# OSHAWA CREEK WATERSHED 2011 ADDENDUM TO THE 2002 MANAGEMENT PLAN: EXISTING CONDITIONS

Central Lake Ontario Conservation

**May 2011**

**Final**

DURHAM REGION

Conservation ONTARIO
Natural Champions

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# THE ADDENDUM

The information provided in this report is intended as an addendum to the existing Oshawa Creek Watershed Management Plan (CLOCA, 2002) and should be read as a companion document. The Oshawa Creek Watershed Management Plan, hereafter termed "Plan (2002)", outlines the watershed's conditions and management strategies based on the best available information at the time of reporting (2002). This addendum, updates several sections of the Plan (2002) to reflect the current watershed conditions and to address the watershed planning requirements of several new or amended policy initiatives. As some sections of the Plan (2002) did not require revision, these section titles and numbers are noted in the addendum followed by the text (*no revisions*). Reference to the Plan (2002) will be required for these unchanged sections.

Since the release of the Plan (2002), numerous changes in land use and policy direction have had an influence on the watershed health and implemented protection measures. Assessments of the effects is an on-going activity by all partners in an effort to maintain, restore and improve where possible the watersheds important hydrologic and ecological features and functions. Indeed, significant advances have been made since the release of the Plan (2002) in understanding the functioning of the watershed and its response to existing and predicted stressors.

With the enactment of the provincial Oak Ridges Moraine Conservation Plan (ORMCP) in 2002, numerous requirements have been set out that must now be addressed in a watershed plan. The ORMCP has a stronger emphasis on ground and surface water quality/quantity and water budgets, and is intended to protect the integrity of the moraine as an integral feature within the watershed. In addition to the ORMCP, the 2005 Provincial Policy Statement (PPS) requires that planning authorities identify those natural features that are necessary to the hydrological and ecological integrity of the watershed. Passage of the Greenbelt Plan, Growth Plan, Durham Region Official Plan Amendment #128, and a rapidly changing and urbanizing watershed, further emphasizes the need for this addendum. Recommendation #19 from the Plan (2002) 'Summary of Key Recommendations' states that "CLOCA undertake a review of the Oshawa Creek Watershed Management Plan within a 10 year time frame." This addendum will fulfill that requirement.

It is important to recognize that each watershed has its own unique characteristics and that a watershed study must be specifically designed in order to place the necessary emphasis on key watershed characteristics in addition to meeting legislative requirements.

Also, key recommendations noted in the Plan (2002) have been acted upon to varying degrees since being released. Within the context of recent land use and policy change, a review of status and applicability of these recommendations is required along with the provision of new insights, management options, and implementation and monitoring plans.

The focus of the overall approach used to develop the content of this addendum is listed below.

- The update to the Plan (2002) is to be in the form of an addendum;
- The assessments and updates will maintain consistency with those undertaken in the recent Lynde Creek and Black/Harmony/Farewell Creek Watershed Existing Conditions reports (CLOCA, 2008 and CLOCA 2010);
- The content will be undertaken at both the watershed and subwatershed scale, where appropriate;
- The content will address the ORMCP watershed planning requirements;
- The content will also include key non-ORMCP updates as identified through a gap analysis of the information in the existing Plan (2002);
- Terrestrial and aquatic information provided in the Plan (2002) required updates to reflect changing methodology and new resource management plans; and,
- It will fulfill the recommended 10-year review as required in the Plan (2002).

This document currently focuses on updating the existing conditions within the watershed. As such, Section 5 of the Plan (2002), being the Watershed Management Plan, has not been revised at this time. Section 5 will be consolidated with this document comprising a complete addendum in the future.

Many sections in the Existing Conditions part of the Plan (2002) require either revisions and/or additions due to both the changed landscape and advances in scientific knowledge and analytical assessments. One fundamental reporting change that has occurred, which impacts on the various assessments and mapping products in this report, is a reworking of the watershed and subwatershed boundaries presented in the Plan (2002). **Figure 1** shows the limits of the revised watershed and subwatershed boundaries. These adjustments are intended to present a more refined representation of the actual drainage boundaries of each basin, and reflect the advance of digital terrain modeling and the availability of more recent stormwater drainage information. The revised boundaries were used in the assessments of spatial information and in the mapping products produced for this report. Lastly, the subwatershed names in the Plan (2002) have been changed, making the subwatershed drainage areas more recognizable to the reader. They are as follows:

| Plan (2002) | Addendum |
|---|---|
| WN | Raglan |
| EN | Enfield |
| WS | Windfields |
| ES | Kedron |
| GC | Goodman |
| MB | Main Branch |
| Mont | Montgomery |
| H | Harbour |

The City of Oshawa and other stakeholders have been consulted with respect to the preparation of this addendum. Upon completion of this draft addendum a public information centre will be held to obtain feedback and comments from stakeholders and the public.

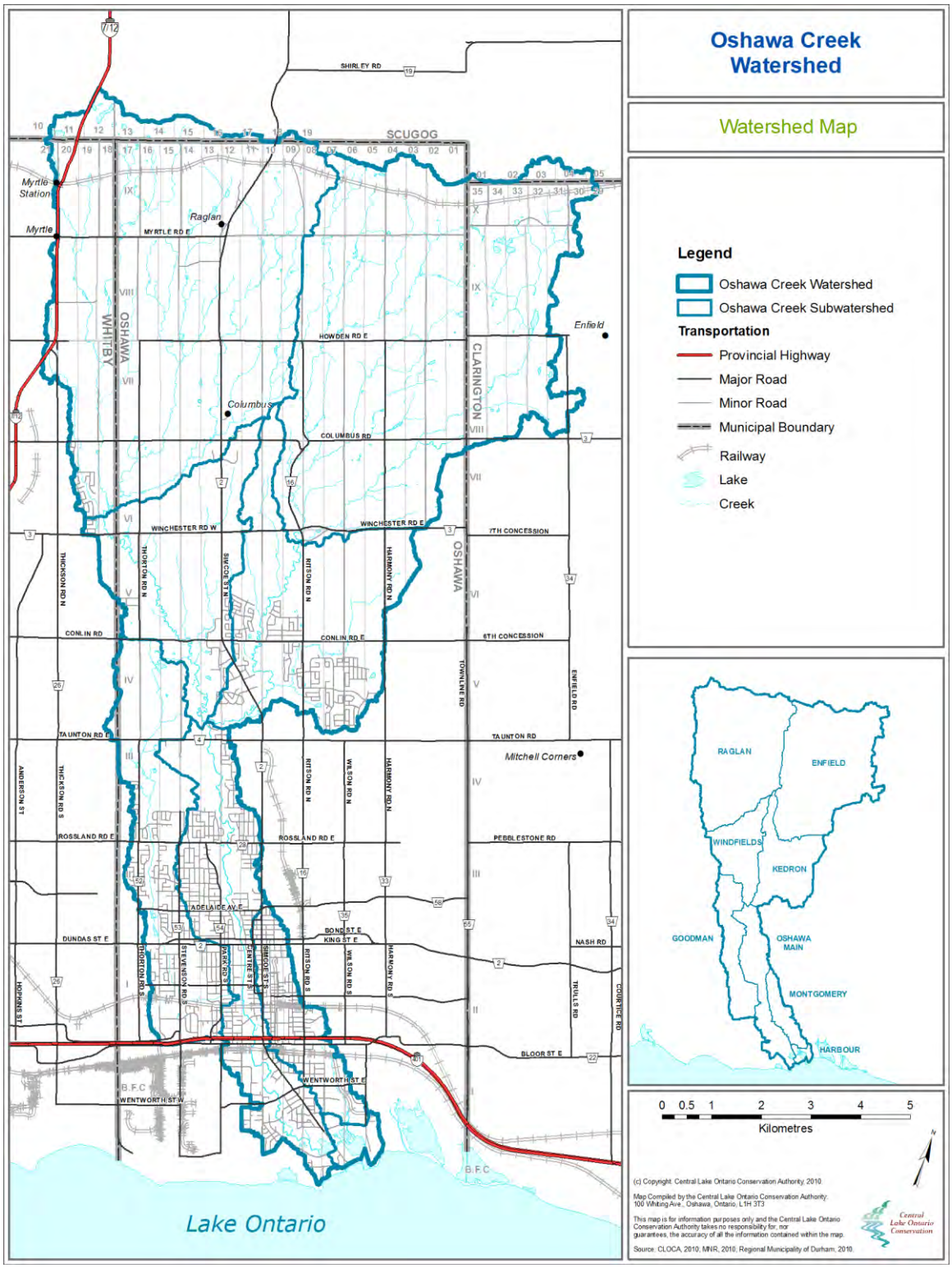


**Figure 1:** Oshawa Creek watershed and subwatersheds

# 1.0 INTRODUCTION (no revisions)

# 2.0 HISTORY OF WATERSHED (no revisions)

# 3.0 EXISTING CONDITIONS

## 3.1 People (no revisions)

### 3.1.1 Land Use and Policy

Since 2002, there have been some substantial changes to provincial and regional land use policies that will influence development within the Oshawa Creek Watershed. Growth and changing land uses have also occurred and the technically preferred alignment for Highway 407 has been selected. Also of significance is that in 2006 the Authority received approval of our 'Development Interference with Wetlands and Alteration to Shorelines and Watercourses, Ontario Regulation 42/06' (Generic Regulation). This new regulation enables the Authority to regulate not only lands susceptible to flooding and hazards, but also wetlands and shoreline areas. These changes have, and will continue to have, impact on land use within this watershed.

The following provides a review of the function that various levels of government play in land use planning and how some of the major pieces of legislation impact planning and development within the watershed.

#### 3.1.1.1 Federal Government

The role of the federal government in land use planning is minimal, generally only directly affecting federally owned lands, federal infrastructure (airports) and communications (telecommunications towers). Within the Oshawa Creek Watershed, the Oshawa Harbour, located at the outlet of the Oshawa Creek into Lake Ontario is federally owned and operated. This is a deepwater industrial port and until May 2009, was operated by the Oshawa Harbour Commission in accordance with the federal Harbour Commissions Act, 1964. In May 2009, the Federal Government announced that the Port will now be operated by the Oshawa Port Authority, created in accordance with the National Marine Policy. Directly east of the Port are other lands owned by the federal government. It is important to note that federal legislation supersedes all other levels of government and as such, the federal government is not bound by provincial or municipal land use policies. Although there is an airport located within this watershed, the Oshawa Municipal Airport is not federally owned or operated.

However, there is direct involvement of the federal government with respect to implementation of the federal Fisheries Act. All development must satisfy the requirements of the federal Fisheries Act. CLOCA has a Level 3 agreement with Fisheries and Oceans Canada (DFO) under Section 35 of the federal Fisheries Act. This agreement enables CLOCA to conduct the review of development occurring within a watercourse to determine if the proposed development will have any impact on fish and fish habitat. If impacts cannot be mitigated, CLOCA works with the proponent of the development and DFO to prepare a fish habitat compensation plan and to receive authorization from DFO under the Fisheries Act.

#### 3.1.1.2 Provincial Government

The provincial government has a more direct role in land use planning through the Planning Act. This Act sets out the rules with which municipalities must comply when making land use planning decisions. The province also establishes other pieces of legislation and policy that have direct implications on land use planning. In the last few years, the Province has recognized that in order to ensure the resources of the province are available for future generations, growth and development must be economically and environmentally sustainable. This position has generated a suite of legislation that directs growth in a sustainable fashion. This includes an amended Planning Act, revised Provincial Policy Statement, the Oak Ridges Moraine Conservation Act and Plan, the Greenbelt Act and Plan, and the Places to Grow Act and Growth Plan. This suite of initiatives focus on sustainable development including promotion of more intensive development, efficient and cost-effective infrastructure, and protection of significant natural features and resources. A brief review of the Oak Ridges Moraine Conservation Plan, the Greenbelt Plan, and the Growth Plan are provided below. For more information about the other pieces of legislation mentioned, the reader is referred to the Province of Ontario web site www.gov.on.ca.

There are other pieces of legislation that, in certain planning applications, may be applicable and must be complied with. Some of these include the Environmental Assessment Act, the Environmental Protection Act, the Aggregate Resources Act, the Drainage Act, the Lake and Rivers Improvement Act, the Endangered Species Act, and the Conservation Authorities Act.

Oak Ridges Moraine Conservation Plan (ORMCP)

The Oak Ridges Moraine is an "environment – first" plan, protecting the ecological and hydrological features and functions that support healthy watersheds, healthy ecosystems, and support the health and well-being of residents (ORMCP, 2002). The ORMCP identifies the following land use designations across the moraine: "Natural Core Area"; "Natural Linkage Area"; "Countryside Area"; and "Settlement Area". The ORMCP also identifies Landform Conservation Areas and Areas of High Aquifer Vulnerability. The ORMCP requires that for those watersheds that drain the ORM, watershed plans are to be prepared. Guidance as to what information is to be included in these watershed plans has been provided by the Province. Implementation of the ORMCP is the responsibility of municipalities. Municipalities are required to incorporate the policies of the ORMCP into their planning documents. All the municipalities within the Oshawa Creek watershed (City of Oshawa, Municipality of Clarington, Town of Whitby and Township of Scugog) have adopted the necessary amendments to their respective Official Plans in order to implement the ORMCP.

Two of the four ORMCP designations are represented within the Oshawa Creek watershed. These are: "Countryside Area" and "Natural Linkage Area". There are no "Natural Core Areas" within that portion of the ORM in the Oshawa Creek watershed (Figure 2).

The "Natural Linkage Area" designation in the Oshawa Creek watershed generally runs along the upper reaches of the watershed and along the valleys of the Oshawa Creek and its tributaries providing corridors that facilitate both north/south and east/west wildlife movement.

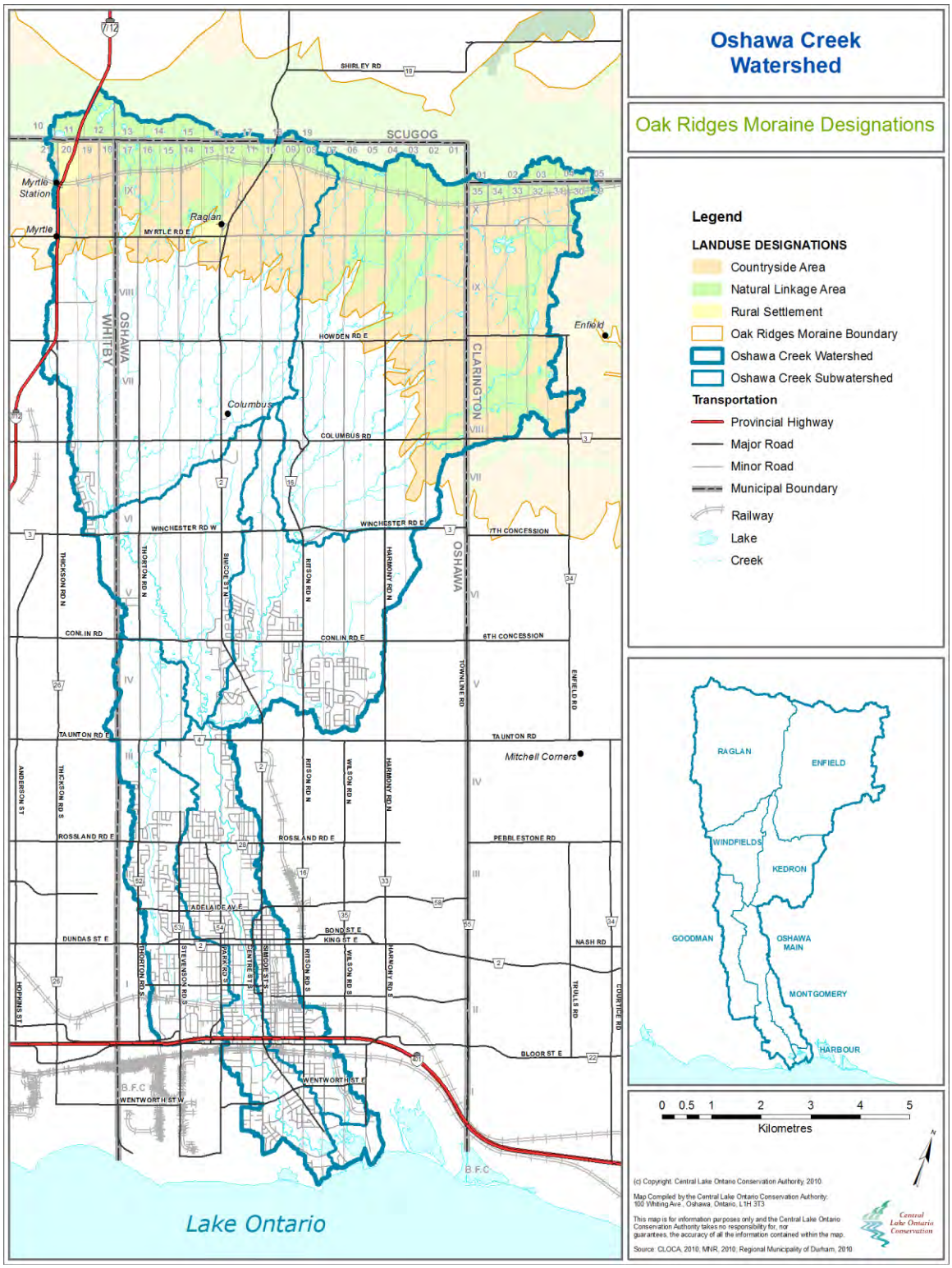


**Figure 2:** ORMCP land use designations within Oshawa Creek watershed (source: ORMCP; MMAH, 2002)

Lands designated "Countryside Area" represent the majority of the ORM lands within this watershed. Rural land uses such as agriculture and recreation are dominant within the "Countryside Area". "Rural Settlements" (hamlets) are considered part of the "Countryside Area" designation. The hamlets of Raglan, Myrtle and Myrtle Station are designated "Rural Settlements" in the ORMCP. The Oak Ridges Moraine covers 3831 ha of land and represents 32% of the watershed. Lands within the ORM only fall within two subwatersheds being Raglan and Enfield. Within these subwatersheds, the ORM represents 42% (1470ha) of land within the Raglan subwatershed and 67% (2362ha) of land in the Enfield subwatershed. Development of lands within the Oak Ridges Moraine is subject to the policies of the Oak Ridges Moraine Conservation Plan (ORMCP). As the ORMCP promotes protection of the natural environment and agriculture, urban development is not expected. As such, the portion of the Oshawa Creek Watershed where the ORM is found will not see major development pressures.

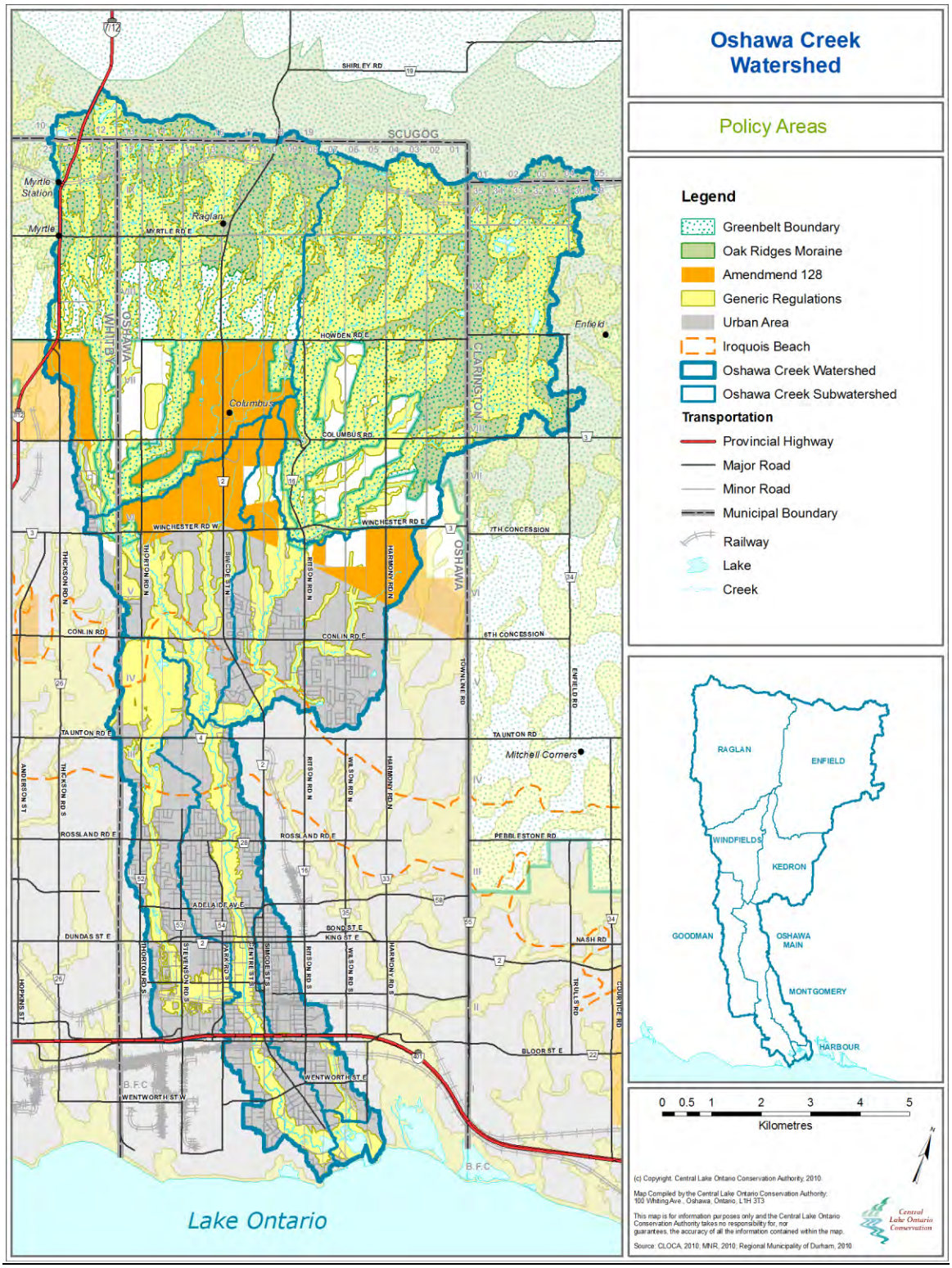


**Figure 3:** Land use policy areas within the Oshawa Creek watershed

Greenbelt Plan

The provincial Greenbelt Plan includes lands within the ORM. But for the purpose of the discussion within this chapter, and in order to better convey the intent and implication of these provincial documents, lands within the Greenbelt and lands within the ORM will be considered individually.

The provincial Greenbelt Plan identifies where urban development should not occur, permanently protecting agricultural lands as well as ecological features and functions. The Plan identifies agricultural lands and a natural system. The agricultural lands are identified as "Protected Countryside". Lands within the Protected Countryside are either identified as "Prime Agricultural Areas" or "Rural Areas" to coincide with the land use designation of local municipal plans. Meanwhile, the Greenbelt Natural Heritage System is an overlay of the 'Protected Countryside' designation.

Like the ORMCP, implementation of the Greenbelt plan is the responsibility of municipalities. The Regional Municipality of Durham's Official Plan has been amended to reflect the provisions of the Greenbelt Plan (Amendment #114), but the local municipalities have yet to incorporate the Greenbelt provisions into their local Official Plans. The Region of Durham, when incorporating the Greenbelt provisions into the Region's Official Plan, designated all lands within the Protected Countryside, "Prime Agricultural Areas" and "Major Open Space".

With respect to natural features and functions, the Greenbelt Plan provides permanent protection to the natural heritage and water resource systems that sustain ecological and human health (Greenbelt Plan, 2005). The Greenbelt "Natural System" identifies those areas where regard for the natural and hydrological features shall be given, and includes the Natural Heritage System, Water Resources System and key natural heritage and hydrologic features. In other words, development of land is subject to the constraints of the "Natural System" as outlined in the Greenbelt Plan. Within the "Protected Countryside" area, key natural heritage and hydrologic features may exist, but have not been identified on the schedules to the Plan. However this does not negate the policies of the "Natural System" which continue to apply in the "Protected Countryside", even though these features may not be identified in the mapping.

Approximately 48% of the Oshawa Creek watershed is within the Greenbelt, and the majority is found in the Raglan (46% / 2645 ha) and Enfield (53% / 3021 ha) subwatersheds (Figure 3). Large portions of the Greenbelt in the Oshawa Creek watershed follow the watershed's stream valleys connecting the northern and central portions of the watershed. These areas are identified as "Natural Heritage System". Between Howden Road and the south limit of the ORM in the western half of the watershed, lands are identified as "Protected Countryside". The Greenbelt Plan recognizes the importance of valley lands in providing broader landscape connectivity at a local, regional and provincial scale through identifying external connectors. In the Oshawa Creek watershed, these external connectors follow the main branches of the Oshawa Creek through the urban area. Although identified within the Greenbelt Plan, these external connectors are not considered within the regulatory boundary of the Greenbelt Plan.

As the Greenbelt Plan promotes protection of the natural environment and agriculture, urban development is not expected. As such, the portion of the Oshawa Creek Watershed where the Greenbelt is found will not see major development pressures.

Growth Plan for the Greater Golden Horseshoe

In response to the fact that the Greater Golden Horseshoe is one of the fastest growing regions in North America, the Province prepared "The Growth Plan for the Greater Golden Horseshoe" under the Places to Grow Act. The Act was passed in 2005 and the Growth Plan was approved in 2006. The intent of the Growth Plan is to provide a growth management framework that will guide decisions regarding "transportation, infrastructure planning, land use planning, urban form, housing, natural heritage and resource protection in the interest of promoting economic prosperity" (Growth Plan, 2006). This framework builds on other provincial initiatives including the Greenbelt and the Provincial Policy Statement (PPS). The Plan recognizes the importance of natural heritage features in the long term environmental health of our areas and encourages planning authorities to identify natural heritage features and areas that compliment, link or enhance natural systems, including shoreline areas. Municipalities are required to implement the Growth Plan through amendments to their Official Plans.

The Growth Plan identifies that by 2031 the population of Durham Region will be 960,000 and the number of people working in the Region will be 350,000. The Region of Durham completed its conformity amendment (Amendment #128) in June 2009, and is awaiting Provincial approval. The local municipalities have yet to complete their conformity amendments.

3.1.1.3 Regional Government

With respect to land use planning, the Region of Durham sets out broad policy initiatives and objectives having a regional context. These policies implement provincial legislation and provide planning guidance to the lower tier municipalities. This is done through an Official Plan which establishes policies that guide future growth and development of a municipality over 20 to 30 years. Specifically, the Official Plan establishes future growth objectives, including setting out the population and employment numbers to be achieved during the life of the plan. It also identifies where growth shall occur, including where residential, commercial and industrial land uses shall locate, and contains policies regarding services and infrastructure. In addition to identifying how an area shall grow and to what extent, Official Plans also identify those areas, such as creeks, valley systems, wetlands, and woodlots, which shall be protected and or preserved, including areas where restoration may be warranted. As well, these plans must identify hazard lands, being those lands where damage to property or human life may occur if developed. Natural hazards can include flooding, organic soils, steep slopes, etc. Lastly, Official Plans, not only reflect, but implement the planning framework established by the Province through legislation and policies such as the Planning Act, Greenbelt, Oak Ridges Moraine Conservation Plan, Growth Plan for the Greater Golden Horseshoe, and the Provincial Policy Statement.

The scale, detail and context of the information within an Official Plan are determined by the scope of the document. For example, the Region of Durham Official Plan sets out broad policies, goals and objectives for the entire Region. Local Municipal Official Plans can provide greater detail to their policies reflecting local growth patterns, local circumstances and needs, as well as diverse neighbourhoods or areas. It is important to note that while municipal policies can be more restrictive than higher tier government policies; local policies cannot be more lenient or flexible unless so prescribed.

The Region of Durham has been amending their Official Plan to ensure compliance with the recent Provincial changes. To start, the Region prepared and adopted Oak Ridges Moraine Conformity Amendments receiving Ministerial Approval in October 2004. In September 2006, the Region adopted Amendment 114 providing some new environmental, rural, commercial and transportation policies. This amendment also incorporated the necessary provisions implementing the Greenbelt Plan. Lastly, in June 2009, Regional Council adopted Amendment #128, being the Region's Growth Plan conformity amendment. Amendment #128 provides direction as to where Durham's anticipated population of 960,000 people will live and where 350,000 people will work. The population and employment growth was allocated between the local municipalities. For the City of Oshawa, the Region of Durham anticipates there will be an additional 43, 400 people living in the City by 2031 and that 22,500 people will be working in Oshawa (Table_1).

**Table 1:** Population and Employment Growth Forecast for the City of Oshawa

| | 2011 | 2016 | 2021 | 2026 | 2031 |
|---|---|---|---|---|---|
| **Urban Population** | 152,565 | 164,355 | 173,650 | 183,405 | 195,935 |
| **Rural Population** | 1,020 | 1,035 | 1,045 | 1,055 | 1,065 |
| **Total Population** | 153,585 | 165,390 | 174,695 | 184,460 | 197,000 |
| **Households** | 59,100 | 64,535 | 70,415 | 75,655 | 82,590 |
| **Employment** | 68,270 | 75,305 | 84,660 | 86,835 | 90,790 |

Source: DROP Amendment #128

In order to accommodate this anticipated growth, the Region identified additional urban lands. Essentially, Amendment #128 identifies all lands within the Oshawa Creek Watershed situated between the existing urban limits and the limit of the Greenbelt as either "Living Area", "Employment Area", "Future Living Area" or "Future Employment Area" (Figure_3). This will result in 45% of the Oshawa Creek Watershed being urbanized, which is a 9% increase in the amount of urban land in the Oshawa Creek Watershed.

3.1.1.4 Local Government

Local municipalities are required to implement provincial legislation and policies when making land use planning decisions. They are also required to ensure that all land use decisions are in conformity with both provincial and regional policies.

As the majority of the Oshawa Creek watershed falls within the City of Oshawa, much of the land use discussion will focus on Oshawa's policies. That being said, it is equally important to know the existing and future land use policies for the other municipalities in the Oshawa Creek watershed. Discussion regarding land use in the other municipalities follows the review of land use in the City of Oshawa.

In 2008, the City's population was estimated at 156,025 (City of Oshawa, 2008) with approximately 56,675 occupied housing units. The current approved Official Plan identifies the lands south of the Highway 407 alignment as within the urban boundary and the lands north of the Highway 407 alignment, as predominantly "Agricultural" or "Open Space and Recreation". It should be noted that the alignment for Highway 407 as depicted in the current Oshawa Official Plan does not reflect the 2010 approved route. North of the Highway 407 alignment there is one aggregate extraction area identified, one industrial area identified and one estate residential area identified. The City of Oshawa has undertaken its ORMCP conformity amendment and the designation of lands within the ORM are in accordance with the ORMCP.

There are three hamlets found within this watershed, being Raglan, Myrtle and Myrtle Station. Myrtle and Myrtle Station are within the Town of Whitby. The hamlet of Columbus is, from all appearances today, a hamlet. However, Columbus and surrounding lands have been identified as part of the urban area for a number of years.

The City of Oshawa is presently updating their Official Plan to ensure conformity with the Greenbelt Plan, Growth Plan, and Durham Region Amendment #128. By 2031, it is anticipated that the population of Oshawa will be 197,000 and that there will be 90,790 jobs (Regional Amendment #128). This is a significant increase in population and with this growth comes increased pressure on the existing natural resources within the watershed.

Presently, the majority of the Oshawa Main, Goodman and Montgomery subwatersheds are developed and future growth is anticipated to predominantly be in the form of infill and intensification. With the identification of downtown Oshawa as an Urban Growth Centre in the Provincial Growth Plan, the focus of development in this area will be through intensification and revitalization in order to satisfy the density targets of 200 jobs and residents per hectare.

Phasing of this new growth will be determined in the Official Plan, but it can be expected that it will be accommodated first within the current urban area as defined by the Oshawa Official Plan, and then when capacity no longer exists, development will take place within the "Living Areas" as identified in the Durham Region Official Plan. In other words, future urban development will occur on those lands situated between the current urban area and expanded urban boundary as identified in Amendment #128 to the Region of Durham Official Plan.

The lands within the Whitby portion of the watershed situated north of Howden Road are in the Greenbelt and Oak Ridges Moraine and are designated "Natural Areas", "Agricultural Areas" or "Hazard Lands" in the Town of Whitby Official Plan. Lands situated between Howden and Columbus Road in Whitby are within the recently identified "Future Urban Area" in Amendment #128 to the Durham Region Official Plan. Only a very small portion of the Oshawa Creek Watershed falls within the urban area of the Town of Whitby. These lands are designated "Residential" and are found in the southwest part of the Raglan subwatershed and the northwest section of the Winchester subwatershed.

The upper northwest reaches of the watershed are located within the Township of Scugog. This part of the watershed is within the Oak Ridges Moraine and as such, the Official Plan for the Township reflects the policies of the Oak Ridges Moraine Conservation Plan. Similarly, the north east corner of the watershed above Regional Road 3, is in the Municipality of Clarington, and the designation of these lands in the Clarington Official Plan reflects the policies of the ORMCP.

With the exception of the small area in the Raglan and Windfields subwatershed in Whitby, those portions of the watershed in the Town of Whitby, Township of Scugog and Municipality of Clarington are not situated within the limit of urban development and as such will not see major residential, commercial or industrial development.

#### 3.1.1.5 Highway 407

Highway 407, when built, will have an impact not only on growth and growth patterns, but on the overall health of this watershed. This highway will cross through the central portion of the watershed in the vicinity of Winchester Road, impacting the Windfields, Kedron and Enfield subwatersheds. It is important that Highway 407 does not environmentally sever the Oshawa Creek watershed and the subwatersheds through which it passes. Every attempt has been made through review of the Environmental Assessment to ensure that connectivity and wildlife movement is maintained and that surface water flows and groundwater flows are not adversely affected (Figure 4).

#### 3.1.1.6 Zoning By-laws

A zoning by-law implements the policies of the Official Plan. It specifies permitted land uses and provides regulations for establishing those land uses. An application for development must conform with the zoning by-law prior to receiving a building permit.

With respect to zoning, CLOCA defers all zoning interpretations to the respective municipality.

#### 3.1.1.7 Development, Interference with Wetlands and Alteration to Shorelines and Watercourses Regulation

At the time the Oshawa Creek Watershed Plan was first prepared, the Authority was responsible for the administration of the "Fill, Construction and Alteration to Waterways, Ontario Regulation 145/90". Since then, Ontario Regulation 97/04 was passed enabling Conservation Authorities to regulate wetlands and shorelines in addition to those areas susceptible to flooding, erosion or hazards. In accordance with this new regulation, Ontario Regulation 42/06 was adopted, identifying the areas that CLOCA can regulate. These "regulated areas" can be generally described as areas subject to flooding and erosion (including dynamic beaches), wetlands and their adjacent lands (30 – 120m), river or stream valleys or hazard lands. The Conservation Authority may grant permissions for development in or on the areas described in the Regulation if, in its opinion, the control of flooding, erosion, dynamic beaches, pollution or the conservation of land will not be affected by the development.

In this regulation, development is defined as being:

- construction, reconstruction or placing of a building or structure;
- any change to a building whereby the use is altered, increasing the size or increasing the number of dwelling units in the structure;
- site grading; and
- temporary or permanent placing, dumping, or removal of material.

Within the Oshawa Creek Watershed, 5593 ha of land falls within the regulation area. This accounts for 47% of the watershed. Figure 41, found later in this document, shows the regulated areas in the watershed. Figure 3 identifies the regulated areas in relation to other important land use policy areas.

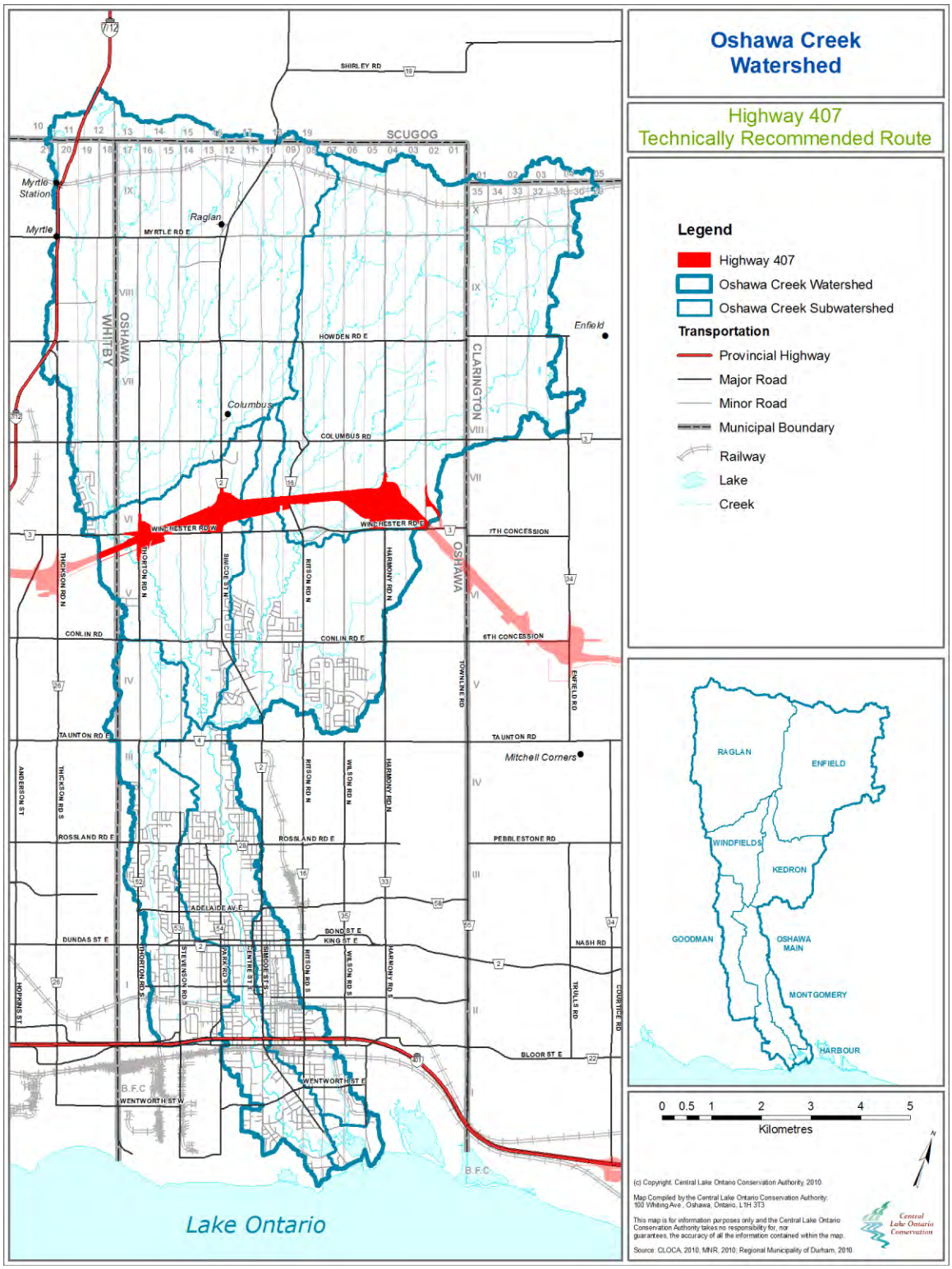


**Figure 4:** Highway 407 alignment

3.1.1.8 CLOCA Land Cover

CLOCA's land use information is derived from its Land Classification Mapping. This mapping is a desktop exercise using the latest orthophotography (2008) available to CLOCA. This information is not meant to reflect and/or represent planning land use designations or zoning; rather it provides an overview of dominant land uses within the watershed and subwatershed. The mapping is based on land use categories (Table 2) reflecting what existed in 2008 which provides the reader with an understanding of the dominant land uses existing at that time. By virtue of mapping the human influenced landscape (the anthropogenic land uses), the natural areas have been identified.

**Table 2:** CLOCA Land Classification Categories

| Land Use Category | Examples of Land Use |
|---|---|
| **Aggregate** | Mineral aggregate operations |
| **Agriculture** | Barns, greenhouses, cropped fields, pasture, tree nursery, hay field, orchard, sod farm, irrigation pond |
| **Commercial** | Retail facilities, storage yards, marinas |
| **Industrial** | Factories, warehouses, scrapyards, landfill |
| **Institutional** | Schools, hospitals, libraries, school fields and play areas including lawns |
| **Open Space** | Park, water feature, athletic field |
| **Recreational** | Golf facility, ski hill |
| **Residential** | Urban and rural residential, stormwater pond, estate residential |
| **Transportation and Utilities** | Airport, railway, transportation corridor, transportation green space, utility transfer station |

Source: CLOCA 2008

Figure_5, developed using CLOCA's land cover classification system, indicates that agriculture is the dominant land use within the watershed, primarily north of Conlin Road, followed by residential and natural areas. Of note are 5 aggregate extraction operations, not all of which are actively being operated. There are 6 golf courses within the watershed, and a multitude of parks, almost all within the urban areas. As well, there are commercial and industrial areas, found mostly within the urban areas of Oshawa. Substantial residential growth has occurred north of Taunton since 2002, including development of the University of Ontario Institute of Technology campus.

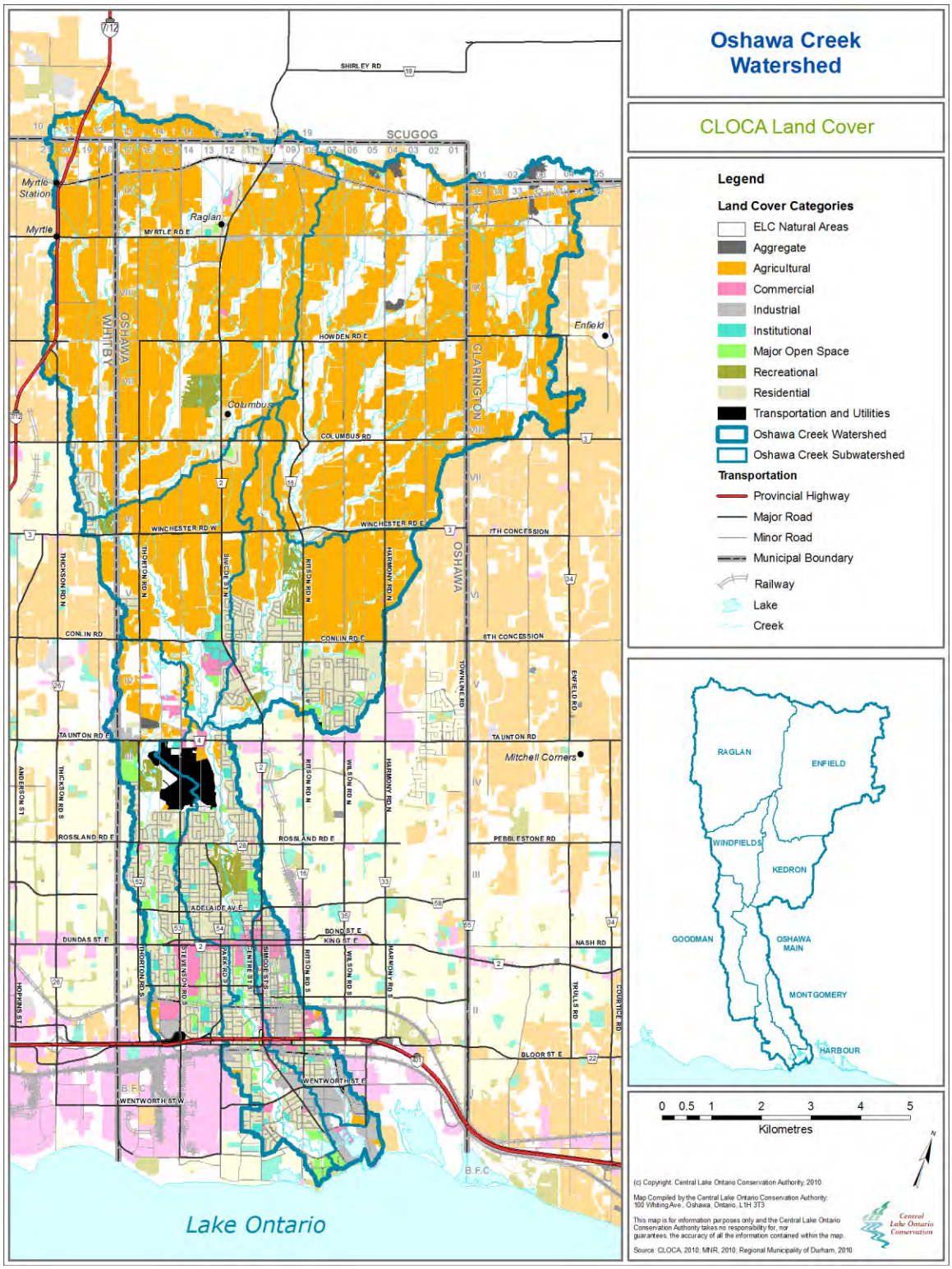


**Figure 5:** Oshawa Creek watershed land cover

### 3.1.2 Public Recreation

3.1.2.1 Conservation Areas

Although the number of Conservation Areas within this watershed has remained the same, the areas themselves have changed with the City of Oshawa acquiring the Cedar Valley Conservation Area lands and with CLOCA acquiring the Rahmani Tract in 2003. The Rahmani Tract is approximately 28 ha in size and is situated on the ORM, about 0.5 km west of the Purple Woods Conservation Area. Purple Woods is 17 ha in size and has long been operated as a sugar bush and is the site of CLOCA's annual Maple Syrup Demonstration program each spring. Lastly, the Oshawa Valleylands Conservation Area (approximately 61 ha) is located in the southern extent of the Oshawa Creek valley. The land within the Oshawa Valleylands is under a lease agreement with the City of Oshawa (Figure_6).

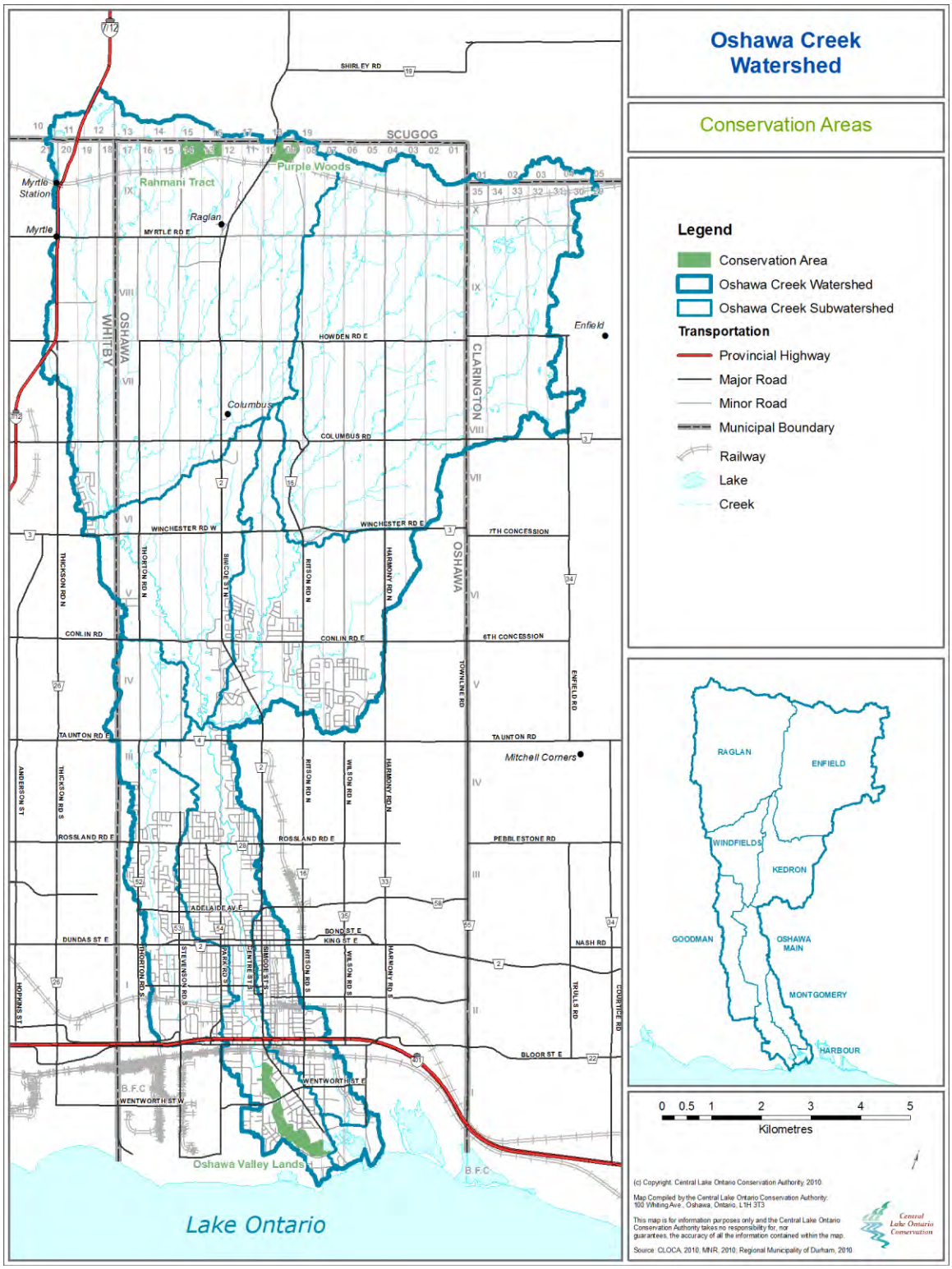


**Figure 6:** Conservation Areas in the Oshawa Creek watershed

#### 3.1.2.2 Green Space

For the purposes of watershed planning, green space is defined as parkland and natural areas. Parklands are those areas that have been created to provide active and passive recreational activities. Municipalities provide the majority of parkland within a watershed and examples include municipal parks, playing fields, public trails, recreational facilities such as arenas and community centres. Private recreational facilities such as golf courses or ski hills are also considered parkland. The natural areas are the forests, wetlands, valleys, stream corridors and naturalized areas. Infrastructure corridors (hydro, utility, and abandoned rail corridors) have been included in the green space system as these areas provide connections (formal or informal) through otherwise impassable areas.

The City of Oshawa provides many park and recreation facilities including trails throughout the watershed and the City recognizes that having quality parks and trails is very important. In the past, some of these facilities such as baseball diamonds, soccer fields and play equipment had been located within valleylands. However, these facilities interfere with valley system functions, specifically, conveyance of stream flows. It is no longer acceptable to permit active recreational playing fields or playground equipment within the valleylands. There is a place for many of these activities on lands adjacent to valley systems which would further consolidate and contribute to a connected open space system.

Parks and recreational facilities require on-going maintenance which may require the use of pesticides, herbicides or fertilizers. In the past, park maintenance has often resulted in a manicured landscape up to the edge of a creek and has included non-native plantings. The overall impact of maintenance activities is recognized and consideration to reduce, eliminate and manage maintenance activities, including identifying opportunities for naturalization, is warranted.

With the projected increase in population that will be experienced within the Oshawa Creek watershed, there will be an increased demand for recreational opportunities, ultimately placing more stress on existing parks, trails and natural areas. Planning for and management of these areas is essential in order to not only reduce user conflict, but reduce impacts to the natural features and functions that share these areas. Wherever possible, optimization of opportunities to expand upon and connect fragmented sections of the open space system should be facilitated. The City is actively working on connecting the trail system, particularly through valleylands. Parks and trails provide opportunities to enhance connectivity between natural areas and provide habitat opportunities for many species. However, consideration of the sensitivity of some natural areas is important when planning facility location and ongoing maintenance. Some areas may be so sensitive to disturbance that the only measure to ensure survival is protection. It is important that these sensitive areas be identified and protected.

## 3.2 Land

### 3.2.1 Hydrologic Cycle (no revisions)

### 3.2.2 Climate

Monitoring of climate information and its components provides fundamental information for some of the Authority's core programs. Climate information is used on a daily basis for flood warning and forecasting. It is also used in conjunction with other collected data to analyze long term trends. Precipitation, temperature, solar radiation, evaporation and transpiration are some of the key elements of on-going hydrologic assessments necessary to fulfill the requirements of the Oak Ridges Moraine Conservation Plan.

Climate information is collected at stations within and around the Oshawa Creek watershed by CLOCA and Environment Canada. The data collected has been used to predict the spatial distribution of net precipitation and evapotranspiration across the watershed. The daily precipitation and temperature data was used as input into a numerical modeling tool (computer software) to distribute the net precipitation and evapotranspiration across the watershed. This information is an important component of the hydrology and water budget work. In addition, a discussion of climate change is included along with its possible impacts on watershed functions.

#### 3.2.2.1 Climate Data

Climatic data are collected in and around the Oshawa Creek watershed under two monitoring networks: the Environment Canada Climate Network and CLOCA's climate monitoring program. The Environment Canada Climate Network monitors daily precipitation and temperature. Environment Canada posts climate normals (averages) at http://climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html for 1971 to 2000.

Available data in Environment Canada's (EC) climate monitoring network posted at http://climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html for 1971 to 2000 was reported on for stations in or around the Oshawa Creek watershed. Only stations with a minimum of 10 years of continuous data sets were included. While some stations have recently been commissioned in the vicinity of CLOCA's watersheds, the period of records (POR) or operational periods of time are not sufficient to establish meaningful long-term averages. Mean daily temperatures were also explored for the Kawartha Region, Lake Simcoe Region and Ganaraska Region Conservation Authority's regions to the north, northeast, and east to provide a regional context in temperature variations. Climate data, primarily daily maximum and minimum temperature and precipitation are noted in Table_3 for selected Environment Canada stations in the vicinity of the Oshawa Creek watershed.

**Table 3:** Climate normals for selection Environment Canada climate stations

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | **Annual** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bowmanville Mostert (#6150830)** | | | | | | | | | | | | | |
| Daily Maximum Temp (°C) | -1.9 | -0.9 | 4.0 | 10.9 | 17.8 | 22.8 | 25.5 | 24.5 | 20.2 | 13.4 | 6.9 | 1.2 | **12.0** |
| Daily Minimum Temp (°C) | -10.7 | -9.7 | -4.9 | 1.1 | 6.6 | 11.3 | 14 | 13.2 | 9.2 | 3.4 | -0.7 | -6.6 | **2.2** |
| Rainfall (mm) | 33.1 | 30.8 | 47.2 | 70 | 73.7 | 81.5 | 63.7 | 81 | 90.5 | 67.8 | 77.9 | 47.4 | **764.6** |
| Snowfall (cm) | 30.0 | 16.4 | 13.5 | 2.9 | 0 | 0 | 0 | 0 | 0 | 0.1 | 6.1 | 24.2 | **93.2** |
| Precipitation (mm) | 63.1 | 47.2 | 60.7 | 72.9 | 73.7 | 81.5 | 63.7 | 81 | 90.5 | 67.9 | 84.0 | 71.6 | **857.9** |
| **Burketon McLaughlin (#6151042)** | | | | | | | | | | | | | |
| Daily Maximum Temp (°C) | -4.0 | -2.8 | 2.4 | 10.0 | 17.5 | 22.1 | 24.9 | 23.9 | 19.1 | 12.3 | 5.1 | -1.0 | **10.8** |
| Daily Minimum Temp (°C) | -12.1 | -10.9 | -5.8 | 0.8 | 7.3 | 12.0 | 14.8 | 14.0 | 9.9 | 3.9 | -1.5 | -8.1 | **2.0** |
| Rainfall (mm) | 24.5 | 21.1 | 39.1 | 66.7 | 83.2 | 95.7 | 74.9 | 88.5 | 92.4 | 79.2 | 73.9 | 34.9 | **774.1** |
| Snowfall (cm) | 38.2 | 27.2 | 19.5 | 5.8 | 0.1 | 0 | 0 | 0 | 0 | 0.6 | 11.5 | 32.1 | **135** |
| Precipitation (mm) | 62.7 | 48.3 | 58.6 | 72.5 | 83.3 | 95.7 | 74.9 | 88.5 | 92.4 | 79.8 | 85.4 | 67.0 | **909** |
| **Claremont (#6151545)** | | | | | | | | | | | | | |
| Rainfall (mm) | 21.1 | 25.9 | 52.3 | 68.8 | 78.2 | 75.5 | 72.7 | 92.4 | 82.2 | 73.0 | 76.0 | 46.3 | **764.3** |
| Snowfall (cm) | 33.4 | 27.1 | 16.5 | 2.8 | 0 | 0 | 0 | 0 | 0 | 0.4 | 4.5 | 31.4 | **116.0** |
| Precipitation (mm) | 54.5 | 53.0 | 68.8 | 71.5 | 78.2 | 75.5 | 72.7 | 92.4 | 82.2 | 73.4 | 80.5 | 77.7 | **880.3** |
| **Greenwood MTRCA (#6153020)** | | | | | | | | | | | | | |
| Rainfall (mm) | 19.9 | 26.7 | 54.2 | 68.3 | 70.3 | 75.4 | 69.2 | 91.5 | 83.6 | 72.6 | 76.0 | 48.2 | **755.9** |
| Snowfall (cm) | 37.4 | 27.8 | 20.3 | 4.0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 5.5 | 34.9 | **130.3** |
| Precipitation (mm) | 57.2 | 54.5 | 74.4 | 72.3 | 70.3 | 75.4 | 69.2 | 91.5 | 83.6 | 73.0 | 81.5 | 83.2 | **886.1** |
| **Leskard (#6154410)** | | | | | | | | | | | | | |
| Rainfall (mm) | 31.3 | 24.5 | 45.4 | 82.4 | 78.9 | 77.2 | 79.3 | 91.4 | 100 | 88.2 | 87.7 | 38.9 | **825.1** |
| Snowfall (cm) | 47.1 | 36.5 | 24.5 | 8.1 | 0 | 0 | 0 | 0 | 0 | 1.2 | 12.8 | 46.2 | **176.4** |
| Precipitation (mm) | 78.4 | 61.0 | 69.8 | 90.5 | 78.9 | 77.2 | 79.3 | 91.4 | 100 | 89.4 | 100.4 | 85.1 | **1001.4** |
| **Orono (#6155854)** | | | | | | | | | | | | | |
| Daily Maximum Temp (°C) | -2.7 | -1.6 | 3.6 | 11.0 | 18.4 | 23.2 | 26.3 | 24.9 | 20.0 | 13.4 | 6.6 | 0.2 | **11.9** |
| Daily Minimum Temp (°C) | -11.4 | -10.9 | -5.6 | 0.8 | 6.6 | 11.3 | 14.4 | 13.5 | 9.3 | 3.5 | -1.1 | -7.7 | **1.9** |
| Rainfall (mm) | 31.2 | 25.1 | 47.0 | 69.7 | 75.6 | 75.1 | 63.7 | 85.7 | 89.6 | 78.1 | 78.1 | 40.2 | **759.1** |
| Snowfall (cm) | 32.9 | 25.1 | 15.8 | 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 7.4 | 29.7 | **114.1** |
| Precipitation (mm) | 64.1 | 50.2 | 62.8 | 72.9 | 75.6 | 75.1 | 63.7 | 85.7 | 89.6 | 78.1 | 85.5 | 69.9 | **873.2** |
| **Oshawa WPCP (#6155878)** | | | | | | | | | | | | | |
| Daily Maximum Temp (°C) | -1.4 | -0.6 | 4.1 | 10.5 | 17.0 | 21.9 | 25.0 | 24.0 | 19.7 | 13.1 | 7.2 | 1.5 | **11.8** |
| Daily Minimum Temp (°C) | -9.2 | -8.2 | -3.8 | 2.0 | 7.6 | 12.4 | 15.5 | 15.2 | 11.2 | 5.2 | 0.7 | -5.4 | **3.6** |
| Rainfall (mm) | 32.1 | 29.5 | 46.8 | 70.1 | 74.7 | 80.6 | 67.3 | 83.3 | 87.9 | 66.2 | 74.2 | 46.8 | **759.5** |
| Snowfall (cm) | 38.9 | 23.2 | 15.5 | 3.1 | 0 | 0 | 0 | 0 | 0 | 0.1 | 5.7 | 31.9 | **118.4** |
| Precipitation (mm) | 71.0 | 52.7 | 62.3 | 73.1 | 74.7 | 80.6 | 67.3 | 83.3 | 87.9 | 66.3 | 79.9 | 78.7 | **877.9** |
| **Tyrone (#6159048)** | | | | | | | | | | | | | |
| Daily Maximum Temp (°C) | -3.1 | -2.1 | 3.1 | 10.7 | 18.1 | 23.0 | 25.7 | 24.6 | 20.0 | 13.0 | 5.9 | -0.1 | **11.6** |
| Daily Minimum Temp (°C) | -12.3 | -11.3 | -6.3 | 0.5 | 6.5 | 11.2 | 14.0 | 13.2 | 9.0 | 3.0 | -1.7 | -8.1 | **1.5** |
| Rainfall (mm) | 33.7 | 29.9 | 48.8 | 74.4 | 75.7 | 80.0 | 76.1 | 88.6 | 93.7 | 77.1 | 82.4 | 44.5 | **804.9** |
| Snowfall (cm) | 46.6 | 29.6 | 23.3 | 4.8 | 0 | 0 | 0 | 0 | 0 | 0.4 | 9.4 | 34 | **147.9** |

Source: Earthfx, 2007.

Below in Figure_7 the variation in average annual precipitation collected at five climate stations is depicted. If an average annual value of 886mm/yr is assumed for all station data combined, the annual fluctuations around this average helps visualize the wet, dry and average years over the period of record. As depicted in Figure_7 four of the Environment Canada stations have been decommissioned over the last 10 to 12 years including Burketon McLaughlin, Orono, Tyrone, Bowmanville Mostert.

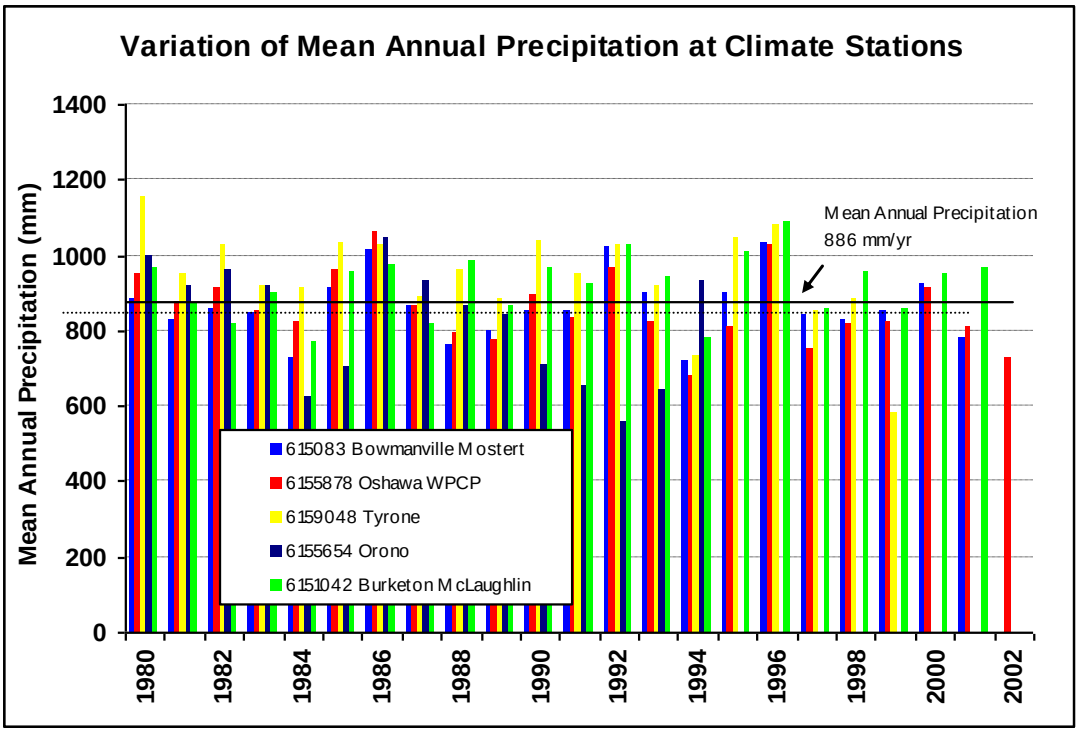


**Figure 7:** Variation of mean annual precipitation at selected climate stations with extended periods of record

While several CLOCA monitoring stations have recently been commissioned in and around the watershed to advance the flood forecasting program, they do not yet have sufficient periods of record to be used for long-term climate assessments (Table 4). CLOCA climate stations, for the most part, collect rainfall information whereas the Environment Canada stations also account for other forms of precipitation (such as snow accumulation and collected temperature data).

**Table 4:** CLOCA precipitation stations within or around the Oshawa Creek watershed

| Station Name (ID) | Year Commissioned |
|---|---|
| Purple Woods (Prec1) | 1999 |
| Howden Road (Prec2) | 1999 |
| CLOCA Admin Office (Prec3) | 2001 |
| Lynde Creek (02HC018) | 2002 |
| Heber Down (55) | 2003 |
| Hampton CA (3) | 2003 |
| Chalk Lake (Prec4) | 2003 |
| Enniskillen (Prec5) | 2003 |
| Oshawa Airport | 2008 |

### 3.2.2.2 Climatic Regions

Climate varies appreciably across the study area both spatially and temporally with local variations created by such factors as topography, prevailing winds and proximity to the Great Lakes. Chapman and Putnam (1984) describe two climatic regions across the Oshawa Creek watershed area: the Lake Ontario Shore and the South Slope. The Lake Ontario Shore climatic region is influenced by Lake Ontario whereby the lake temperature moderates the air temperature, and will provide 1 to 2 $^{o}$C of warming in the winter months, and cooling breezes in the summer. The Lake Ontario climatic region is similar in extent from the Lake Ontario shoreline to the northern boundaries of the Lake Iroquois Beach area.

### 3.2.2.3 Temperature

Mean daily temperatures recorded at the Bowmanville Mostert, Burketon McLaughlin, Orono, Oshawa WPCP, and Tyrone stations (Table 3) averages approximately 6.9 $^{o}$C. The average annual temperatures range from 6.4 $^{o}$C at the Burketon McLaughlin station to 7.7 $^{o}$C at the Oshawa WPCP station, which resides closest to Lake Ontario. This temperature range falls within the regional pattern. For instance, the mean daily temperatures for the period 1931 to 1960 range from 5.6 to 6.7 $^{o}$C in the Simcoe and Kawartha Lakes region north and northeast of the Oshawa Creek watershed to 6.7 to 7.8 $^{o}$C along the Lake Ontario shore. In the Simcoe and Kawartha Lakes Region, the mean daily temperature for January (coldest month) is from -8.9 to -7.8 $^{o}$C. The mean daily temperature for July (warmest month) is 20 $^{o}$C. For the Lake Ontario shore, mean daily temperatures for January and July are -6.7 to -4.4 and 20 to 21.1 $^{o}$C respectively (Brown *et al.*, 1980).

### 3.2.2.4 Precipitation

The mean annual precipitation for southern Ontario is 813 mm (1931-1960) compared to the mean value of 724 mm for Ontario (Brown *et al.*, 1980; Ontario Ministry of Natural Resources, 1984; Phillips and McCulloch, 1972). Ontario's mean annual snowfall is 235 cm (Ontario Ministry of Natural Resources, 1984). Mean annual snowfall for the Great Lakes Region is approximately 203 cm. (Brown *et al.*, 1980; Phillips and McCulloch, 1972). Growing season (May to September) mean precipitation ranges from 380 mm along the moraine to 356 mm along the Lake Ontario shore (Brown *et al.*, 1980).

Net precipitation across the watershed was generated from long-term climatic data detailed in Figure 7 using the Precipitation-Runoff Modeling System (PRMS) numerical model. The results of the simulation are shown for the Oshawa Creek watershed in Figure 8. Net precipitation is important to depict, in that it represents the amount of available water that will eventually be infiltrated, evaporated or that runs off surfaces and is expressed as;

**Net Precipitation = Evapotranspiration + Runoff + Groundwater Infiltration**

And also as;

**Net Precipitation = Observed Precipitation – Interception Losses**

The estimates for the Oshawa Creek watershed simulations approximate that evapotranspiration is 396 mm/yr; runoff to be 167.68 mm/yr; and groundwater infiltration at 167.73 mm/yr: and that approximately 733 mm/yr of precipitation reaches the ground surface as net precipitation.

It can be seen in Figure 8 that more precipitation is expected to reach the ground surface of urbanized areas where there is generally less natural cover, or for instance in gravel pits where there is no natural cover and all precipitation is anticipated to reach the ground surface. The effects of interception storage may be visually noted by the amount of water that is stored on water or snow-laden trees or shrubs following a precipitation event; water stored on these surfaces is eventually evaporated or sublimated back to the atmosphere.

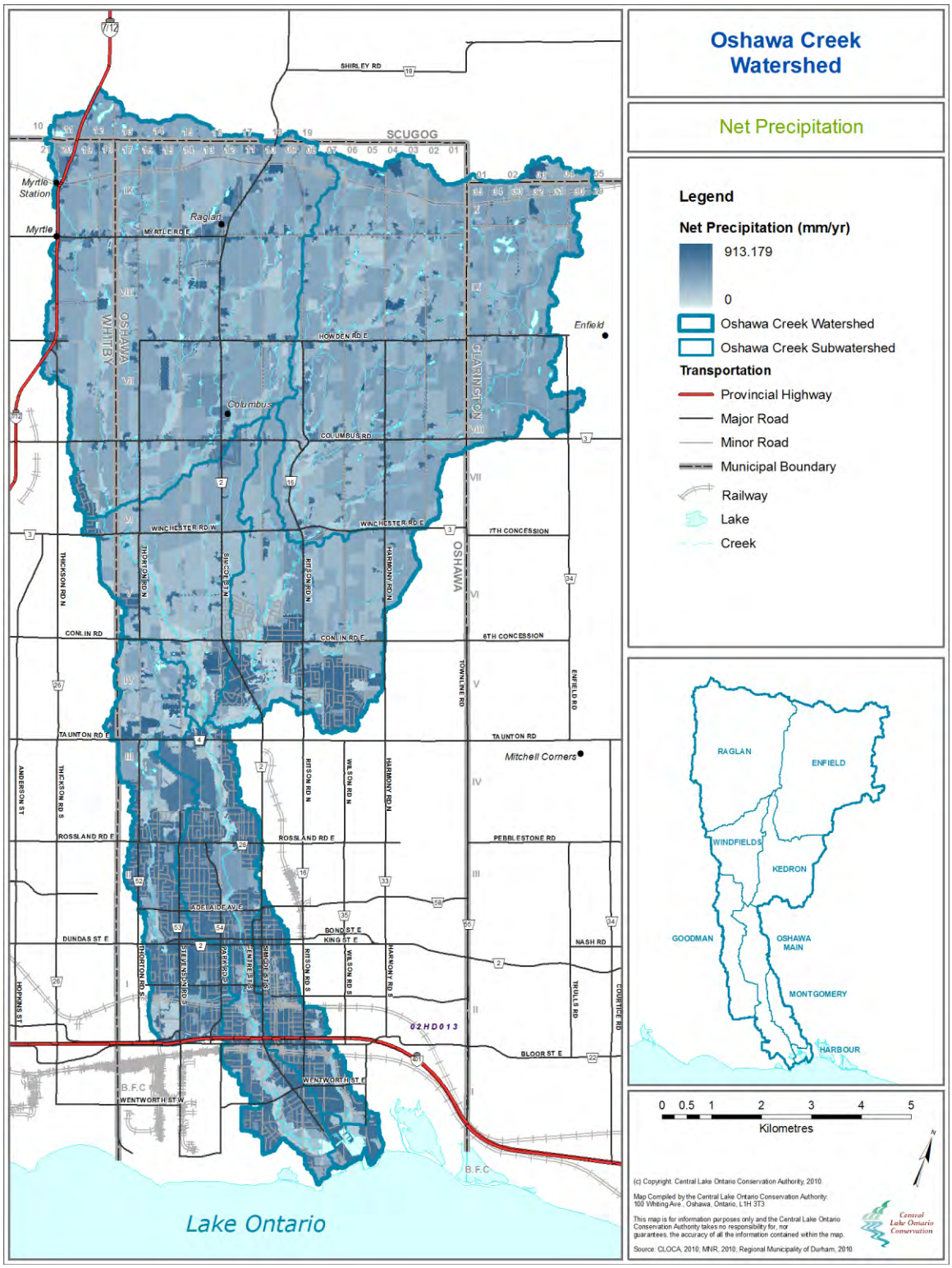


**Figure 8**: Net precipitation distribution (source: PRMS Model simulations).

3.2.2.5 Evapotranspiration

While there are several methods for collecting evaporation data in the field, estimating the amounts of evaporation and transpiration typically rely on empirical calculations as part of commonly-used methodologies. Evapotranspiration information is important for hydrology and water budget investigations.

The mean annual potential evapotranspiration (PET) was calculated for the Ecodistrict 553 in which the Oshawa Creek watershed resides (Table 5) (Efx, 2007). Ecodistrict 553 covers CLOCA's watersheds area as well as the Ganaraska and Trent watersheds. Ecodistricts are mapped across Canada by Agriculture and Agri-food Canada (http://sis.agr.gc.ca/cansis/nsdb/ecostrat/district/climate.html). Table 5 presents monthly and annual estimates of potential evapotranspiration (PET) calculated using two methodologies: the Thornthwaite and the Penman methods. Comparison with average precipitation data shows that PET exceeds available precipitation from May to August (Penman method) or June to August (Thornthwaite method). Actual evapotranspiration in those months will depend on the ability of plants to extract moisture from the soil.

**Table 5:** Monthly and Annual Estimated Potential Evapotranspiration for the CLOCA Area

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Potential ET (mm) Thornthwaite Method** | 0 | 0 | 0 | 30.8 | 72.5 | 108.3 | 127.6 | 112.7 | 77.4 | 38.0 | 10.1 | 0 | **577.3** |
| **Potential ET (mm) Penman Method** | 0 | 0 | 11.7 | 63.0 | 97.6 | 114.5 | 129.4 | 103.0 | 64.7 | 30.5 | 8.2 | 0 | **622.56** |
| **Precipitation (mm)** | 62.2 | 57.5 | 65.9 | 67.0 | 74.0 | 73.8 | 67.2 | 82.5 | 79.1 | 73.9 | 84.5 | 81.6 | **867.4** |

Source: Efx, 2007

Estimates of long-term actual evapotranspiration (AET) were generated using the Precipitation-Runoff Modelling System (PRMS) numerical model are shown for the Oshawa Creek watershed in Figure 9. The estimates depicted represent the long-term average millimetres per year (mm/yr) of evapotranspiration that is predicted from all sources including intercepted and stored precipitation that is eventually evaporated. AET depends on soil type, soil water storage capacity, vegetation rooting depths, amount of interception storage based on land cover type, temperature, and solar radiation. The model estimates an evapotranspiration rate of approximately 396 mm/yr for the watershed.

Urban areas are depicted in Figure 9 as having on average lower evapotranspiration rates than the watershed average. This is largely influenced by the greater percentage of impervious surfaces in urban areas such as roadways, parking lots and rooftops. While some of the precipitation including melting snowpacks remains stored in surface depressions and is evaporated by the model, much of the precipitation is diverted from these surfaces as runoff.

In addition, pervious rural areas in the northern extent of the ORM are predicted to have evapotranspiration rates lower than those in the southern ORM. This is largely influenced by the permeability and water holding capacity of the soils. The highly permeable soils to the north have a lower water holding capacity and as such on average, less active soil zone water is available for evapotranspiration. Similar pockets exist throughout the watershed.

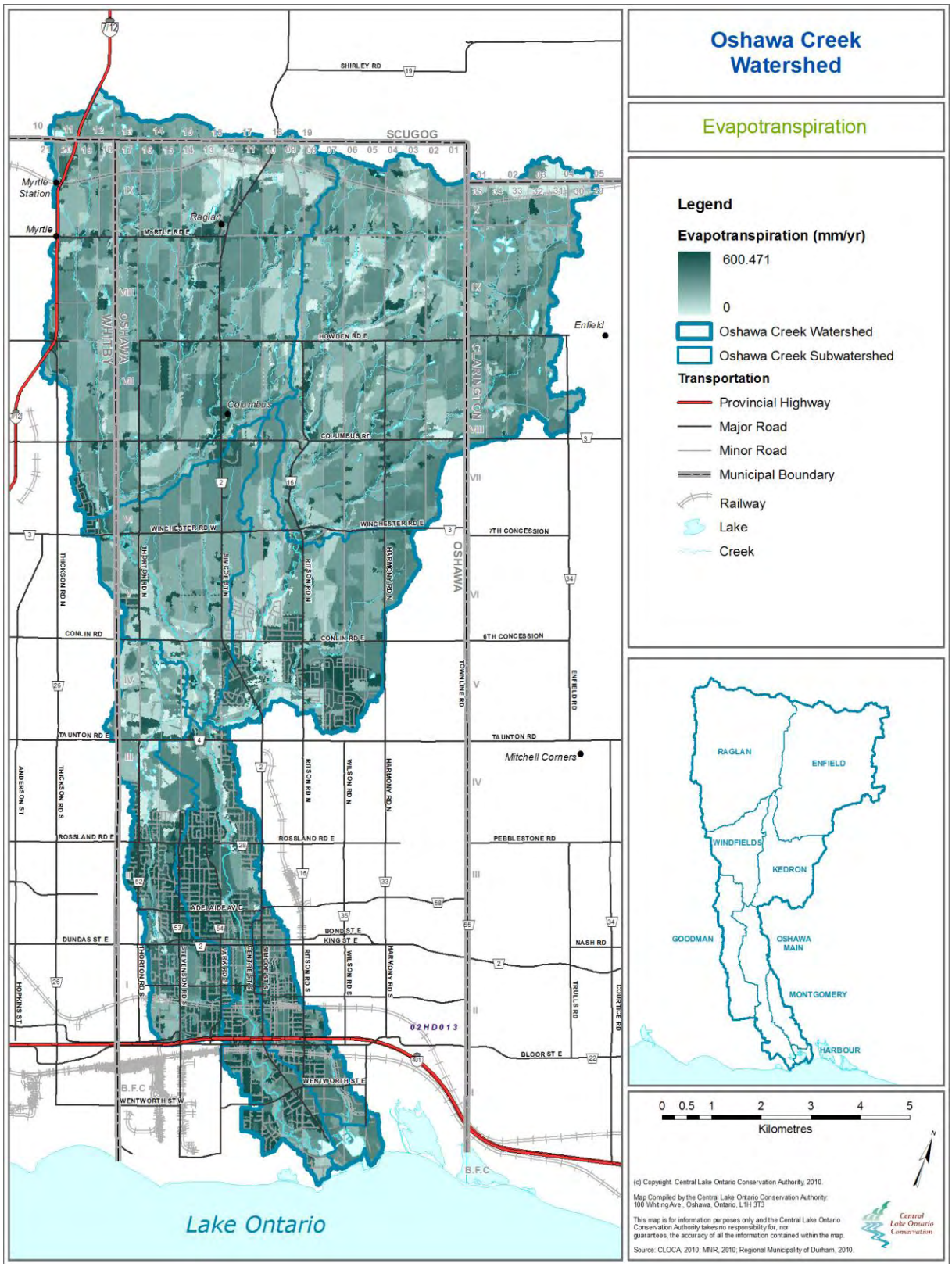


**Figure 9:** Evapotranspiration(source: PRMS Model simulation).

Due to the decommissioning of many of the local Environment Canada operated stations over the past several years within and around CLOCA's jurisdiction, the spatial distribution of current climate monitoring stations has been identified as a gap locally in the support of flood forecasting and current and future local water budget modeling. Efforts are being made by CLOCA to address these gaps through the installation of local precipitation/temperature stations. CLOCA has recently commissioned a comprehensive climate station located on the Oshawa Airport lands to supplement the existing network.

3.2.2.6 Climate Change

Although we all have a vision of "normal" climate conditions, our climate is ever changing. On a large time scale, scientists believe Canada has at various times been covered by glaciers, tropical forest, salt water seas, and fresh water lakes. Our climate is controlled by the amount of energy our atmosphere allows to pass through to or from the earth. Our atmosphere is composed of gases that allow light energy from the sun to penetrate through to the earth surface, warming our land and water. Some of the heat from the earth is released back into the atmosphere. Some of the heat waves pass through the atmosphere into space, but most of the heat is trapped under the atmosphere's blanket of gases. This "greenhouse effect" is vital to the survival of life on earth. The naturally occurring gases in the atmosphere control the energy transfer to maintain liveable temperatures on the earth.

Adding to the atmosphere's gases has a similar affect to throwing a heavier blanket on your bed – more heat will be held against the earth's surface. Since the 18$^{th}$ century, humanity has been adding gases to the atmosphere such as carbon dioxide, methane, nitrous oxide and Freon, resulting in a 25% increase in greenhouse gases in our atmosphere. According to Environment Canada (1998), the scientific community generally agrees that average global temperatures could rise by 1 to 3.5$^{\circ}$C over the next century as a result of our changing atmosphere and air temperatures in Southern Ontario may rise by 2 to 5$^{\circ}$C by the end of this century. These anticipated changes will have serious consequences to our environment. Climate change will impact precipitation, hence affecting surface runoff, evapotranspiration and infiltration. The following describes, in more detail, this relationship.

<u>Precipitation</u>
Precipitation events are predicted to be less frequent, but more severe. The potential for more frequent and extended summer droughts will increase.

<u>Surface Runoff</u>
The less frequent, more intense precipitation is likely to cause more flooding and stream erosion throughout our waterways. The snow accumulation and melt patterns that we are familiar with are likely to be replaced with multiple accumulations and melt events.

<u>Evapotranspiration</u>
Warmer temperatures generate longer growing seasons, and therefore an increase in the evapotranspiration rate. The combination of temperature change and the change to soil moisture conditions may stress many of our plant species. Additionally, the warmer temperatures will allow additional pests and diseases to migrate north into our area.

Infiltration

The additional uptake of water by vegetation and the less frequent, more intense precipitation will have negative impacts on the ability of the ground to absorb and store water. Environment Canada scientists predict that southern Ontario will be 16% drier than our current conditions. The reduction in groundwater infiltration (and the increased demand for water for domestic use) will potentially result in a lowering of water tables, and the loss of groundwater discharge in many areas.

Specifically, the predicted climate change could have the following impacts on our watershed over the next century.

- Stress on the forest community due to drier conditions, and increased pests, disease, and competition. New vegetation species and wildlife may shift into the area from the south.
- Less stream baseflow due to lower water table levels, leading to fewer permanently flowing tributaries, and the warming of stream temperature, thus increasing stress on cold water dependant aquatic species. The increased air temperatures and periods of hot weather will also stress cold water systems.
- More intense runoff events will affect stream channel stability and lead to increased erosion of the watercourses. As stream channels adjust to accommodate increased storm flow, the width of the channel may increase. If the base flow is conveyed through the wider channel, the wider, shallower, slower condition will allow for additional warming of the stream temperature.
- Wetlands will be stressed by the change in precipitation and the lowering of the water table.

Overall, the impacts of climate change on our forests, wetlands, and fish populations could be extreme, and socio-economic impacts will be felt such as:

- longer growing seasons, but also risks to agriculture such as moisture deficits, pests, and disease, resulting in the need to re-evaluate crops;
- reduction in available freshwater, lower water table and dry wells,
- impacts on fish populations, and reduction of cold water sport fisheries;
- projected changes in the occurrence and severity of extreme weather events, causing increased property damage and personal injury;
- increases in the frequency and severity of forest fires;
- more days when heat stress and air pollution adversely affect people's health; and
- low water levels in the Great Lakes could reduce commercial shipping capacity.

### 3.2.3 Physiography and Surficial Geology

While the 2002 Watershed Plan describes and maps various landform features within the watershed such as the Oak Ridges Moraine, the South Slope and the Lake Iroquois Plain, the advent of the ORMCP necessitates a brief description of Landform Conservation Areas designations (Figure 10).

The Ministry of Natural Resources (MNR) mapped at a 1:50,000 scale two distinct Landform Conservation Areas (LCA) in the ORM (Figure 10). The landforms depicted in this mapping are areas of high landform complexity and as such are subject to a higher level of protection. Category 1 landforms are dominated by areas where 50% or more of the land surface has slopes >10%, lands with distinctive landform features and/or land with diverse slope classes. Category 2 lands are identified where 20% to 50% of the land surface met the same criteria. A total of 5 slope classifications (0 – 2%, 2-5%, 5-10%, 10-25%, >25%) were used to determine Categories 1 and 2.

Landform Conservation is defined in the ORMCP guidance material as 'the protection and wise use of the land base including its form, soils and associated biophysical processes' (Ministry of Natural Resources (MNR), 2004a). Category 1 and 2 Landforms represent approximately 8.68% and 11.97% respectively of the ORM area within the watershed; therefore 20.65% of the ORM within the watershed has been identified for added conservation measures through the ORMCP. It should also be noted that the Ontario Ministry of Natural Resources (MNR) has mapped hummocky terrain throughout the watershed. This information is based on land slope information, predates the ORMCP LCA designations, and delineates slightly broader areas.

### 3.2.4 Surface Water

3.2.4.1 Water Quantity

Quantifying the amount of water within a watershed assists in the understanding of the hydrologic cycle for the watershed. Monitoring the changes in water quantity can assist in identifying changes that may affect the aquatic health, geomorphic stability and water quality of a creek. In addition, stream gauging provides critical information needed for CLOCA's flood forecasting and warning program.

Further, the flows calculated from the stream gauge data support groundwater and surface water modelling and calibration efforts, surface water quality assimilative studies, water use and aquatic health investigations. It is important to monitor changes in flow conditions that reflect changes in climate (precipitation, evapotranspiration, air temperature), water demands, land use (urban, rural, agricultural, recreational) and natural areas (loss of natural heritage features). Changes in flow rates affect urban and rural run-off and wash-off and transport, channel stability and fish habitat. Issues result from groundwater discharge reduction including reduced assimilative capacity, and increased water temperature.

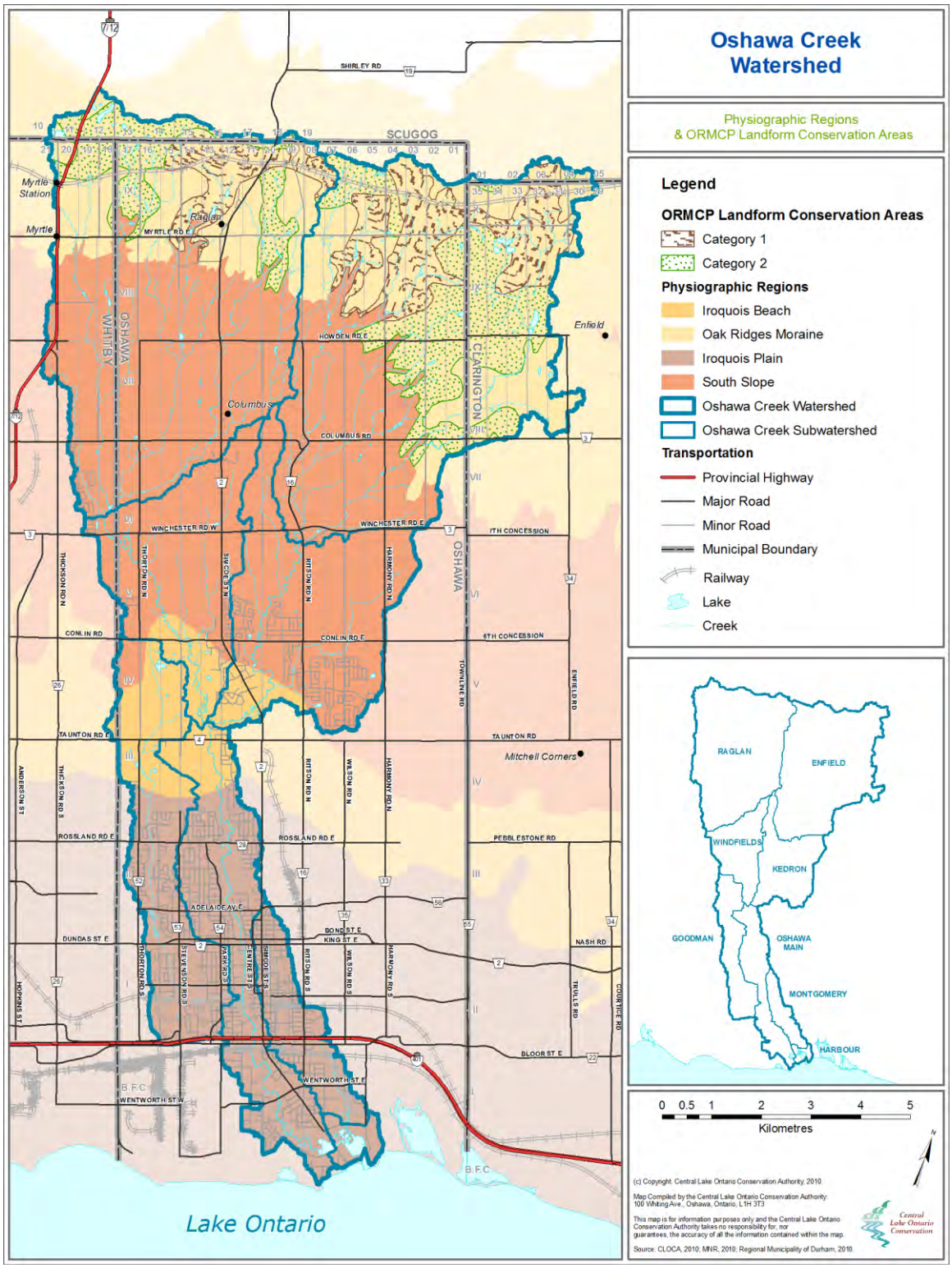


**Figure 10:** Watershed physiographic regions and ORMCP Landform Conservation Categories (sources: Chapman and Putnam, 1984; MMAH, 2002)

Modeling

Water quantity modeling can be broken down into 2 components, hydrology and hydraulics. Each component is modeled using different software and is used in CLOCA's daily routine. In order to determine water quantity over time, monitoring is crucial. CLOCA undertakes a monitoring program, the results of which are used in many different Authority programs, including water quantity modeling and predictions.

Hydrology – Transient Modeling

While Visual Otthymo is a single event hydrologic model used to predict peak flows, The United States Geological Survey's transient numerical model Precipitation-Runoff Modeling System (PRMS) has been applied to the watershed by CLOCA as part of water budgeting activities, consistent with the model developed for the Source Water Protection program (Earthfx, 2007). A transient model simulates runoff over days, months and years based primarily on daily average precipitation data recorded at local gauge stations. This model has been constructed for a myriad of uses including water budget investigations, estimate land development impacts, water supply investigations, fisheries and aquatics management, and water use reviews. This model was, in-part, calibrated using the existing groundwater flow model developed in 2007 for the Source Water Protection Program.

One of the key outputs of the model is the long-term average distribution of annual runoff over the watershed. This information further refines the spatial distribution of estimated runoff by calculating runoff rates on a 25mx25m grid covering the watershed.

The distribution of long-term average annual watershed runoff in mm/year is shown in Figure 11. Note that the higher runoff values are reflected in the urban areas of higher imperviousness. Areas of less permeable surficial soils generally reflect higher runoff also depending on the degree of slope, on the land cover and the amount of precipitation intercepted. Many stream corridors are predicted to have low runoff potential based on the extent of riparian cover, related rates of evapotranspiration and interception, and soil types. The long-term average annual runoff is estimated at approximately 168mm/year for the watershed (data from Earthfx, 2007).

Monitoring

CLOCA maintains a network of monitoring stations that monitor water quantity parameters including rainfall and stream water level (Table 6). These stations are permanent gauges that record information on a set interval. Some gauges can be downloaded remotely and others require information to be retrieved on site. The information collected from the stream gauges can be used to identify trends and averages for each of the gauges. Within the Oshawa Creek there are 4 water level stations, 1 of which also monitors rainfall (Figure 12).

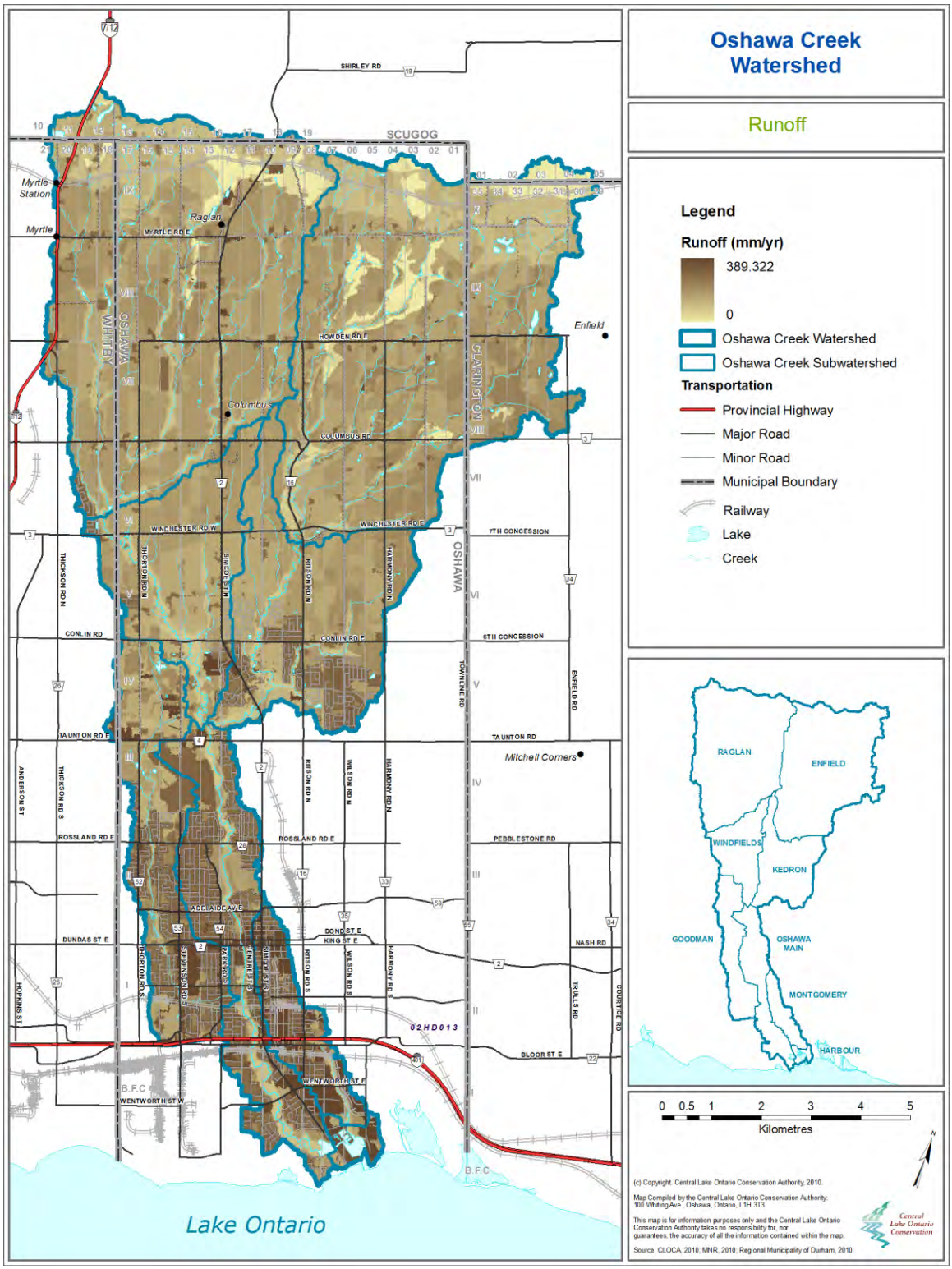


**Figure 11**: Runoff in the Oshawa Creek Watershed (source: Earthfx, 2007)

**Table 6**: Oshawa Creek watershed stream flow measuring

| Station | Description | Period of Record (Flow) | Parameters |
|---|---|---|---|
| **02HD008** | Taunton Rd. | 1959 - Current | Water Level (Flow), Rainfall, Water Temperature, Air Temperature |
| **OshWest** | Conlin Rd. | 2001 - Current | Water Level (Flow), Air Temperature |
| **OshEast** | Conlin Rd. | 2001 - Current | Water Level (Flow), Air Temperature |
| **OshMain** | Thomas St. | 2001 - Current | Water Level (Flow), Air Temperature |

In addition to stream flow monitoring CLOCA maintains a snow pack monitoring program, where snow depth and density is obtained on a preset schedule of twice monthly. Within the watershed there is 1 snow pack monitoring station located at Coates Road in the Purple Woods Conservation Area. This information is used to assist in the development and calibration of the hydrology and hydraulic models.

Baseflow Monitoring

CLOCA also maintains a baseflow monitoring network. The baseflow monitoring network was established in 2002 and consists of 138 stations jurisdiction wide, 39 of which are in the Oshawa Creek watershed. These stations are monitored manually during the summer months after 3 consecutive days with no rainfall.

The information collected through CLOCA's baseflow monitoring network (Figure 13) has been formatted and summarized to allow for the identification of trends and relationships for each site. The average baseflow measurement for each site, for the period of record (2002 to 2009), has been determined and is shown on the figure. In addition the relationship between baseflow sites is currently being examined in an effort to identify stream reaches that are gaining groundwater (groundwater discharge) or losing stream flow to groundwater (groundwater recharge).

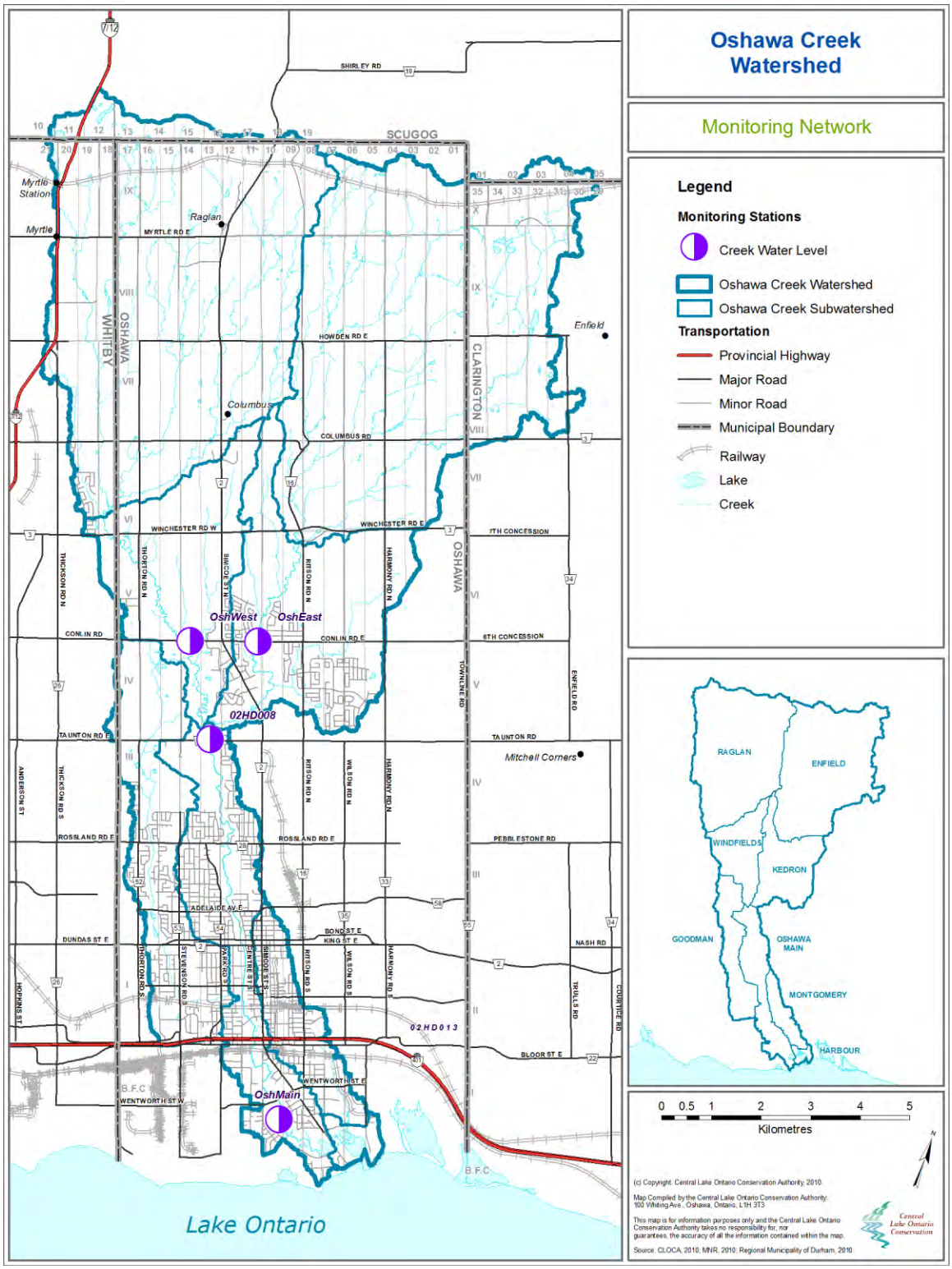


**Figure 12:** CLOCA's surface water monitoring network in the Oshawa Creek watershed

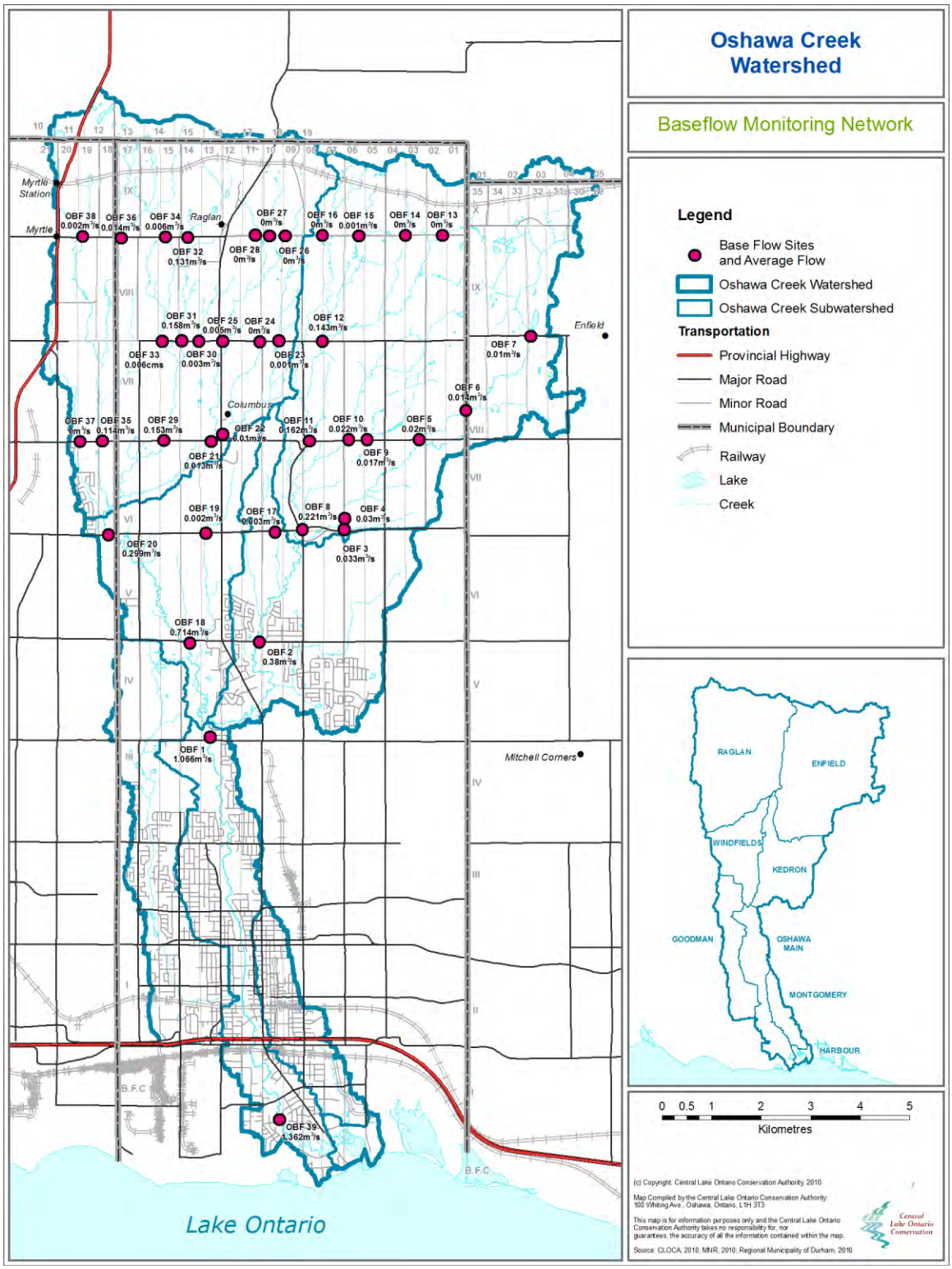


**Figure 13:** Baseflow stations with average flow in the Oshawa Creek watershed

### 3.2.4.2 Rapid Stream and Rapid Geomorphic Assessments

Since 2002, several Stream Erosion Projects have been completed within Oshawa Creek, three of which were sites that were assessed in the 2002 Oshawa Creek Watershed Management Plan. Sites 1, 3 and 10 have all been improved, using live crib walls, vegetated boulder treatments, native plantings and other standard techniques, through the City of Oshawa's annual capital works projects.

### 3.2.4.3 Water Quality

Water is a valued public resource; streams with unimpaired water quality satisfy a wide variety of needs, such as fisheries and wildlife habitat, human consumption, recreation, and industry. Streams with impaired water quality can pose health risks for local residents, livestock, or wildlife. In order to provide effective management recommendations, it is imperative that water quality of the watershed is well understood.

Surface water quality is generally described with measures of chemical, physical and biological characteristics. These measured values can then be compared with established standards. The water quality can assist in determining the level at which existing conditions in the watershed are able to sustain and promote wildlife diversity and fish populations, to support vegetation, and to ensure adequate safe water supplies for human consumption, agriculture, and recreational uses. Degradation of water quality can diminish the aesthetic value of water resources, adversely affect terrestrial and aquatic species, and/or create health hazards for humans.

Considerable changes in water quality may be attributed to both natural and human-related causes. Natural causes such as physical and geochemical rock weathering often result in an increase in turbidity and concentrations of some constituents in stream waters. These natural causes, however, have been surpassed by water quality changes brought about by human activities that are mostly related to changes in land use, behavioural changes and other developments. It was observed through the years that these changes generate more and more pollution which adversely affects the physical, chemical and/or biological conditions in both surface and groundwater environments. The general and most common types of pollution, among others, include toxic, organic, nutrient, bacterial and sediment (turbidity). Thermal impairment from land use alteration also impacts water quality and is described in detail in Section 3.3.1 Fisheries and Aquatic Habitat. Stormwater management facilities assist in the reduction of sediment transport to creek systems (see Section 3.2.4.4 Stormwater Management for more detail). CLOCA requires an 80% reduction of sediment in runoff from proposed development, in accordance with the Ministry of Environment (MOE) guidelines for Enhanced Protection.

In addition to pollution types, it is also essential to determine whether contaminants come from point or non-point sources. Point source pollutants are those originating from specific site sources such as an industrial establishment, a storage structure or a processing plant while non-point sources are widespread and generally mobile. Non-point sources include acid rain, road salting, fertilizer and pesticide applications, and accidental chemical spills from moving vehicles.

| |
|---|
| **Toxic pollution** is caused by the addition of elements such as heavy metals and inorganic and organic compounds, which can be toxic to all life forms. |
| **Organic pollution** is caused by the addition of biomass, which requires chemical breakdown, thus resulting in oxygen depletion. Primary sources are industrial waste and sewage. |
| **Nutrient pollution** is caused by the introduction of excessive concentrations of plant nutrients such as nitrogen and phosphorus from agricultural runoff, lawn fertilizers, domestic wastewater, sewage and industrial discharges. Depletion of dissolved oxygen levels results from increased bio-production. |
| **Bacterial (Pathogenic) pollution** results from coliform (e.g., *E. coli*) and/or disease-carrying organisms from mammals. Sources are generally domestic sewage and livestock wastes. |
| **Sediment pollution** is caused by the excessive suspension of soil materials that may be eroded from development sites, agricultural areas or streambanks in the watercourses. Concentration of solids or high turbidity may reduce biological activity, deplete oxygen levels and eventually result in stream sterilization. |

Applicable Legislation and Policies

Surface water quality monitoring activities in the Oshawa Creek watershed and all watersheds within CLOCA jurisdiction are governed by principles, regulations and guidelines embodied in federal and provincial legislations on water resources management and protection. The Environmental Protection Act, 1990 and Ontario Water Resources Act, 1990 are two of the prominent legislations related to the protection and management of water resources. These legislations have been subjected to numerous amendments to keep up with changes and developments. The Ontario Water Resources Act has provisions that prescribe and regulate standards of quality for water supplies, sewage and industrial waste effluents discharging to streams and water courses. The Environmental Protection Act pertains specifically to on site

standards and exceedances brought about by construction developments. The Safe Drinking Water Act 2002 focuses on the protection of human health through the control and regulation of drinking-water systems and drinking-water testing, including the treatment and testing requirements for all categories of regulated water systems. The Nutrient Management Act 2002, deals with nutrient load management mostly originating from agricultural lands and septic sources. The recently enacted Clean Water Act 2006 is aimed at ensuring the safety of drinking water by identifying potential risks to local sources. The source water protection strategies developed in CLOCA as well as in each of the other Conservation Authorities are directed towards attaining the Clean Water Act's objectives at the community level.

In line with the above-mentioned legislative and regulatory instruments, a surface water quality monitoring strategy was developed to generate tools that will assist managers, decision-makers and implementers to properly address water contamination concerns and immediately mitigate if not totally eliminate its adverse effects during the early stage of detection.

## Water Quality Sampling

Surface water quality information is collected by CLOCA at monitoring sites throughout the watershed (Figure 14). This information is used to identify trends in the quality of the water using various indicators. Different types of water quality information have been collected by CLOCA and MOE through the Provincial Water Quality Monitoring Network Program since 1964. Biological water quality is based on aquatic life, while chemical water quality is assessed by analyzing the concentrations of various chemicals in the water.

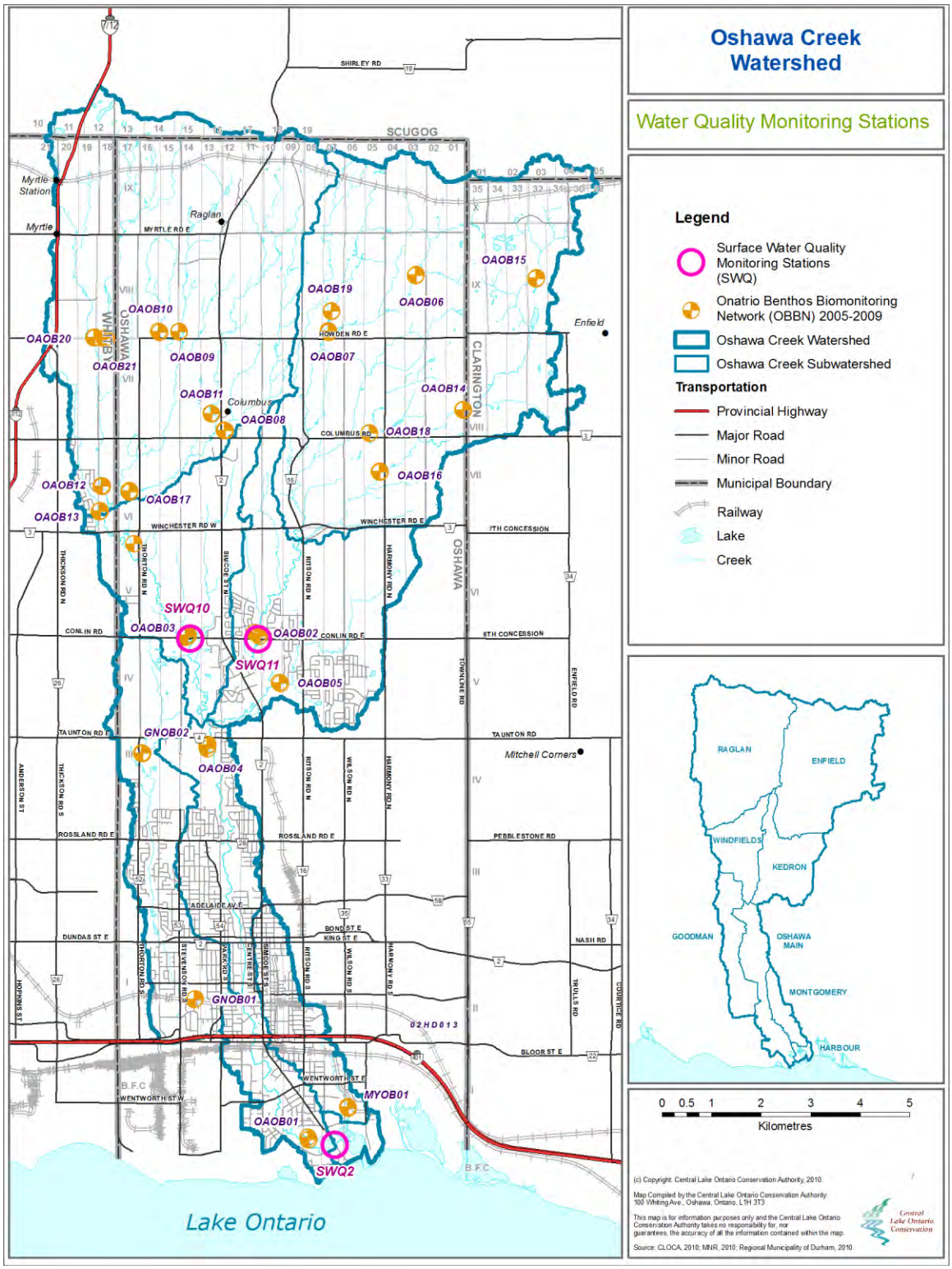


**Figure 14:** Surface water quality monitoring stations in the Oshawa Creek watershed

Biological Water Quality Monitoring

CLOCA has used three programs to collect and assess Biological Water Quality Information. These programs have included; the Biological Monitoring and Assessment Protocol (BioMAP); Hilsenhoff Biotic Index (HBI) scores derived from invertebrate sampling data collected under the Ontario Stream Assessment Protocol (OSAP); and the Ontario Benthos Biomonitoring Network (OBBN) (Table 7). The protocols for these different sampling techniques are described briefly, followed by a discussion on the findings.

Using the BioMAP protocol (Griffiths, 1999) invertebrates are collected from each site and identified generally to the species level. Certain aquatic invertebrates are known to be tolerant of poor water quality conditions, while others are more sensitive (i.e. intolerant) and are only found in areas of good water quality. The numbers of tolerant/intolerant individuals at each site were used to evaluate whether or not the water quality was impaired.

Hilsenhoff scores are calculated from benthic invertebrate sampling conducted as part of the OSAP protocol (Stanfield *et al.* 1998). Hilsenhoff scores are a qualitative measure of water quality and organic pollution using tolerance values from benthic invertebrate families.

The OBBN (Jones, et al., 2005) protocol also involves the sampling and identification of benthic microinvertebrates to serve as indicators of environmental quality. Through this program, test sites are compared to minimally impacted "reference" sites to determine the level of degradation.

Biological quality was assessed historically using BioMAP in 1999 at 18 sites throughout the watershed (Figure 14). Of the 18 sites sampled, 10 sites (55.6%) were considered impaired seasonally or year-round. These sites were typically located in the older urban areas of Oshawa where stormwater management is lacking, or in agricultural areas with insufficient riparian buffers or where cattle have access to the creek. Biological water quality (i.e. macroinvertebrates) was also assessed in 2000 while conducting fish community sampling at 65 sites using Hilsenhoff scores and the Ontario Stream Assessment Protocol (Stanfield *et al.* 1998). Like BioMAP, the Hilsenhoff scores from this program showed a contrast from poor in the older urban areas of Oshawa and some agricultural areas, to fair in the upper urban areas where stormwater management has been implemented in recent years, to good in areas where natural cover is abundant or riparian corridors are still intact (CLOCA/MNR 2007).

In 2005 and 2007, CLOCA used OBBN to sample 28 sites. Preliminary results do show a response to human disturbance. Taxa richness and % EPT (the percent of sensitive taxa in the overall catch, including **E**phemeroptera (Mayflies), **P**lecoptera (Stoneflies) and **T**richoptera (Caddisflies)) were calculated. With both of these indices, large values imply a healthy biological community, while low values imply reduced health or impaired water quality (Jones *et al*. 2005). Percent EPT ranged from low or even zero in the older urban areas of Oshawa to moderate in the newer urban areas or agricultural areas with minimal riparian cover. Sites showing impairment were typically related to the cumulative effects of nutrient enrichment from urban or agricultural sources. Areas with higher percent EPT values were typically found within the larger upper reaches of the watershed where creeks remained relatively undisturbed compared to the downstream reaches. Taxa richness at each site ranged from 4 to 13. The greatest richness typically occurred within third and forth order streams, particularly those dominated by natural cover. Preliminary results from this assessment at individual sites are presented within this chapter; however, comparisons to minimally impacted sites had not yet been conducted at the time of writing this report.

It would be worthy to note that the BioMAP and Hilsenhoff information is historical and these methodologies have not been used by CLOCA since 2004. The only benthic sampling procedure that CLOCA currently uses is the OBBN methodology. A comparison of the sample sites is available in Figure 15.

**Table 7:** Biological water quality monitoring in the Oshawa Creek watershed between 1999 and 2007

| Subwatershed | Site | Year | Method | Status |
|---|---|---|---|---|
| **Harbour** | OA01 | 1999 | BioMAP | Impaired |
| | OA02 | 1999 | BioMAP | Impaired |
| | OA03 | 1999 | BioMAP | Impaired |
| **Montgomery** | OA04 | 1999 | BioMAP | Impaired |
| | MYOB01 | 2007 | OBBN | %EPT = 0.0, Taxa Richness = 4 |
| **Goodman** | OA07 | 1999 | BioMAP | Impaired |
| | OB01 | 2000 | OSAP/HBI | Poor |
| | OB02 | 2000 | OSAP/HBI | Very Poor |
| | OB03 | 2000 | OSAP/HBI | Very Poor |
| | OB04 | 2000 | OSAP/HBI | Poor |
| | OB05 | 2000 | OSAP/HBI | Poor |
| | OB06 | 2000 | OSAP/HBI | Poor |
| | OB07 | 2000 | OSAP/HBI | Poor |
| | OB08 | 2000 | OSAP/HBI | Poor |
| | OB09 | 2000 | OSAP/HBI | Poor |
| | OB10 | 2000 | OSAP/HBI | Very Poor |
| | OB11 | 2000 | OSAP/HBI | Poor |
| | OB12 | 2000 | OSAP/HBI | Fairly Poor |
| | SOB1 | 2000 | OSAP/HBI | Fairly Poor |
| | GNOB01 | 2007 | OBBN | %EPT = 0.0, Taxa Richness = 10 |
| | GNOB02 | 2007 | OBBN | %EPT = 14.7, Taxa Richness = 12 |
| **Oshawa Main** | OA05 | 1999 | BioMAP | Seasonally Impaired |
| | OA06 | 1999 | BioMAP | Unimpaired |
| | OA08 | 1999 | BioMAP | Unimpaired |
| | OA09 | 1999 | BioMAP | Unimpaired |
| | OA01 | 2000 | OSAP/HBI | Poor |
| | OA02 | 2000 | OSAP/HBI | Poor |
| | OA03 | 2000 | OSAP/HBI | Poor |
| | OA04 | 2000 | OSAP/HBI | Fairly Poor |
| | OA05 | 2000 | OSAP/HBI | Poor |
| | OA06 | 2000 | OSAP/HBI | Poor |
| | OA07 | 2000 | OSAP/HBI | Poor |
| | OA08 | 2000 | OSAP/HBI | Fairly Poor |
| | OA09 | 2000 | OSAP/HBI | Poor |
| | OA10 | 2000 | OSAP/HBI | Fairly Poor |
| | OA11 | 2000 | OSAP/HBI | Fairly Poor |
| | OAOB01 | 2005 | OBBN | %EPT = 8.0, Taxa Richness = 9 |
| | OAOB01 | 2007 | OBBN | %EPT = 5.4, Taxa Richness = 11 |
| | OAOB02 | 2007 | OBBN | %EPT = 14.8, Taxa Richness = 9 |
| **Kedron** | OA10 | 1999 | BioMAP | Unimpaired |
| | OA12 | 1999 | BioMAP | Unimpaired |
| | OE01 | 2000 | OSAP/HBI | Fair |
| | OE02 | 2000 | OSAP/HBI | Fairly Poor |

| Subwatershed | Site | Year | Method | Status |
|---|---|---|---|---|
| | OE03 | 2000 | OSAP/HBI | Very Poor |
| | OE04 | 2000 | OSAP/HBI | Poor |
| | OE05 | 2000 | OSAP/HBI | Poor |
| | OE06 | 2000 | OSAP/HBI | Fairly Poor |
| | OAOB03 | 2007 | OBBN | %EPT = 1.0, Taxa Richness = 5 |
| | OAOB02 | 2005 | OBBN | %EPT = 24.3, Taxa Richness = 10 |
| | OAOB05 | 2007 | OBBN | %EPT = 9.3, Taxa Richness = 13 |
| **Raglan** | OA13 | 1999 | BioMAP | Unimpaired |
| | OA14 | 1999 | BioMAP | Unimpaired |
| | OA15 | 1999 | BioMAP | Impaired |
| | OA16 | 1999 | BioMAP | Impaired |
| | OA17 | 1999 | BioMAP | Impaired |
| | OC01 | 2000 | OSAP/HBI | Fair |
| | OC02 | 2000 | OSAP/HBI | Fair |
| | OC03 | 2000 | OSAP/HBI | Fair |
| | OC04 | 2000 | OSAP/HBI | Fair |
| | OD01 | 2000 | OSAP/HBI | Good |
| | OD02 | 2000 | OSAP/HBI | Poor |
| | OD03 | 2000 | OSAP/HBI | Fairly Poor |
| | OD04 | 2000 | OSAP/HBI | Fair |
| | OD05 | 2000 | OSAP/HBI | Fair |
| | SOC1 | 2000 | OSAP/HBI | Fair |
| | SOC2 | 2000 | OSAP/HBI | Fairly Poor |
| | SOC3 | 2000 | OSAP/HBI | Fairly Poor |
| | SOD1 | 2000 | OSAP/HBI | Good |
| | SOD2 | 2000 | OSAP/HBI | Good |
| | SOD3 | 2000 | OSAP/HBI | Fair |
| | SOD4 | 2000 | OSAP/HBI | Good |
| | OAOB08 | 2007 | OBBN | %EPT = 12.6, Taxa Richness = 10 |
| | OAOB11 | 2007 | OBBN | %EPT = 29.1, Taxa Richness = 13 |
| | OAOB12 | 2007 | OBBN | %EPT = 36.8, Taxa Richness = 10 |
| | OAOB13 | 2007 | OBBN | %EPT = 44.2, Taxa Richness = 10 |
| | OAOB17 | 2007 | OBBN | %EPT = 36.9, Taxa Richness = 12 |
| | OAOB09 | 2007 | OBBN | %EPT = 70.3, Taxa Richness = 10 |
| | OAOB10 | 2007 | OBBN | %EPT = 6.7, Taxa Richness = 9 |
| | OAOB20 | 2007 | OBBN | %EPT = 46.2, Taxa Richness = 6 |
| | OAOB21 | 2007 | OBBN | %EPT = 16.7, Taxa Richness = 11 |
| **Enfield** | OA18 | 1999 | BioMAP | Impaired |
| | OE07 | 2000 | OSAP/HBI | Fairly Poor |
| | OE08 | 2000 | OSAP/HBI | Fair |
| | OE09 | 2000 | OSAP/HBI | Fair |
| | OE10 | 2000 | OSAP/HBI | Fair |
| | OE11 | 2000 | OSAP/HBI | Fair |
| | OE12 | 2000 | OSAP/HBI | Poor |
| | OE13 | 2000 | OSAP/HBI | Fairly Poor |
| | OF01 | 2000 | OSAP/HBI | Fair |
| | OF02 | 2000 | OSAP/HBI | Good |
| | OF03 | 2000 | OSAP/HBI | Good |
| | OF04 | 2000 | OSAP/HBI | Fairly Poor |
| | OF05 | 2000 | OSAP/HBI | Poor |
| | OF06 | 2000 | OSAP/HBI | Fairly Poor |
| | SOE1 | 2000 | OSAP/HBI | Fair |
| | SOE2 | 2000 | OSAP/HBI | Fairly Poor |
| | OAOB16 | 2007 | OBBN | %EPT = 47.8, Taxa Richness = 13 |
| | OAOB06 | 2007 | OBBN | %EPT = 13.0, Taxa Richness = 9 |
| | OAOB07 | 2007 | OBBN | %EPT = 4.4, Taxa Richness = 7 |
| | OAOB14 | 2007 | OBBN | %EPT = 33.0, Taxa Richness = 13 |
| | OAOB18 | 2007 | OBBN | %EPT = 37.5, Taxa Richness = 10 |
| | OAOB19 | 2007 | OBBN | %EPT = 18.3, Taxa Richness = 6 |
| | OAOB15 | 2007 | OBBN | %EPT = 18.2, Taxa Richness = 6 |
| **Windfields** | OA11 | 1999 | BioMAP | Unimpaired |
| | OA12 | 2000 | OSAP/HBI | Fairly Poor |
| | OA13 | 2000 | OSAP/HBI | Fairly Poor |
| | OA14 | 2000 | OSAP/HBI | Fair |
| | OA15 | 2000 | OSAP/HBI | Poor |
| | OAOB03 | 2005 | OBBN | %EPT = 20.4, Taxa Richness = 10 |
| | OAOB04 | 2007 | OBBN | %EPT = 21.0, Taxa Richness = 7 |
| | PROB01 | 2005 | OBBN | %EPT = 9.5, Taxa Richness = 9 |

In conclusion, biological water quality monitoring from 2000 indicated that impairment within urban areas originated from untreated sewer discharge, contaminated stormwater, direct pollution, organic enrichment, nutrient enrichment from agricultural practices (e.g. livestock in the creek, pesticide application, and lack of riparian vegetation), and the cumulative effects of these stressors from upstream areas. Water quality was not as impaired in newer developments which could be a result of improved stormwater management, or simply that upstream areas are still somewhat natural and therefore cumulative effects are not as apparent. The healthiest areas of the watershed were typically located within areas dominated by natural land cover, including well vegetated valley sections. This spatial trend can also be observed during the 2000, 2005 and 2007 sampling events. Additional analyses comparing 2007 monitoring data to reference conditions has yet to be completed. Future results of this work, and follow-up monitoring scheduled for 2012 (CLOCA 2008) may provide further insight into current watershed health.

Despite the degraded water quality in some areas of the watershed, it is interesting to note that Oshawa Creek continues to provide a productive fishery supporting many sensitive coldwater species like Rainbow Trout, Brown Trout, Chinook Salmon, and Brook Trout in the headwaters. These species are all naturally reproducing as indicated by the presence of young-of-year (YOY) fish during summer electrofishing studies.

Water Quality Sampling (Chemical)

CLOCA has two chemical water quality sampling programs in place, the Provincial Water Quality Monitoring Network (PWQMN) and CLOCA's own water quality monitoring program. The location of the chemical water quality sites within the Oshawa Creek watershed is shown in Figure 14.

The PWQMN was designed to collect surface water quality information province wide. The objectives of the PWQMN are to collect, document and assess long term water quality. The Ministry of Environment operates the program across the province while CLOCA assists in collecting samples from ten sites, two that are located within the Oshawa Creek watershed, on monthly intervals from April through November. The samples collected under the PWQMN program are sent to the Ministry of Environment (MOE) laboratory and tested for 41 parameters (Appendix 1).

Supplemental to the PWQMN water quality sampling, CLOCA independently conducts water quality sampling at 10 stations, one of which is located within Oshawa Creek watershed. The samples from these stations are collected twice during the summer months on the same day that the PWQMN sampling occurs. The samples collected under this program are submitted to the Durham-York Region Environmental Laboratory for analysis of 46 physical-chemical parameters (Appendix 2).

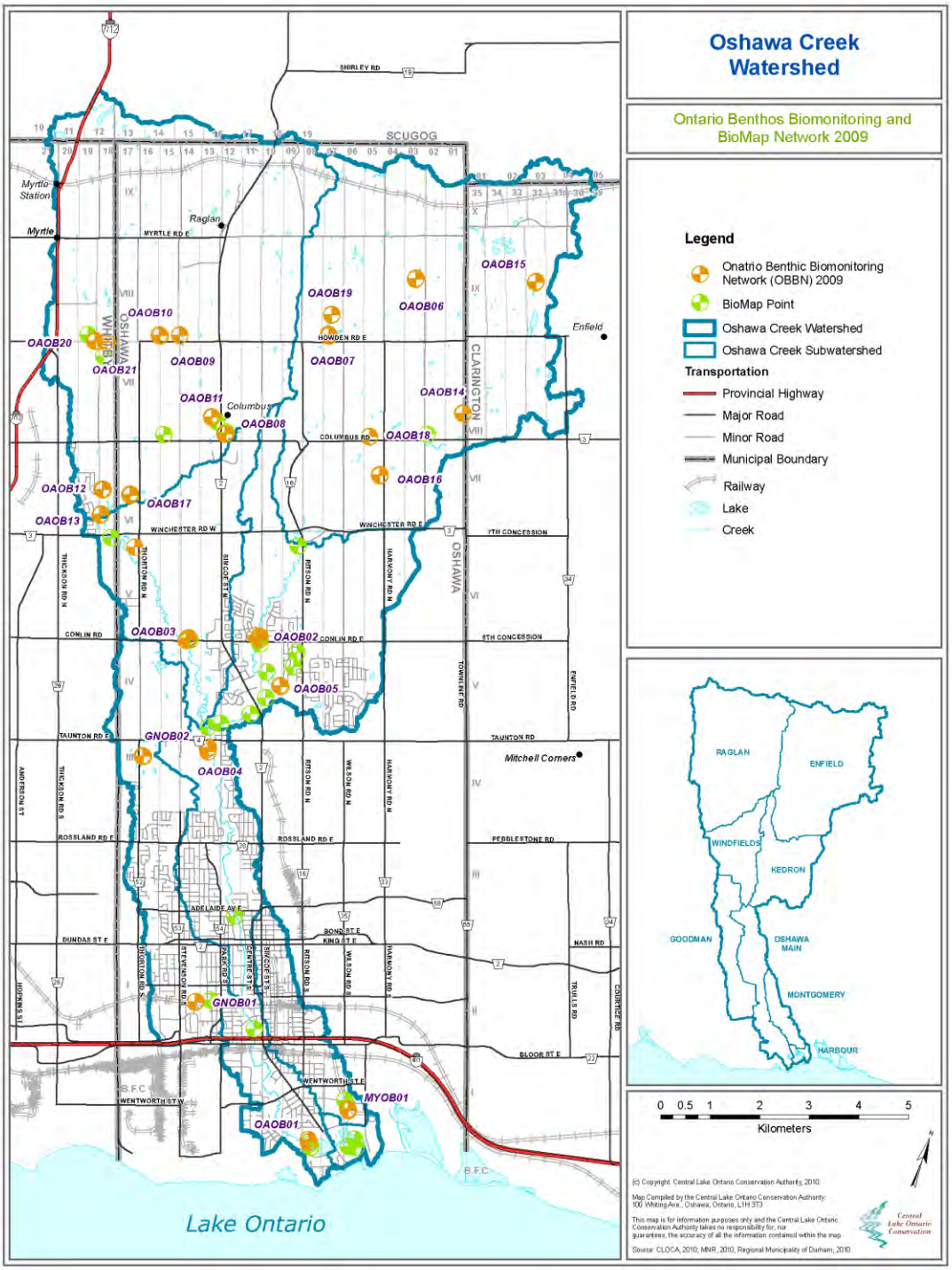


**Figure 15:** Comparison of Ontario Benthic Biomonitoring and BioMap Network

Water Quality Index (WQI)

The Water Quality Index (WQI) is a collection of chemical water quality parameters that assist in determining the surface water quality conditions. The WQI parameters were chosen based on the monitoring programs in place, historical studies, and their significance as a water quality indicator. Table 8 presents the WQI parameters, their descriptions, method of calculation and significance as an indicator of watershed condition. Also, the Canadian Environmental Sustainability Indicators (CESI) reporting product, which is a joint undertaking of Environment Canada, Statistics Canada and Health Canada, released in 2008 various water quality guidelines used to support aquatic life in each provincial jurisdiction. Where applicable, the updated guideline for Ontario was utilized in this report.

Both parametric and non-parametric tests were used for statistical trend analyses. Parametric tests are hypothesis tests for probability, which assume that data has a particular distribution (usually a normal distribution). Non-parametric tests (also called distribution-free) are hypothesis tests for probability not requiring the assumption that data follow a particular distribution (Helsel, D.R., et. al., 2002). Water quality data, including the parameters that are not in the WQI list, were statistically analyzed using Microsoft Excel for most parametric analysis and AquaChem[1] was used for both parametric and non-parametric analysis.

Chemical Water Quality

Statistical tests (trend analyses) were performed for the WQI parameters that have sufficient data to process. Trend analysis results either show downward or upward trends are indicative of improving or deteriorating water quality, respectively. This is in exception of dissolved oxygen (DO) where the condition improves proportional with increase in concentration. In the Oshawa Creek watershed, statistical trend analysis was performed on chloride, phosphorus, nitrogen compounds (nitrite and nitrate), copper, biochemical oxygen demand (BOD) and dissolved oxygen. Although statistical and parametric trend analyses that include mean, standard deviation and simple linear regression may be used to graphically show trends, the variability of water quality data, as influenced by changes in season, streamflow and other environmental factors, render parametric trend analysis unreliable. Non-parametric trend analysis is considered to be more reliable because it is not restricted by distributional assumptions, nor grossly affected by data errors, outliers, non-detects, missing data, and irregularly spaced measurement periods. In this test, non-detects are assigned the smallest measured value such that all samples are taken into consideration in the analysis. In view of this, the non-parametric trend analysis, specifically the Mann-Kendall Test trend estimator included in the AquaChem water quality management software, was utilized instead. This statistical tool determines whether chemical concentrations are significantly increasing or diminishing over time in a more complex and reliable method.

The results of statistical analyses and parametric and non-parametric tests are presented in Table 9.

[1] *Aquachem* is a software package developed by Waterloo Hydrogeologic, Inc. for graphical and numerical modeling of water quality data.

**Table 8:** Description of parameters in the surface Water Quality Index (WQI)

| Indicator | What it Measures | Why it is important |
|---|---|---|
| Chloride | The concentration of Chloride in the water | Once Chloride is dissolved in a solution it tends to remain there. Chloride is present in road salt, fertilizers and industrial wastewater. In high concentrations chloride can be toxic to aquatic organisms. |
| Phosphorus | The concentration of Phosphorus in the water | Phosphorus binds to soil particles and thus is an indicator of soil delivery to streams. Phosphorus is present in soaps, fertilizers and pesticides. Increased concentrations in water can cause algae blooms. |
| Nitrogen Compounds | The concentration of the various compounds of Nitrogen (i.e. Nitrate and Nitrite) | Nitrogen, in the form of Nitrate, is a nutrient with sources and effects similar to Phosphorus. It is also potentially toxic in aquatic systems when in the form of ammonia or nitrite the latter of which is a very transient stage in the nitrification process converting ammonia to nitrite. The existing Provincial Water Quality Objectives (PWQO, 1999) has not established a firm concentration limit for nitrate, however, the province recently adopted the Environment Canada nitrate concentration limit of 2.93 mg/L (CCME, 2005b).(2) |
| Copper | The concentration of Copper in water | The toxicity of copper to marine organisms is difficult to generalize and the level of tolerance varies among marine organisms. Aquatic invertebrates are thought to be slightly more sensitive to copper than fish. Copper has a limit of 1 mg/L under the Ontario Drinking Water Standard (ODWS) while the PWQO set a lower limit 5 µg/L limit in stream waters. |
| Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) | BOD and DO in mg/L | The BOD of water corresponds to the amount of oxygen required for aerobic microorganisms to oxidize organic matter into a stable inorganic form. High BOD level corresponds to low Dissolved Oxygen concentrations which could lead to stress responses in aquatic organisms. No official guideline for BOD level exists. BOD levels above 2 mg/L (or 5 mg/L during exclusively dry weather) indicate the presence of a persistent organic load to the system. The Canadian water quality objective for DO ranges from 5.0 – 6.0 mg/L for warm water biota and 6.5 – 9.5 mg/L for cold water biota depending on life stages.(2) |
| Benthic | The benthic invertebrate organisms living in the stream sediments | Benthic organisms generally:<br>• have limited mobility, making them vulnerable to many stresses in the creek;<br>• have short life cycles;<br>• are easily collected and identified; and,<br>• exists in almost all aquatic habitats. |

Note: (1) This table was taken in part from the Upper Thames River Watershed Report Cards 2001.(2) Water Quality Indicator Data Sources Methods, CESI, Environment Canada, May 2010.

**Table 9:** Summary statistics and trends in surface water quality parameters from stations in the Oshawa Creek watershed, analyzed using parametric and non-parametric statistical tests

| Parameter | Sampling Period | Number of Samples | Min | Max | Mean | Standard Deviation | Linear Regression | 25th Percentile | Median 50th Percentile | 75th Percentile | MKS (1) *(S)* | MKS (2) *(Z)* | MKS (3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SWQ2** | **1964-97, 2005-08** | | | | | | | | | | | | |
| Chloride (mg/L) | | 425 | 1.1 | 2000 | 61.5 | 108.8 | 0.0506 | 30.4 | 43 | 65 | 13226 | 4.5 | increasing trend |
| Phosphorus, Total (ug/L) | | 433 | 4 | 1700 | 130 | 179 | -0.4652 | 24 | 62 | 16 | -50717 | -16.9 | decreasing trend |
| Nitrate, total, filtered (mg/L) | | 147 | 0.275 | 14.5 | 1 | 1.26 | -0.129 | 0.475 | 0.7 | 1.17 | -323 | -0.54 | no trend |
| Nitrate, total, unfiltered (mg/L) | | 33 | 0.055 | 2.3 | 0.87 | 0.4 | 0.0223 | 0.64 | 0.82 | 1.02 | 28 | 0.42 | no trend |
| Nitrate as N (mg/L) | | 46 | 0.59 | 3.04 | 1.09 | 0.546 | 0.1318 | 0.74 | 0.845 | 1.2 | -89 | -0.83 | no trend |
| Copper (ug/L) | | 300 | 0.2 | 80 | 10.3 | 15 | -0.5977 | 1.27 | 3.4 | 10 | -28008 | -16.1 | decreasing trend |
| BOD, 5 day, total demand | | 360 | 0.06 | 55 | 3.4 | 6 | -0.4535 | 0.8 | 1.4 | 3.23 | -28259 | -12.4 | decreasing trend |
| Dissolved Oxygen (mg/L) | | 414 | 1.34 | 16.7 | 9.8 | 2.78 | 0.1842 | 8.2 | 10 | 11.6 | 14022 | 5 | increasing trend |
| **SWQ10** | **2003-08** | | | | | | | | | | | | |
| Chloride (mg/L) | | 68 | 22.4 | 80 | 33.1 | 9.7 | 0.2941 | 26.1 | 29.8 | 38.7 | 513 | 2.7 | increasing trend |
| Phosphorus, Total (ug/L) | | 68 | 5 | 130 | 17.6 | 20.3 | 0.1136 | 8 | 11.5 | 18 | -18 | -0.09 | no trend |
| Nitrate, total, filtered (mg/L) | | 0 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| Nitrate, total, unfiltered (mg/L) | | 23 | 0.524 | 1.27 | 0.76 | 0.19 | 0.3685 | 0.6 | 0.73 | 0.85 | 65 | 1.69 | increasing trend |

| Parameter | Sampling Period | Number of Samples | Min | Max | Mean | Standard Deviation | Linear Regression | 25th Percentile | Median 50th Percentile | 75th Percentile | MKS (1) *(S)* | MKS (2) *(Z)* | MKS (3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrate as N (mg/L) | | 45 | 0.37 | 2.26 | 0.95 | 0.4 | -0.2441 | 0.71 | 0.755 | 1.05 | -176 | -1.71 | decreasing trend |
| Copper (ug/L) | | 50 | 0.057 | 5 | 0.57 | 0.73 | 0.0364 | 0.2 | 0.4 | 0.635 | 32 | 0.26 | no trend |
| BOD, 5 day, total demand (mg/L) | | 2 | 0.6 | 0.8 | 0.7 | 0.141 | -1.00 | N/A | N/A | N/A | -1 | 0 | no trend |
| Dissolved Oxygen (mg/L) | | 62 | 1.41 | 16.3 | 10.5 | 4.2 | 0.4999 | 6.74 | 11.9 | 13.5 | 553 | 3.35 | increasing trend |
| **SWQ11** | **2004-08** | | | | | | | | | | | | |
| Chloride (mg/L) | | 42 | 21.1 | 38 | 25.1 | 3.37 | 0.3156 | 22.6 | 23.8 | 26.9 | 193 | 2.08 | increasing trend |
| Phosphorus, Total (ug/L) | | 42 | 6 | 230 | 16.2 | 35 | 0.0127 | 6 | 6 | 13 | 12 | 0.119 | no trend |
| Nitrate, total, filtered (mg/L) | | 0 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| Nitrate, total, unfiltered (mg/L) | | 0 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| Nitrate as N (mg/L) | | 42 | 0.76 | 2.06 | 1.15 | 0.282 | -0.205 | 0.99 | 1.07 | 1.29 | -256 | -2.76 | decreasing trend |
| Copper (ug/L) | | 42 | 0.2 | 5 | 0.55 | 0.756 | 0.0694 | 0.2 | 0.4 | 0.575 | 181 | 1.95 | increasing trend |
| BOD, 5 day, total demand (mg/L) | | 10 | 0.2 | 1.5 | 0.8 | 0.386 | 0.5838 | 0.525 | 0.75 | 1.05 | 22 | 1.88 | increasing trend |
| Dissolved Oxygen (mg/L) | | 22 | 4.03 | 16 | 12 | 3.6 | 0.6606 | 11.4 | 13.2 | 14 | 55 | 1.52 | no trend |

*(1) Mann Kendall Statistics (MKS) S (trend statistic) indicating increasing or decreasing trends*

*(2) Mann Kendall Statistics (MKS) Z (test statistics) approximated Z-value for calculating probability*

*(3) Mann Kendall Statistics (MKS) results 95% significance*

Water Quality Index (WQI) Findings

This section is organized such that summaries on the concentration and distribution of each index parameter are shown, where applicable, at all stations. Figure 16 identifies the sampling locations for water quality. Station SWQ2 is located at the Simcoe Street South bridge crossing near the Oshawa Harbour. This station is situated in a more developed area relative to the locations of SWQ10 and SWQ11 being at the Conlin Road bridge crossings of the western and eastern branches of Oshawa Creek. Long-term but not necessarily continuous data records were only available at station SWQ2 whereas station SWQ10 has records that were started when the Provincial Water Quality Monitoring Network (PWQMN) program was revived in 2003. The CLOCA maintained water quality station (SWQ11) was started in 2004. Statistical trend analyses become more valid when more data is processed, and since the datasets for these stations are limited, reported trends were processed using datasets that satisfy statistical requirements. There are instances where excessive concentrations were determined and, after careful evaluation, disregarded in some trend analyses. The extremely high concentrations, also known as outliers, were not entirely removed from the database, but rather subjected to investigation for validity. A number of valid reasons for the occurrence of outliers include, among others, accidental spill immediately before sampling or extreme rainfall after extended dry spell. The invalid results, however, may include, but are not limited to, errors in sampling procedure or laboratory analysis.

### *Chloride*

Chlorides are natural constituents in the hydrologic environments. This chemical may originate from natural sources like dissolution of rocks containing salt or from anthropogenic activities such as road salting, agricultural and wastewater runoffs. Environment Canada's May 2010 report on Canadian Environmental Sustainability Indicators (CESI) specified 150 mg/L as the chloride concentration limit to protect aquatic life in Ontario.

The Mann-Kendall statistical analysis at all three stations (SWQ2, SWQ10 and SWQ11) showed increasing trends of the chloride concentrations (Figure 17). Historically, the recorded chloride concentrations at this station went as high as 2,000 mg/L in the late 1980s. Throughout the sampling events, however, chloride concentrations occasionally exceeded the 150 mg/L limit set by Environment Canada (BCMOE,2001; EC,2005c) to protect aquatic life.

The provincial monitoring activity at SWQ2 station was discontinued after 1986, but was revived by CLOCA in 2005. The data gap, between 1985 and 2005, is illustrated in Figure 16. All samples taken at Stations SWQ10 and SWQ11 did not exceed the Environment Canada prescribed limit.

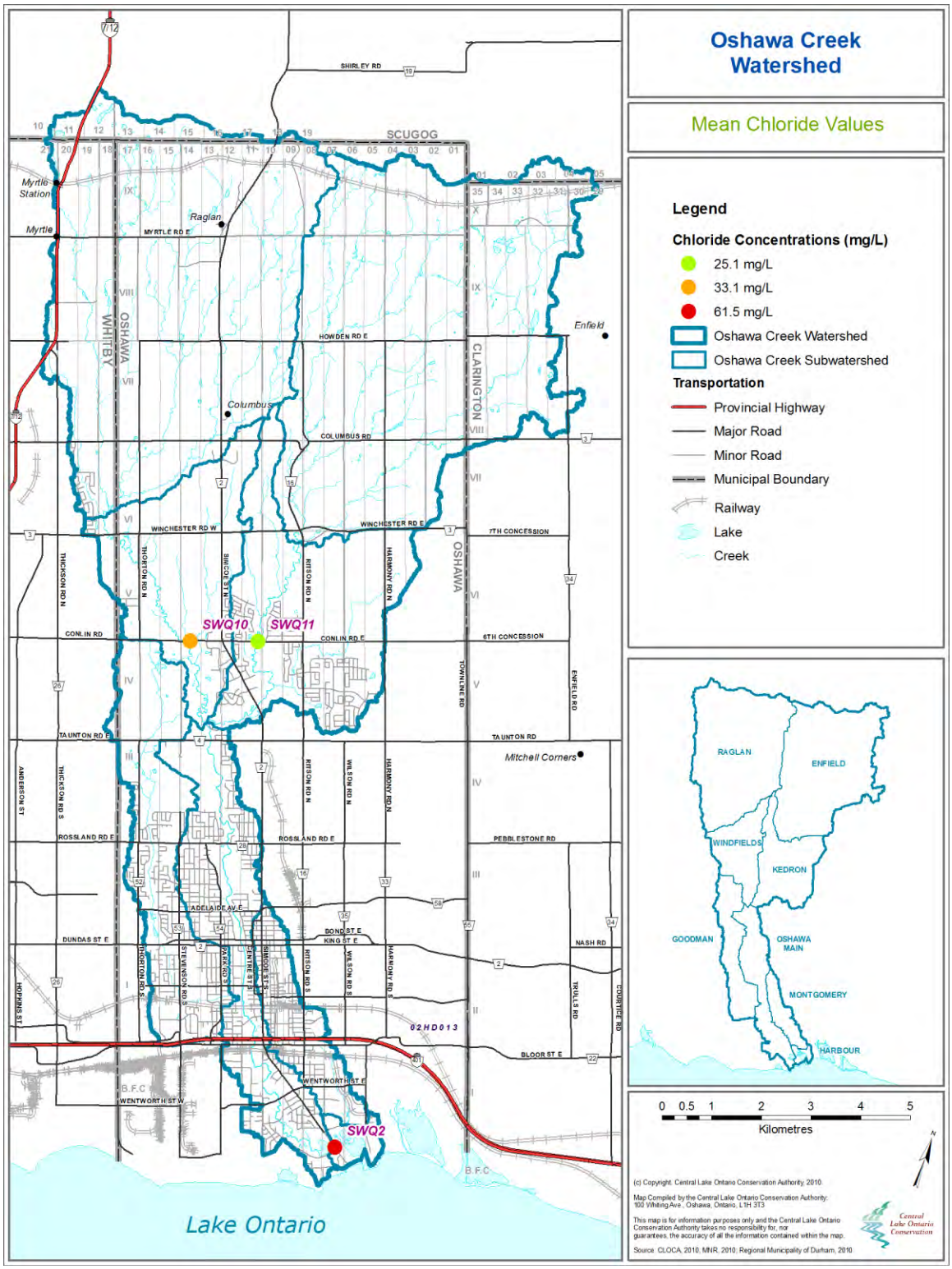


**Figure 16:** Spatial distribution of chloride concentration in Oshawa Creek

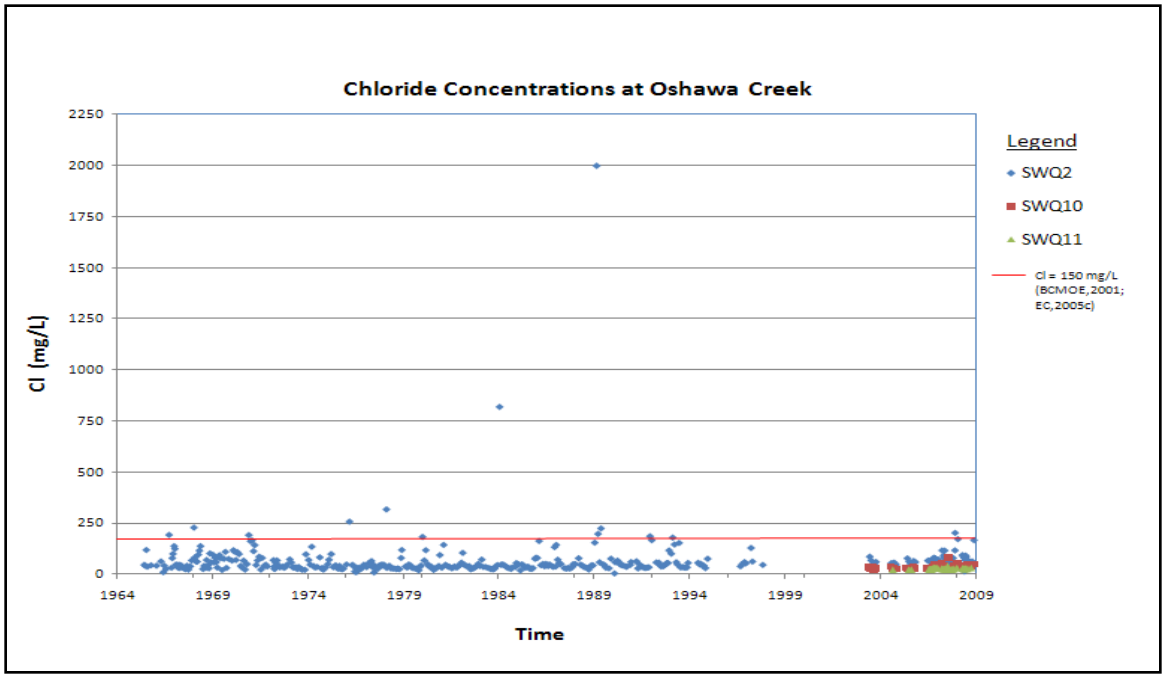


**Figure 17:** Chloride Concentrations at Oshawa Creek

Although increasing trends of chloride concentrations were observed on all surface water quality monitoring stations in Oshawa Creek, exceedance to the prescribed limits were only recorded at SWQ2, which is located at the highly urbanized area at the lower reaches of the channel. Statistical analysis shows that the mean concentration of chloride is higher at SWQ2 relative to the other monitoring stations.

### *Phosphorus*

Phosphorous may have little adverse effects on human health but excessive concentrations of this chemical in an aquatic environment could lead to a number serious effects including, increase in algae and plant growth, decrease in biodiversity and an increase in turbidity. Human activities related to land disturbance, industrial, domestic and livestock wastes may contribute to increase phosphorous levels.

A statistical analysis of phosphorous showed a decreasing trend in concentrations at SWQ2 while no trends were established at stations SWQ10 and SWQ11. Historical records show that the majority of the samples at SWQ2 have phosphorus concentrations exceeding the provincially and federally prescribed limit of 30 ug/L. The maximum concentration recorded at this station sometime in 1964 went as high as 1,699 ug/L, while the mean concentration remained over four times the prescribed limit. Samples taken from all stations after the program was revived in 2003 still show some exceedance to the prescribed limit but these were neither extremely high nor numerous (Figure 18).

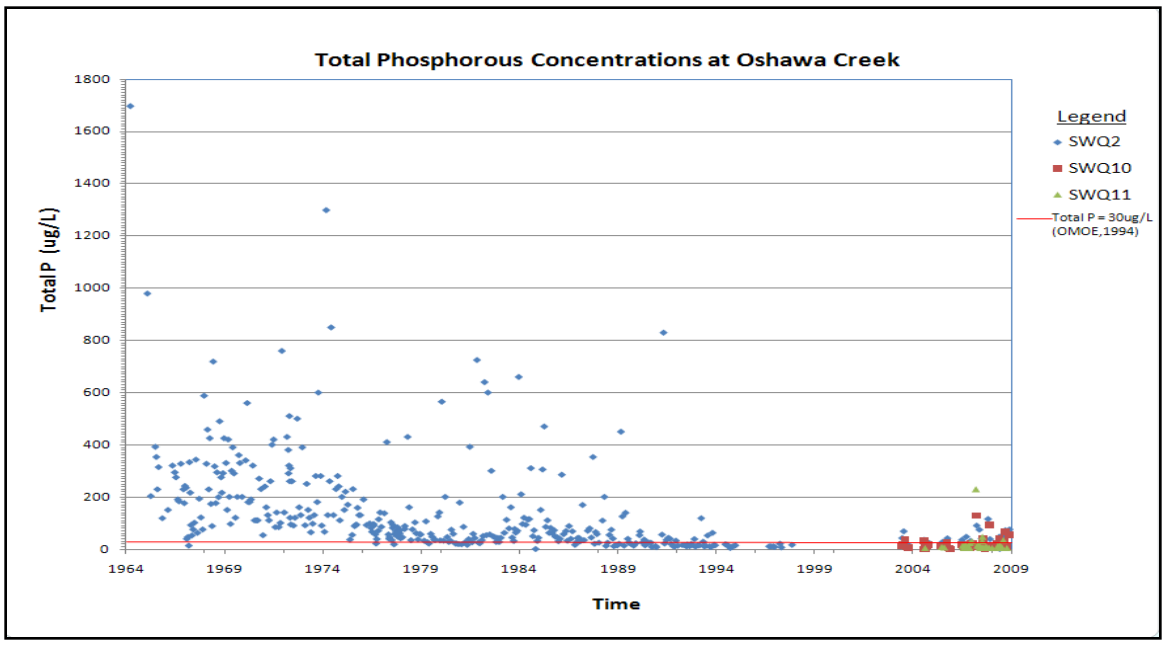


**Figure 18**: Phosphorous Concentrations at Oshawa Creek

### *Nitrate*

Nitrate concentrations in water environments generally originate from decaying plants and animals, agricultural fertilizers, domestic sewage and wastewater. Similar to phosphorous, excessive concentration of nitrate in surface waters encourages excessive growth of algae causing algal blooms and euthrophication[2]. Environment Canada – CESI report suggested a guideline limit of 2.93 mg/L (CCME,2005b) for this chemical parameter.

Over the years, there have been significant changes in the methods for testing nitrate. These changes have enabled only partial statistical analysis of laboratory results using different methods at different sampling durations. The earlier method (1964-1981) required water samples to be filtered before testing. In comparison, stations SWQ2 did not show any trend on any of the three different laboratory testing methods. The 45 and 42 unfiltered samples collected at stations SWQ10 and SWQ11, respectively, were tested at the York Durham Environmental Laboratory. Both set of samples showed decreasing trends. However, an increasing trend in nitrate concentrations was observed on the 23 unfiltered SWQ10 samples that were tested at the MOE laboratory (Table 9). In general, the current procedure for testing nitrate in unfiltered samples specifically at SWQ10 and SWQ11 has inadequate number of test results to allow for valid statistical analyses. At least six samples from the historical data and one after the program revival starting 2003 were observed to have exceeded the 2.93 mg/L limit prescribed by CCME,2005b to protect aquatic life (Figure 19).

[2] Eutrophication is a natural process of excessive algae growth taking nutrients, mainly phosphorous and nitrogen (nitrate) that commonly adversely affect bio-diversity.

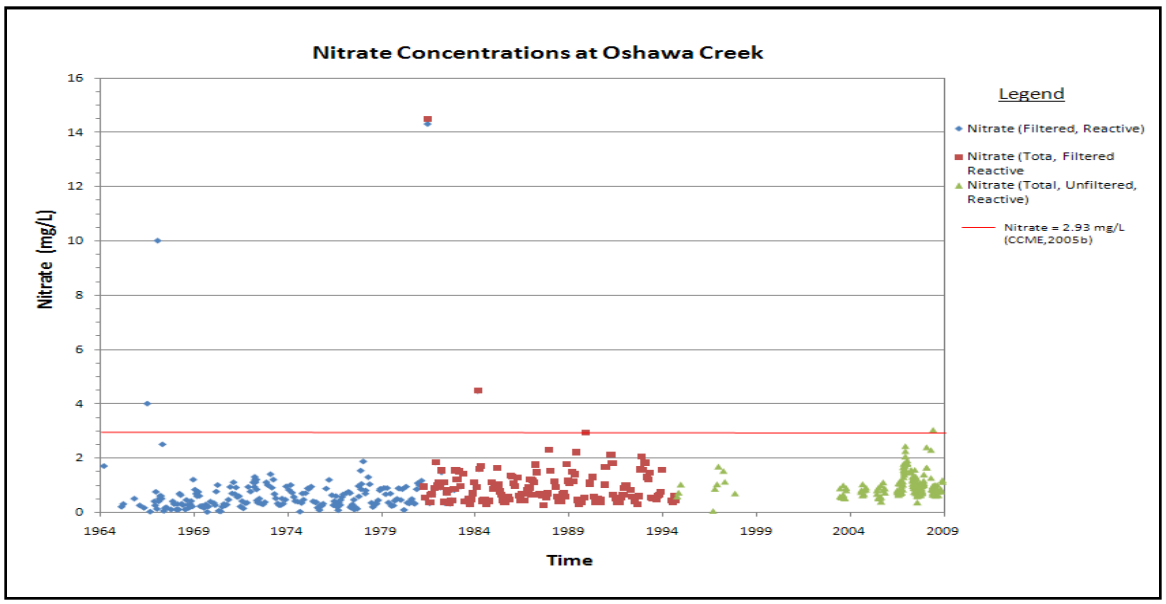


**Figure 19:** Nitrate Concentration in Oshawa Creek

### *Copper*

Copper is introduced in the environment from industrial and domestic wastes, mining and mineral leaching. In the aquatic environment, copper is toxic to plants and algae even at moderate levels. In ionic form (free metal), copper becomes toxic towards aquatic organisms and may result to inhibited growth, decreased production and offspring survival rates, increased mortality, deformities and abnormalities.

Copper concentration on samples collected at SWQ2 historically exceeded the 5 ug/L PWQO limit although in a statistically declining trend (Table 9). After 2003, only one sample at SWQ2 went beyond the prescribed limit while none of the samples from SWQ10 and SWQ11 recorded exceedance (Figure 20).

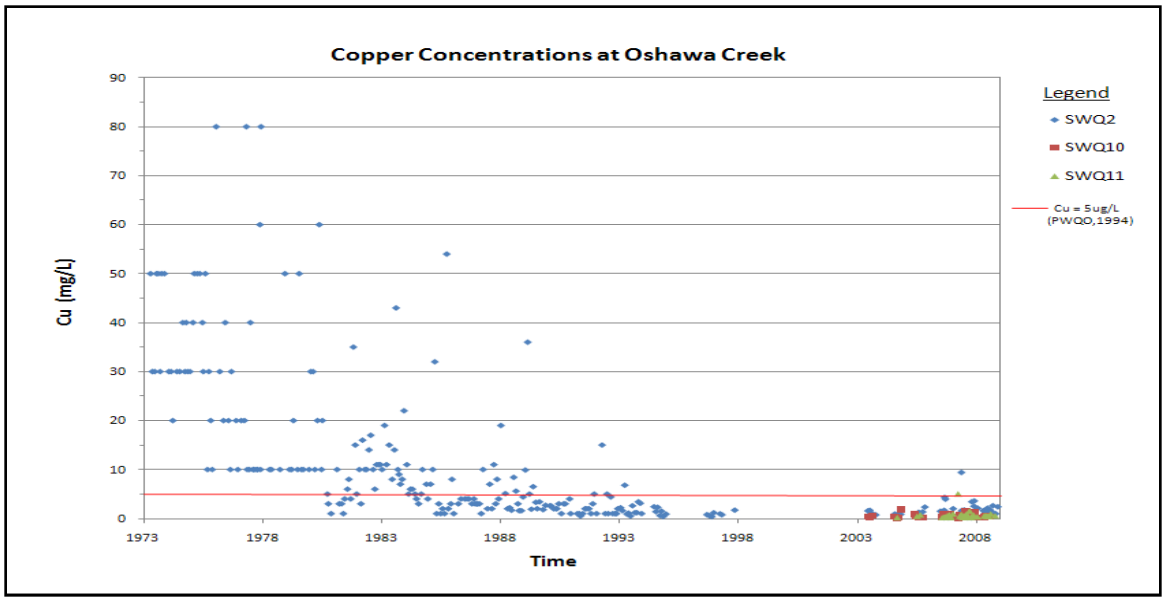


**Figure 20:** Copper Concentrations at Oshawa Creek

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

Higher concentrations of dissolved oxygen (DO) in water suggest better quality. The solubility of oxygen in water is influenced by temperature and organic content. Aside from fish, other aquatic vertebrates survival depends on DO, as this chemical is utilized by microorganisms to decompose organic wastes in water. The index used to qualify the amount of oxygen needed by these microorganisms is termed as biochemical oxygen demand (BOD) and it is generally inversely proportional to DO. In principle, therefore, an increase in biochemical oxygen demand (BOD) tends to deplete the amount of dissolved oxygen (DO) in the natural water environment. This relationship, however, may be direct or indirect considering that there are factors other than BOD that could cause the decrease of DO concentration in waterbodies. Some of these factors include temperature variability and severity of weather conditions.

For the purposes of determining the relationship between DO and BOD parameters linear regression analysis was performed on all DO and BOD values tested in all three stations. The data show poor linear distribution and this variability is common in most hydrologic records (Figure 21). The graph, however, is conclusive on the inversely proportional relationship between the two parameters. This means that the higher the demand for oxygen in the water, or the BOD commonly needed to decompose organic materials, the lower the concentration of dissolved oxygen will be as it is constantly consumed in the process.

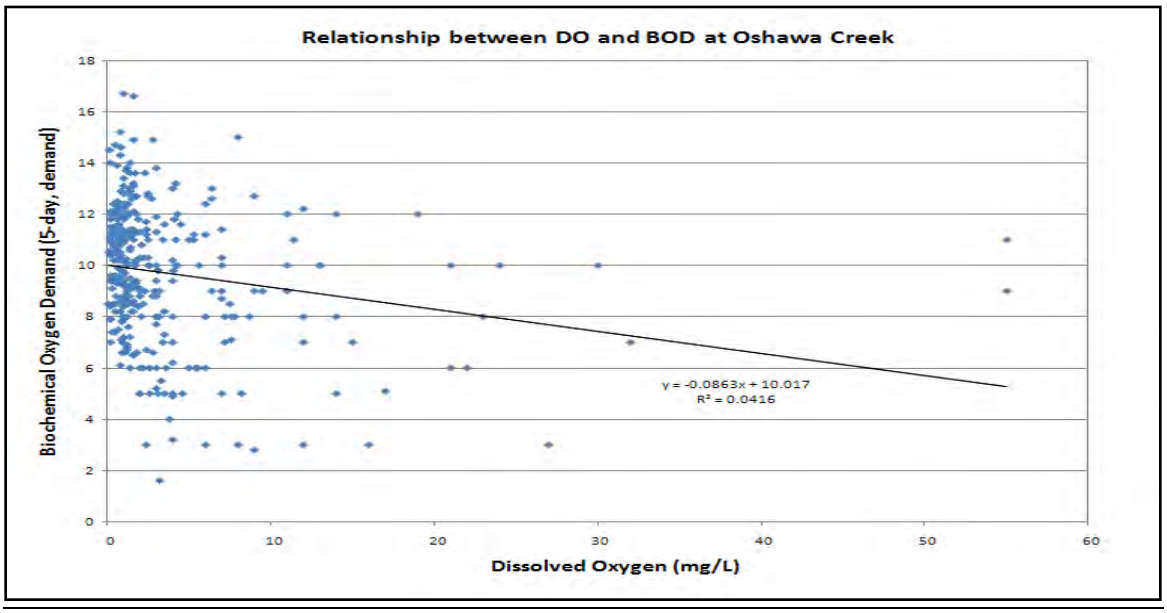


**Figure 21:** Relationship between Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD), Oshawa

The following figure, Figure 22 exhibits the historical relationship of DO and BOD (1964-1981). It would be worthy to note that the absence of DO concentrations in the graphs after 1997 denotes missing data rather than non-detects.

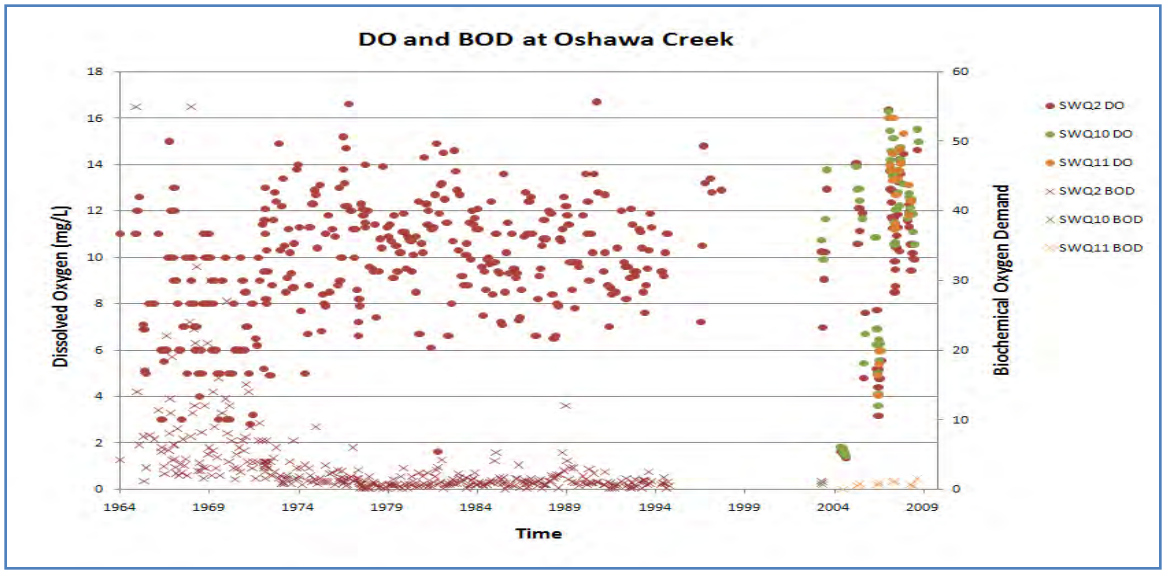


**Figure 22:** Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) at Oshawa Creek

Recent water quality analysis from Station SWQ2 shows that the BOD remained relatively low and may not have any adverse affect on DO concentrations in the natural water environment. In view of this, it would be safe to assume that present DO concentrations at this station are not critical despite the fact that historic concentrations occasionally dipped below the critical level to support aquatic life (Figure 23).

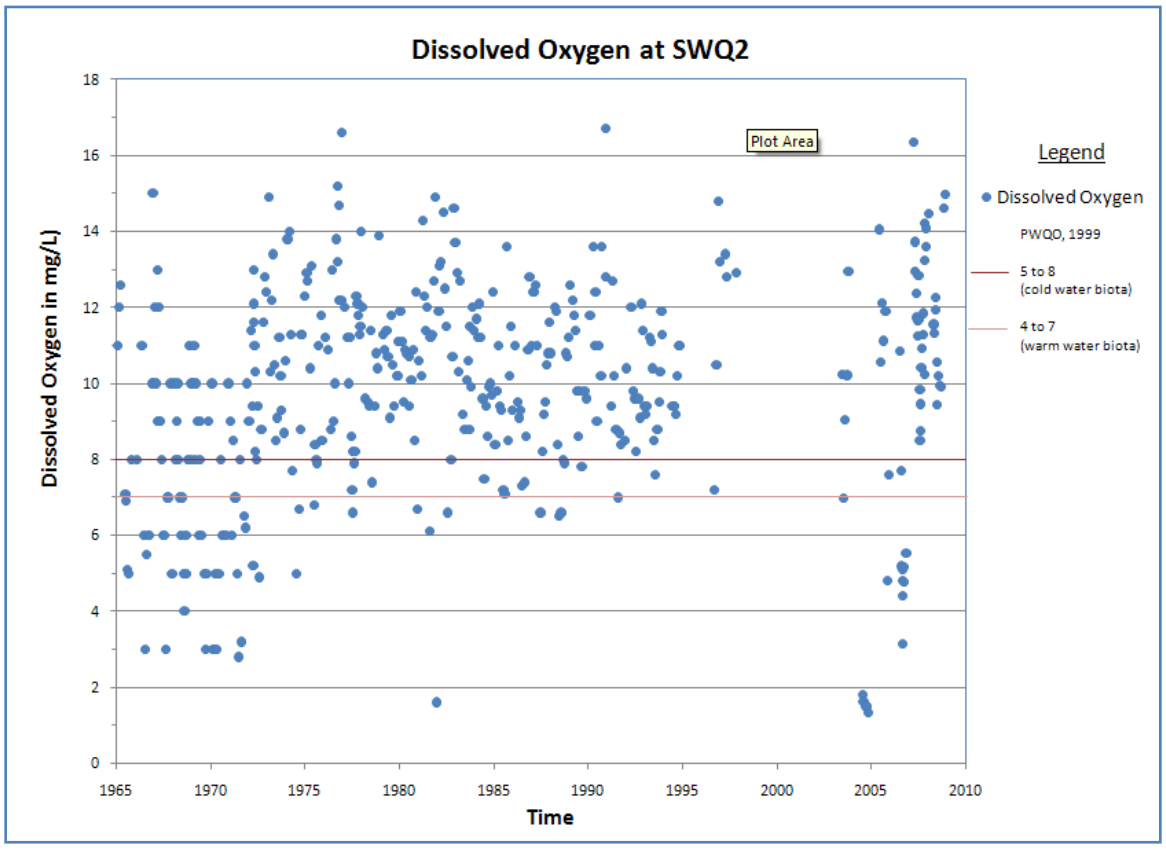


**Figure 23:** Dissolved Oxygen (DO) Concentrations at SWQ2

Water Quality Exceedances

There are 54 chemical and physical water quality parameters tested, which include the water quality index (WQI) parameters, for each sample collected. All the tested parameters were chosen as standard Ministry of Environment requirements as well as parameters identified to be related to the natural features and predominant activities in the watershed. Parameters excluded in the WQI are monitored with respect to existing provincial and federal water quality standards. Exceedances are regularly noted and monitored for trends and potential adverse effects in the aquatic environment. The list of all water quality parameters tested in the laboratory is presented in Appendix 1 and 2.

All throughout the monitoring period, 15 of the 54 monitoring parameters recorded exceedance on either, or both, provincially and federally prescribed limits to protect aquatic life. Total phosphorus, phenolics, cyanide and compounds have shown exceedances to more than half the number of samples tested for these parameters. Depending on the number of samples analyzed, most metals specifically copper, iron, nickel, lead and zinc have high exceedance to total sample ratio. Among the WQI parameters, exceedances were recorded higher on total phosphorus and copper and lesser on chloride and nitrate (Appendix 3).

## Water Quality Summary

Water is critical for all living things on this planet, but quantities of water can be polluted by minute amounts of harmful substances. In addition, substances that are considered useful to humans, such as fertilizers, pesticides and metals, can make their way into surface water through runoff from roads, lawns, agricultural fields, industrial sites, etc. The contaminants can accumulate to levels that may be harmful to humans or wildlife (Appendix 4). While the results reported in this chapter are specific to a few parameters that have been measured over the long term, other contaminants were being monitored as early as 1964.

Evaluation of the tested chemical parameters within the Oshawa Creek watershed resulted in the following conclusions:

- Despite the increasing trend in chloride concentrations on all stations in Oshawa Creek, mean concentrations remain below the prescribed limit.

- Phosphorous concentrations are consistently high in Oshawa Creek with more than half of all samples collected from SWQ2, SWQ10 and SWQ11 showing concentrations exceeding the 30 ug/L provincially and federally prescribed limit. The mean phosphorous concentration at SWQ2 is over four times the prescribed limit while mean concentrations at SWQ10 and SWQ11 remains below the prescribed limit. However, exceedance at SWQ10 and SWQ11 are still common with maximum recorded concentrations observed to be four to eight times the limit. Trend analysis, which can only be statistically established at SWQ2, shows an optimistic indication of declining trend.

- Trend analysis of nitrate concentrations on the monitoring station with the longest monitoring record (1964-2008 not necessarily continuous), SWQ2, yielded no distinct trends on any of the dataset results for each of the different testing methods performed. Although trends of nitrate concentrations were established on the unfiltered samples at SWQ10 and SWQ11, the different findings from MOE laboratory and York Peel Environmental Laboratory (YPEL) test results suggests the need for more data to produce more valid conclusions.

- One hundred thirty two of the 392 samples collected at the monitoring stations in Oshawa Creek exceeded the PWQO limit of 5 ug/L for copper. Although the figure may be significant as it constitutes approximately a third of all samples tested, majority of these exceedances were observed in the 1970's and 1980's. The time series graph clearly shows a declining trend and considerable improvement in the concentration of copper in Oshawa Creek after 2003.

- BOD index values at Oshawa Creek were found to be relatively low to adversely affect the amount of DO in the creek. Moreover, BOD trend analysis shows decreasing and increasing trends at SWQ2 and SWQ11, respectively. However, based on a longer period of observation the declining trend at SWQ2 offers greater validity. Figure 23 suggests that there may be some occasions that DO concentrations dip below the recommended amount, but overall DO concentration in Oshawa Creek is generally more than adequate to sustain aquatic life.

- Fifteen of the 54 chemical parameters were tested to exceed the provincially and federally prescribed limit. The number of samples having excessive concentration is highly variable with respect to time and frequency in each chemical parameter. Most notably, metals such as cadmium, copper, iron, nickel, lead, phosphorus, and zinc appear to have the most number of exceedances, which also depends on the number of tests performed for each of these parameters. Also, it was observed that most exceedances occurred on the historical datasets (1964 – 1997) while, proportionately, very few were recorded after 2003. This suggests that the water quality condition at Oshawa Creek has considerably improved with time.

Parameters that frequently show exceedance as well as those showing excessive concentration in one or more sampling events will be closely monitored and investigated to determine the cause. This will enable the managers and implementers to formulate possible measures to improve the water quality in the future.

#### 3.2.4.4 Stormwater Management

Stormwater management is the practice of controlling runoff to prevent downstream erosion, flooding and water quality degradation as well as assist in maintaining groundwater recharge where relevant. It is a vital component to maintaining watershed health in a developing watershed. Stormwater management is not the sole responsibility of any one organization but must be considered by several planning agencies. As such CLOCA works with municipal partners to ensure that all development applications prepare a plan for managing urban runoff to ensure that the impacts of development are minimized and that watershed health is not jeopardized.

The Ministry of the Environment (MOE) has published a Stormwater Management Planning and Design Manual (SWMPDM) (MOE, 2003) that provides minimum design standards. These standards are used by land developers and CLOCA to assist in stormwater management design. In addition to the guidelines set by the province, CLOCA has its own watershed-specific guidelines. The CLOCA developed guidelines were created considering the specific characteristics and needs of each watershed.

Stormwater management has three main components:

- Stormwater Quality;
- Stormwater Quantity; and
- Sedimentation and Erosion Control.

A complete stormwater management plan considers all three aspects in an integrated treatment train. Each component is discussed in the sections below.

Stormwater Quality

The minimum standards for stormwater quality control are set out in the MOE's SWMPDM (MOE, 2003). There are three (3) levels of quality control that can be applied within Ontario; Enhanced (Level 1), Normal (Level 2) and Basic (Level 3). Each level of protection corresponds to specific aquatic habitat characteristics to which the area drains. Enhanced (Level 1) protection should be applied to areas that drain to sensitive aquatic habitat including areas sensitive to sediment and siltation, areas of high baseflow discharge and areas with high permeability soils. Normal (Level 2) protection should be applied to areas that have natural upstream sediment loads, and less sensitive spawning areas. Basic (Level 3) protection can only be applied when the receiving area is proven to be insensitive to stormwater impacts or has little potential for long-term rehabilitation.

The MOE's SWMPDM (MOE,2003) includes a volumetric sizing guideline for the removal of suspended sediments that is based on the various types of stormwater management facility (SWMF), upstream imperviousness, drainage area and level of protection required.

Within the entire Oshawa Creek watershed Enhanced (Level 1) Protection is required by CLOCA, as the Oshawa Creek consists primarily of cool water fisheries and drains to a provincially significant coastal wetland.

The 2003 Ministry of the Environment's SWMPDM discusses mitigation measures for increased temperature due to end-of-pipe SWM facilities. The bottom-draw (reverse draw or reverse graded) outlet allows the cooler water, from the bottom of the facility, to be discharged to the receiving water course, therefore reducing the thermal impact. CLOCA requires that all SWM facilities that discharge to cool or cold water receiving systems must incorporate mitigative measures such as the bottom-draw outlet.

A study of the thermal effects of stormwater management ponds is currently underway within CLOCA. One SWMF within the Oshawa Creek watershed has been selected for study, which is located on Pondview Ct. in the City of Oshawa.

Stormwater Quantity

Stormwater quantity control criteria within CLOCA's jurisdiction have been set by CLOCA, with reference to the MOE's SWMPDM (MOE, 2003). CLOCA mandates that:

- every effort should be made to maintain existing watershed boundaries and drainage patterns;
- unless specified otherwise by the municipality, subwatershed study, or fluvial geomorphic analysis, the post-development peak flow rates must not exceed corresponding pre-development rates for the 1:2-year through 1:100-year design storm events and the Regional Event (Hurricane Hazel); and
- if there are known undersized pipes/culverts downstream that could impede water conveyance or if there is private property within the riparian area that could be affected, then quantity control must be provided.

In addition, all quantity control facilities are to be designed in accordance with recommendations set out in the MOE's SWMPDM (MOE, 2003). The amount of water produced during a storm event is predicted through modelling a synthetic design storm. A synthetic design storm, or model storm, is a single event rainfall that is assumed to produce flows of a desired return period. Each design storm has a unique variation of intensity over time. Synthetic design storms are developed from compiled intensity-duration-frequency (IDF) curves. The frequency, or return period is simply the inverse of the probability of a storm of a certain intensity, duration and frequency of occurring, expressed in years. The Regional storm is a historical design storm, constructed from a large single storm event usually containing the maximum precipitation on record. In Southern Ontario, Hurricane Hazel is used.

In some areas of a watershed significant amounts of precipitation are naturally intercepted and absorbed by the ground. These areas indicate high groundwater recharge. In these areas special measures are taken to ensure the balance between surface water and groundwater is maintained.

Within the Oshawa Creek watershed, quantity control for the 2 through 100-year and Regional storm is not required on the main branch, but is required on all tributaries unless otherwise noted in master plans. In the lower and mid-portions of the watershed it is preferable to discharge drainage from new developments without stormwater quantity controls, so that this drainage can flow through the system before the larger discharges from the upper portion of the watershed arrive. A hydrologic and hydraulic assessment may be necessary to determine if the drainage from the new developments will have local impacts on the floodplain of smaller receiving streams.

Master Plans which address stormwater management within the Oshawa Creek watershed include:

- Oshawa Creek Watershed Management Plan, CLOCA, 2002
- Oshawa Creek Watershed Study, Totten, Sims & Hubicki, 1995
- Stormwater Management Plan, Champlain East Sector, GM Sernas & Associates, 1997
- Goodman Creek Stormwater Management Study, Dillon & Associates, 1983
- Northwoods Industrial Park Stormwater Management and Servicing Study, Aquafor Beech, 2004

Sedimentation and Erosion Control

Sedimentation and erosion control within CLOCA's jurisdiction is jointly prescribed by CLOCA and the MOE. The MOE SWMPDM (MOE, 2003) requires that the 25 mm 4 hr Chicago storm be stored and released over a 24 to 48 hour period. This ensures that the peak flows are released slowly reducing high volumes and velocities that can cause erosion.

In addition, preventative measures must be taken during construction activities to reduce the transport of sediments from the stripped site to waterways. Such measures include silt fencing, rock check dams and sedimentation ponds. These measures slow the rate at which stormwater runoff drains and encourage the settling out of suspended sediments.

Existing Stormwater Management Facilities

The first step taken to identify the existing stormwater management facilities within the Oshawa Creek Watershed was to examine CLOCA's 2008 orthophotography for any obvious pond areas. The findings were then cross referenced with CLOCA's land development files, discussed with development review staff, and verified by field visits. In cases where the development files were still retained by CLOCA, the stormwater management design reports were reviewed and key information was extracted and input into a database.

Within the Oshawa Creek watershed there are many end-of-pipe stormwater management facilities in place. End-of-pipe stormwater management facilities receive stormwater from a conveyance system (ditches, sewers) and discharge the treated water to the receiving waters (MOE, 2003). The primary types of facilities are oil grit separators (OGS) and stormwater management ponds. Oil grit separators, typically installed below grade in highly impervious areas such as parking lots, are designed to help remove sediment, screen debris, and separate oil from stormwater. Wet ponds are the most commonly used end-of-pipe stormwater management facility in Ontario (MOE, 2003). Wet ponds provide for water quality and quantity, and erosion control. Unlike a wet pond, a dry pond does not have a permanent pool of water. As such, while they can be effectively used for erosion control and flood control, the removal of stormwater contaminants in these facilities is purely a function of the detention time in the pond (MOE, 2003).

There are sixteen stormwater management ponds (SWM ponds) and eleven known OGSs within the Oshawa Creek watershed Figure 24. The SWM ponds are designed to provide control for quality, quantity, or both. Typically, stormwater ponds have not been designed to provide or promote wildlife habitat, as the primary purpose are stormwater quality and quantity control. That being said, various wildlife species are often found using these ponds.

Using the location map and the available development files, areas that are receiving quality and/or quantity treatment have been delineated. Figure 25 shows the areas receiving quality and/or quantity treatment within the Oshawa Creek watershed. OGS units typically treat very small sites and thus the areas treated by the units are not shown on this figure.

The areas that are not receiving quality treatment are the older parts of Oshawa Creek watershed within the City of Oshawa. This is a direct result of the fact that the treatment of stormwater quality and quantity has only been a requirement of development for the last 20 or so years. The results from the biological water quality sampling, that are discussed in Section 3.2.4.3 Surface Water Quality, indicate that these older urbanized areas of the watershed are impaired, where the newer areas that are receiving stormwater treatment are not impaired.

Kedron Park Stormwater Facility ©CLOCA

Windfields Stormwater Facility ©CLOCA

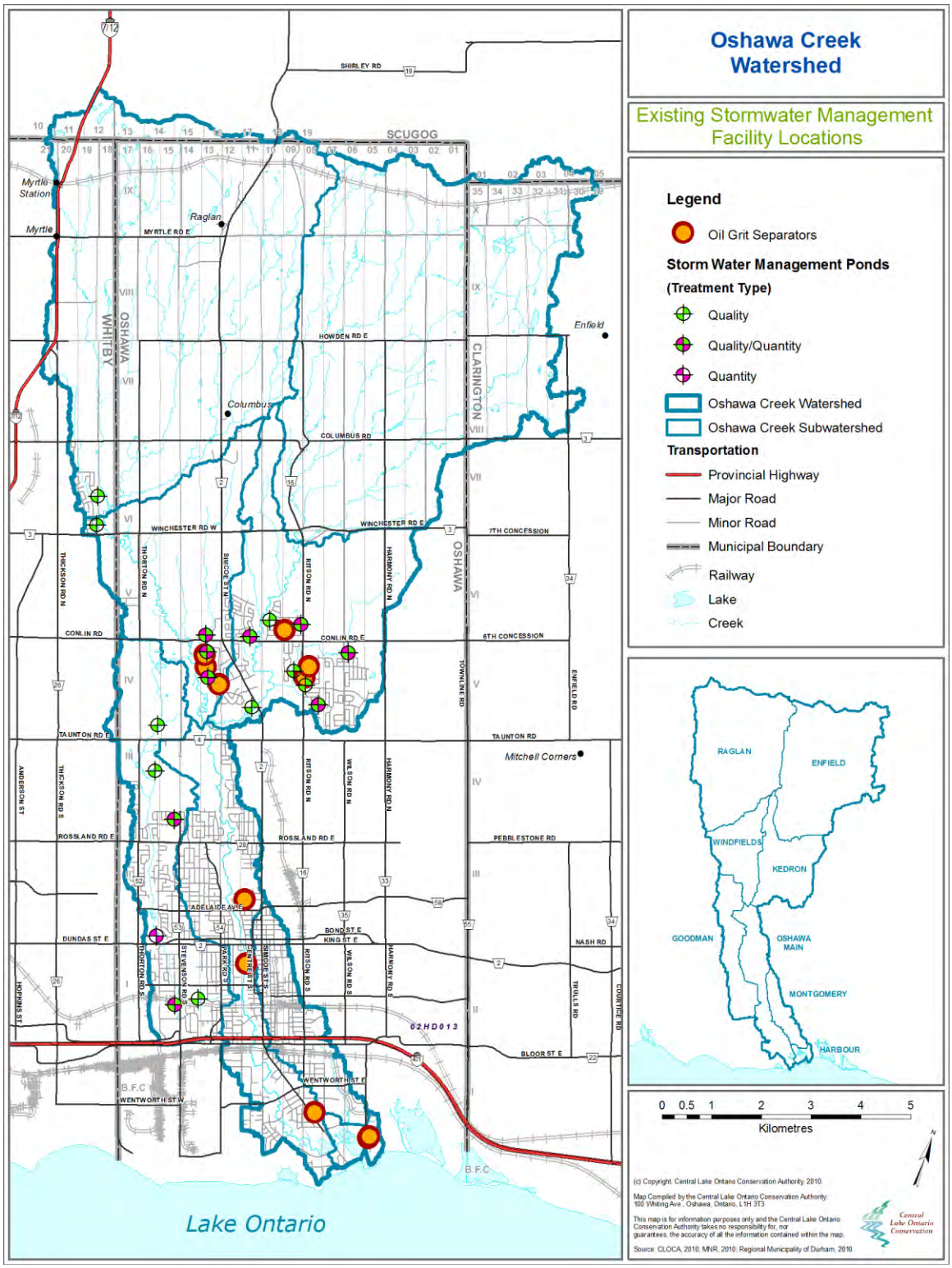


**Figure 24:** Existing Stormwater Management Pond (SWM) and Oil Grit Separator (OGS) locations within the Oshawa Creek watershed

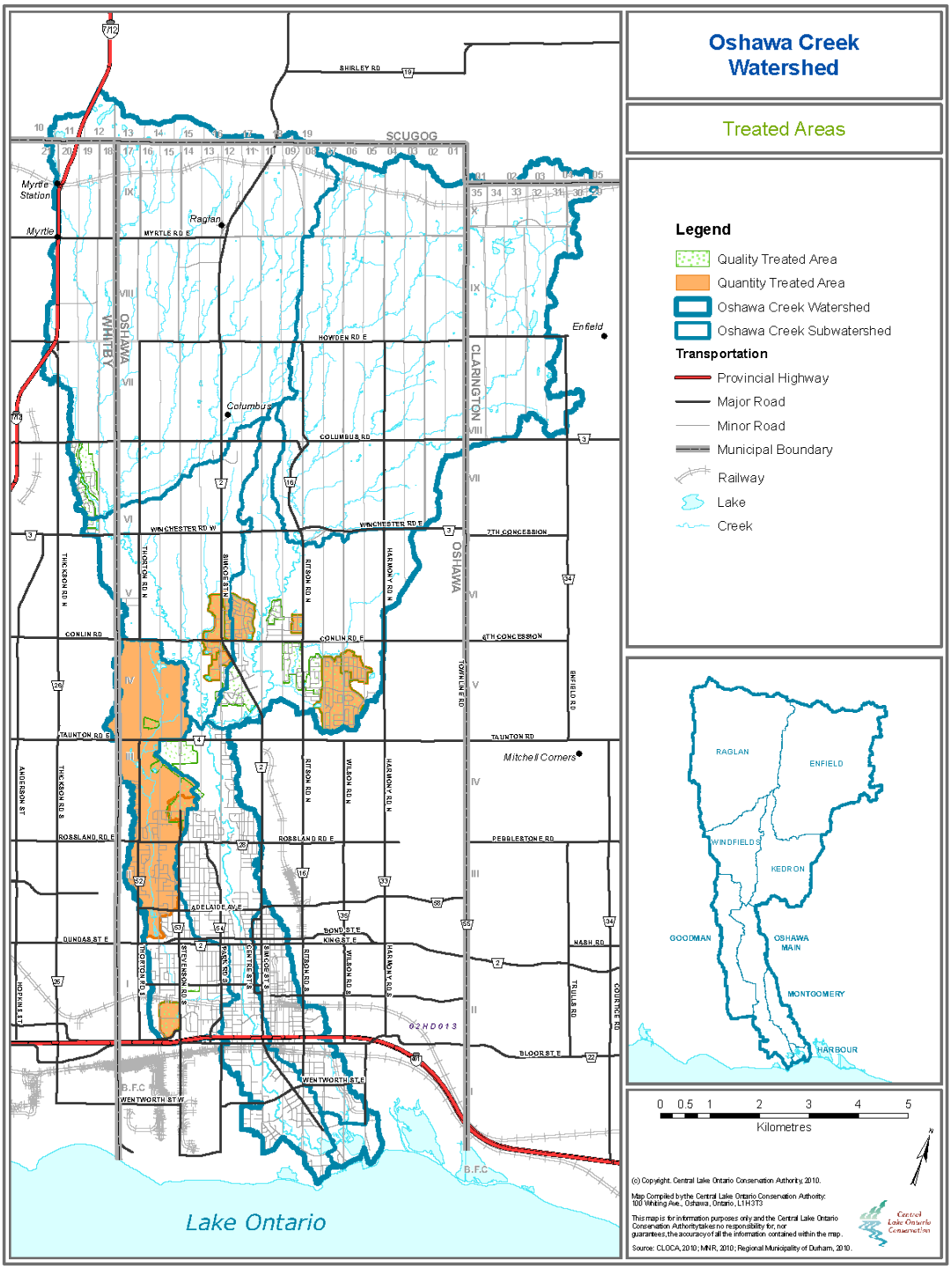


**Figure 25:** Treated drainage areas within the Oshawa Creek watershed

#### 3.2.4.5 Impervious Surfaces

Impervious surfaces are impenetrable surfaces that prevent rainwater from infiltrating into the soil. Impervious surfaces affect a watershed in many ways, they:

- reduce the rate of groundwater recharge;
- increase the volume and rate of stormwater runoff;
- increase the temperature of stormwater runoff; and
- increase the concentration of pollutants carried to the receiving watercourse

Cumulatively, these changes may adversely impact the aquatic and other biological communities. Examples of impervious surfaces include sidewalks, paved driveways, roadways or parking lots, and rooftops.

Imperviousness may be considered a direct result of land development, as such it can be used as a general indicator of potential water quantity and quality impacts to the watershed and subwatershed. Targets for the percent imperviousness for watersheds may be set to assist in managing land development to mitigate impacts on streams locally and cumulatively at a watershed scale. Therefore, it is important to investigate and report on the location and the percentages of impervious surfaces within the Oshawa Creek watershed and subwatersheds.

For lands within the Oak Ridges Moraine, the total percentage of the area of the subwatershed that has impervious surfaces shall not exceed 10% or any lower percentage prescribed in the applicable watershed plan (Ministry of Municipal Affairs and Housing (MMAH), 2002), with the exception of those portions of the ORM within Settlement areas. Development and site alteration will not be permitted if it would result in the impervious surfaces to exceed 10%. With respect to lands within Settlement Areas, approval authorities are to consider keeping impervious surfaces and their impacts on water quality and quantity to a minimum (Ministry of the Environment (MOE), 2007).

Calculating the level of imperviousness within the watershed was carried out using three main steps:

- reclassification of the Ecological Land Classifications (ELC) categories;
- a literature review of land use designation and the associated impervious values; and
- a spatial analysis of imperviousness within the watershed.

The Oak Ridges Moraine Conservation Plan (ORMCP) technical guidance document #13 (MOE, 2007) suggests three GIS based methods for calculating the impervious areas within a watershed including random sampling, digitizing or land classification.
The method that CLOCA has chosen to use is a variation of digitizing. It is felt that the method is reliable and uses data that is already complete and available. The methodology used to determine the impervious areas is described below.

Impervious surfaces are directly related to land use and thus to obtain values describing this characteristic, the land cover for the area must be known. CLOCA has developed an extensive inventory of the Ecological Land Classification and land use for the watershed. The ELC/land use data was derived from 2008 colour orthophotos and the ELC categories are as defined in the Ecological Land Classification for Southern Ontario (Lee et al. 1998). It is this data set that is used to determine the impervious area for the subject area.

A literature review of land use designations and typical impervious values was conducted. Sources such as the Ministry of Transportation Drainage Manual (MTC, 1982) and Visual Otthymo Manual (Greenland, 2002) provide a range of average parameters that are typically used in hydrology applications. In order to apply the typical values a reclassification of the ELC/land use values is necessary. The values from the ELC and land use were assigned a more general classification, referred to as the dissolved land use. The ELC/land use categories that were assigned to the dissolved land use categories are shown in Table 10.

**Table 10:** Imperviousness and ELC/land use

| Dissolved Land Use | GIS Classification | |
|---|---|---|
| | **CLOCA Land Use** | **ELC** |
| Crop & Improved | Agricultural Facility<br>Crop Field<br>Nursery | |
| Pasture & Unimproved | Pasture<br>Transportation Greenspace<br>Treed Field<br>(Orchard) | Cultural Meadow<br>Cultural Savannah<br><br>Cultural Thicket |
| Urban Residential | Urban Residential | |
| Rural Residential | Rural Residential | |
| High Density Urban Residential | Apartment Buildings | |
| Industrial & Commercial | Commercial<br>Industrial<br>Institutional<br>Building | |
| Lakes and Wetlands | Stormwater Pond<br>Water Feature | Open Fen<br>Meadow Marsh<br>Shallow Marsh<br>Open Aquatic<br>Submerged shallow aquatic<br>Floating-leaved shallow aquatic<br>Deciduous Swamp<br>Coniferous Swamp<br>Mixed Swamp<br>Thicket Swamp |
| Woodlot & Forest | | Cultural Plantation<br>Cultural Woodland<br>Coniferous Forest<br>Deciduous Forest<br>Mixed Forest |
| Manicured Green space | Athletic field<br>Golf facility<br>Institutional green space<br>Park<br>Ski hill | |
| Landfill and Aggregate | Aggregate<br>Landfill | |
| Transportation & Utility | Transportation Corridor<br>Utility Corridor<br>Utility Transfer Station | |

Table 11 below details the compiled values for imperviousness for each land use classification used by CLOCA.

**Table 11:** Maximum impervious values as a percent

| Land Use | Maximum (%) |
|---|---|
| Crop & Improved | 0 |
| Pasture & Unimproved | 0 |
| Urban Residential | 45 |
| Rural Residential | 20 |
| High Density Urban Residential | 85 |
| Industrial & Commercial | 85 |
| Lakes and Wetlands | 0 |
| Woodlot & Forest | 0 |
| Manicured Green space | 0 |
| Landfill and Aggregate | 50 |
| Transportation & Utility | 50 |

The percent imperviousness values for the specified land use have been paired with a land use map to illustrate the imperviousness for the Oshawa Creek watershed. The overall imperviousness for the watershed is approximately 13%. The spatial distribution of impervious area is shown in Figure 26 where shading represents the estimated percent imperviousness. Urban areas predominate from Conlin Road south to Lake Ontario. Above Taunton Road, development is primarily situated within the easterly half of the watershed. The sum of paved roadway surfaces represents the majority of the remaining watershed impervious areas. It is noted that the proposed Highway 407 will be crossing the watershed. The development of this infrastructure will alter the amount of imperiousness in the watershed and subwatersheds.

In addition to the mapping in Figure 25, Table 12 was prepared that summarizes the imperviousness of each subwatershed within the Oshawa Creek watershed.

**Table 12:** Subwatershed imperviousness

| Subwatershed | Imperviousness (%) |
|---|---|
| Oshawa Main | 39 |
| Harbour | 58 |
| Goodman | 34 |
| Montgomery | 57 |
| Winchester | 8 |
| Kedron | 15 |
| Raglan | 4 |
| Enfield | 2 |

A review of Figure 26 and Table 12 indicates that the Harbour subwatershed is the most impervious of the Oshawa Creek subwatersheds with a value of 58%, followed closely by the Montgomery subwatershed with an imperviousness value of 57%. These high levels of imperviousness are due mainly to the urbanization, including the industrialization of these subwatersheds.

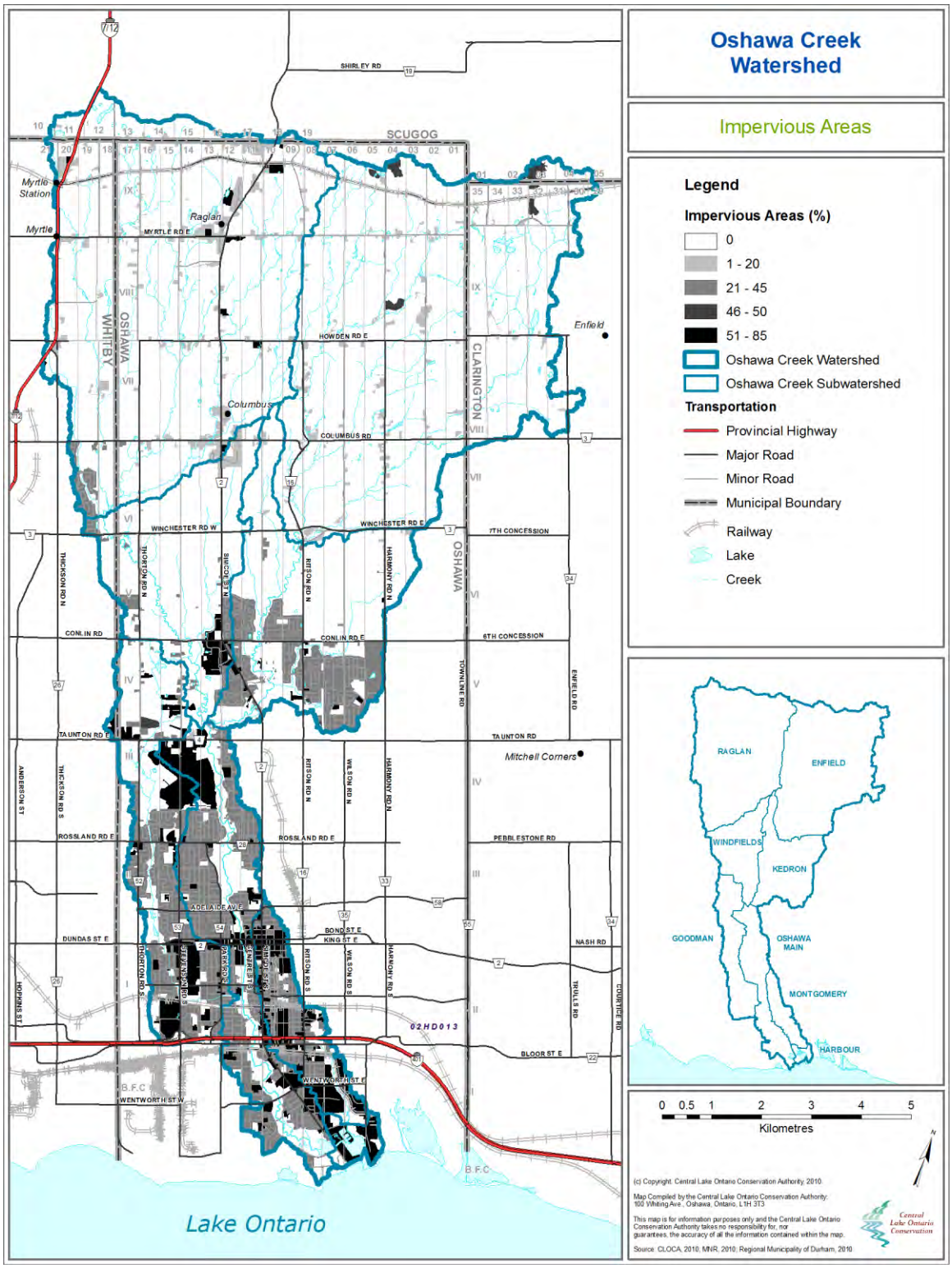


**Figure 26:** Oshawa Creek watershed impervious areas

### 3.2.5 Groundwater

#### 3.2.5.1 Hydrogeology

Information detailed in the Plan (2002) presents a preliminary overview of the watersheds hydrogeological conditions regarding groundwater recharge and discharge. This section updates that information primarily based on several more recent groundwater reports that further assess the hydrogeology of the watershed. The key reports referenced include the Groundwater Modelling of the Oak Ridges Moraine Area (York, Peel Durham, Toronto – Conservation Authority Moraine Coalition (YPDT-CAMC) Technical Report #01-06), the draft Watershed Characterization (CLOCA, 2006), the draft Conceptual Water Budget (CLOCA, 2007) and Tier 1 (Earthfx, 2009) reports prepared under the Source Water Protection (SWP) program. These reports have yielded considerable information regarding the local setting such as:

- development of a conceptual geologic model or framework;
- numerical groundwater flow modeling through geological framework loosely coupled with a groundwater infiltration model; and
- quantification of the groundwater recharge and discharge.

#### 3.2.5.2 Geology

The centralized database developed under the YPDT-CAMC groundwater study includes the collection, review, quality control, and rectification of water well and other hydrological data. The database in conjunction with borehole logging software enables the delineation of the various geologic layers and the aquifer systems of the watershed.

The geology of the watershed generally consists of Quaternary sediments of variable thickness overlying Ordovician bedrock. The sediments overlying bedrock consist of a sequence of glacial and interglacial (lacustrine/fluvial) units deposited over the last 135,000 years.

According to the Ontario Geologic Survey (OGS), the underlying bedrock in the watershed serves as a base unit of younger surficial overburden deposits and is made up of sedimentary rocks of the Late Ordovician (Whitby Formation) grey black shale that for the most part is carbonaceous (Figure 27). Below Hwy 401, the Middle Ordovician limestone deposits of the Simcoe Group (Lindsay Formation) underlie the overburden. The bedrock surface appears to approximate the ground surface topography of the watershed. The bedrock is not exposed at surface throughout the watershed except at one identified stream bed site located in the Oshawa Main subwatershed.

The surficial deposits of the watershed are generally of glaciolacustrine, glaciofluvial, or glacial origin (Figure 28). These sediments were deposited during successive periods of advance and retreat of glaciers through to the last ice age. Also, evidence of eolian beach and swamp deposits of Recent age has also been identified.

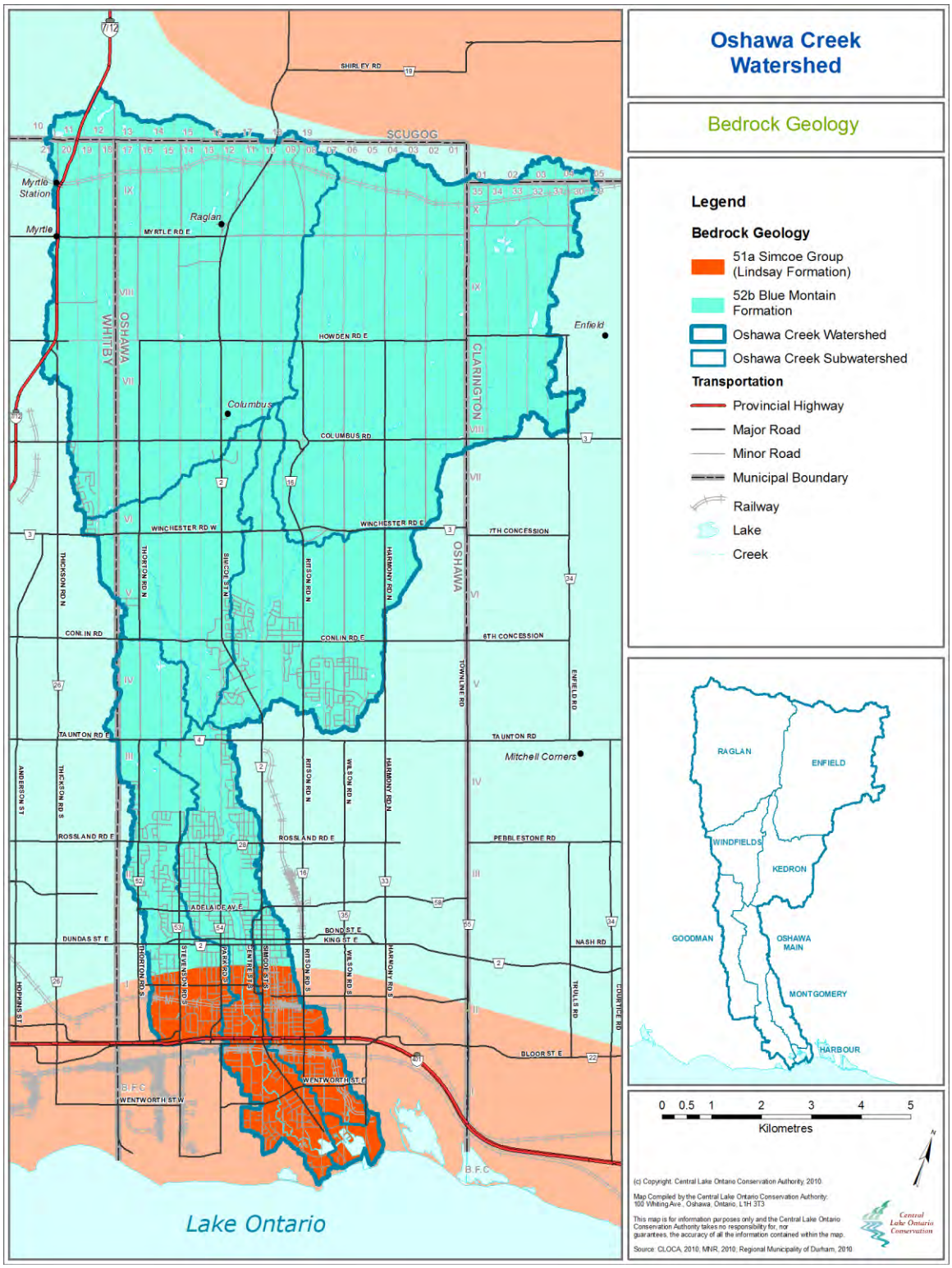


**Figure 27:** Bedrock geology of the Oshawa Creek watershed

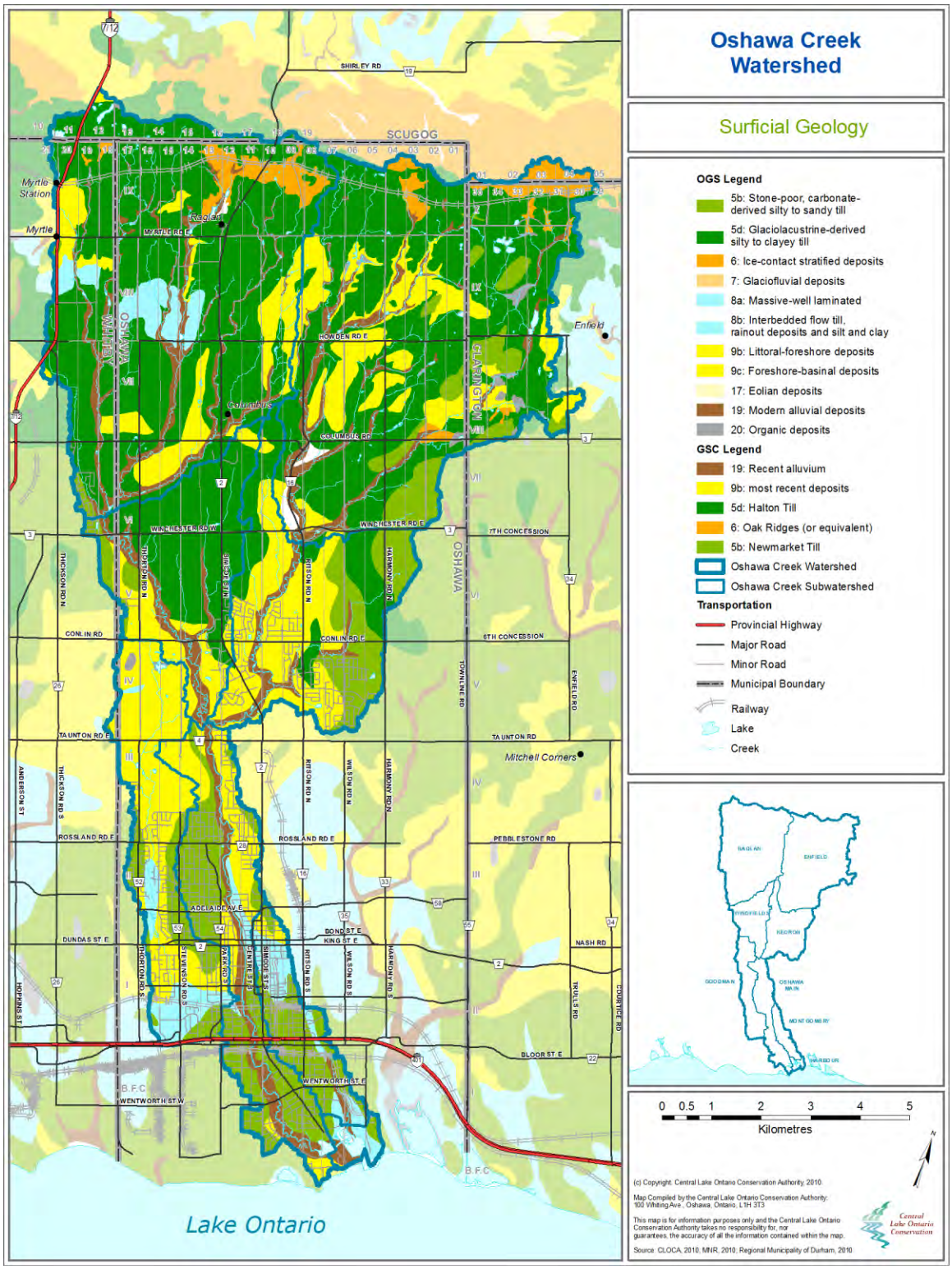


**Figure 28:** Surficial geology of the Oshawa Creek watershed

3.2.5.3 Hydrostratigraphy

The regional stratigraphic framework prepared by the Geologic Survey of Canada and refined further through the YPDT-CAMC study has delineated eight geologic units within the Oshawa Creek watershed:

1. Glaciolacustrine Deposits (sand, silt and clay);
2. Halton Till;
3. Oak Ridges Moraine/Mackinaw Interstadial Deposits; Regional Unconformity – channel infill deposits
4. Newmarket Till;
5. Thorncliffe Formation;
6. Sunnybrook Drift;
7. Scarborough Formation; and
8. Bedrock.

The chronological arrangement of the rock units and their corresponding hydrostratigraphic characterization are presented in Figure 29 and Table 13 respectively. The Don Formation and underlying York Till depicted in Figure 29 have not been mapped within the watershed due to the scarcity of deep detailed borehole information that would be necessary to delineate these deposits. These formations it is believed from the data that exists, were eroded in this area prior to subsequent deposition of the younger units.

Three main geologic features of the stratigraphic framework (Figure 29) are considered to largely control the flow of shallow groundwater through the unconsolidated sediment. One feature is the orientation and connection of the valleys in the bedrock. Sand and gravel deposits often occur upon these bedrock lows and can form productive aquifers. The second is the architecture of the Newmarket Till that separates the upper part of the flow system from the deeper part of the flow system. The third major geologic control on the groundwater flow system is the thickness and location of the granular deposits of the Oak Ridges Moraine and the Lake Iroquois Beach that form recharge areas.

It is important to acquire an understanding of the sedimentary deposits overlying bedrock in the watershed. These deposits include, for the most part, the major aquifers in the watershed. An estimated 95% of wells in the watershed are tapping aquifers within these sedimentary deposits because wells drilled to bedrock are generally low yielding and may have poor water quality.

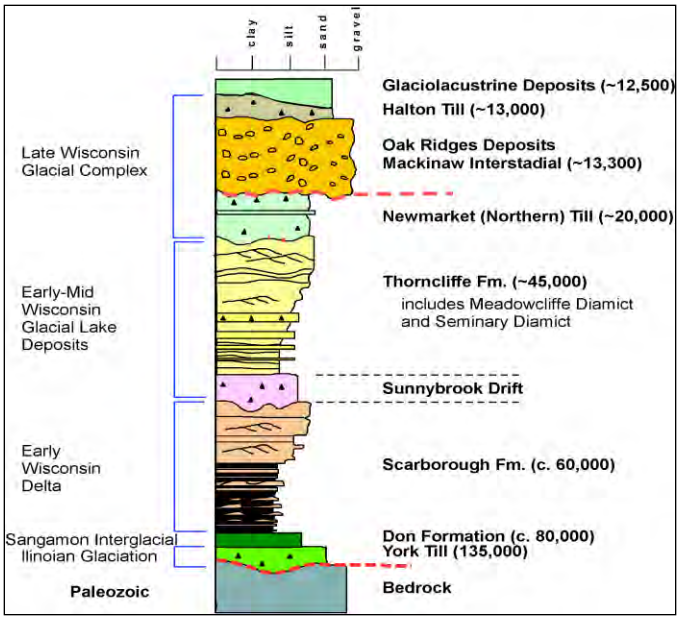


**Figure 29**: Oshawa Creek watershed geological profile

**Table 13:** Hydrostratigraphic units

| Geologic Unit | | Hydrostratigraphic Unit<br>Aquifer | |
|---|---|---|---|
| **Shallow Groundwater Flow System** | | | |
| 1 | Glaciolacustrine and Recent | Iroquois Beach Deposits | |
| 2 | Halton Till | | Halton aquitard |
| 3 | Oak Ridges Moraine / Mackinaw Interstadial | Oak Ridges aquifer complex | |
| | Tunnel Channel infill | Channel aquifer complex | Channel silt aquitard |
| 4 | Newmarket Till | | Newmarket aquitard |
| **Deep Groundwater Flow System** | | | |
| 5 | Thorncliffe Fm. (or equivalent) | Thorncliffe aquifer complex | |
| 6 | Sunnybrook Drift (or equivalent) | | Sunnybrook aquitard |
| 7 | Scarborough Fm. (or equivalent) | Scarborough aquifer complex | |
| 8 | Bedrock | Limestone aquifer | |

Glaciolacustrine (Recent) deposits are widespread in this watershed and represent the uppermost geologic layer. These deposits form a veneer over the underlying Halton and Newmarket Tills and vary from near shore sands and gravel beach deposits of the Lake Iroquois Beach located within the southern watershed, to fine sands, silts and clays of ancestral glaciolacustrine pondings that occur north of the Lake Iroquois Beach. Around Conlin Road and to the south are deposits associated with the Iroquois Beach shoreline physiographic region. These deposits form an approximate 2km-wide band which transverses the watershed in an east to west direction. Although relatively thin with average thicknesses that seldom exceed two meters, this deposit consists of well sorted medium to fine beach sand that is highly permeable and capable of transmitting a considerable quantity of water both vertically and horizontally. Similar materials found in the south part of the Kedron subwatershed area are interpreted as outwash deposits.

The latest glacial ice advance over the southern part of the study area occurred from the Lake Ontario Basin about 13,000 years ago and resulted in the deposition of the Halton Till. The Halton Till is interpreted to drape along the south slope of the Oak Ridges Moraine overriding the granular Oak Ridges Moraine deposits from northern reaches of the watershed and forms the surficial till unit extending southward to the Lake Iroquois shoreline. Hydraulic properties of the Halton Till indicate that for the most part the till acts as an aquitard.

The Oak Ridges aquifer complex is an interlobate glacial deposit composed mostly of sand and gravel and is the most prominent geologic feature in the watershed. The moraine itself extends 160 km in its entire length across south-central Ontario trending east-west, and is observed in the study area outcropping south of Coates Road along Simcoe and Ritson Roads, just east of Harmony Road and along Boundary Road to the north east. Geologic interpretations indicate that moraine or equivalent deposits (Mackinaw Interstadial sediments) in this watershed range

from absent near Lake Ontario to 30m in thickness near Coates Road. Note that the Oak Ridges Moraine sediments at distance from the moraine itself are considered to be Mackinaw Interstadial sediments. Mackinaw Interstadial sediments generally only occur locally within areas of low topography upon the surface of the underlying Newmarket Till. These sand bodies are not present everywhere, that is, where Halton Till is in contact with Newmarket Till, they are non-existent.

Beneath the moraine is an extensive and fairly continuous till (Newmarket Till) which overlies the lower sedimentary sequences consisting of the Thorncliffe Formation, the Sunnybrook Diamicton, and the Scarborough formation. The Newmarket Till (sometimes referred to as the Northern Till) was deposited by the Laurentide ice sheet when it was at its maximum extent approximately 18-20,000 years ago. The Newmarket Till is an important formation in this area as it hydraulically separates the upper and lower aquifers and serves as a protective barrier to the deeper groundwater resources in the area. Available geological records show no evidence of breaches in the till in this watershed. Breaches in the till allow for a hydraulic connection between the upper and lower aquifer systems and can affect the vulnerability of deeper wells.

The Thorncliffe Formation was deposited approximately 45,000 years ago and consists of sedimentary deposits of silt-clay rythmites and cross-laminated and cross-bedded sands. Exposures of this formation are common along lake bluffs. Though its recorded thickness reaches 50 meters west of CLOCA's jurisdiction at the Scarborough Bluffs, the sequence thins to about 20 meters or less within the Oshawa watershed. The extent and relative thickness of this formation nonetheless makes it a significant aquifer in the watershed.

Beneath the Thorncliffe Formation are clay-till layers with very few stones and silty-clay laminations that is stratigraphically termed as the Sunnybrook Till (Diamicton). This formation was deposited in close proximity to an ice sheet as it finally reached the watershed about 45,000 years ago. This aquitard is for the most part absent south of Conlin Road.

The Scarborough Formation marks the start of the Wisconsinan glaciation which started approximately 100,000 years ago. The Scarborough Formation is a deltaic deposit consisting of lower clay layer overlain by sands showing varieties of cross-beddings. Series of numerous thin peat beds are common in this formation. The formation exceeds 40 meters west of the watershed and pinches out in areas underneath the Oshawa Creek watershed south of Conlin Road.

### 3.2.5.4 Groundwater Flow

Groundwater flows from areas of high to low hydraulic head. The direction of movement at any point within the system is dependent on the distribution of hydraulic potential (Funk, 1977). Groundwater moves continuously but at different rates based on the hydraulic properties of the formations. In each formation, groundwater migrates in both horizontal and vertical directions. Since the water table commonly follows the ground surface topography, horizontal flow can be topographically mapped using water table data obtained from shallow wells (usually constructed less than 20m below ground surface (bgs)). In the Oshawa Creek watershed, water table mapping confirms that the groundwater flows generally in a north-south direction from the Oak Ridges Moraine southward to Lake Ontario (Figure 30). The groundwater flow patterns indicate that surface water features have a strong influence on the direction of shallow flow. Regional flow lines also suggest groundwater contribution to streams in the upper area of the Oshawa Creek watershed. Investigations of deeper aquifer systems reveal a similar pattern of flow which is in the general north to south direction towards Lake Ontario.

A geologic profile in the general north-south direction along Oshawa Creek (Figure 31) helps in the understanding of the various components of the hydrogeologic system and flow patterns in this watershed. This graphical presentation shows the dominant areas of groundwater recharge, movement and discharge in the different lithologic layers underlying the watershed. This simplified approach in characterizing the hydrogeological components is useful in building models that could simulate as well as predict the behaviour of groundwater given a defined set of conditions.

### 3.2.5.5 Groundwater Recharge and Discharge

Groundwater is a very important resource as it is used for drinking water and it sustains important ecological systems within the watershed such as wetlands, vegetation, wildlife habitat and stream baseflow. Knowing where groundwater discharge and recharge is occurring within the watershed is important to ensure the sustainability of groundwater supplies and is a key component of water resource management.

Groundwater Recharge Areas

Groundwater aquifers are periodically replenished by precipitation or snowmelt that infiltrates the ground surface passing though the unsaturated zones of the soil profile. The more permeable the soil, the greater the likelihood precipitation will move towards the aquifer. Factors that influence the amount of groundwater recharge include the soil permeability, surface topography, land use, and vegetation cover.

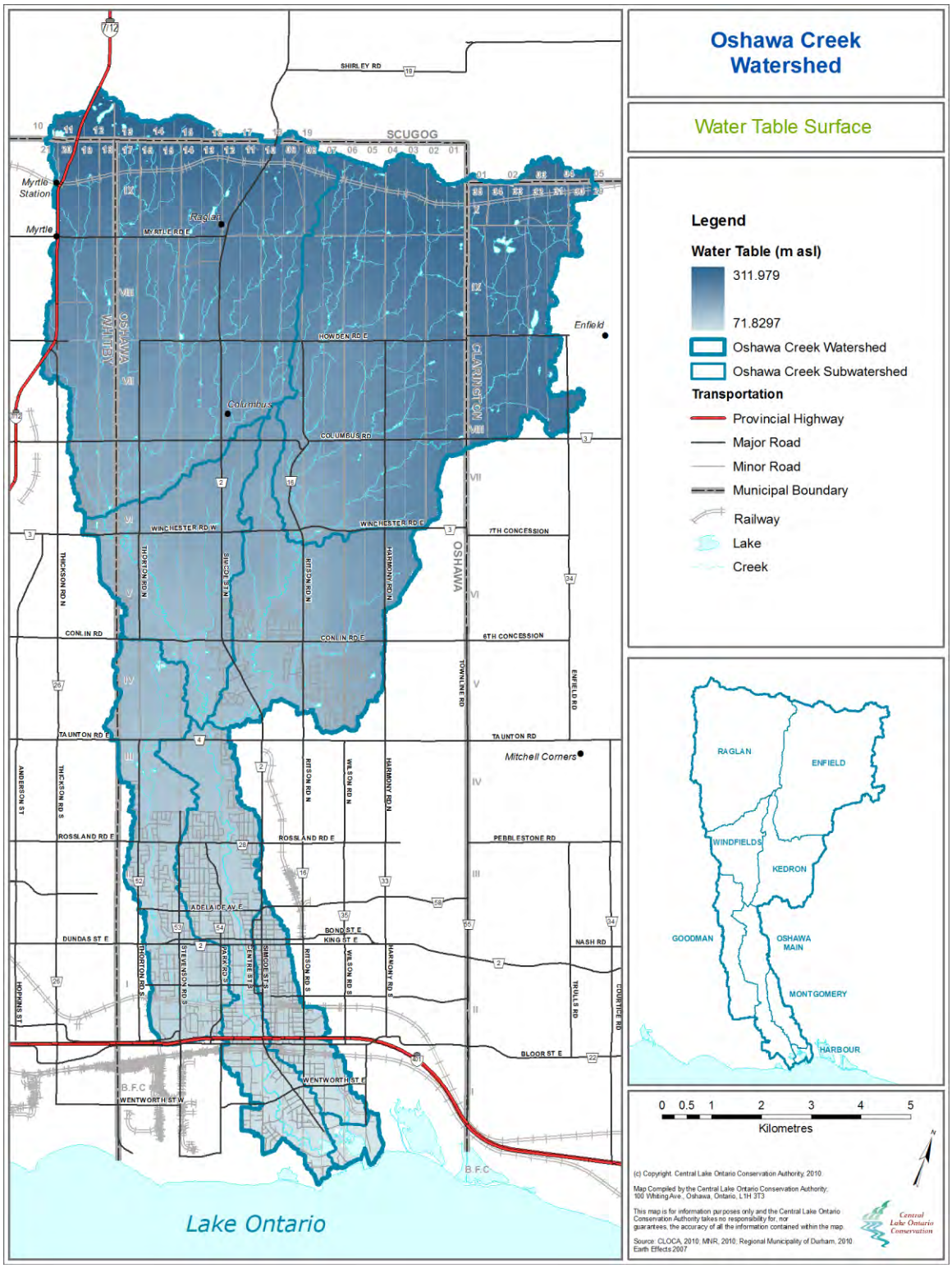


**Figure 30:** Water table in the Oshawa Creek watershed

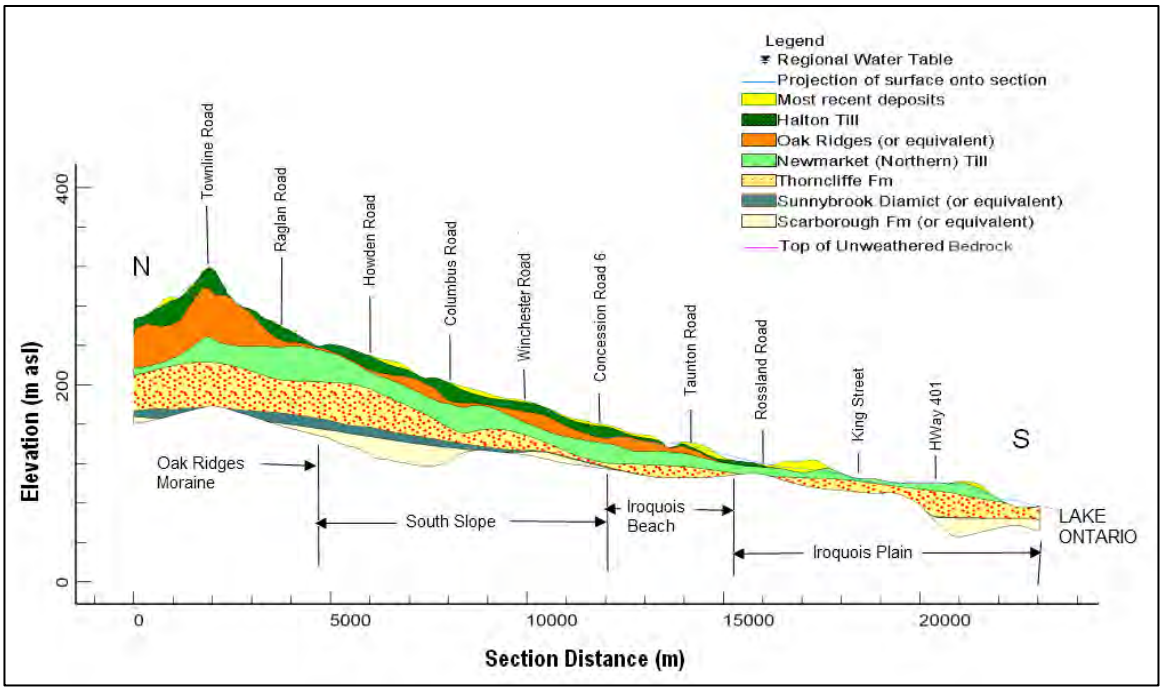


**Figure 31:** Oshawa Creek watershed geologic profile

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Significant recharge areas (high volume recharge areas- HVRAs) can be generalized as areas having a strong capacity to replenish available groundwater resources. These are areas where the predicted recharge is at least 15% above the mean recharge calculated for an area such as the watershed. HVRAs include areas of groundwater interflow to streams and recharge to the saturated zone. This methodology is detailed in the Assessment Report: Guidance Module 7, Water Budget and Water Quantity Risk Assessment (MOE, 2007a) and Directors Rules 2009, 44 (1), 44 (2) and 45 prepared for the Source Water Protection program. In the Directors Rules, these areas are now called Significant Groundwater Recharge Areas (SGRAs) and defined as areas significant to sustaining drinking water supplies associated with a 'system' as defined in the Safe Drinking Water Act (SDWA). The SDWA defines a drinking water system as one that serves 5 or more individuals.

The mean groundwater recharge rate for the Oshawa Creek watershed was predicted to be 168 mm/yr. As such the High Volume Recharge Area minimum threshold was set at 193 mm/yr (168 mm/yr x 1.15, rounded down). It is noted that highly permeable soils with perched or shallow water can also be considered a significant recharge area.

The most significant areas for groundwater recharge in this watershed are within the Oak Ridges Moraine and the ancestral Lake Iroquois Beach. The influence of the permeable ORM and the Iroquois Beach deposits, along with the most recent glaciofluvial deposits overlying the tills north of the shoreline are evident in Figure 32. Analysis of various potentiometric surface maps from different geologic layers (shallow and deep) also yielded information on the recharge pattern within the watershed. A difference between the potentiometric surfaces of the shallow and deeper aquifers indicates the downward vertical flow of water from the upper to the lower aquifer systems. Closely spaced contour lines of equal level of water (isolines) also suggest areas where recharge is particularly pronounced.

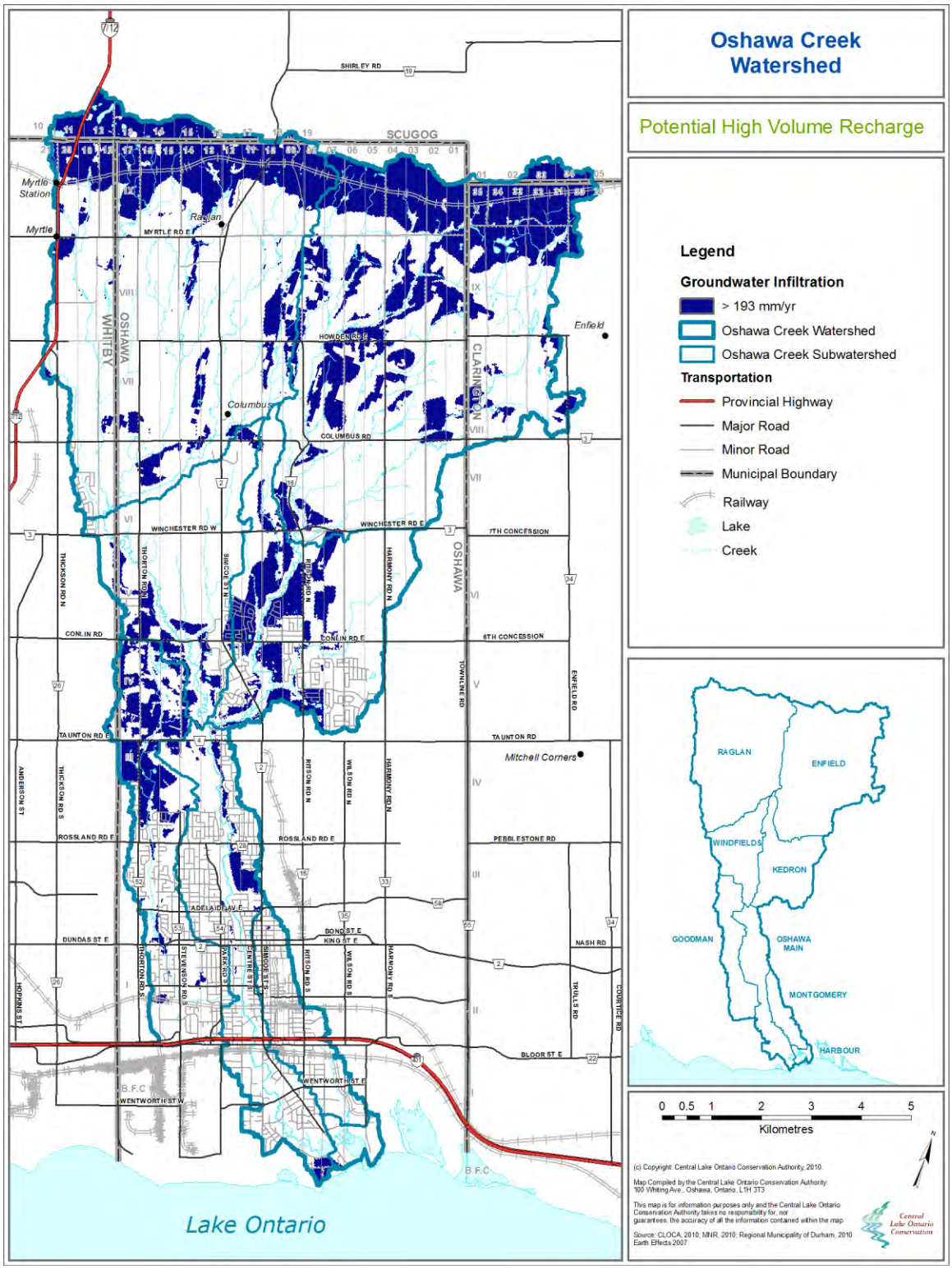


**Figure 32:** Potential high volume recharge areas in the Oshawa Creek watershed

The Oak Ridges Moraine, which is the most important recharge zone in the watershed, is capable of infiltrating an estimated 300-450 millimetres of water per year (or approximately 40-50% of the annual precipitation). The Iroquois Beach sands are also effective at infiltrating precipitation, second only to the Oak Ridges Moraine (GRIP, 2004; Soo Chan, 2006; SooChan, 2007) and transmitting it laterally to the adjacent streams.

Additionally, reverse particle tracking analyses were used to determine the significant recharge areas for the watershed. This method employs the tracking of a particle from the point of high-relatively high discharge to a stream to the point of infiltration (i.e. the source). This mapping can then be used to highlight the most important areas within a watershed with respect to the protection of ecological functions around water courses. Reverse particle tracking mapping is still in draft form for the Source Water Protection analyses and as such is not presented in this chapter.

Aquifer Vulnerability

Groundwater is vulnerable to changes in water quality and quantity by virtue of the fact that surface water will eventually get to the aquifer, potentially altering the characteristics of the groundwater in the aquifer. However, low permeability soils, such as silts and clays, have low infiltration capacities and, thus, are materials not typically associated with higher recharge zones. These fine materials, are more effective at attenuating contaminants compared to sand and gravels. The depth of the water table from ground surface is also a factor in determining the vulnerability of the aquifer to contamination and changes in water quantity.

An interpreted aquifer vulnerability index (AVI) map for CLOCA was developed using the methodologies provided under the Oak Ridges Moraine geological study and the YPDT-CAMC groundwater study (Figure 33) It should be noted that the AVI developed at the time of the ORM study utilized the geological descriptions and elevations in the water well records. It is important to note further that the well records, though useful on a regional scale, cannot be used in support of site specific decisions. Individual well records vary widely in quality in terms of the geology (logged material) and hydrogeology (ground and water level elevations). This explains some of the areas of low vulnerability occurring randomly in areas expected to be high in vulnerability based on surficial geological mapping. The Authority is currently reviewing the AVI methodology and is looking into alternative methodologies under the provincial Source Water Protection program to revise the existing AVI. Also, more advanced work using professionally interpreted geological surfaces and associated hydraulic conductivity values to calculate time of travel and associated vulnerability is being conducted. This work is currently in progress and not available for this report.

In any case, however, it should be noted that regional vulnerability mapping is useful as a guide and is appropriate only for regional scale assessments. Site specific planning decisions should be based on local data which should ultimately feed back into the regional understanding.

Changes in land use could have significant impact on our groundwater resources. In order to protect these groundwater resources from changes in water quantity or quality, the preparation of hydrogeological studies should be a requirement of development approvals within groundwater recharge areas and areas of groundwater vulnerability.

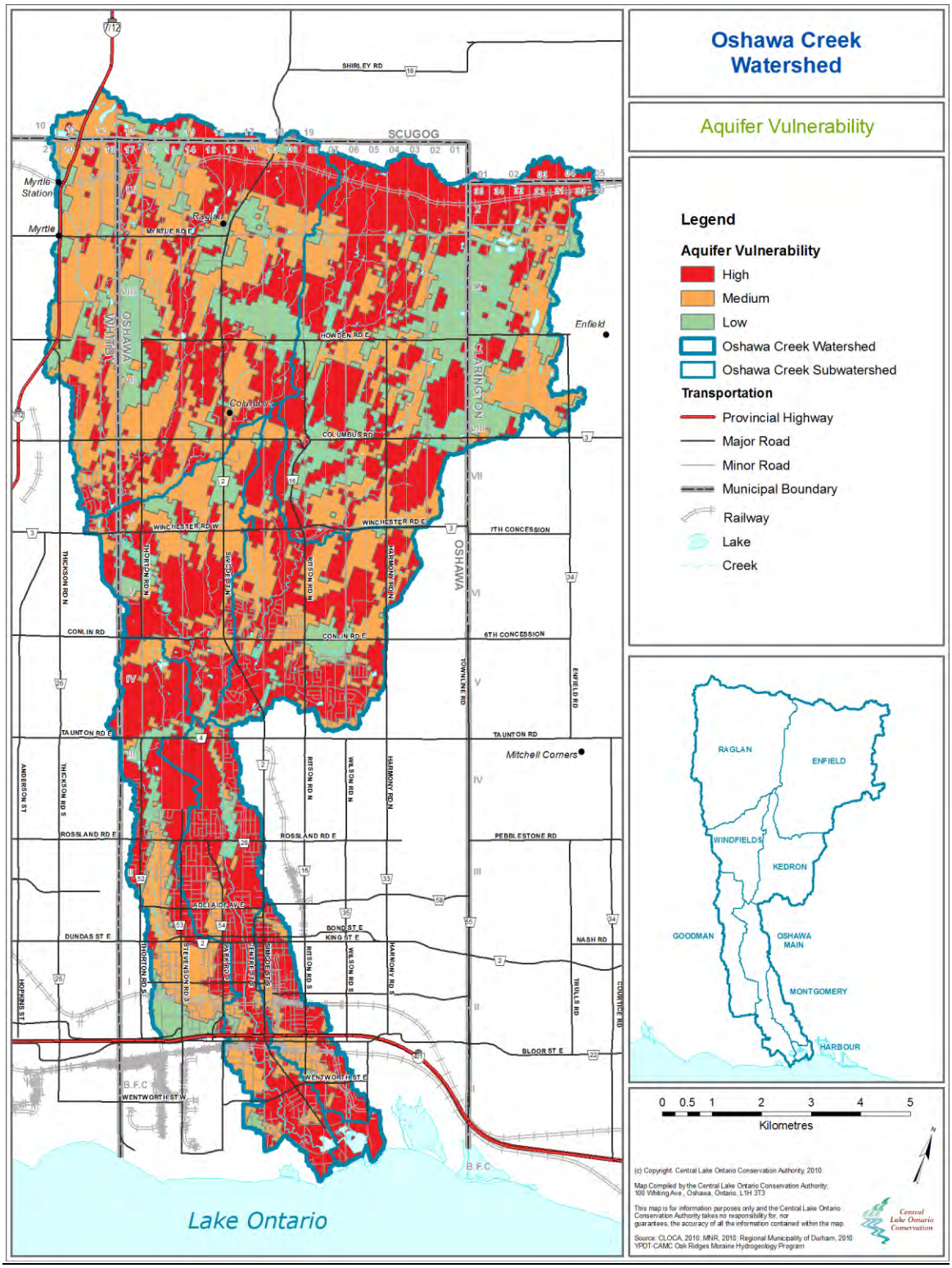


**Figure 33:** Aquifer vulnerability in the Oshawa Creek watershed using AVI

Groundwater Discharge

Groundwater discharge is often observed in and around water courses in the form of springs and seeps, or as baseflow to streams. These areas are characterized by upward vertical hydraulic gradients. Recent studies mapped potential discharge areas in the watershed as those areas where the interpreted water table surface occurs within 1 m of the ground surface (as represented by the digital elevation model). Some of these potential discharge areas are corroborated by the observation of seeps, springs, or wetland areas. The most prominent potential discharge areas are along the southern fringe of the Oak Ridges Moraine and along water courses (Figure 34). Numerical models have also been used to predict locations and rates of groundwater discharge to streams and wetlands throughout the watershed.

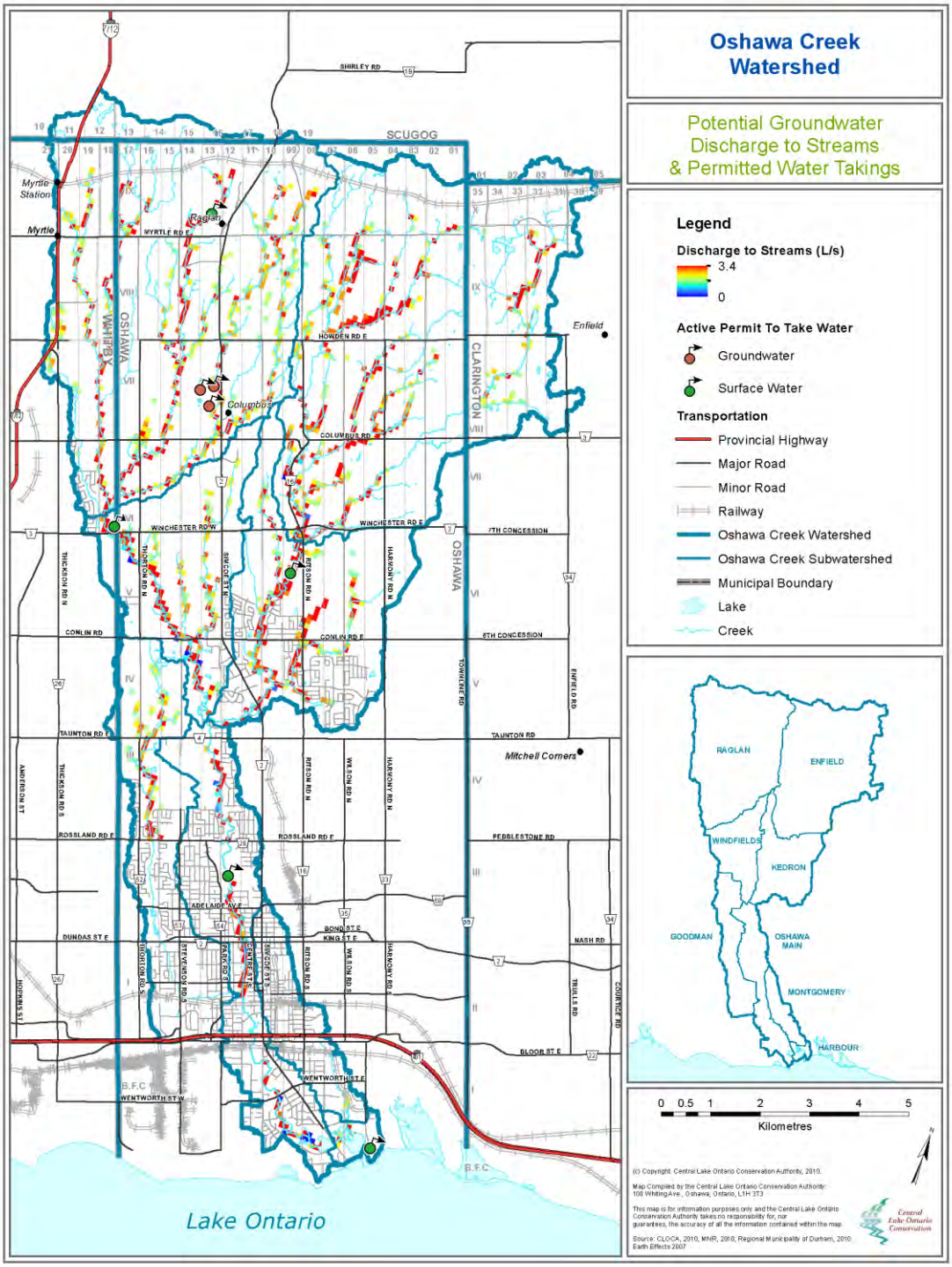


**Figure 34:** Potential groundwater discharge areas and Permitted Water Taking in the Oshawa Creek watershed

### 3.2.5.6 Water Budget

While a water budget is generally developed in a manner that estimates the amount and location of water conceptually, it may be refined by applying surface and groundwater computer models termed numerical models. The conceptual water budget presented in the Plan (2002) was intended as a starting point from which specific water budget analyses could be conducted. As recommended, and in order to meet the requirements of the Oak Ridges Moraine Conservation Plan amongst other hydrological and ecological objectives, an updated water budget study for the watershed has been undertaken using numerical models.

Peer reviewed water budget models were constructed through the Source Water Protection Program under the Clean Water Act, and are consistent with the provincial direction provided in the draft Assessment Report: Guidance Module 7, Water Budget and Water Quantity Risk Assessment (OMOE, 2006b). The water budget is also consistent with the draft Technical Paper #10 (MOE, 2005b) prepared for the Oak Ridges Moraine Conservation Plan (ORMCP). This document can be found at:
http://www.mah.gov.on.ca/userfiles/HTML/nts_1_24493_1.html

The water budget equation presented is used to help quantify the major components of the hydrologic cycle. For the Oshawa Creek watershed, the surface water flow into the watershed is considered to be zero as the boundaries of the watershed are the surface drainage boundaries or topographic divides. Similarly, human inputs are considered to be negligible within the watershed (e.g. water pollution control plant discharge, etc.) and as such are not accounted for quantitatively. The remaining terms in the equation are evaluated using computer models.

A modified Precipitation-Runoff Modelling System (PRMS: surface water model) code developed by the United States Geologic Survey (USGS) was used to estimate quantitatively the various water budget fluxes such as precipitation, interception, evaporation, potential and actual evapotranspiration, snowmelt, runoff, and groundwater underflow and infiltration. Square grid cells, 25 metres on a side, were used to represent the distribution of the characteristics within the watershed, and a daily water balance was calculated for each cell for the simulation period. Estimates were averaged over a 19-year simulation period to determine average annual rates expressed as millimetres per year (mm/yr). The model was calibrated to total surface water flow data and baseflow estimates from stream gauging, and to the groundwater flow model simulations.

The groundwater flow model MODFLOW, referred to as the 'East Model' was used to simulate groundwater budget components such as groundwater levels and groundwater discharge to streams. The model integrates data on the physical, geologic, and hydrologic features that govern groundwater flow in the watershed. Calibration was conducted in an iterative process where results of successive model runs were primarily matched to hydraulic heads and flows interpolated from observed static water levels obtained from the MOE Water Well Information System (WWIS). Matching baseflow in the watershed was a second calibration target. A post-processing programme was used to determine lateral groundwater inflows and outflows (underflows) across the watershed boundaries. These underflows were used to adjust the calibration of both the PRMS model and the simulated groundwater discharge from the MODFLOW model.

The terminology of the water budget parameters used in this update consist of Precipitation (P), Net Precipitation (Pnet or precipitation minus interception), Interception (I), Evapotranspiration (ET), Groundwater Infiltration (GWI), Groundwater Lateral (underflow) in (GWLin) and out (GWLout) of the watershed, Discharge to Streams or Groundwater Discharge (GWD) and Runoff (RO). For the purposes of this update, GWI is assumed to include groundwater interflow to streams and groundwater recharge to the saturated zone.

Water withdrawals are represented by groundwater use (GW use) or surface water use (SW use). These water budget components represent the key items discussed in this chapter. Long term average annual values are reported at a watershed scale, along with mapping of areas of GWI and GWD. Water budget estimates are typically normalized to units of millimetres of water distributed over a drainage area per year (mm/yr or mm/a). This is accomplished by converting flow or accumulation rates (e.g. $m^3/s$ or L/s) to total volumes per year, and then dividing by the contributing drainage area.

Estimates of water withdrawn from the watershed (consumptive water use) were in-part calculated using information from the current MOE Permit to Take Water (PTTW) database for water withdrawals greater than 50,000 litres per day. Domestic water consumption was generated using the water well information in the MOE Water Well Information System (WWIS) database. Other water uses were assessed qualitatively, as reasonable quantitative estimates were difficult to calculate with any degree of certainty.

Table 14 lists the numerical model water budget estimates for the Oshawa Creek watershed including the Montgomery and Goodman subwatersheds. The predicted GWI rate of 164 mm/yr and the GWD rate of 172 mm/yr represent the long-term averages The long-term lateral groundwater flow (steady-state) into the watershed from other areas is estimated at approximately 56 mm/yr while the outflow is estimated at 48 mm/yr for a net gain annually of 8mm/yr. This analysis suggests that that the total groundwater inflow (infiltration and lateral flow) into the watershed is approximately 220mm/yr (164mm/yr plus 56 mm/yr). This approximates the groundwater outflow (discharge and lateral outflow) out of the watershed (172 mm/yr + 48 mm/yr = 220mm/yr).

**Table 14:** Oshawa Creek Watershed water budget estimates (mm/yr)

| **Water Budget Parameters (mm/yr)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| P | **I** | **AET** | **RO** | **GWI** | **GWD** | **GWLin** | **GWLout** | **SWuse** | **GWuse** |
| 893 | 157 | 555 | 174 | 164 | 172 | 56 | 48 | <1 | 2.1 |

Infiltration

Groundwater infiltration (GWI) is primarily influenced by the distribution and thickness of surficial deposits and associated soil infiltration properties, topography, land cover and use. It can be seen in Figure 35 that the relative imperviousness of roadways and industrial areas in general reduces the rate of infiltration while areas of sands and sandy loams, particularly in the ORM and Iroquois Beach regions, show noticeable higher GWI rates. While the beach deposits have higher rates of infiltration, they are generally underlain by till and represent a limited aquifer system vulnerable to varying climatic conditions. As a result, shallow water tables and higher ET losses can occur. Due to their nature and architecture, the beach deposits are naturally highly vulnerable to contamination and are experiencing development pressures. Anomalies in the spatial distribution of groundwater infiltration appear such as in gravel pits, where runoff would be anticipated to be negligible.

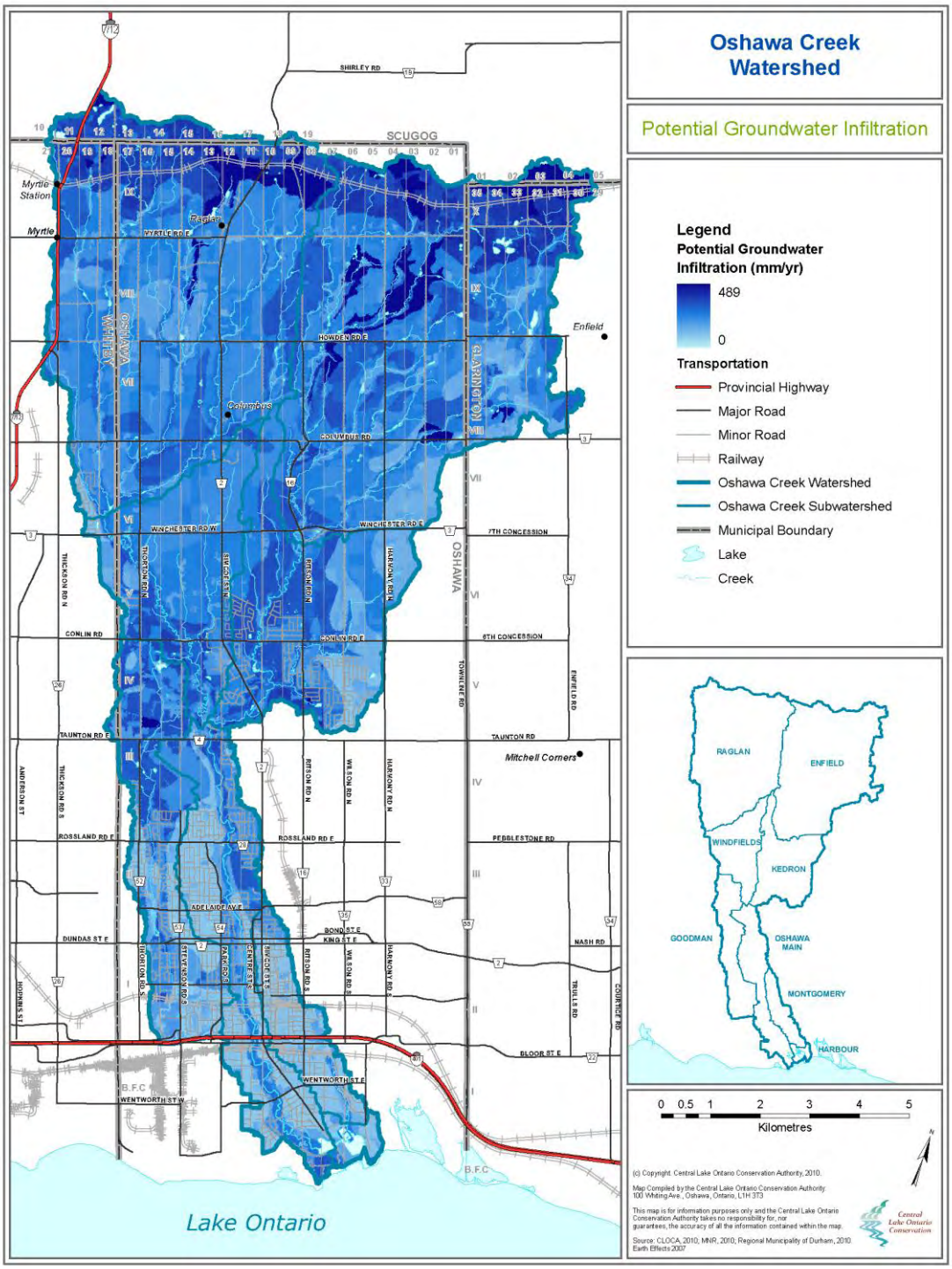


**Figure 35:** Potential groundwater infiltration

Discharge

Figure 36 shows simulated discharge to streams (GWD) generated from the groundwater model in litres per second (L/s). Discharge to streams includes discharge to drains (smaller creeks) and discharge to rivers (larger tributaries) where the creek may be either gaining groundwater discharge or losing streamflow to the groundwater system depending on the depth to groundwater. From Figure 36 higher rates of discharge are predicted to primarily occur in streams along the south flank of the ORM, areas of the South Slope physiographic region and throughout the Iroquois Beach area. Efforts are underway to further calibrate the simulations to baseflow field data.

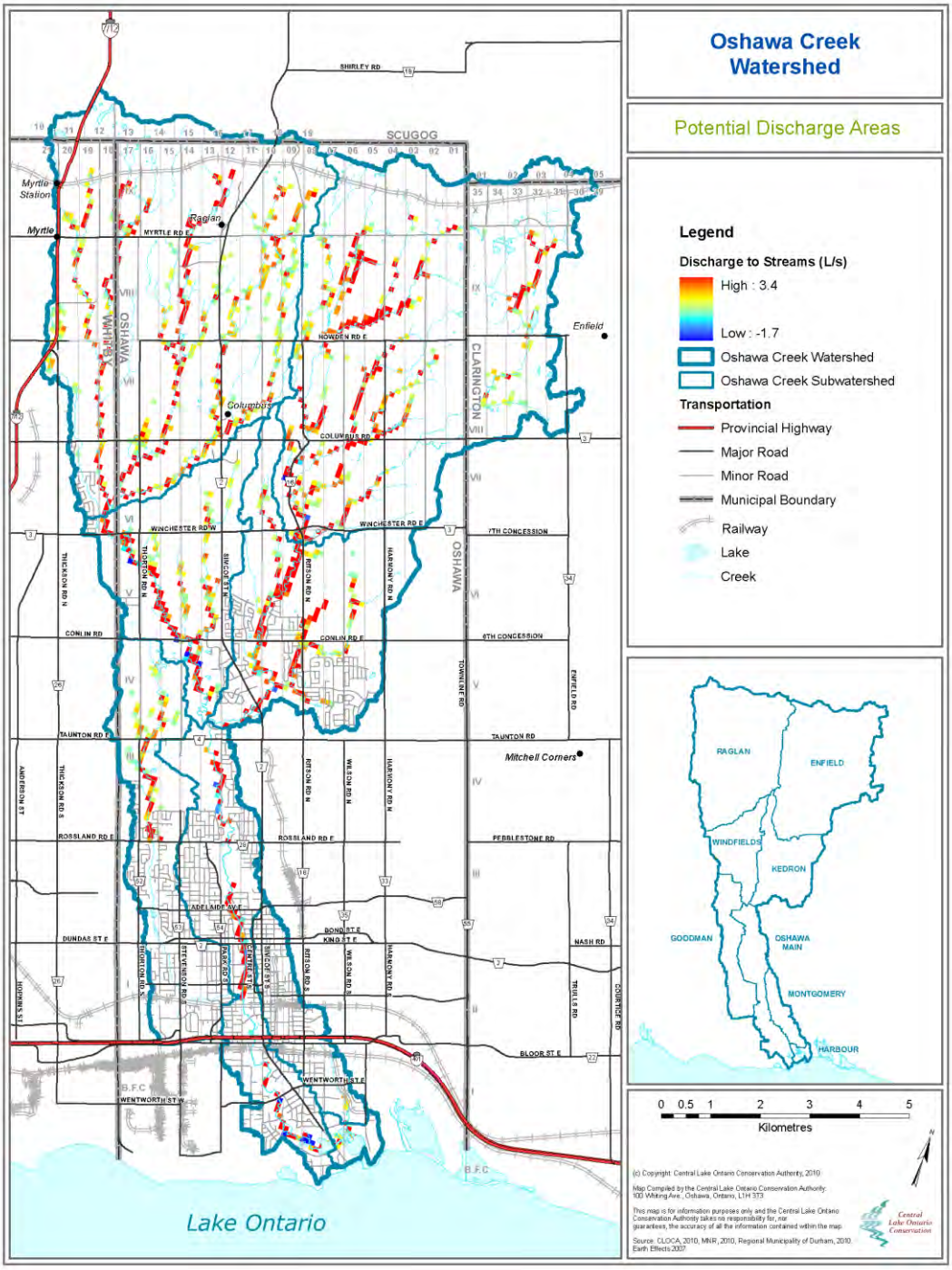


**Figure 36:** Potential groundwater discharge to streams in the Oshawa Creek watershed

Water Use

In rural areas, municipal water services are not available. Consequently, local residents and businesses rely on private water wells to fulfill their water needs. Drinking water is drawn from water wells while some users require access to surface water (stream water takings) and/or water wells to satisfy other water needs. Any person taking more than 50,000 litres of water per day (L/day) is required to be permitted to do so by Ministry of the Environment (MOE) by obtaining a Permit to Take Water (PTTW). Rural water wells and PTTWs are considered consumptive water uses; in other words, a percentage of the water taken is not returned to the watershed and is consumed. In the Oshawa Creek watershed, municipal water supply is drawn from Lake Ontario (a surface water supply) and as such is not considered as taking water from the watershed for water budget purposes. The following provides information with respect to domestic private water well use and MOE approved PTTWs within the watershed.

Domestic Water Use

The Oshawa Creek watershed has approximately 373 domestic water wells (2003) in non-serviced areas. To estimate domestic water use in non-serviced areas, demand was based on population as estimated through Municipal Property Assessment data (MPAC), in accordance with the City of Oshawa Community Profile, 2005. The estimated population was then multiplied by 260 L/capita/day, which is the coefficient for domestic per capita water use recommended in the MOE Fact Sheet (MOE May, 2010). Domestic water use outside of the serviced areas is conservatively assumed to be 100 % consumptive. The results are presented in the Table 15.

**Table 15:** Domestic consumptive water use estimates.

| Watershed Name | Estimated Pop. Serviced by private services | Estimated Consumption (L/Day) | Estimated Consumption (L/Year) |
|---|---|---|---|
| Windfields Branch | 96 | 24,960 | 9,110,400 |
| Raglan Branch | 657 | 170,820 | 62,349,300 |
| Kedron Branch | 63 | 16,380 | 5,978,700 |
| Enfield Branch | 300 | 78,000 | 28,470,000 |
| Goodman Creek | 3 | 780 | 332,150 |
| Main Branch | 163.8 | 23,940 | 284,700 |
| Montgomery Creek | 0 | 0 | 0 |
| Oshawa Harbour | 0 | 0 | 0 |
| **Total – Oshawa Creek** | **1,119** | **290,240** | **106,193,100** |

Permits to Take Water (PTTW)

Permits to take water are authorized by the Ministry of the Environment (MOE) and as such, MOE maintains the provincial database providing the PTTW information. Information reported herein came from this database and from information received through MOE Permit notifications process. In addition, the online Environmental Registry provides notifications of applications/approvals for PTTW. In total there were 7 permitted sources identified in the Oshawa Creek watershed, with some sites drawing from multiple sources. For instance, a site may draw from several wells, and each well would be considered a permitted source for this chapter. A summary of the total groundwater and surface water consumptive use is included in Table 16 and Table_17 respectively. Permitted takings within the watershed are shown on Figure 36. Also included in the tables, though not used in the calculations, are water takings within a 2 km buffer zone around the watershed (a total of 2 permitted sources). Buffer areas are of particular interest when considering the potential for impacts across watershed boundaries. Water takings from Lake Ontario were included in the buffer zone.

Permits to take water authorize the number of litres that the permit holder is allowed to take per hour, day and year. Not all permit holders utilize the full allotted amount nor use the same amount of water throughout the year. As such, permitted volumes per year are multiplied by monthly use factors and subsequently by consumptive factors (percentage of water not returned to the natural system) based on the type of use. These factors are intended to adjust the permitted maximum rates to be more representative of actual use. Consideration was also given to those sources where water is drawn from a well or stream to supply a storage pond that is not connected to the groundwater supply.

Most of the permitted takings within the watershed are for commercial use, either snowmaking or golf course irrigation; no permitted horticultural or agricultural use were identified in the watershed. There are certain water uses which for the most part are exempt from the permitting process, including water drawn for livestock production.

The water budget findings suggest:

- low stresses to water supplies at the watershed scale;
- from a watershed perspective the impact of the identified consumptive groundwater takings (2.1 mm/yr/total watershed) would represent approximately 1% of the available groundwater discharge to streams (GWD: 170 mm/yr); and
- surface water consumptive use (<1 mm/yr/total watershed) would represent less than 1% of the total available discharge to streams within the watershed.

Further, some areas are currently under development pressure with a potential for significant land use change. While the models indicate that there are appreciable groundwater supplies in this watershed, there will be growth and a growing demand for water. Accordingly, the water budget within this watershed needs to be further understood and managed accordingly.

**Table 16:** Estimated consumptive groundwater use – PTTW (compiled by CLOCA 2007).

| Subwatershed | L/Day Estimated | L/Year with Monthly Use Factors applied | L/Year with Consumptive Use Factors applied |
|---|---|---|---|
| Windfields Branch | 24,960 | 9,110,400 | 9,110,400 |
| Raglan Branch | 820,707 | 172,864,380 | 103,574,664 |
| Kedron Branch | 16,380 | 5,978,700 | 5,978,700 |
| Enfield Branch | 77,220 | 28,185,300 | 28,185,300 |
| Goodman Creek | 780 | 284,700 | 284,700 |
| Main Branch | unknown | unknown | unknown |
| Montgomery Creek | unknown | unknown | unknown |
| Oshawa Harbour | unknown | unknown | unknown |
| **Total – Oshawa Creek** | **940,047** | **216,423,480** | **147,133,764** |
| 2 Km Buffer Zone | 1,217,254 | 289,487,100 | 156,402,980 |
| **Final Total** | **2,157,301** | **505,910,580** | **303,536,744** |

**Table 17:** Estimated consumptive surface water use - PTTW (compiled by CLOCA , 2007)

| Subwatershed | L/Day Estimated | L/Year with Monthly Use Factors applied | L/Year with Consumptive Use Factors applied |
|---|---|---|---|
| Windfields Branch | 364,800 | 72,960,000 | 27,432,960 |
| Raglan Branch | 662,400 | 241,776,000 | 193,904,352 |
| Kedron Branch | unknown | unknown | unknown |
| Enfield Branch | 1,635,000 | 147,150,000 | 55,328,400 |
| Goodman Creek | unknown | unknown | unknown |
| Main Branch | 1,632,000 | 326,400,000 | 122,726,400 |
| Montgomery Creek | unknown | unknown | unknown |
| Oshawa Harbour | unknown | unknown | unknown |
| **Total – Oshawa Creek** | **4,294,200** | **788,286,000** | **399,392,112** |
| 2 Km Buffer Zone | 0 | 0 | 0 |
| **Final Total** | **4,294,200** | **788,286,000** | **399,392,112** |

### 3.2.5.7 Monitoring Groundwater Quality and Quantity

Well construction records extracted from the YPDT-CAMC database provide invaluable information necessary to characterize the nature of subsurface materials and groundwater. As well drilling work progresses, penetrated materials are sampled and recorded as lithologic logs. Lithologic logs, which are records of soil or rock types against depth, allow the determination of where aquifer materials reside and where groundwater is available.

Monitoring stations on the other hand, yield long-term groundwater information necessary to determine the quantity and quality of groundwater over time. CLOCA, in partnership with the MOE operates numerous groundwater monitoring stations as part of the Provincial Groundwater Monitoring Network (PGMN). Sixteen monitoring wells within the CLOCA jurisdiction are currently maintained under the PGMN program. These wells are operated for the purpose of monitoring groundwater levels and quality. Two of the PGMN wells are located within the Oshawa Creek watershed. Well W0000049-1, located at Raglan has been recording water levels since 2001 and W0000262-1 located just east of Columbus on Grass Grove Road was commissioned in 2003.

In the spring of 2008, a new well was constructed within Purple Woods Conservation Area in Oshawa North. This new well is a continuously cored bore well drilled to bedrock to the depth of 151.80 metres. The core samples recovered during drilling showed various undisturbed soil and rock units and their relative depths of occurrences measured with higher level of accuracy. This well is to be one of Ontario's "Golden Spike" wells; where "Golden Spike" is the term used on wells that provide high quality geological and hydrogeological information. Purple Woods Monitoring Well will soon become part of the PGMN within the CLOCA jurisdiction.

The variability in the quality of groundwater differs from that of surface water quality because of its interaction with the surrounding rocks. The hydrogeochemical analysis of the collected groundwater samples was undertaken using a statistical analytical software tool (AquaChem) which characterized the origin and influence of the subsurface materials on the groundwater samples. The same tool was used to store and interpret the chemical characteristics of samples to track the water chemistry and identify potential contamination. Also discussed in this chapter are the static water levels recorded in the monitoring wells. The fluctuating water levels represent external influences on the aquifer.

Groundwater Quality

During the summer of 2002 under the Regional Groundwater Mapping Study (Soochan, 2004), CLOCA undertook groundwater quality sampling on 894 domestic wells. This undertaking assisted in the characterization of the various aquifers and established a general baseline record of groundwater quality for future reference. The result of this "snapshot" data do not show the temporal trends generally obtained from longer term observations or monitoring. The data from the PGMN provide more comprehensive information and temporal trends but in fewer representative locations. The distribution of the major ions (calcium, magnesium, sodium, potassium, chloride, sulphate, and carbonate ions) collected from water samples taken at PGMN wells generally reflected the chemistry of the groundwater in the natural environment and can be correlated to the depth, age and reduction-oxidation (redox) conditions. The trends were also evaluated to discern natural patterns from human-induced impacts.

Information based on the borehole logs of the two monitoring wells located within the watershed revealed that W0000049-1, located at Raglan which is drilled to the depth of 16 m below ground surface, is tapping the Oak Ridges Moraine aquifer complex. The 19m deep W0000262-1 well located just east of Columbus, penetrated a deeper aquifer within the Oak Ridges Moraine aquifer complex. Although both wells are tapping the same aquifer system, W0000049-1 is envisioned to have direct hydraulic connection with the nearby stream while W0000262-1, located approximately five kilometres southeast of the former, taps an aquifer complex that is partially to completely capped by poorly permeable till materials (Halton Till) resulting in a semi-confined aquifer condition.

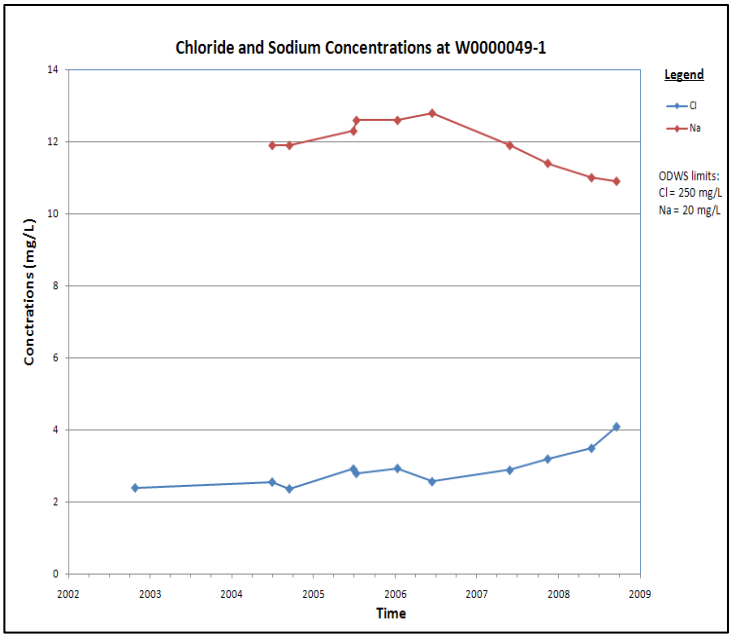


**Figure 37**: Chloride and sodium concentrations in PGMN Station W0000049-1

Initial evaluations of chloride and sodium suggest that, for the most part, these chemicals originated from the natural environment at W0000049-1 as evidenced by their respective trends (Figure 37). The erratic behaviour of these chemicals at W0000262-1 (Figure 38) requires further investigation to determine possible sources and detect any influence of human activities.

Water Sampling at W0000262-1 ©CLOCA

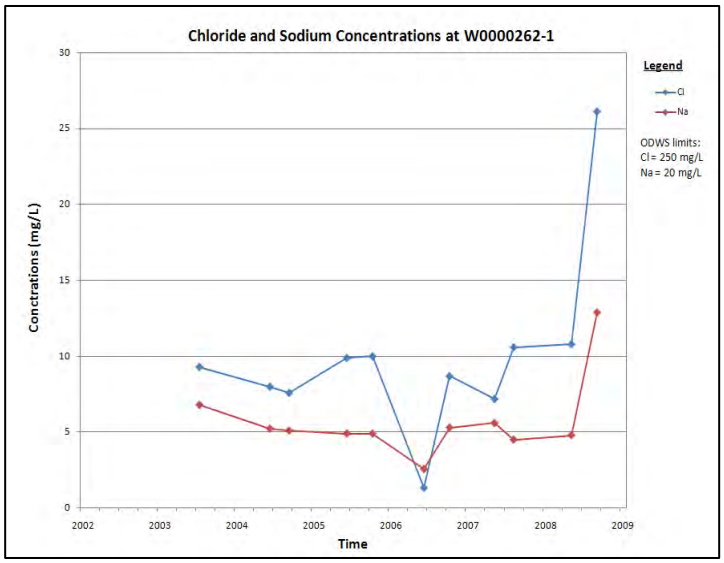


**Figure 38:** Chloride and sodium concentrations in PGMN Station W0000262-1

The 0.3mg/L iron concentration limit under the Ontario Drinking Water Standard (OWDS) was exceeded in all of the 11 samples at W0000049-1 and one sample at W0000262-1. Seven samples exceeded the 5 true colour units (TCU) at W0000049-1. Iron is abundant and commonly found in most sedimentary deposits. It may also come from industrial wastes, corroding metals and mining activities, to mention a few. TCU is usually elevated in the presence of iron and other suspended or dissolved solids in the groundwater. Although excessive iron concentrations in domestic water supply do not generally result in serious health concerns, its presence in domestic water supply can cause staining of laundry, plumbing fixtures and the water itself.

Groundwater Quantity

The static water levels measured in the monitoring wells are indicative of the amount of water stored in an aquifer, aquifer complex or saturated portion of the subsurface system. Groundwater levels fluctuate in response to various factors including precipitation, barometric pressure, temperature, and water abstractions. Monitoring the water level in a network of wells also provides information on groundwater movement and flow directions. Figure 39 shows the water level trend at PGMN station W0000049-1.

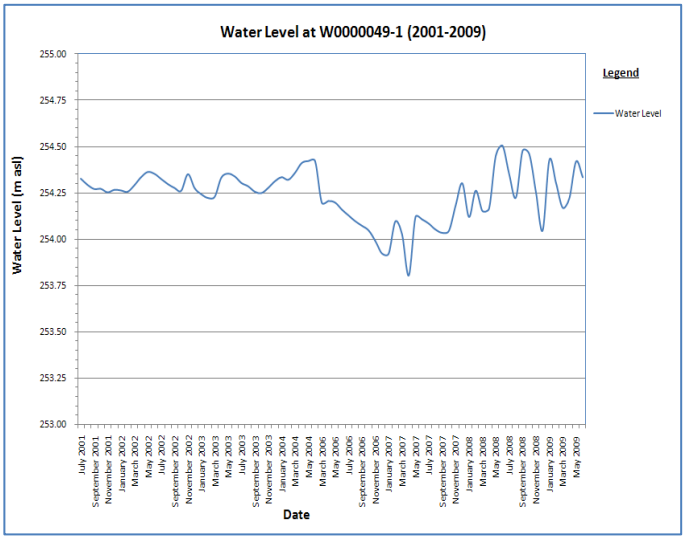


**Figure 39**: Hydrograph showing groundwater levels at PGMN Station W0000049-1

The graph depicts relatively drier 2007 while 2008 has been wet particularly the latter months. Although water level fluctuates more in the order of about three meters at PGMN station W0000262-1, the graph similarly discerns a drier 2007 (Figure 40). Water level readings at this station from July 2009 onwards are currently under review.

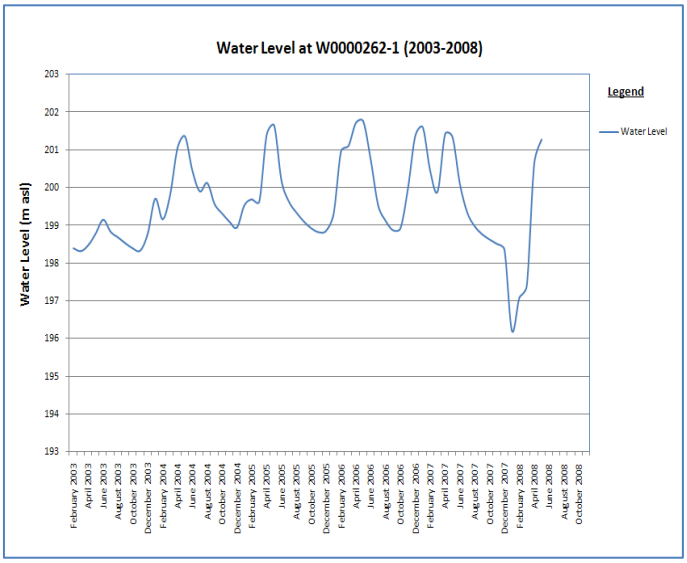


**Figure 40:** Hydrograph showing groundwater levels at PGMN Station W0000262-1

### 3.2.6 Natural Hazards

3.2.6.1 Hydraulic Modelling

Hydraulic modeling is undertaken primarily to establish areas of potential riverine flooding hazards within the watershed. The current hydraulic model was created by Totten Sims Hubicki in HEC2, and was completed in 1994. Identified areas of possible flooding hazards are assessed with areas of slope instability, stream erosion, and the shifting tendencies of meandering riverine systems to generate an environmental hazard protection limit commonly referred to as 'hazard limits'.

CLOCA is also working towards the creation of a prediction model and a flood vulnerable database. The two models, when used in conjunction with each other, are used to identify structures, roads and bridges that will be inundated under specific rainfall events. The results from the flood plain mapping are required to run the models, and hence the completion of the prediction model and flood vulnerable database is dependent on the completion of the flood plain mapping.

The 'Generic Regulation limits' include the identified areas of flooding hazards generated by the 1994 hydraulic model, and the 2010 calculated erosion hazard lands and wetlands limits, are shown in Figure 41. These limits are used by CLOCA as part of administering Ontario Regulation 42/06: Regulation of Development, Interference with Wetlands and Alteration to Shorelines and Watercourses.

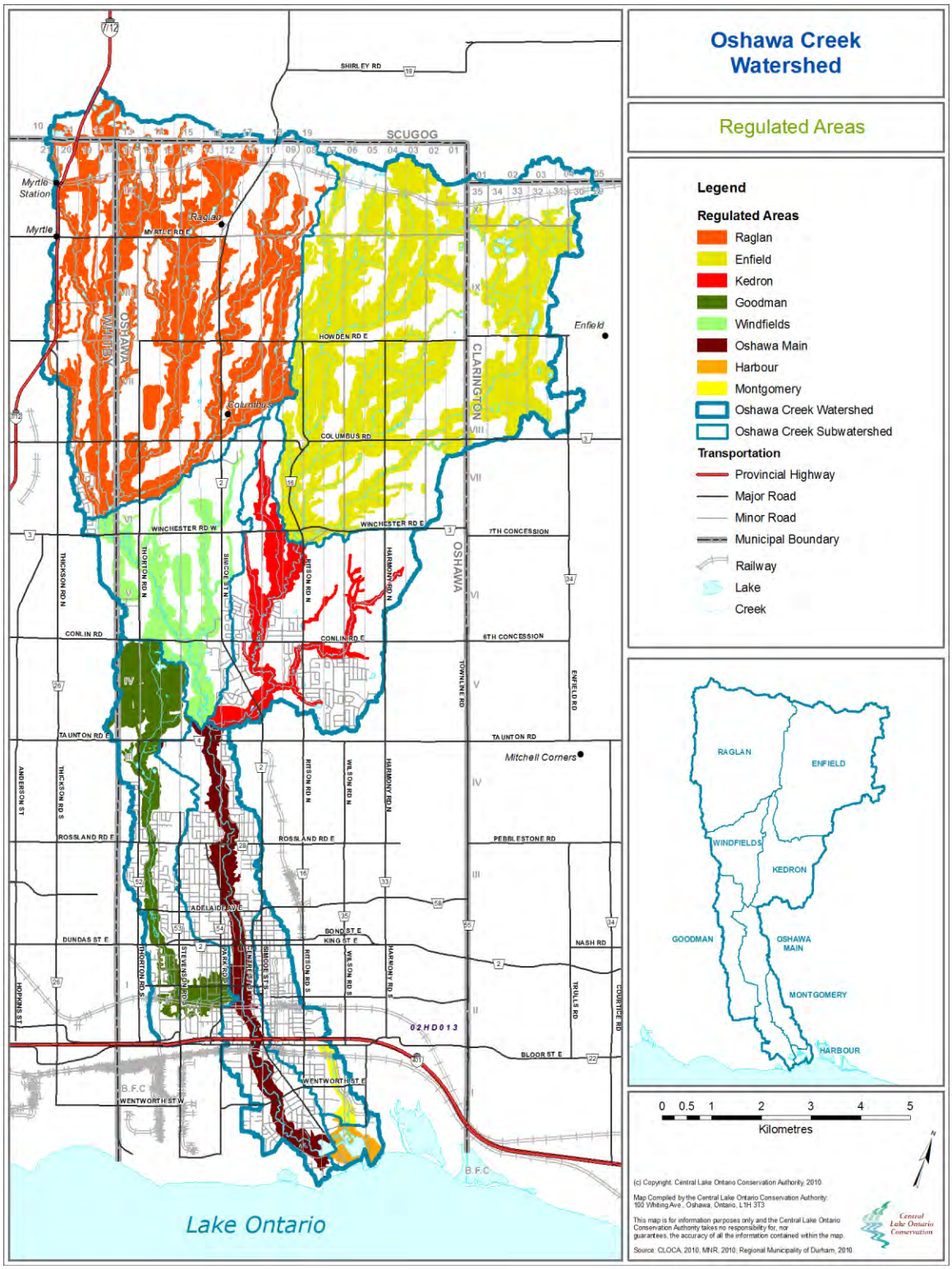


**Figure 41:** Generic Regulations limits for the Oshawa Creek watershed by subwatershed

## 3.3 Life

### 3.3.1 Fisheries and Aquatic Habitat

The aquatic habitat in a stream and the health of the fishery within it are largely influenced by numerous variables, including:

- Flow and sediment regimes;
- Water quality and quantity;
- Land use and land cover (including wetlands and riparian habitats);
- Local climate, geography, physiography and surficial geology.

While these topics are discussed in other sections of the Plan (2002) and this addendum, the relationship and relevance of these variables to fisheries and aquatic habitat will be addressed here. The fisheries and aquatic information provided in the Plan (2002) provides excellent background information and is important in assessing change and trends in this resource over time. Yet due to rapid urbanization of the watershed, collection of additional field data, updated methodologies and mapping, changes in Provincial and Regional planning and growth objectives (including key provincial planning legislation) and the preparation of CLOCA's Fisheries Management Plan and Aquatic Resource Management Plan for Oshawa Creek, revisiting the fisheries section of the Plan (2002) is needed.

Under section 35 of the Fisheries Act, CLOCA has a Level 3 agreement with the Department of Fisheries and Oceans Canada (DFO) to review development proposals including Municipal Class Environmental Assessment (EA) projects. In this agreement, CLOCA conducts initial reviews on projects to determine if there will be an impact to fish and fish habitat. If impacts are likely, CLOCA will determine if and how the proponent can mitigate potential impacts. If potential impacts can be mitigated, the Authority will issue a Letter of Advice. If impacts to fish and fish habitat cannot be fully mitigated, the Authority works with the proponent and DFO to prepare a fish habitat compensation plan, at which time the project is forwarded to the local DFO office for authorization under the Fisheries Act.

In addition to Fisheries Act requirements, the Authority works to protect hazard lands such as floodways, erodible or unstable soils, and watercourses and wetlands through the Conservation Authorities Act and Ontario Regulation #42/06. This regulation identifies those areas where a permit would be required prior to work taking place within a floodplain or regulated area. Potential impacts to fisheries and aquatic habitat as a result of proposed works is reviewed. This includes consideration of construction timing windows for in-water works. These timing windows are established by MNR and are based upon the sensitive life history stages (e.g. migration, spawning and rearing) for warm and cold water species.

With the exception of biological water quality (discussed in Section 3.2.4.3), and desktop analyses which utilize Geographic Information System (GIS) software and finer resolution data, the methodologies used to assess fish communities and aquatic habitat in recent years are consistent with those used and reported on in the Plan (2002). Any discrepancies between the historical (2000 and earlier) and more recent (2007) sampling events are described below.

Habitat characteristics were assessed in 2000 and 2007 using the Ontario Stream Assessment Protocol (Stanfield et al., 1998). Fish communities were largely assessed throughout the watershed in 1996, 1997, 2000 and 2007, with some limited sampling occurring annually as part of training or research initiatives. All sites were assessed according to fish sampling methods from the Ontario Stream Assessment Protocol (Stanfield et al., 1998). Sample locations were randomly selected at numbers suitable to accurately represent a variety of instream habitat conditions, physiographic regions, and adjacent land use types. The Oshawa Harbour represents a different habitat type, and as such was sampled using boat electrofishing as part of the Durham Region Coastal Wetland Monitoring Project (2008 & 2009).

In the past, stream temperature in the Oshawa Creek watershed has been assessed using various methodologies. Some of these historical datasets date back to 1959 and are described in greater detail in the *Central Lake Ontario Fisheries Management Plan* (CLOCA/MNR 2007) or the *Oshawa Creek Aquatic Resource Management Plan* (CLOCA 2002).

More recently, the thermal regime of Oshawa Creek has been assessed using two methodologies. The first method, used in 2000, classified sites into cold, cool or warm water based on the methodology developed by Stoneman and Jones (1996). This method uses a point in time measurement of water and air temperature collected during periods of extreme heat (mid-summer). There are limitations to this data collection technique and as such the results do not always accurately reflect the thermal regime. This was identified by Stoneman and Jones (1996) which stated "…when resources are available, continuous temperature data collected over a period of weeks or months will invariably provide a more accurate description of the stream's thermal regime."

In 2007, CLOCA adopted a continuous temperature data collection approach by using temperature loggers (CLOCA 2009). Using this methodology, classification of stream temperature is divided into three categories: coldwater, coolwater and warmwater (Coker et al., 2001). The thermal classification for each site was determined by analyzing data summarized through the Stream Temperature Analysis Tool and Exchange (STATE) (Jones and Chu, 2007). Temperature loggers are deployed in the stream in the spring and retrieved in the winter with temperatures logged every half hour. This allows for a more robust dataset and an overall

better understanding of the thermal regime. Further, by recording stream temperature in the winter, CLOCA is able to develop an understanding of groundwater contributions (Conant 2004).

In addition to field studies, stream habitat analyses were performed historically using 1:10,000 OBM mapping and aerial photography, and more recently desktop GIS software, and spatial datasets such as orthoimagery, hydrologic stream layers and Ecological Land Classification information. These analyses include assessments of stream order, slope, and riparian cover. The historic and current methodologies and any discrepancies associated with the current results and those reported on in the Plan (2002) are described in the corresponding sections that follow.

For greater detail on the methodology used to assess aquatic habitat and fisheries, the reader is referred to the 2007 CLOCA Aquatic Monitoring Report, or the Aquatic Monitoring Program 2009-2013 Report.

The following sections summarize the current state of Oshawa Creek aquatic habitat and fisheries resources. In addition, relevant historical information regarding fisheries in the watershed is provided. Key indicators of aquatic habitat conditions are described including Strahler stream order, stream slope, instream barriers to fish migration and movement of sediment and large woody material, riparian vegetation, thermal regimes, and the influence of land use and land cover. Fish species composition and distribution will also be discussed as it relates to these habitat conditions.

Aquatic Habitats

## Strahler Stream Order and Stream Gradient (Slope)

Stream-order is a classification system based on a drainage network and uses the Strahler Method (1964). Based on this method, streams increase in order upon converging with a stream of equal order. For example, a first-order stream (typically headwaters) is a small stream without tributaries. A second-order stream begins at the confluence of two first-order streams and continues until it meets with another second-order stream, forming a third-order stream, and so forth.

Stream-order is directly related to other morphometric and fluvial characteristics and can be useful in describing fish habitat. Based on concepts developed by Strahler (1964), stream-order is directly related to length, width, depth and discharge. As order increases, so too does the size of the stream and the current flowing within. Stream-order is also related to stream slope (or gradient). As stream-order increases, stream slope decreases. Finally, stream-order is related to fish species diversity, where fish diversity increases as a function of stream-order (Mackie, 2001). Stream-orders 1 to 3 can be described as narrow, with an erosional substrate (e.g., rocks, boulders) and an input of leaf-litter. Stream-orders 4 to 6 are wider, characterized by riffle and pool areas, and contain both erosional and depositional (e.g., sand) substrate. Stream-orders greater than 7 are wide, often with turbid water and contain depositional substrates (Mackie 2001).

The dendritic nature of Oshawa Creek gives rise to the majority of stream length as first-order tributaries, which come together to form fewer large-order streams (Figure 42). First-order streams represent over half (59%) of the total stream length in the watershed (Table 18). Of these first order tributaries 71% originate from the Oak Ridges Moraine, and 23% arise from the Lake Iroquois Beach, indicating substantial groundwater inputs from both physiographic units (CLOCA, 2008). The numerous streams that originate upon the Oak Ridges Moraine and Lake Iroquois Beach emphasize the importance of these physiographic features as groundwater recharge and discharge areas.

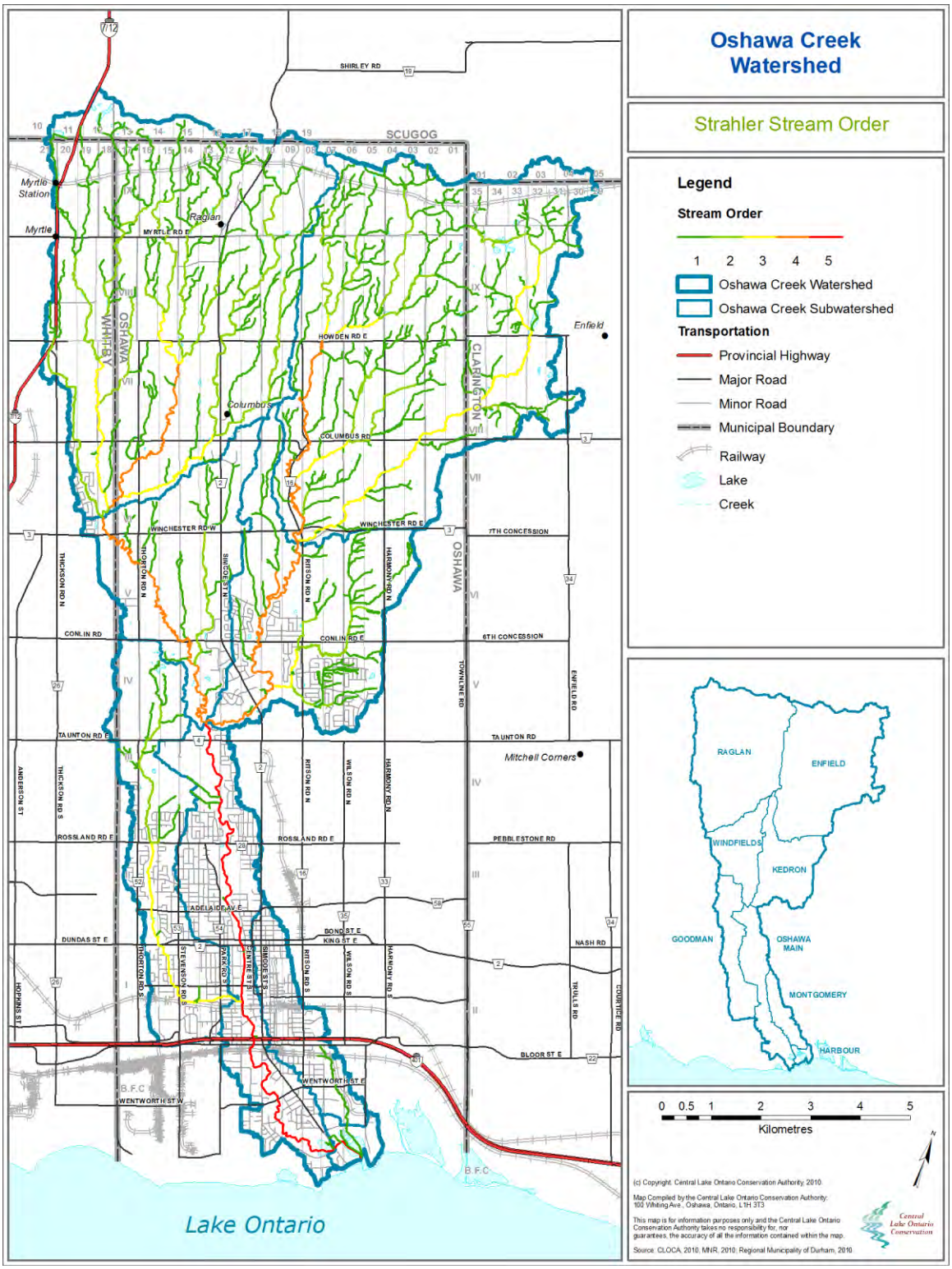


**Figure 42:** Strahler stream order of the Oshawa Creek

Note that the total length of streams by stream order presented below is not consistent with the values presented in the Plan (2002). This discrepancy is the result of different stream datasets used in the analysis. The dataset used below was created at a finer scale and as a result is a more detailed hydrologic layer. While the total stream lengths differ from the Plan (2002), the trends are consistent with over half of the stream length being comprised of first order streams and over two-thirds originating from the Oak Ridges Moraine.

**Table 18:** Oshawa Creek Watershed Strahler Stream Order

| | Strahler Stream Order | | | | | |
|---|---|---|---|---|---|---|
| **Subwatershed** | **1** | **2** | **3** | **4** | **5** | **Grand Total** |
| **Enfield** | 84.47 (67%) | 19.25 (15%) | 15.41 (12%) | 6.55 (5%) | 0.00 (0%) | 125.68 |
| **Goodman Creek** | 8.82 (49%) | 3.80 (21%) | 5.27 (29%) | 0.00 (0%) | 0.00 (0%) | 17.90 |
| **Oshawa Main** | 3.42 (22%) | 0.0 (0%) | 0.14 (1%) | 0.0 (0%) | 11.89 (77%) | 15.45 |
| **Montgomery Creek** | 2.91 (100%) | 0.00 (0%) | 0.00 (0%) | 0.00 (0%) | 0.00 (0%) | 2.91 |
| **Kedron** | 20.65 (59%) | 5.69 (16%) | 1.36 (4%) | 7.42 (21%) | 0.00 (0%) | 35.12 |
| **Windfields** | 12.20 (48%) | 4.65 (18%) | 0.00 (0%) | 8.39 (33%) | 0.00 (0%) | 25.25 |
| **Harbour** | 1.01 (49%) | 0.00 (0%) | 0.00 (0%) | 0.00 (0%) | 1.04 (51%) | 2.05 |
| **Raglan** | 72.01 (58%) | 34.31 (27%) | 13.34 (11%) | 4.86 (4%) | 0.00 (0%) | 124.52 |
| **Grand Total** | 205.50 (59%) | 67.71 (19%) | 35.51 (10%) | 27.22 (8%) | 12.93 (4%) | 348.88 |

Total stream length (km) and proportion of the total stream length (in parenthesis) by stream-order of each subwatershed in the Oshawa Creek watershed (values calculated from the 2002 CLOCA drainage layer).

The slope or gradient of a stream is one of a number of variables used to characterize the type of habitat available to aquatic organisms and can be used to predict fish habitat structure. The substrate in high gradient streams is typically composed of large materials such as boulders, cobble and gravel, because fast-flowing water tends to wash smaller particles downstream. Silts and sandy materials characterize the substrate of low gradient streams, since water velocity is low enough along the channel bottom water interface to allow fine materials to settle out (Mackie, 2001).

Examination of gradient maps may also reveal areas of potential groundwater discharge. In high gradient areas, where the energy of flowing water has scoured away soil materials, the water may be flowing at the elevation of the water table and leading to the discharge of groundwater. The identification of groundwater seepage areas assists in identifying habitat suitable for the reproduction of Salmonids such as Brook Trout.

The rise of the creek (elevation in m) was divided by the length of the creek (m) to determine slope. Slopes were categorized into four groups: low slope (0.0 to 0.3%), moderate slope (0.3 to 1.0%), steep slope (>1.0 to 5.0%), and very steep slope (>5.0%). A profile of the Oshawa Creek watershed from the headwaters on the Oak Ridges Moraine planning boundary and Till

Plain to the outflow into Lake Ontario, including location of physiographic and geographic features can be found in Figure 31**.**

Stream-order and slope determine the water velocity of a stream, which dictates the types of habitat and aquatic organisms found within streams. Some fish species are adapted to fast-flowing water, while others are more suited to slower velocities. Understanding stream-order and slope provides insight into fish habitat and communities within the watershed.

## Stream Temperature

From an integrated watershed perspective, knowledge of the existing in-stream thermal regime and trends supports on-going aquatic, groundwater recharge/discharge, stream baseflow and water budget studies. In addition, water temperature information may be used as a qualitative field-verification data set for various hydrology models used to predict conditions that may result from future land use changes. This section provides a base understanding of the existing spatial variations of in-stream water temperatures within the watershed and points out gaps in that knowledge. This approach in turn supports an integrated ecosystem approach to the protection, conservation and enhancement of the ecological integrity of the watershed. Areas of concern may be identified and thermal classification targets may be developed in support of resource management.

From a fish and fish habitat perspective, water temperature is one of many criteria used to assess the quality of a stream and the health of the aquatic habitat within it. Many organisms have particular thermal requirements for existence, and cannot tolerate large changes in water temperature. For instance, summer stream temperature is considered the single most important factor influencing distributions of Brook Trout (MacCrimmon and Campbell, 1969).

In addition to fish species distribution noted above, water temperature can be correlated with the presence or absence of creekside shade-providing vegetation referred to as riparian cover, and various types of land uses within the watershed. Accurate temperature representation also provides key validation information with respect to identifying areas of potential groundwater discharge. This in turn supports the knowledge around potential groundwater flow path and recharge area identification.

It should be noted that the interpretation of stream temperature data can be confusing due to overlapping terminology. Historically in Ontario only two thermal classification categories were used, coldwater and warmwater. In continuing with the fish community-based definition for coldwater stream as to be consistent with past usage and policy within OMNR, the definition of a coldwater stream is 'a stream supporting or capable of supporting coldwater fishes' (Bowlby, 2008). Coldwater fishes include but are not limited to Salmon and Trout. Salmon and Trout can be found in both coldwater and coolwater temperature zones and so these zones represent coldwater streams in the traditional sense (Bowlby, 2003).

The following describes the most current available in-stream temperature information for the Oshawa Creek watershed. Additionally, influencing factors such as discharge to streams, stream order, land use, and fisheries information are briefly described. All reported stream temperatures are the results of thermal monitoring using either thermometers or temperature data loggers and not the fish community-based definitions. For example, Oshawa Creek is a coldwater stream based on the presence of resident and migratory Salmonids and local fisheries management objectives (CLOCA/MNR 2007); however, cool or warm water stream temperatures may be present in some areas depending on local conditions.

In 2007, thermal regimes were assessed in Oshawa Creek as part of the CLOCA Aquatic Monitoring Program. Temperature data was collected using hobo loggers at 41 sites throughout the watershed, including 4 in Goodman Creek and 2 in Montgomery Creek. The results from the 41 loggers were analyzed in the spring of 2008 using the STATE tool and the results are summarized below.

Figure 43 depicts the thermal classifications at measurement points within the watershed as cold or cool-water sites. Note that no warm-water sites were identified through this monitoring. Water temperature at any given site is influenced by the cumulative effects of all landscape characteristics upstream including the state of the riparian vegetation, groundwater discharge, land use and ambient air temperature. Headwaters generally refer to zero-order swales, first-order and second-order streams and represent reaches of potential groundwater discharge. Predicted discharge to streams is also depicted in Figure 43 to provide an indicator of where shallow, cold groundwater is potentially discharging to a stream and possibly influencing the surface water temperature.

Cold water sites are typically characterized by upstream naturally vegetated landscapes and/or evidence of groundwater discharge, while warm-water sites tend to be dominated by agricultural and urban land uses with a lack of natural cover and groundwater discharge that is insufficient to moderate the anthropogenic impacts on stream temperature. Temperature data from 2000 using the Stoneman and Jones (1996) methodology (Figure 44) shows a general trend in the watershed from cold temperatures in undisturbed headwater streams surrounded by natural vegetation, to cool mid-reaches dominated by agricultural land uses or urbanized areas with well vegetated valleys and stormwater management, to warm-water higher-ordered branches in the lower urbanized reaches and in some cases agricultural areas with little natural cover. This overall north-south warming trend within the watershed is reflective of stream order increases, land use changes towards the lake, and the gradient of groundwater contribution from the high discharge areas of the Oak Ridges Moraine and Lake Iroquois Beach, to the low discharge areas of the Till Plains.

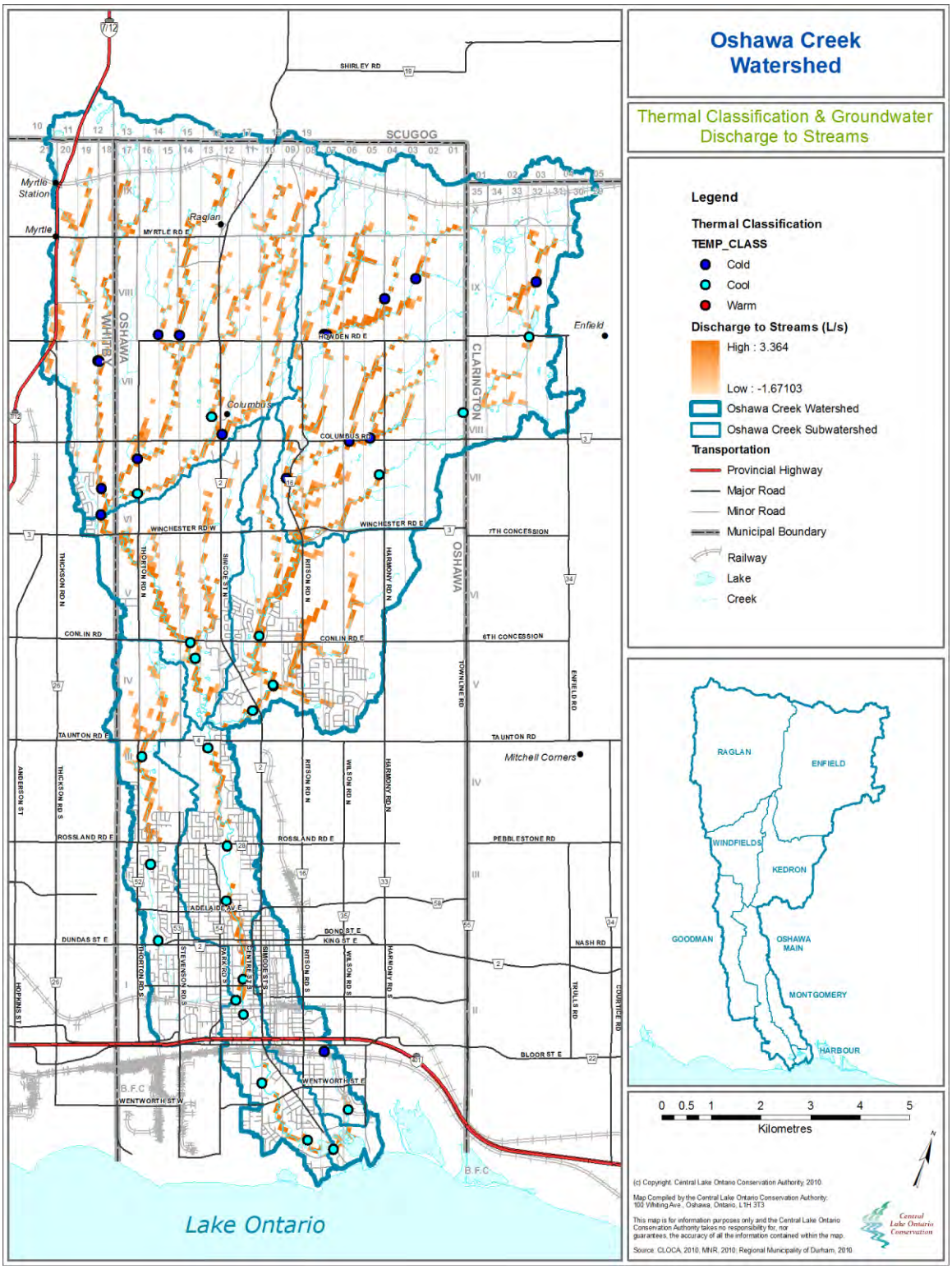


**Figure 43:** Oshawa Creek thermal classifications and discharge to streams

This trend is less obvious in the more comprehensive 2007 temperature logger data. Coldwater sites are still present in the mid to upper reaches of the watershed typically dominated by natural land cover in areas with evidence of groundwater discharge, although the range of coldwater habitat is much larger. Coolwater habitat is present throughout the majority of the middle and lower reaches of the watershed where groundwater discharge is less evident and urban and agricultural impacts are greater. Warmwater sites are altogether absent in the comprehensive dataset. During the warmer summer months, the coolwater temperatures indicate that habitat is still suitable for sensitive fish species like Salmon and Trout. This discrepancy with the 2000 results and the historical information reported on in the Plan (2002) reflects the limitations with the point-in-time sampling methodology which has been acknowledged in literature (Stoneman and Jones 1996).

Stormwater input and a lack of stormwater management in the older urban areas, and high proportions of impervious cover are contributing to the stream temperature degradation, particularly in the southern reaches. Temperature monitoring using in-stream loggers is helping CLOCA to gain comprehensive knowledge of thermal influences in the watershed. This information will also provide invaluable validation data to apply against numerical model results involving baseflow simulations, along with the identification of reaches sensitive to disturbances such as land development or water takings.

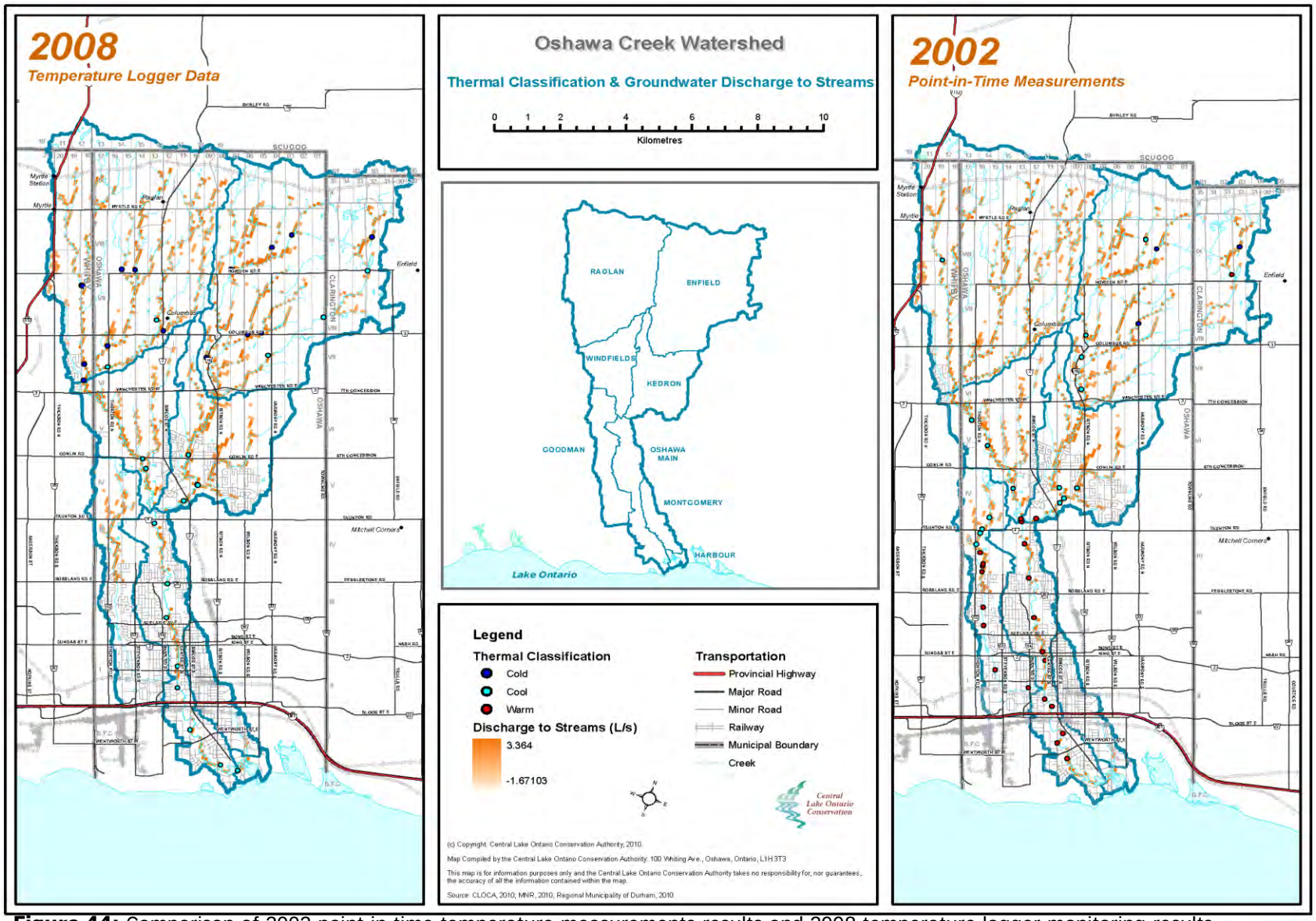


**Figure 44:** Comparison of 2002 point in time temperature measurements results and 2008 temperature logger monitoring results

## Instream Barriers

Instream barriers may be any type of water control structure, culvert, or weir that obstructs or limits fish movement, particularly from accessing upstream habitat, or causing fish to congregate at the base of the barrier for prolonged time periods. Not only do instream barriers have direct effects on fish, they also affect water quality and habitat conditions within the stream. Impoundment of water behind a physical structure causes the sediment to settle out from the stream water, leading to silt build-up in the pond and sediment depravation downstream. Sediment depravation downstream of the barrier causes an increased rate of stream bank erosion as the sediment-reduced water flowing past the barrier has more energy and scours the stream banks more quickly. This also leads to increased erosion of sediments in depositional areas of the lower stream reaches. Sediment accumulation in a pond requires periodic dredging, or sediment will be flushed into downstream creek sections. Flushing silt downstream can smother fish spawning beds and habitat.

In some cases within the watersheds, instream barriers act to separate upstream fish communities from down-stream fish communities. The isolation of upstream fish populations may be either beneficial or detrimental. For example, an instream barrier may be beneficial by protecting upstream fish populations from competition of invasive species, or it may be detrimental by restricting migrating species like Rainbow Trout from accessing spawning habitats upstream of an impassable barrier.

Instream barriers within the Oshawa Creek watershed were assessed based on the obstruction of fish movement of migratory species. Currently, there are 25 known instream barriers within the watershed (Figure 45), many of which do not restrict the movement of migratory species. A detailed description and photographs of the more significant barriers can be found in the *Oshawa Creek Aquatic Resource Management Plan* (CLOCA 2002). The majority of the barriers reported on in the 2002 report are still present, with the exception of the CLOCA Weir which has since been removed.

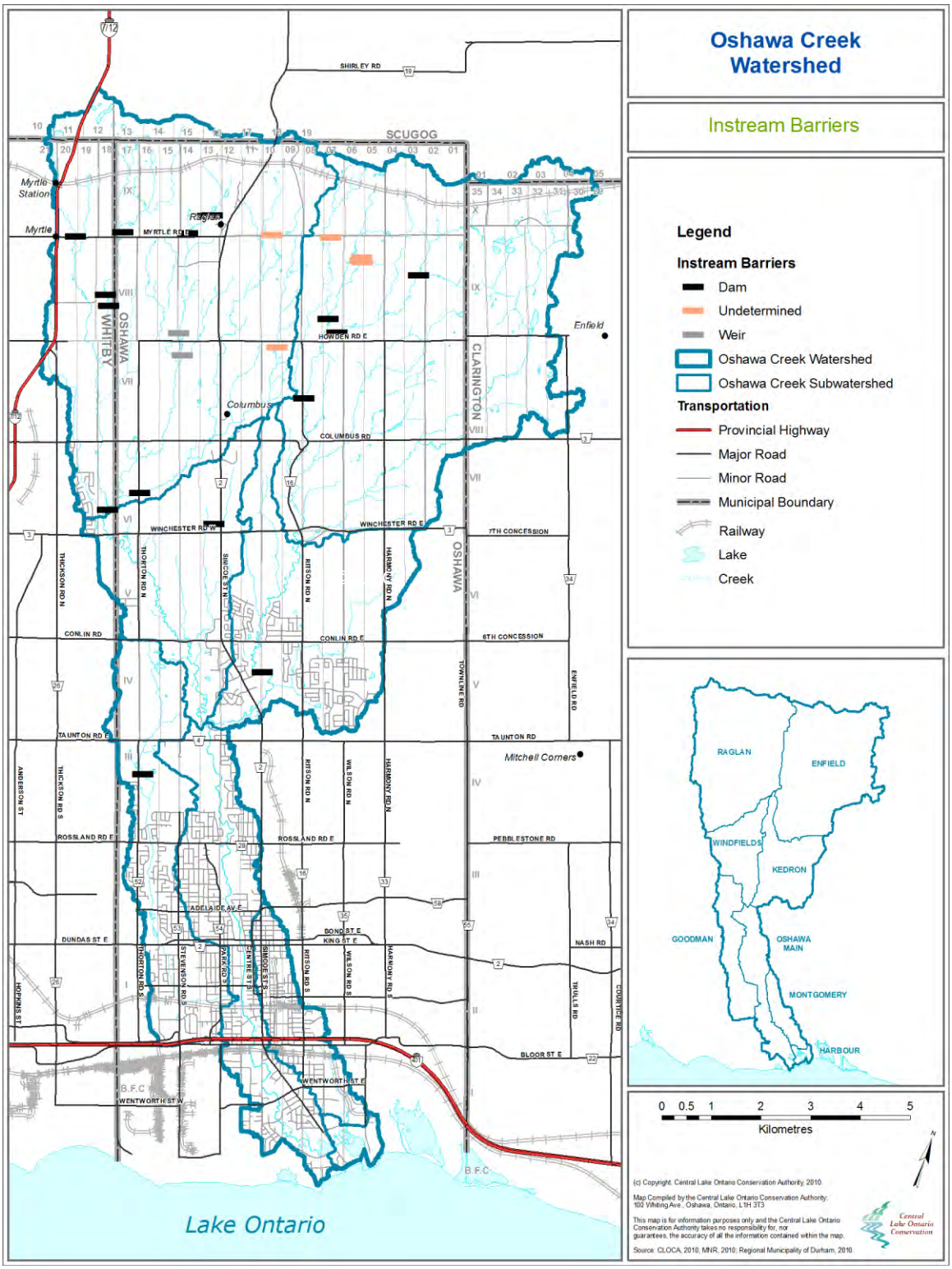


**Figure 45:** Instream Barriers in the Oshawa Creek watershed

Several of the instream barriers within the Oshawa Creek watershed need further inventory work to assess whether they are passable for jumping fishes (Salmonids). Of the barriers where fish passage is known, further details are listed below.

### *Airport Golf Course Dam (Goodman Subwatershed)*

This dam is considered to be un-passable for Salmonids and other fish species and represents the upper most limits for fish migration within Goodman Creek. During the 2000 and 2007 fish sampling events and spring spawning surveys, Salmonids were not observed in Goodman Creek, so it cannot be conclusively determined if this barrier impedes the migration of Salmonids. While Salmonids have not been observed in Goodman Creek, White Sucker (another migratory species) has been caught as far upstream as the airport; however, none have been observed upstream of the dam. Above the dam, Blacknose Dace, Creek Chub and Northern Redbelly Dace were caught within the main channel of the creek. In future, if the presence of Salmonids is recorded in Goodman Creek, review of this instream barrier's impact on migration would be warranted.

### *Camp Samac Pond (Kedron Subwatershed)*

Camp Samac Pond Dam is, by design, un-passable for Salmonids and other fish species attempting to access upstream habitats in Enfield Branch subwatershed. This dam is of particular management concern because it impedes the migration of Rainbow Trout and Brown Trout. Historically, Salmonids were lifted over the dam during migration. Currently the dam is kept open from October to May to allow for fish passage. Based on the 2000 and 2007 sampling events, Rainbow Trout, Brown Trout and White Sucker, including young-of-year (YOY), were found in various locations upstream of the dam, indicating that the current management practice of keeping the dam open is working to allow for spawning upstream. It is unclear whether the Rainbow and Brown Trout found above the dam were able to pass through the structure un-assisted, while the dam was open.

### *McTavish Ponds (Enfield Subwatershed)*

McTavish Ponds (formerly known as Algers Ponds) are considered to be un-passable for migrating Salmonids. During the 2000 sampling events, Brook Trout were caught directly upstream of these ponds. It is possible that the McTavish Ponds are restricting migrating Rainbow Trout from accessing upstream Brook Trout habitat. These ponds are an important management concern because they may be protecting upstream populations of Brook Trout from competition with Rainbow and Brown Trout.

### *Kehoe Pond (Enfield Subwatershed)*

The Kehoe Pond dam is considered to be un-passable for both Salmonids and other fishes. During the 2000 sampling events, Brook Trout were caught down-stream of the Kehoe Pond; however, fish sampling was not conducted above the Kehoe Pond. It is likely that this barrier restricts Brook Trout populations from accessing upstream habitats; however, the majority of these reaches are likely intermittent in nature and would provide only limited seasonal habitat. Further sampling and inventory work are necessary to support this.

### *Raglan and Ritson Pond (Enfield Subwatershed)*

The Raglan and Ritson Pond dam is considered to be un-passable for both Salmonids and other fishes. This pond barrier was not surveyed until 2006, and as such information regarding this barrier was not provided in the Plan (2002). During the 2000 sampling events, Brook Trout and Brown Trout were caught down-stream of the pond; however, fish sampling was not conducted above the pond. It is possible that this barrier restricts Brook Trout populations from accessing upstream habitats however, the majority of these reaches are likely intermittent in nature and

would provide only limited seasonal habitat. Further sampling and inventory work are necessary to support this.

### *Winchester Golf Course Pond (Raglan Subwatershed)*

By design, the Winchester Golf Course Dam is un-passable for migrating Salmonids; however, the dam is left open from December to April to allow for passage. During the 2000 and 2007 sampling events, Rainbow Trout and Brown Trout were caught upstream and downstream of the dam. There are too few sampling sites within the subwatershed to make inferences about whether Rainbow Trout and Brown Trout actively pass through this barrier each year. This dam is of particular management concern because it is located at the base of the Raglan subwatershed, and may restrict Salmonids from accessing upstream habitats within the entire subwatershed.

### *Hamer Pond (Raglan Subwatershed)*

The Hamer Dam is considered to be un-passable for migrating fish species. During the 2000 and 2007 sampling events, Brook Trout were captured upstream of the dam (down-stream of Wallace Dam). There are too few sampling sites to determine whether migrating Rainbow Trout can access the Hamer Dam; however, given the size of the structure passage is unlikely. Further investigation is needed to determine whether Brook Trout are found down-stream of the dam, although they have not been observed in recent sampling events.

### *Wallace Pond (Raglan Subwatershed)*

The Wallace Dam is located directly upstream of the Hamer Dam, and is a barrier to all fish species. Between the 2000 and 2007 sampling events, four sites were sampled upstream of the dam. No fish were caught during any of these sampling events. As noted above in the description for Hamer Pond, Brook Trout were caught directly down-stream of Wallace Pond. This dam is an important management concern because of the restriction of movement of Salmonid species, particularly Brook Trout. Furthermore, the lack of fishes caught upstream of the dam may indicate that fish populations are low or non-existent in the upstream reaches, possibly due to limited or intermittent habitat and/or potential impacts from alternative land uses.

### *Grandy Pond (Raglan Subwatershed)*

The Grandy Pond dam is directly upstream of the Winchester Dam. The Winchester Dam is not passable to Salmonids, unless it is left open (reportedly it is open from December to April). During the 2000 and 2007 sampling events, Rainbow and Brown Trout were captured directly below the Grandy Pond but no Salmonids have been captured above the dam. Due to limited sampling effort, it cannot be ascertained whether any Trout actually pass through the Grandy Pond. Grandy Pond dam is of particular management concern because it restricts access to approximately half of the Raglan Branch subwatershed.

### *Hyde Dam and Pine Ridge Fishing Club Ponds (Raglan Subwatershed)*

Both the Hyde Dam and upstream Pine Ridge Fishing Ponds are considered un-passable for Salmonids. The Hyde Dam is a 4.0m berm with a stop-log structure and steel culvert outfall, and the Pine Ridge ponds are equipped with rock-lined spillways that act as barriers to resident Brook Trout. Above the Pine Ridge ponds, Rainbow and Brook Trout were caught during the 2000 sampling events. Brook Trout were caught again in this location during 2007 sampling efforts. Historically, these ponds were stocked with Rainbow Trout which may be the source of this species upstream. At the downstream end, the ponds are equipped with outfall screens designed to prevent the escape of Rainbow Trout. Of particular interest at this location is the presence of slimy sculpin upstream of the fishing club ponds. This species is particularly

sensitive to stream warming which indicates that there is significant groundwater contributions in this area which provide thermal refuge for this species.

### *Russo and Goldman Ponds (Raglan Subwatershed)*

Both the Russo and Goldman ponds are considered to be passable by Salmonids during high-flow events. During the 2000 sampling events, Brown Trout were captured upstream of the Goldman and Russo dams. It is likely that these were resident fish and as such may be present in the creek year-round. This location was not resampled during the 2007 monitoring efforts.

Riparian Vegetation

Riparian vegetation plays an important role in water quality and aquatic life. A buffer strip of riparian vegetation helps filter land-flowing water before it enters the stream, provides shade to help moderate stream temperature, provides allochthanous nutrient input (e.g. external nutrients like dead leaves or other terrestrial debris), and helps to maintain the stability of the stream bank (Mackie, 2001). While all streams benefit from riparian cover, lower order streams (Table 19) in particular benefit greatly from riparian cover and the positive effects are apparent in higher order areas downstream.

Environment Canada guidelines (EC, 2004) indicate that 75% of stream length should have 30m riparian vegetation buffers on each side of the stream. Riparian vegetation cover in the Oshawa Creek watershed falls short of the Environment Canada guidelines (EC, 2004), as only 30% of the entire stream length has 30m riparian buffers based on 2005 Orthophoto interpretation (Table 19). By stream-order, the proportion of riparian cover is greatest along forth (65%) and fifth-order (57%) streams; however these stream orders combined only account for 11% of the watercourse length in Oshawa Creek. The proportion of riparian cover is worst along first (18%), second (36%) and third-order (46%) streams where it would typically provide the most benefit. These lower order tributaries represent the vast majority of stream length in the watershed (approx. 89%). Riparian cover is especially important for low-order streams, which are more affected by environmental change than large-order streams (EC 2004). While it is difficult to make watershed-wide predictions of stream and fishery quality based on the absence of riparian vegetation, it is known that riparian cover benefits aquatic life and the low proportion of riparian cover in the watershed may be correlated with poor stream and fishery health in some areas.

**Table 19:** Status of riparian vegetation in the Oshawa Creek watershed

| Subwatershed | Strahler Stream Order | | | | | Grand Total |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Enfield Branch | 35.9 (29%) | 15.2 (12%) | 13.6 (11%) | 6 (5%) | 0 (0%) | 71.1 (57%) |
| Goodman Creek | 4 (27%) | 3 (19%) | 2.6 (17%) | 0.00 (0%) | 0.00 (0%) | 10 (63%) |
| Oshawa Main Branch | 1.6 (10%) | 0 (0%) | 0.05 (4%) | 0 (0%) | 10 (68%) | 11.8 (79%) |
| Montgomery Creek | 2.6 (93%) | 0.00 (0%) | 0.00 (0%) | 0.00 (0%) | 0.00 (0%) | 2.6 (93%) |
| Kedron Branch | 5.5 (16%) | 3.6 (10.7%) | 1.3 (3.8%) | 5.5 (16%) | 0.00 (0%) | 15.9 (47%) |
| Windfield Branch | 5.2 (21%) | 3.8 (15.6%) | 0 (0%) | 7.9 (33%) | 0.00 (0%) | 16.8 (69%) |
| Harbour Branch | 0.6 (27%) | 0.00 (0%) | 0.00 (0%) | 0.00 (0%) | 1 (50%) | 1.6 (77%) |
| Raglan Branch | 25 (21%) | 23 (19%) | 9.5 (7.8%) | 4.4 (3.6%) | 0.00 (0%) | 62 (51%) |
| Grand Total | 80.8 (24%) | 48.8 (14%) | 27.2 (8%) | 24 (7%) | 11.2 (3%) | 19.2 (56%) |

Total stream length with 30m riparian cover (km) and percent of total stream length with cover (in parenthesis) by stream-order. Highlighted columns represent lower order streams which benefit greatly from riparian cover and may be given priority when determining areas for restoration. All results are based on the 2002 CLOCA drainage layer and 2005 Orthophotography Ecological Land Classification (ELC) interpretation.

## Landscape Influences

Natural land cover and various land uses have direct and indirect effects on the physical, chemical, and biological characteristics of streams. The use of models to quantify the impacts of land use on aquatic ecosystems has become a powerful tool and is well represented in scientific literature (Kilgour and Stanfield, 2006; Stanfield and Kilgour, 2006; Stanfield et al., 2006). To quantify the relationship between land use disturbance and aquatic ecosystem health in Southern Ontario streams, Stanfield and Kilgour (2006) developed a locally derived model called the Land Disturbance Index (LDI) which incorporates fish, benthic invertebrates, instream habitat and landscape data from sites across the north shore of Lake Ontario, including CLOCA watersheds (Figure 46). The LDI model predicts a threshold response for fish communities in response to increased land disturbance such that Salmonids are present in streams with low amounts of impervious cover and an absence from those with high amounts of impervious cover (Stanfield and Kilgour 2006). The high to moderately disturbed areas are manifested through below average water quality and high stream temperatures. As noted in the Stream Temperature discussion above, temperature is a limiting factor for the survival and productivity of fish and other aquatic organisms. Cold-water contains more dissolved oxygen than warm-water, and can support fishes that are sensitive to dissolved oxygen levels, such as Trout and Salmon. Warm-water fishes are able to tolerate lower oxygen levels.

A similar response in aquatic communities to landscape influences on water quality is also evident in the Oshawa Creek watershed. This response is most obvious in the distribution and proportion of sensitive benthic macroinvertebrates in Oshawa Creek. The results of this monitoring are described in greater detail in the Biological Water Quality section under Surface Water Quality (see Section 3.2.4.3).

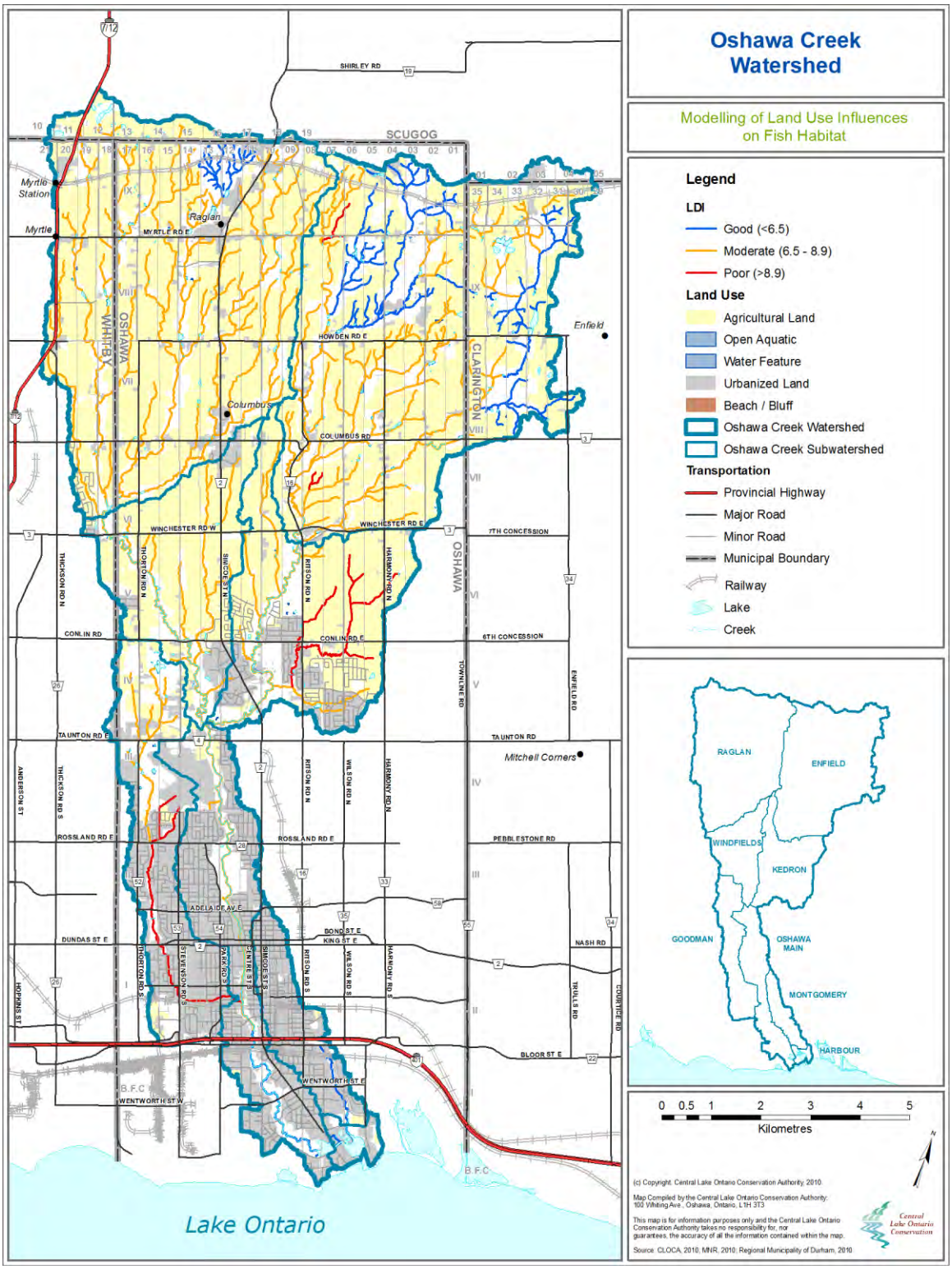


**Figure 46:** Modelled Land Use Influence on Fish Habitat in the Oshawa Creek watershed

3.3.1.1 Fisheries

The following section provides a brief summary of the fish community within Oshawa

Creek and the Oshawa Harbour. Additional information including fish species and family abundance can be found in the Central Lake Ontario Fisheries Management Plan (CLOCA/MNR, 2007), the Oshawa Creek Aquatic Resource Management Plan (CLOCA, 2002), or results from the 2007 CLOCA Aquatic Monitoring Program (CLOCA 2008).

Fish sampling was conducted using back-pack electrofishing at 65 stream sites in 2000, and 34 of these sites were revisited in 2007 (Figure 47). There was also limited sampling conducted in 1996 (2 sites), 1997 (3 sites) 2003 (1 site), and 2008 (4 sites) as part of various investigation and research projects. In addition to stream monitoring, CLOCA conducts coastal wetland fisheries surveys using a boat electrofisher as part of the Durham Region Coastal Wetland Monitoring Project (DRCWMP). This project has sampled the Oshawa Coastal Wetland and Oshawa Harbour at the mouth of Oshawa Creek annually since 2008.

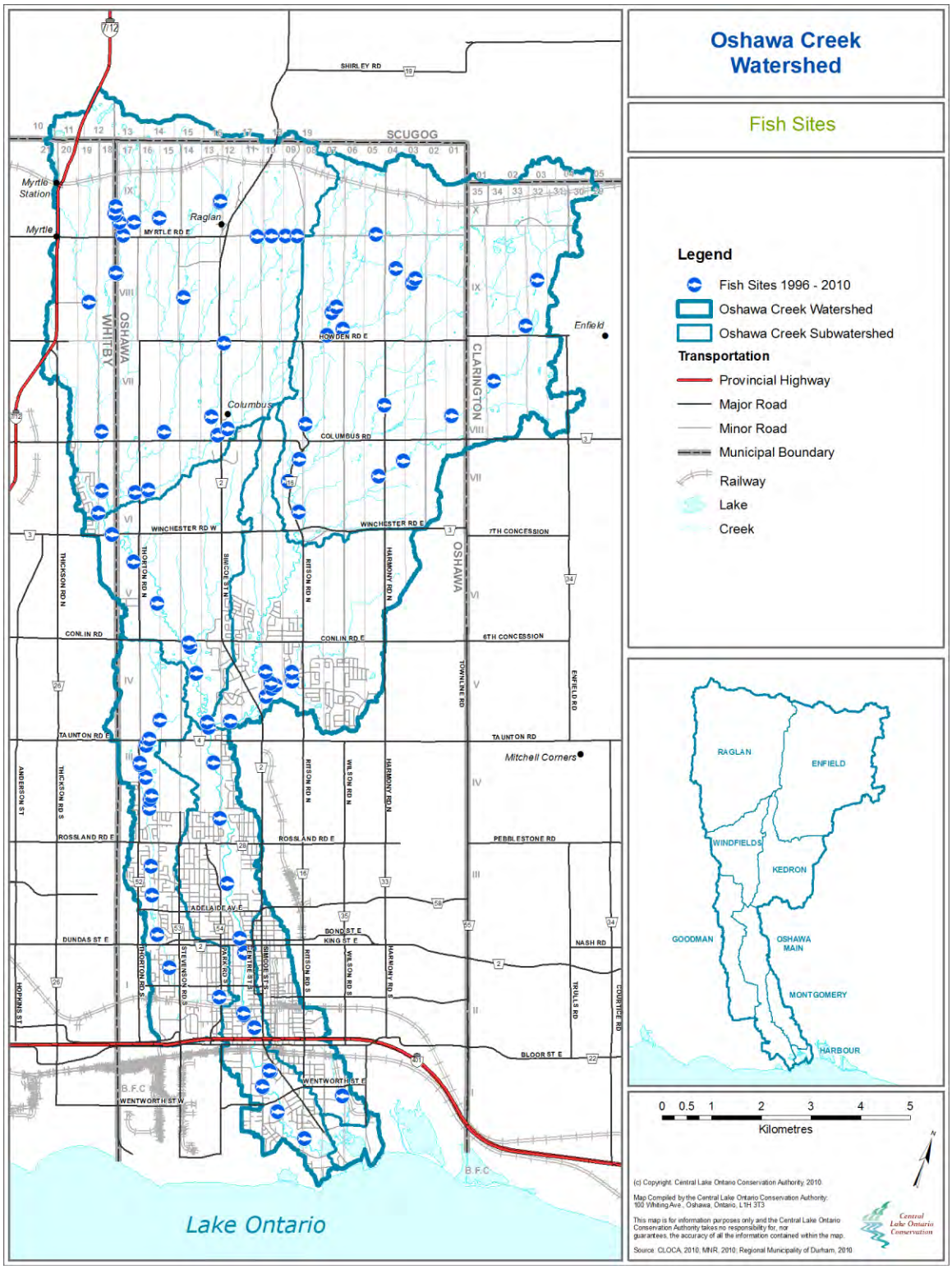


**Figure 47:** Fish Sampling Sites in the Oshawa Creek watershed

Currently, there are 35 fish species, representing 14 families, known to occur within the watershed including those found only within the Oshawa Coastal Wetland or Oshawa Harbour (Table 20). This list does not include species that have been reported on historically but were not present during recent monitoring efforts (e.g. Atlantic Salmon), but does include species that are new to the watershed either through range expansion or not having been detected during historical monitoring (e.g. Green Sunfish). While this only represents 48% of the 73 species known to inhabit CLOCA's jurisdiction and Lake Ontario, there may be other species using the creek that have not been identified due to the timing of sampling and biases associated with the sampling gear. Many of the fishes distributed within the CLOCA's jurisdiction and Lake Ontario will use either stream, marsh or lake habitats; however, some species are particular to Lake Ontario or are present in the stream during part of the year but difficult to detect due to the timing of aquatic monitoring. These include: American Eel, Burbot, Lake Trout, Splake, Lake Herring, Rainbow Smelt, and White Perch.

There are no fish species at risk known to currently exist within the Oshawa Creek watershed.

There are a number of aquatic invasive species present in the Oshawa Creek watershed. Perhaps most abundant, Goldfish, have been caught in Goodman Creek. This species likely originated from the release of aquarium or water garden fish into local streams or ponds. Goldfish have been observed in stormwater management ponds within the urban areas within CLOCA's jurisdiction. Another common invasive species is Common Carp which are present in the lower reaches of the watershed in close proximity to the Oshawa Creek Coastal Wetland where it has been known to uproot aquatic plants, and increase turbidity further inhibiting plant growth. Round Goby is present at various locations in the lower reaches of Oshawa Creek but to date has not been observed upstream of Highway 401.

Other non-native species are present in the watershed although not considered to be invasive. These naturalized species, which include Rainbow Trout, Brown Trout, and Chinook Salmon, were historically introduced to create additional recreational fishing opportunities. These species are now naturally reproducing in the watershed as indicated through observations of spawning activity and the presence of young-of-year (YOY) fish during summer electrofishing surveys.

In 2007, Green Sunfish were caught by CLOCA fisheries staff in the lower reaches of Oshawa Creek. This species is native to Ontario but has not been historically documented in this watershed. It is possible that this species was present in the watershed during the last round of monitoring in 2000 and misidentified as a Pumpkinseed, although all of the individuals observed were smaller (younger) fish suggesting that this range expansion is recent.

**Table 20:** Fish species currently found within the Oshawa Creek and Oshawa Creek Coastal Wetland and Oshawa Harbour

| Number | Common Name | Family | Scientific Name |
|---|---|---|---|
| 1 | Alewife [2] | Clupeidae | *Alosa pseudoharengus* |
| 2 | American Brook Lamprey [1] | Petromyzontidae | *Lampetra appendix* |
| 3 | Banded Killifish [1] | Fundulidae | *Fundulus diaphanous* |
| 4 | Blacknose Dace [1] | Cyprinidae | *Rhinichthys obtusus* |
| 5 | Bluntnose Minnow [1] | Cyprinidae | *Pimephales notatus* |
| 6 | Brook Stickleback [1] | Gasterosteidae | *Culaea inconstans* |
| 7 | Brook Trout [1] | Salmonidae | *Salvelinus fontinalis* |
| 8 | Brown Bullhead [12] | Ictaluridae | *Ameiurus nebulosus* |
| 9 | Brown Trout [1] | Salmonidae | *Salmo trutta* |
| 10 | Chinook Salmon [12] | Salmonidae | *Oncorhynchus tshawytscha* |
| 11 | Common Carp [123] | Cyprinidae | *Cyprinus carpio* |
| 12 | Common Shiner [1] | Cyprinidae | *Luxilus cornutus* |
| 13 | Creek Chub [1] | Cyprinidae | *Semotilus atromaculatus* |
| 14 | Emeral Shiner [12] | Cyprinidae | *Notropis atherinoides* |
| 15 | Fathead Minnow [1] | Cyprinidae | *Pimephales promelas* |
| 16 | Gizzard Shad [2] | Clupeidae | *Dorosoma cepedianum* |
| 17 | Goldfish [13] | Cyprinidae | *Carassius auratus* |
| 18 | Green Sunfish [1] | Centrarchidae | *Lepomis cyanellus* |
| 19 | Johnny Darter [1] | Percidae | *Etheostoma nigrum* |
| 20 | Logperch [1] | Percidae | *Percina caprodes* |
| 21 | Longnose Dace [1] | Cyprinidae | *Rhinichthys cataractae* |
| 22 | Mottled Sculpin [1] | Cottidae | *Cottus bairdii* |
| 23 | Northern Pike [2] | Esocidae | *Esox lucius* |
| 24 | Northern Redbelly Dace [1] | Cyprinidae | *Phoxinus eos* |
| 25 | Pumpkinseed [12] | Centrarchidae | *Lepomis gibbosus* |
| 26 | Rainbow Darter [1] | Percidae | *Etheostoma caeruleum* |
| 27 | Rainbow Trout [1] | Salmonidae | *Oncorhynchus mykiss* |
| 28 | Rock Bass [12] | Centrarchidae | *Ambloplites rupestris* |
| 29 | Round Goby [13] | Gobiidae | *Neogobius melanostomus* |
| 30 | Sea Lamprey [13] | Petromyzontidae | *Petromyzon marinus* |
| 31 | Slimy Sculpin [1] | Cottidae | *Cottus cognatus* |
| 32 | Smallmouth Bass [1] | Centrarchidae | *Micropterus dolomieu* |
| 33 | Spottail Shiner [12] | Cyprinidae | *Notropis hudsonius* |
| 34 | White Sucker [12] | Catostomidae | *Catostomus commersonii* |
| 35 | Yellow Perch [2] | Percidae | *Perca flavescens* |

[1] Species caught during CLOCA Stream Electrofishing (1996, 1997, 2000, 2007)
[2] Species caught in the Oshawa Creek Coastal Wetland and Oshawa Harbour (2008 & 2009 DRCWMP)
[3] Introduced/Non-native

In conclusion, the fisheries and aquatic habitat of Oshawa Creek and its respective tributaries face many environmental stressors including impacts from adjacent land uses (e.g. urbanization and intensive agriculture). This is manifested through water quality degradation, increased stream temperatures and ultimately impacts to aquatic life. While the watershed has its challenges, it still supports healthy fisheries including Chinook Salmon, Brook Trout, Brown Trout and Rainbow Trout populations, in addition to sensitive non-game species like Slimy Sculpin. Many opportunities exist for restoration in the watershed which has the potential to improve aquatic habitat and overall watershed health. These opportunities include riparian restoration, enhanced stormwater management, and retrofitting instream barriers to allow for fish passage into currently fragmented habitats.. While these restoration initiatives are important, emphasis should be placed on protecting the natural areas that exist which provide the last refuge for sensitive coldwater fish species from land use changes.

### 3.3.2 Vegetation, Wetlands, ESA's and ANSI's

The health of a watershed is evaluated using a number of criteria, including the vegetation and wildlife within its boundaries. Interestingly, the terrestrial conditions within a watershed both describe and contribute to the health of a watershed. For instance, vegetation and wildlife communities are successful when their environment is healthy. It is also known that increased vegetation in a watershed moderates flooding, stream temperature, and soil loss, which contributes to watershed health. As such, our knowledge of the existing terrestrial conditions in the Oshawa Creek watershed plays a key role in the evaluation of its overall health.

Due to a quickly changing landscape, including legislative changes, rapid urban development, new data, recent provincial wetland evaluations and a new methodology for determining core areas and corridors, an updated, comprehensive section on the existing conditions of Oshawa Creek's Terrestrial Natural Heritage has been prepared. This updated information will further advise and support new or revised management goals, objectives and targets. The terrestrial work that was undertaken and presented in the Plan (2002) is important in helping to assess

change over time and to determine if any of the Plan (2002)'s recommendations need to be revised.

The following summarizes applicable legislation which had not been described elsewhere, and sets out the methodology used to identify the terrestrial and wildlife features in the Oshawa Creek watershed. Following the methodology are the findings for the terrestrial environment followed by a description of the wildlife habitat.

### 3.3.2.1 Applicable Legislation and Policies

In the Province of Ontario, both Federal and Provincial legislation enable the protection of significant natural heritage features.

Species at Risk Act (SARA)

This Federal Act provides legal protection for extirpated, endangered or threatened species, as assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), as well as their residences. The Act aims to prevent wildlife species from becoming extinct, and to secure the necessary actions for their recovery by providing immediate protection to aquatic species, migratory birds, and any listed species on federal lands.

Ontario Endangered Species Act

On June 30th, 2008, Ontario's new Endangered Species Act came into effect. This legislation, which updated the previous Endangered Species Act, significantly expands the protection afforded to Species at Risk in Ontario by protecting Extirpated, Endangered and Threatened species as well as the habitat of Endangered and Threatened species. It applies to all private and public lands in the province of Ontario. The Ministry of Natural Resources is responsible for the administration of this Act, including enforcement and permitting. The assessment of Species at Risk in Ontario is carried out by the Committee on the Status of Species at Risk in Ontario (COSSARO).

### 3.3.2.2 Methodology

Significant Features

For the purposes of this discussion, significant features are Areas of Natural and Scientific Interest, Provincially Significant Wetlands, and Environmentally Sensitive Areas. These significant features within the Oshawa Creek Watershed are shown on Figure 48.

### *Areas of Natural and Scientific Interest (ANSI)*

ANSIs are areas of land and water having natural landscapes or features that have been identified as having life or earth science values warranted for protection, scientific study or education. ANSIs are classified as either Life Science (an area having provincially or regionally significant representative ecological features) or Earth Science (an area having provincially or regionally significant representative geological features). ANSIs are identified by the OMNR and are either provincially or regionally significant.

The reader will find that, generally, discussion on individual ANSIs is somewhat limited. This is due to the fact that those qualities that lend themselves to the identification of an area as an ANSI are often the same qualities that result in an area being identified as a PSW or ESA. Where an ANSI is also a PSW or ESA the description of the ANSI is covered in the text regarding PSWs or ESAs.

Some ANSIs are identified as "candidate", meaning that they have had the field work completed by OMNR; however, they are not "official" until such time as final approval is granted by OMNR. The fact that an ANSI may be categorized as "candidate" does not in any way imply that the values or features for which the ANSI has been identified are any less significant. For this reason, recognition of these "candidate" ANSIs as being a valuable component of the terrestrial natural heritage system is warranted.

### *Provincially Significant Wetlands (PSW)*

PSWs have been evaluated using the Ontario Wetland Evaluation System, which recognizes four types of wetlands: marsh, swamp, fen, and bog. They can occur as single contiguous areas or as groupings of smaller wetlands known as wetland complexes. They can also be designated as locally or provincially significant, depending on their evaluation scores. The OMNR is responsible for evaluating and designating PSWs in Ontario.

### *Environmentally Sensitive Areas (ESA)*

The Environmentally Sensitive Areas Mapping Study prepared by Gartner Lee, (1978) on behalf of the Central Lake Ontario Conservation Authority identifies the environmentally sensitive areas in the CLOCA jurisdiction. The study (Gartner Lee, 1978) entailed the collection and interpretation of biophysical data using specific criteria (Table 21).

**Table 21:** ESA biophysical criteria

| Criteria | Description |
|---|---|
| **Significant Terrain** | Flood-prone areas and wetlands<br>Areas serving groundwater functions<br>Headwater source areas<br>Erosion-prone areas<br>Significant geomorphological landforms |
| **Significant Forests** | Forests serving important environmental functions<br>Forests possessing unusual attributes |
| **Significant Wildlife** | Areas of suitable habitat for important wildlife considerations<br>Areas where uncommon animals have been known to occur including game birds or fur-bearing mammals |
| **Significant Fisheries** | Suitable spawning areas<br>Conditions suitable for and/or presence of cold and warm water fisheries |

Source: Gartner Lee, 1978

The identified ESAs were then assigned a level of sensitivity between high and low. High sensitivity areas are those which, on their own merit or in combination with other significant biophysical factors, are highly sensitive to disturbance. They usually possess several interrelated environmental factors of significance such that the alteration of one part of the environmental system may negatively influence others (Gartner Lee, 1978). Only the high and moderately high sensitivity ESAs have been identified and discussed in this document with the exception of the Oak Ridges Moraine and the Lake Iroquois Beach, which are generally considered of "medium sensitivity" with some "high sensitivity" features.

## Vegetation

In the Oshawa Creek watershed, the Ecological Land Classification System for southern Ontario (ELC) has been used to categorize vegetation communities. This system is described in more detail in Appendix 5: Ecological Land Classification.

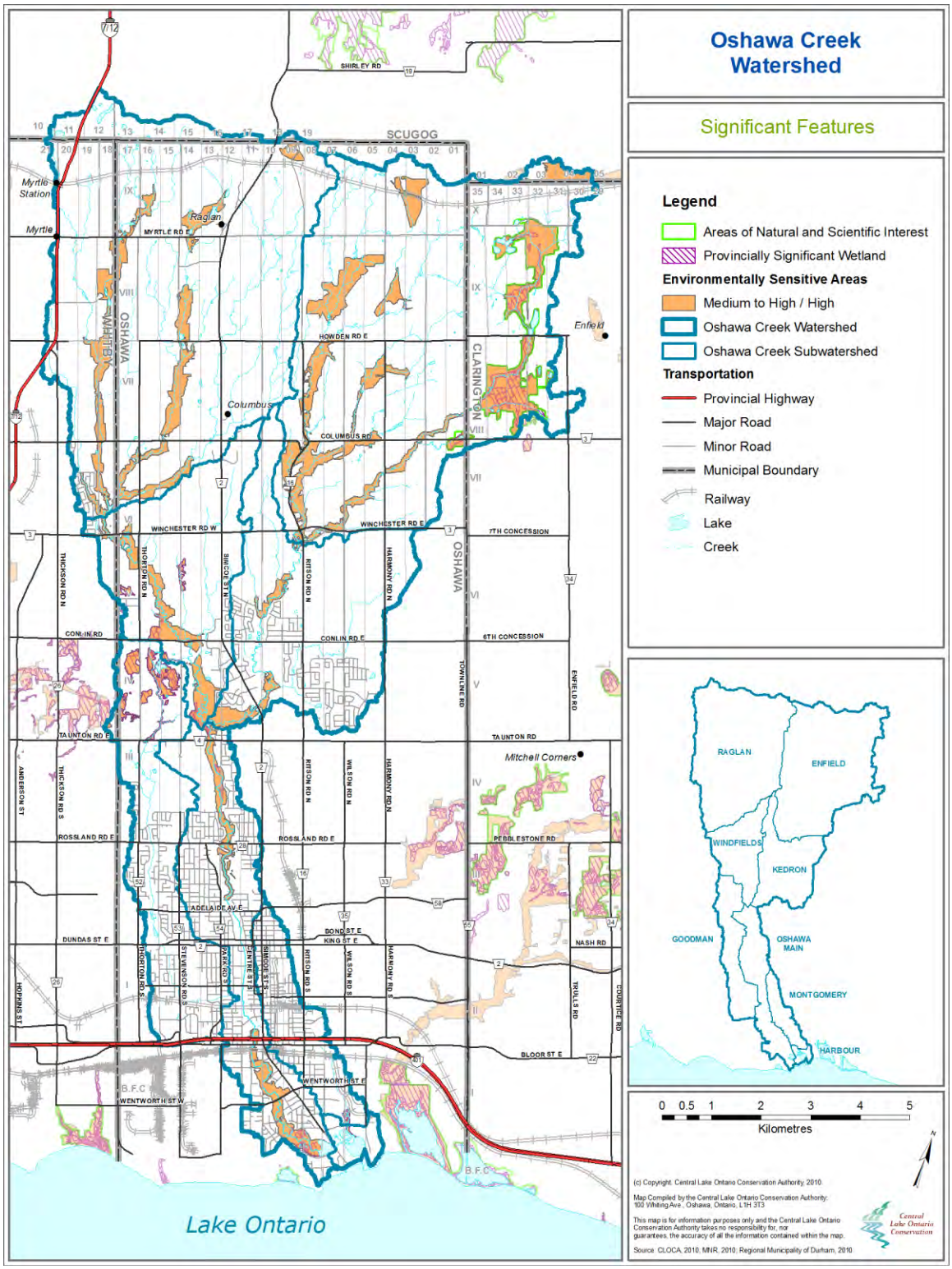


**Figure 48:** Significant features in the Oshawa Creek watershed

## Wildlife Habitat

Wildlife species have a variety of habitat needs and consequently occupy a wide range of habitat types. Broadly, these habitats can be subdivided into the following groups: forests, including upland and wetland forests; wetlands, including marshes and open water wetland areas; and regenerating habitats, including meadows, grasslands, prairies and thickets.

Forests

The term 'forest' is a broad description of a treed area, but there are many types of forests and some wildlife species are specially adapted to particular forest types. Table 22 describes the main forest types found within the Oshawa Creek watershed and highlights their value to wildlife.

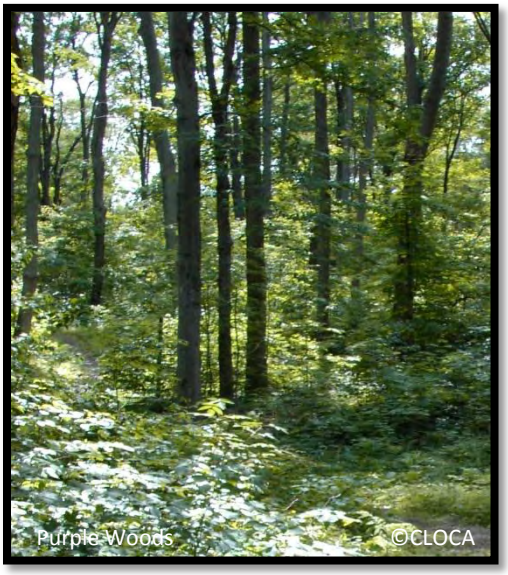

**Table 22:** Forest attributes and their wildlife functions
(See Appendix 5 for acronym descriptions)

| Type | Attributes and Functions |
|---|---|
| **Deciduous Forests (FOD)** | Deciduous forests do not provide much cover in the winter due to loss of leaves so they tend to be seasonal habitats, although wildlife may continue to use them throughout the winter months if the forest is adjacent to another habitat type with suitable winter cover. The key wildlife habitat components in a deciduous forest include:<br><br>• Good vertical structure, which exists when all of the layers of forest vegetation are present such as ground cover, understory, mid-story, canopy, and super canopy. Ideally, these layers should be arranged in a random fashion, as would be created through natural processes (e.g. single trees falling down creating canopy gaps).<br>• Habitat trees that provide opportunity for creating cavities and dens. An abundance of these trees is preferable.<br>• A stable food supply in the form of herbaceous vegetation, woody browse, and/or fruit and nuts.<br><br>Examples of wildlife species most commonly associated with deciduous forests are deer, woodpeckers, grouse, fox, and squirrels. If a forest block is of sufficient size and shape it may also support forest interior breeding birds and mammal specialists. |
| **Coniferous Forests (FOC)** | Coniferous forests tend to be dense, dark and damp with limited undergrowth since very little light ever reaches the forest floor. These conditions appeal to a number of wildlife species, including wild turkey and some amphibians, which are dependent on the good cover and moist soil conditions that coniferous forests provide. Other species, such as deer and songbirds, utilize coniferous forests during the winter when the dense forest cover protects them from the harsh winter environment. Coniferous forests are excellent habitat for species such as red squirrel that specialize in exploiting specific food sources like seed cones. |
| **Mixed Forests (FOM)** | A mixed forest is composed of both deciduous and coniferous species. Because of this mix, these forests are able to provide year-round cover as well as an abundance of food, which makes this forest type very desirable for wildlife.<br><br>Mixed forests tend to have a good representation of tree species that produce fruit or nuts, such as red oak, black cherry, and beech. Mixed forests also offer a diversity of habitat niches, which supports a wide variety of animal species. Songbirds, small and large mammals, raptors, amphibians, and reptiles may all inhabit mixed forests. As with deciduous forests, habitat quality is closely linked with forest structure: the more vertical layers, the better the cover and potential food production. Structural complexity within a forest is critical for most habitat specialists or area sensitive species. |
| **Deciduous, Coniferous and Mixed Swamps** | Swamps, like upland forests, vary in their tree composition. The attributes that distinguish deciduous, coniferous and mixed forests are generally the same for deciduous, coniferous and mixed swamps. The major difference between upland forests and swamps however is the soil moisture. In |

| Type | Attributes and Functions |
|---|---|
| **(SWD, SWC, SWM)** | swamps, the soil ranges from moist to having standing water.<br><br>Seasonal standing water offers specialized breeding habitat for frogs and salamanders, so swamps are key habitat areas for amphibians. The vegetation in swamps is also different as plants that prefer wet conditions are able to thrive. |
| **Cultural Plantation (CUP)** | A plantation is typically a forest that has been planted by humans for the purpose of timber production. The species are almost exclusively coniferous, and the trees are often planted in rows like a crop to provide easy access for maintenance and harvesting.<br><br>Plantations have limited habitat opportunities for wildlife. There is usually little cover and the straightness of the tree rows offers poor structure for escape or refuge. One of the values of plantations to wildlife is in providing a buffer to other more important habitats.<br><br>As a plantation matures, deciduous species may establish in the undergrowth layer and it may succeed into a healthy mixed forest. Thus plantations have the potential to become good wildlife habitats. Wildlife typically associated with plantations includes red squirrels and predators such as weasels that exploit the abundance of small mammals. |

Wetlands

Wetlands come in many forms and offer a wide range of wildlife services, depending on the amount and type of vegetation. For marshes, good quality habitats are associated with well established aquatic vegetation and nearby upland cover. The edges of this habitat are typically the most productive areas, and thus are the most important for wildlife. These habitats are particularly important for amphibians, wading birds, shorebirds, and waterfowl.

Grasslands, Meadows, and Thickets

Regenerating habitats are those habitats that are in the process of reverting from meadow or thicket into forest. In the past, these features would have existed as a result of fire or other destructive occurrences. In today's landscape, regenerating habitats are most often the result of previously cleared areas being left un-maintained.

These habitats are varied in their composition and structure, as they are usually in more than one stage of succession, and they provide a maximum amount of habitat edge. As such, they are able to support a large number of species associations. Because regenerating habitats are in a constant state of change, their value to particular wildlife species also changes, so it is often more practical to consider regenerating habitats collectively rather than as individual areas. Generally speaking, grasslands and meadows, which are the first stage of succession, appeal to grassland birds, small mammals, and insects such as bees and butterflies that are attracted to the abundance of flowers. Meadows and grasslands can be highly productive habitats and are important features in the landscape, but unless they are maintained as such by human activity or fire, over time they succeed to thickets, which contain more shrubs and small trees. As the vegetation changes, the suite of wildlife also changes in favour of those species that prefer more shrub cover. Over longer periods of time, young forests will begin to emerge, and generalist birds and mammals will increasingly occupy the area.

Core Habitat Areas

Although virtually all vegetated areas provide some habitat for wildlife, there are some habitats that can be considered "core" habitats because they are able to provide for a large suite of wildlife or support sensitive wildlife species. Deciding which habitats should be considered core habitats is a somewhat subjective exercise depending on the species that are being considered, but for the purposes of this document, the designation of core habitat areas has been made using the following criteria:

**Size** being the physical size of the habitat being measured. Larger sized habitats are preferable to smaller sized habitats.
**Shape** refers to the geometric shape of the habitat being measured. Compact habitat patches (e.g. square or circular) are preferable to linear (e.g. rectangular) patches as they have fewer edges.
**Juxtaposition** being the position of the habitat on the landscape relative to other features such as settled areas or natural areas. Natural areas that are adjacent to other natural areas are preferable to natural areas adjacent to urban developments.
**Representation** is the range of a specific habitat type in the watershed. A high diversity of well-distributed habitat types is preferable.
**Multiple Function** is the ability of a habitat to provide more than one function for local wildlife communities.
**Species at Risk** refers to the ability of a habitat patch to support species at risk (as identified by COSEWIC and COSSARO).

Habitat size and shape are important factors for any habitat, however in forests, size and shape are particularly important because they determine the amount of forest interior (100 m from forest edge) and deep forest interior (200 m from forest edge) that may be present. Forest interior is a prerequisite for many breeding birds as it provides increased protection from wind, light, nest parasitism and predation. In the evaluation of core habitats, these criteria were assessed using a Landscape Analysis Model (see Appendix 6).

A Landscape Analysis Model was also used to evaluate habitat juxtaposition (see Appendix 6). As human development approaches, and in some cases surrounds, wildlife habitats, the effects of noise, light, disturbance from recreation or pets, and other stressors are increased. Consequently, species that are sensitive to disturbance are less likely to occupy these habitats even if they meet their needs for food or cover, and the result is a loss in overall biodiversity.

Representation and multiple function have been assessed using ELC (see Appendix 5) Because wildlife have varying needs, and some have very specific needs, a wide variety of habitats must exist within a watershed to support biodiversity. Representation is not limited to broad habitats such as forests and wetlands; it includes types of forests as well as types of wetlands.

The evaluation of habitats for species at risk within the Oshawa Creek watershed was done using information from the Natural Heritage Information Centre (NHIC), from data collected through field work, external documents or Environmental Impact Studies, and from data reported to the Authority by the public.

Wildlife Movement

Animals are not stationary. Species have a tendency to move between habitats to fulfill dietary or lifecycle needs, seek refuge, and escape predation, so connectivity between habitat patches is important for maintaining wildlife populations. At a broader scale, connectivity enables animal migration, which is integral to maintaining genetic diversity and facilitating the repopulation of habitats after local extinction events.

Because corridors serve a number of functions and operate at varying scales, they can be categorized in the following manner (Table 23).

**Table 23:** Wildlife corridor categories

| Type | Description |
|---|---|
| **Regional Corridors** | These are major movement corridors which connect a number of watersheds at a large landscape scale. Regional corridors are often comprised of upland areas since they exist across watershed divides. |
| **Landscape Corridors** | These are major movement routes within the watershed that connect core areas and/or are robust enough to be sustainable as habitat units themselves. They typically follow linear features such as creeks and valleys, and can be composed of a series of independent habitats that allow wildlife to "hopscotch" across the landscape. |
| **Local Corridors** | These are minor movement routes within the watershed that help to connect habitat patches into a continuous series. They are often associated with creek valleys and typically function at a sub-watershed scale. They function with landscape corridors to connect the smaller habitats to the larger ones. |

When identifying core habitats and movement corridors, it is important to note that the distinction between cores and corridors is human-made as a result of forest fragmentation from development. Prior to settlement, the Oshawa Creek watershed would have been largely forested, so cores and corridors most likely would not have existed at this scale. Consequently, categorizing natural areas into cores and corridors is not always black and white, particularly when a corridor contains high quality habitat. In these instances corridors may also be core habitats, and the ultimate designation is based on judgment. Additionally, what is habitat to one species may be a corridor to another. This is evident when comparing the habitat needs of a coyote to those of a frog.

Finally, it is also worth noting that core and corridor designations are influenced by the scale at which they are being identified. The Oak Ridges Moraine is an example of a number of core habitats which connect much larger core habitats across the province. At the watershed scale, the forest patches on the moraine are identified as core wildlife habitats, however, at the provincial scale the moraine is a corridor.

Additional Habitat Areas

During the course of the evaluation of core habitat areas and movement corridors, a number of smaller habitat patches were excluded. Although they did not necessarily meet the criteria for either of these categories, it was felt that they still served important wildlife functions at a local level and should not be overlooked as contributors to overall wildlife habitat. As such, these vegetation units were included in the Core Habitat and Corridor maps under the term "Vegetation".

## Watershed Health

In 2004, Environment Canada published a document entitled "How Much Habitat is Enough?" which offered a framework for restoring natural habitats in areas of concern. The guidelines offered within the document were adopted to assist with an overall evaluation of the terrestrial conditions within the Oshawa Creek watershed, Table 24 outlines the parameters used to indicate watershed health.

**Table 24:** Environment Canada's AOC Wetland and Forest Habitat Restoration Guidelines

| Parameter | Guideline(s) |
|---|---|
| **Wetland Habitat Guidelines** | |
| Percent wetlands in watersheds and subwatersheds | Greater than 10% of each major watershed in wetland habitat;<br>Greater than 6% of each subwatershed in wetland habitat;<br>or<br>Restore to original percentage of wetlands in the watershed. |
| Wetland type | The only wetland types suitable for widespread rehabilitation are swamps and marshes |
| Wetland location | Wetlands are key in headwater areas for groundwater discharge and recharge, flood plains for flood attenuation, and coastal wetlands for fish production |
| **Forest Habitat Guidelines** | |
| Percent forest cover | Greater than 30% of watershed should be in forest cover |
| Size of largest forest patch | At least one 200 ha forest patch which is a minimum of 500 m wide |
| Percent of watershed that is forest cover 100 m (forest interior) and 200 m (deep forest interior) from forest edge | Greater than 10% forest interior (forest cover 100 m or further from a forest edge);<br>Greater than 5% deep forest interior (forest cover 200 m or further from a forest edge). |
| Forest shape | Forest patches should be circular or square in shape |
| Proximity to other forested patches | Forest patches should be within 2 km of one another or other supporting habitat features |
| Fragmented landscapes and the role of corridors | Corridors designed to facilitate species movement should be a minimum of 50 m to 100 m in width. |

Source: modified from Environment Canada, 2004

## Data

While efforts have been made to accurately present the findings reported in this chapter, factors such as rounding, computer digitizing and data interpretation may influence results. For instance, in data tables no relationship between significant digits and level of accuracy is implied, and values may not always sum to the expected total.

Furthermore, it should be noted that the species reports from which the tables in this chapter are populated are derived from a number of sources. The accuracy of these reports may vary according to the knowledge and experience of the observer. As such, it is recognized that the species lists in this document may contain errors or misidentifications. In addition, species at risk in Ontario and in Canada are periodically reviewed and updated. The species at risk presented in this report are current as of June 2009.

For the purposes of visual presentation, the mapped data layers (where available) have been shown as faded areas beyond the watershed and subwatershed boundaries. For areas outside of the Oshawa Creek watershed boundary, these visual data layers may not have been analyzed for discussion purposes and therefore have not been included in this discussion.

Great Blue Heron ©Keith Isnor

Cedar Waxwing ©Keith Isnor

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3.3.2.3 Findings – Terrestrial Environment

Areas of Natural and Scientific Interest & Provincially Evaluated Wetlands

The Oshawa Creek watershed contains 1 Life Science ANSI and all or part of 3 PSWs. These are listed in Table 25.

**Table 25:** Significant Features within the Oshawa Creek Watershed

| Name | Significance | Subwatershed |
|---|---|---|
| **ANSIs** | | |
| Enfield Wetlands (Life Science) | Regional (Candidate) | Enfield |
| **PSWs** | | |
| Oshawa Creek Coastal Wetland Complex | Provincial | Main, Montgomery and Harbour |
| Whitby-Iroquois Beach Wetland Complex | Provincial | Main, Windfields, and Goodman |
| Enfield Wetland Complex | Provincial | Enfield |

### *Enfield ANSI and PSW Complex*

The Enfield Wetland Complex is 102 ha in size and is made up of 24 wetland units, all of which are privately owned. All but 4 of the wetlands in this complex are located in the Oshawa Creek watershed (Enfield subwatershed). The remaining wetlands are situated within the Black/Harmony/Farewell Creek watershed to the east (Varga, 2006).

Following its original evaluation in 1994, the wetland complex was identified as locally significant. In 2006 however, the evaluation was updated and the Enfield Wetland Complex was upgraded to provincially significant because of the identification of numerous locally significant species in the wetlands as well as an acknowledgement of the wetland's contribution to groundwater discharge. This wetland complex is incorporated into the provincially significant Enfield ANSI, which is the best display of kettle and headwater wetlands on the Pontypool Lobe of the Oak Ridges Moraine (Varga, 2006).

### *Whitby-Oshawa Iroquois Beach Wetland Complex*

This provincially significant wetland complex originates within the Anderson Street Woods in Whitby and follows the Lake Iroquois Beach through to Simcoe St. in Oshawa, straddling the Lynde Creek, Pringle Creek and Oshawa Creek watersheds. Specifically, the wetland complex is centred on the headwater reaches of the Pringle and Goodman Creeks (Varga, 2005). It was evaluated in 2004 and is entirely within private ownership.

The majority of these wetlands are swamps with some marsh communities represented. It is considered significant due to its contribution to biodiversity, water quality maintenance, and flood attenuation. It also provides habitat for Butternut, which is an endangered species, as well as a number of birds and plants that are regionally or locally significant. Furthermore, like most wetlands in southern Ontario, it is a rare feature (Varga, 2005).

The Whitby-Oshawa Iroquois Beach wetland complex is recognized as being situated in the middle of a major east-west "green" corridor along the Iroquois Beach and reforestation of gaps between the wetlands and woodlots in this complex is one of OMNR's recommendations for improving this wetland (Varga, 2005).

### *Oshawa Creek Coastal Wetland Complex*

This 20.2 ha wetland complex, comprised of 7 wetland units, is entirely contained within the Oshawa Creek watershed and is the watershed's only coastal wetland. It was evaluated in 2007 and received a provincially significant designation primarily because of its 'special features' score.

One such feature is the fact that it is a coastal wetland. Coastal wetlands, being wetlands that are situated along the shoreline, are considered rare in this ecodistrict as they have historically been drained or developed. As such, remaining coastal wetlands, particularly in this region, tend to be regarded as provincially significant regardless of size or quality. Additional features include the presence of Tufted Titmouse (provincially significant bird), Nuttall's Waterweed (regionally significant plant), and 4 locally significant plant species.

In the Oshawa Creek watershed this wetland is generally well-connected to other habitats via the Oshawa Creek valley, however, connections to the east and west, particularly Oshawa Second Marsh, need improvement.

Environmentally Sensitive Areas

Excluding the Oak Ridges Moraine and the Lake Iroquois Beach, the Oshawa Creek watershed has 10 ESAs, 8 of which exhibit the highest level of sensitivity (Table 26). High and moderately high sensitivity ESAs are shown in Figure 48 and are described in further detail below

The Oak Ridges Moraine (ORM) is generally identified as moderately sensitive. In the Oshawa Creek watershed, only the Raglan and Enfield subwatersheds contain areas of this ESA. The ORM was identified as an ESA because it is a major groundwater recharge area and because major alterations or changes in land use may impact groundwater and/or surface water. The headwaters of the Oshawa Creek originate, for the most part, in the ORM. Those parts of the Moraine exhibiting significant wildlife habitat, significant forest and significant terrain features, such as Purple Woods and Mt. Carmel Woods, have been identified as areas of high sensitivity.

The Lake Iroquois Beach, which is also generally considered to be moderately sensitive, is a local ground water recharge area that is found throughout much of the CLOCA jurisdiction. Characteristics of the Beach include a shallow water table, wetlands and seepage zones. These features play an important role with streams, forests and wildlife habitat. The Lake Iroquois Beach falls within the Oshawa Main, Windfields and Kedron subwatersheds.

**Table 26:** ESAs in the Oshawa Creek watershed

| Name | Sensitivity | Subwatershed |
|---|---|---|
| Oshawa Harbour | Low to Moderate | Harbour |
| Oshawa Creek Woods | High | Oshawa Main |
| Oshawa-Goodman Creek Valleys | Moderately Low | Oshawa Main & Goodman |
| Oshawa Creek into Iroquois Beach | High | Oshawa Main, Windfields and Kedron |
| West Branch of Oshawa Creek | Moderate to High | Raglan & Windfields |
| East Branch of Oshawa Creek | Moderate to High | Enfield & Kedron |
| Townline Pond | High | Enfield |
| Enfield Woods | High | Enfield |
| Purple Woods | High | Raglan |
| Mt. Carmel Woods | High | Enfield |

***Oshawa Creek Woods*:**
This reach of lower Oshawa Creek from the mouth virtually to Highway 401 exhibits high sensitivity. The steep valley walls which predominate in this section of the stream are highly erodible and the presence of the Oshawa Creek Woods which cover the valley margins is important in minimizing streambank erosion. The woods represent a significant wildlife area offering shelter and cover for migrating birds. The white ash-hard maple-hemlock forest is a major natural resource in an urban setting.

***Oshawa Creek into Iroquois Beach*:**
This area extends from halfway through Oshawa to the Lake Iroquois shoreline and is characterized by erodible steep valley walls and substantial forest cover. The interrelationship of forest and physical setting and the increased potential of the creek to support warm water sports fish make this area highly sensitive to land use alteration.

***West Branch of Oshawa Creek*:**
Most of the west branch of the Oshawa Creek valleys and tributaries exhibits high sensitivity. Significant forested areas serve hydrological and erosion control functions and in upper reaches provide shade and cover for sensitive coldwater sports fisheries.

***East Branch of Oshawa Creek*:**
Thin ribbons of forest cover the margins of gently sloping stream valleys. Forests are functional in providing shade and cover for coldwater fisheries and buffering fluctuations in flow and temperature. These valley bottom lands, associated streams and forests are considered highly sensitive.

***Townline Pond*:**
This small but reportedly deep pond is set in a wetland area which contributes flow to a suspected trout stream. Forest growth in and around the wetland serves a water quality function and is composed of unusual species. It is considered highly sensitive.

***Enfield Woods*:**
Set in a large wetland, this extensive and highly diverse forest area exhibits high sensitivity as a result of a number of biophysical factors. Waters supplied year-round by the wetland aid in sustaining a coldwater sports fishery downstream. The forest provides excellent wildlife habitat and contributes to the water regulatory function of the wetland. Uncommon birds and fur-bearing mammals are reported to reside here.

***Purple Woods*:**
This highly sensitive woodlot provides wildlife cover and supports some uncommon wildflowers. Birds uncommon in the CLOCA jurisdiction nest here.

***Mt. Carmel Woods*:**
Serves the environmental functions of forests and represents a significant wildlife area. Uncommon birds are reported to nest here. The area is regarded as highly sensitive.

Vegetation
The vegetated cover within a watershed greatly affects overall watershed health. Natural vegetation provides benefits including:

- Reduced soil erosion and sedimentation of watercourses;
- Reduced intensity and volume of stormwater;
- Reduced surface water temperatures;
- Maintenance of associated habitat resources;
- Improved water quality;
- Carbon sequestration; and,
- Aesthetic and recreational values.

Turkey Tail Mushroom ©CLOCA

Larger Red Trillium ©CLOCA

Like many of the watersheds in the CLOCA jurisdiction, the Oshawa Creek watershed contains a number of distinct physiographic regions, resulting in a variety of distinct vegetation communities.

Jack-in-the-Pulpit © CLOCA

Table 27 summarizes the vegetation communities present in the Oshawa Creek watershed. In addition to the amount of land each community represents in the watershed, the table identifies each community as a percentage of all the naturalized areas in the watershed as well as a percentage of the total watershed land area.

**Table 27:** Summary of the habitat types and their representation in the Oshawa Creek watershed

| Habitat Type | Oshawa Creek Watershed | | As a % of total land area in watershed |
|---|---|---|---|
| | Cover (ha) | As a % of total natural cover in watershed | |
| Beach/Bar | 0.00 | 0.00% | 0.00% |
| Meadow | 467.04 | 16.50% | 3.92% |
| Successional | 491.42 | 17.36% | 4.12% |
| Forest | 1790.45 | 63.24% | 15.02% |
| Wetland | 816.16 | 28.83% | 6.85% |
| Open Water | 19.10 | 0.67% | 0.16% |
| Total Natural Cover* | **2831.19** | **100%** | **23.76%** |

*Swamp communities appear in both forest and wetland calculations. Totals have been adjusted to account for this duplication.

Overall, the Oshawa Creek watershed contains a moderate amount of natural cover (23%). Although most of this cover is forest (63%), the watershed only has 15% forest cover across its entire area. This falls well below Environment Canada's 2004 recommendation of 30% minimum forest cover in a watershed. Total wetland cover is just under 7%, which is also well below Environment Canada's recommendation of 10% wetland cover per watershed.

### *Forests*

Forest associations in the Oshawa Creek watershed are typical of the Great Lakes-St. Lawrence Forest Region whereby:

- upland forests are generally composed of Sugar maple, American beech, White ash, Red oak, White pine and White birch;
- common valley associations include Eastern white cedar, Eastern hemlock, Green ash, Manitoba maple and Yellow birch;
- treed swamps are commonly comprised of species such as Poplar, American white elm, Basswood, Willow, Silver maple, Red maple, Black ash, Eastern hemlock, Yellow birch, and Eastern white cedar; and,
- conifer plantations consist primarily of Red pine, Scots pine and White pine.

Cultural plantations, deciduous forest and mixed swamps account for the majority of the forest types in the watershed and they are concentrated within the ORM and the Lake Iroquois Beach (Figure 49). Appendix 5 provides a description of the Ecological Land Classification communities. Large tableland forests are virtually absent within the urban landscapes.

The ORM and its south slope contain the largest forest blocks within the watershed, although few are in excess of 20 ha and many are somewhat fragmented. Within the Lake Iroquois Beach there are also a number of forest units, mostly deciduous and mixed swamps, which coincide with the Whitby – Oshawa Iroquois Beach PSW complex and are remnants of that which would have once been characteristic of the region. Urban development in this part of the watershed is ongoing and efforts to maintain and improve connections between these forest blocks should be a priority.

### *Valleylands*

Although highly developed, the Oshawa Creek valleylands, through the urban centre (from the Lake Iroquois Beach south to Highway 401) are moderately vegetated, with limited riparian cover; an expansive park system forms much of the urban valley. The valleylands south of Highway 401 to Lake Ontario provide the most vegetative cover within the urban area, and are also documented as an Environmentally Sensitive Area (ESA) (Gartner Lee, 1978).

Between the Lake Iroquois Beach and the ORM, the valleys are also moderately vegetated, although there are some valley sections that are robust enough to contain forest interior conditions. They are most often coniferous in nature: lowland Cedar forest is the dominant vegetation type within this feature. Small deciduous forests, hedgerows and windbreaks divide agricultural and pasture lands on the tableland between the Oshawa Creek tributaries.

### *Wetlands*

Wetland communities are relatively well-distributed across the Oshawa Creek watershed within the valleys, particularly north of the Lake Iroquois Beach, but outside of the valleys there are virtually no wetlands. The vast majority of the wetlands that do exist in the watershed are forested swamps, with marsh communities only represented along creek edges and in the Oshawa Creek coastal wetland complex (Figure 49).

### *Grasslands, Meadows, and Thickets*

Approximately 33% of the vegetation in the Oshawa Creek watershed is regenerating habitat (roughly 8% of the landscape). Most of these areas are cultural meadows, thickets, and regenerating swamps, which will succeed into forest if left undisturbed. These communities appear across the watershed and vary in both productivity and quality. No true prairie-like habitats have been identified within this watershed.

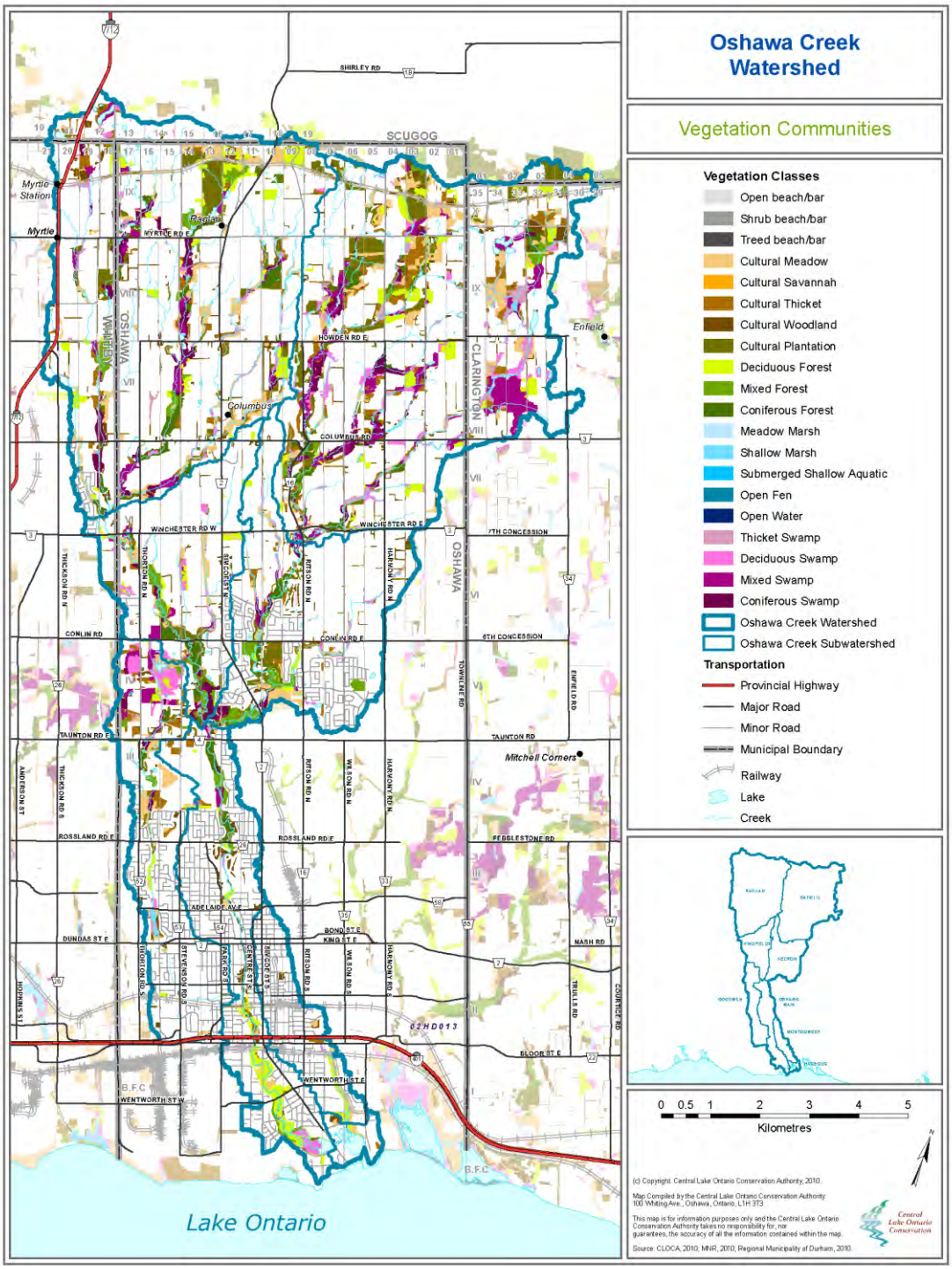



**Figure 49:** ELC vegetation communities for the Oshawa Creek watershed

Subwatershed Findings

At a subwatershed scale (Table 28), natural cover and community diversity varies widely.

The Enfield subwatershed is the largest of the Oshawa Creek subwatersheds and has both the highest percentage (31%) and the largest area (1114 ha) of natural cover. It also has the highest wetland cover (11%) of all of the Oshawa Creek subwatersheds. Not surprisingly, it is the biggest contributor of natural cover (9%) to the watershed as a whole. In other words, of Oshawa Creek's 15% forest cover and 6% wetland cover, the Enfield subwatershed contains over a third of the forests (5.9%) and half of the wetlands (3.2%).

The Raglan subwatershed is the second largest subwatershed and is comparable in size to the Enfield subwatershed. As with the Enfield subwatershed, the Raglan subwatershed also has some of the highest forest cover (15%) and wetland cover (6.5%) in the watershed, and is a significant contributor to the watershed's overall natural cover. Together, these two subwatersheds contain almost ¾ of the watershed's natural cover, 70% of the watershed's wetlands, and 2/3 of the watershed's forests. Clearly there is a disproportionate distribution of natural heritage features and services across the Oshawa Creek watershed.

The Windfields, Kedron, Goodman, and Oshawa Main subwatersheds are all relatively equal in size and have comparable amounts of natural cover and forest cover (10-14%). Where they differ significantly is in their wetland cover. Both the Goodman and Windfields subwatersheds contain a good proportion of wetland cover. Environment Canada (2004) recommends that a subwatershed have at least 6% wetland cover, and the Goodman subwatershed is at 8% while the Windfields subwatershed is just below that line at 5%. The Kedron and Oshawa Main subwatersheds, by comparison, have only 2.75% and 1.6% wetland cover respectively. In the case of the Windfields and Goodman subwatersheds, their wetland cover is directly related to the presence of deciduous and mixed swamps, part of the Whitby – Oshawa Lake Iroquois Beach wetland complex, which are representative of this physiographic region as is demonstrated throughout the CLOCA jurisdiction. Despite having portions of the Lake Iroquois Beach in their subwatersheds, the Kedron subwatershed in particular, and the Oshawa Main subwatersheds no longer (or never did) contain such an abundance of swamps. Consequently they have very little wetland cover.

At the bottom of the watershed are the Montgomery and Harbour subwatersheds. Despite being less than ¼ of the size of the Montgomery subwatershed, the Harbour subwatershed has almost as much natural cover (22.7 ha) as the Montgomery subwatershed (28.6 ha). At 7% natural cover, the Montgomery subwatershed is Oshawa Creek's least vegetated subwatershed.

**Table 28:** Summary of the habitat types and their representation in each of the Oshawa Creek subwatersheds

| Habitat Type | Raglan Subwatershed | | | | Enfield Subwatershed | | | | KedronSubwatershed | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover (ha) | As a % of total natural cover in the subwatershed | As a % of total land use in the subwatershed | % of natural cover contribution to watershed | Cover (ha) | As a % of total natural cover in the subwatershed | As a % of total land use in the subwatershed | % of natural cover contribution to watershed | Cover (ha) | As a % of total natural cover in the subwatershed | As a % of total land use in the subwatershed | % of natural cover contribution to watershed |
| **Beach/Bluff** | 0.00 | 0.00% | 0.00% | 0.00% | 0.00 | 0.00% | 0.00% | 0.00% | 0.00 | 0.00% | 0.00% | 0.00% |
| **Meadow** | 144.38 | 17.71% | 4.13% | 1.21% | 158.38 | 14.21% | 4.51% | 1.33% | 44.05 | 19.07% | 3.27% | 0.37% |
| **Successional** | 114.06 | 13.99% | 3.26% | 0.96% | 227.75 | 20.44% | 6.49% | 1.91% | 44.91 | 19.45% | 3.33% | 0.38% |
| **Forest** | 527.69 | 64.73% | 15.10% | 4.43% | 706.19 | 63.37% | 20.12% | 5.93% | 139.38 | 60.36% | 10.34% | 1.17% |
| **Wetland** | 230.15 | 28.23% | 6.59% | 1.93% | 390.80 | 35.07% | 11.13% | 3.28% | 37.04 | 16.04% | 2.75% | 0.31% |
| **Open Water** | 0.33 | 0.04% | 0.01% | 0.00% | 4.76 | 0.43% | 0.14% | 0.04% | 0.14 | 0.06% | 0.01% | 0.00% |
| **Total Natural Cover*** | **815.25** | **100.00%** | **23.33%** | **6.84%** | **1114.36** | **100.00%** | **31.74%** | **9.35%** | **230.91** | **100.00%** | **17.13%** | **1.94%** |

| Habitat Type | Goodman Subwatershed | | | | Oshawa Main Subwatershed | | | | Montgomery Subwatershed | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover (ha) | As a % of total natural cover in the subwatershed | As a % of total land use in the subwatershed | % of natural cover contribution to watershed | Cover (ha) | As a % of total natural cover in the subwatershed | As a % of total land use in the subwatershed | % of natural cover contribution to watershed | Cover (ha) | As a % of total natural cover in the subwatershed | As a % of total land use in the subwatershed | % of natural cover contribution to watershed |
| **Beach/Bluff** | 0.00 | 0.00% | 0.00% | 0.00% | 0.00 | 0.00% | 0.00% | 0.00% | 0.00 | 0.00% | 0.00% | 0.00% |
| **Meadow** | 61.87 | 26.46% | 6.17% | 0.52% | 10.56 | 6.25% | 1.01% | 0.09% | 7.58 | 26.52% | 1.96% | 0.06% |
| **Successional** | 45.62 | 19.51% | 4.55% | 0.38% | 20.90 | 12.38% | 2.00% | 0.18% | 7.43 | 25.99% | 1.92% | 0.06% |
| **Forest** | 120.00 | 51.31% | 11.96% | 1.01% | 131.54 | 77.89% | 12.58% | 1.10% | 13.29 | 46.48% | 3.43% | 0.11% |
| **Wetland** | 83.34 | 35.64% | 8.31% | 0.70% | 16.77 | 9.93% | 1.60% | 0.14% | 2.63 | 9.20% | 0.68% | 0.02% |
| **Open Water** | 0.84 | 0.36% | 0.08% | 0.01% | 0.68 | 0.40% | 0.06% | 0.01% | 0.00 | 0.00% | 0.00% | 0.00% |
| **Total Natural Cover*** | **233.84** | **100.00%** | **23.31%** | **1.96%** | **168.87** | **100.00%** | **16.16%** | **1.42%** | **28.59** | **100.00%** | **7.38%** | **0.24%** |

| Habitat Type | Windfields Subwatershed | | | | Harbour Subwatershed | | | |
|---|---|---|---|---|---|---|---|---|
| | Cover (ha) | As a % of total natural cover in the subwater-shed | As a % of total land use in the subwater-shed | % of natural cover contribu-tion to watershed | Cover (ha) | As a % of total natural cover in the subwater-shed | As a % of total land use in the subwater-shed | % of natural cover contribution to watershed |
| **Beach/Bluff** | 0.00 | 0.00% | 0.00% | 0.00% | 0.00 | 0.00% | 0.00% | 0.00% |
| **Meadow** | 32.14 | 14.83% | 3.09% | 0.27% | 8.08 | 35.65% | 9.25% | 0.07% |
| **Successional** | 28.50 | 13.15% | 2.74% | 0.24% | 2.26 | 9.95% | 2.58% | 0.02% |
| **Forest** | 152.37 | 70.32% | 14.64% | 1.28% | 0.00 | 0.00% | 0.00% | 0.00% |
| **Wetland** | 54.48 | 25.14% | 5.23% | 0.46% | 0.94 | 4.14% | 1.07% | 0.01% |
| **Open Water** | 0.03 | 0.01% | 0.00% | 0.00% | 12.33 | 54.40% | 14.11% | 0.10% |
| **Total Natural Cover*** | **216.69** | **100.00%** | **20.81%** | **1.82%** | **22.67** | **100.00%** | **25.95%** | **0.19%** |

*Swamp communities appear in both forest and wetland calculations. Totals have been adjusted to account for this duplication.

### 3.3.3 Wildlife

3.3.3.1 Core Habitat Areas

Three core wildlife habitat areas have been identified within the Oshawa Creek watershed (Figure 50). These areas are generally contained within the Lake Ontario shoreline, the Iroquois Shoreline, and the Oak Ridges Moraine physiographic regions of the watershed, and consist of multiple habitat patches. For the purposes of this discussion, the core habitat areas in the Oshawa Creek watershed have been labelled (from south to north) as follows:

Oshawa Valleylands

Between Bloor Street and Oshawa Harbour the Oshawa Creek valley has remained relatively robust and unfragmented. In some sections it is even large enough to contain small patches of forest interior (Figure 50). Although recreational and urban disturbances in the Oshawa Valleylands are high, its proximity to Lake Ontario makes it a prime stopover site for migratory songbirds flying along the shoreline. This important function, in addition to the fact that it is the largest forest block remaining in the Oshawa Main subwatershed, and indeed the south part of the watershed, makes this section of the Oshawa Creek valley an important wildlife area.

At the bottom of this core habitat is a portion of the Oshawa Creek Coastal Wetland Complex. This marsh is small and of low quality, but does contribute to the diversity of habitats in the Oshawa Valleylands thereby increasing its value to wildlife. It is also the only coastal wetland in the Oshawa Creek watershed.

The habitat diversity contained within this one small section of the watershed is surprising. Habitat types include: meadow, thicket, deciduous and mixed forest, deciduous and thicket swamp, and meadow and shallow marsh. It is also in close proximity to both Pumphouse (west) and Oshawa Second (east) marshes, making it an ideal stepping stone for wildlife movement. This core habitat area, although small in relation to some of the other habitats in the CLOCA jurisdiction, is an important component of the natural heritage system within the Oshawa Creek watershed.

Taunton North

This core habitat area is made up of numerous habitat patches, all within 250 m of each other and all contained within the Iroquois Beach physiographic region of the watershed. It spans the entire width of the watershed and encompasses the top end of the Goodman subwatershed and the bottom of the Windfields and Kedron subwatersheds.

The Taunton North core habitat includes a good diversity of habitat types. In fact, every ELC community present within the entire Oshawa Creek watershed (Appendix 5) is represented in this core habitat area. This includes regenerating habitats, plantations, forests, swamps, open water and marshes.

Many of the forest blocks in this core habitat area are large enough to contain forest interior conditions. Altogether they contain approximately 10.5 ha of forest interior, which is about 10% of all of the forest interior in the Oshawa Creek watershed. No forest blocks are large enough to contain deep forest interior however (Figure 50).

Although there is little habitat connectivity between Taunton North and the core habitats within the Black-Harmony-Farewell watershed to the east, there is a very strong connection between this core habitat and those to the west within the Pringle and Lynde Creek watersheds (Figure 50). The close proximity of the numerous habitat patches along the Lake Iroquois Beach (Ritson Rd. to Audley Rd.) enables them to function, in many aspects, as one habitat area because many wildlife species can move between them for resources or refuge. Maintaining direct connectivity between these habitats is extremely important to maintaining overall biodiversity in the central part of the Oshawa Creek watershed. Efforts should be made to preserve and enhance the connectivity within the Taunton North core habitats. Decisions with respect to future development within this area should be cognizant of this important core habitat and its connectivity to similar core habitats to the west, recognizing this as a significant watershed resource.

Enfield – Purple Woods

Across the Oak Ridge Moraine there are a number of larger habitats. Among these are the Purple Woods Conservation Area, Trillium Valley (west of Simcoe St. N.), Mt. Carmel Woods, and Enfield Woods in Clarington, as well as several other unnamed habitat areas. For the purposes of this discussion they have been grouped into one core habitat area, largely because of their geographic location on the Moraine.

Although the habitats are not all the same, they are all within 2 km of each other, and therefore have the capacity to function as one larger core habitat area for many wildlife species. A very high diversity of habitat types exists in this core area and some of the watershed's largest and highest quality deciduous and mixed forests, deciduous and mixed swamps, and regenerating habitats are also found here.

Wildlife species within each of the habitats varies with the type of habitat present: amphibian breeding areas are present within the deciduous and mixed swamp habitats, particularly in the Enfield wetlands where vernal pooling occurs; and, forest interior and area sensitive birds have been identified in many of the larger habitat patches such as Trillium Valley, Purple Woods, Mt. Carmel, and Enfield Woods.

Much of the watershed's forest interior, and all of its deep forest interior, is also located in the Enfield – Purple Woods core habitat area (Figure 50). Approximately 75 ha of forest interior is scattered throughout the forest patches in this area. Many of the units are small, but 3 of the patches (Trillium Valley, Enfield Woods and a woodlot at the north end of Enfield Rd) are large enough to contain deep forest interior conditions. Altogether, the Enfield – Purple Woods core habitat area contains roughly 76% of all of the forest interior in the Oshawa Creek watershed, and 100% (6.7 ha) of the deep forest interior in the watershed.

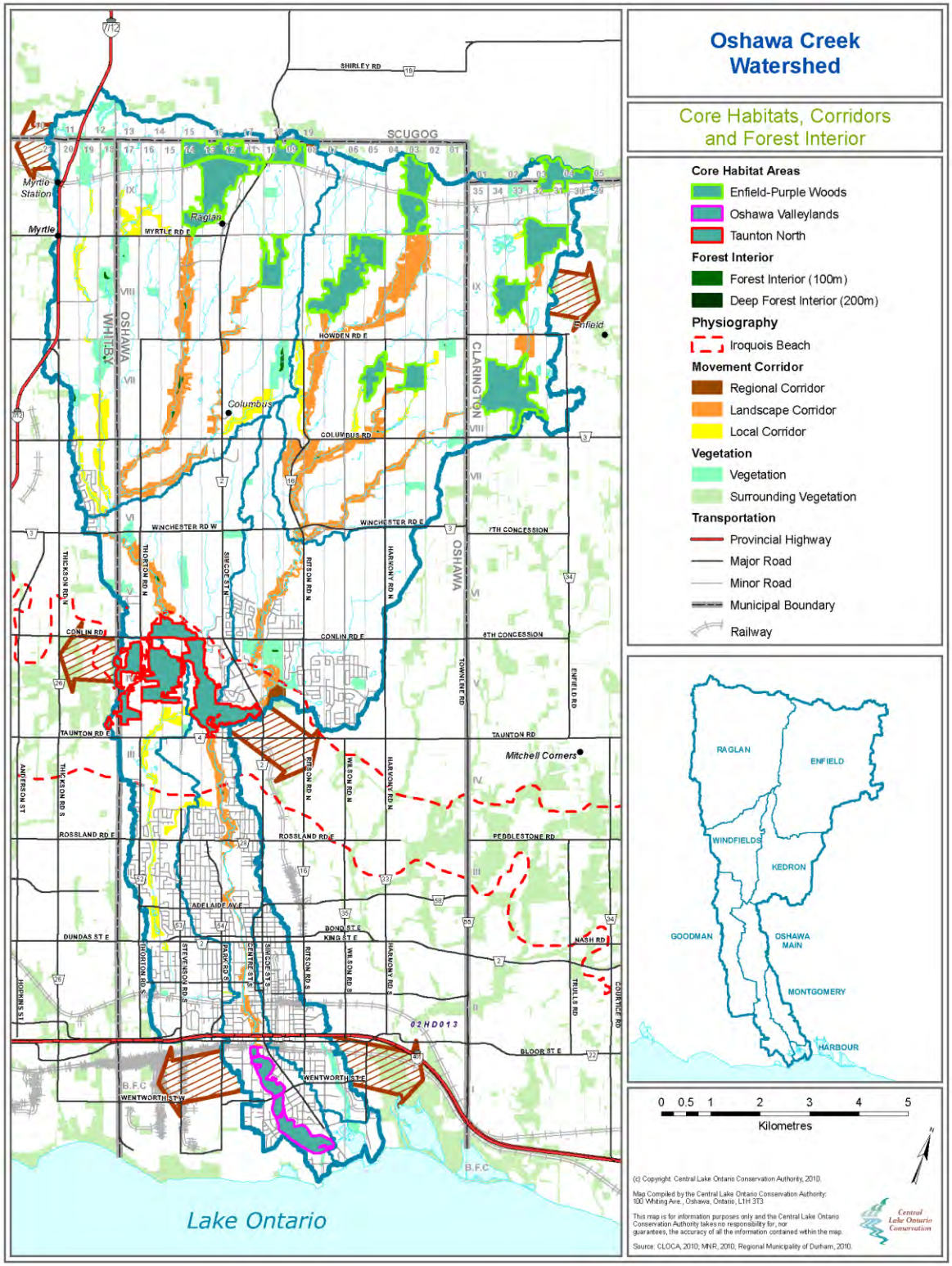



**Figure 50:** Habitat Network and Forest Interior for the Oshawa Creek Watershed

### 3.3.3.2 Wildlife Movement

The Oshawa Creek watershed has examples of regional, landscape and local corridors, and these are shown in Figure_50.

Regional Corridors

Within the Oshawa Creek watershed, there are 3 recognized regional corridors. They run in an east to west direction along the Lake Ontario Shoreline, the Lake Iroquois Beach, and the Oak Ridges Moraine. These corridors include the core habitat areas as well as vegetation patches within these physiographic regions. This overlap exists because regional corridors function at a large scale and include multiple watersheds. When the CLOCA jurisdiction is viewed in its entirety these regional corridors become much more evident.

The Lake Ontario Shoreline corridor connects the shoreline habitats in the Oshawa Creek watershed (Oshawa Valleylands) with adjacent shoreline habitats to the west (Goldpoint Marsh and Pumphouse Marsh) and east (Oshawa Second Marsh and McLaughlin Bay). This corridor is used by all sorts of wildlife, but is particularly important to migratory songbirds, waterfowl, shorebirds and raptors.

Although a corridor width for the Lake Ontario Shoreline has not been prescribed, some guidelines have been developed. The Significant Wildlife Habitat Decision Support System (OMNR, 2002) states that habitats within 5 km of the shoreline are important to migratory birds and recommends that they be maintained in natural cover. A study conducted by the Nature Conservancy of Canada (NCC) states that habitat sites within 1 km of the shoreline support a greater abundance and richness of migrants compared with sites located 3-4 km inland (Agard et al., 1993). Based on this data, the NCC recommends maintaining brushy or forested habitats within 1 km of the Lake Ontario Shoreline to positively affect migrant songbird populations. In the Oshawa Creek watershed, within the Oshawa Main subwatershed, the maximum shoreline corridor width exceeds this recommendation; however it is very narrow as it is confined to the Oshawa Valleylands. The Harbour and Montgomery subwatersheds, which make up the remainder of the available habitat in this regional corridor, are poorly vegetated. As such, the Lake Ontario Shoreline regional corridor in the Oshawa Creek watershed is highly degraded.

The Lake Iroquois Beach corridor is surprisingly continuous throughout the Oshawa Creek watershed. Strong connections exist between this watershed and the Pringle and Lynde Creek watersheds to the west across the Lake Iroquois Beach, and efforts should be made to preserve and enhance this corridor. Unfortunately this regional corridor has been severely impacted by urban development to the east. Connectivity between the Taunton North core habitats and the Harmony – Farewell Iroquois Beach wetland complex in the Black/Harmony/Farewell Creek watershed is virtually nonexistent.

Landscape Corridors

Landscape corridors generally connect core habitat areas and/or extend across the length of the watershed. In the Oshawa Creek watershed, these corridors traverse through the Oshawa Main, Windfield, Raglan, Kedron, and Enfield subwatersheds.

Within the Oshawa Main subwatershed, the landscape corridor which connects the Lake Ontario shoreline to the Taunton North core habitats and the Lake Iroquois Beach regional corridor is highly fragmented. South of Bloor St. and north of Rossland Rd. the corridor is generally of high quality and regularly exceeds 100 m in width. Between these roads there are isolated patches of higher quality habitat but overall this section is poorly vegetated. Manicured park lands and dense urban development along this section of the creek have resulted in a severe break in this corridor.

To the north of the Iroquois Beach the landscape corridors branch out to the east and west. In the Windfields and Raglan subwatersheds, the corridors are generally continuous with some areas of high quality vegetation that are large enough to support forest interior conditions. In areas where the corridor is not well vegetated, the surrounding land use is at least undeveloped or agricultural, making the corridor suitable for many wildlife species.

In the Kedron and Enfield subwatersheds, the landscape corridors are similarly robust. There is some fragmentation, but not as a result of intense urban development, and much of the corridor is continuously vegetated.

Local Corridors

Local corridors generally connect larger corridors or core habitat areas with secondary habitat areas, labelled as vegetation in Figure 50. Several local corridors exist throughout the Oshawa Creek watershed and one or more can be found in every subwatershed except Harbour and Montgomery. The Harbour subwatershed is so small that there is little opportunity or need for a corridor, however, the only natural cover in the Montgomery subwatershed is along the creek and consequently there are no habitats to connect.

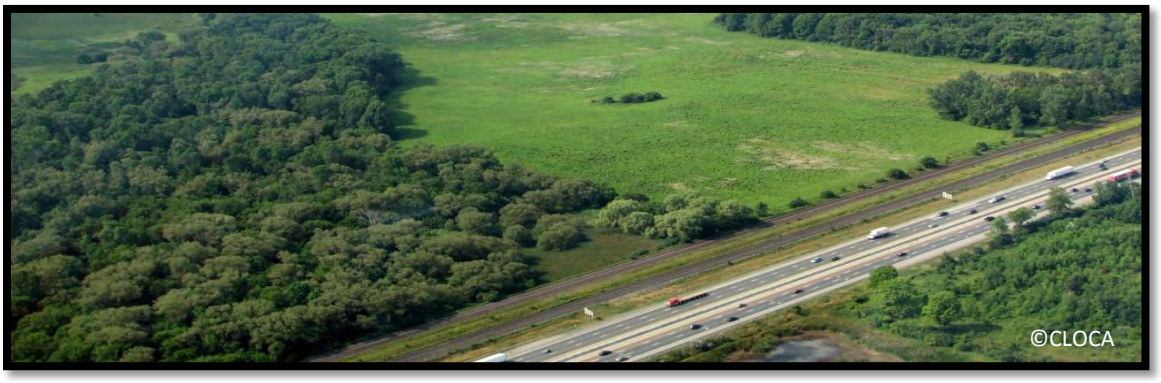
A local corridor connects the landscape corridor in the Oshawa Main subwatershed with the Taunton North core habitats in the Goodman subwatershed. Ideally the local corridor that follows the length of the creek should be a landscape quality; however urban development on either side of the creek is so dense that it is unlikely that a landscape quality corridor could ever be achieved in this subwatershed. Consequently it has been identified as a local corridor only. Despite some restoration works that have been done on this corridor, it remains highly degraded.

To the north of the Iroquois Beach, in the Windfields, Raglan, Kedron, and Enfield subwatersheds, there are numerous local corridors of varying lengths and qualities. In some instances the size of the corridors exceeds 100 m and they have remained relatively continuous. In other locations the corridors have been fragmented by agriculture or have been cleared for other reasons.

3.3.3.3 Movement Barriers

As with most corridors in urban environments, movement barriers exist in the Oshawa Creek watershed. Roads are a primary barrier, and between Lake Ontario and the Oak Ridges Moraine there are many.

Although deer and other large mammals are not as impeded by roads as reptiles or amphibians, they are certainly not immune to their impacts. Even birds are susceptible to road collisions. While it is not reasonable to expect that roads within movement corridors be removed, there are means of making roads more passable for wildlife. Culverts or bridges beneath busy roads at vulnerable locations, such as known corridors, can make roads less of a barrier to movement and reduce road mortalities from automobiles.




3.3.3.4 Species at Risk

Many species have particular habitat needs and are sensitive to habitat loss, fragmentation and degradation. Often, these species are species at risk, as identified federally by COSEWIC and provincially by COSSARO.

Because of their sensitivities to habitat change, it is valuable to know what species at risk are present in an area as they can indicate the types of habitat present, as well as the quality and quantity of those habitats. This information also helps with the management of existing habitat areas.

Table 29 provides a list of the species that have been observed and reported within this watershed. The list includes only those species that have been designated as either federally or provincially at risk, or are currently tracked by the OMNR via the Natural Heritage Information Centre (NHIC). A "tracked" species is generally one that has been given a provincial rank of 1, 2, or 3 by the Ontario Ministry of Natural Resources.

While some of the species at risk observed in the Oshawa Creek watershed are not known to use the Oshawa Creek habitats for breeding, the seasonal or temporary presence of these species for foraging or shelter still offers insight into the value that these natural areas provide for wildlife. Similarly, historical records of species at risk (>20 years old) have been included in the table as they can be considered relevant for monitoring change in a watershed over time, or acting as targets to guide potential habitat restoration.

It should be noted that this list, while valuable, is not comprehensive. Species observations tend to be concentrated in public natural areas as these locations are accessible to observers. Observations from privately owned lands, which constitute the vast majority of the watershed, are much more difficult to obtain.

In conclusion, overall, the Oshawa Creek watershed is in moderate condition from a terrestrial resources perspective. It has some high quality, well-connected habitat areas, many of which provide forest interior conditions and support area sensitive species. However, the quality of the entire terrestrial network is degraded as a result of some habitat and corridor fragmentation from land use development. Growth, while feasible in this watershed, must be done strategically with consideration for the maintenance of the habitat network. Numerous restoration opportunities also exist, which could contribute significantly to the strength of the natural heritage system in this watershed.

Table 30 outlines the parameters used to indicate watershed health and the conditions which currently exist in the Oshawa Creek watershed.

**Table 29:** Species of Conservation Concern* in the Oshawa Creek Watershed

| Common Name | Scientific Name | Breeding Record | Location (Sub-watershed) | Tracked Species** | COSEWIC[a] | COSSARO[a] | SARA[b] | Global Rank[c] | Provincial Rank[c] | Durham Rank[d] | BSC Priority[e] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Birds** | | | | | | | | | | | |
| Bald Eagle | *Haliaeetus leucocephalus* | No | ES, GC, MB | Yes | N | E | | 4 | 4 | N | 1 |
| Barn Owl | *Tyto alba* | No | EN, ES, MB | Yes | E | E | | 5 | 1 | N | |
| Black Tern | *Chlidonias niger* | No | MB | Yes | N | S | | 4 | 3 | S | 1 |
| Black-crowned Night-heron | *Nycticorax nycticorax* | No | H | Yes | | | | 5 | 3 | I | 1 |
| Bohemian Waxwing | *Bombycilla garrulus* | No | WN | Yes | | | | 5 | 2 | N | |
| Bufflehead | *Bucephala albeola* | No | WN, MB | Yes | | | | 5 | 3 | N | |
| Canada Warbler | *Wilsonia canadensis* | No | MB | No | T | | | 5 | 5 | R | 2 |
| Chimney Swift | *Chaetura pelagica* | No | ES, MB | No | T | | | 5 | 5 | U | |
| Common Eider | *Somateria mollissima* | No | H | Yes | | | | 5 | 1 | N | |
| Common Nighthawk | *Chordeiles minor* | No | WN, GC, MB, MONT | No | T | | | 5 | 4 | S | 1 |
| Golden Eagle | *Aquila chrysaetos* | No | MB | Yes | N | E | | 5 | 1 | N | |
| Great Black-backed Gull | *Larus marinus* | No | H | Yes | | | | 5 | 2 | N | |
| Great Gray Owl | *Strix nebulosa* | No | WS, GC, MB | Yes | N | S | | 5 | 3 | N | |
| Ivory Gull | *Pagophila eburnea* | No | H | No | E | | 1 | 5 | | N | |
| Loggerhead Shrike | *Lanius ludovicianus* | No | GC, MB | Yes | E | E | 1 | 4 | 2 | I | 1 |
| Northern Bobwhite | *Colinus virginianus* | No | WN | Yes | E | E | 1 | 5 | 1 | N | |
| Northern Shrike | *Lanius excubitor* | No | GC, MB | Yes | | | | 5 | 2 | N | |
| Olive-sided Flycatcher | *Contopus cooperi* | No | MB | No | T | | | 4 | 5 | I | 2 |
| Parastic Jaeger | *Stercorarius parasiticus* | No | H | Yes | | | | 5 | 2 | N | |
| Peregrine Falcon | *Falco peregrinus* | No | GC, MB | Yes | S | T | 1 | 4 | 2 | N | |
| Prothonotary Warbler | *Protonotaria citrea* | No | MB | Yes | E | E | 1 | 5 | 1 | N | |
| Red-headed Woodpecker | *Melanerpes erythrocephalus* | No | MB | Yes | T | S | 3 | 5 | 3 | V | 1 |
| Red-necked Grebe | *Podiceps grisegena* | No | H | Yes | N | | | 5 | 3 | N | |
| Red-shouldered Hawk | *Buteo lineatus* | No | WN, ES, MB | Yes | N | | 3 | 5 | 4 | R | 1 |
| Red-throated Loon | *Gavia stellata* | No | MB | Yes | | | | 5 | 1 | N | |
| Rough-legged Hawk | *Buteo lagopus* | No | GC, MB | Yes | N | | | 5 | 1 | N | |
| Ruddy Duck | *Oxyura jamaicensis* | No | H | Yes | | | | 5 | 2 | I | |
| Rusty Blackbird | *Euphagus carolinus* | No | GC, MB | No | S | | | 5 | 5 | N | |
| Short-eared Owl | *Asio flammeus* | No | GC | Yes | S | S | 3 | 5 | 3 | N | 1 |
| Tufted Titmouse | *Baeolophus bicolor* | No | MB | Yes | | | | 5 | 2 | N | |
| Tundra Swan | *Cygnus columbianus* | No | MB | Yes | | | | 5 | 3 | N | |

| Common Name | Scientific Name | Breeding Record | Location (Sub-watershed) | Tracked Species** | COSEWIC[a] | COSSARO[a] | SARA[b] | Global Rank[c] | Provincial Rank[c] | Durham Rank[d] | | BSC Priority[e] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vegetation** | | | | | | | | | | | | | |
| American Ginseng | *Panax quinquefolius* | | N/A | EN | | Yes | | E | E | 1 | 3 | 2 | R |
| Arrow-arum | *Peltandra virginica* | | N/A | MB | | Yes | | | | | 5 | 2 | |
| Black Gum | *Nyssa sylvatica* | | N/A | MB | | Yes | | | | | 5 | 3 | |
| Brainerd's Hawthorn | *Crataegus brainerdii* | | N/A | ES | | Yes | | | | | 5 | 2 | |
| Burning Bush | *Euonymus atropurpurea* | | N/A | WS | | Yes | | | | | 5 | 3 | R |
| Butternut | *Juglans cinerea* | | N/A | WN, EN, ES, MB | | Yes | | E | E | 1 | 3 | 3 | C |
| Cherry Birch / Sweet Birch | *Betula lenta* | | N/A | MB | | Yes | | E | E | 1 | 5 | 1 | |
| Flowering Dogwood | *Cornus florida* | | N/A | WS, ES, MB | | Yes | | E | | | 5 | 2 | |
| Hairy Small-leaved Tick-treefoil | *Desmodium ciliare* | | N/A | MB | | Yes | | | | | 5 | | |
| Honey Locust | *Gleditsia triacanthos* | | N/A | WS, ES, GC | | Yes | | | | | 5 | 2 | C |
| Northern Fox Grape | *Vitis labrusca* | | N/A | WS, ES | | Yes | | | | | 5 | 1 | |
| Nuttall Waterweed | *Elodea nuttallii* | | N/A | MB | | Yes | | | | | 5 | 3 | |
| Pale Avens | *Geum virginianum* | | N/A | MB | | Yes | | | | | 5 | 1 | |
| Prairie June Grass | *Koeleria macrantha* | | N/A | ES | | Yes | | | | | 5 | 3 | |
| Red Mulberry | *Morus rubra* | | N/A | MB | | Yes | | E | E | 1 | 5 | 2 | R |
| Small-flower Groovebur | *Agrimonia parviflora* | | N/A | ES | | Yes | | | | | 5 | 3 | |
| Spring Birch / River Birch | *Betula occidentalis* | | N/A | ES | | Yes | | | | | 4 | 3 | |
| Swamp Rose-mallow | *Hibiscus moscheutos* | | N/A | MB | | Yes | | S | S | 1 | 5 | 3 | |
| Virginia Yellow Flax | *Linum virginianum* | | N/A | MB | | Yes | | | | | 4 | 2 | |
| White Milkweed / Variegated Milkweed | *Asclepias variegata* | | N/A | MB | | Yes | | | | | 5 | | |
| Wild Hyacinth | *Camassia scilloides* | | N/A | GC | | Yes | | T | T | 1 | 4 | 2 | |
| Winged Loosestrife | *Lythrum alatum* | | N/A | WS | | Yes | | | | | 5 | 3 | |
| Winter Bentgrass | *Agrostis hyemalis* | | N/A | MB | | Yes | | | | | 5 | 1 | |

[*] Listed as Endangered, Threatened or Special Concern either federally or provincially, or tracked by the NHIC.

** Breeding occurrences are tracked by the OMNR via the NHIC

[a] Ranks as determined by COSEWIC (Feb 2008) and COSSARO (Feb 2008). E (Endangered), T (Threatened), S (Special Concern), N (Not at Risk), DD (Data Deficient)

[b] Species appears on Schedule 1, 2, or 3 of the Species at Risk Act

[c] Most recent global and provincial rankings listed by OMNR.

[d] Bird rankings: Tozer & Richards, 1974 and Bain & Henshaw, 1993. Butterfly rankings: Kamstra, 1992. Reptile rankings: Kamstra, 1990. Vegetation rankings: Varga et al., 2000. A (Abundant), C (Common), U (Uncommon), S (Scarce), R (Rare), V (Very Rare), I (Irregular), N (Non-breeder), H (Historical)

[e] Bird Studies Canada List of Priority Species for the Regional Municipality of Durham (2000). Conservation priorities ranked from 1 (highest concern) to 5 (lowest concern).

**Table 30:** Summary of Environment Canada's AOC Wetland and Forest Habitat Restoration Guidelines (modified from Environment Canada, 2004).

| Parameter | Guideline(s) | Existing Conditions |
|---|---|---|
| Wetland Habitat Guidelines | | |
| Percent wetlands in watersheds and subwatersheds | Greater than 10% of each major watershed in wetland habitat;<br>Greater than 6% of each subwatershed in wetland habitat; or<br>Restore to original percentage of wetlands in the watershed. | Oshawa Creek watershed has approximately 7% wetland habitat.<br><br>Only 3 of the 8 subwatersheds in the Oshawa Creek watershed have greater than 6% wetland habitat (Table 7). |
| Wetland type | The only wetland types suitable for widespread rehabilitation are swamps and marshes | Swamps are the predominant wetland type with some marsh representation. |
| Wetland location | Wetlands are key in headwater areas for groundwater discharge and recharge, flood plains for flood attenuation, and coastal wetlands for fish production | Many wetlands occur in headwater areas and within the Lake Iroquois Beach but the majority are found in the floodplains and along the creek.<br>The watershed has 1 provincially significant coastal marsh. Significant coastal wetlands also occur on either side of the watershed. |
| Forest Habitat Guidelines | | |
| Percent forest cover | 30% (minimum) of watershed should be in forest cover | 15% of the Oshawa Creek watershed is in forest cover. |
| Size of largest forest patch | At least one 200 ha forest patch which is a minimum of 500 m wide | There are no 200 ha forest patches within the Oshawa Creek watershed. The largest forest patch is just over 60 ha. |
| Percent of watershed that is forest interior and deep forest interior | Greater than 10% forest interior (100 m from forest edge);<br>Greater than 5% deep forest interior (200 m from forest edge). | 0.83 % of the Oshawa Creek watershed is 100 m or further from a forest edge.<br>0.06 % of the Oshawa Creek watershed is 200 m or further from a forest edge. |
| Forest shape | Forest patches should be circular or square in shape | There are a few compact forest patches in the watershed, but the majority of them are fragmented by roads, agriculture, or residential development. |
| Proximity to other forested patches | Forest patches should be within 2 km of one another or other supporting habitat features | Within the physiographic regions of the Oak Ridges Moraine, the Lake Iroquois Beach and the Lake Ontario Shoreline, the larger forest patches are generally within 2 km of one another. Outside of these regions, forest patches are generally not within 2 km of each other. |
| Fragmented landscapes and the role of corridors | Corridors designed to facilitate species movement should be a minimum of 50 m to 100 m in width. | Corridors in the watershed are generally greater than 50 m wide but not consistently. In some locations corridor widths exceed 100 m. |

## 3.4 Conclusion

It has been 8 years since the original Oshawa Creek Watershed Plan (2002) was adopted. Since that time, some things within the watershed have changed and some things continue to remain the same. This report provides updates to *Section 3.0 – Existing Conditions* and *Section 4.0 – Summary of Existing Conditions*. A new subsection – *1.7- Addendum* has been added to *Section 1.0 – Introduction* outlining the need for the addendum and the approach taken. *Section 2.0 – History of the Watershed* has not been revised. One significant change the reader will note is the use of different names for the subwatersheds. These new names better reflect the geographical location of the drainage area, making the subwatershed areas more recognizable to the reader.

Since 2002 there have been many changes in Provincial Policy and local municipal planning policy that play a significant role in guiding future growth within this watershed. These changes set out both the amount and form of growth that will occur within this area. In tandem with these growth policies came the establishment of environmental and agricultural protection policies through the adoption of the ORMCP, the Greenbelt Plan and the 2005 PPS. These policies in totality have very much changed the planning policy regime within this watershed. Information regarding these different planning initiatives and their importance with respect to future growth within this watershed is discussed in Section 3.1.1. These new policies will play a guiding role in the development and evaluation of alternative management scenarios and watershed management recommendations to be undertaken and reported on in Section 5.0.

New water quality and water quantity information for both groundwater and surface water has been provided reflecting new methodologies and analysis as well as updated information. This information has been made possible through the scientific advances and significant investment made in recent years in modeling and reporting on water budgets; work which has been vital in understanding the important groundwater contribution of the ORM, and fulfilling the requirements of the Clean Water Act and Source Water Protection initiative. In Durham, the work of the York/Durham/Peel/Toronto (YPDT) Groundwater Study has been significant in the continued advancement of knowledge with respect to understanding the hydrogeological regime of watersheds within CLOCA. Climatic information is an important element in the modeling of water budget components. As such, more detailed climate information is available and has been presented in this report.

Stormwater management and imperviousness play important roles in the functioning and health of the watershed. As such, two new sections have been added, reporting on these areas. Stormwater management controls within an urbanizing watershed are important in controlling flow during storm events, and in filtering sediment and contaminants which would otherwise go directly to the streams through runoff and overland flow. Determining imperviousness within the watershed is an important component in evaluating watershed health because as imperviousness increases, it negatively influences groundwater infiltration, affects the health of the aquatic environment, impacts wetland health and resiliency, and can increase stream flow rate and volume during storms.

The hydrologic model has not been changed or updated, so much of the hydrologic information remains the same, including fluviogeomorphology. Yet it is important to note that since the Plan (2002) was released, the areas in which the Authority governed development activities through the Fill Construction and Alteration to Waterways Regulation" has changed as this Regulation was amended through Ontario Regulation 97/04. CLOCA now regulates development through the Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses – Ontario Regulation 42/06.

Lastly, the Fisheries and Aquatic Habitat and Terrestrial Natural Heritage (vegetation and wildlife) sections have been revised and updated. Although the information provided in the Plan (2002) provides valuable background information and will be important in trend analysis, there was a need to revisit these sections in part due to the considerable change in land use that has been experienced within this watershed, but also to include the significant fisheries, terrestrial and wildlife monitoring data that has been collected in the last 8 years within this watershed.

At this time, *Section 5.0 – Watershed Management Plan*, has not been revised. The next step for the Authority will be to review the applicability of the recommendations made in the Plan (2002) as some may no longer be relevant, some may have been implemented, and some may need to be updated and revised. Also, the information collected and reported on in the Addendum will enable the Authority to evaluate the watershed's response to various future scenarios. Modeling, review, and assessment will be undertaken to evaluate the potential changes and the watershed's response. Findings will be reported on in the next step and management recommendations will be made, essentially revising Section 5.0 of the Plan (2002).

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# APPENDIX 1 & 2 CLOCA Surface Water Monitoring Sampling Parameters

## Central Lake Ontario Conservation Authority – Surface Water Monitoring Sampling Parameters

### Appendix 1. Surfacewater Samples - MOE Laboratory

| PARAMETER DESCRIPTION | UNITS | Grp |
|---|---|---|
| ALKALINITY, TOTAL | mg/L | C |
| ALUMINIUM, UNFILTERED TOTAL | ug/L | M |
| AMMONIUM, TOTAL UNFIL.REAC | mg/L | |
| BARIUM, UNFILTERED TOTAL | ug/L | M |
| BERYLIUM,UNFILTERED TOTAL | ug/L | M |
| CADMIUM, UNFILTERED TOTAL | ug/L | M |
| CALCIUM, UNFILTERED TOTAL | mg/L | C |
| CHLORIDE, UNFIL.REAC | mg/L | C |
| CHROMIUM, UNFILTERED TOTAL | ug/L | M |
| COBALT, UNFILTERED TOTAL | ug/L | M |
| CONDUCTIVITY, 25C | ug/L | C |
| CONDUCTIVITY, AMBIENT | ug/L | C |
| COPPER, UNFILTERED TOTAL | ug/L | M |
| DISSOLVED OXYGEN | mg/L | C |

| PARAMETER DESCRIPTION | UNIT | Grp |
|---|---|---|
| MOLYBDENUM,UNFILTERED TOTAL | ug/L | M |
| NICKEL, UNFILTERED TOTAL | ug/L | M |
| NITRATES TOTAL, UNFIL.REAC | mg/L | C |
| NITRITE, UNFILTERED REACTIVE | mg/L | C |
| NITROGEN,TOT,KJELDAHL/UNF.REA | mg/L | C |
| PH (-LOG H+ CONCN) | none | C |
| PH FIELD | none | C |
| PHOSPHATE,FILTERED REACTIVE | mg/L | C |
| PHOSPHORUS,UNFILTERED TOTAL | mg/L | C |
| POTASSIUM,UNFILTERED TOTAL | mg/L | C |
| RESIDUE,PARTICULATE | mg/L | |
| SODIUM, UNFILTERED TOTAL | mg/L | C |
| STRONTIUM, UNFILTERED TOTAL | ug/L | M |
| TEMPERATURE, WATER | ° C | |

### Appendix 2. Surfacewater Samples - York-Durham Environmental Laboratory

| ANALYTE | Transfer Code | UNIT | MDL | Grp |
|---|---|---|---|---|
| Alkalinity as CaCO3 | ALK | mg/L | 10.0 | C |
| Aluminium as Al | Al | mg/L | 0.0007 | M |
| Ammonia + Ammonium as N | NH3 | mg/L | 0.03 | |
| Antimony as Sb | Sb | mg/L | 0.003 | |
| Arsenic as As | As | mg/L | 0.0007 | |
| Barium as Ba | Ba | mg/L | 0.0001 | M |
| Beryllium as Be | Be | mg/L | 0.0002 | M |
| BOD (5 day) | BOD | mg/L | 0.2 | |
| Cadmium as Cd | Cd | mg/L | 0.0001 | M |
| Calcium as Ca | Ca | mg/L | 0.13 | C |
| Calculated Conductivity | CCD | umho/cm | 0.01 | C |
| Calculated Dissolved Solids | CDS | mg/L | 20 | C |
| Chloride as Cl | CHL | mg/L | 0.1 | C |
| Chromium as Cr | Cr | mg/L | 0.0003 | M |

| ANALYTE | Transfer Code | UNIT | MDL | Grp |
|---|---|---|---|---|
| Lead as Pb | Pb | mg/L | 0.0007 | M |
| Magnesium as Mg | Mg | mg/L | 0.04 | C |
| Manganese as Mn | Mn | mg/L | 0.0001 | M |
| Molybdenum as Mo | Mo | mg/L | 0.0002 | M |
| Nickel as Ni | Ni | mg/L | 0.0001 | M |
| Nitrate as N | NO3 | mg/L | 0.03 | C |
| Nitrite as N | NO2 | mg/L | 0.05 | C |
| pH (Units) | pH | Units | 0.01 | C |
| Phosphate as P | PHO | mg/L | 0.1 | C |
| Potassium as K | K | mg/L | 0.02 | C |
| Selenium as Se | Se | mg/L | 0.002 | M |
| Sodium as Na | Na | mg/L | 0.2 | C |
| Strontium as Sr | Sr | mg/L | 0.0001 | M |
| Sulphate as SO4 | SO4 | mg/L | 0.2 | C |

## Appendix 1. Surfacewater Samples - MOE Laboratory

| PARAMETER DESCRIPTION | UNITS | Grp | PARAMETER DESCRIPTION | UNIT | Grp |
|---|---|---|---|---|---|
| HARDNESS, TOTAL | mg/L | C | TITANIUM, UNFILTERED TOTAL | ug/L | M |
| IRON, UNFILTERED TOTAL | ug/L | M | TURBIDITY | Forman | |
| LEAD, UNFILTERED TOTAL | ug/L | M | VANADIUM, UNFILTERED TOTAL | ug/L | M |
| MAGNESIUM,UNFILTERED TOTAL | mg/L | C | ZINC, UNFILTERED TOTAL | ug/L | M |
| MALATHION | nanogram | P | | | |
| MANGANESE,UNFILTERED TOTAL | ug/L | M | | | |
| METHOPRENE | nanogram | | | | |
| METHOPRENE ACID | nanogram | | | | |
| METHOXYCITRONELLAL | nanogram | | | | |

| **Parameter Groups** | (From MOE Lab) |
|---|---|
| General Chemistry | C |
| Metals | M |
| Pesticides | P |
| Pesticides Special | PS |
| Pesticides 1 | P1 |
| List 3196 | L |

## Appendix 2. Surfacewater Samples - York-Durham Environmental Laboratory

| ANALYTE | Transfer Code | UNIT | MDL | Grp | ANALYTE | Transfer Code | UNIT | MDL | Grp |
|---|---|---|---|---|---|---|---|---|---|
| Cobalt as Co | Co | mg/L | 0.0002 | M | Suspended Solids | SUS | mg/L | 0.9 | C |
| Colour | COL | TCU | 1 | C | Titanium as Ti | Ti | mg/L | 0.0001 | M |
| Conductivity (umho/cm) | CON | umho/cm | 0.01 | C | Total Anions | TAN | meq/L | 0.01 | L |
| Copper as Cu | Cu | mg/L | 0.0002 | M | Total Cations | CAT | meq/L | 0.01 | L |
| Fluoride as F | FLU | mg/L | 0.04 | C | Total Kjeldahl Nitrogen | TKN | mg/L | 0.05 | C |
| Hardness as CaCO3 | HAR | mg/L | 1.0 | C | Total Phosphorus as P | P | mg/L | 0.006 | C |
| Ionic Balance | ION | % | 0.01 | L | Turbidity (NTU) | TUR | NTU | 0.050 | C |
| Iron as Fe | Fe | mg/L | 0.0002 | M | Vanadium as V | V | mg/L | 0.0003 | M |
| Langelier Index | LIX | | -2.0 | | Zinc as Zn | Zn | mg/L | 0.0002 | M |

# APPENDIX 3 Water Quality Exceedances on PWQO and CESI

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *PWQO, 1994* | | | *0.005* | *0.0002* | | *0.9* | *5* | *5* | *0.3* | *25* | | | | *5* | | *30* | |
| *CESI, 2010 (CCME)* | | | | | *150* | | | | | | *2.93* | *2.93* | *2.93* | | *1000* | *30* | *7.5* |
| *Unit* | | | *mg/l* | *mg/l* | *mg/l* | *ug/l* | *ug/l* | *ug/l* | *mg/l* | *ug/l* | *mg/l* | *mg/l* | *mg/l* | *ug/l* | *ng/L* | *ug/l* | *ug/l* |
| | SWQ2 | 26/10/1965 | | | 41 | | | | 0.6 | | 0.5 | | | | | 118 | |
| | SWQ2 | 07/02/1966 | | | 39 | | | | 0.59 | | 0.25 | | | | | 150 | |
| | SWQ2 | 03/05/1966 | | | 60 | | | | 0.66 | | 0.16 | | | | | 320 | |
| | SWQ2 | 15/06/1966 | | | 7 | | | | | | | | | | | 294 | |
| | SWQ2 | 06/07/1966 | | | 39 | | | | 1.73 | | 4 | | | | | 275 | |
| | SWQ2 | 13/02/1967 | | | 44 | | | | 0.77 | | 0.4 | | | | | 46 | |
| | SWQ2 | 13/03/1967 | | | 36 | | | | 3.6 | | 0.6 | | | | | 333 | |
| | SWQ2 | 28/03/1967 | | | 29 | | | | 3.58 | | 0.6 | | | | | 216 | |
| | SWQ2 | 10/04/1967 | | | 44 | | | | 2.15 | | 0.5 | | | | | 92 | |
| | SWQ2 | 27/04/1967 | | | 28 | | | | 0.78 | | 2.5 | | | | | 52 | |
| | SWQ2 | 23/05/1967 | | | 41 | | | | 0.55 | | 0.05 | | | | | 75 | |
| | SWQ2 | 13/06/1967 | | | 31 | | | | | | 0.15 | | | | | 101 | |
| | SWQ2 | 11/07/1967 | | | 27 | | | | 1.92 | | 0.18 | | | | | 343 | |
| | SWQ2 | 09/08/1967 | | | 22 | | | | 1.55 | | | | | | 4000 | 62 | |
| | SWQ2 | 11/09/1967 | | | 39 | | | | 1.12 | | | | | | | 193 | |
| | SWQ2 | 11/10/1967 | | | 20 | | | | 1.73 | | 0.1 | | | | | 121 | |
| | SWQ2 | 13/11/1967 | | | 36 | | | | 2.3 | | 0.4 | | | | | 75 | |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 11/12/1967 | | | 65 | | | | 0.98 | | 0.3 | | | | | 588 | |
| | SWQ2 | 23/01/1968 | | | 226 | | | | | | 0.1 | | | | | 327 | |
| | SWQ2 | 12/02/1968 | | | 80 | | | | | | 0.3 | | | | | 458 | |
| | SWQ2 | 05/03/1968 | | | 59 | | | | | | 0.1 | | | | | 229 | |
| | SWQ2 | 25/03/1968 | | | 59 | | | | 2.92 | | 0.68 | | | | | 425 | |
| | SWQ2 | 16/04/1968 | | | 93 | | | | | | 0.63 | | | | | 173 | |
| | SWQ2 | 06/05/1968 | | | 113 | | | | 1.75 | | 0.31 | | | | 120000 | 88 | |
| | SWQ2 | 28/05/1968 | | | 135 | | | | 0.98 | | 0.26 | | | | | 719 | |
| | SWQ2 | 24/06/1968 | | | | | | | | | | | | | | 317 | |
| | SWQ2 | 15/07/1968 | | | 23 | | | | 2.6 | | 0.1 | | | | | 176 | |
| | SWQ2 | 06/08/1968 | | | 38 | | | | 2.28 | | 0.45 | | | | | 294 | |
| | SWQ2 | 03/09/1968 | | | 28 | | | | | | 0.27 | | | | | 199 | |
| | SWQ2 | 23/09/1968 | | | 67 | | | | | | 0.16 | | | | | 490 | |
| | SWQ2 | 22/10/1968 | | | 41 | | | | 2.25 | | 0.29 | | | | | 275 | |
| | SWQ2 | 04/11/1968 | | | 26 | | | | | | 0.41 | | | | | 216 | |
| | SWQ2 | 25/11/1968 | | | 99 | | | | | | 0.21 | | | | | 291 | |
| | SWQ2 | 16/12/1968 | | | 55 | | | | | | 1.2 | | | | | 425 | |
| | SWQ2 | 20/01/1969 | | | 93 | | | | | | 0.83 | | | | | 330 | |
| | SWQ2 | 10/02/1969 | | | 56 | | | | | | 0.68 | | | | | 150 | |
| | SWQ2 | 03/03/1969 | | | 78 | | | | 1.9 | | 0.59 | | | | | 420 | |
| | SWQ2 | 24/03/1969 | | | 56 | | | | | | 0.75 | | | | | 200 | |
| | SWQ2 | 14/04/1969 | | | 30 | | | | 0.95 | | 0.6 | | | | | 96 | |
| | SWQ2 | 05/05/1969 | | | 80 | | | | 1.5 | | 0.22 | | | | | 300 | |
| | SWQ2 | 26/05/1969 | | | 90 | | | | | | 0.21 | | | | | 390 | |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 16/06/1969 | | | 76 | | | | | | 0.23 | | | | | 290 | |
| | SWQ2 | 14/07/1969 | | | 18 | | | | | | 0.16 | | | | | 120 | |
| | SWQ2 | 18/08/1969 | | | 73 | | | | 0.6 | | 0.28 | | | | | 200 | |
| | SWQ2 | 15/09/1969 | | | 107 | | | | 3.6 | | 0.01 | | | | | 360 | |
| | SWQ2 | 06/10/1969 | | | 28 | | | | | | 0.21 | | | | | 330 | |
| | SWQ2 | 17/11/1969 | | | 72 | | | | | | 0.39 | | | | | 200 | |
| | SWQ2 | 20/01/1970 | | | 64 | | | | 0.7 | | 0.34 | | | | | 340 | |
| | SWQ2 | 17/02/1970 | | | 115 | | | | | | 0.26 | | | | | 560 | |
| | SWQ2 | 09/03/1970 | | | 108 | | | | | | 0.76 | | | | | 180 | |
| | SWQ2 | 06/04/1970 | | | 67 | | | | | | 1 | | | | | 180 | |
| | SWQ2 | 28/04/1970 | | | 106 | | | | | | 0.05 | | | | | 190 | |
| | SWQ2 | 02/06/1970 | | | 96 | | | | 0.6 | | 0.03 | | | | | 320 | |
| | SWQ2 | 06/07/1970 | | | 38 | | | | 0.45 | | 0.2 | | | | | 110 | |
| | SWQ2 | 05/08/1970 | | | 30 | | | | | | 0.3 | | | | | 110 | |
| | SWQ2 | 31/08/1970 | | | 64 | | | | 0.8 | | 0.25 | | | | | 110 | |
| | SWQ2 | 27/09/1970 | | | 20 | | | | 1.95 | | 0.28 | | | | | 270 | |
| | SWQ2 | 02/11/1970 | | | 47 | | | | | | 0.46 | | | | | 230 | |
| | SWQ2 | 08/12/1970 | | | 189 | | | | | | 0.93 | | | | | 53 | |
| | SWQ2 | 12/01/1971 | | | 159 | | | | 0.85 | | 0.69 | | | | | 240 | |
| | SWQ2 | 08/02/1971 | | | 163 | | | | | | 1.1 | | | | | 160 | |
| | SWQ2 | 08/03/1971 | | | 110 | | | | | | 0.67 | | | | | 130 | |
| | SWQ2 | 29/03/1971 | | | 140 | | | | | | 0.91 | | | | | 110 | |
| | SWQ2 | 26/04/1971 | | | 42 | | | | 0.8 | | 0.56 | | | | | 260 | |
| | SWQ2 | 25/05/1971 | | | 65 | | | | | | 0.59 | | | | | 400 | |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 24/06/1971 | | | 83 | | | | | | 0.21 | | | | | 420 | |
| | SWQ2 | 27/07/1971 | | | 20 | | | | | | 0.41 | | | | | 84 | |
| | SWQ2 | 19/08/1971 | | | 77 | | | | 0.8 | | 0.14 | | | | | 140 | |
| | SWQ2 | 27/09/1971 | | | 37 | | | | | | 0.33 | | | | | 84 | |
| | SWQ2 | 28/10/1971 | | | 44 | | | | | | 0.35 | | | | | 100 | |
| | SWQ2 | 24/11/1971 | | | 35 | | | | | | 0.93 | | | | | 760 | |
| | SWQ2 | 07/01/1972 | | | | | | | 1.1 | | 0.76 | | | | | 140 | |
| | SWQ2 | 17/04/1973 | | | 29 | | 50 | 10 | 0.44 | 90 | 0.67 | | | | 4000 | 120 | 40 |
| | SWQ2 | 15/05/1973 | | | 32 | | 30 | | 0.6 | 40 | 0.51 | | | | 4000 | 64 | 10 |
| | SWQ2 | 20/06/1973 | | | 23 | | 30 | 10 | 0.55 | 150 | 0.32 | | | | 2000 | 97 | 30 |
| | SWQ2 | 17/07/1973 | | | 33 | | 50 | | | 70 | 0.26 | | | | 2000 | 130 | 10 |
| | SWQ2 | 14/08/1973 | | | 25 | | 50 | 10 | 0.95 | | 0.26 | | | | 3000 | 280 | |
| | SWQ2 | 11/09/1973 | | | 21 | | 30 | 10 | 0.75 | 1600 | 0.5 | | | | 2000 | 180 | 60 |
| | SWQ2 | 01/10/1973 | | | 20 | | 50 | 10 | 0.28 | 270 | 0.31 | | | | | 600 | 60 |
| | SWQ2 | 15/11/1973 | | | 19 | | 50 | 10 | 2.4 | 70 | 0.46 | | | | 8000 | 280 | 70 |
| | SWQ2 | 03/12/1973 | | | 95 | | | | | | 0.95 | | | | 2000 | 90 | |
| | SWQ2 | 24/01/1974 | | | 67 | | 30 | | 0.15 | 120 | 0.82 | | | | 10000 | 66 | 30 |
| | SWQ2 | 25/02/1974 | | | 44 | | 30 | 10 | 0.55 | 50 | 1 | | | | 4000 | 1300 | 30 |
| | SWQ2 | 25/03/1974 | | | 132 | | 20 | 10 | 0.85 | 400 | 0.72 | | | | 6000 | 130 | 40 |
| | SWQ2 | 29/04/1974 | | | 37 | | | | | | 0.56 | | | | | 260 | |
| | SWQ2 | 27/05/1974 | | | 30 | | 30 | | 0.3 | 240 | 0.41 | | | | 2000 | 850 | 30 |
| | SWQ2 | 10/07/1974 | | | 33 | | 30 | | | 60 | 0.39 | | | | 5000 | 130 | 30 |
| | SWQ2 | 26/08/1974 | | | 80 | | 40 | | 0.45 | 180 | 0.02 | | | | 1000 | 230 | 80 |
| | SWQ2 | 25/09/1974 | | | 25 | | 30 | | 1.3 | 200 | 0.34 | | | | 2000 | 280 | 30 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 15/10/1974 | | | 28 | | 40 | | 0.7 | 24000 | 0.69 | | | | 7000 | 240 | 40 |
| | SWQ2 | 04/11/1974 | | | 20 | | 30 | | 0.2 | 260 | 0.46 | | | | 2000 | 110 | 30 |
| | SWQ2 | 13/12/1974 | | | 30 | | 30 | 10 | 0.88 | 110 | 0.7 | | | | 1000 | 200 | 30 |
| | SWQ2 | 28/01/1975 | | | 47 | | 40 | | 1.1 | 80 | 0.88 | | | | 1000 | 150 | 30 |
| | SWQ2 | 17/02/1975 | | | 68 | | 50 | 10 | 0.95 | 170 | 0.86 | | | | 3000 | 220 | 20 |
| | SWQ2 | 01/04/1975 | | | 96 | | 50 | 10 | 0.88 | 170 | 0.94 | | | | 1000 | 170 | 20 |
| | SWQ2 | 12/05/1975 | | | 32 | | 50 | 10 | 0.25 | 90 | 0.4 | | | | | 36 | |
| | SWQ2 | 23/06/1975 | | | 41 | | 40 | 10 | 0.38 | 450 | 0.36 | | | | 2000 | 54 | 40 |
| | SWQ2 | 06/07/1975 | | | 32 | | 30 | 20 | 0.33 | 60 | 0.37 | | | | | 230 | 30 |
| | SWQ2 | 06/08/1975 | | | 25 | | 50 | 10 | 0.55 | 50 | 0.17 | | | | 1000 | 88 | 30 |
| | SWQ2 | 26/08/1975 | | | 27 | | | | | | 0.16 | | | | | 91 | |
| | SWQ2 | 08/09/1975 | | | 38 | | 10 | 10 | 0.24 | 50 | 0.08 | | | | 1000 | 94 | 10 |
| | SWQ2 | 30/09/1975 | | | 23 | | 30 | | 0.08 | 50 | 0.26 | | | | 1000 | 158 | 30 |
| | SWQ2 | 28/10/1975 | | | 22 | | 20 | | 0.25 | 40 | 0.24 | | | | 1000 | 130 | 20 |
| | SWQ2 | 20/11/1975 | | 0.01 | 25 | | 10 | | 0.25 | 80 | 0.31 | | | 10 | 1000 | 130 | 10 |
| | SWQ2 | 19/01/1976 | | | 45 | | 80 | | 0.56 | 100 | 0.87 | | | | 1000 | 190 | 700 |
| | SWQ2 | 15/03/1976 | | | 255 | | 30 | | 0.71 | 30 | 1.19 | | | | 1000 | 92 | 40 |
| | SWQ2 | 11/05/1976 | 0.001 | 0.01 | 43 | | 20 | | 0.5 | 30 | 0.627 | | | 20 | 1000 | 98 | 30 |
| | SWQ2 | 07/06/1976 | | | 36.5 | | 40 | 10 | 0.8 | | 0.259 | | | | 1000 | 81 | |
| | SWQ2 | 25/06/1976 | | | 10.5 | | | | 0.58 | | 0.404 | | | | 1000 | 66 | |
| | SWQ2 | 23/07/1976 | | | 7.1 | | | | 0.62 | | 0.329 | | | | 1000 | 96 | |
| | SWQ2 | 27/07/1976 | | | 24.5 | | 20 | 10 | 1.34 | 40 | 0.593 | | | | 1000 | 90 | 50 |
| | SWQ2 | 24/08/1976 | | | 29 | | 10 | 10 | 0.3 | 40 | 0.187 | | | | 1000 | 56 | 10 |
| | SWQ2 | 09/09/1976 | 0.001 | 0.01 | 27 | | 30 | | 0.29 | 60 | 0.074 | | | 10 | 1000 | 21 | 30 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 21/09/1976 | | | 22.5 | | | | | | 0.354 | | | | | 38 | |
| | SWQ2 | 18/10/1976 | | | 23 | | | | 0.41 | | 0.266 | | | | 2000 | 70 | |
| | SWQ2 | 26/10/1976 | | | 29.5 | | | | | | 0.451 | | | | 1000 | 114 | |
| | SWQ2 | 22/11/1976 | | | 32 | | 20 | | 0.87 | 60 | 0.557 | | | | 12000 | 140 | 30 |
| | SWQ2 | 16/12/1976 | 0.001 | 0.005 | 43.5 | | 10 | | 0.43 | 50 | 0.654 | | | 10 | 1000 | 85 | 30 |
| | SWQ2 | 07/02/1977 | 0.001 | 0.005 | 32 | | 20 | | 1.5 | 100 | 0.695 | | | 10 | 1000 | 137 | 100 |
| | SWQ2 | 28/03/1977 | 0.001 | 0.005 | 53 | | 20 | 20 | 0.54 | 80 | 0.751 | | | 10 | 4000 | 410 | 60 |
| | SWQ2 | 26/04/1977 | | | 53 | | 80 | 10 | 0.01 | 20 | 0.703 | | | | 2000 | 56 | 40 |
| | SWQ2 | 11/05/1977 | 0.001 | 0.005 | 62 | | 10 | | 0.29 | 40 | 0.172 | | | 10 | 1000 | 39 | 10 |
| | SWQ2 | 16/05/1977 | | | 38.5 | | | | | | 0.21 | | | | 1000 | 45 | |
| | SWQ2 | 13/06/1977 | | | 30 | | 10 | 10 | 0.57 | 50 | 0.284 | | | | 2000 | 102 | 20 |
| | SWQ2 | 28/06/1977 | 0.001 | 0.01 | 6.1 | | 40 | | 0.62 | 40 | 0.171 | | | 20 | 1000 | 34 | 60 |
| | SWQ2 | 12/07/1977 | | | 38.5 | | | | | | 0.46 | | | | 1000 | 81 | |
| | SWQ2 | 19/07/1977 | | | 27.5 | | | | 0.51 | | 0.101 | | | | 1000 | 92 | |
| | SWQ2 | 08/08/1977 | 0.001 | 0.005 | 27.5 | | 10 | | 0.3 | 20 | 0.143 | | | 30 | 1000 | 18 | 20 |
| | SWQ2 | 15/08/1977 | | | 27 | | 10 | 10 | | 40 | 0.175 | | | | 1000 | 57 | 20 |
| | SWQ2 | 12/09/1977 | 0.001 | 0.005 | 25 | | 10 | 10 | | 70 | 0.125 | | | 30 | 1000 | 68 | 20 |
| | SWQ2 | 12/10/1977 | 0.001 | 0.005 | 41 | | 10 | | 0.71 | 40 | 0.963 | | | 30 | 1000 | 83 | 20 |
| | SWQ2 | 17/10/1977 | | | 38 | | 10 | 10 | 0.46 | 410 | 0.58 | | | | 1000 | 47 | 10 |
| | SWQ2 | 21/11/1977 | | | 42.5 | | 60 | | 1.06 | 60 | 1.53 | | | | 3000 | 60 | 200 |
| | SWQ2 | 30/11/1977 | 0.001 | 0.005 | 44.5 | | 10 | | 0.71 | 60 | 0.845 | | | 30 | 1000 | 72 | 10 |
| | SWQ2 | 07/12/1977 | | | 40 | | 80 | | | 60 | 1.04 | | | | 1000 | 41 | 10 |
| | SWQ2 | 09/01/1978 | | | 43 | | | | 0.52 | | 1.87 | | | | 1000 | 45 | |
| | SWQ2 | 20/02/1978 | | | 315 | | | | | | 0.685 | | | | | 77 | |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 24/02/1978 | | | 28.5 | | | | 0.84 | | 0.8 | | | | 1000 | 88 | |
| | SWQ2 | 17/04/1978 | 0.001 | 0.005 | 39 | | 10 | | 1.5 | 40 | 1.29 | | | 30 | 2500 | 430 | 650 |
| | SWQ2 | 15/05/1978 | 0.001 | 0.005 | 26 | | 10 | | 2.5 | 20 | 1.03 | | | 30 | 3000 | 160 | 20 |
| | SWQ2 | 19/06/1978 | | | 25.5 | | | | 0.31 | | 0.345 | | | | 1000 | 34 | |
| | SWQ2 | 17/07/1978 | | | 25.5 | | | | 0.3 | | 0.193 | | | | 1000 | 75 | |
| | SWQ2 | 01/09/1978 | | | 22.5 | | | | 0.44 | | 0.325 | | | | 1000 | 102 | |
| | SWQ2 | 25/09/1978 | 0.001 | 0.005 | 25.5 | | 10 | | 1.4 | 200 | 0.31 | | | 30 | 1000 | 60 | 10 |
| | SWQ2 | 27/10/1978 | | | 22.5 | | | | 0.4 | | 0.44 | | | | 1000 | 37 | |
| | SWQ2 | 29/11/1978 | | | 77 | | | | 0.58 | | 0.807 | | | | 2000 | 58 | |
| | SWQ2 | 11/12/1978 | 0.001 | 0.005 | 116 | | 50 | | 0.6 | 230 | 0.863 | | | 30 | 1000 | 55 | 10 |
| | SWQ2 | 19/02/1979 | | | 35.5 | | 10 | | | 300 | 0.893 | | | 30 | 1000 | 32 | 10 |
| | SWQ2 | 23/03/1979 | | | 30 | | 10 | | 1.4 | 300 | 0.661 | | | 30 | 1000 | 106 | 20 |
| | SWQ2 | 19/04/1979 | | | 44.5 | | 20 | | 0.32 | 230 | 0.89 | | | 30 | 1000 | 26 | 10 |
| | SWQ2 | 17/05/1979 | | | 42 | | | | | | 0.354 | | | | 1000 | 21 | |
| | SWQ2 | 22/06/1979 | | | 30 | | 10 | | | 80 | 0.685 | | | 40 | 1000 | 58 | 10 |
| | SWQ2 | 16/07/1979 | 0.005 | 0.01 | 28 | | 50 | | 0.39 | | 0.23 | | | 30 | | 47 | 10 |
| | SWQ2 | 21/08/1979 | | | 25.5 | | 10 | | 0.35 | 70 | 0.246 | | | 30 | 1000 | 35 | 10 |
| | SWQ2 | 17/09/1979 | | | 24.5 | | 10 | | 0.22 | 120 | 0.424 | | | 30 | 1000 | 35 | 10 |
| | SWQ2 | 30/10/1979 | | | 16.5 | | | | | | 0.49 | | | | 1000 | 125 | |
| | SWQ2 | 27/11/1979 | | | 34.5 | | | | | | 0.881 | | | | 1000 | 140 | |
| | SWQ2 | 14/12/1979 | 0.001 | 0.005 | 40 | | 10 | | | | 0.871 | | | 30 | 1000 | 33 | 10 |
| | SWQ2 | 11/01/1980 | 0.003 | 0.01 | 180 | 20 | 30 | | | 50 | 0.45 | | | 210 | 5000 | 565 | 170 |
| | SWQ2 | 14/02/1980 | | | 65 | | 30 | | | 80 | 0.85 | | | 30 | 1000 | 32 | 10 |
| | SWQ2 | 14/03/1980 | 0.001 | 0.005 | 115 | | 10 | | | | 0.085 | | | 30 | 1000 | 200 | 10 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 22/04/1980 | 0.001 | | 46 | | 20 | | 0.58 | 50 | 0.94 | | | 30 | 1000 | 46 | 40 |
| | SWQ2 | 20/05/1980 | 0.001 | 0.005 | 34.5 | 20 | 60 | | | 160 | 0.345 | | | 30 | 1000 | 27 | 10 |
| | SWQ2 | 23/06/1980 | | | 32 | | 10 | | 0.46 | | 0.322 | | | 30 | 1000 | 31 | 10 |
| | SWQ2 | 07/07/1980 | | | 32.5 | | 20 | | | 20 | 0.395 | | | 30 | 1000 | 74 | 10 |
| | SWQ2 | 12/08/1980 | | | 18.5 | | | | 0.58 | | 0.486 | | | 3 | 1000 | 58 | |
| | SWQ2 | 22/09/1980 | | | 26.5 | | 5 | | 0.55 | 73 | 0.34 | | | 3 | 1000 | 21 | 5 |
| | SWQ2 | 07/10/1980 | | | 29.5 | | 3 | | 0.21 | 34 | 0.31 | | | 3 | | 21 | 3 |
| | SWQ2 | 08/12/1980 | | | 91 | | | | | | 1.07 | | | | 4000 | 178 | |
| | SWQ2 | 17/02/1981 | | | 141 | | 10 | | 1.1 | | 1.16 | | | 13 | 1000 | 85 | 33 |
| | SWQ2 | 23/03/1981 | | | 43 | | 3 | | 0.42 | 10 | 0.945 | 0.95 | | 3 | 1000 | 26 | 3 |
| | SWQ2 | 27/04/1981 | | | 38 | | 3 | | 0.34 | 9 | 0.52 | 0.54 | | 3 | 1000 | 16 | 4 |
| | SWQ2 | 25/05/1981 | | | 33.5 | | 1 | | 0.57 | 4 | | | | 10 | 1000 | 38 | 3 |
| | SWQ2 | 15/06/1981 | | | 33 | | 4 | | 0.39 | | 14.3 | 14.5 | | 5 | 1000 | 392 | 5 |
| | SWQ2 | 27/07/1981 | | | 26.5 | | 6 | | 0.32 | 5 | 0.325 | 0.365 | | 3 | 1000 | 26 | 10 |
| | SWQ2 | 17/08/1981 | | | 30 | | 8 | | 0.7 | 7 | 0.63 | 0.66 | | 6 | 1000 | 58 | 7 |
| | SWQ2 | 14/09/1981 | | | 35 | | 4 | | 0.6 | 3 | 0.67 | 0.67 | | 3 | 1000 | 42 | 3 |
| | SWQ2 | 26/10/1981 | | | 30 | | 35 | | 0.42 | 6 | 0.89 | 0.91 | | 20 | 2000 | 725 | 18 |
| | SWQ2 | 23/11/1981 | | | 37 | | 15 | | 1.85 | 3 | 1.83 | 1.85 | | 3 | 1000 | 25 | 57 |
| | SWQ2 | 15/12/1981 | | | 41 | | 5 | | 0.36 | 29 | 0.975 | 0.985 | | 6 | 1000 | 22 | 7 |
| | SWQ2 | 25/01/1982 | | | 54 | | 10 | | 0.55 | 12 | 1.01 | 1.1 | | 22 | 1000 | 34 | 30 |
| | SWQ2 | 18/02/1982 | | | 102 | | 3 | | 0.47 | 300 | 0.9 | 0.935 | | 4 | 1000 | 50 | 13 |
| | SWQ2 | 15/03/1982 | | | 44.5 | | 16 | | 7.9 | 39 | 1.47 | 1.55 | | 28 | 1000 | 640 | 46 |
| | SWQ2 | 19/04/1982 | | | 38.5 | | 10 | | 0.68 | 97 | 1.065 | 1.1 | | 3 | 1000 | 53 | 11 |
| | SWQ2 | 17/05/1982 | | | 35.4 | | 10 | | 0.415 | 180 | 0.33 | 0.385 | | 10 | 400 | 600 | 8 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 21/06/1982 | | | 36.8 | | 14 | | 0.465 | 26 | 0.705 | 0.725 | | 3 | 1200 | 56 | 7 |
| | SWQ2 | 19/07/1982 | | | 21.6 | | 17 | | 2.55 | 20 | 0.77 | 0.82 | | 3 | 400 | 300 | 38 |
| | SWQ2 | 24/08/1982 | | | 25.3 | | 10 | | 0.25 | 160 | 0.31 | 0.325 | | 3 | 600 | 48 | 7 |
| | SWQ2 | 20/09/1982 | | | 27.5 | | 6 | | 0.725 | 34 | 0.448 | 0.45 | | 3 | | 46 | 4 |
| | SWQ2 | 18/10/1982 | | | 33.1 | | 11 | | 0.29 | 17 | 0.41 | 0.43 | | 3 | 400 | 27 | 4 |
| | SWQ2 | 16/11/1982 | | | 37.7 | | 11 | | 0.305 | 29 | 0.811 | 0.85 | | 7 | 200 | 43 | 5 |
| | SWQ2 | 13/12/1982 | | | 48.2 | | 11 | | 0.78 | 180 | 1.55 | 1.55 | | 8 | 200 | 27 | 8 |
| | SWQ2 | 10/01/1983 | | | 37.6 | | 10 | | 0.805 | 18 | 1.2 | 1.2 | | 15 | 1200 | 43 | 20 |
| | SWQ2 | 17/02/1983 | | | 69 | | 19 | | 3.4 | 32 | 1.506 | 1.51 | | 26 | 400 | 200 | 30 |
| | SWQ2 | 18/03/1983 | | | 33.4 | | 11 | | 0.41 | 130 | 0.94 | 0.98 | | 3 | 800 | 62 | 9 |
| | SWQ2 | 28/04/1983 | | | 32.7 | | 15 | | 0.365 | 120 | 1.43 | 1.43 | | 7 | 200 | 112 | 11 |
| | SWQ2 | 13/06/1983 | | | 29 | | 8 | | 0.9 | 1200 | 0.406 | 0.415 | | 3 | | 79 | 4 |
| | SWQ2 | 18/07/1983 | | | 26.3 | | 14 | | 0.51 | 1200 | 0.404 | 0.41 | | 7 | 200 | 160 | 9 |
| | SWQ2 | 12/08/1983 | | | 22 | | 43 | | 0.425 | 1200 | 0.513 | 0.52 | | 3 | 200 | 44 | 11 |
| | SWQ2 | 09/09/1983 | | | 23 | | 10 | | 0.215 | 1100 | 0.285 | 0.29 | | 3 | 200 | 31 | 4 |
| | SWQ2 | 26/09/1983 | | | 22 | | 9 | | 0.225 | 1800 | 0.421 | 0.43 | | 4 | 400 | 77 | 5 |
| | SWQ2 | 17/10/1983 | | | 24.19 | | 7 | | 0.33 | 1100 | 0.469 | 0.475 | | 4 | 200 | 63 | 5 |
| | SWQ2 | 14/11/1983 | | | 36.11 | | 8 | | 0.225 | 31 | 0.694 | 0.7 | | 5 | 200 | 70 | 3 |
| | SWQ2 | 12/12/1983 | | | 42.13 | | 22 | | 9.375 | 57 | 1.09 | 1.1 | | 63 | | 660 | 79 |
| | SWQ2 | 24/01/1984 | | | 817.8 | | 11 | | 2.1 | 82 | 0.91 | 0.94 | | 29 | 3400 | 210 | 57 |
| | SWQ2 | 20/02/1984 | | | 43.46 | | 5 | | 0.915 | 16 | 4.46 | 4.5 | | 3 | 200 | 96 | 13 |
| | SWQ2 | 19/03/1984 | | | 44.99 | | 6 | | 1.36 | 48 | 1.58 | 1.6 | | 3 | | 120 | 12 |
| | SWQ2 | 18/04/1984 | | | 42.14 | | 6 | | 0.645 | 28 | 1.688 | 1.7 | | 3 | | 93 | 9 |
| | SWQ2 | 28/05/1984 | | | 34.01 | | 5 | | 0.235 | 24 | | 0.425 | | 3 | 200 | 113 | 9 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 22/06/1984 | | | 29.79 | | 4 | | 0.545 | 19 | | 0.47 | | 5 | | 115 | 9 |
| | SWQ2 | 23/07/1984 | | | 26.89 | | 3 | | 0.26 | 13 | | 0.315 | | 3 | 200 | 310 | 5 |
| | SWQ2 | 31/08/1984 | | | 23.15 | | 5 | | 0.405 | 7 | | 0.435 | | 3 | 1200 | 49 | 7 |
| | SWQ2 | 20/09/1984 | | | 30.42 | | 10 | | 0.23 | 15 | | 0.42 | | 30 | 200 | 72 | 10 |
| | SWQ2 | 19/11/1984 | | | 32.7 | | 7 | | 0.295 | 10 | | 1.1 | | 3 | 200 | 31 | 4 |
| | SWQ2 | 10/12/1984 | | | 51.86 | | 4 | | 0.39 | 6 | | 0.875 | | 3 | 200 | 43 | 7 |
| | SWQ2 | 22/01/1985 | | | 46.11 | | 7 | | 0.245 | 13 | | 1.04 | | 3 | 200 | 150 | 8 |
| | SWQ2 | 25/02/1985 | | | 15.9 | | 10 | | 4.25 | 2 | | 1.64 | | 5 | 1600 | 305 | 20 |
| | SWQ2 | 28/03/1985 | | | 45.9 | | 32 | | 9 | 27 | | 1.02 | | 110 | 4600 | 470 | 150 |
| | SWQ2 | 26/04/1985 | | | 38.7 | | 1 | | 0.725 | 7 | | 0.775 | | 3 | 600 | 85 | 9 |
| | SWQ2 | 27/05/1985 | | | 28.95 | | 3 | | 0.595 | 19 | | 0.66 | | 7 | 5400 | 110 | 14 |
| | SWQ2 | 28/06/1985 | | | 32.6 | | 1 | | 0.37 | 15 | | 0.44 | | 3 | 800 | 62 | 6 |
| | SWQ2 | 26/07/1985 | | | 34.05 | | 2 | | 0.26 | 60 | | 0.36 | | 4 | 200 | 81 | 8 |
| | SWQ2 | 26/08/1985 | | | 24.4 | | 1 | | 0.19 | 10 | | 0.57 | | 3 | 200 | 60 | 4 |
| | SWQ2 | 27/09/1985 | | | 22.98 | | 54 | | 8.5 | 270 | | 0.565 | | 130 | 200 | 72 | 220 |
| | SWQ2 | 22/10/1985 | | | 27.6 | | 2 | | 0.13 | 2 | | 0.475 | | 4 | 200 | 47 | 4 |
| | SWQ2 | 29/11/1985 | | | 72.9 | | 3 | | 0.24 | 16 | | 1.35 | | 6 | 200 | 45 | 10 |
| | SWQ2 | 17/12/1985 | | | 78 | | 8 | | 0.26 | 24 | | 1.33 | | 5 | 600 | 30 | 10 |
| | SWQ2 | 13/01/1986 | | | 76.7 | | 1 | | 0.18 | 36 | | 1.06 | | 3 | 200 | 39 | 6 |
| | SWQ2 | 17/02/1986 | | | 160 | | | | | | | 0.96 | | | 200 | 285 | |
| | SWQ2 | 25/03/1986 | | | 41.6 | | 3 | | 0.63 | 32 | | 1.29 | | 30 | 800 | 57 | 8 |
| | SWQ2 | 06/05/1986 | | | 47.6 | | 4 | | 0.38 | 66 | | 0.62 | | 30 | 3600 | 69 | 8 |
| | SWQ2 | 02/06/1986 | | | 36 | | | | | | | 0.455 | | | 2600 | 32 | |
| | SWQ2 | 02/07/1986 | | | 48 | | 4 | | 0.86 | 94 | | 0.675 | | 3 | 2400 | 88 | 18 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 06/08/1986 | | | 37 | | 4 | | 0.46 | 170 | | 0.43 | | 30 | 400 | 39 | 7 |
| | SWQ2 | 03/09/1986 | | | 45.5 | | 4 | | 0.35 | 140 | | 0.675 | | 30 | 200 | 68 | 4 |
| | SWQ2 | 21/10/1986 | | | 37 | | 3 | | 0.26 | 90 | | 0.835 | | 30 | 400 | 16 | 4 |
| | SWQ2 | 17/11/1986 | | | 33.5 | | 4 | | 0.26 | 100 | | 0.915 | | 30 | 200 | 26 | 7 |
| | SWQ2 | 09/12/1986 | | | 130 | | 3 | | 0.48 | 110 | | 1.22 | | 30 | 200 | 42 | 8 |
| | SWQ2 | 01/01/1987 | | | 35.2 | | 3 | | 0.21 | 85 | | 0.655 | | 30 | 200 | 43 | 4 |
| | SWQ2 | 12/01/1987 | | | 141 | | 3 | | 0.28 | 90 | | 1.17 | | 30 | 400 | 29 | 4 |
| | SWQ2 | 10/02/1987 | | | 68.5 | | 3 | | 0.32 | 83 | | 1.1 | | 30 | 600 | 32 | 11 |
| | SWQ2 | 10/03/1987 | | | 53 | | 1 | | 0.44 | 57 | | 1.76 | | 3 | 200 | 169 | 5 |
| | SWQ2 | 08/04/1987 | | | 47 | | 10 | | 0.56 | 42 | | 1.48 | | 30 | 600 | 34 | 10 |
| | SWQ2 | 15/06/1987 | | | 27.15 | | 2 | | 0.55 | 72 | | 0.67 | | 3 | 200 | 70 | 11 |
| | SWQ2 | 20/07/1987 | | | 24.6 | | 7 | | 1.5 | 48 | | 0.615 | | 10 | 200 | 79 | 14 |
| | SWQ2 | 20/08/1987 | | | 28.25 | | 2 | | 0.37 | 64 | | 0.275 | | 3 | 200 | 44 | 4 |
| | SWQ2 | 21/09/1987 | | | 25.55 | | 11 | | 2.5 | 90 | | 0.635 | | 19 | 400 | 353 | 46 |
| | SWQ2 | 19/10/1987 | | | 28.1 | | 3 | | 0.15 | 59 | | 0.535 | | 3 | 200 | 20 | 5 |
| | SWQ2 | 09/11/1987 | | | 32.5 | | 8 | | 0.71 | 43 | | 0.7 | | 3 | 200 | 65 | 26 |
| | SWQ2 | 03/12/1987 | | | 46.9 | | 4 | | 0.73 | 50 | | 2.31 | | 6 | 200 | 57 | 10 |
| | SWQ2 | 07/01/1988 | | | 46.9 | | 19 | | 0.28 | 67 | | 1.53 | | 11 | 600 | 24 | 12 |
| | SWQ2 | 15/03/1988 | | | 75.4 | | 5.1 | | 0.71 | 56 | | 1.15 | | 3 | | 109 | 9.1 |
| | SWQ2 | 19/04/1988 | | | 44.3 | | 2 | | 0.26 | 27 | | 0.925 | | 3 | 200 | 200 | 7 |
| | SWQ2 | 20/05/1988 | | | 40.3 | | 2.2 | | 0.24 | 40 | | 0.57 | | 5 | | 12 | 5.1 |
| | SWQ2 | 17/06/1988 | | | 33.6 | | 1.7 | | 0.3 | 44 | | 0.4 | | 5 | 1400 | 24 | 4.3 |
| | SWQ2 | 21/07/1988 | | | 30.5 | | 8.4 | | 0.78 | 32 | | 0.425 | | 5 | 1200 | 54 | 8 |
| | SWQ2 | 26/08/1988 | | | 28.3 | | 5.6 | | 0.43 | 28 | | 0.69 | | 5 | 2000 | 74 | 5 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 23/09/1988 | | | 20.4 | | 3 | | 0.53 | 28 | | 0.715 | | 5 | 2800 | 40 | 5.8 |
| | SWQ2 | 13/10/1988 | | | 30.6 | | 1.6 | | 0.16 | 33 | | 0.585 | | 5 | 1400 | 11 | 4.4 |
| | SWQ2 | 16/11/1988 | | | 41.2 | | 1.6 | | 0.23 | 23 | | 1.77 | | 5 | | 15 | 3.3 |
| | SWQ2 | 13/12/1988 | | | 40.5 | | 4.4 | | 0.32 | 37 | | 1.16 | | 89 | 3000 | 14 | 20 |
| | SWQ2 | 16/01/1989 | | | 152 | | 9.9 | | 0.17 | 25 | | 1.07 | | 5 | 100000 | 20 | 8.2 |
| | SWQ2 | 21/02/1989 | | | 2000 | | 36 | | 9 | 27 | | 1.49 | | 160 | 27200 | 450 | 290 |
| | SWQ2 | 20/03/1989 | | | 195 | | 5 | | 2.1 | 30 | | 1.13 | | 50 | 3000 | 125 | 12 |
| | SWQ2 | 19/04/1989 | | | 55.8 | | 1.9 | | 0.28 | 22 | | 1.41 | | 5 | 1600 | 13 | 4.6 |
| | SWQ2 | 16/05/1989 | | | 222 | | 6.5 | | 0.34 | 25 | | 2.22 | | 5 | 3600 | 139 | 4.3 |
| | SWQ2 | 27/06/1989 | | | 43.9 | | 3.3 | | 0.5 | 31 | | 0.455 | | 5 | 1800 | 39 | 7.2 |
| | SWQ2 | 17/07/1989 | | | 43 | | 2 | | 0.2 | 30 | | 0.295 | | 5 | 3200 | 25 | 2.7 |
| | SWQ2 | 21/08/1989 | | | 28.7 | | 3.4 | | 0.26 | 20 | | 0.375 | | 5 | 1800 | 20 | 3.1 |
| | SWQ2 | 16/10/1989 | | | 26.6 | | 1.8 | | 0.18 | 8 | | 0.54 | | 5 | 3800 | 13 | 3.2 |
| | SWQ2 | 23/11/1989 | | | 73.4 | | 2.7 | | 0.35 | 36 | | 2.94 | | 5 | 600 | 22 | 3.8 |
| | SWQ2 | 30/01/1990 | | | 1.1 | | 2.6 | | 0.3 | 37 | | 1.12 | | 5 | 2400 | 53 | 8.7 |
| | SWQ2 | 12/02/1990 | | | 55.7 | | 2.6 | | 0.71 | 50 | | 1.05 | | 5 | 1600 | 67 | 6.7 |
| | SWQ2 | 28/03/1990 | | | 64 | | 2 | | 0.37 | 54 | | 1.3 | | 5 | 1600 | 25 | 4.2 |
| | SWQ2 | 30/04/1990 | | | 54.7 | | 2 | | 0.22 | 48 | | 0.59 | | 5 | 600 | 36 | 3.3 |
| | SWQ2 | 15/05/1990 | | | 45.6 | | 2 | | 0.18 | 47 | | 0.385 | | 5 | 800 | 14 | 3 |
| | SWQ2 | 14/06/1990 | | | 41.4 | | 3 | | 0.28 | 46 | | 0.395 | | 5 | 600 | 26 | 4 |
| | SWQ2 | 23/07/1990 | | | 39.6 | | 1 | | 0.19 | 38 | | 0.5 | | 5 | 200 | 24 | 4 |
| | SWQ2 | 29/08/1990 | | | 36 | | 3 | | 0.14 | 49 | | 0.37 | | 5 | 800 | 24 | 3 |
| | SWQ2 | 18/09/1990 | | | 33.6 | | 3 | | 0.1 | 62 | | 0.475 | | 5 | | 8 | 2 |
| | SWQ2 | 26/11/1990 | | | 43 | | 4 | | 0.18 | 48 | | 1.02 | | 5 | 200 | 11 | 2 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 11/12/1990 | | | 57.2 | | 1 | | 0.2 | 85 | | 1.66 | | 5 | 800 | 7 | 4 |
| | SWQ2 | 25/03/1991 | | | 60.9 | | 1 | | 0.33 | 38 | | 2.14 | | 5 | 400 | 55 | 7 |
| | SWQ2 | 22/04/1991 | | | 25.8 | | 1 | | 0.27 | 14 | | 1.8 | | 5 | 800 | 830 | 11 |
| | SWQ2 | 13/05/1991 | | | 47.1 | | 0.5 | | 0.16 | 37 | | 0.66 | | 5 | 600 | 21 | 4 |
| | SWQ2 | 17/06/1991 | | | 33.4 | | 1 | | 0.18 | 39 | | 0.51 | | 5 | 200 | 35 | 7 |
| | SWQ2 | 22/07/1991 | | | 34.2 | | 2 | | 0.26 | 38 | | 0.38 | | 5 | | 43 | 7 |
| | SWQ2 | 19/08/1991 | | | 29 | | 2 | | 0.31 | 27 | | 0.36 | | 5 | 200 | 39 | 8 |
| | SWQ2 | 17/09/1991 | | | 28.2 | | 2 | | 0.15 | 26 | | 0.385 | | 5 | 200 | 18 | 4 |
| | SWQ2 | 21/10/1991 | | | 29.9 | | 1 | | 0.08 | 49 | | 0.555 | | 5 | 400 | 11 | 0.5 |
| | SWQ2 | 18/11/1991 | | | 31.2 | | 3 | | 0.19 | 40 | | 0.655 | | 5 | 1000 | 10 | 12 |
| | SWQ2 | 09/12/1991 | | | 183 | | 5 | | 0.46 | 97 | | 0.89 | | 5 | 200 | 32 | 10 |
| | SWQ2 | 13/01/1992 | | | 164 | | 1 | | 0.11 | 38 | | 0.99 | | 5 | 400 | 13 | 7 |
| | SWQ2 | 08/04/1992 | | | 55 | | 15 | | 0.14 | 19 | | 0.84 | | 5 | 600 | 15 | 7 |
| | SWQ2 | 25/05/1992 | | | 54.1 | | 1 | | 0.052 | 20 | | 0.57 | | 5 | 200 | 15 | 3 |
| | SWQ2 | 22/06/1992 | | | 41.4 | | 5 | | 0.13 | 20 | | 0.475 | | 6 | 200 | 10 | 46 |
| | SWQ2 | 10/07/1992 | | | 34.7 | | 1 | | 0.048 | 2 | | 0.42 | | 5 | 600 | 17 | 0.5 |
| | SWQ2 | 19/08/1992 | | | 36.6 | | 4.4 | | 0.17 | 10 | | 0.31 | | 5 | 600 | 11 | 45 |
| | SWQ2 | 18/09/1992 | | | 42.4 | | 1 | | 0.16 | 8 | | 0.6 | | 5 | 200 | 19 | 4 |
| | SWQ2 | 23/10/1992 | | | 52.1 | | 1 | | 0.16 | 6 | | 1.58 | | 5 | 600 | 14 | 7 |
| | SWQ2 | 16/11/1992 | | | 52.1 | | 1 | | 0.2 | 12 | | 2.06 | | 5 | 200 | 38 | 12 |
| | SWQ2 | 07/12/1992 | | | 114 | | 2 | | 0.1 | 14 | | 1.57 | | 5 | 200 | 9 | 4 |
| | SWQ2 | 18/01/1993 | | | 97.9 | | 2.2 | | 0.11 | 9 | | 1.83 | | 5 | | 15 | 5.3 |
| | SWQ2 | 15/02/1993 | | | 177 | | 1.6 | | 0.15 | 9 | | 1.3 | | 5 | 200 | 14 | 9 |
| | SWQ2 | 22/03/1993 | | | 143 | | 6.8 | | 0.37 | 22 | | 1.22 | | 7 | 600 | 118 | 30 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 27/04/1993 | | | 55.9 | | 0.9 | | 0.17 | 10 | | 1.45 | | 5 | 1200 | 28 | 7.6 |
| | SWQ2 | 17/05/1993 | | | 45.6 | | 1.1 | | 0.12 | 10 | | 0.54 | | 5 | 2000 | 10 | 6.8 |
| | SWQ2 | 18/06/1993 | | | 150.5 | | 0.5 | | 0.12 | 12 | | 0.5 | | 5 | 200 | 12 | 5 |
| | SWQ2 | 19/07/1993 | | | 30.2 | | 2.6 | | 0.36 | 6 | | 0.54 | | 5 | 400 | 52 | 8.9 |
| | SWQ2 | 25/08/1993 | | | 32.6 | | 1.2 | | 0.085 | 3 | | 0.475 | | 5 | 200 | 10 | 1.6 |
| | SWQ2 | 24/09/1993 | | | 30 | | 1.2 | | 0.11 | 5 | | 0.615 | | 5 | 600 | 8 | 8.9 |
| | SWQ2 | 18/10/1993 | | | 29.8 | | 3.4 | | 0.51 | 2 | | 0.645 | | 5 | 200 | 62 | 15 |
| | SWQ2 | 15/11/1993 | | | 30.7 | | 3.1 | | 0.13 | 8 | | 0.75 | | 5 | 600 | 16 | 8.6 |
| | SWQ2 | 06/12/1993 | | | 52.7 | | 1 | | 0.16 | 5 | | 1.57 | | 5 | 200 | 14 | 7.1 |
| | SWQ2 | 15/06/1994 | | | 53.3 | | 2.4 | | 0.17 | 14 | | 0.44 | | 5 | 600 | 18 | 3.2 |
| | SWQ2 | 14/07/1994 | | | 45.5 | | 1.4 | | 0.11 | 36 | | 0.38 | | 5 | 200 | 16 | 1.5 |
| | SWQ2 | 09/08/1994 | | | 47.8 | | 2.3 | | 0.12 | 12 | | 0.62 | | 5 | 1000 | 12 | 3.9 |
| | SWQ2 | 13/09/1994 | | | 38.3 | | 0.6 | | 0.1 | 21 | | 0.445 | | 5 | 400 | 4 | 2.4 |
| | SWQ2 | 06/10/1994 | | 0.0005 | 38.5 | 0.5 | 1.5 | | 0.12 | 21 | | | | 1 | 600 | 8 | 1.2 |
| | SWQ2 | 02/11/1994 | | 0.0005 | 27.4 | 0.5 | 0.4 | | 0.0006 | 10 | | | | 1 | 400 | 10 | 0.2 |
| | SWQ2 | 15/12/1994 | | 0.0001 | 72.8 | 0.5 | 0.9 | | 0.15 | 19 | | | | 5 | 1200 | 14 | 3.5 |
| | SWQ2 | 24/03/1997 | | | 126 | 0.31 | 0.961 | | 0.264 | 37 | | | | | | 20 | 4.4 |
| | SWQ2 | 11/06/2003 | | | 83 | 1.13 | 1.56 | | 0.235 | 2 | | | | | | 42 | 4.41 |
| | SWQ2 | 09/07/2003 | | 0.000453 | 64.8 | 1.28 | 1.68 | | 0.391 | 2 | | | | 0.694 | | 68 | 6.23 |
| | SWQ2 | 13/08/2003 | | | 48.9 | 1.66 | 1.04 | | 0.153 | 2 | | | | 0.866 | | 14 | 1.93 |
| | SWQ2 | 28/07/2004 | | 0.000143 | 51.5 | | 0.929 | | 0.203 | 2 | | | | 2.99 | | 35 | 1.85 |
| | SWQ2 | 25/08/2004 | | | 50 | 1.07 | 0.704 | | 0.201 | 2 | | | | 8.97 | | 23 | 1.73 |
| | SWQ2 | 21/09/2004 | | 0.0012 | 53.7 | 0.579 | 0.792 | | 0.198 | 1 | | | | | | 17 | 0.608 |
| | SWQ2 | 26/10/2004 | | 0.000029 | 43.9 | 1.54 | 0.851 | | 0.149 | 0 | | | | | | 23 | 1.57 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 28/07/2005 | | 0.000269 | 50.3 | 0.343 | 1.28 | | 0.219 | 1 | | | | | | 24 | 3.61 |
| | SWQ2 | 17/08/2005 | | 0.00034 | 36.2 | | 0.704 | | 0.204 | 1 | | | | | | 19 | 2.01 |
| | SWQ2 | 28/09/2005 | | | 62.1 | | 1.36 | | 0.322 | 1 | | | | | | 41 | 1.72 |
| | SWQ2 | 28/06/2006 | | | 64 | | 1.49 | | 0.167 | 1 | | | 0.817 | 2.09 | | 35 | 0.718 |
| | SWQ2 | 25/07/2006 | | 0.000283 | 60.3 | | 0.888 | | 0.0972 | 2 | | | 0.647 | 2.38 | | 22 | |
| | SWQ2 | 30/08/2006 | Below MDL | 0.0001 | 55.3 | Below MDL | 4.3 | | 0.132 | 1 | | | 0.74 | Below MDL | | 15 | 13.2 |
| | SWQ2 | 13/09/2006 | | 0.000413 | 33.4 | | 3.95 | | 0.361 | | | | 0.749 | | | 47 | 12 |
| | SWQ2 | 18/09/2006 | Below MDL | 0.0002 | 60.5 | 0.4 | 0.3 | | 0.246 | 0 | | | 0.98 | Below MDL | | 10 | 2.8 |
| | SWQ2 | 04/12/2006 | Below MDL | 0.0001 | 65.5 | Below MDL | 0.3 | | 0.204 | 1 | | | 2.44 | Below MDL | | 31 | 2.3 |
| | SWQ2 | 08/01/2007 | Below MDL | Below MDL | 69.4 | Below MDL | 2 | | 0.327 | 26 | | | 1.78 | 1.2 | | 20 | 8.7 |
| | SWQ2 | 26/03/2007 | Below MDL | Below MDL | 114 | Below MDL | Below MDL | | 0.53 | Below MDL | | | 1.57 | Below MDL | | 90 | 6 |
| | SWQ2 | 30/04/2007 | | 0.000768 | 80.7 | | 1.22 | | 0.146 | 1 | | | 1.21 | 0.721 | | 14 | 1.01 |
| | SWQ2 | 15/05/2007 | 0.0005 | 0.0002 | 113 | 0.3 | 9.4 | | 0.565 | 14 | | | 1.18 | 3.9 | | 74 | 34.6 |
| | SWQ2 | 23/05/2007 | | 0.000689 | 76.7 | 0.662 | 1.64 | | 0.2 | 2 | | | 0.892 | | | 12 | 1.98 |
| | SWQ2 | 26/06/2007 | | 0.000256 | 57.7 | 0.81 | 1.75 | | 0.359 | 1 | | | 0.746 | 3.46 | | 40 | 4.69 |
| | SWQ2 | 23/07/2007 | | 0.000669 | 48.7 | 0.908 | 0.758 | | 0.0238 | 1 | | | 0.592 | 3.51 | | 23 | |
| | SWQ2 | 24/07/2007 | Below MDL | Below MDL | 44.6 | Below MDL | 0.6 | | 0.116 | 1 | | | 0.79 | Below MDL | | 38 | 2.8 |
| | SWQ2 | 25/09/2007 | | 0.00057 | 50.7 | | 0.733 | | 0.000893 | 0 | | | 0.713 | | | 11 | |
| | SWQ2 | 23/10/2007 | | 0.000645 | 76.6 | 0.307 | 3.42 | | 0.00587 | 2 | | | 0.963 | | | 115 | 3.98 |
| | SWQ2 | 29/11/2007 | | 0.000801 | 200 | | 3.58 | | 0.0054 | 1 | | | 1.4 | 1.56 | | 38 | 1.78 |
| | SWQ2 | 21/01/2008 | 0.0002 | Below MDL | 169 | 0.3 | 2.1 | | 0.161 | 2 | | | 2.4 | 0.2 | | Below MDL | 1.3 |
| | SWQ2 | 16/04/2008 | | 0.000837 | 90.3 | 0.325 | 1.61 | | 0.201 | 1 | | | | 11.2 | | 22 | 3.71 |
| | SWQ2 | 21/05/2008 | | 0.000619 | 80.7 | 1.41 | 0.773 | | 0.144 | 2 | | | | | | 47 | 2.04 |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ2 | 27/05/2008 | 0.0003 | Below MDL | 10.8 | 0.5 | 0.4 | | 0.0009 | 1 | | | 3.04 | Below MDL | | 0 | 0.7 |
| | SWQ2 | 09/06/2008 | 0.0003 | Below MDL | 65.6 | 0.2 | 1.7 | | 0.196 | 5 | | | 0.74 | 0.9 | | 41 | 3.9 |
| | SWQ2 | 19/06/2008 | | 0.00154 | 88.4 | 0.843 | 2.11 | | 0.28 | 2 | | | | | | 29 | 2.46 |
| | SWQ2 | 25/06/2008 | 0.0005 | Below MDL | 82.6 | 0.3 | 1.6 | | 0.36 | 2 | | | 0.67 | 1.6 | | 28 | 6 |
| | SWQ2 | 22/07/2008 | | 0.000233 | 67.2 | 1.37 | 1.79 | | 0.391 | 2 | | | | 5.2 | | 46 | 3.73 |
| | SWQ2 | 14/08/2008 | | 0.000817 | 61 | | 1.5 | | 0.319 | 2 | | | | 1.55 | | 42 | 2.1 |
| | SWQ2 | 09/09/2008 | | 0.00132 | 45.6 | 1.12 | 2.62 | | 0.42 | 3 | | | | 1.86 | | 72 | 10.4 |
| | SWQ2 | 22/10/2008 | | 0.00084 | 60.3 | 1.77 | 0.975 | | 0.136 | 1 | | | | 1.64 | | 13 | 1.43 |
| | SWQ2 | 25/11/2008 | | 0.00098 | 164 | Below MDL | 2.39 | | 0.499 | 2 | | | | 6.21 | | 75 | 8.19 |
| | SWQ10 | 13/08/2003 | | | 33.1 | 0.687 | 0.647 | | 0.23 | 1 | | | | 7.79 | | 36 | 0.991 |
| | SWQ10 | 08/10/2003 | | | 26.1 | 0.0236 | | | 0.0705 | | | | | 8.16 | | 7 | 0.606 |
| | SWQ10 | 28/07/2004 | | | 37.2 | | 0.448 | | 0.185 | | | | | | | 32 | 1.08 |
| | SWQ10 | 25/08/2004 | | | 26.2 | | 0.0569 | | 0.113 | 0 | | | | 9.97 | | 10 | 0.173 |
| | SWQ10 | 26/10/2004 | | 0.000218 | 25.2 | | 1.88 | | 0.0744 | 1 | | | | 8.2 | | 18 | 11.2 |
| | SWQ10 | 17/08/2005 | | 0.000214 | 24.5 | 0.18 | 0.274 | | 0.092 | | | | | 4.79 | | 8 | 0.112 |
| | SWQ10 | 31/10/2005 | | 0.000406 | 27.3 | | | | 0.0722 | 1 | | | | | | 5 | |
| | SWQ10 | 18/09/2006 | Below MDL | 0.0001 | 26.1 | 1.2 | Below MDL | | 0.195 | Below MDL | | | 0.73 | Below MDL | | 9 | 2.1 |
| | SWQ10 | 31/10/2006 | | 0.000147 | 45.7 | 1.4 | 0.801 | | 0.117 | 1 | | | 1.57 | 0.963 | | 15 | |
| | SWQ10 | 26/03/2007 | Below MDL | Below MDL | 51.5 | 0.5 | Below MDL | | 0.565 | Below MDL | | | 1.49 | Below MDL | | 130 | Below MDL |
| | SWQ10 | 30/04/2007 | | 0.000936 | 42.6 | | 0.824 | | 0.0934 | 1 | | | 0.971 | 2.15 | | 10 | 0.212 |
| | SWQ10 | 24/07/2007 | Below MDL | Below MDL | 80 | 0.2 | 1.5 | | 0.16 | 1 | | | 0.37 | Below MDL | | 41 | 1.9 |
| | SWQ10 | 26/11/2007 | 0.0003 | Below MDL | 38.2 | 0.9 | 1.3 | | 0.642 | 1 | | | 1 | 1.1 | | 94 | 2.4 |
| | SWQ10 | 21/05/2008 | | | 34.7 | | | | | | | | | | | 40 | |

| Limits | Station | Sampling Date | Arsenic | Cadmium | Chloride | Cobalt | Copper | Cyanide and compounds | Iron | Nickel | Nitrate (Filtered Reactive) | Nitrate (Total, Filtered Reactive) | Nitrate as N | Lead | Phenolics | Phosphorous, Total | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWQ10 | 09/09/2008 | | | 33.4 | | | | | | | | | | | 66 | |
| | SWQ10 | 25/11/2008 | | | 47.9 | | | | | | | | | | | 55 | |
| | SWQ11 | 13/11/2006 | Below MDL | 0.0002 | 29.4 | Below MDL | 0.7 | | 0.0757 | Below MDL | | | 1.4 | Below MDL | | 6 | 0.6 |
| | SWQ11 | 08/01/2007 | 0.0008 | Below MDL | 30 | Below MDL | 0.9 | | 0.362 | 0 | | | 1.92 | Below MDL | | 31 | 2 |
| | SWQ11 | 26/03/2007 | Below MDL | Below MDL | 25.9 | 0.8 | 5 | | 1.43 | 2 | | | 1.48 | Below MDL | | 230 | Below MDL |
| | SWQ11 | 23/07/2007 | Below MDL | Below MDL | 22.6 | Below MDL | 0.6 | | 0.12 | 0 | | | 0.997 | Below MDL | | 31 | 0.7 |
| | SWQ11 | 24/07/2007 | Below MDL | Below MDL | 38 | Below MDL | 0.5 | | 0.0987 | 1 | | | 0.84 | Below MDL | | 48 | 0.4 |
| | SWQ11 | 19/09/2007 | 0.0012 | 0.001 | 21.3 | 1.6 | 1.5 | | 0.0602 | 1 | | | 1.09 | 1.1 | | 8 | 1.3 |
| | SWQ11 | 06/05/2008 | 0.0003 | Below MDL | 27.9 | 0.9 | 0.5 | | 0.0677 | Below MDL | | | 0.83 | Below MDL | | 13 | Below MDL |
| | SWQ11 | 14/08/2008 | 0.0005 | Below MDL | 26.3 | 0.3 | 0.9 | | 0.25 | 1 | | | 0.76 | 0.2 | | 35 | 1.3 |

0.362 *Exceedance*

*MDL - method detection limit*

# APPENDIX 4 List of exceeded parameters; possible sources; potential adverse effect to human health and aquatic life

| PARAMETER | SOURCES | INFLUENCES ON HUMAN HEALTH* | INFLUENCES ON AQUATIC LIFE | GUIDELINES *(1) ODWS* *(2) PWQO* (3) *CCME* |
|---|---|---|---|---|
| **Arsenic** | Arsenic can contaminate water supplies if the water has been in contact with certain rocks and minerals. Typical sources of arsenic are natural processes, pesticide residues, industrial waste, and smelter operations (copper, lead and zinc). Arsenic is found at higher levels in groundwater but is present at very low concentrations in most surface waters. | Arsenic can cause acute and chronic toxicity, liver and kidney damage and can decrease blood haemoglobin. Arsenic is a known carcinogen and can cause other nervous system effects; it must be removed from drinking waters at levels above the Maximum Allowable Concentration (MAC) of 0.025 mg/L. | | 0.025 mg/L (1)<br>5 ug/L (2) (3) |
| **Biological Oxygen Demand (BOD)-5 day** | The BOD is the amount of dissolved oxygen required by microorganisms to decompose organic waste in water. The more organic material there is in the water the higher the BOD exerted by the microorganisms will be. BOD is a measurement of the rate at which oxygen is used over a period of time. Sources of organic material in the water can include pulp and paper mills, meat-packing plants, food processing industries and wastewater treatment plants. As well urban and agricultural runoff can contribute to organic pollution. A natural source of organics in the water is leaf fall. | | In water bodies where there are high BOD levels organisms that are more tolerant of low levels of dissolved oxygen (carp, midge larvae and sewage worms) may appear and become abundant. Organisms that are intolerable of low oxygen levels such as caddisfly larvae, mayfly nymphs and stonefly nymphs will not survive. As organic pollution increases a low diversity of pollution tolerant organisms will take the place of a diverse ecologically stable and complex set of organisms. | |
| **Cadmium** | Cadmium is present in rocks coal and petroleum. It enters ground and surface waters when dissolved by acidic waters. Cadmium may also enter | Cadmium replaces zinc biochemically in the body and causes high blood pressure, liver and kidney damage, and | Cadmium is toxic to aquatic biota. | 0.005 mg/L (1)<br>0.1-0.5 ug/L (2)<br>0.017 ug/L (3) |

| PARAMETER | SOURCES | INFLUENCES ON HUMAN HEALTH* | INFLUENCES ON AQUATIC LIFE | GUIDELINES<br>*(1) ODWS*<br>*(2) PWQO*<br>(3) *CCME* |
|---|---|---|---|---|
| | the environment from industrial discharge, mining waste, metal plating, water pipes, batteries, paints and pigments, plastic stabilizers, landfill leachate and atmospheric fallout. Most cadmium that enters water bodies becomes associated with bottom sediments. | anaemia. It also destroys testicular tissue and red blood cells. | | |
| **Chloride** | Chlorides occur naturally in surface water but can also enter water through the use of road salts, agricultural runoff and wastewater pollution. It is widely distributed in nature as NaCl, KCl and $CaCl_2$. | Chloride is present in small amounts in drinking water and can produce a detectable salty taste at 250 mg/L. | Fish and other aquatic communities cannot survive in high levels of chlorides. According to the EPA the acute threshold for chloride for aquatic life is 860 mg/L and the chronic threshold is 230 mg/L. CCME recently reported that Ontario uses chloride limit of 150 mg/L for the protection of aquatic life. | 150 mg/L (3) |
| **Cobalt** | Cobalt is a relatively rare element found naturally in the environment. It is essential in trace amounts for human and other mammals (found in vitamin $B_{12)}$. Anthoropogenic sources in aquatic environment come from Co mining and processing, sewage effluents, urban and agricultural run-offs. | | Cobalt is toxic to aquatic biota. The acute toxicity of this metal increases with hardness. However, there appear to be no direct relation between chronic toxicity and hardness. | 0.9 ug/L (2) |
| **Copper** | Copper enters the environment from metal plating, industrial and domestic waste, mining and mineral leaching. It is also used extensively in domestic plumbing and is an essential trace component in food. | In drinking water copper may produce an objectionable taste; as well it can cause significant staining to clothes and fixtures. When consumed in large doses (much higher than the aesthetic objective) copper may result in adverse health effects such as stomach and intestinal distress, | Copper is an essential trace element but toxic to plants and algae at moderate levels. The toxicity of copper towards aquatic organisms is greatest in its ionic form (Cu2+). It becomes less toxic as it complexes and precipitates with various freshwater organic and inorganic components. Increased concentrations of copper may include | 1 mg/L (1)<br>5 ug/L (2)<br>2-4 ug/L (3) |

| PARAMETER | SOURCES | INFLUENCES ON HUMAN HEALTH* | INFLUENCES ON AQUATIC LIFE | GUIDELINES<br>*(1) ODWS*<br>*(2) PWQO*<br>(3) *CCME* |
|---|---|---|---|---|
| | | liver and kidney damage and anaemia. | growth inhibition, decreased production, mortality, decreased offspring survival rates, as well as various abnormalities and deformities in aquatic organisms. | |
| **Cyanide and compounds** | May be found in water from discharges from organic chemical industries, iron and steel works, and wastewater treatment facilities. | Exposure to small amounts of cyanide compounds over long periods of time is reported to cause loss of appetite, headache, weakness, nausea, dizziness, and symptoms of irritation of the upper respiratory tract and eyes.<br><br>Exposure to large amounts of all forms of cyanide for a short time can harm the brain, lungs, and heart, and cause coma and death. The health effects of all forms of cyanide are similar when large amounts are eaten, drunk, breathed, or touched. The first symptoms of cyanide poisoning are rapid, deep breathing and shortness of breath, followed by convulsions and loss of consciousness. In cases of acute cyanide poisoning, death is extremely rapid. | Fish are impacted by relatively low cyanide concentrations. Acute toxicity (20 to 640 ug/L) if fatal to various fish species within 96 hours of exposure. Chronic exposure (exposure of 5 to 20 ug/L up to 10 days) may affect reproduction, physiology, and levels of activities of many fish species. | 5 ug/L (2) |
| **Dissolved Oxygen** | The higher the concentration of DO in water, the better the water quality. The solubility of oxygen in water is subject to temperature, and the amount of organic material in the water. | DO has no direct effect on public health but drinking water with very little oxygen concentration can taste flat. DO also plays a role in the corrosion of metal pipes. | Dissolved oxygen is needed in the water for the survival of fish and other organisms. A reduction in oxygen can be lethal to many organisms. Fish may migrate away or die off with a decrease in DO. Juvenile fish may be more | 5500-9500 ug/L (3) |

| PARAMETER | SOURCES | INFLUENCES ON HUMAN HEALTH* | INFLUENCES ON AQUATIC LIFE | GUIDELINES<br>*(1) ODWS*<br>*(2) PWQO*<br>(3) *CCME* |
|---|---|---|---|---|
| | | | susceptible to low levels of DO than adults. | |
| **Iron** | Iron occurs naturally as a mineral from sediment and rocks. It can also come from mining, industrial waste, and corroding metal. | In drinking water supplies, excessive amount of iron may cause staining of laundry, plumbing fixtures and the water itself. Iron may also produce a bitter taste, or precipitate to promote the growth of iron bacteria in water mains and service pipes. | | 0.3 mg/L (1)<br>300 ug/L (3) |
| **Lead** | Lead enters the environment through industrial processes, mining, plumbing, gasoline and coal; it is also a water additive. | Lead affects red blood cell chemistry and delays normal physical and mental development in babies and young children. Causes slight deficits in attention span, hearing, and learning in children. It can also cause a slight increase in blood pressure in some adults. Lead is a probable carcinogen. Ingestion of lead should be avoided mainly by pregnant women and young children as they are the most susceptible. | | 0.01 mg/L (1)<br>1-7 ug/L (3) |
| **Nickel** | Nickel occurs naturally in soils, ground water, and surface water. It is often used in electroplating, stainless steel and alloy products, mining, and refining. | In the general population, most people are not affected by the typical amounts of nickel encountered. However, laboratory animals exposed to large amounts nickel over their lifetime experienced damages the heart and liver. Almost all water supplies in Canada contain | | 25-150 ug/L (3) |

| PARAMETER | SOURCES | INFLUENCES ON HUMAN HEALTH* | INFLUENCES ON AQUATIC LIFE | GUIDELINES<br>*(1) ODWS*<br>*(2) PWQO*<br>(3) *CCME* |
|---|---|---|---|---|
| | | a small amount of nickel. | | |
| **Nitrate** | Nitrates are present in water as a result of decay of plant or animal material, agricultural fertilizers, domestic sewage and wastewater. Nitrates are found in ground water under extensively developed areas. They can enter the environment from fertilizer, feedlots, and sewage. They are essential to the growth of plants | Nitrates pose a risk of methaemoglobinaemia to humans, especially infants (blood related problems). Methaemoglobinaemia is caused by the reaction of the nitrate ion with intestinal bacteria; the nitrate ion reacts with iron and prevents blood from carrying oxygen to body tissues. This is also known as Blue Baby Syndrome. | Excessive concentrations of nitrates in surface waters encourage the growth of algae; excessive algae growth degrades water quality. Nitrate nitrogen is one of the major nutrients that cause algal blooms and eutrophication. | 10.0 mg/L (1)<br>13000 ug/L (3) |
| **Phenols and Phenolics** | Phenols may occur naturally in aquatic environments from the decomposition of aquatic vegetation (Dobbins et al. 1987). The major anthropogenic sources are industrial effluents from chemical, petroleum, tinctoral and pharmaceutical industries; and domestic sewage. | Phenol irritates skin and causes its necrosis, it damages kidneys, liver, muscle and eyes. Phenols also affect the function of the hormonal system. Some phenols are capable of disturbing sexual hormones function, which finally may lead to sterility of animals and humans. | Phenol contaminated waters have varying toxicity levels on various aquatic species depending on concentrations. Also, it generates unpleasant taste in fish and shellfish. | 5 ug/L Interim (2)<br>1 ug/L (2) |
| **Phosphorus** | Human, animal and industrial waste, as well as anthropogenic disturbances to the land and vegetation are the main contributors of phosphorus to aquatic environments. | The presence of phosphorus in drinking water has little effect on human health. | Increased algae and plant growth are a surface water system's first response to phosphorus inputs. Further phosphorus additions can lead to (a) a decrease in biodiversity and a change in dominant biota; (b) a decline in ecologically sensitive species and an increase in tolerant species; (c) an increase in plant and animal biomass; (d) an increase in turbidity; (e) an increase in organics, leading to sedimentation and; (f) anoxic conditions. As well if the excessive plant growth includes cyanobacteria, | See CCME for Trigger Ranges |

| PARAMETER | SOURCES | INFLUENCES ON HUMAN HEALTH* | INFLUENCES ON AQUATIC LIFE | GUIDELINES<br>*(1) ODWS*<br>*(2) PWQO*<br>(3) *CCME* |
|---|---|---|---|---|
| | | | toxins that can be harmful to humans, aquatic life and livestock may be produced. | |
| **Zinc** | Zinc is found naturally in water, most frequently in areas where it is mined. It enters the environment from industrial waste, metal plating, and plumbing, and is a major component of sludge. | In small concentrations zinc is non-toxic and essential to human health. It aids in the healing of wounds. The ODWS for zinc is set for aesthetic purposes. At high concentrations zinc may cause water to have a milky appearance. The concentration of zinc may be higher in the tap than in standing water due to corrosion, this can be cleared by flushing. | Zinc can also be toxic to aquatic biota at elevated concentrations. Sediments act as an important route for the exposure of zinc to the environment. Zinc builds up in sediments when it associates with particles such as manganese and iron. Adverse effects of zinc can include a decrease in the diversity and abundance of aquatic invertebrate species, as well as increased mortality and behavioural changes. | 5 mg/L (1)<br>30 ug/L (3) |

q Applies only to treated drinking water samples and not on raw water samples which are being discussed in this report.

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# APPENDIX 5 Ecological Land Classification (ELC)

In southern Ontario a classification system called ELC has been developed to identify recurring ecological patterns on the landscape (Lee et al., 1998). The goal of this system is to reduce complex natural variation to a reasonable number of meaningful ecosystem units (Bailey et al. 1978) and to enable the consistent description, inventory and interpretation of ecosystems across the province. The key focus is to improve our ability to manage both natural resources and the information about those resources.

Following the ELC framework for southern Ontario, CLOCA produced watershed-scale vegetation mapping to the Community Series level (distinguishes the difference between a coniferous and deciduous forest) for its jurisdiction. Vegetation communities greater than 0.5 ha were mapped through the interpretation of aerial photography, although some limited site-level information on vegetation types was gathered to supplement the analysis. This information was then entered into a database and the boundaries of independent vegetation communities were mapped in a GIS program to link the spatial and database information in order to perform queries and analyze results.

The ELC communities in the Oshawa Creek watershed are listed below.

| ELC Code | Vegetation Community | Community Description |
|---|---|---|
| **CUM** | Cultural Meadow | Tree cover is less than 25%; shrub cover is less than 25%<br>Often having a large proportion of non-native plant species<br>Community resulting from, or maintained by, cultural or anthropogenic-based disturbances |
| **CUP** | Cultural Plantation | Tree cover is greater than 60%<br>Community resulting from, or maintained by, cultural or anthropogenic-based disturbances |
| **CUT** | Cultural Thicket | Tree cover is less than 25%; shrub cover is greater than 25%<br>Often having a large proportion of non-native plant species<br>Community resulting from, or maintained by, cultural or anthropogenic-based disturbances |
| **CUW** | Cultural Woodland | Tree cover is between 35% and 60%<br>Often having a large proportion of non-native plant species<br>Community resulting from, or maintained by, cultural or anthropogenic-based disturbances |
| **FOC** | Coniferous Forest | Conifer tree species make up greater than 75% of the canopy cover |
| **FOD** | Deciduous Forest | Deciduous tree species make up greater than 75% of the canopy cover |
| **FOM** | Mixed Forest | Both conifer and deciduous tree species make up greater than 25% of the canopy cover |
| **MAM** | Meadow Marsh | Tree and shrub cover is less than 25%<br>Dominated by emergent hydrophytic macrophytes<br>Flooding is seasonal; species less tolerant of prolonged flooding<br>Represents the wetland-terrestrial interface; Water depth less than 2 m |
| **MAS** | Shallow Marsh | Tree and shrub cover is less than 25%; Water up to 2 m deep<br>Hydrophytic emergent macrophyte cover is greater than 25%<br>Standing or flowing water for much or all of the growing season<br>Varies from bare bedrock or parent mineral material to organic substrates |
| **OAO** | Open Aquatic | No macrophyte vegetation; no tree or shrub cover; Plankton dominated<br>Water is greater than 2 m deep |
| **SAS** | Submerged Shallow Aquatic | Dominated (> 25%) by submerged macrophytes<br>Emergent vegetation may be present but is never dominant<br>No tree or shrub cover; Water up to 2 m in depth<br>Standing water always present |
| **SWC** | Coniferous Swamp | Tree cover is greater than 25%; trees more than 5 m in height<br>Conifer tree species make up greater than 75% of canopy cover<br>Dominated by hydrophytic shrub and tree species<br>Standing water or vernal pooling constitutes more than 20% of ground coverage; Water depth less than 2 m |
| **SWD** | Deciduous | Tree cover is greater than 25%; trees more than 5 m in height |

| ELC Code | Vegetation Community | Community Description |
|---|---|---|
| | Swamp | Deciduous tree species make up more than 75% of the canopy cover<br>Dominated by hydrophytic shrub and tree species; fern and sedge rich<br>Standing water or vernal pooling constitutes more than 20% of ground coverage; Water depth less than 2 m |
| **SWM** | Mixed Swamp | Tree cover is greater than 25%; trees more than 5 m in height<br>Both coniferous and deciduous tree species make up more than 25% of the canopy cover<br>Dominated by hydrophytic shrub and tree species; Typically fern rich<br>Standing water or vernal pooling constitutes more than 20% of ground coverage; Water depth less than 2 m |
| **SWT** | Thicket Swamp | Tree cover is less than 25%; hydrophytic shrubs greater than 25%<br>Dominated by hydrophytic shrub and tree species<br>Standing water or vernal pooling constitutes more than 20% of ground coverage; Water depth less than 2 m |

(Lee et al., 1998)

# APPENDIX 6 Landscape Analysis Model

In ecological systems, connectivity between habitat patches is important because it facilitates the movement of wildlife, both plant and animal, and maintains genetic diversity across large landscapes. As such, land use planning agencies have started to shift away from preserving isolated habitat patches and towards preserving networks of natural spaces. One means of identifying these networks is through computer modelling.

In the late 1990's the Toronto and Region Conservation Authority (TRCA) initiated a Terrestrial Natural Heritage Program to address the loss of habitat and biodiversity in their watersheds. The program goals were to reduce further landscape fragmentation, increase the ecological function and integrity of existing natural areas, and identify restoration opportunities. This led to the development of a computer program called the Landscape Analysis Model (LAM) which would analyze and evaluate the quality of existing natural areas, and produce a habitat quality map known as the Terrestrial Natural Heritage System.

In late 2006, after making minor modifications to the TRCA model, CLOCA completed its own Landscape Analysis (Figure 51). This process began with the identification of land uses and their categorization as either natural (e.g. forests, wetlands, meadows), urban (e.g. residential, commercial, roads), or rural (e.g. agriculture). Those areas classified as natural were then analyzed for size, shape, and proximity to urban or agricultural land uses (called the matrix influence). These criteria (size, shape and matrix influence) are key indicators of habitat quality.

"Scores" were assigned to habitat patches based on the following criteria:
Larger natural areas received a higher score than smaller natural areas.
Areas with less edge received a higher score than areas with a lot of edge.
Natural areas that were surrounded by or adjacent to urban areas received a lower score than those surrounded by rural or natural land uses.

Finally, the model used the criteria scores for each natural area and assigned them a weighted score based on the size of the area. This was done because as forest size increases, its shape and proximity to urban areas becomes less important. The sum of the weighted scores for each natural area became the model's total score for each area. Total scores range from 0 to 15 with 0 being a very poor quality habitat and 15 being an excellent quality habitat.

These scores were mapped to produce a preliminary terrestrial natural heritage system and enable planning agencies to identify areas of concern in the watershed and make informed planning decisions.

The second stage in the development of a Terrestrial Natural Heritage System, was the identification of restoration targets. A scenario-based approach was used to establish targets that would maximize overall habitat quality. The scenario selected also happened to be consistent with the Environment Canada recommendations for 30% forest cover in the watershed. The end product is a map that identifies priority restoration areas and which can be used to direct restoration efforts to areas of the watershed where increased natural cover will be most beneficial.

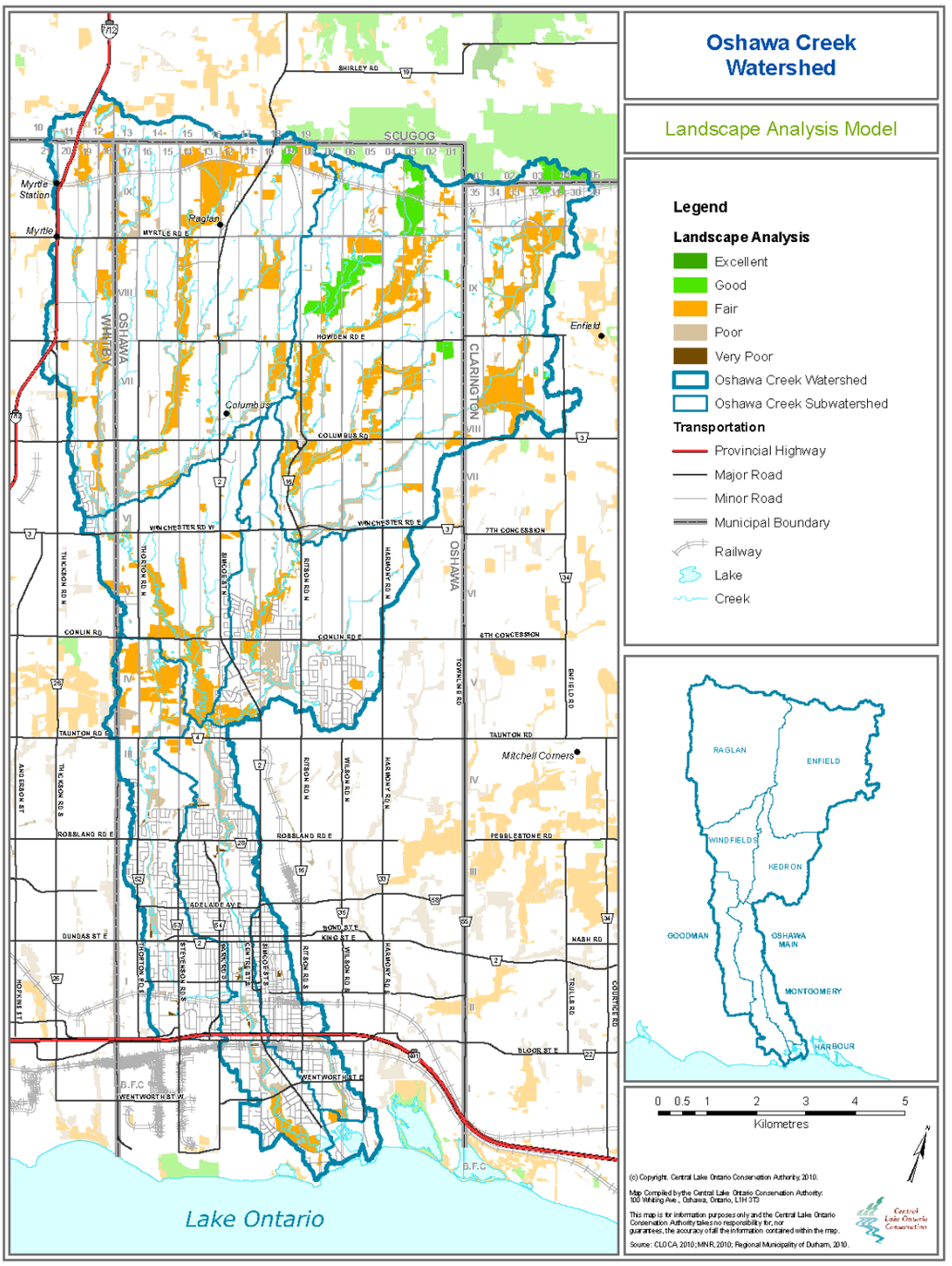


**Figure 51:** Landscape Analysis Model results for the Oshawa Creek