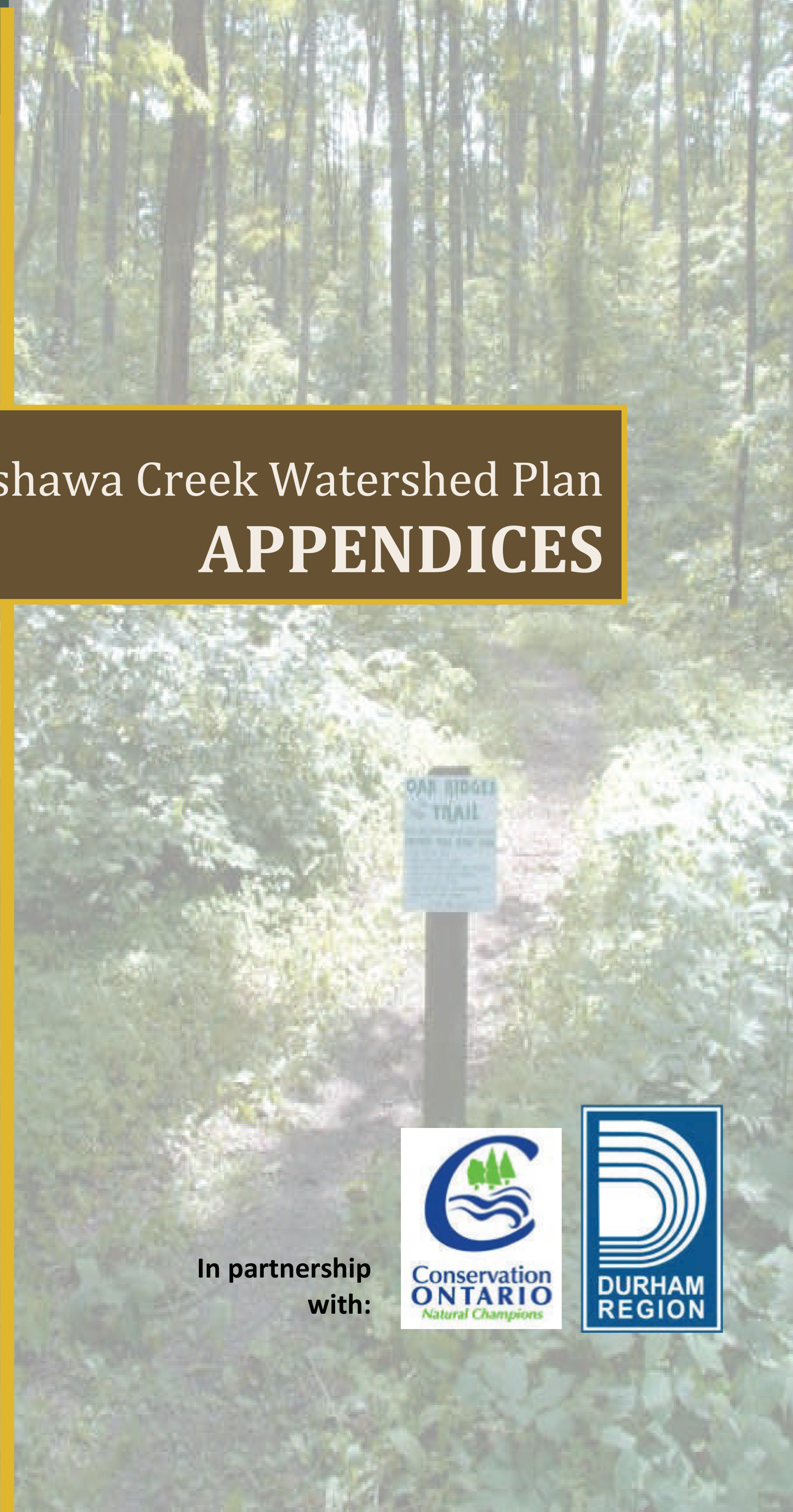
Oshawa Creek Watershed Plan
APPENDICES



Central Lake Ontario Conservation

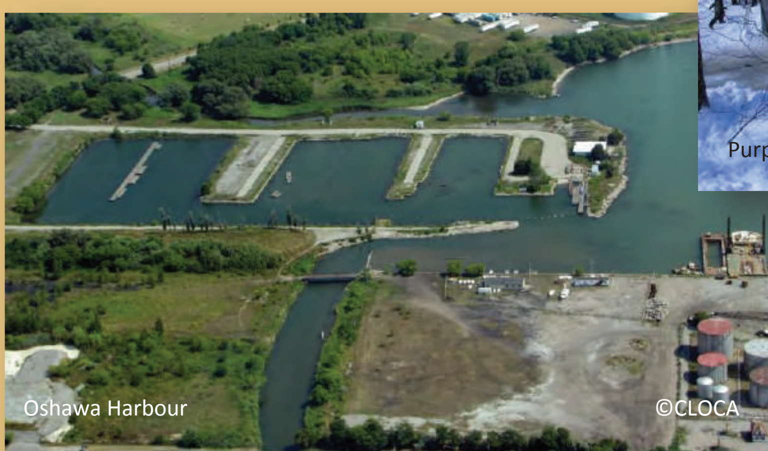
In partnership with:

Conservation ONTARIO Natural Champions

DURHAM REGION


Enfield Wetland @CLOCA


Purple Woods ©CLOCA


Oshawa Harbour ©CLOCA

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.

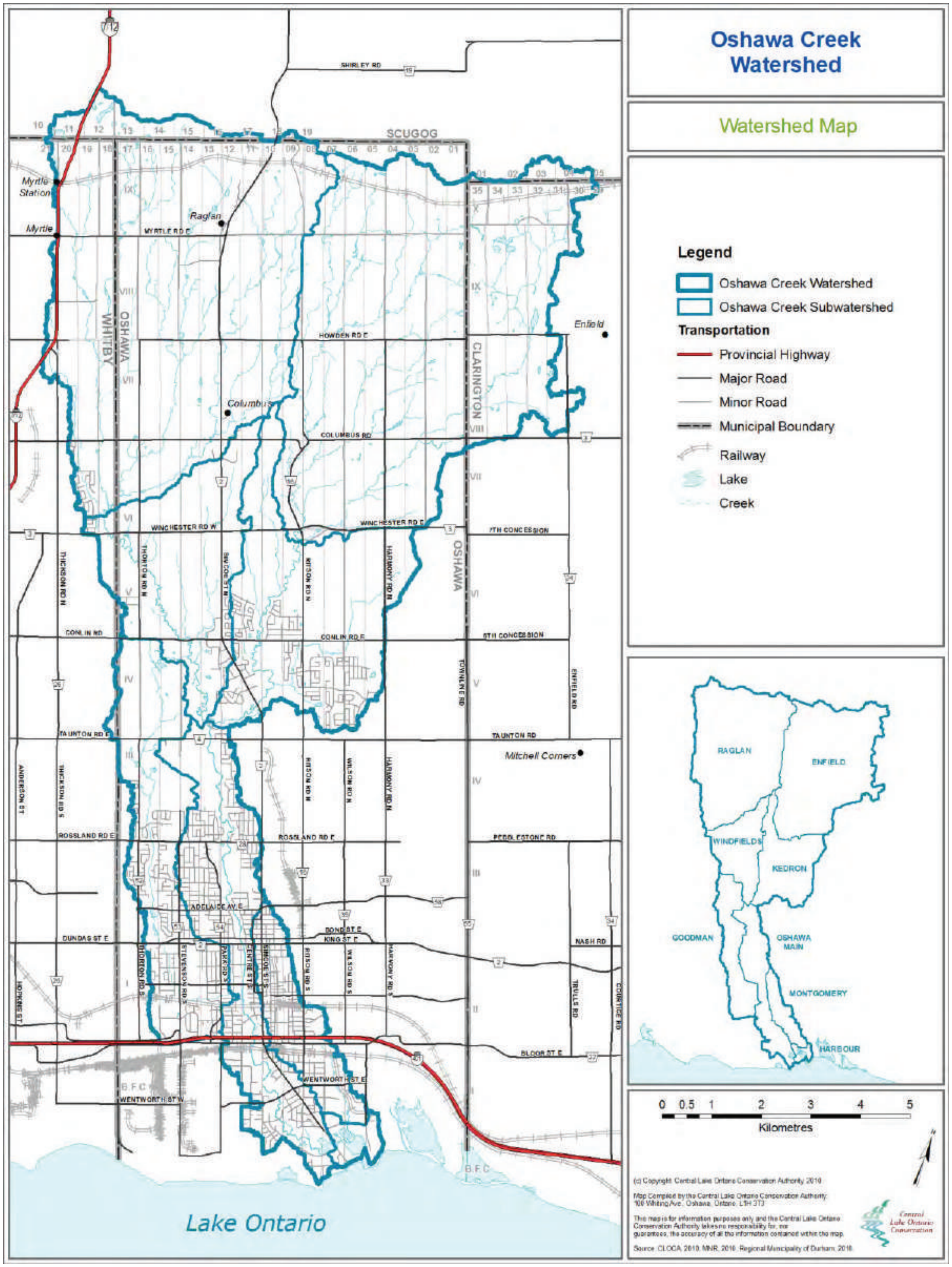


Figure 1: Oshawa Creek watershed and subwatersheds

1.0 INTRODUCTION (no revisions)

2.0 HISTORY OF WATERSHED (no revisions)

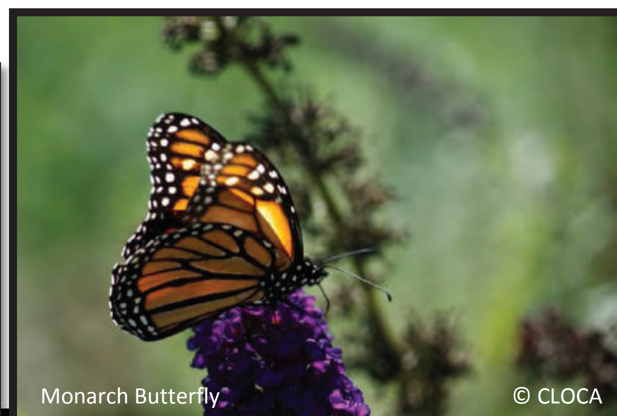
3.0 EXISTING CONDITIONS

3.1 People (no revisions)

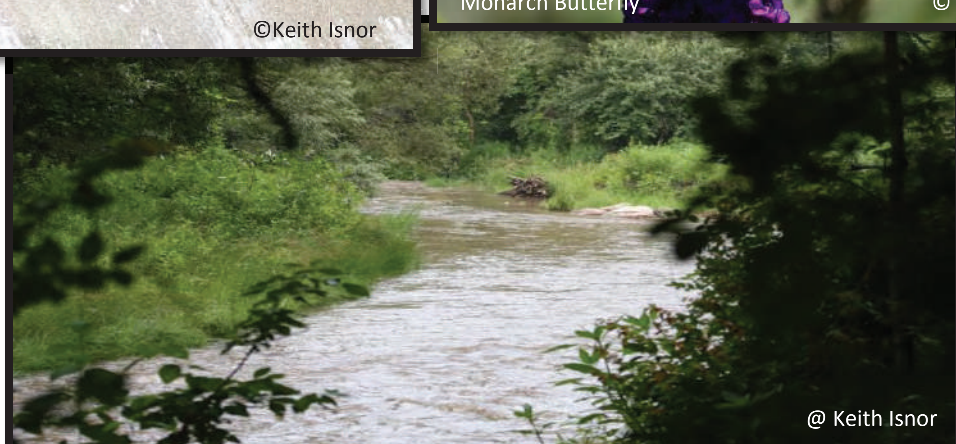
3.1.1 Land Use and Policy

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.



Monarch Butterfly



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.

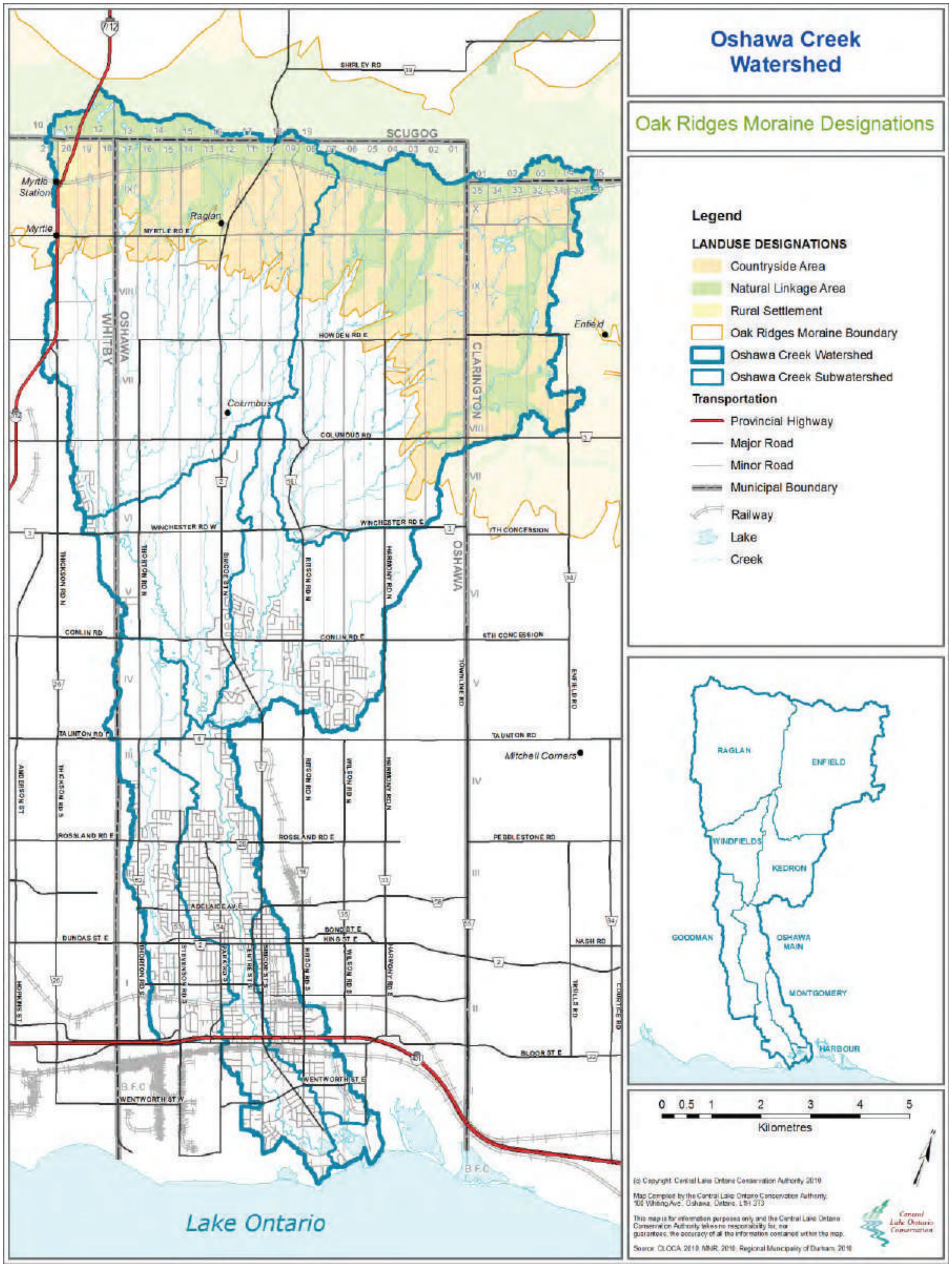
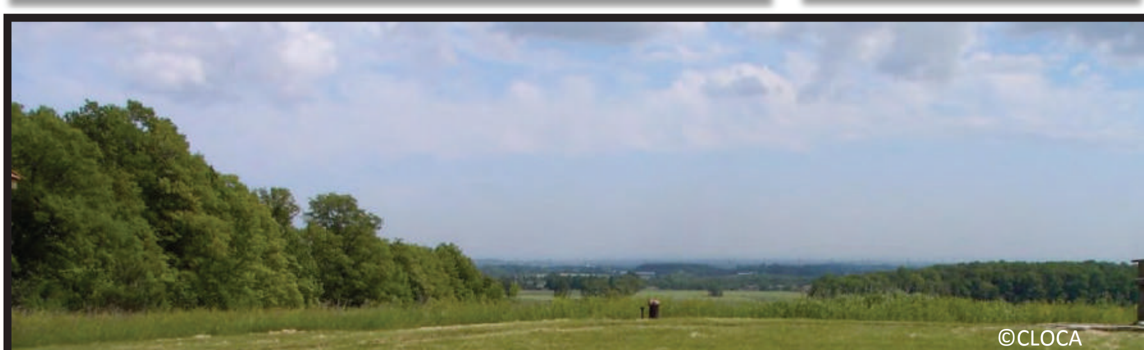


Figure 2: ORMCP land use designations within Oshawa Creek watershed (source: ORMCP; MMAH, 2002)

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.



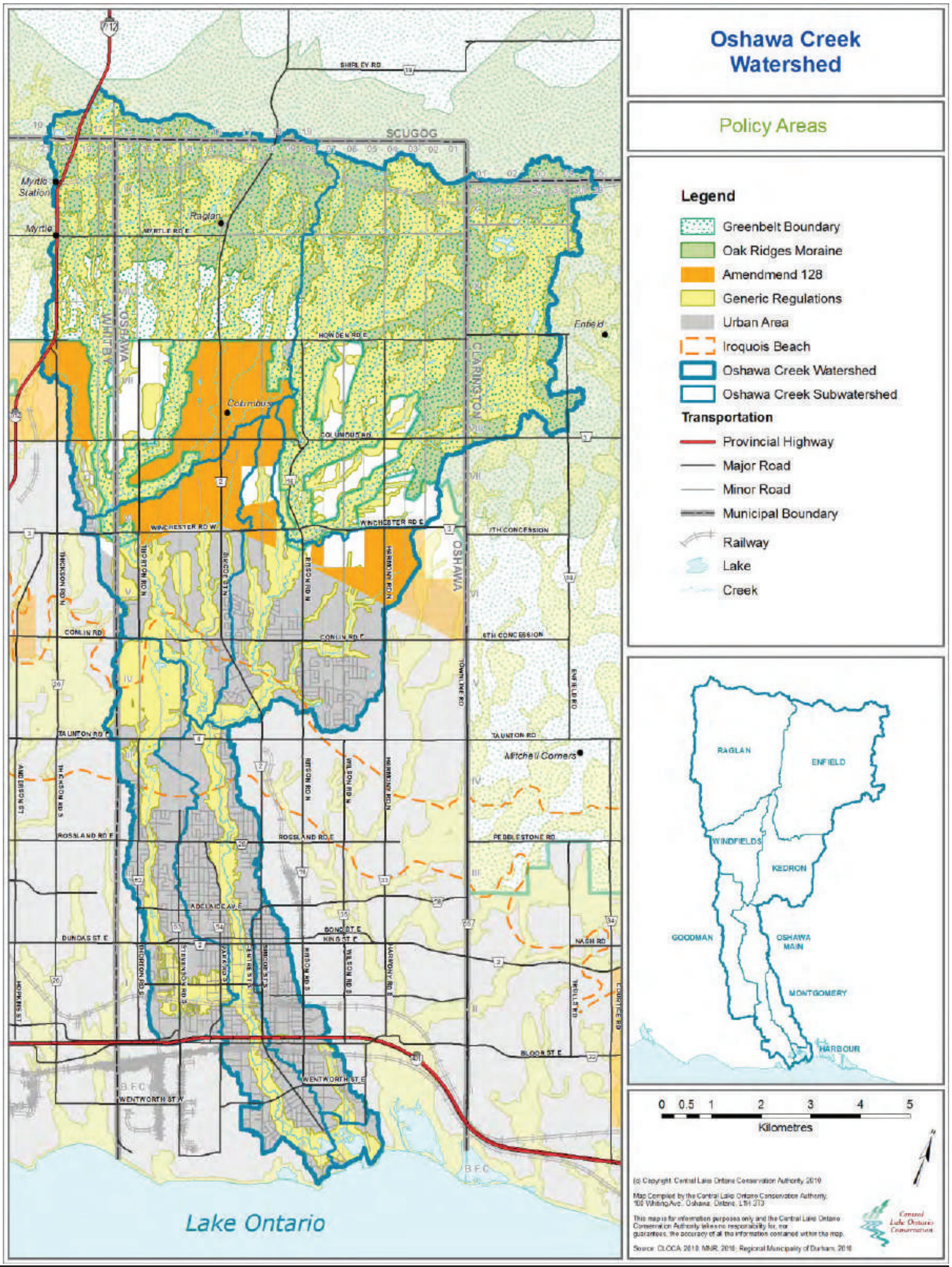


Figure 3: Land use policy areas within the Oshawa Creek watershed

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.

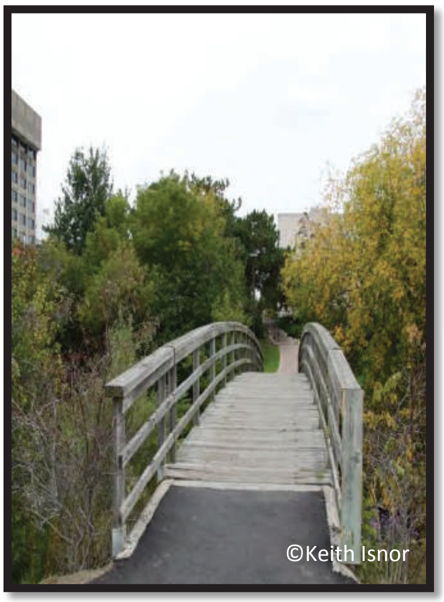
Presently, the majority of the Oshawa Main, Goodman and Montgomery subwatersheds are developed and future growth is anticipated to predominantly be in the form of infill and intensification. With the identification of downtown Oshawa as an Urban Growth Centre in the Provincial Growth Plan, the focus 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.

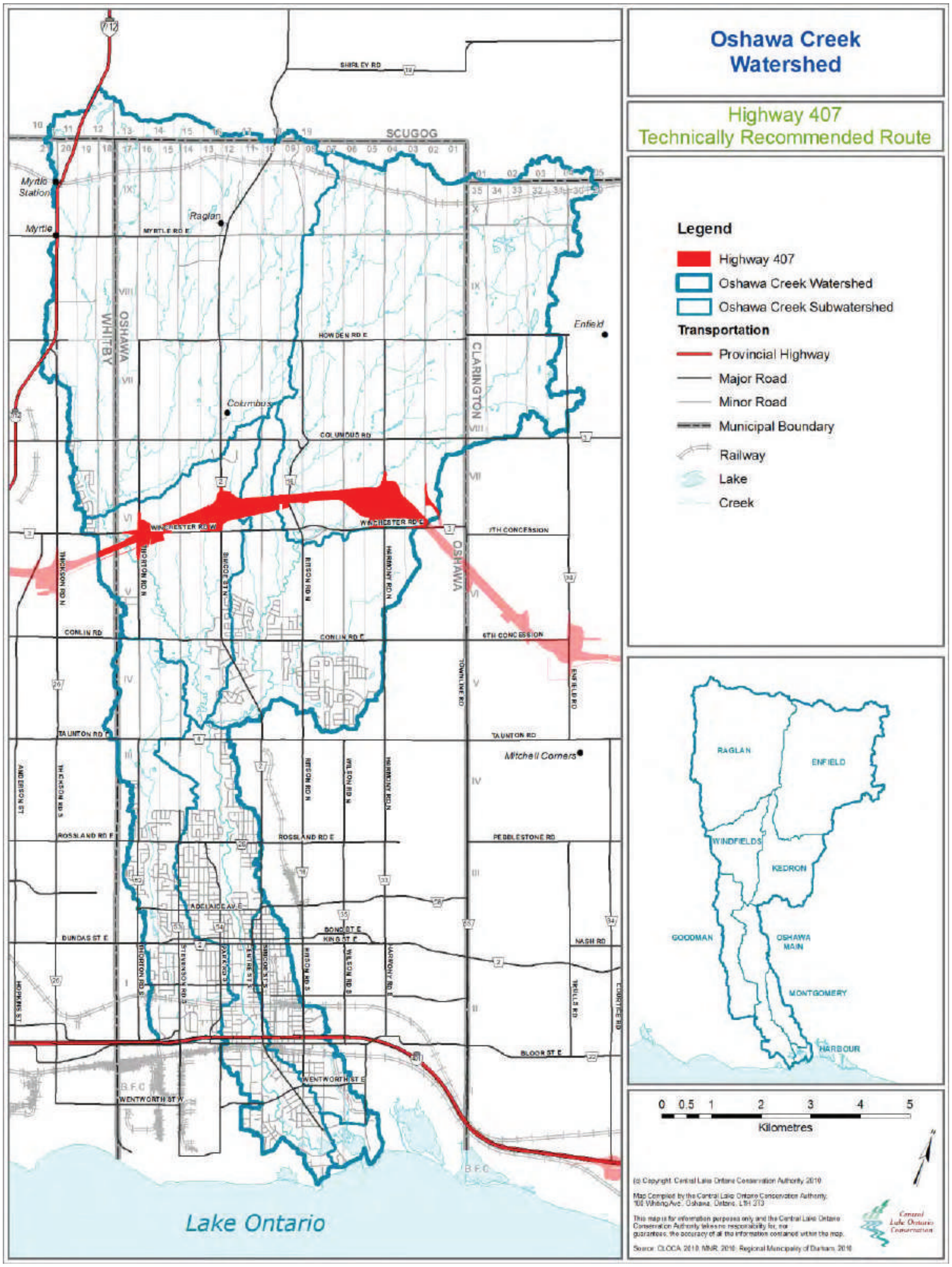


Figure 4: Highway 407 alignment

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.

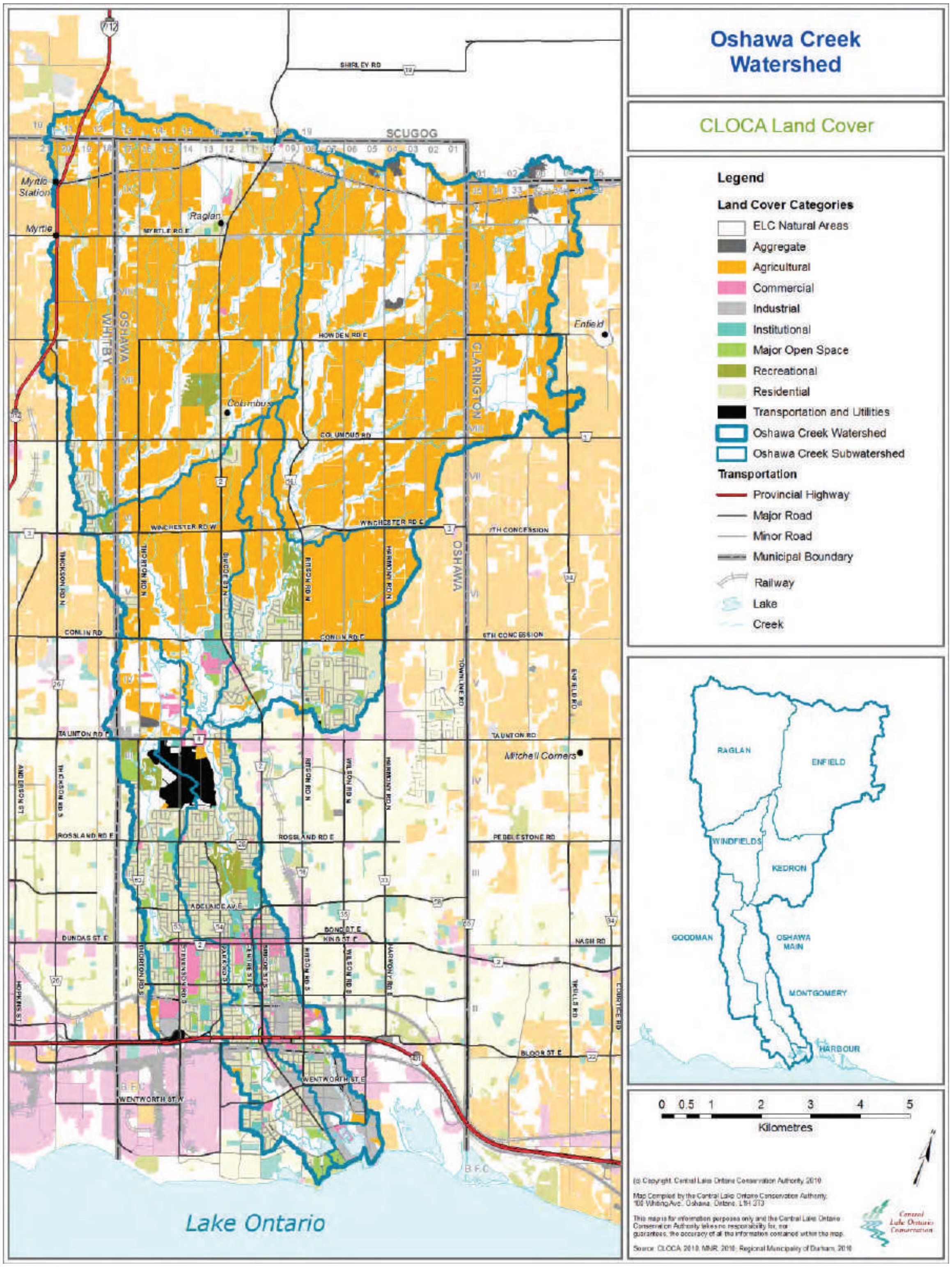


Figure 5: Oshawa Creek watershed land cover

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).


Purple Woods ©CLOCA


Rahmani Tract ©CLOCA


Purple Woods ©CLOCA


Purple Woods ©CLOCA

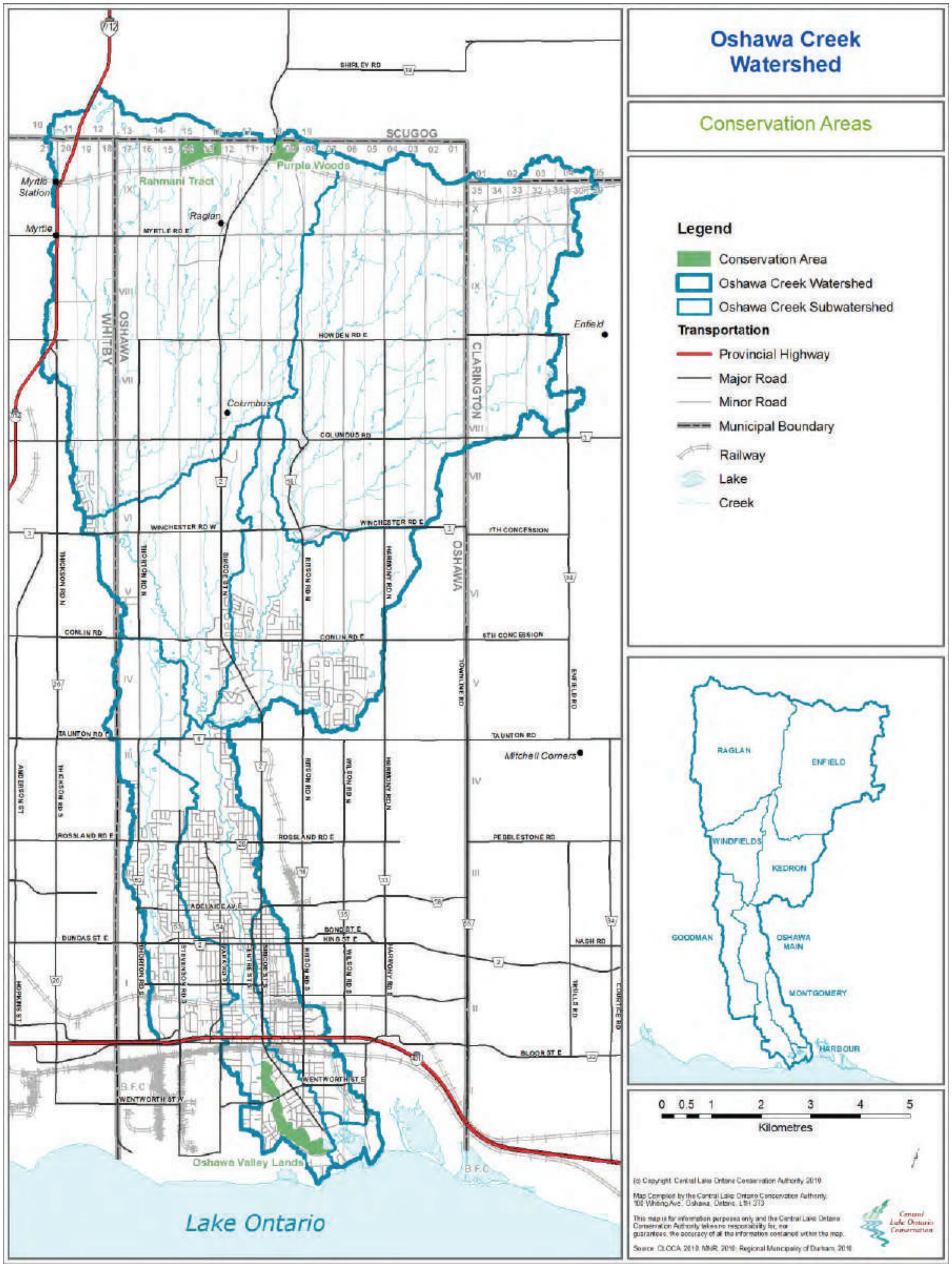


Figure 6: Conservation Areas in the Oshawa Creek watershed

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.

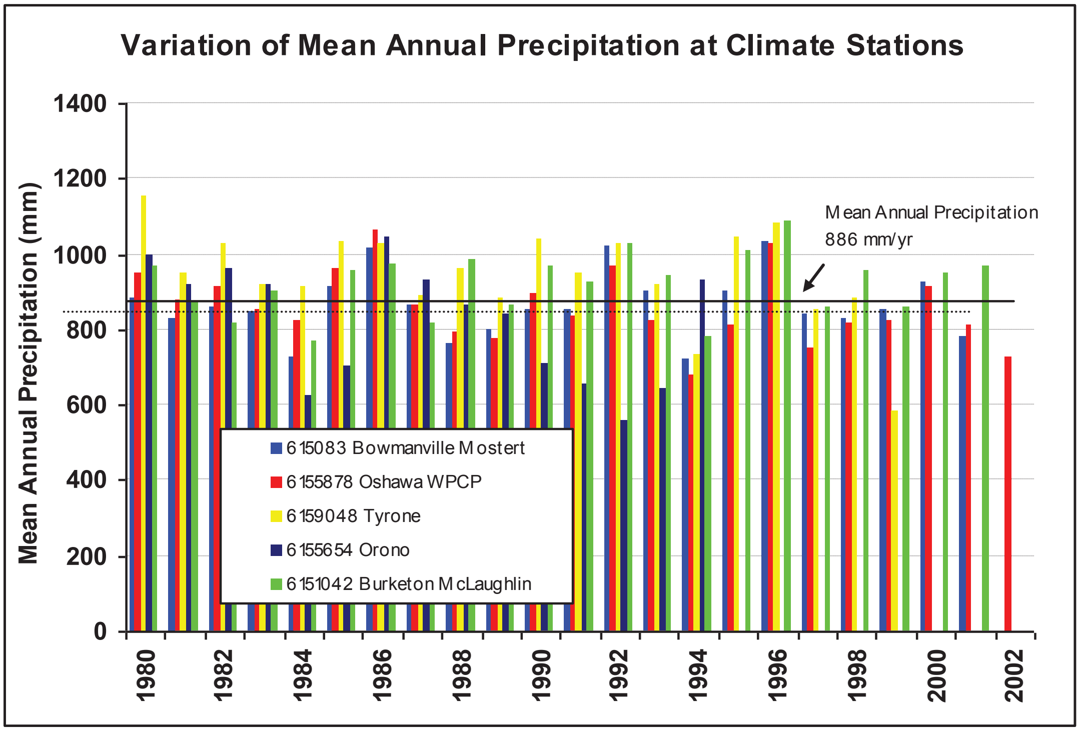


Figure 7: Variation of mean annual precipitation at selected climate stations with extended periods of record

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;

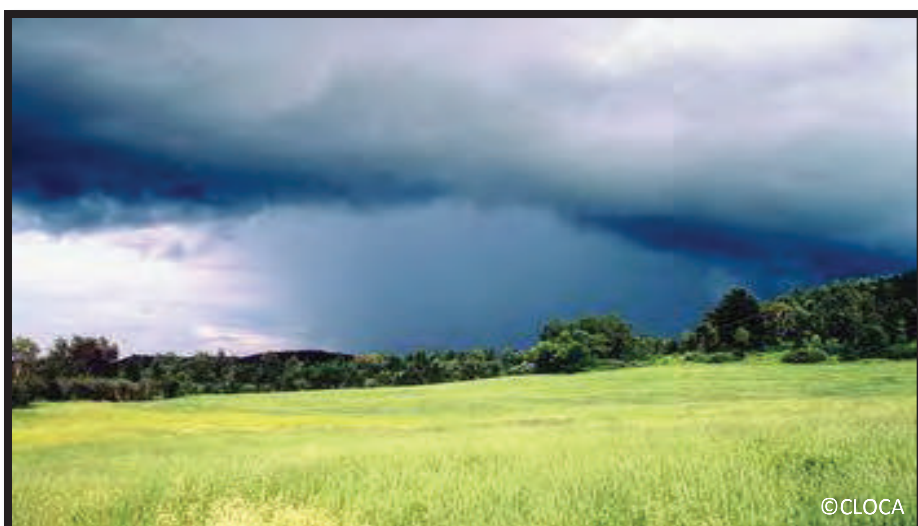
Net Precipitation = Evapotranspiration + Runoff + Groundwater Infiltration

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.



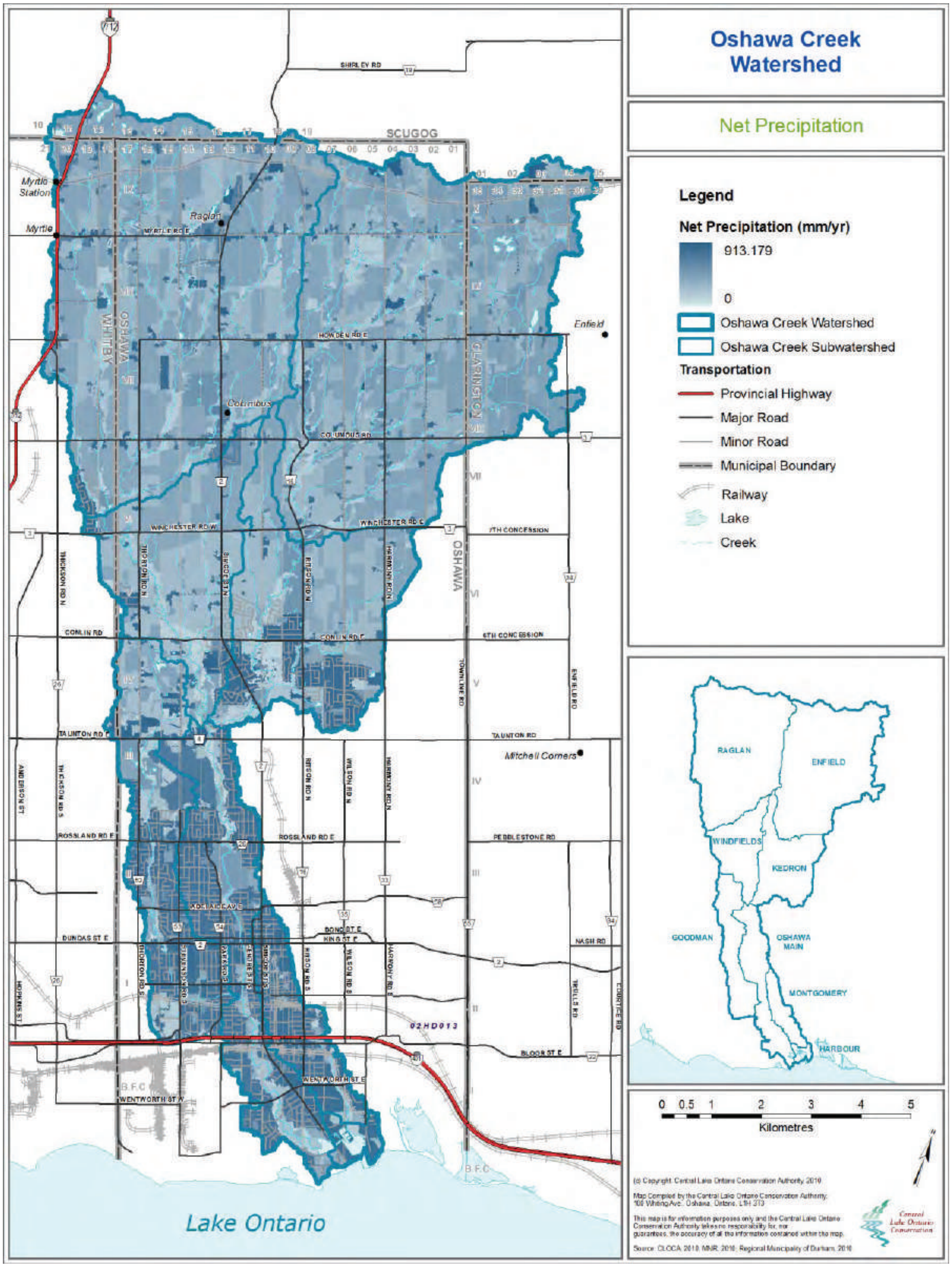


Figure 8: Net precipitation distribution (source: PRMS Model simulations).

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.

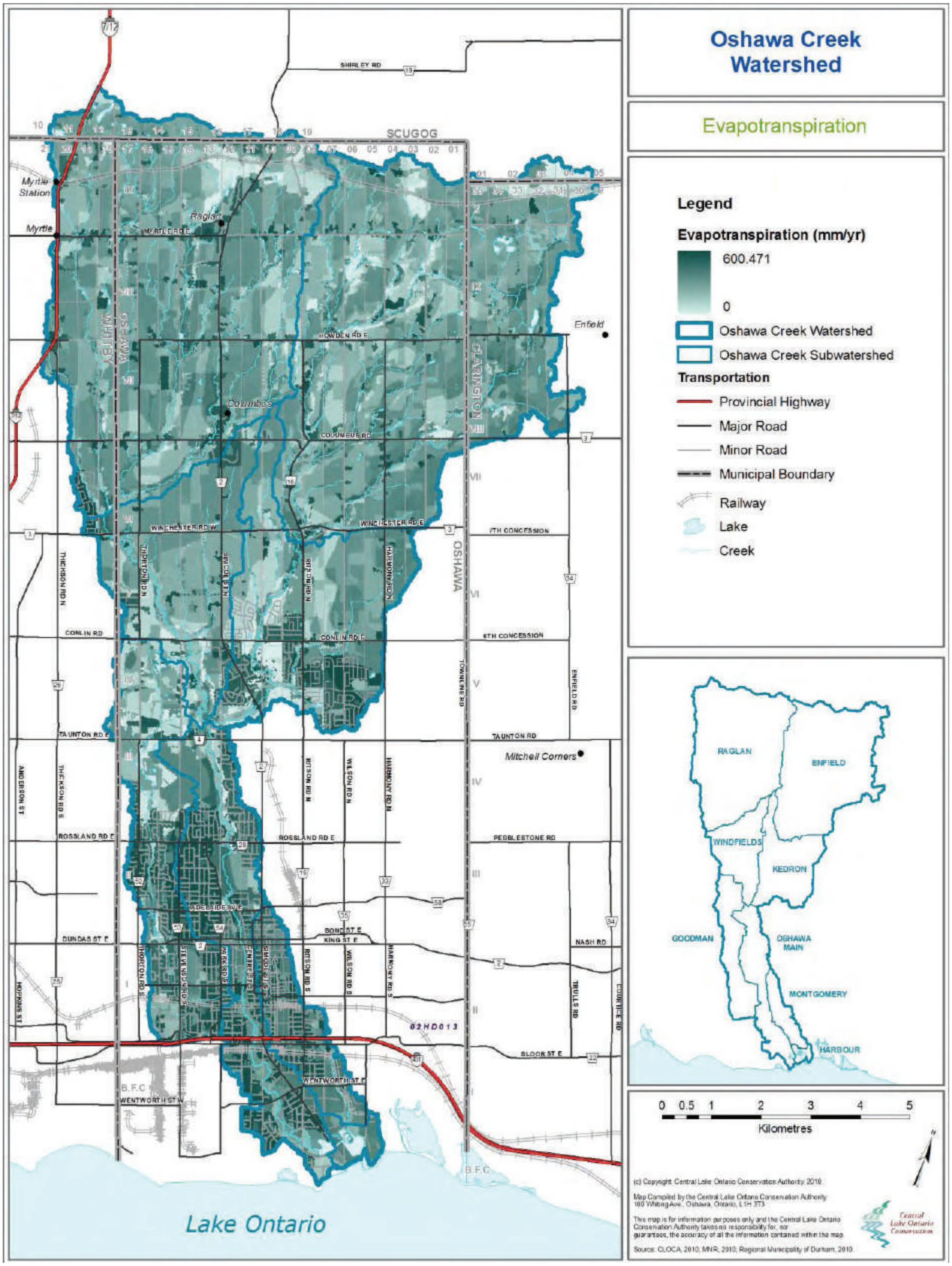


Figure 9: Evapotranspiration(source: PRMS Model simulation).

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 18th 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°C over the next century as a result of our changing atmosphere and air temperatures in Southern Ontario may rise by 2 to 5°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.

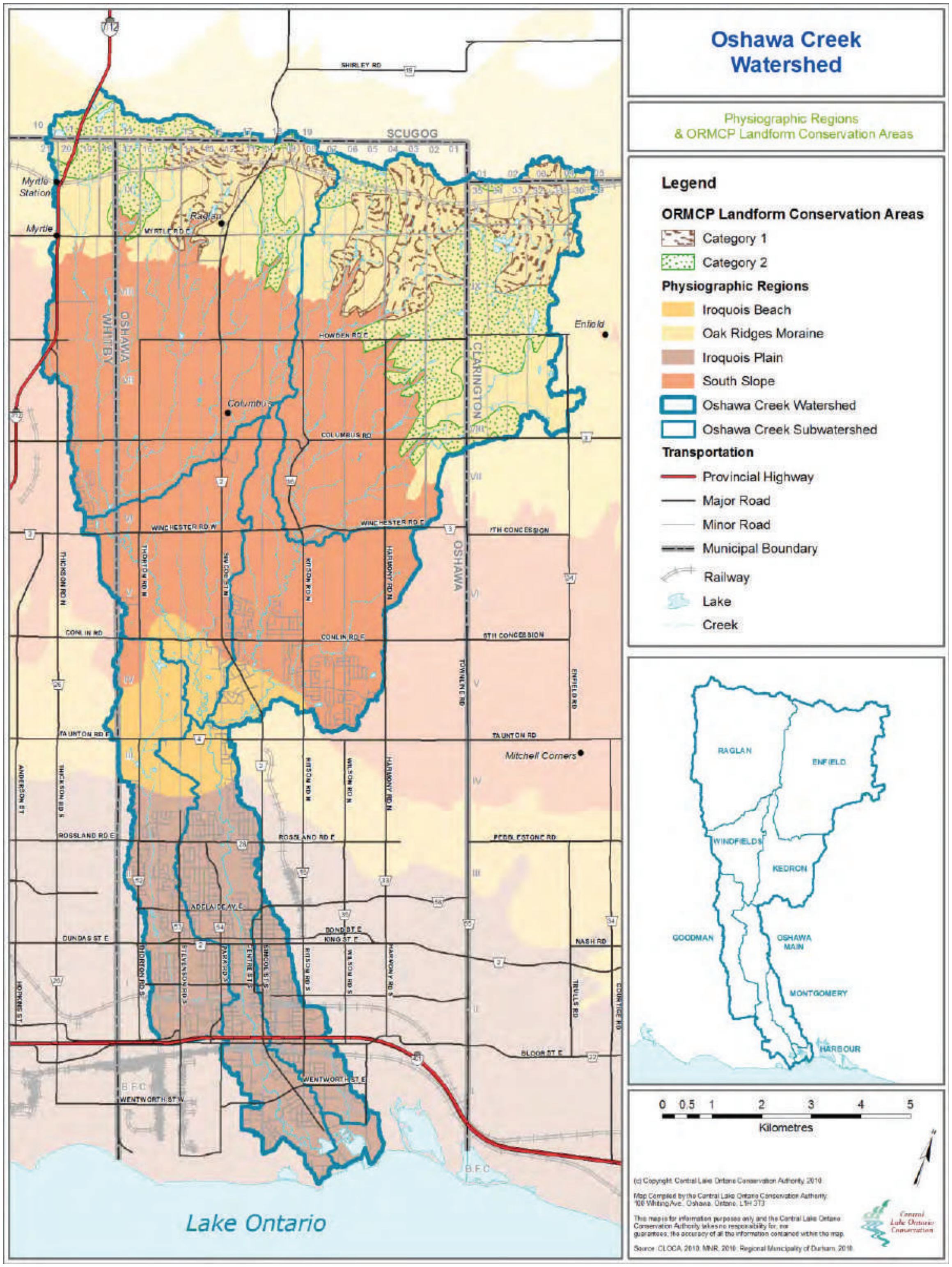


Figure 10: Watershed physiographic regions and ORMCP Landform Conservation Categories (sources: Chapman and Putnam, 1984; MMAH, 2002)

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).

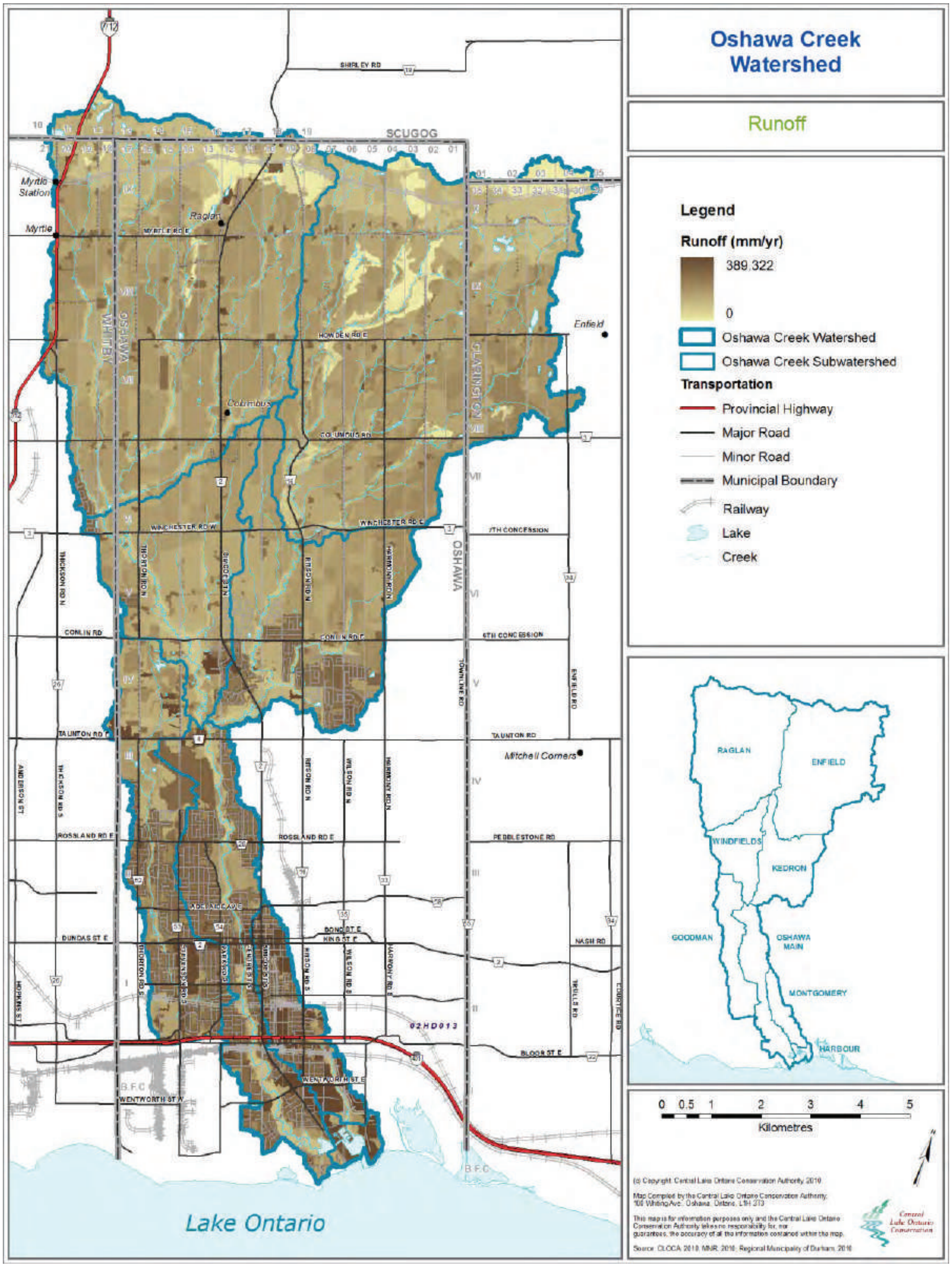


Figure 11: Runoff in the Oshawa Creek Watershed (source: Earthfx, 2007)

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).

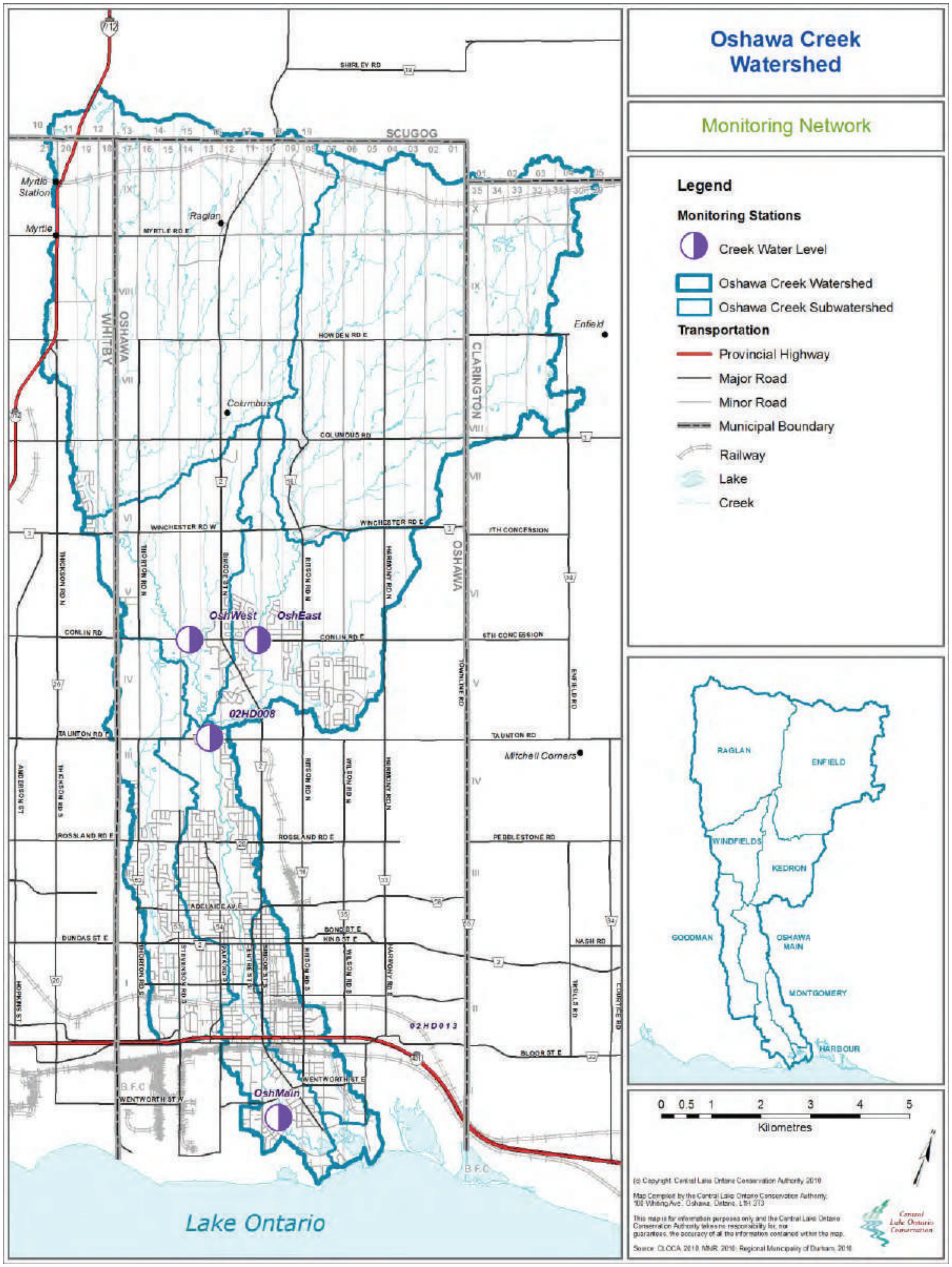


Figure 12: CLOCA's surface water monitoring network in the Oshawa Creek watershed

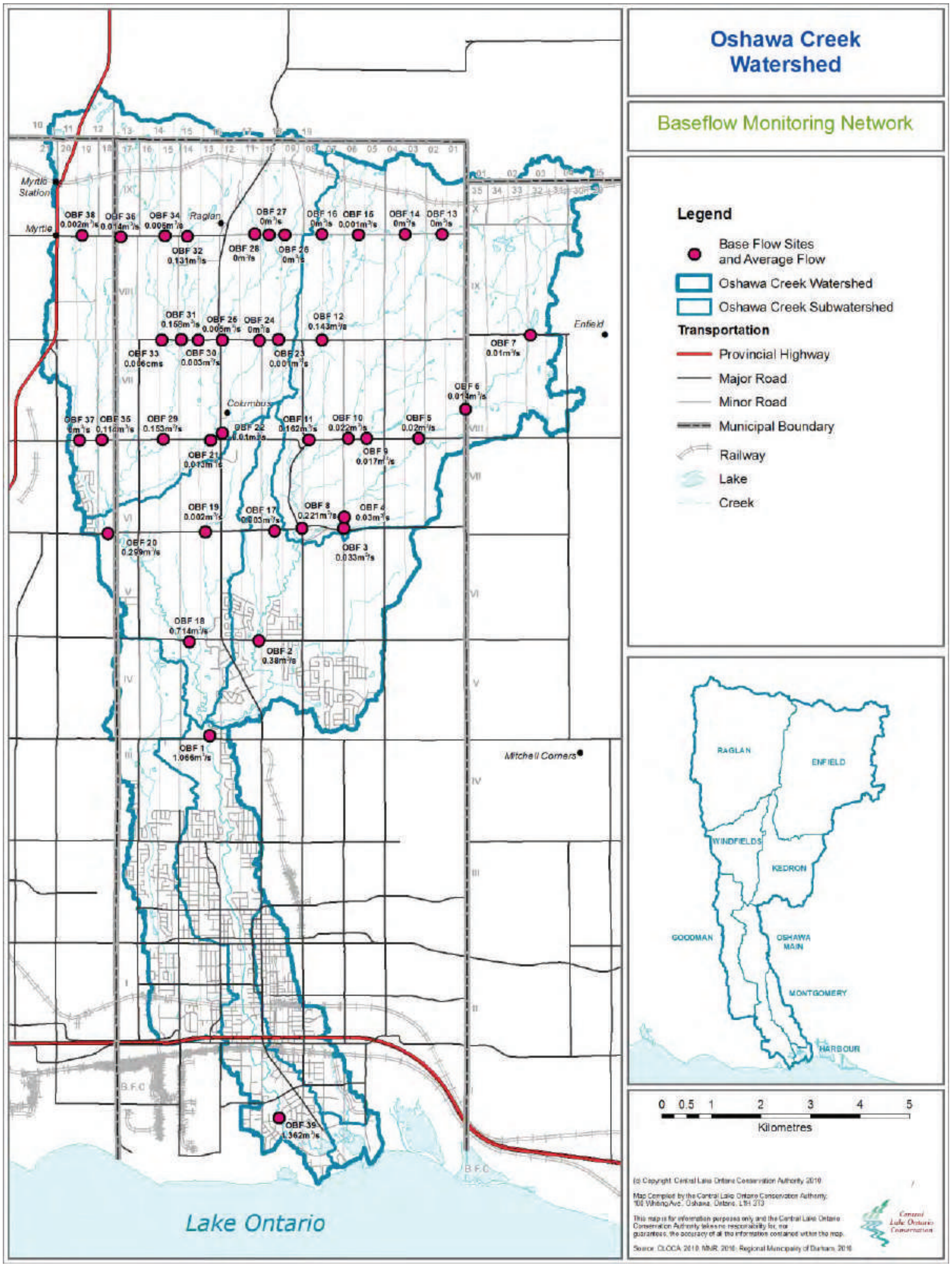


Figure 13: Baseflow stations with average flow in the Oshawa Creek watershed

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.

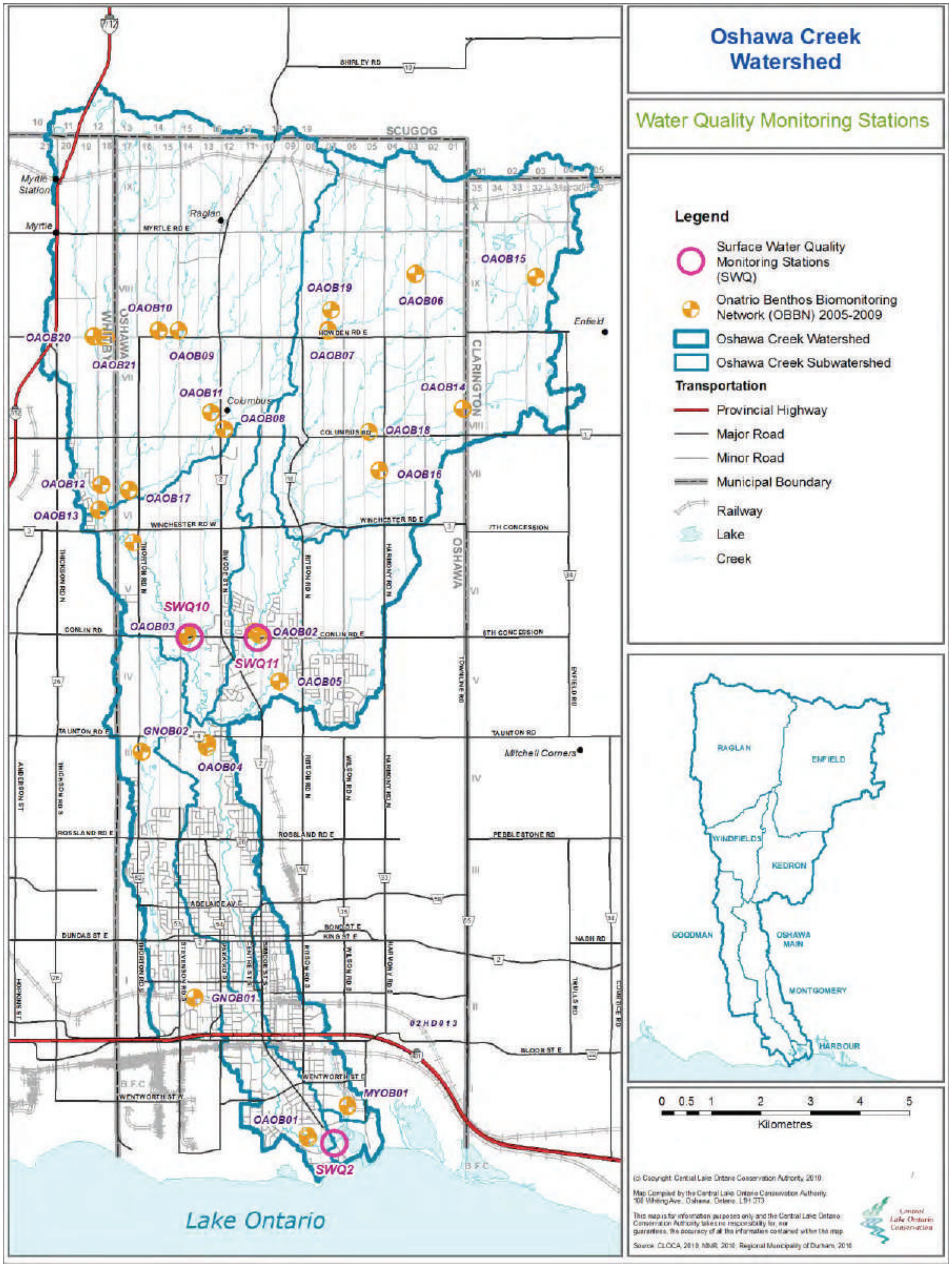


Figure 14: Surface water quality monitoring stations in the Oshawa Creek watershed

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).

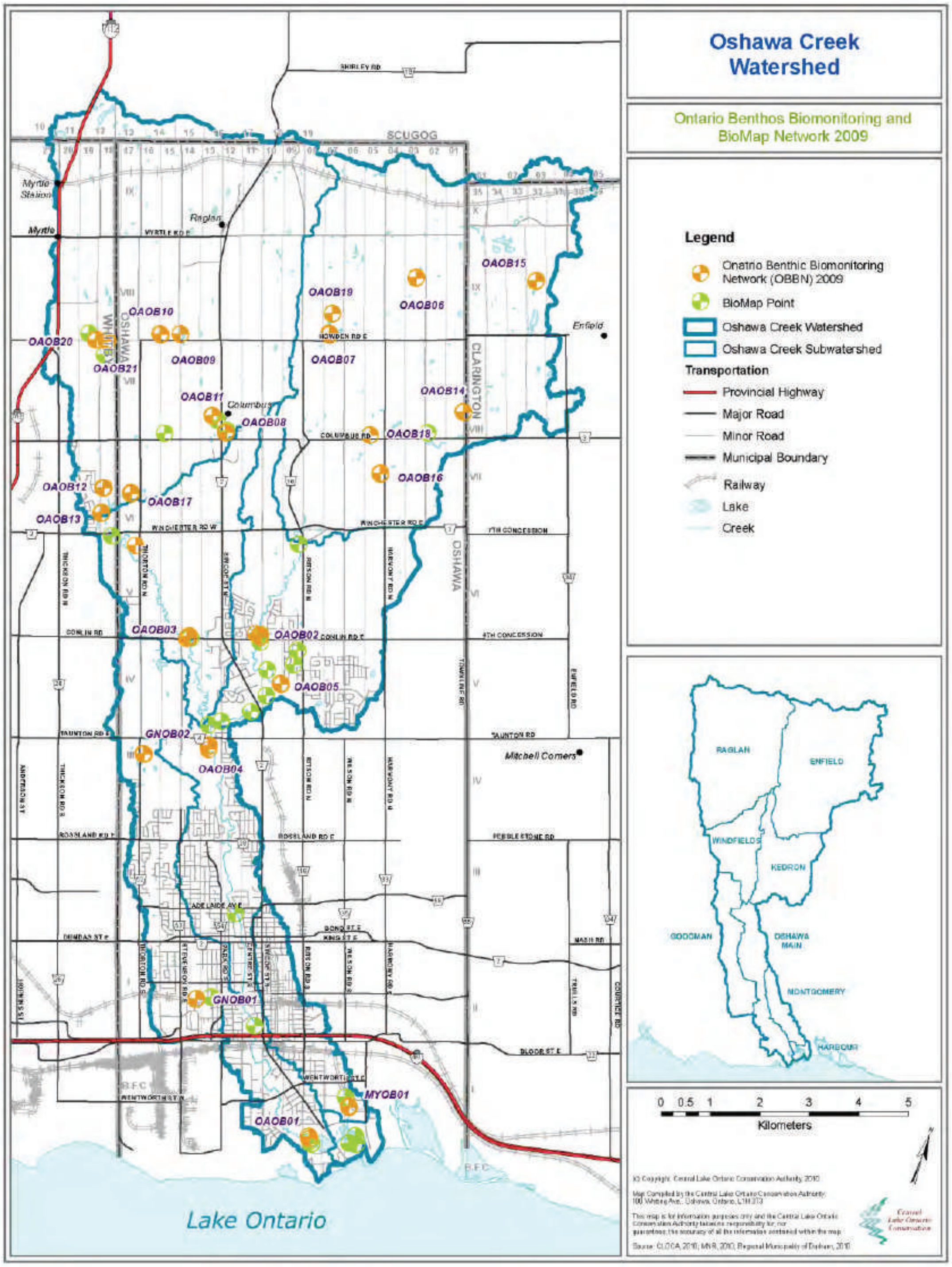


Figure 15: Comparison of Ontario Benthic Biomonitoring and BioMap Network

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: • have limited mobility, making them vulnerable to many stresses in the creek; • have short life cycles; • are easily collected and identified; and, • 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.

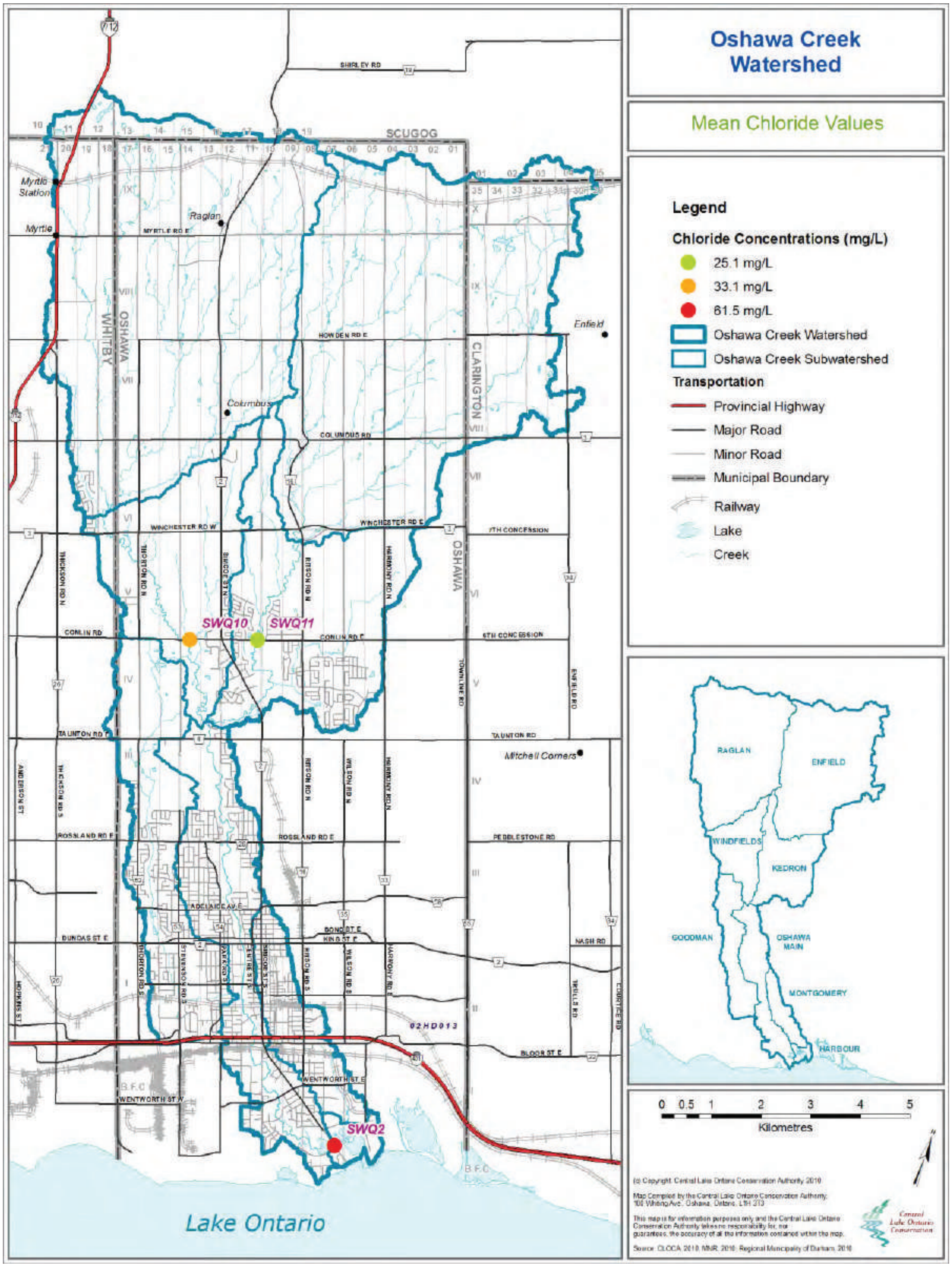


Figure 16: Spatial distribution of chloride concentration in Oshawa Creek

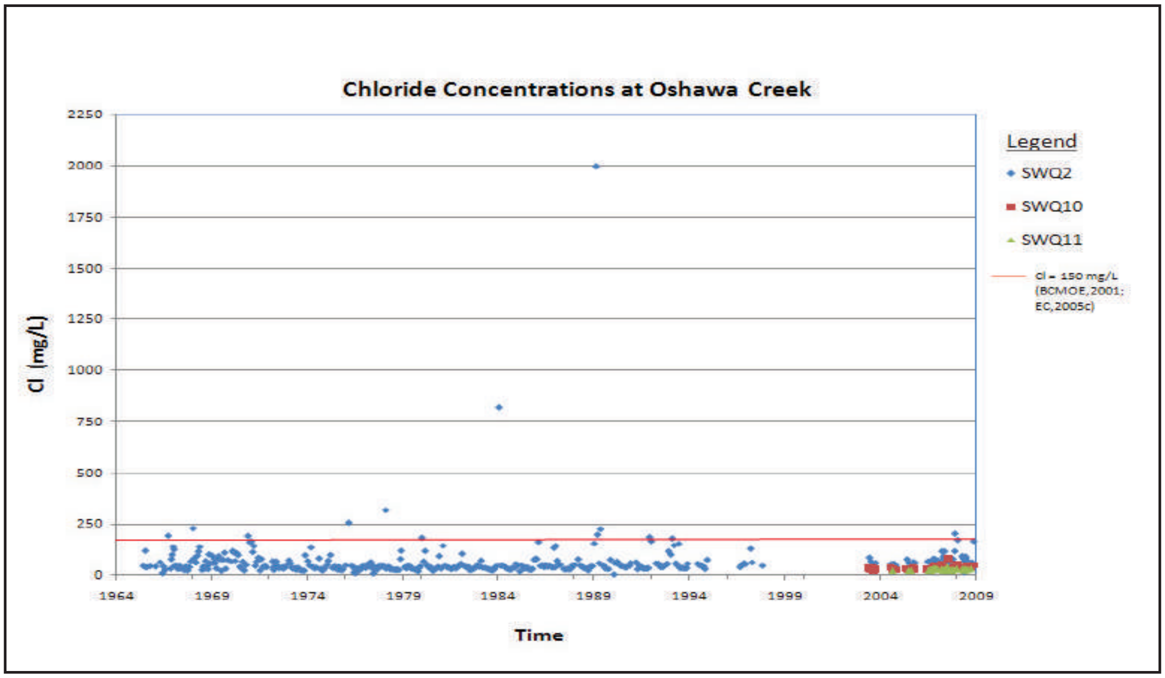


Figure 17: Chloride Concentrations at Oshawa Creek

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).

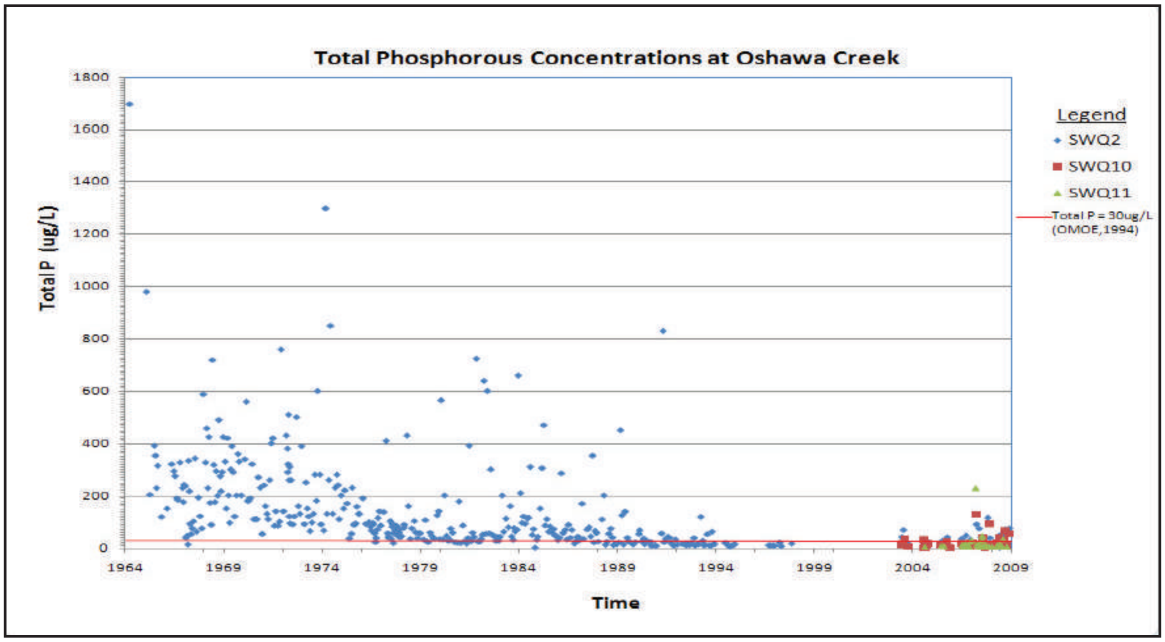


Figure 18: Phosphorous Concentrations at Oshawa Creek

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).

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

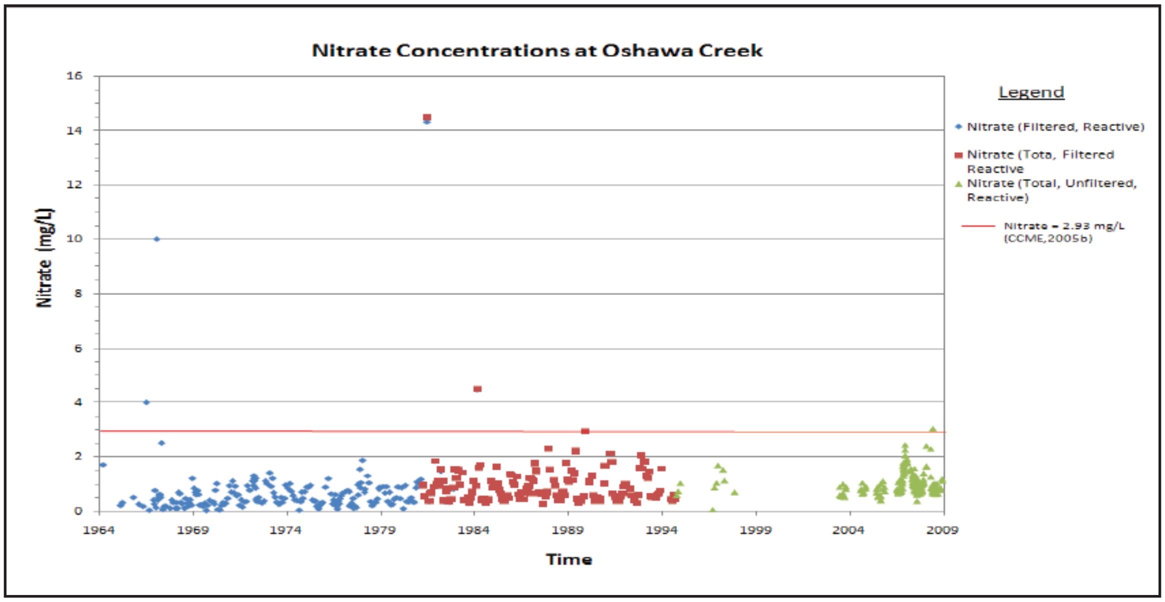

Figure 19: Nitrate Concentration in Oshawa Creek

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).

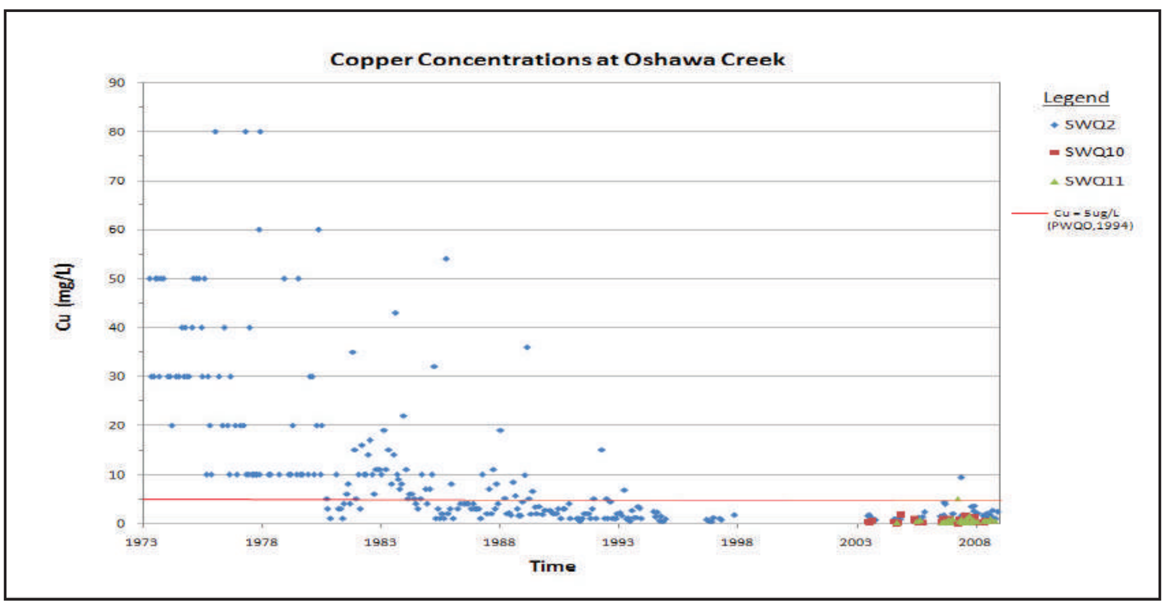

Figure 20: Copper Concentrations at Oshawa Creek

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.

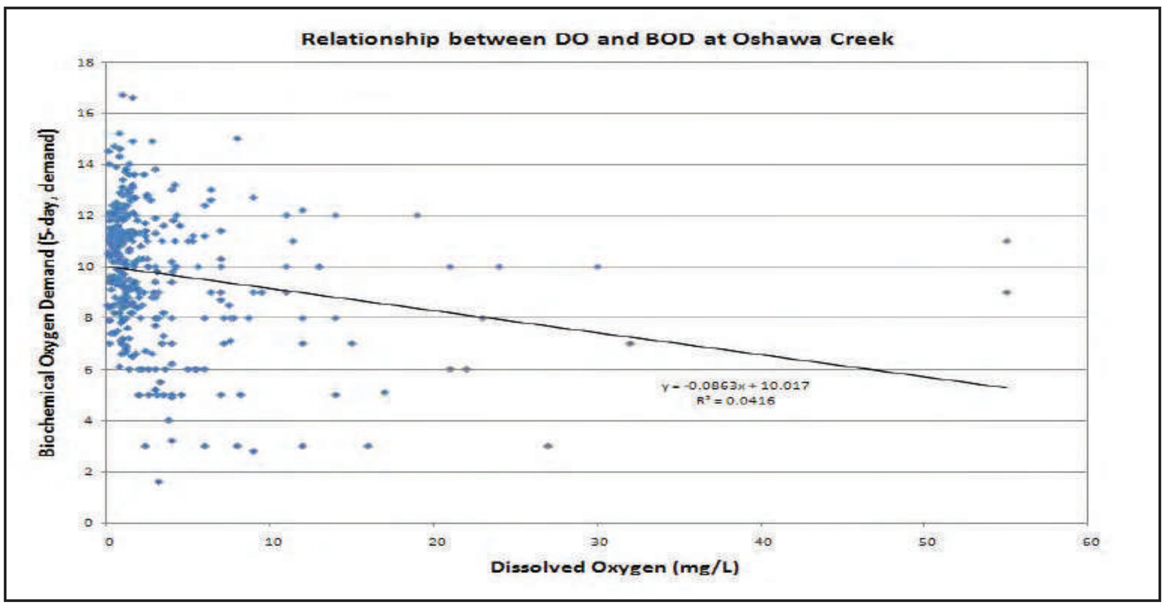

Figure 21: Relationship between Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD), Oshawa

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.

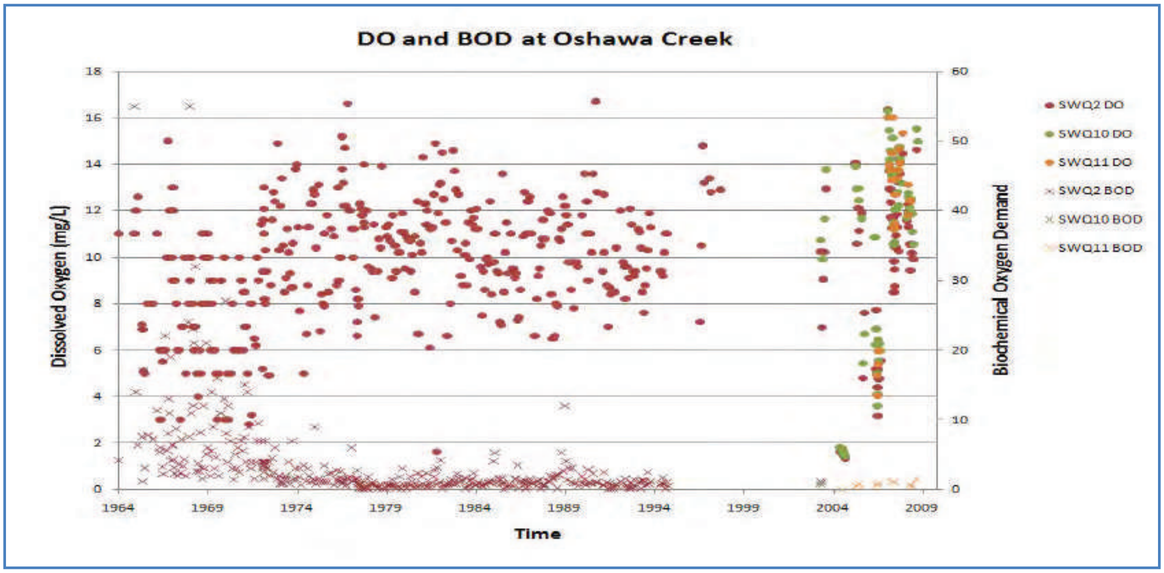

Figure 22: Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) at Oshawa Creek

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).

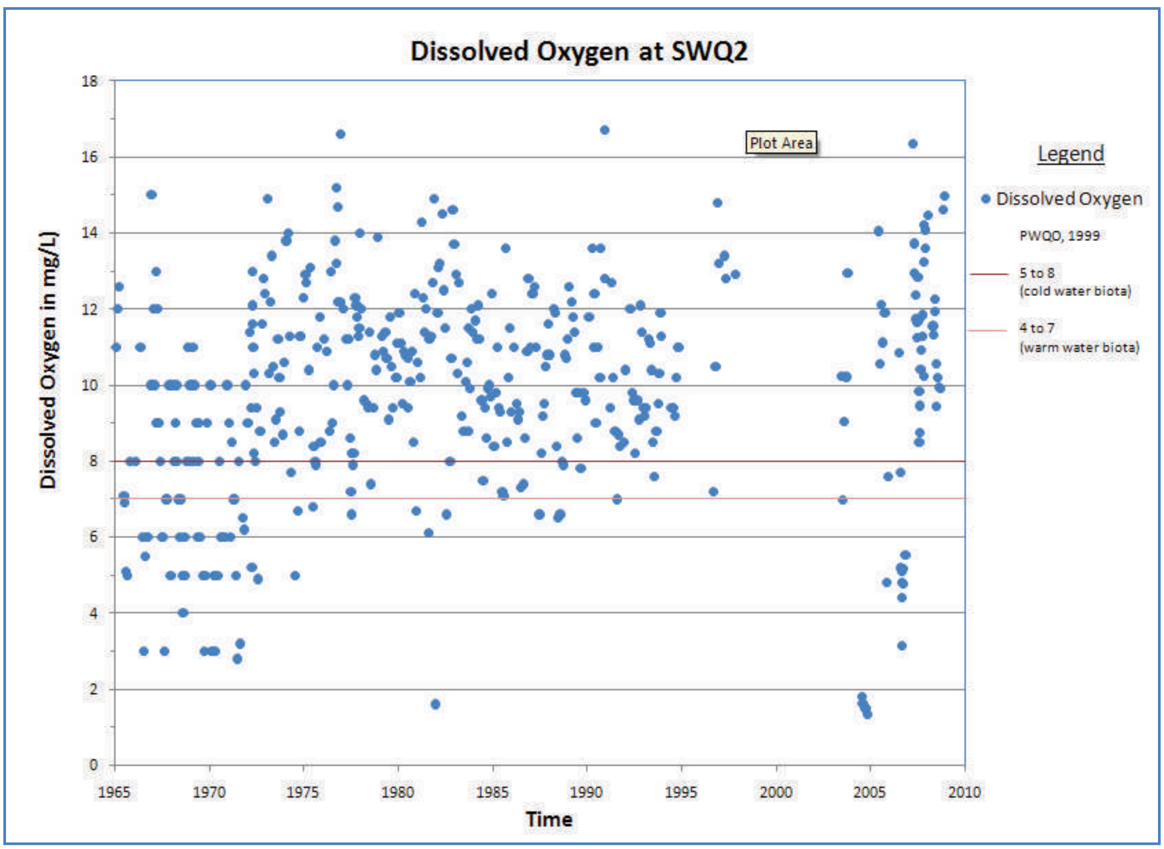

Figure 23: Dissolved Oxygen (DO) Concentrations at SWQ2

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.


Kedron Park Stormwater Facility ©CLOCA

<u>Stormwater Quantity</u>
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

<u>Sedimentation and Erosion Control</u>

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.


Windfields Stormwater Management Facility ©CLOCA

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

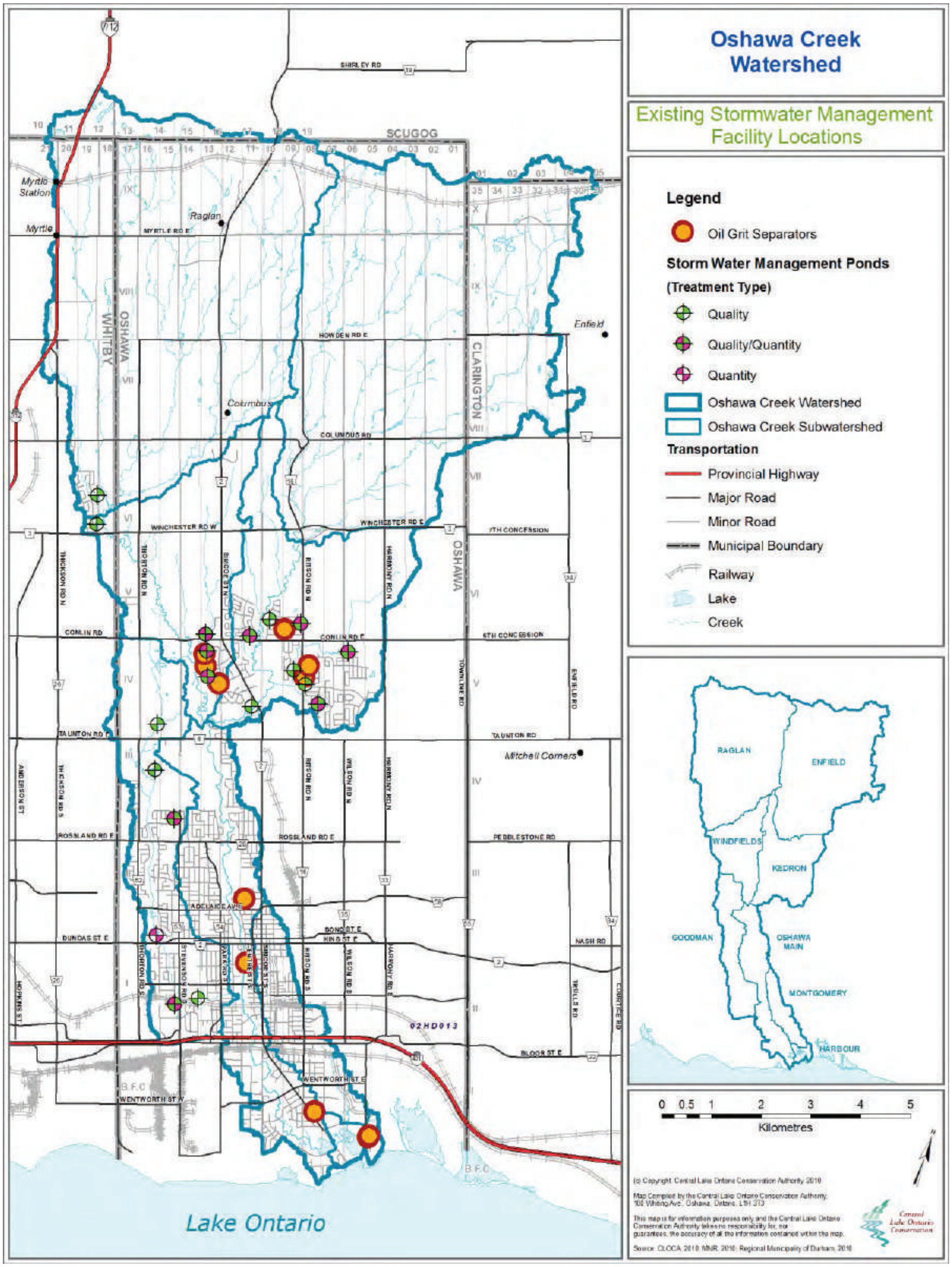

Figure 24: Existing Stormwater Management Pond (SWM) and Oil Grit Separator (OGS) locations within the Oshawa Creek watershed

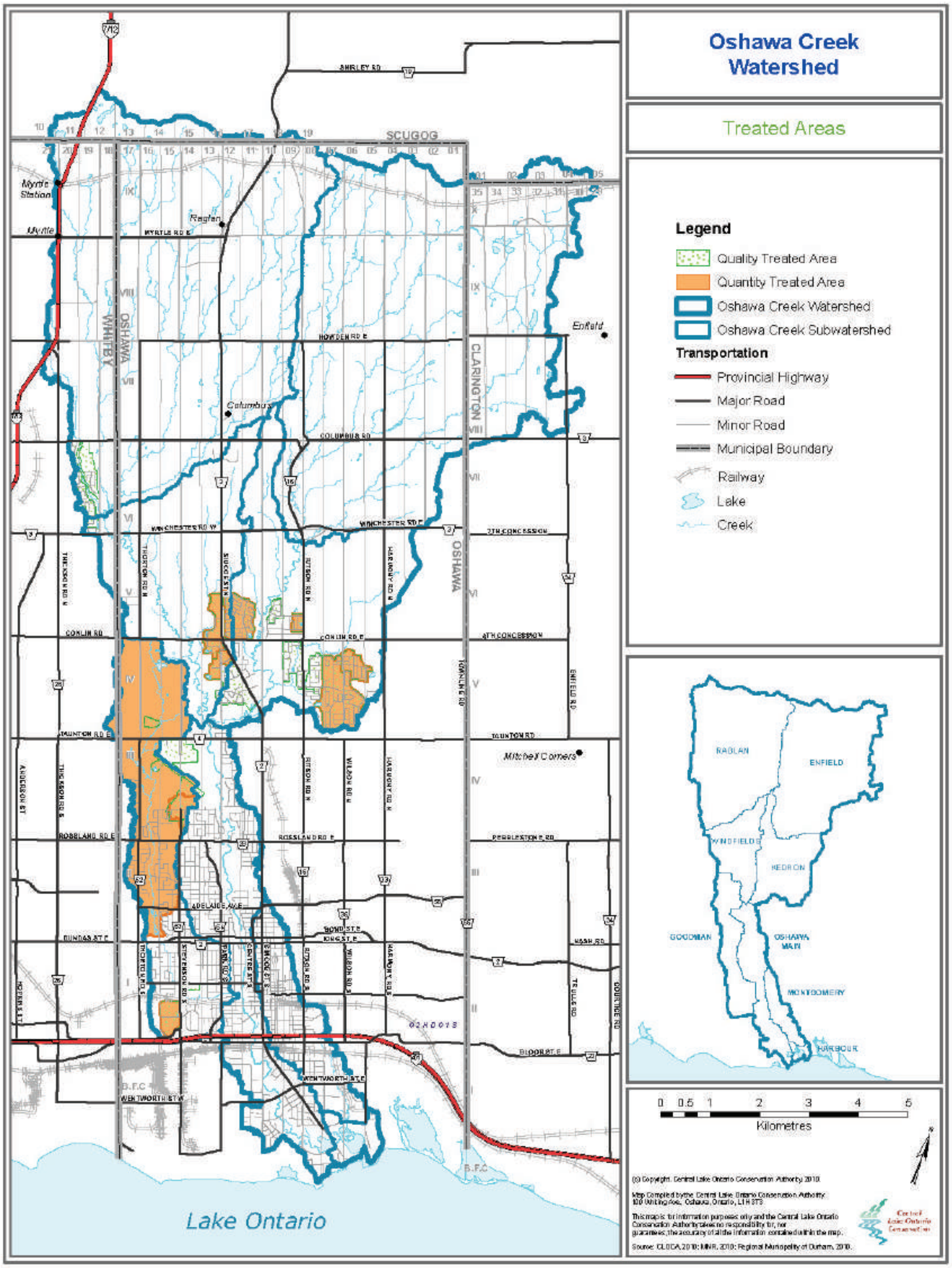

Figure 25: Treated drainage areas within the Oshawa Creek watershed

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.

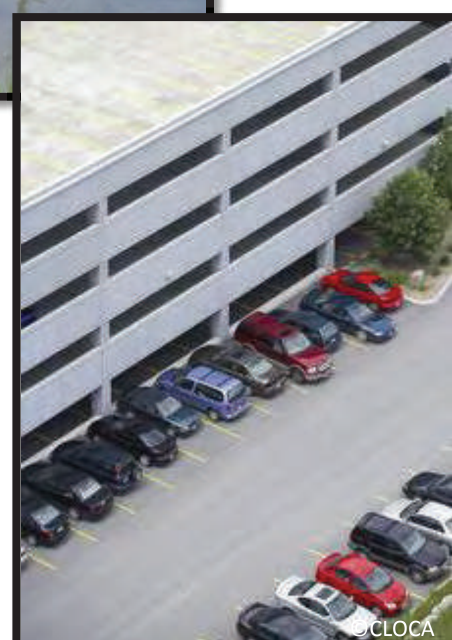

Table 10: Imperviousness and ELC/land use

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

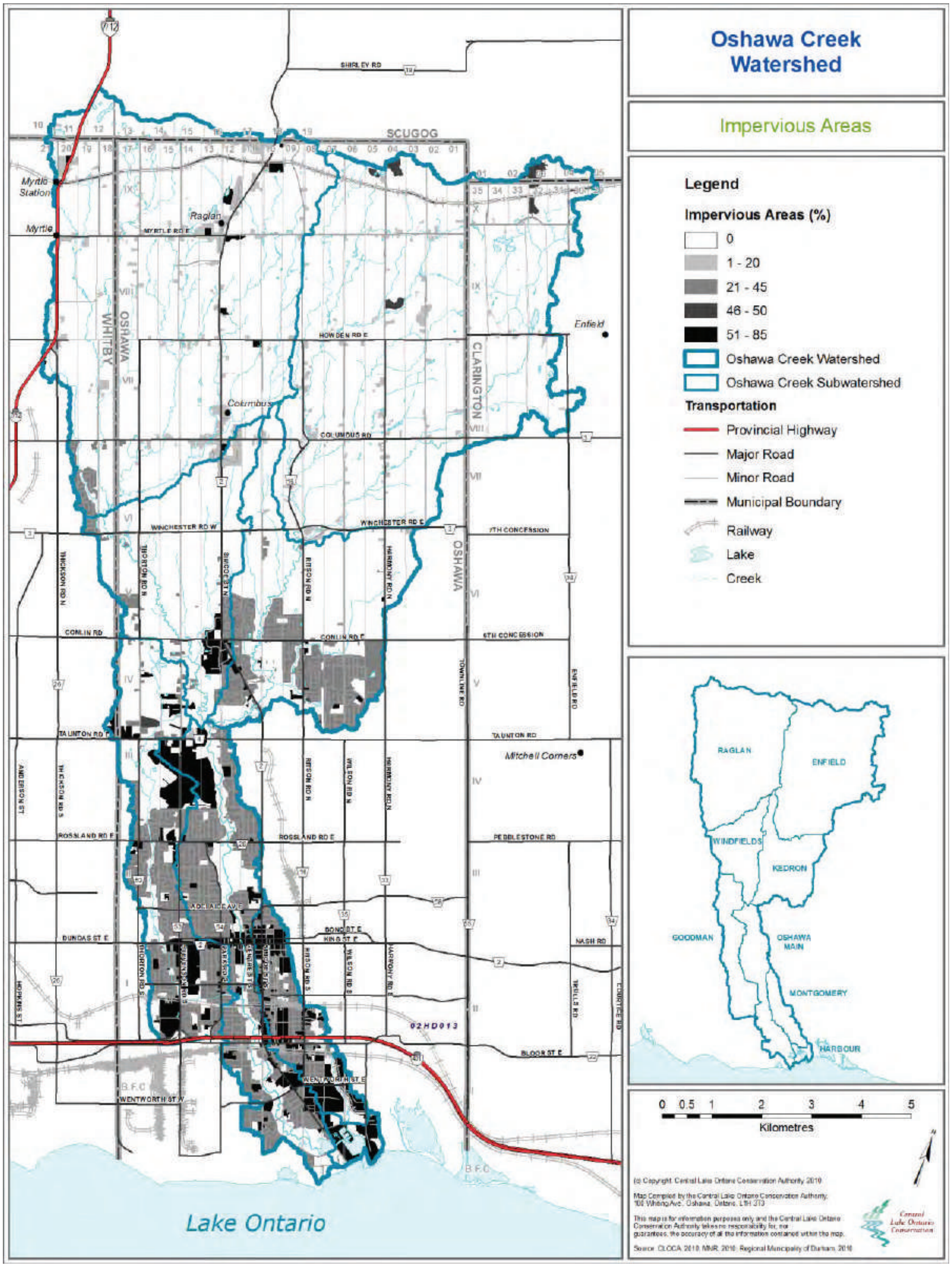

Figure 26: Oshawa Creek watershed impervious areas

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.

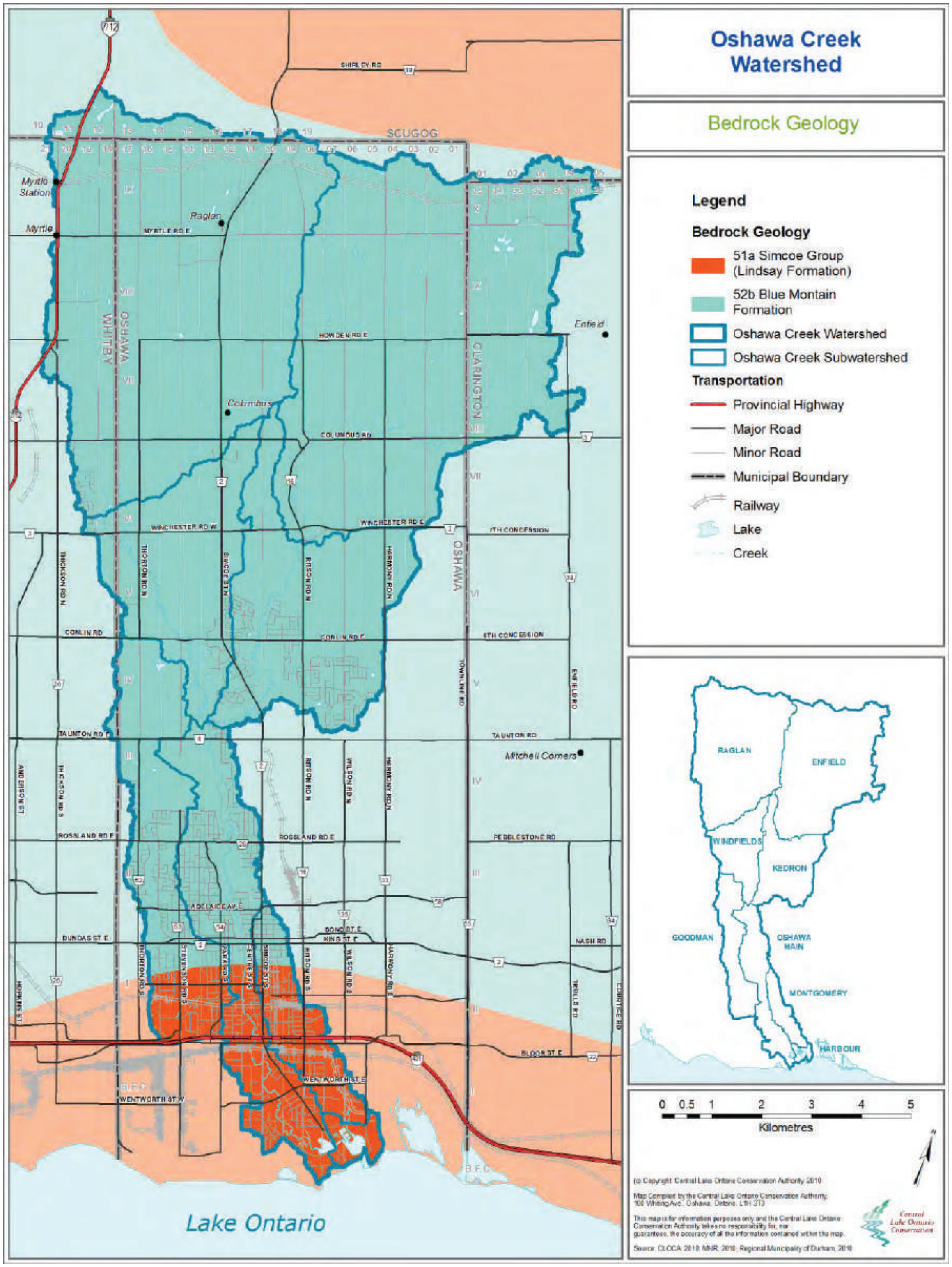

Figure 27: Bedrock geology of the Oshawa Creek watershed

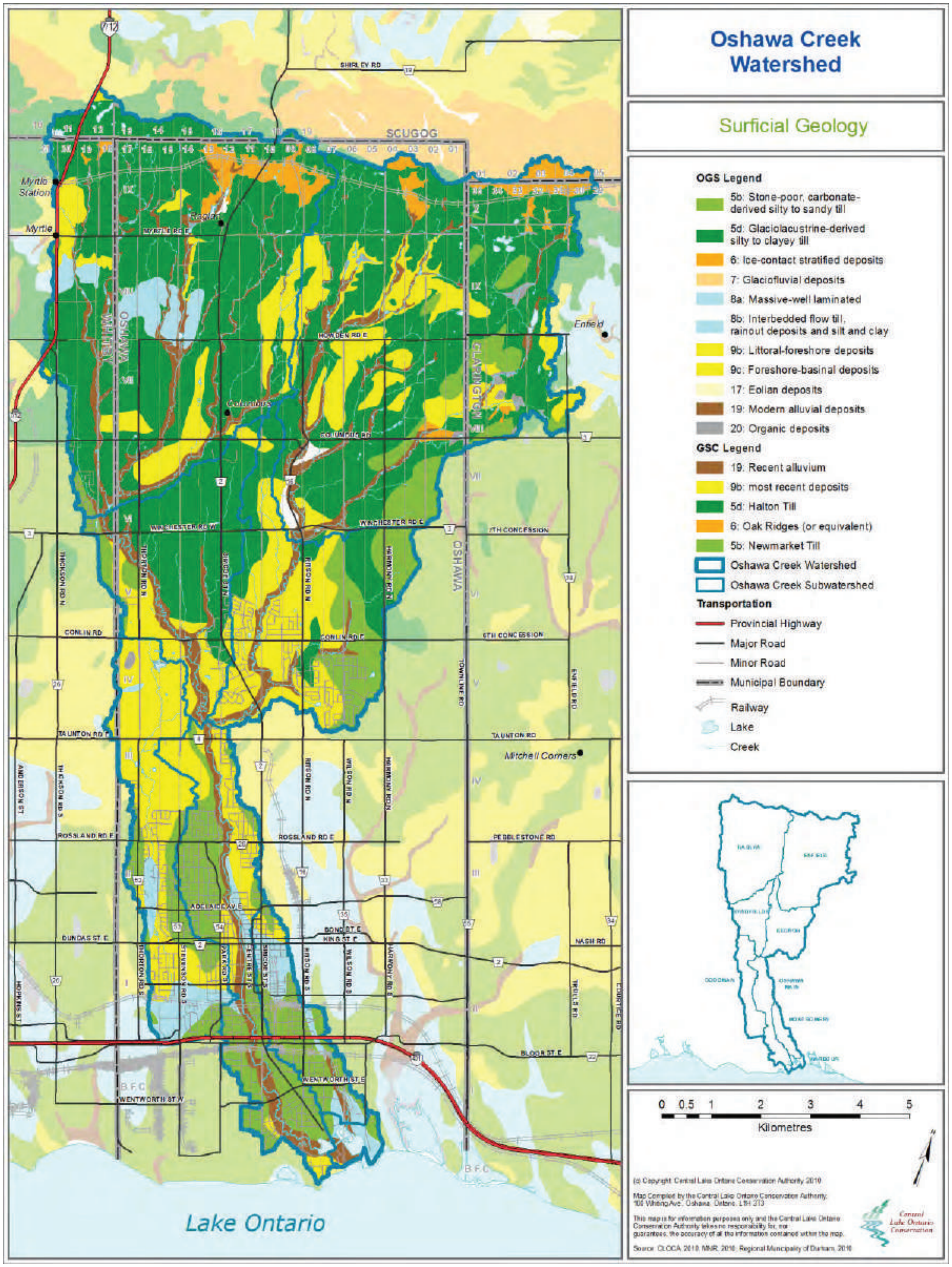

Figure 28: Surficial geology of the Oshawa Creek watershed

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.

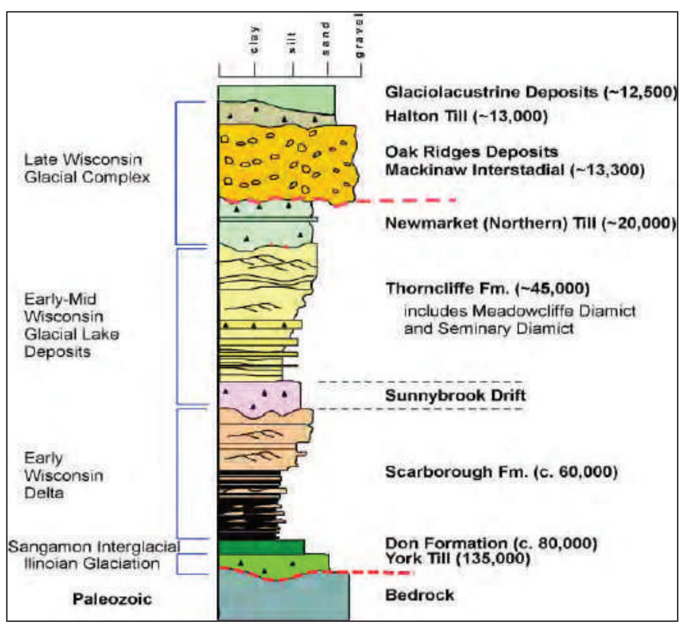

Figure 29: Oshawa Creek watershed geological profile

Table 13: Hydrostratigraphic units

Geologic Unit		Hydrostratigraphic Unit 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.

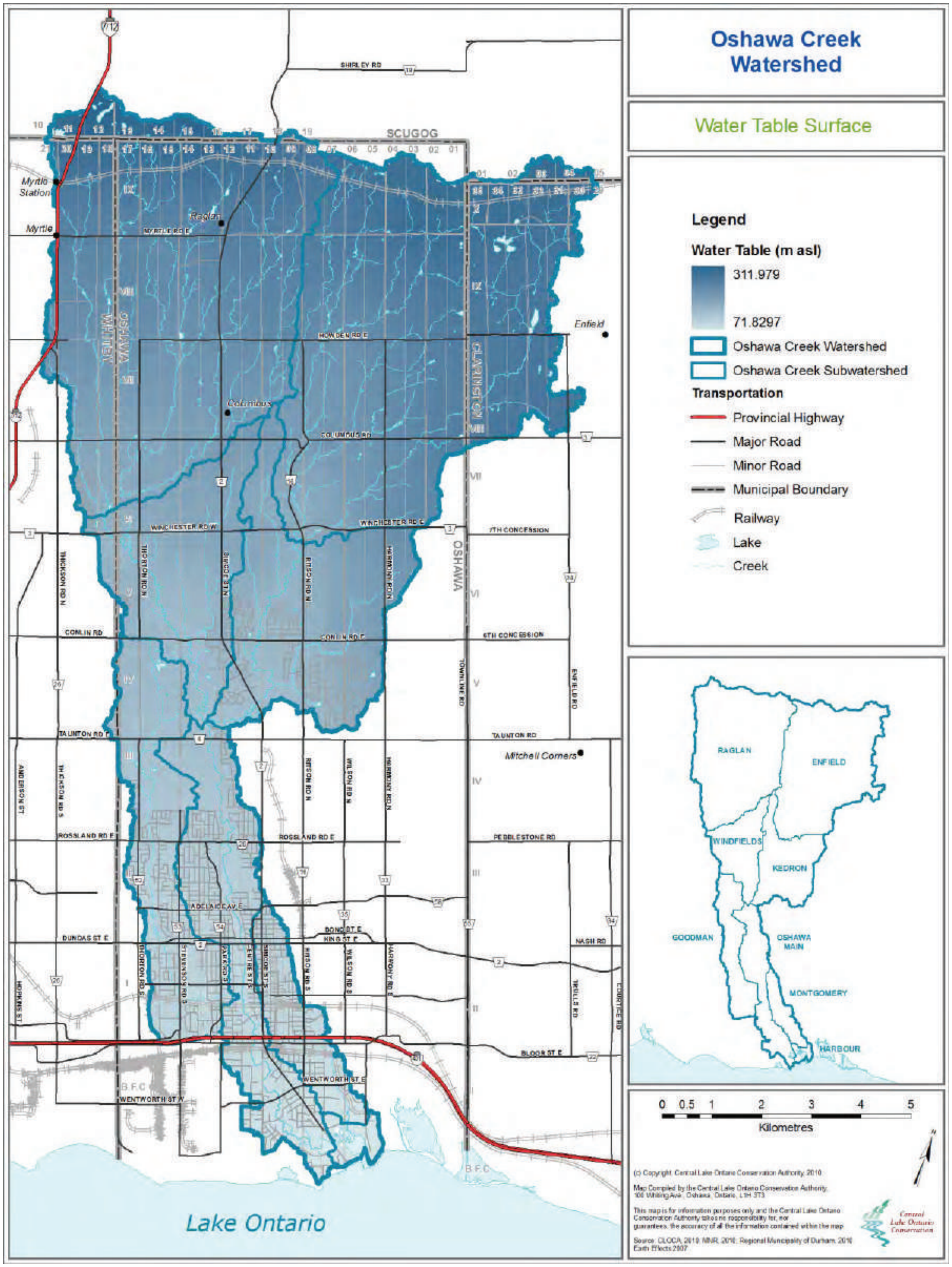

Figure 30: Water table in the Oshawa Creek watershed

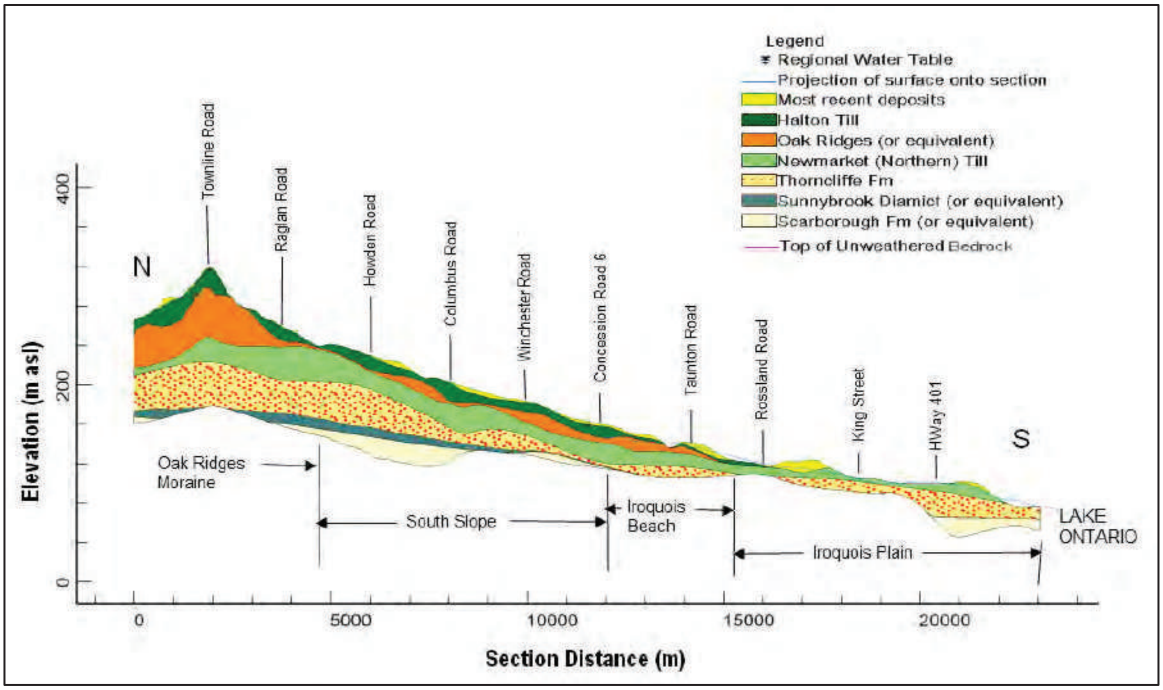

Figure 31: Oshawa Creek watershed geologic profile

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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.

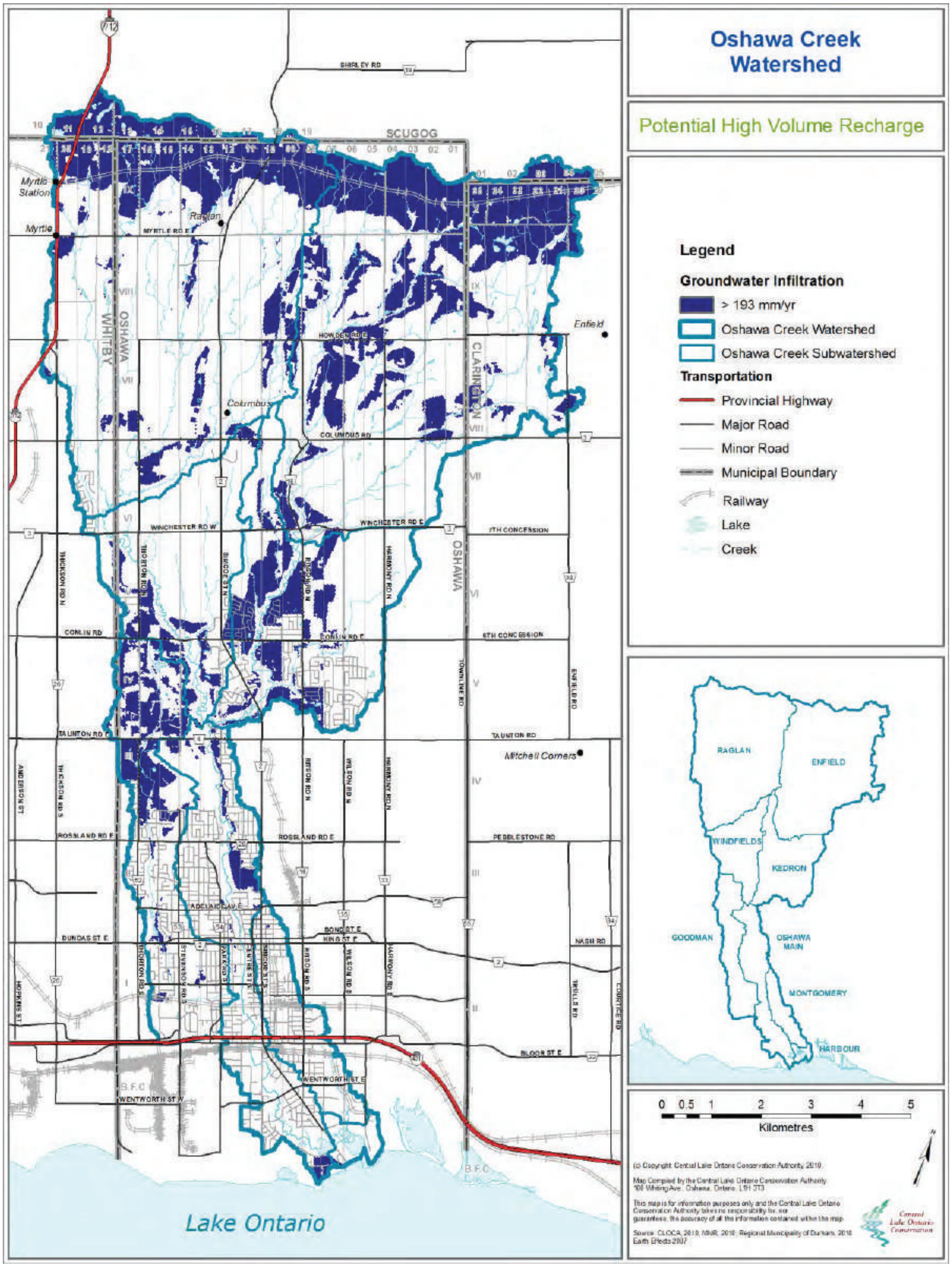

Figure 32: Potential high volume recharge areas in the Oshawa Creek watershed

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.

<u>Aquifer Vulnerability</u>

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.

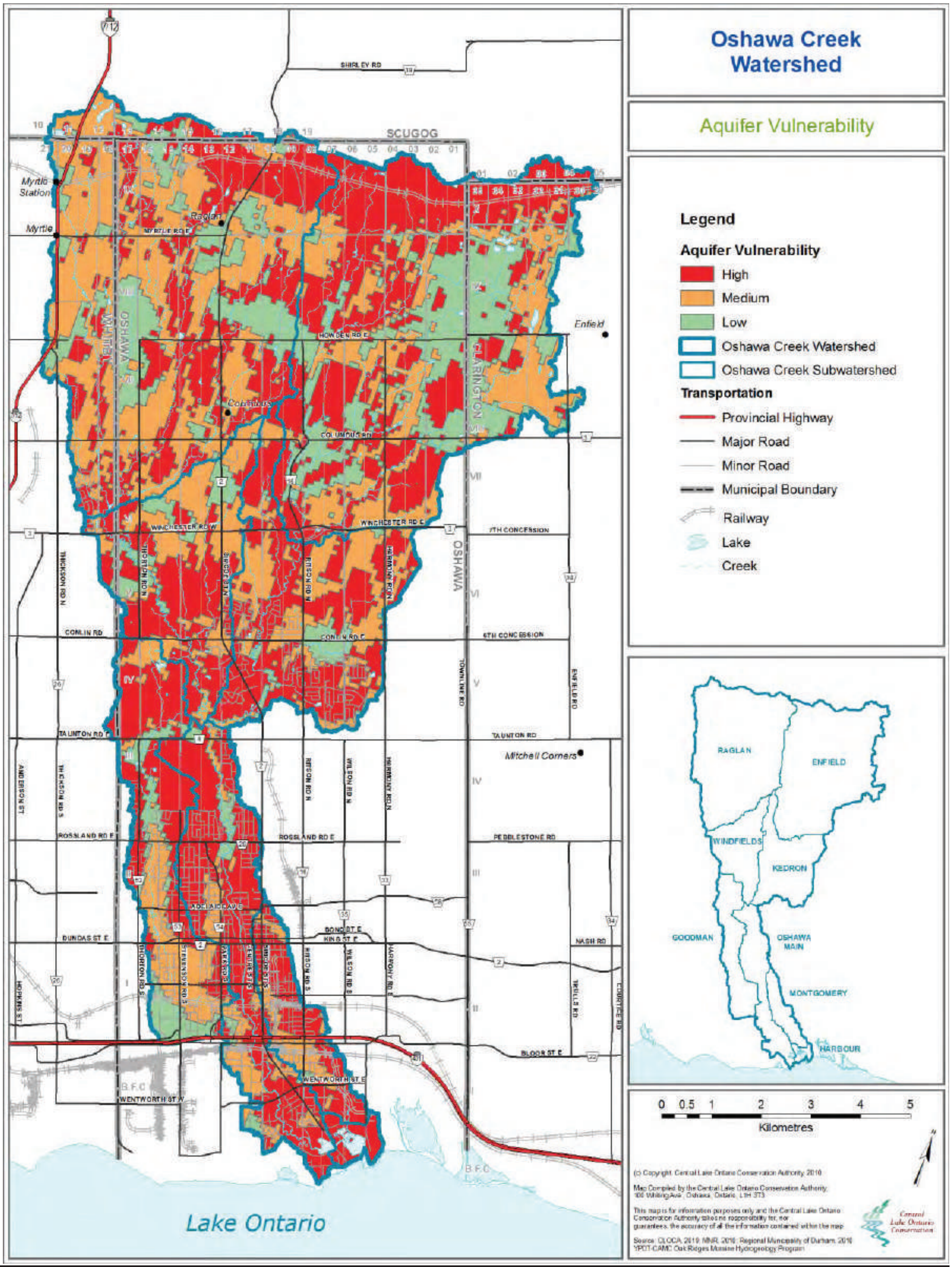

Figure 33: Aquifer vulnerability in the Oshawa Creek watershed using AVI

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.

Dutchman Breeches © CLOCA

Cardinal Flower © CLOCA

Marsh Marigold © CLOCA

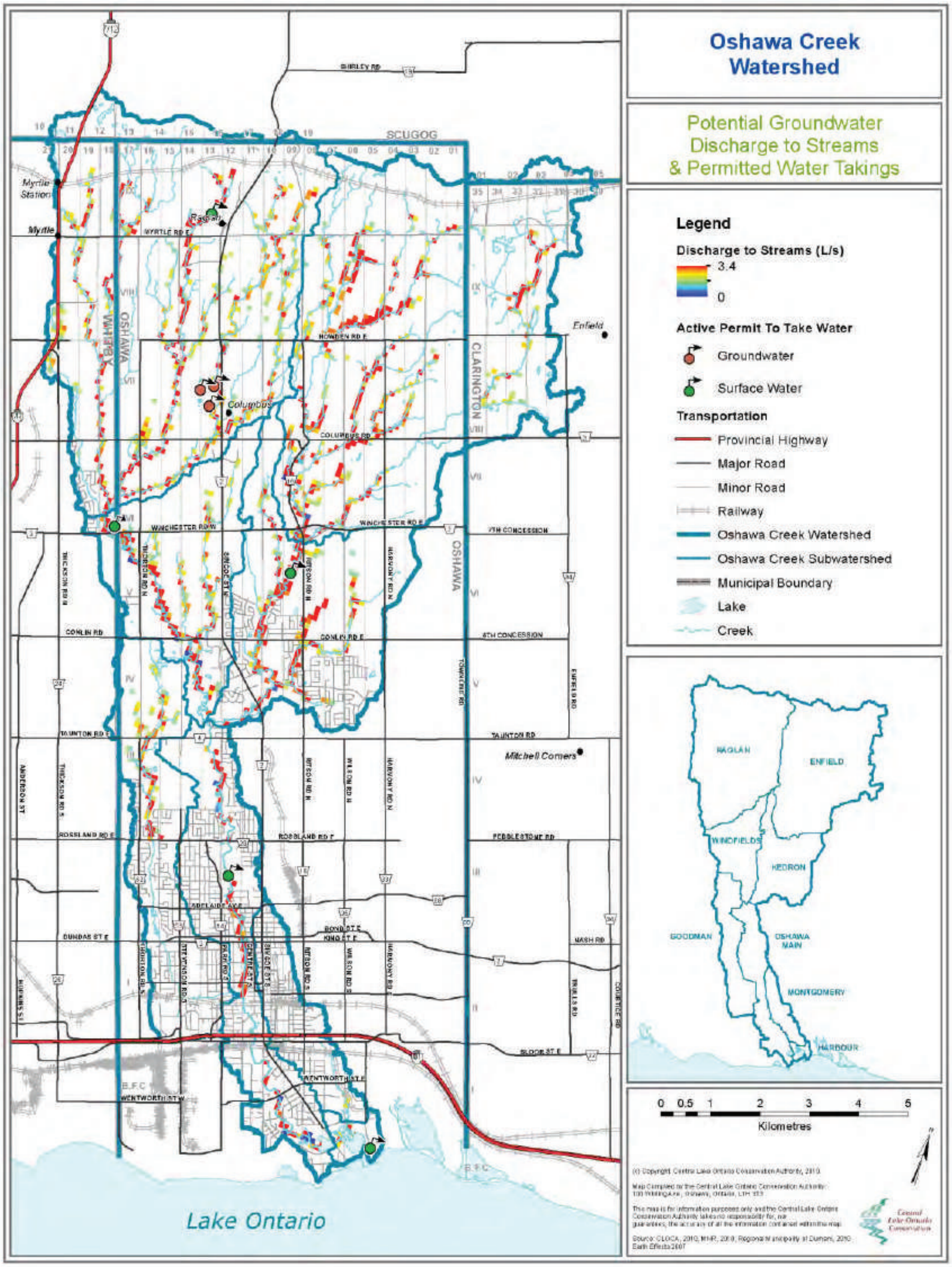

Figure 34: Potential groundwater discharge areas and Permitted Water Taking in the Oshawa Creek watershed

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.

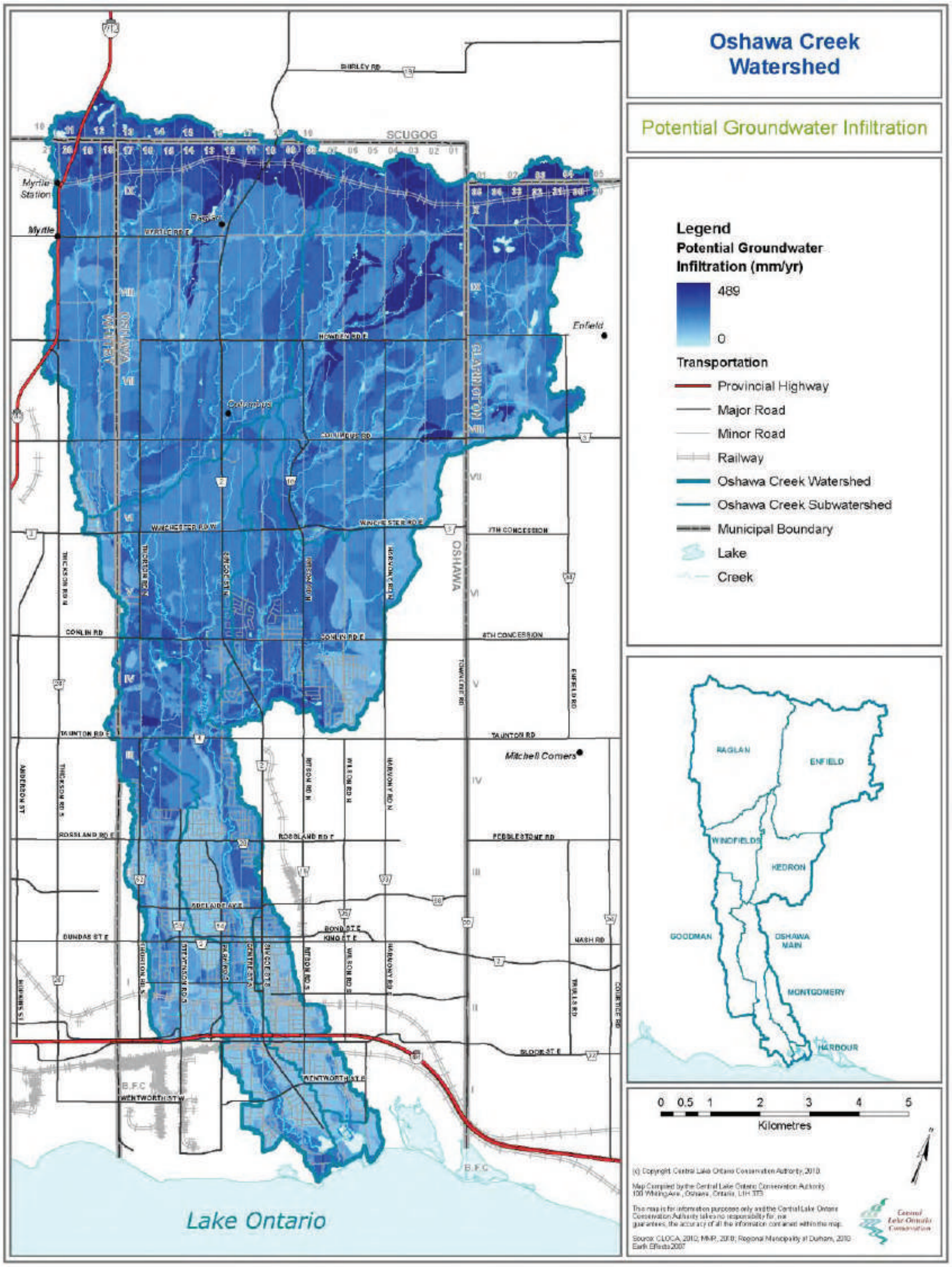

Figure 35: Potential groundwater infiltration

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.

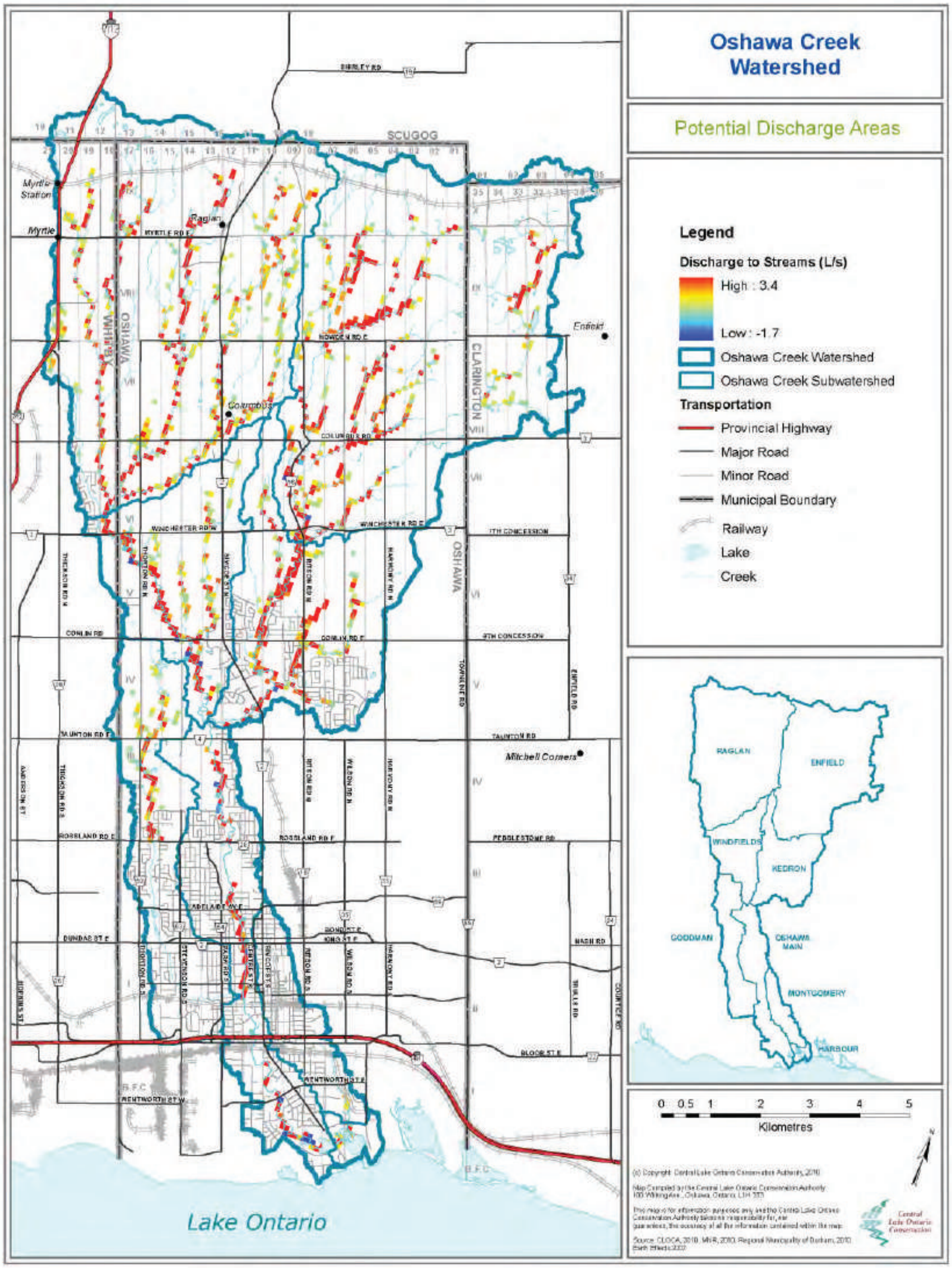

Figure 36: Potential groundwater discharge to streams in the Oshawa Creek watershed

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.

<u>Groundwater Quality</u>

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.

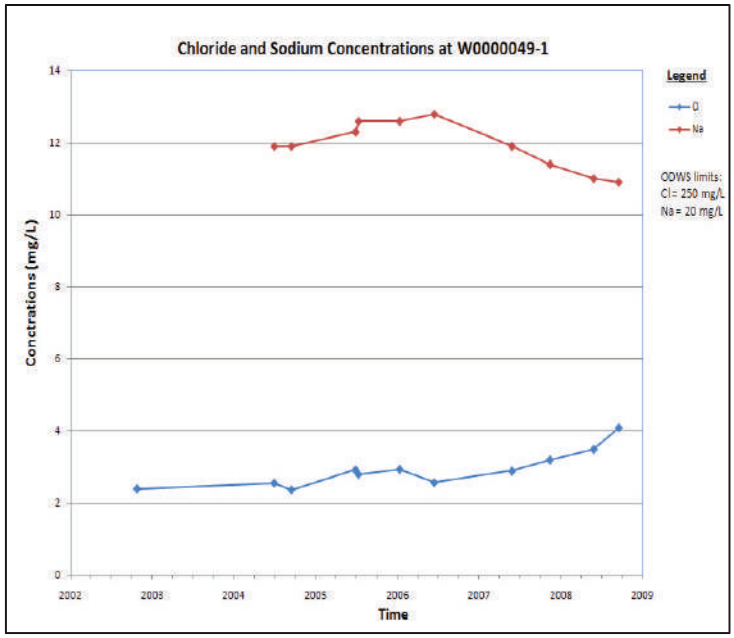

Figure 37: Chloride and sodium concentrations in PGMN Station W0000049-1

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.

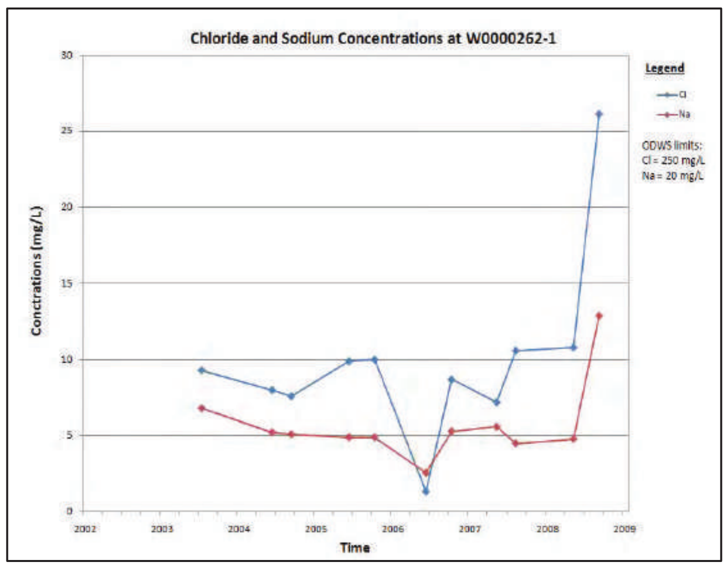

Figure 38: Chloride and sodium concentrations in PGMN Station

W0000262-1

Water Sampling at W0000262-1 ©CLOCA

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.

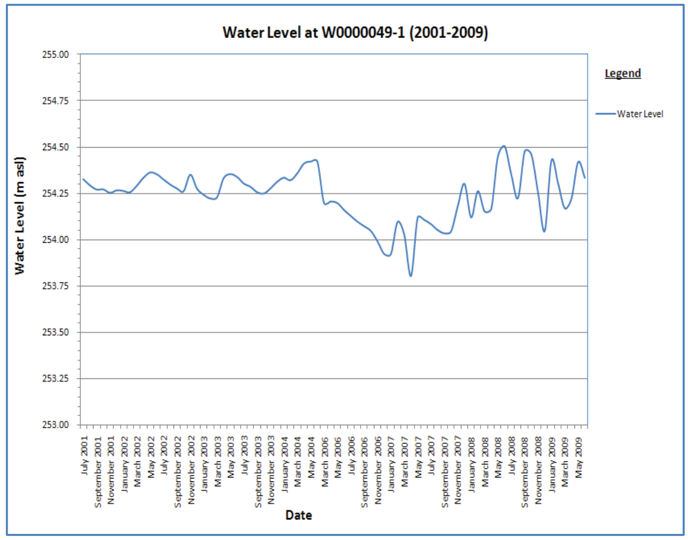

Figure 39: Hydrograph showing groundwater levels at PGMN Station W0000049-1

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.

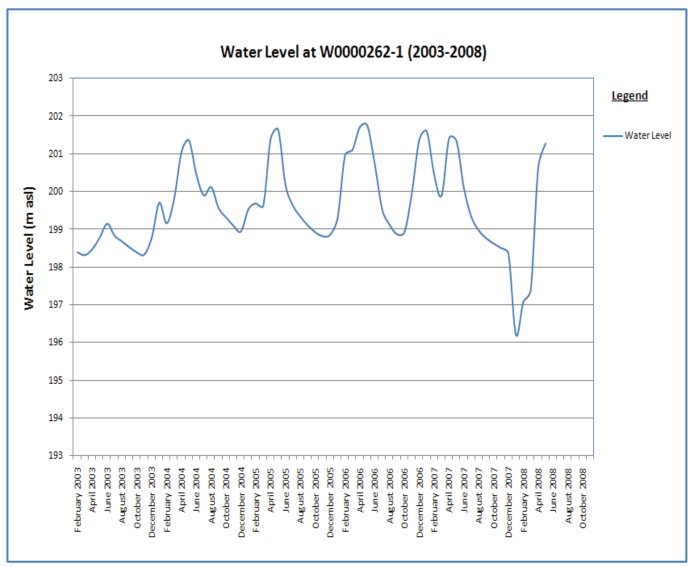

Figure 40: Hydrograph showing groundwater levels at PGMN Station W0000262-1

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.

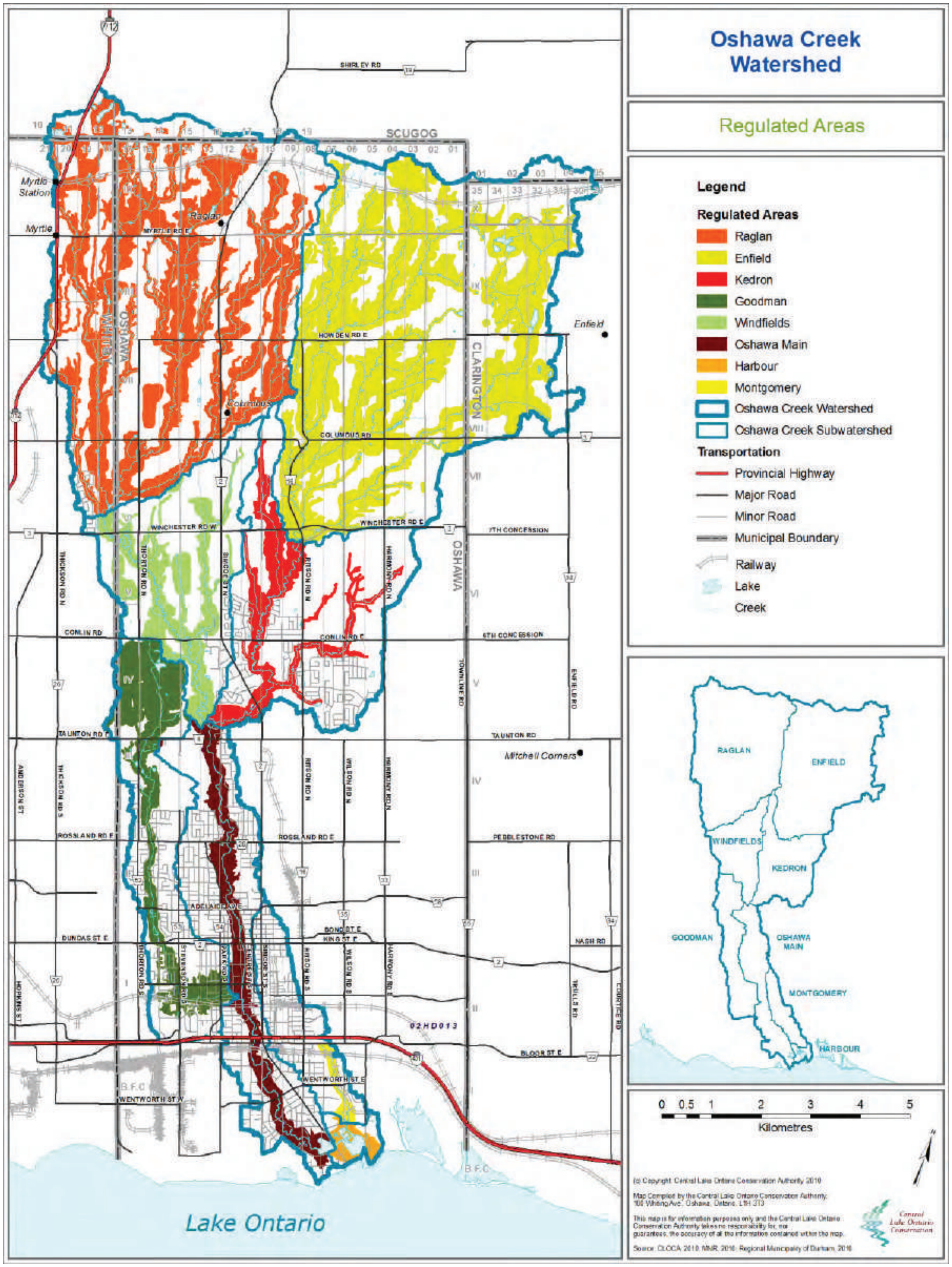

Figure 41: Generic Regulations limits for the Oshawa Creek watershed by subwatershed