Growth rate projections for municipalities in the *UTRSPA* are discussed in the Watershed Characterization Report.

Table 2-3 Population Density of Municipalities in the Upper Thames River SPA Watershed

Census Division	2006 Population	2001 Population	1996 Population	1996 to 2001 Population Change	2001 to 2006 Population Change
Middlesex (incl. City of London)	422,333	403,165	389,616	3.50%	4.70%
Elgin	85,351	81,553	79,159	3.00%	4.70%
Huron	59,325	59,701	60,220	-0.9%	-0.6%
Perth	74,344	73,675	72,106	2.2%	0.9%
Oxford	102,756	99,270	97,142	2.2%	3.5%

Map 30 of Appendix 5 shows the generalized land cover in the Thames Watershed & Region. Agriculture is the dominant land use, but a wide variety of industrial, commercial and institutional land uses also provide employment for people. General locations of federal lands in and around the Upper Thames River Source Protection Area are shown in Figure 2-1. The Figure was generated using an on-line tool available at the Treasury Board of Canada Secretariat website (http://www.tbs-sct.gc.ca/dfrp-rbif/home-accueil.asp?Language=EN), map navigator page.

Figure 2-1 Federal Lands in and around the Upper Thames River SPA

Looking into converting this figure to a map

Interaction between Physical and Human Geography

The watershed characterization report discusses the interaction between human and physical geography.

The original amount of wetland cover in the UTRSPA watershed is unknown. The total area of wetland cover (evaluated wetlands) is now less than 2% of the conservation authority's watershed area.

The smaller watercourses (first to third order streams) have, on average, 20% woodland riparian cover. The larger watercourses (fourth order and higher) have approximately 28% riparian cover. This difference is to be expected as many of the first and second order streams are farm drains that are often without any buffer at all.

Hardwood forests covered the majority of the upper Thames River watershed prior to European settlement with smaller pockets of grassland and savanna habitat. Species diversity was very high in this region due to the long growing season, rich soils and productive waterways. However, these same factors also made the area attractive for farming and urban development.

Today, the woodland/forest cover in the *UTRSPA* is highly fragmented, existing as small woodlots separated by agricultural fields, urban development and other land uses. Over 70% of the woodlots in the upper Thames watershed are less than 10 hectares. Due to the practice of clearing the acreage closest to the concession road for farming, many woodlots represent the 'back 40' of farms and are distributed in a linear fashion parallel to the roads.

Over the past century, several diseases and pests introduced by man have had a significant impact on the local tree species. The American Chestnut was destroyed by chestnut blight, caused by an Asian bark fungus accidentally introduced to America on imported Asiatic chestnut trees. The Blight was probably imported into North America from Asia in the early 1900s. Similarly, the American Elm has been seriously affected by an introduced fungal disease, Dutch Elm Disease, with heavy mortality. The disease was accidentally introduced into North America in 1931, in shipments of logs from the Netherlands destined for use as veneer. More recently, the Emerald Ash Borer, which is native to China and eastern Asia, has left a path of destruction in Essex County in southwestern Ontario (as well as southeastern Michigan, northern Ohio and Indiana). It has been found in Chatham-Kent and Elgin County. Its significance for woodlands in the region is not yet known but ash trees form an important part of the local tree cover in many woodlots.

Oxford County is characterized by significant reserves of mineral aggregates from both naturally occurring sand and gravel deposits and bedrock-derived crushed stone. The presence of substantial, highquality deposits has led to the establishment of significant quarrying and sand and gravel extraction industries in the County. Much of the activity is located in Zorra Township. Several sections of Middlesex County contain abundant Quaternary deposits of sand and gravel. Portions of the City of London, including the Byron area and land surrounding Fanshawe Conservation Area, contain valuable deposits in close proximity to a large market with high demands for aggregate resources. In the Komoka area of Middlesex Centre Township, most of the aggregate resources have been extracted, although some pits are still active. In Perth County, excessive overburden limits the accessibility of limestone deposits that underlay most of the county, with St. Marys being the notable exception. Here, extensive quarrying activity since the 1880s has produced a significant percentage of limestone used for the production of cement products in the Great Lakes region.

In the *UTRSPA* watershed, there are 11 active landfills, most of which are in Perth County. The active landfills are small and for local communities. In the *UTRSPA* watershed, there are brownfield areas in all of the major urban centres. Brownfields are generally abandoned or underused commercial or industrial areas thought to be contaminated by past activties but which have a potential for redevelopment. Municipalities have either developed or are developing policies and incentives to encourage brownfield re-development. In the smaller urban settings, brownfields are limited in size and location. The Brownfield and Community Improvement Plans (*CIP*) vary from municipality to municipality. Inthe City of London, the *CIP* for brownfields cover lands within the Urban Growth Boundary identified on the Land Use Map (Schedule “A”) of the Official Plan, allowing those lands possible remediation.

Southwestern Ontario has a long history related to the oil and gas industry. Map 31 of Appendix 5 shows the concentration of oil and gas wells across the area. Middlesex, Oxford and Perth Counties are underlain by Paleozoic sedimentary rocks that have the potential for occurrence of oil and gas resources. However, very few commercial discoveries of hydrocarbons have been made other than the Innerkip gas pool in the northwestern corner of the *UTRSPA* watershed. Natural gas has been produced from the Innerkip gas pool since 1961. Only non-commercial shows of oil or natural gas have been encountered in the rest of the watershed. Relatively few wells have been drilled over 100 m to explore for hydrocarbons in the area and there is potential for additional undiscovered pools.

Due to a number of factors, including moderate temperatures, adequate rainfall, adequate growing season and good soil, the major land use in the region is agricultural and, more specifically, cash crop land. As shown on Map 33 of Appendix 5, 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. Farming dates back more than 1,000 years in the Thames watershed, when the Woodland peoples grew corn on fertile flood plain lands. These areas were considered to be highly suitable for agriculture as well as trade, transportation and later, industry. In the *UTRSPA*, agriculture being the predominant land use in 26 of the 28 subwatershed units. Farmland makes up over 80% of the land use in the region. Most of the farmland is used in the raising of field crops. Soybeans, corn and wheat are the three main crops. 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. Notably, the land area used in the production of soybeans has increased dramatically in this time. The other major field crop is corn and the land area used in the production of corn has only slightly increased. Therefore, the land area used for producing soybeans has resulted in significant reductions in the production of wheat, oats, dry beans and hay. Most of the soybeans and corn are sold for commercial use. Other significant crops include tomatoes, sweet corn, peas, and other vegetables or fruits grown for sale to the consumer or the food processing industry.

Another major component of the agricultural industry in Ontario is the raising of livestock. Hog and poultry production is cost-efficient due to the reliable supply of locally-grown feed grain. Dairy farming is still the main commodity for farm cash receipts in Oxford County, an area historically well known for its milk production.

In the 20 year period from 1986 to 2006, the number of farm operations has decreased and the farm operation size has increased. Many factors have contributed to this change. One of these is the increased use of reduced and no-till farming practices. While these practices were promoted as methods to reduce water runoff and soil erosion, they also reduce costs, maintain crop yields and result in substantial individual productivity increases. Therefore, a single operator was able to work larger acreages. Other factors that have contributed to increased farm productivity are the availability of larger and more efficient farm machinery, better plant hybrids and more effective pest management.

Navigation by vessels is limited to the Thames River below London. The Thames River, although not navigable for large craft, still provides a picturesque locale for recreational boating, canoeing, rowing, and kayaking. Canoeing can be done in much of the upper Thames and small boats can be used on the impoundments behind some of the dams on the river. Fishing takes place in these waters and many of the other creeks and streams in the region. The Wildwood, Pittock and Fanshawe dams provide flood control. Map 22 of Appendix 5 shows the dams and control structures in the Thames watershed. These structures may affect water quality and restrict fish migration. Along the shoreline of the Thames River are pockets of cottages as well as low density residential and estate residential development with direct access to both public

and private roads. Permanent dwellings in these locations are attractive because of their scenic vistas, recreational amenities and relatively easy commute to urban centres.

There are 17 private and municipal/conservation authority campgrounds in the *UTRSPA*. There are more than 30 public and private golf courses located throughout the *UTRSPA* including several that incorporate lands (flood plains) adjacent to local watercourses.

As mentioned earlier, there are several significant protected areas in the *UTRSPA* watershed. Ellice Swamp in Perth County, Golspie Swamp in Oxford County, Dorchester Swamp in Dorchester and Middlesex County, Sifton Bog in the City of London, and the Westminster Ponds/Pond Mills Conservation Area in the City of London are some of the protected areas in the *UTRSPA*. These areas are protected from developmental changes that could alter their natural characteristics.

2.3.4. Water Quality

This component describes the water quality across the *SPA*. The selection of indicator substances (parameters) is discussed. The watershed inland surface water, the ambient groundwater, municipal well raw (untreated) water, and the municipal surface water intake raw water quality data is reviewed and assessed using certain standards or guidelines. Where possible, trend lines are shown and statistical analyses performed.

Both drinking water quality standards and aquatic protection guidelines are used to assess water quality. 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 (untreated) water to the standards or guidelines. The operation of a water treatment plant, including treated and distributed water quality, is governed separately under the Safe Drinking Water Act.

To evaluate inland surface water quality, data from 24 surface water quality monitoring stations across the Upper Thames River Source Protection Area were reviewed for certain parameters. These stations are monitored under the Provincial Water Quality Monitoring Network (PWQMN) program. At all stations in the UTRCA subwatersheds, the current 75th percentile phosphorus

levels are above the Interim Provincial Water Quality Objective (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 phosphorus values are generally between two and eight times the IPWQO. Seven of 30 UTRCA stations have current 75th percentile nitrate values that are higher than the Ontario treated drinking water standard (ODWS) of 10 mg/L. To evaluate water quality for aquatic life, a nitrate level of 2.93 mg/L has been used for comparison. Only two UTRCA stations have current 75th percentile nitrate values that are less than 2.93 mg/L. Historically, the levels at all UTRCA stations were above 2.93 mg/L with the exception of Dorchester Swamp Creek which has been consistently below 2.93 mg/L.

The current 75th percentile chloride concentrations at all UTRCA sites are below the ODWS of 250 mg/L. Historically, most UTRCA sites have concentrations that are below 100 mg/L. However, the chloride 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 75th 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 stations have chloride concentrations below 210 mg/L.

A review of data for *Escherichia coli (E. coli)*, a bacterial indicator, shows that the indicator is consistently above the recreational use guideline (100 counts per 100 mL) at most of the monitoring stations. Copper and zinc levels are lower than the guidelines at all stations. At the UTRCA stations in 1980-84, all stations had samples above the lead 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.

To evaluate the groundwater quality, data from 23 groundwater monitoring wells across the Upper Thames River Source Protection Area were reviewed. The monitoring is part of the Provincial Groundwater Monitoring Network (PGMN) program. 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.

Fluoride levels were above the ODWS of 1.5 mg/L in seven UTRCA monitoring wells. Fluoride can occur naturally in groundwater at levels that are above the drinking water standard. Two monitoring wells had nitrate + nitrite or nitrate results above the ODWS of 10 mg/L, one monitoring well had arsenic above the ODWS of 0.025, and one monitoring well had cadmium above the ODWS of 0.005 mg/L. In the UTRCA, 13 monitoring wells had iron above the Ontario Drinking Water aesthetic objective (AO) of 0.3 mg/L and six monitoring wells had manganese above 0.05 mg/L. Iron and manganese in groundwater are usually due to the natural weathering of rocks and minerals. In the UTRCA watershed, dissolved solids (five monitoring wells), dissolved organic carbon (three monitoring wells) and chloride (one monitoring well) were found abovethe AOs. 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 the ODWS of 200 mg/L) was found in nine UTRCA monitoring wells. There were 19 UTRCA monitoring wells that had hardness levels that were not within the Ontario Drinking Water Operational Guideline (OG) range of 80 to 100 mg/L. In addition to hardness, four UTRCA monitoring wells had high aluminum and one UTRCA monitoring well had high pH.

In the Upper Thames River Source Protection Area, there are 23 municipal groundwater and no surface water drinking water systems. Data used to evaluate water quality of raw water to the drinking water systems were: Drinking Water Surveillance Program (*DWSP*), Drinking Water Information System (*DWIS*), Annual Drinking Water System Reports, Ministry of Environment Inspection reports and minimal water treatment plant laboratory data. Similar to the findings of the groundwater monitoring data review, fluoride in raw (untreated) municipal well water is generally higher than the treated drinking water standard. Bacterial indicator total coliform is present in untreated water of most municipal wells, but *E. coli* was present in untreated water of only 5 systems.

Nitrates occur above the treated drinking water standard of 10 mg/L in the Thornton wellfield of the Woodstock wells. Flourides occur above the treated drinking water standard of 1.5 mg/L in most wells, and is known to be naturally occurring in the groundwater.

In Middlesex County and City of London back up wells, sodium was below the treated drinking water standard of 200 mg/L but above the 20 mg/L Health Unit notification level. One instance of fluoride above ODWS of 1.5 mg/L occurred in the Thorndale system in 2004. In Oxford County, the Embro, Thamesford, Woodstock and Ingersoll systems had wells that had sodium levels below the drinking water standard of 200 mg/L but over the Health Unit notification level of 20 mg/L. The Ingersoll, Lakeside and Thamesford systems had wells that had instances of fluoride above the ODWS.

In Perth County, St. Marys and City of Stratford systems, the Sebringville, St. Pauls and Stratford well systems, sodium levels above the 20 mg/L Health Unit notification level are observed but the sodium levels are below the drinking water standard of 200 mg/L. The Mitchell, Sebringville, St. Pauls and Stratford well systems had instances of fluoride levels above the ODWS. In the Sebringville and Stratford systems, fluoride levels are noticeably high, often above 2.0 mg/L.

In addition, in Middlesex County, iron is above the ODWS in the Komoka-Kilworth and Melrose systems, with manganese above ODWS also in the former. Iron and manganese levels above the ODWS are also observed in a few Oxford County wells. In the City of London back up wells, organic nitrogen and phosphorus also are above ODWS and IPWQO, respectively. Hardness and total dissolved solids are seen in City of London and St. Marys wells. In Perth, iron levels above the ODWS are observed.

2.3.5. Water Quantity

In this component, the water use across the Source Protection Area is discussed. 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*). Water taking includes uses which return the water to the source, as well as those which do not. Water taking also includes taking water into storage. In Section 3 – Water Budget and Water Quantity Stress Assessment water use is considered in more detail, including quantifying how much of the water taking is consumptive.

Water takers have a responsibility to ensure that the amount of water they use does not threaten the environment or existing water users. 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. The approximate water taking (use) by sector (agricultural, commercial, industrial, municipal, water supply, dewatering, remediation, construction) is presented and described. The water taking for each subwatershed catchment area is also presented. These catchment areas are delineated through the Conceptual Water Budget study, which is described in a Section 3 – Water Budget and Water Quantity Stress Assessment.

In the Thames watershed and region, while the agricultural sector has around 33% of the total permits, 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. Water supply makes up about 24% of the water taking permits, and includes takings by municipalities, campgrounds and communal uses.

2.3.6. Drinking Water Systems

There are 25 municipal drinking water systems which service people living in the Upper Thames River *SPA* of which two are located outside the *SPA*. The drinking water supply systems servicing the Upper Thames River *SPA* are shown in Map 1-3 of Appendix 1. Details are provided in Table 2-4. The 23 municipal drinking water systems located within this *SPA* are included in the Upper Thames River Source Protection Area Terms of Reference document, and therefore in this Assessment Report.

Table 2-4 Municipal Drinking Water Systems Serving the Upper Thames River Source Protection Area

Drinking Water System (No. of wells)	Source Water	Operating Authority	Approx. Population Served	Pumping Rates (cubic meter per day)			
				Well	Maximum Annual	Average Annual	Average Monthly
Birr (1)	GW	American Water Systems	63				
Melrose (2)	GW		224				
Komoka (3)	GW		2600				
Fanshawe (6)	GW	Corporation of the City of London	Back up				
Hyde Park (1)	GW		Back up				
Thorndale (2)	GW	Municipality of Thames Centre	675				
Dorchester (8)	GW		5586				
Mitchell (4)	GW	West Perth Power Inc.	4000				
Sebringville (1)	GW	Ontario Clean Water Agency	90				
Shakespeare (1)	GW	American Water Canada Corp.	220				
St. Pauls (1)	GW	Township of Perth South	90				
Stratford (11)	GW	City of Stratford	30,460				
St. Marys (3)	GW	Town of St. Marys	6200				
Beachville (1)	GW	County of Oxford	180				
Embro (2)	GW		828				
Hickson (1)	GW		99				
Ingersoll (7)	GW		13,572				
Innerkip (2)	GW		840				
Lakeside (1)	GW		310				
Mt Elgin (2)	GW		369				
Tavistock (3)	GW		2300				
Thamesford (3)	GW		2016				
Woodstock (10)	GW		34,000				
Lake Huron Primary Water Supply System*	SW						
Elgin Area Water Supply System**	SW						

*Located outside of Upper Thames River Source Protection Area and therefore not included in this Assessment Report; see the Ausable Bayfield Source Protection Area Assessment Report for information

**Located outside of Upper Thames River Source Protection Area and therefore not included in this Assessment Report; see the Kettle Creek Source Protection Area Assessment Report for information

Residents in the northern part of the Thames watershed rely on treated groundwater for their drinking water. These include communities of Shakespeare, Mitchell, St. Paul's and Sebringville in Perth County, City of Stratford and Town of St. Marys, and communities of Beachville, Embro, Hickson (King subdivision), Ingersoll, Innerkip, Lakeside, Mt elgin, Tavistock, Thamesford, Woodstock and Sweaburg in Oxford County.

Some parts of Middlesex County (communites of Birr, Melrose and Komoka-Kilworth in Middlesex Centre, and Thorndale and Dorchester in Thames Centre) also have municipal systems that use groundwater sources.

Residents in the City of London and some neighbouring Middlesex communities (including Delaware and Ballymote) use treated surface water piped from Lake Huron (Lake Huron Primary Water Supply System) and Lake Erie (Elgin Area Water Supply System). The Fanshawe and Hyde Park well systems serve as back up drinking water systems to the City of London. Most of the water for residents in Elgin County is from Lake Erie.

2.4 Data Gaps

The Data gaps encountered during the preparation of the watershed characterization report are listed in Table 2-5 below.

Table 2-5: Watershed Characterization Data Gaps relevant to the Lower Thames Valley Source Protection Area

Subject	Data Gaps
Aquatic Ecology	
Fisheries Evaluation	Cold water refuges in natural water systems, historic evidence of cold water streams has not been investigated, application of indices such as the Index of Biological Integrity (IBI) to existing fish data.
Aquatic Macroinvertebrates - Habitat Conditions & Water Quality	Simpson's Diversity Index should also be considered, Analysis of physiography & land use to identify potential communities and groundwater quality/quantity stressors and impacts.
Reptile - Survival habitat and population dynamics	Extent , abundance and population demographics of prey (needed for some species); lack of species information, habitat identification, seasonal dispersal, population isolation, reproductive success, past distribution.
Species At Risk - Range and numbers of fish species at risk	Sections of the Thames River have little or no sampling, population, abundance, distribution or status unknown for some species.
Human Characterization	
Landfills	Information on active, closed landfills and expansions not provided for the Upper Thames watershed
Water Quality	
Inland surface water quality - physical, chemical and microbial	Data from 1997 to 2001 from the commonly used provincial water quality monitoring network (PWQMN) dataset does not exist.
Additional sources of information	COA, Health Unit, sediment analysis and Research data have not been reviewed.
Inland and intakes surface water and groundwater quality – emerging pollutants	Not enough data on emerging contaminants (fire retardants, pharmaceuticals, algae toxins, etc.).
Groundwater monitoring well data	Comprehensive data not available
Municipal groundwater well physical and chemical data	Comprehensive, long term data not available; alternate sources of data used.
Wildlife impact on water quality	Locations of large populations of wildlife and the resulting effect on water quality (pathogen contamination and nutrient loading) require a better understanding.
Water Quantity	
Permit To Take Water Data	Data out of date - Many permits in database have expired dates and it is unclear if they have been renewed.
Water uses	Data Incomplete - Older permits only have maximum water taking per day. Difficult to determine actual usage.