Characterization of Ottawa's Watersheds:

An Environmental Foundation Document with Supporting Information Base

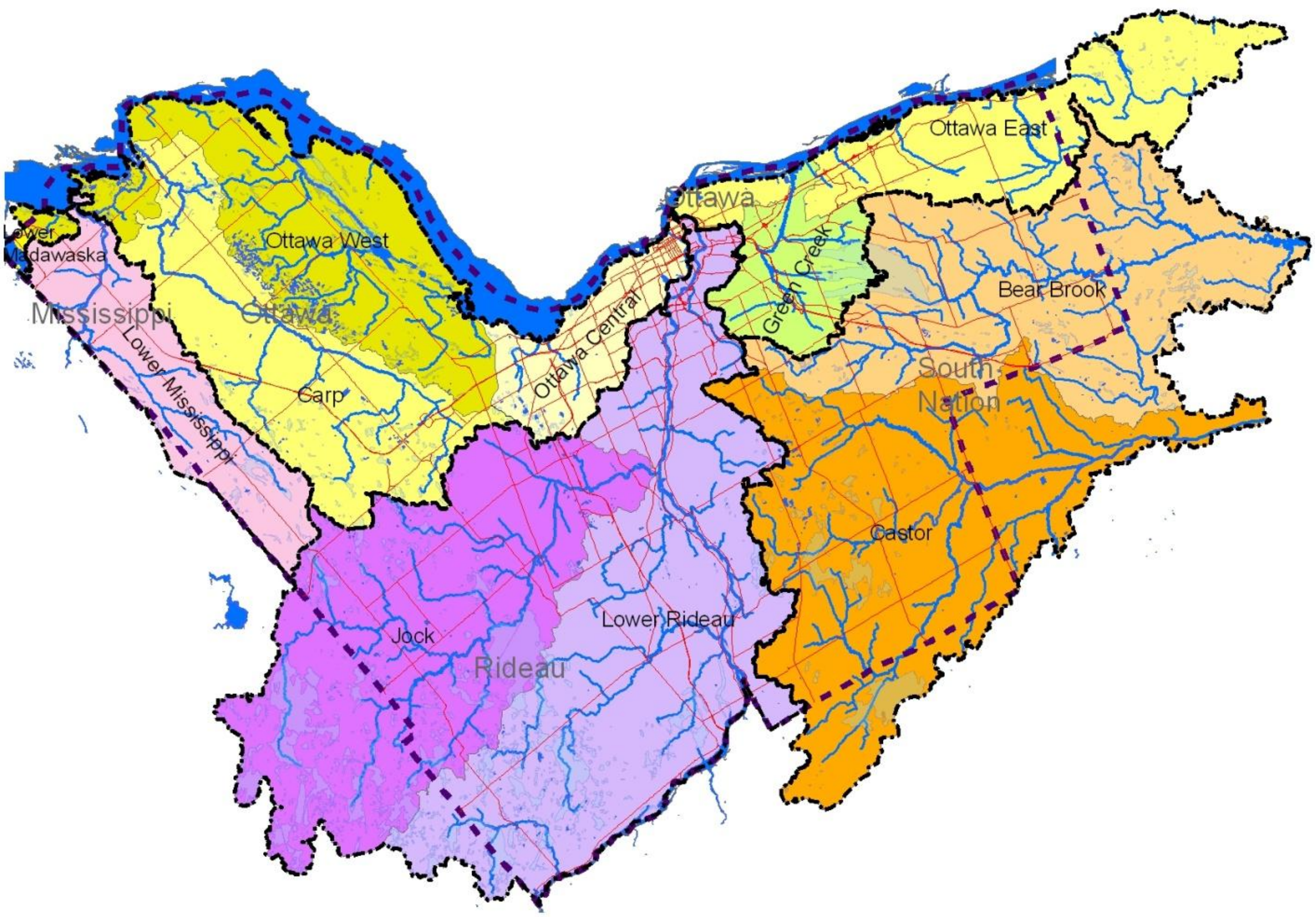


TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This document was developed through the use of data, methods, insights, and tools developed and supported by numerous agencies and individuals. Groups and agencies of note including:

- Ontario Ministries of: Natural Resources, Agriculture, Food and Rural Affairs, Northern Development, Mines and Forestry;
- Statistics Canada and Agriculture and Agri-Food Canada, Environment Canada
- City of Ottawa: Water Environment Protection Program, Research and Forecast Unit, Surveys and Mapping, Stormwater Facility, Water System Asset Management Group

Of particular note are the unnamed dedicated individuals that not only collected the original data but ensured its integrity and contributed it to build consolidated data sets that are the essential assets and basis to our knowledge and insight. Finally, acknowledgement is given to those who provided the support to complete this work.

NOTE

This document is a work in progress. Some sections, notably the section on groundwater, requires significant enhancement to appropriately characterize the function. However, this first edition of this document provides sufficient environmental information to benefit City projects. Subsequent editions will be released as soon as the further development of information warrants.

1 INTRODUCTION

1.1 Purpose

The City of Ottawa is traced with an extensive network of rivers and streams. This includes portions of four major rivers (the Rideau, South Nation, Mississippi and Ottawa Rivers), four major tributaries (the Carp, Jock and Castor Rivers and the Bear Brook), and hundreds of smaller creeks and streams. The total length of these watercourses is more than 4,500 km. Ottawa's rivers and streams help to define the region and are some of its most invaluable resources. They supply water for farms, industries, institutions and homes. They carry away pollutants and drain away stormwater. They support complex communities of terrestrial and aquatic plants and animals. For residents and visitors, Ottawa's rivers and streams provide beauty and a host of recreational opportunities including fishing, swimming, canoeing, boating and skating.

In recent years, the residents of Ottawa have taken an increased interest in the health of its watercourses. The City of Ottawa (the City) has responded to this interest by increasing its efforts on monitoring, planning and protection of its rivers and streams. This has included initiatives to reduce combined sewer overflows (CSOs), improve stormwater management, enhance wastewater treatment, and improve water quality in local rivers and streams.

This document – the *Characterization of Ottawa's Watersheds* – provides an overview, context, and supporting technical information on the existing conditions in the City's watersheds and subwatersheds. The purpose of Report is to:

- compile, present and synthesize existing information on the City's watersheds and subwatersheds;
- provide a characterization of the major watersheds and subwatersheds;
- identify data sources and data gaps; and
- describe the function of the watersheds by examining the interrelationships among key environmental components (such as climate, soils, drainage, ground and surface water, etc.)

Using available citywide data, the Report provides information on the following components on the environment and their interrelationships:

- topography, geology and soils;
- climate;
- surface water (hydrology, water balance and water quality);
- groundwater;
- land use; and
- terrestrial and aquatic ecology.

Data on these components of the environment come from many different sources. Some data is collected through the City's Water Environment Protection Program. Other data comes from the development of subwatershed plans, environmental impact reports, and stormwater management plans, and as part of other municipal planning processes. Still other data comes from provincial and federal agencies. The City now has ready access to the best available information through established contacts with Provincial Ministries under the umbrella of the Ontario Geospatial Data Exchange.

1.2 Benefits

Understanding our watersheds – their condition, form and function, and how the various components of the environment interrelate with each other – is the bedrock of good land use planning. It allows us to answer key questions, such as:

- How and where should development take place?
- What infrastructure is needed to support existing and future development?
- What existing environmental problems need to be addressed?
- What resources need additional protection or restoration?

The watershed and subwatershed characterization provides a framework that encourages consistent planning approaches across the City, and supports an improved understanding of the nature of each subwatershed, along with a reduced level of effort to define the 'present setting'. The information presented in this Report will aid professionals, planners, developers and others working on environmental projects and will be readily accessible for project and ad hoc analyses. Beyond the mere facts, the interpretation of the major thematic interrelationships between environmental components will provide a "portrait" of Ottawa's watersheds and subwatershed that will help guide planning, management and decision-making.

1.3 Approach

The Watershed Approach

Where possible, this Report uses watershed boundaries as the lens through which to view environmental information. The watershed has been recognized as an appropriate unit for managing water resources for at least 70 years. A recent review identified a number of reasons why structuring policy, planning, management and implementation on a watershed basis makes good sense.[1] These include:

[1] Watershed Management in Ontario: Lessons Learned and Best Practices. Conservation Ontario (2003)

- water integrates and catalyzes other biophysical processes in air, land and water environments;
- watersheds define distinct biophysical units;
- watersheds are an easily understood ecosystem unit;
- the health of rivers and streams is both influenced by and a personification of the health of the lands through which they flow;
- water systems demonstrate the cumulative effects of environmental stresses;
- quality of life is directly linked to water quality in watersheds;
- most management actions can be integrated using watersheds, at some scale, as a common planning unit; and
- there is strong and growing public support for implementation at the local watershed level.

In general, the characteristics (form and function) of watersheds and subwatersheds are defined by the interplay of the following factors:

- topography – surface features including hills, valleys and plains;
- geology and surficial geology – the bedrock that lies beneath the surface and the unconsolidated materials with soils that are the weathered top layer;
- climate – the average weather conditions experienced over long periods of time;
- watershed hydrology – how water is stored in and moves through the landscape;
- water quality – how surface and groundwater reflects the landscape and land use; and
- land use and cover – how land is used and the proportion of natural cover on it.

As explored in this Report, these factors are interrelated in complex ways. Topography, geology, soils, climate and hydrology influence vegetation. Geology and climate influence soils. Topography and soils influence land use to a large degree. Topography, geology, soils, climate, land use and cover influence watershed hydrology, stream form, water quality, water temperatures and aquatic communities.

Organization of Information

The information on topography, geology, soils, climate, surface water, land use and terrestrial and aquatic ecology has been collected, consolidated and analyzed using a typology of watersheds within which are minor watersheds defined by the main tributaries to watersheds. Minor watersheds are in turn comprised of a number of tributary subwatersheds. The typology is presented in Table 1-1 and the location of these watersheds and minor watersheds is shown in Figure 1-1. Information has been summarized in tabular and graphical formats to compare and contrast the relative distribution of characteristics across the City. In some cases, as identified in the text, information is also presented at a subwatershed level of detail. (Extensive subwatershed detail is presented in the Appendices B and C).

The Maps in Appendix A use a slightly different typology that is also based on geography (see Table 1-2). For each theme (e.g., surficial geology), maps are presented first at the Study Area-wide scale, and then at geographic groupings of the minor watersheds.

Table 1-1 Typology of Information on Watersheds and Minor Watersheds

Watershed	Minor Watershed
Mississippi	Lower Mississippi
Ottawa River	Lower Madawaska
	Ottawa West
	Carp
	Ottawa Central
	Green Creek
	Ottawa East
South Nation	Bear Brook
	Castor
Rideau	Jock
	Lower Rideau

Table 1-2 Typology of Maps in Appendix A

Map	Contents
XA	Study Area-wide
XB	Carp River, Lower Mississippi and Ottawa West
XC	Jock River
XD	Rideau River, Ottawa Central
XE	Castor River
XF	Bear Brook, Green Creek, Ottawa East

Geographic Scope of Report

Because of the benefits of using the watershed approach, the Report steps outside the boundary of the City of Ottawa to include the entire watersheds of the Jock River, Bear Brook, the Castor River and the Ottawa East minor watersheds (see Figure 1-1). This gives a total area of 3,554 $km^{2,}$ which is used for most of the tables in the Report. This area is referred to in the Report as the Study Area. The exception to this is the City of Ottawa Land Use data in chapter 5, which uses the actual area of the City of Ottawa, which is 2,826 km^2.

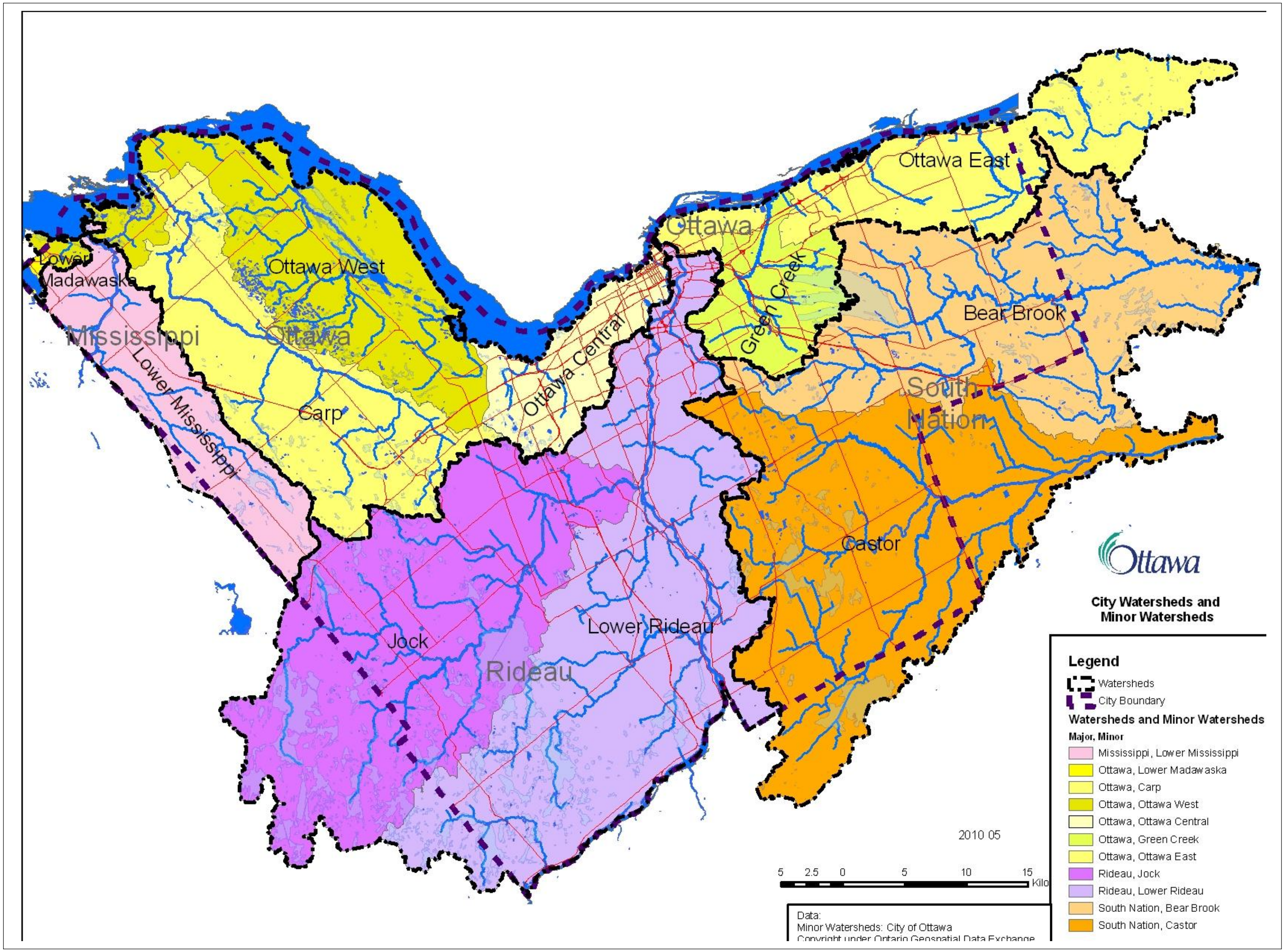
Sources of Data and Information

This Report uses the most recent readily available data and information. The sources of this data and information are presented in Table 1-3. More detail is found in section 9 (Information Sources).

Table 1-3 Sources of Data and Information

Data/Information		Source	Date
Topography	Surface	MNR	1988
	Bedrock	OGS	2003
Slope	Surface	MNR	1988
	Bedrock	OGS	2003
Bedrock Geology		GSC	2003
Depth of Overburden		OGS	2003
Soils	Agricultural Capability	OMAFRA	2009
	Hydrologic Soil Group	OMAFRA	2009
Temperature and Precipitation		Environment Canada	2009
Land Use	Survey 2005 – Simplified	City of Ottawa	2005
	Official Plan Schedules A & B Land Use Designation	City of Ottawa	2006
Draft Natural Heritage System Elements		City of Ottawa	2009
Evaluated Wetlands		MNR	2008
Hydrography	Streams	MNR	2007
	Municipal drains	OMAFRA	2008
	Tile drains	OMAFRA	2008
Farm Census Data		Statistics Canada	2001, 2006
Water Quality: Baseline Program		City of Ottawa	1998 to 2007

Figure 1-1 Watershed and Minor Watershed Boundaries



2 TOPOGRAPHY, GEOLOGY, AND SOILS

Topography, geology and soils are major influences on the watersheds and subwatersheds in the Study Area. The location of a slope relative to the sun, the depth and type of soils and underlying overburden is a fundamental determinant of vegetation. Topography, geology and soils also heavily influence land use. Valley lands and steep slopes are often not suitable for development and areas with exposed bedrock are not suitable for agriculture.

The topography in the Ottawa area has been created over geologic time through the formation of bedrock and subsequent deposition and erosion by glaciations and water. The topography in the area continues to be shaped by on-going weathering, erosion, and sedimentation processes, and by human alteration.

2.1 Topography

2.1.1 General Characteristics

The City is relatively flat with a number of noted valley lands and escarpment features. The elevation is highest in the southwestern part of the City where it reaches a high of 165 m above mean sea level (amsl). The elevation decreases as one moves in a northeast direction and is lowest at 42 m amsl along the eastern portion of Ottawa River Valley. See Figure 2-1 and Maps 1A to 1F (Topography) in Appendix A.

2.1.2 Valley Lands and Escarpments

The identification of valleys within the Study Area was carried out using the approach described in the second edition of the Ministry of Natural Resources (MNR's) Natural Heritage Reference Manual (2010), which provides guidance for meeting the requirements of the Provincial Policy Statement (PPS) under the *Planning Act*. For this Report, valleys were identified where the features had slopes greater than 15%, a minimum length of 50 m, and a well-defined morphology with an average width of 25 m. The review identified a total of 189 valleys. The subwatersheds with the longest valleys and largest elevation changes are shown in Table 2-1. The range of lengths and elevations changes are presented in Figure 2-2. The steepness of slopes is shown in Maps 2A to 2F (Slope) in Appendix A.

Why are Valleylands important?

As the "backbone" of a watershed, valleys perform important ecological functions. (e.g., diverse habitats in valleylands due to microclimate variations). Planning authorities should carefully assess their valleyland systems relative to the overall protection of natural heritage features. Planning authorities may choose to designate an entire valley or portions of a valley as a significant valleyland, depending on the extent and quality of the valleyland resource within the jurisdiction of the planning authority.

As the natural drainage systems for watersheds, valleys provide an appropriate context for planning and evaluating water-related resources. It is suggested that the natural heritage significance of valleylands be assessed within the context of the overall watershed.

Aside from their natural heritage value, valleys are also extremely important to our social well-being and cultural history. They enhance our quality of life and provide economic diversity and vitality through the resources they contain. Some of the cultural values of valleys are:

- representation of European colonization in settlement towns, bridges and mills;
- archaeological resources representative of Aboriginal cultures;
- important economic resources such as aggregates, agriculture and forestry;
- a wide variety of recreation activities such as nature appreciation, hiking, fishing and hunting, swimming, boating, parks and golf courses;
- centres of contemporary human habitation in towns and cities; and
- a source of drinking water and an area for treating wastewater.

In highly urbanized or fragmented landscapes, valleylands may constitute the only remaining natural areas within the planning area and are often considered essential in defining the basic character of a community. In these planning areas, valleylands are essential for establishing connectivity for a natural heritage system. Consequently, valleylands should be identified as an integral part of a planning authority's overall natural heritage system.

MNR (2010), Natural Heritage Reference Manual, Second Edition

The Study Area's steep and well-defined valley lands include:

- Cody Creek, tributary to the Mississippi River on the western edge of the City with a total length of 40 km and a change in elevation of 38 m; and
- four tributaries to the Ottawa River in the eastern portion of the City, which are downcutting from the table lands:
  - Green Creek, within the Greenbelt just east of the urban area;
  - Bilberry Creek, a sub-urban subwatershed in central Orleans;
  - Cardinal Creek, on the eastern edge of the urban boundary, extending into rural and agricultural areas; and
  - Becket's Creek, at the eastern edge of the City.

The Jock River watershed has a notable lack of significant valley systems.

Table 2-1 Subwatersheds with the Longest Valleys and Largest Elevation Change

Length (m)	Height (m)	Grade %	Minor Watershed	Subwatershed
39,295	38 (3)	0.10%	Lower Mississippi	Cody Creek
16,000	34 (4)	0.21%	Green Creek	
12,000	50 (1)	0.42%	Ottawa East	Cardinal Creek
10,992	14	0.13%	Lower Rideau	Mosquito Creek
8,586	24	0.28%	Bear Brook	South Indian Creek
8,232	46 (2)	0.56%	Ottawa East	Bilberry Creek

Escarpments are steep slopes or long cliffs formed by erosion or by the vertical movement of the Earth's crust along a fault. In this Report, escarpments were identified using the Southern Ontario Land Resource Information System (SOLRIS, 2008) definition of cliffs and talus as being 'vertical or near vertical' and greater than 3 metres in height. In this Report, areas with naturally formed slopes greater than 75% and heights greater than 3 metres, with bedrock at or near surface were classified as escarpments. A length of 1,500 m was used as a minimum length with exceptions for features less than 1,500 m but within 1,000 of another escarpment feature. In total, there were 139 escarpments identified. The most significant escarpment features in terms of size are listed in Table 2-2.

Table 2-2 Subwatersheds with the Longest Escarpments and Largest Elevation Change

Length (m)	Height (m)	Minor Watershed	Subwatershed
4,655	28	Ottawa West	Casey Creek
4,206	42 (3)	Ottawa East	
3,868	46 (1)	Ottawa East	
3,868	44 (2)	Ottawa East	Cardinal Creek
2,762	32	Ottawa East	Beckett's Creek
2,106	38 (4)	Carp	Mid reach

The shoreline of the Ottawa River is also characterized by the presence of escarpment systems. One of the most recognized of these is Parliament Hill. Other escarpments are found: along the Rockcliffe Outlook; in eastern Orleans (with the longest being in the Cardinal Creek subwatershed); west of the west urban area following the Ottawa River and along the Carp Ridge in the Casey Creek subwatershed and Carp River watershed.

In contrast to the many escarpments found along the Ottawa River, there are no escarpments of significant size in the Jock River, Bear Brook, or Castor watersheds.

The range in characteristics of valleys and escarpment features, in terms of length and change in elevation, is illustrated in Table 2-2. The number and size of valleys and escarpment features by minor watershed and subwatershed are listed in Table 2-3 and Appendix B, Table A.1 respectively, with the steepness of slopes shown in Maps 2A to 2F (Slope) in Appendix A.

Figure 2-1 Study Area Topography and Bedrock Profile West to East: Jock Headwaters to Bear Brook outfall

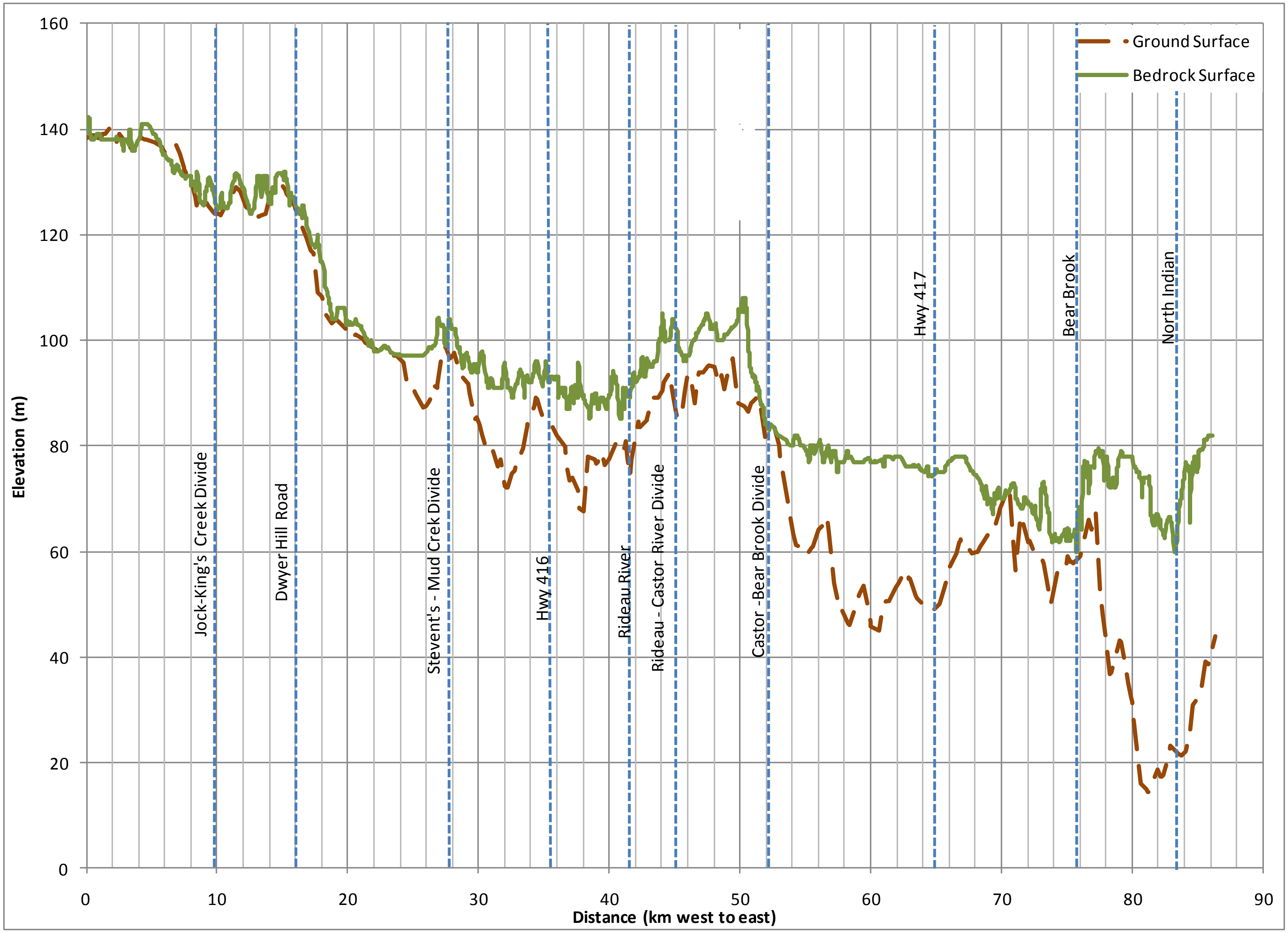


Figure 2-2 Distribution of Valley and Escarpment Length and Change in Elevation

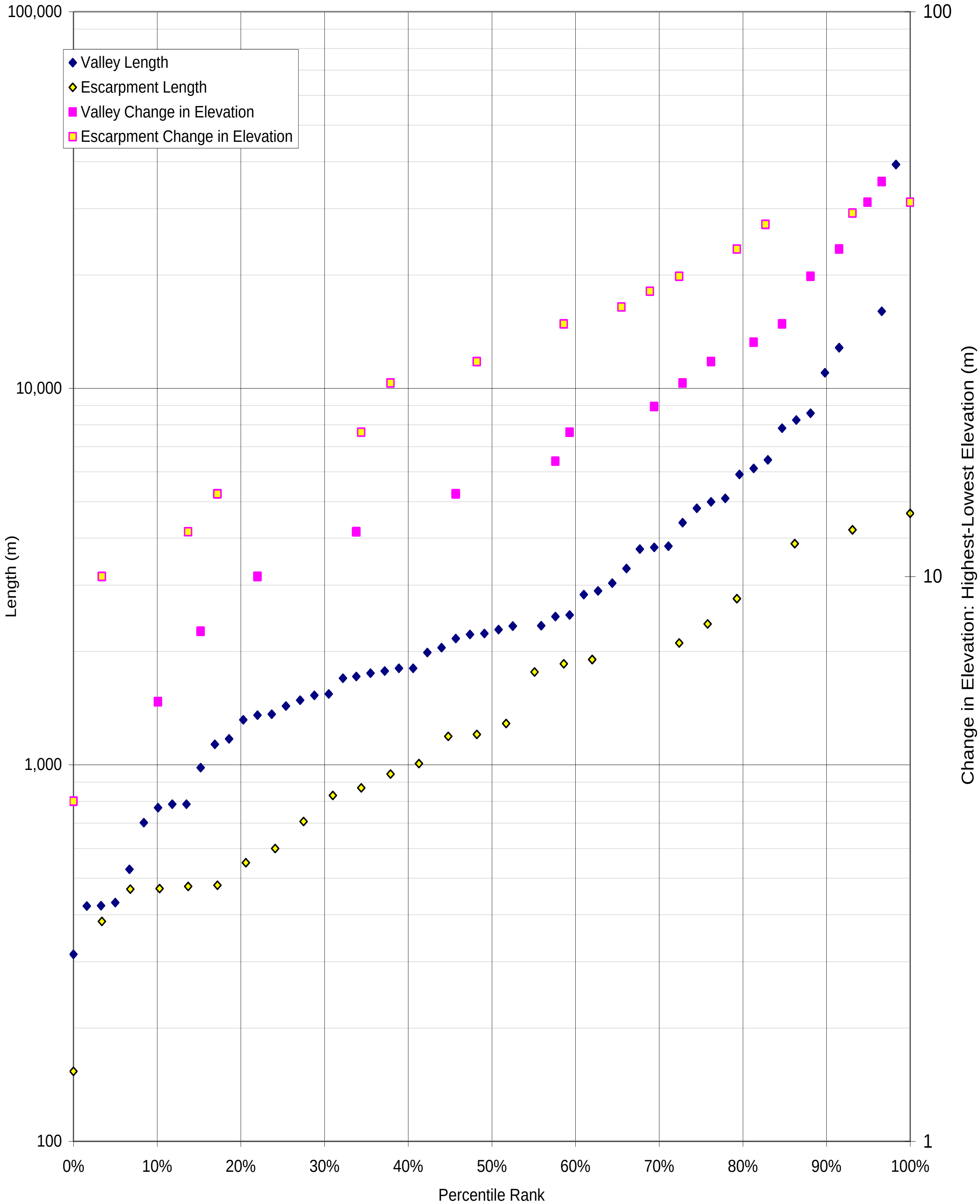


Table 2-3 Characteristics of Valley Lands and Escarpments by Minor Watershed

Watershed	Minor Watershed	Valleys			Escarpments		
		#	Maximum		#	Maximum	
			Length (m)	Elevation Change (m)		Length (m)	Elevation Change (m)
Mississippi	Lower Mississippi	26	**39,295**	38	4	1,288	28
Mississippi Total		*26*			*4*		
Ottawa	Lower Madawaska	0			0		
	Ottawa West	18	1,774	28	34	**4,655**	42
	Carp	20	2,832	24	32	2,106	38
	Ottawa Central	10	2,233	22	7	1,855	44
	Green Creek	10	16,001	34	3	4,206	42
	Ottawa East	30	12,822	**50**	56	4,206	**46**
Ottawa Total		*88*			*132*		
South Nation	Bear Brook	14	8,586	24	0		
	Castor	11	4,992	8	0		
South Nation Total		*25*			*0*		
Rideau	Jock	5	3,740	18	0		
	Lower Rideau	45	10,992	28	3	1,008	14
Rideau Total		*50*			*3*		
Totals		**189**			**139**		
Maximum values are in bold							

2.2 Geology and Soils

2.2.1 Bedrock and the Formation of Surficial Geology

Bedrock is the solid, unweathered rock that underlies soils. While largely unseen, the bedrock across the Study Area plays a formative role in the characteristics of its watersheds and subwatersheds. In places such as the limestone plains of southwestern Ottawa, the bedrock defines the surface. In other places, such as the area's valley systems, erosion and deposition processes (including glacial, lacustrine, and riverine processes) have occurred over time, and the resulting deposits and erosion features form the surficial geology and, with the bedrock features, define the topography.

A map of bedrock elevation can be found in Appendix A, Map 3A (Bedrock Elevation). In general, the elevation of bedrock reflects the elevation of the ground (see Figure 2-1). It is highest in the west, where there is a mixed sedimentary rock feature (primarily limestone) found at 160 m amsl along the Mississippi-Carp River watershed divide and decreases in height as one moves through to the Bear Brook valley in the east. The Carp Ridge, an isolated extension of the Canadian Shield, formed from metamorphic rock, frames the Carp River Valley to the west, and a sandstone formation forms the divide between the Carp, Jock, and Ottawa watersheds. Another sedimentary ridge (dolomite) forms the divide between the Rideau and South Nation watersheds, yielding to the low lands characterized by a shale formation under the Bear Brook and Castor Rivers. The bedrock type by subwatershed is shown in Table 2-4 and in Map 3B (Bedrock Geology by Watersheds) in Appendix A.

During the Upper Wisconsinan period (23,000 to 10,000 years BP), the lowlands between the higher bedrock features received deposits from glaciation and meltwaters as the glaciers started to retreat. The composition of these deposits varies from broad clay till areas in the Carp River Valley to clay plains with drumlin features in the Lower Rideau, to sand plains with clay till in the Castor and Bear Brook watersheds. These surficial deposits are addressed in the next section. The limestone bedrock supports agriculture by providing calcium, a key secondary nutrient for plant growth (Sections 2.3.2 and 5.4) and constituent water chemistry (Sections 4.4.1).

The bedrock outcroppings form an access route for recharging aquifers underlying the clay plains of the Mississippi, Carp, Jock, and Lower Rideau minor watersheds. In the eastern part of the Study Area, sand plains intermixed with clay till support greater groundwater recharge, storage, and discharge functions. Additional recharge areas are found in the drumlin formations in the Lower Rideau (Section 4.1 and 4.2).

Table 2-4 Bedrock Type by Subwatershed

Watershed	Minor Watershed	N/A	Palaeozoic								Precambrian					Total
			Dolomite	Limestone	Limestone and dolomite, interbedded	Limestone and Shale, interbedded	Sandstone	Sandstone and Dolomite, interbedded	Shale	Sub-Total	Dykes	Intrusive Rocks	Metasedimentary Rocks	Migmatic Rocks	Sub-total	
Ottawa	Carp		3%	20%	22%	31%	1%	1%	1%	**79%**		2%	9%	10%	**21%**	100%
	Green Creek		4%	3%	2%	6%			85%	**100%**					**0%**	100%
	Lower Madawaska		8%		11%	24%				**43%**			57%		**57%**	100%
	Ottawa Central		11%	6%	15%	8%	5%	36%	19%	**100%**					**0%**	100%
	Ottawa East		7%	20%	21%	37%			15%	**100%**					**0%**	100%
	Ottawa West		21%	1%	21%		3%	12%	8%	**66%**		5%	12%	16%	**34%**	100%
Ottawa Total		***0%***	***10%***	***12%***	***19%***	***19%***	***2%***	***7%***	***16%***	***84%***	***0%***	***2%***	***6%***	***7%***	***16%***	***100%***
Mississippi	Lower Mississippi		7%	21%	44%	8%	2%		7%	**89%**	0%	2%	9%		**11%**	100%
Mississippi Total		***0%***	***7%***	***21%***	***44%***	***8%***	***2%***	***0%***	***7%***	***89%***	***0%***	***2%***	***9%***	***0%***	***11%***	***100%***
Rideau	Jock	2%	37%	4%	26%			17%	14%	**98%**					**0%**	100%
	Lower Rideau	7%	71%	1%	2%	1%		12%	5%	**93%**					**0%**	100%
Rideau Total		***5%***	***55%***	***2%***	***13%***	***1%***	***0%***	***14%***	***10%***	***95%***	***0%***	***0%***	***0%***	***0%***	***0%***	***100%***
South Nation	Bear Brook					31%			69%	**100%**					**0%**	100%
	Castor		68%	2%	2%	8%	1%	2%	18%	**100%**					**0%**	100%
South Nation Total		***0%***	***37%***	***1%***	***1%***	***18%***	***0%***	***1%***	***41%***	***100%***	***0%***	***0%***	***0%***	***0%***	***0%***	***100%***
Total		**2%**	**33%**	**6%**	**13%**	**12%**	**1%**	**7%**	**21%**	**93%**	**0%**	**1%**	**2%**	**2%**	**5%**	**100%**

2.2.2 Physiographic Units and Surficial Geology

Surficial geology includes the surface deposits that are the loose, unconsolidated sedimentary deposits that lie above bedrock. Physiographic units, as defined by Chapman and Putman (1984) provide a 'broad-brush' representation of the surficial geology across Ottawa. The physiographic units follow a pattern that is similar to topography and bedrock geology with a gradient of change from west to east. The western part of the Study Area is characterized by bedrock outcroppings and shallow overburden (< 1m), defined in physiographic units as limestone plains. These change to moderate (1 to 5m) and deep overburden (> 5 m) with low permeability in the central clay and till plains, then to moderate and deep overburden with high permeability of sand plains in the east. See Maps 4A to 4F (Physiographic Units).

The composition of the physiographic units in terms of surficial geological deposits is summarized in Table 2-5. The genesis of the physiographic units and the primary materials found in the area's geologic deposits are summarized in Table 2-6. Knowing how these deposits were formed gives us important insights into their properties.

- **Limestone plains** cover 23% of the Study Area and are comprised of bedrock outcropping or bedrock with shallow overburden and areas of organic deposits.

- **Clay plains** cover the largest portion of the Study Area (34%). These are largely formed from offshore marine deposits intermixed with patches of till and alluvial deposits. The dominant materials are clay and silt, with diamicton (very poorly sorted sediment with large sedimentary grains set in a matrix of fine grains.) The deposition of clay occurred in both fresh and salt-water units. Clay deposited in salt-water units – known as leda clay – is prone to retrogressive earth flow sliding when exposed on slopes. Leda clay is a unique form of highly sensitive marine clay (a glacio-marine deposit) that has a tendency to change from a relatively stiff condition to a liquid mass when it is disturbed. A number of disastrous landslides have taken place in the Ottawa Valley because of its presence. Special designs are required for foundations and sewers built on and in leda clays.

- **Sand plains** cover 25% of the Study Area and were deposited through a number of processes with the dominant ones being deltaic and estuarine, off shore and near shore.

LEDA CLAY

Slopes comprised of leda clay are vulnerable to catastrophic landslides. More than 250 landslides, historical and ancient, large and small, have been identified within 60 km of Ottawa. Some of these landslides caused deaths, injuries, and property damage, and their impact extended far beyond the site of the original failure. In spectacular flowslides, the sediment underlying large areas of flat land adjacent to unstable slopes liquefies. The debris may flow up to several kilometres, damming rivers and causing flooding, siltation, and water-quality problems or damaging infrastructure.

Source:http://geopanorama.rncan.gc.ca/ottawa/landslides_e.php

- Other significant physiographic units are **peat and muck**, **till plains** (with and without drumlins), and **shallow till and rock ridges** with 7%, 6%, and 3% coverage respectively.

- While comprising less than 1% of the Study Area, **esker** features play a significant local role in both local groundwater supply and maintenance of base flows (see Physiography Maps 4D and 4F for the locations of eskers).

The distribution of physiographic units for watersheds and minor watersheds is shown in Table 2-7 and in Maps 4A to 4F (Physiographic Units) with the distribution of the primary genesis and material of the surficial geology presented in Maps 5A to 5F in (Surficial Geology) Appendix A.

While physiographic information tells us much about the nature of a watershed or subwatershed, there are many local variations in the landscape. The largest of these is the protrusion of the metamorphic rock of the Canadian Shield (shallow till and rock ridges) in the Carp Ridge in northwestern Ottawa and areas of peat and muck / organic material indicating the presence or pre-existence of wetlands. Additional features of note are eskers crossing central Ottawa (Mud Creek, through Stevens Creek and the Rideau River) and eastern Ottawa (Becket's Creek through Bear Brook) and the presence of a series of drumlins in lower central Ottawa. A sand plain feature, although shallow, on the southwest flank of Carp River south through the Jock River watershed feeds Poole, Feedmill, and Huntley Creeks, as well as Flowing Creek and municipal drains through to Richmond.

Permeability of surficial geology is an important factor in drainage and vegetation potential. The permeability of the Study Area's geological deposits is summarized in Table 2-8. The depth and permeability of overburden by watershed and minor watershed is shown in Table 2-9, Maps 6A to 6F (Depth of Overburden and Permeability of Surficial Geology) in Appendix A, and Table 2 in Appendix B. The amount of deep (> 5 m) high permeability overburden gives an indication of infiltration and aquifer potential. Key points of note:

- the Green Creek, Bear Brook, Castor and Lower Rideau minor watersheds have the greatest amount of deep, high permeability overburden;
- almost half (48%) of the Bear Brook watershed has deep, high permeability overburden;
- the lowest amounts of deep, high permeability overburden are found in the Lower Mississippi (3%), Lower Madawaska (5%), Ottawa West (4%), Ottawa East (6%) and Jock River (7%) minor watersheds.

Table 2-5 Composition of Physiographic Units in Terms of Geological Deposits

Physiographic Units	% of Study Area Cover	Alluvial deposits	Bedrock	Organic deposits	Glacio-fluvial deposits	Deltaic and estuarine deposits	Near shore sediments	Offshore marine deposits	Till	Other	Total
Clay Plains	34%	6%	5%	3%			3%	67%	12%	4%	100%
Sand Plains	25%	3%	4%	5%	4%	25%	24%	25%	6%	4%	100%
Limestone Plains	23%		52%	19%			8%	4%	12%	4%	100%
Peat and Muck	7%	3%	14%	67%			6%	2%	4%	3%	100%
Till Plains (drumlinized)	4%		4%	10%			5%	28%	52%	1%	100%
Shallow Till and Rock Ridges	3%		68%	7%			1%	21%	2%	1%	100%
Till Plains (undrumlinized)	2%		7%	35%		3%	3%	27%	22%	2%	100%
Eskers	0%				18%		35%	33%	12%	1%	100%

Distribution of Geologic Deposits		
	>75 percentile	(green)
	> 50 to 75 percentile	(blue)
	> 25 to 50 percentile	(yellow)
	< or = 25 percentile	(no shading)

Table 2-6 Genesis and Primary Materials in Geological Deposits

Material Genesis	Primary Materials	Geological Deposits: Offshore marine deposits	Bedrock	Organic deposits	Till	Near-shore sediments	Deltaic and estuarine deposits	Alluvial deposits	Glacio-fluvial deposits	Total
Bedrock	Palaeozoic		16%							**16%**
	Precambrian		3%							**3%**
Bedrock sub-total			19%							**19%**
Fluvial	clay, silt, sand							1%		**1%**
	sand							3%		**3%**
Fluvial sub-total								4%		**4%**
Glacial	diamicton				12%					**12%**
Glacial sub-total					12%					**12%**
Glacio-fluvial	sand, gravel								1%	**1%**
Glacio-fluvial sub-total									1%	**1%**
Glacio-marine	clay, silt	34%								**34%**
	sand					8%	7%			**15%**
	sand, gravel					3%				**3%**
Glacio-marine sub-total		34%				10%	7%			**52%**
Wetland	organic deposits			13%						**13%**
Wetland sub-total				13%						**13%**
Total		**34%**	**19%**	**13%**	**12%**	**10%**	**7%**	**4%**	**1%**	**100%**

Table 2-7 Physiographic Units by Watershed and Minor Watershed

Watershed	Minor Watershed	Physiographic Units									
		Local Features			Plains						
		Eskers	Peat and Muck	Shallow Till and Rock Ridges	Clay	Sand	Limestone	Till Plains (drumlinized)	Till Plains (undrumlinized)	Other	Total
Mississippi	Lower Mississippi		5%	2%	39%	11%	42%				100%
Mississippi Total			*5%*	*2%*	*39%*	*11%*	*42%*	*0%*	*0%*	*0%*	*100%*
Ottawa	Lower Madawaska				100%						100%
	Ottawa West		4%	25%	38%	7%	26%				100%
	Carp		3%	13%	38%	19%	27%				100%
	Ottawa Central				46%	11%	31%	7%		5%	100%
	Green Creek		10%		47%	34%	2%	7%		0%	100%
	Ottawa East				60%	26%	9%	1%	4%		100%
Ottawa Total		*0%*	*3%*	*11%*	*45%*	*18%*	*20%*	*2%*	*1%*	*1%*	*100%*
South Nation	Bear Brook	1%	4%		32%	55%	3%		6%		100%
	Castor		7%		25%	42%	10%	12%	3%		100%
South Nation Total		*0%*	*6%*	*0%*	*28%*	*48%*	*7%*	*6%*	*4%*	*0%*	*100%*
Rideau	Jock		17%		18%	9%	54%	2%			100%
	Lower Rideau	1%	9%		39%	16%	21%	9%		4%	100%
Rideau Total		*1%*	*13%*	*0%*	*29%*	*13%*	*37%*	*6%*	*0%*	*2%*	*100%*
Totals		**0%**	**7%**	**3%**	**34%**	**25%**	**23%**	**4%**	**2%**	**1%**	100%

Table 2-8 Permeability of Geological Deposits

Permeability			Geological Deposits						Total
	Alluvial deposits	Bedrock	Organic deposits	Glacio-fluvial deposits	Deltaic and estuarine deposits	Near shore sediments	Offshore marine deposits	Till	
High			13%	1%	7%	10%			32%
Medium									0%
Variable	4%	19%							22%
Low-Medium								12%	12%
Low							34%		34%
Total	**4%**	**19%**	**13%**	**1%**	**7%**	**10%**	**34%**	**12%**	**100%**

Table 2-9 Depth and Permeability of Overburden by Watershed and Subwatershed

Watershed	Minor Watershed	Depth and Permeability of Overburden											
		Low Permeability				Medium / Variable Permeability				High Permeability			
		Outcrop (<1 m)	Shallow (1 to 5 m)	Deep (> 5 m)	**Sub-total**	Outcrop (<1 m)	Shallow (1 to 5 m)	Deep (> 5 m)	**Sub-total**	Outcrop (<1 m)	Shallow (1 to 5 m)	Deep (> 5 m)	**Sub-total**
Mississippi	Lower Mississippi	6%	7%	30%	**43%**	24%	10%	5%	**40%**	10%	5%	3%	**18%**
Mississippi Total		*6%*	*7%*	*30%*	***43%***	*24%*	*10%*	*5%*	***40%***	*10%*	*5%*	*3%*	***18%***
Ottawa	Lower Madawaska	7%	3%	86%	**95%**				**0%**			5%	**5%**
	Ottawa West	6%	9%	13%	**28%**	30%	19%	8%	**58%**	7%	3%	4%	**15%**
	Carp	6%	7%	24%	**37%**	14%	15%	5%	**33%**	10%	10%	9%	**29%**
	Ottawa Central	4%	11%	23%	**38%**	14%	24%	12%	**50%**	2%	4%	6%	**12%**
	Green Creek	2%	12%	41%	**55%**	1%	3%	16%	**20%**		4%	22%	**26%**
	Ottawa East	4%	7%	42%	**54%**	5%	7%	22%	**34%**	1%	1%	10%	**12%**
Ottawa Total		*5%*	*9%*	*27%*	***41%***	*15%*	*14%*	*12%*	***41%***	*5%*	*5%*	*9%*	***19%***
South Nation	Bear Brook	1%	2%	25%	**28%**	2%	5%	14%	**21%**	1%	2%	48%	**51%**
	Castor	1%	7%	33%	**42%**	4%	11%	11%	**26%**	2%	7%	24%	**32%**
South Nation Total		*1%*	*5%*	*29%*	***36%***	*3%*	*8%*	*12%*	***24%***	*1%*	*5%*	*34%*	***41%***
Rideau	Jock	0%	2%	12%	**14%**	22%	20%	3%	**45%**	18%	16%	7%	**40%**
	Lower Rideau	1%	5%	27%	**32%**	14%	8%	14%	**35%**	7%	4%	21%	**32%**
Rideau Total		*1%*	*3%*	*20%*	***24%***	*18%*	*13%*	*9%*	***40%***	*12%*	*9%*	*15%*	***36%***
Totals		**2%**	**6%**	**26%**	**34%**	**13%**	**12%**	**11%**	**35%**	**7%**	**6%**	**18%**	**31%**

2.2.3 Soils

Soil is the surface (top) layer of surficial deposits that has been affected over time by weathering, erosion, decomposition of vegetation and other processes. It is comprised of materials from the parent geology, organic materials, fluids, and gases. The parent materials provide some of the key chemical constituents that influence soil fertility. The parent materials are residual (bedrock) or materials that have been transported by water, air, ice, or wind. Water and ice were the major transportation mechanisms for soil parent materials in areas of moderate to deep overburden.

Agriculture and Agri-Food Canada and the Ontario Ministry of Agriculture, Food and Rural Affairs have developed and maintain soils inventories for areas with agriculture potential. Soil Capability (see Table 2-10) provides an indication of the suitability of soils for agriculture. The soils capability of watersheds and minor watersheds is shown in Table 2-11 and illustrated in Maps 7A to 7F (Agricultural Capability) in Appendix A. It should be noted that the dominant classes for agriculture capability (classes 2 and 3) have restricted drainage to poorly drained characteristics consistent with clay and till soils. Key points:

- the Ottawa East (74%), Bear Brook (78%) and Castor (76%) minor watersheds have the greatest amount of Class 1 to 4 soils that are the best for agriculture; and
- the Ottawa Central minor watershed has the least (19%) amount of Class 1 to 4 soils.

Hydrologic Soil Groups provides an indication of the potential for runoff and are described in Table 2-12. Soils with high clay content tend to retain water and nutrients because of high bonding with the small particles. However, the small particles are more susceptible to erosion and compaction. Soils with high sand content tend to lose both water and nutrients due to drainage and an associated leaching of nutrients. Hydrologic soil groups by watershed and minor watershed are shown in Table 2-12 and Maps 8A to 8F (Hydrologic Soil Group) in Appendix A. A key point is that the Study Area contains only a small proportion (8%) of high permeability (Class A) hydrologic soil groups.

It should be noted that soil mapping is applicable only to undeveloped areas as during the development process, top soil is typically removed from a site. Hydrologic characteristics of developed areas may be interpreted from the surficial geology.

Table 2-10 Soil Capability for Agriculture Classes with Limiting Factors [2]

Class	Suitability for Agriculture	Major Limiting Factors
1	No significant limitations in use for crops	None
2	Moderate limitations that restrict the range of crops or require moderate conservation practices	Drainage, although it can be addressed through tile drainage
3	Moderately severe limitations that restrict the range of crops or require special conservation practices	Drainage, fertility, permeability
4	Severe limitations that restrict the range of crops or require special conservation practices	Fertility and aridity (loss of nutrients and drying out)
5	Very severe limitations that restrict capability to produce perennial forage crops	Fertility and aridity (loss of nutrients and drying out)
6	Capable only of producing perennial forage crops	Steep slopes and rockiness
7	No capacity for arable culture or permanent pasture	Steep slopes and rockiness

Table 2-11 Agriculture Soil Capability Class by Minor Watershed

Watershed	Minor Watershed	Agriculture Soil Capability Class									Total
		1	2	3	4	Sub-Total 1 to 4	5	6	7	n/d	
Mississippi	Lower Mississippi		28%	20%	6%	**54%**	1%	28%	7%	9%	100%
Mississippi Total		*0%*	*28%*	*20%*	*6%*	***54%***	*1%*	*28%*	*7%*	*9%*	*100%*
Ottawa	Lower Madawaska		48%	2%		**50%**				50%	100%
	Ottawa West		9%	25%	9%	**43%**	4%	21%	25%	7%	100%
	Carp	1%	24%	26%	7%	**58%**	1%	19%	13%	10%	100%
	Ottawa Central		3%	13%	2%	**19%**		14%	1%	66%	100%
	Green Creek		1%	34%	14%	**50%**	7%		3%	40%	100%
	Ottawa East		2%	56%	16%	**74%**	5%	4%	4%	12%	100%
Ottawa Total		*0%*	*10%*	*32%*	*10%*	***53%***	*3%*	*14%*	*12%*	*18%*	*100%*
South Nation	Bear Brook	0%	11%	32%	35%	**78%**	12%	1%	4%	5%	100%
	Castor	1%	48%	20%	8%	**76%**	3%	8%	2%	11%	100%
South Nation Total		*1%*	*31%*	*25%*	*20%*	***77%***	*7%*	*5%*	*3%*	*8%*	*100%*
Rideau	Jock	2%	14%	17%	8%	**41%**	1%	35%	1%	22%	100%
	Lower Rideau	1%	23%	26%	5%	**55%**	3%	18%	1%	24%	100%
Rideau Total		*1%*	*19%*	*22%*	*7%*	***48%***	*2%*	*26%*	*1%*	*23%*	*100%*
Totals		**1%**	**20%**	**26%**	**12%**	59%	**4%**	**16%**	**5%**	**16%**	**100%**

[2] Adapted from Agriculture and Agri-Food Canada, accessed at http://sis.agr.gc.ca/cansis/nsdb/cli/classdesc.html

Table 2-12 Hydrologic Soil Groups [3]

Group	Runoff Potential	Water transmission	% Clay	% Sand & Gravel	Saturated Hydraulic Conductivity to 50 cm	Depth to water or impermeable layer
A	Low	Freely	<10%	> 90% (i)	> 40 Um/s > 5.67 in/hr	> 50 cm
B	Moderately Low	Unimpeded	10 to 20%	50 to 90 % (ii) loamy sand / sandy loam texture	10 to 40 Um/s 1.47 to 5.67 in/hr	> 50 cm
C	Moderately High	Somewhat restricted	20 to 40%	< 50% (iii)	1 to 10 • 0.14 to 1.42 in /hr	> 50 cm
D	High	Restricted to very restricted	> 40%	< 50% clayey textures	<= 1 Um	< 50 cm

(i) Soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
(ii) Soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments
(iii) Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
Um – micrometers
(vi) Water Transmission – the ability of water to infiltrate and move through the soils

[3] United States Department of Agriculture National Engineering Handbook 2007 May http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba

Table 2-13 Hydrologic Soil Groups by Minor Watershed

Watershed	Minor Watershed	Hydrologic Soil Group					Total
		A	B	C	D	(blank)	
Mississippi	Lower Mississippi	5%	33%	20%	34%	8%	100%
Mississippi Total		*5%*	*33%*	*20%*	*34%*	*8%*	*100%*
Ottawa	Lower Madawaska			41%	9%	50%	100%
	Ottawa West	9%	48%	10%	26%	7%	100%
	Carp	7%	34%	15%	36%	8%	100%
	Ottawa Central	2%	16%	4%	12%	65%	100%
	Green Creek	10%	4%	25%	25%	36%	100%
	Ottawa East	10%	18%	3%	51%	17%	100%
Ottawa Total		*8%*	*29%*	*11%*	*33%*	*18%*	*100%*
South Nation	Bear Brook	14%	33%	28%	22%	3%	100%
	Castor	6%	32%	36%	22%	4%	100%
South Nation Total		*10%*	*32%*	*32%*	*22%*	*3%*	*100%*
Rideau	Jock	8%	42%	16%	31%	3%	100%
	Lower Rideau	5%	33%	16%	32%	14%	100%
Rideau Total		*6%*	*37%*	*16%*	*31%*	*9%*	*100%*
Totals		**8%**	**33%**	**20%**	**29%**	**10%**	**100%**

Distribution of Hydrologic Soil Groups by Watershed		
	> 75 percentile	(dark green)
	> 50 to 75 percentile	(light blue)
	> 25 to 50 percentile	(yellow)
	< or = 25 percentile	(white)

3 CLIMATE

Climate is the meteorological conditions that characteristically prevail in a particular region over a period of time. It includes solar radiation, temperature, humidity, clouds and precipitation (type, frequency, and amount), atmospheric pressure, and wind (speed and direction). Some of the major determinants of climate are latitude, proximity to large water bodies, altitude and topography. Climate is a major influence on watersheds: it is a major driver for hydrology (addressed in Chapter 4), a major factor in agriculture (addressed in Chapter 5), and a significant factor in terrestrial and aquatic ecology (addressed in Chapter 6).

Data Limitations and Assumptions

The source of the temperature and precipitation data used in this Report is Environment Canada, collected at Ottawa CDA (Experimental Farm) for the period 1890 through 2008. In 1890, this station was located in rural Ottawa, but it is now in the core urban area with its associated urban influences including the urban heat island effect. Instrumentation and data collection protocols have changed over time and have influenced results. The analyses presented use primary statistics with no assumption or testing of distributions. Further work will be completed to refine the information presented. However, the overall trends are not expected to fundamentally change. Review of the distribution of the underlying data for four approximately 30 year periods does not indicate any clear inconsistencies. The seasonal analyses are based on dates of equinox and solstice rather than monthly approximations.

3.1 Seasonality

Primarily because of its latitude, Ottawa has four distinct seasons with a large range of temperatures (see Table 3-1). This has a major effect on the hydrologic cycle (how water cycles between the atmosphere, the land, and water bodies). Fall and spring are transitional seasons, moving from the winter sub-zero average temperatures of -9^{o}C to moderate summer average temperatures of 19^{o}C. The maximum temperatures in spring and fall are in the same ranges as the maximum summer temperatures and the minimum temperatures of spring and fall are in the same range as minimum temperatures in winter. The long cold winters lead to the accumulation of water in the form of snow and ice. In the spring melt, this water is released to rivers, streams and lakes.

Table 3-1 Ottawa Seasonal Temperature Ranges (1890 to 2008)

Statistic	Spring	Summer	Fall	Winter
Maximum	36	38	33	19
Average	10	19	3	-9
Minimum	-25	-2	-37	-39

3.2 Temperature

3.2.1 Annual Trends

The average annual temperature in Ottawa (Figure 3-1) has changed over the past 110 years. Average annual daily temperature rose about 1.3°C between the mid-1940s and the mid-2010s. Average annual minimum temperature rose 0.2°C during the same period, while average annual maximum temperatures have essentially remained the same. On more detailed, seasonal basis, this warming trend is further explored in the following section.

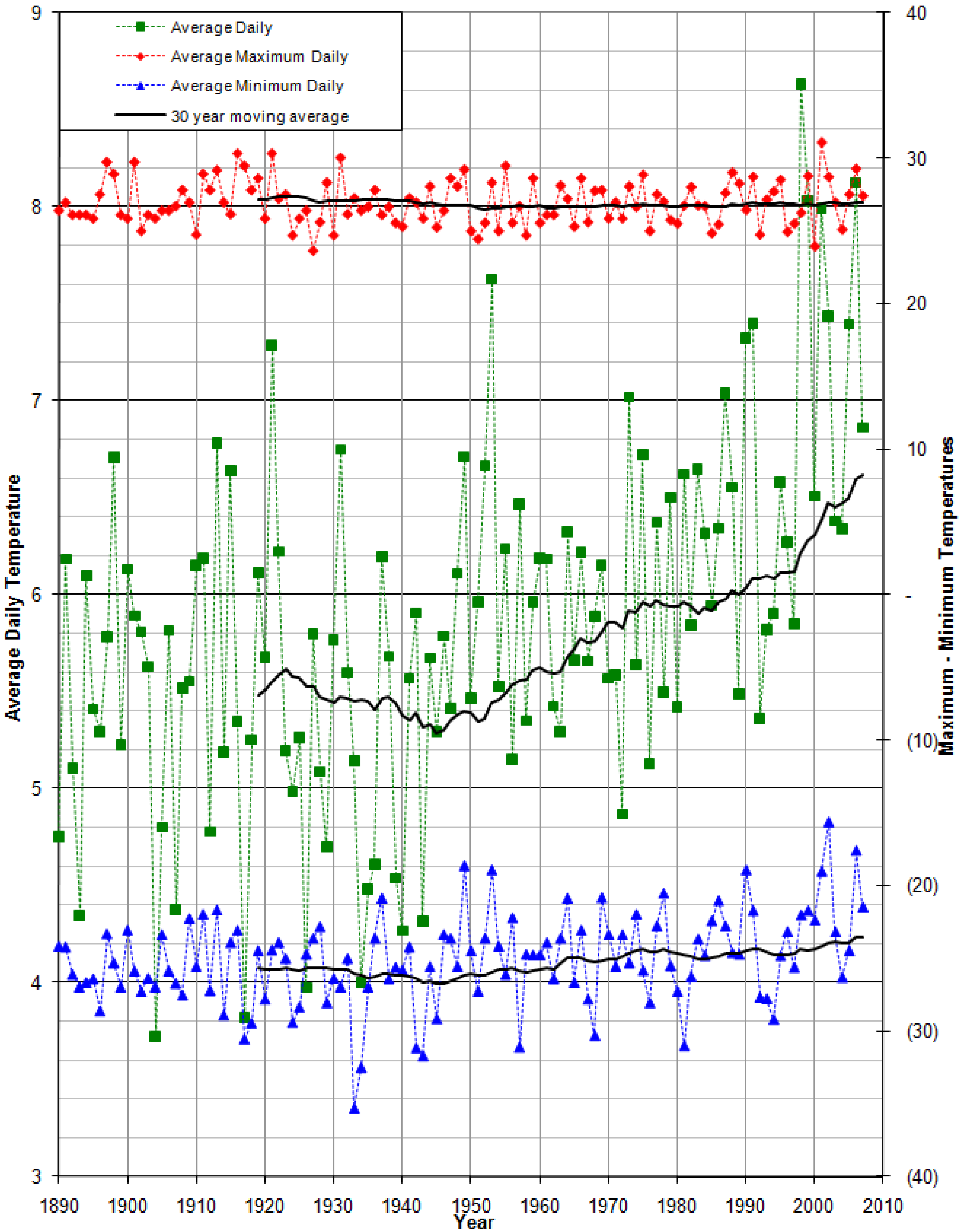
3.2.2 Seasonal Trends

Seasonal temperature trends are shown in Table 3-2, Table 3-3, and Figures 3-2 to 3-5. The analysis of the thirty-year moving average of the average seasonal daily average, minimum, and maximum temperatures shows that the *average seasonal temperature* has been rising for all four seasons since the mid-1940s. This increase in average seasonal temperatures is a result of an increase in minimum temperatures for all seasons and an increase in maximum temperature for the winter months. Of note, the smallest increase since 1919 in average seasonal temperature is about 0.6°C for summer. The increase in average seasonal temperature for spring and fall is close to 1°C. The greatest increase in average seasonal temperature is for winter at 2°C.

Table 3-2 Seasonal Temperatures for Thirty-year Periods from 1890 to 2008

Statistic	Season	Last Year of Moving Average			
		1919	1949	1979	2008
Maximum	Fall	26	26	25	24
	Spring	32	31	31	31
	Summer	35	34	33	33
	Winter	7	8	9	11
Average	Fall	3	3	3	4
	Spring	10	9	10	11
	Summer	19	19	19	20
	Winter	**-10**	**-10**	**-9**	**-8**
Minimum	Fall	**-24**	**-24**	**-22**	**-19**
	Spring	**-14**	**-13**	**-13**	**-12**
	Summer	2	1	2	4
	Winter	**-31**	**-33**	**-31**	**-28**

Figure 3-1 Annual Maximum, Average, and Minimum; Average Daily Temperatures 1890 through 2008 (Source: Experimental Farm)



As shown in Table 3-3, the *seasonal minimum temperatures* have all risen since 1919, with fall and winter temperatures up the most at 4.8°C and 3.1°C respectively. Summer and spring minimum temperatures have risen by 2.2 and 1.3° C, respectively.

Since 1919, the *seasonal maximum temperatures* have dropped for all seasons except the winter. Winter maximums are up by 3.3 °C while spring maximums are down by 0.5°C, summer maximums down by 2.0°C, and fall maximums down by 1.9°C.

Table 3-3 Difference in Seasonal Temperatures Relative to Thirty Years Ending in 1919

Statistic	Season	Last Year of Moving Average			
		1919	1949	1979	2008
Maximum	Fall	0	0.2	**-1.0**	**-1.9**
	Spring	0	**-0.3**	**-0.8**	**-0.5**
	Summer	0	**-1.1**	**-1.9**	**-2.0**
	Winter	0	0.3	1.6	3.3
Average	Fall	0	0.2	1.0	1.1
	Spring	0	**-0.4**	0.0	0.9
	Summer	0	**-0.1**	0.0	0.6
	Winter	0	0.0	0.9	2.0
Minimum	Fall	0	0.2	2.3	4.8
	Spring	0	0.5	1.1	1.3
	Summer	0	**-0.9**	**-0.1**	2.2
	Winter	0	**-1.6**	0.4	3.1

3.2.3 Heating and Cooling Needs

The amount of heating and cooling required was estimated by summing the number of degree-days below or above a given temperature (see Figure 3-6). The trend to warmer winters translates into a theoretical decrease in the need for heating (i.e., a drop in the number of heating days). With warmer average temperatures in spring, summer and fall, one would expect the need for cooling to increase. However, for maintaining a temperature of 23°C, the long-term trend in the need for cooling is flat over the past 120 years, albeit with significant variability. The trend reflects in part the decrease in the number of very hot days. However, if the target for cooling is lower, such as 18°C, there has been increase in the number of cooling days.

Figure 3-2 Change in Average Seasonal Daily Temperature – Thirty-year Moving Average 1890 through 2008 Relative to 1919 Reference Year (Source: Experimental Farm)

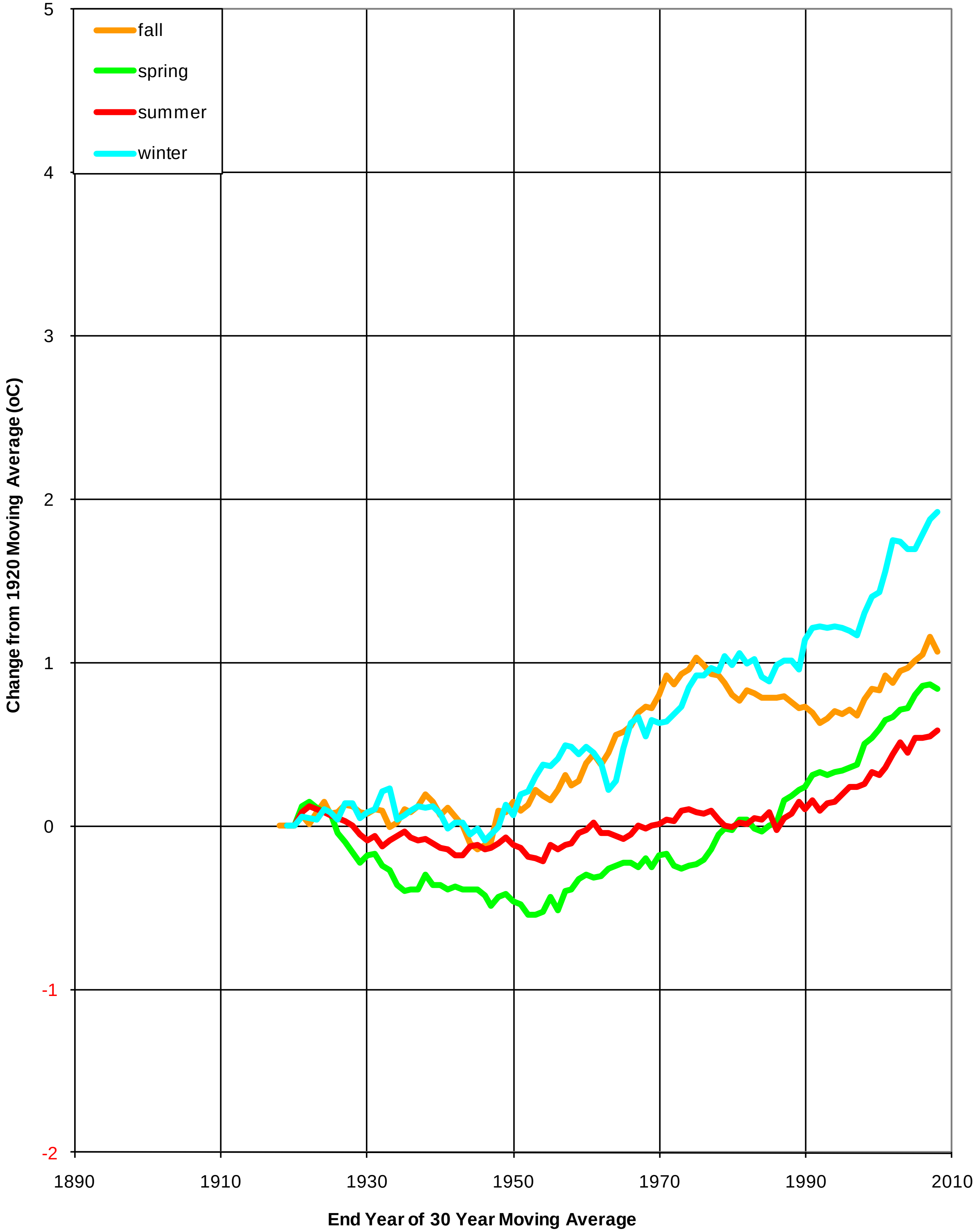


Figure 3-3 Change in Average Seasonal Minimum Temperature – Thirty-year Moving Average 1890 through 2008 Relative to 1919 Reference Year (Source: Experimental Farm)

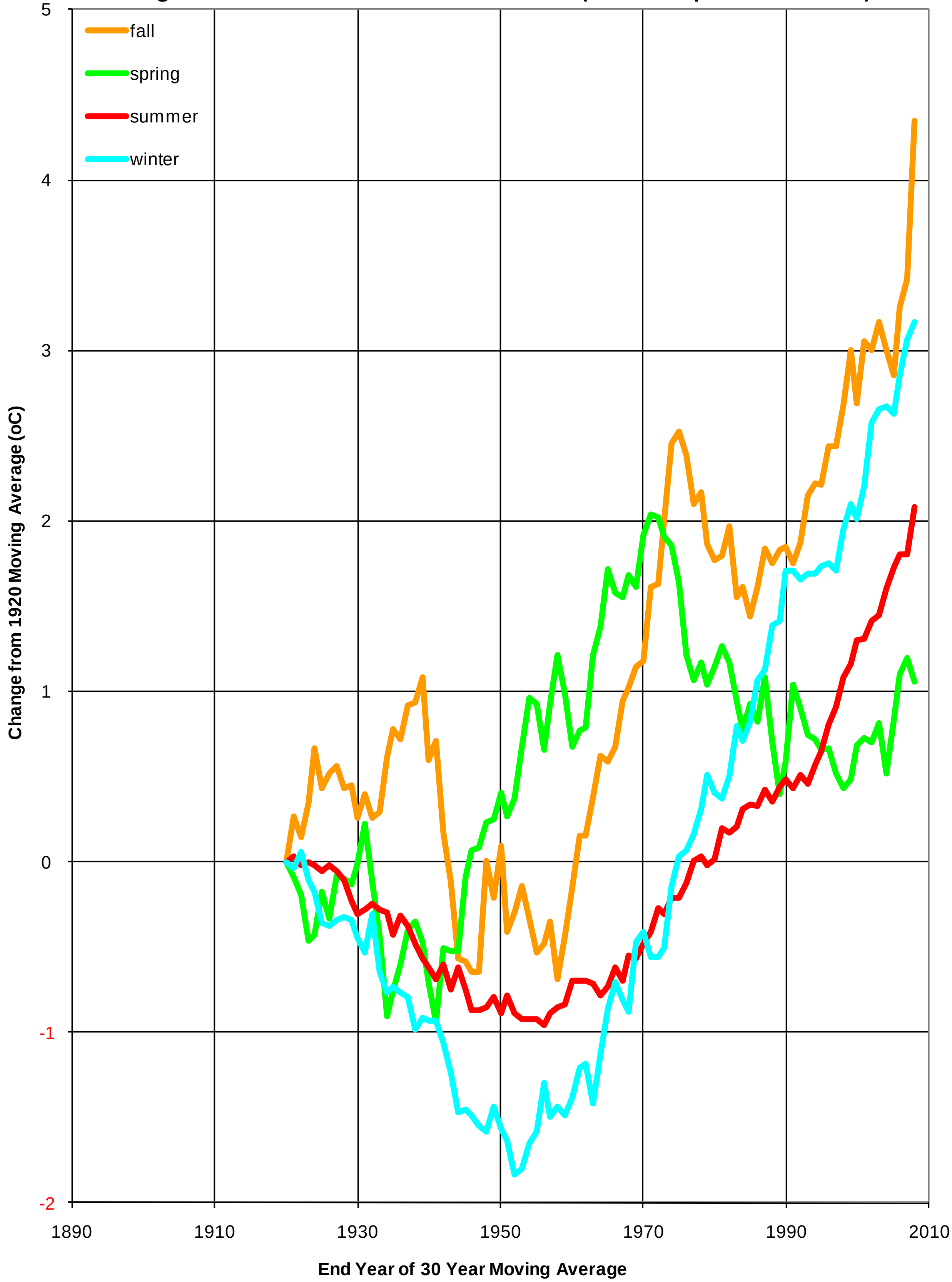


Figure 3-4 Change in Average Seasonal Maximum Temperature – Thirty-year Moving Average 1890 through 2008 Relative to 1919 Reference Year (Source: Experimental Farm)

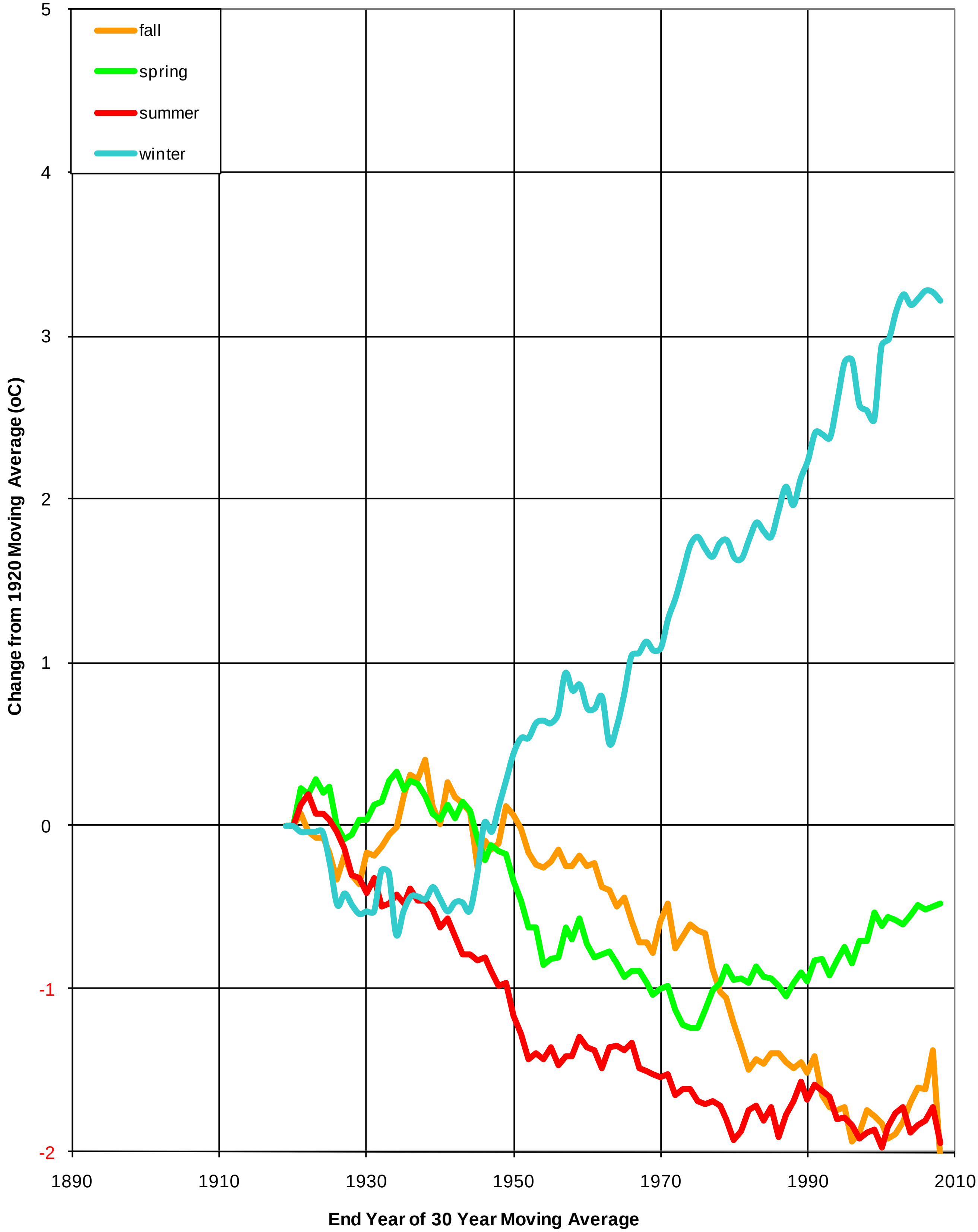


Figure 3-5 Monthly Temperature Statistics 1890 through 2008 – Average for Thirty-Year Periods

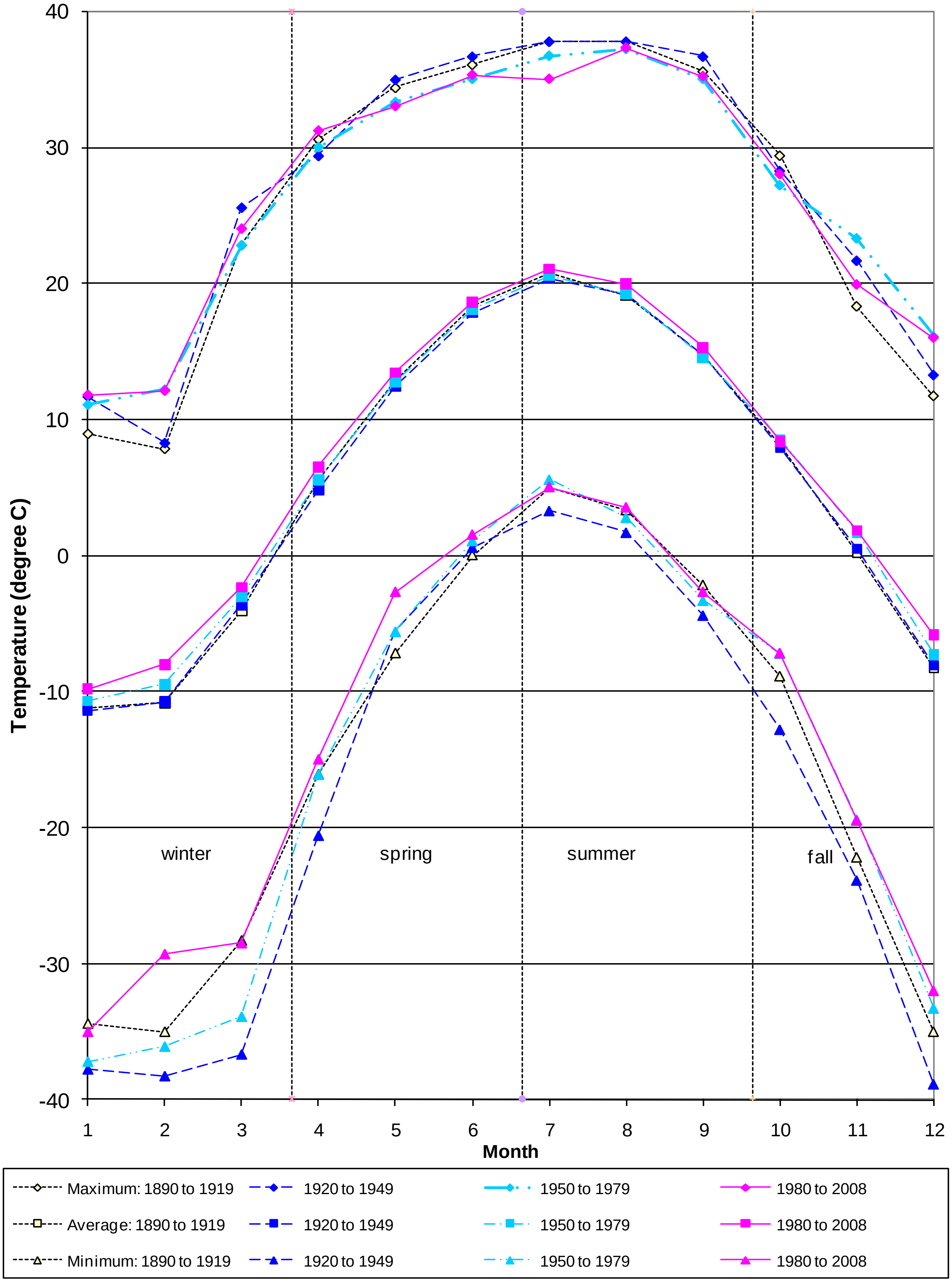
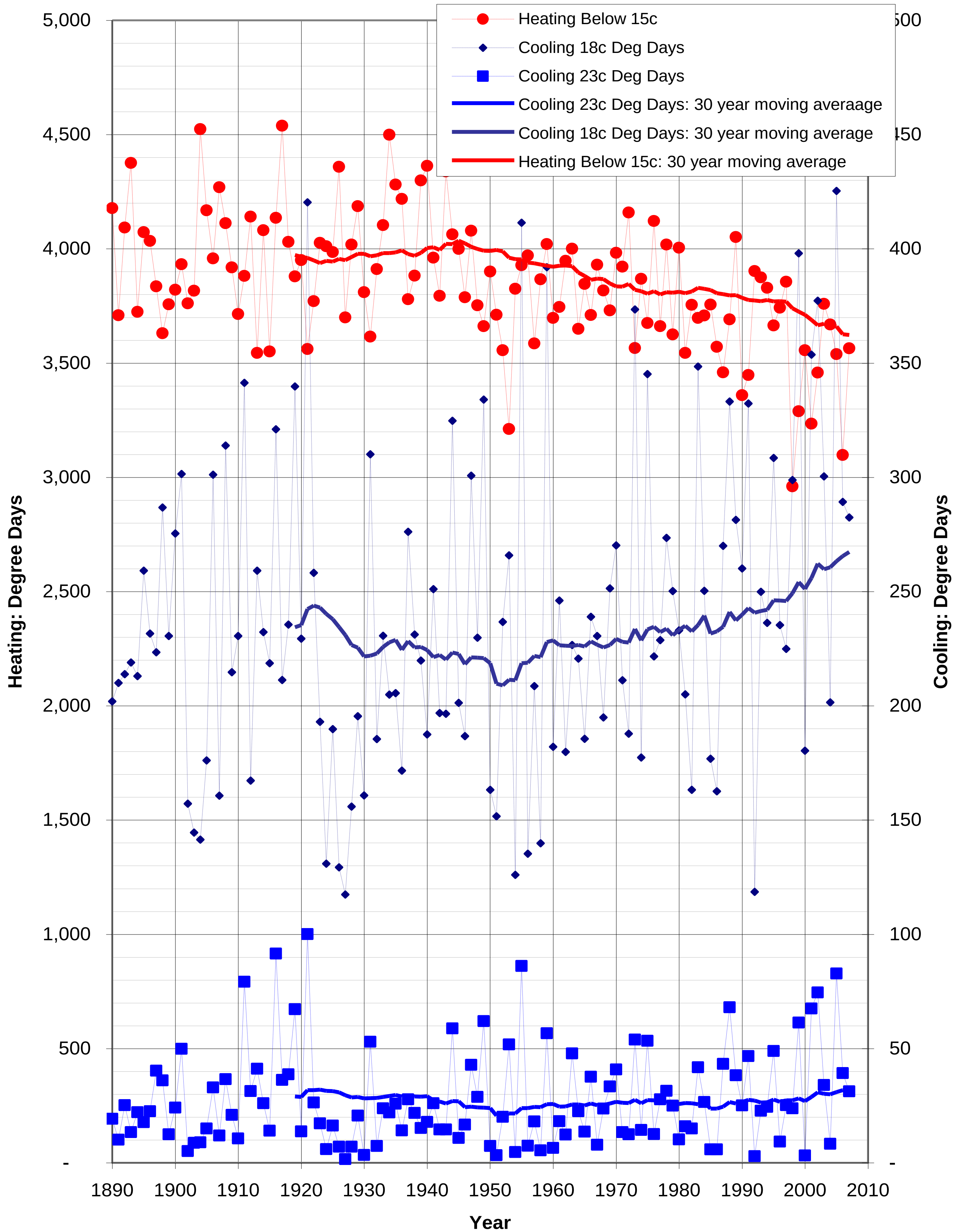


Figure 3-6 Number of Heating and Cooling Days, 1890 to 2008



3.3 Precipitation

The following section looks at a number of key aspects of precipitation. The data is limited to daily accumulations and was collected at the Experimental Farm in Ottawa for the period 1890 through 2008. The information does not address the critical spatial component of rainfall (how much volume falls where in the watershed), or the relationship between storm volume, duration, and intensity and the resultant effects on hydrologic response.

3.3.1 Annual and Seasonal Accumulation

There is an increasing trend in total annual precipitation since the 1920s, but a decrease in the annual amount of snowfall (see Figure 3-7 and Figure 3-8). This increase in rainfall is due to a change in seasonal precipitation not just the change of snow to rain because of warmer winters (see Figure 3-9).

There have been significant changes in seasonal precipitation from the 1920s and 30s, a period when all seasons received similar amounts of rainfall, to the present. Summer rainfall has oscillated around 255 mm/year since the 1960s, after dropping to a low in the 1930s. Winter precipitation has dropped from 220 mm/year in the 1920s and 1930s down to the current 170 mm/year with the most significant decreases in the months of January and February (Figure 3-10), although there have also been increases in rainfall at the expense of snowfall (Figure 3-11, Figure 3-12) during the winter months. The precipitation in fall and spring has been trending up since the 1960s and 1970s to reach the current levels of 245 mm/year. This reflects significant increases in precipitation during September through November and increased rainfall from September through December. The increase in spring rainfall has typically taken place in April and May.

What this means is over the long term we have been experiencing dryer winters with less snowfall, wetter springs and wetter falls. The amount of precipitation in summer has not changed appreciably since the mid-1960s.

3.3.2 Frequency of Multi-day Rainfall Accumulations

For this Report, the analysis of precipitation trends was limited as only daily accumulations were available for the 119-year data set. (Analyses that are more detailed are possible, but only for the past 30 to 40 years for which accumulation has been typically collected for every 0.2 mm of rainfall. This data allows the interpretation of discrete rainfall events and maximum periods of rainfall intensity.) The limitation in the long-term data prevents the discrimination of rainfall events that begin one day and continue into the next day from discrete rainfall events such as afternoon thunderstorms on subsequent days. Due to this limitation, all rainfall that occurred on consecutive days was summed. Ranking the full set of multi-day rainfall events provided an estimate of the frequency of occurrence and a simple estimate of return period (Figure 3-12,

Table 3-4). Examination of the distribution of the events by accumulation shows an evenly distributed data set with no clear 'outliers'. The one-year maximum event total accumulation ranges from 54 to 64 mm while the maximum event of 140 mm for the full period, occurring over 10 days in June 1928, is not that much greater than the 137 mm that resulted from the remnants of Hurricane Francis in over 3 days in 2004. However, there is a significant difference in the average rainfall per day for the two events.

The annual maximum rainfall per day for the multi-day rainfall accumulation and for the annual maximum 1-day rainfall for the available data set are presented in Figure 3-13 and Figure 3-14, respectively, along with the thirty-year moving average for the annual and seasonal maximums. The thirty-year moving averages show the long-term variability with recent increases approaching but not exceeding previous one-day maxima. The seasonal analysis indicates the maximum rainfall/day occurs in the summer.

Table 3-4 Summary Statistics: Multi-Day Accumulation over Consecutive Days with Precipitation

Percentile	For Full Length of Record					**30 Year Subsets**			
				Total Multi-day Accumulation (mm)					
	# of Events	Return Period		**1890 to 2008**	**Duration (days)**	**1890 to 1919**	**1920 to 1949**	**1950 to 1979**	**1980 to 2008**
50	3,295	1.9	Weeks	7.6	1 to 5	6.6	7.6	8.1	8.0
60	2,636	2.3	Weeks	10.4	1 to 5	9.4	10.2	10.7	11.4
75	1,647	3.7	Weeks	17.0	1 to 9	16.1	17.0	16.5	18.5
90	659	9.3	Weeks	29.9	1 to 6	28.7	29.0	28.5	33.0
95	329	0.4	Years	40.6	1 to 8	39.3	39.9	38.9	45.3
98.2	119	1.0	Years	57.0	1 to 8	54.2	58.6	55.8	64.1
99.1	59	2.0	Years	69.5	1 to 12	59.6	69.6	63.9	78.2
99.6	24	5.0	Years	82.6	3 to 9	73.3	84.4	74.7	90.3
99.8	12	10	Years	95.2	2 to 11	74.8	98.7	82.6	101.9
99.93	5	25	Years	109.1	9 and 12	93.6	124.8	88.5	124.1
99.97	2	51	Years	128.4	4 and 7	97.9	133.9	91.9	131.2
100	1	119	Years	140.3	10	101.5	140.3	95.7	137.2
# of Events				6,589		1,643	1,659	1,664	1,623

Trends in more frequent events (50, 75, and 95 percentile annually) are presented in Figure 3-15. The thirty-year moving average indicates an increasing trend in multi-day rainfall accumulation, with the increase being more significant for the larger, less frequent, events. However, this increase is not readily apparent for the largest rare events (those greater than 80 mm or less than a five-year return period). The typical rainfall event, taken as the median or 50-percentile event, is 7.6 mm over the full length of record and occurs on average every two weeks. Looking at the four (4) thirty-year periods over the length of record, this median event varies from 6.6 to 8.1 mm for the period 1950 through 1979.

3.3.3 Extended Wet and Dry Periods

While most precipitation events only last for a day, the *frequency of one-day* events has dropped from 53% of events prior to 1919 to 42% of events in the past 30 years (see Figure 3-16). The Ottawa area is experiencing more frequent multi-day precipitation events. The *frequency of precipitation events lasting three or more days* has increased from 18% to 31%. The *time between precipitation events* shows some changes with a small increase in the occurrence of a single day between precipitation events and a decrease in occurrence of three days between precipitation events (Figure 3-17). Over the last 119 years, there has been a 25% to 30% increase in the *number of days with some precipitation*. Early in the 20^{th} century, the City would have experienced precipitation on about 130 days of the year (i.e., every third day in round numbers). The City now it gets precipitation on about 160 days of the year (or every second day in round numbers).

The bottom line is the City is experiencing more days with precipitation and more multi-day precipitation events.

Figure 3-7 Multi-day Rainfall Accumulation over Consecutive Days with Precipitation 1890 through 2008

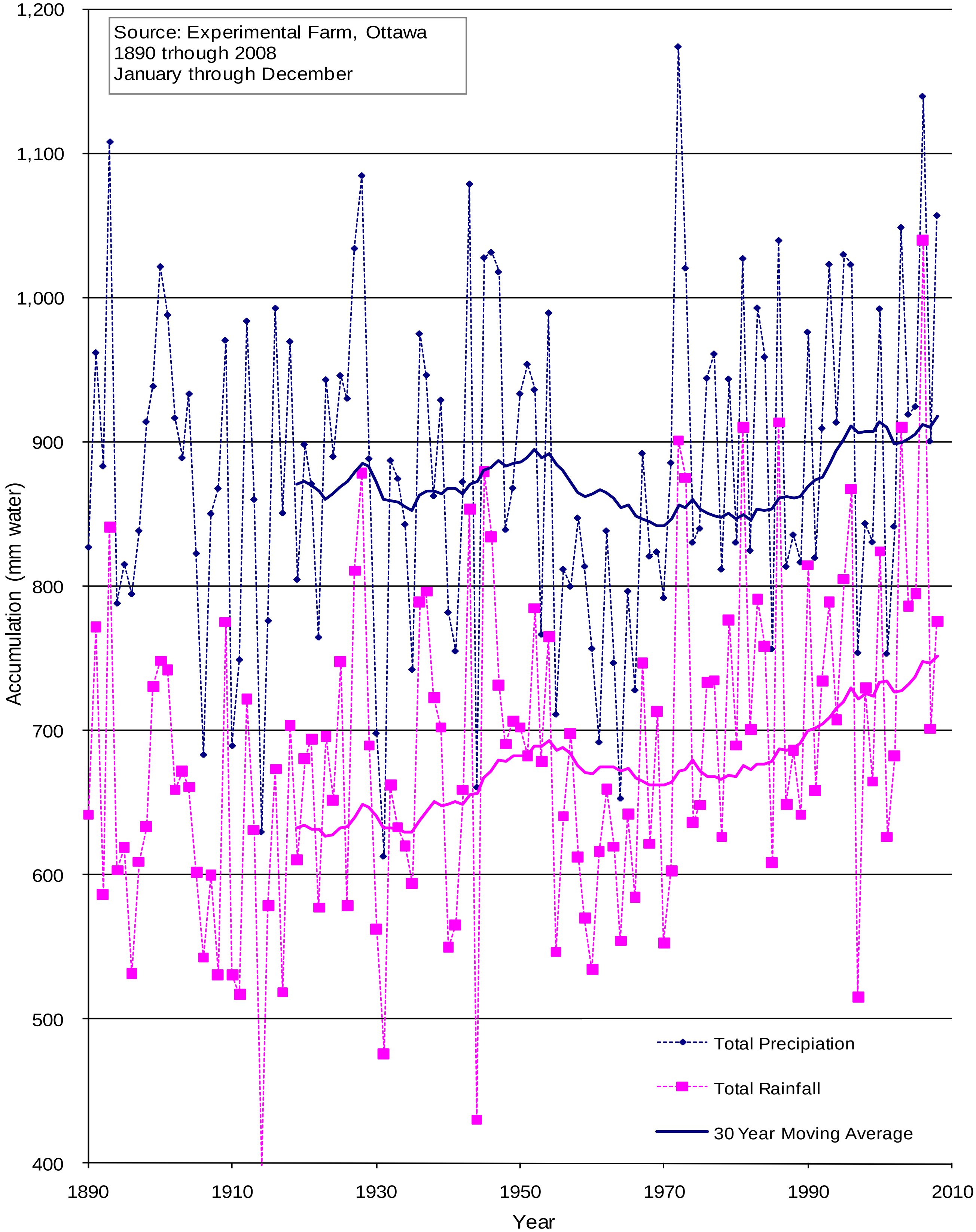


Figure 3-8 Thirty-Year Moving Average of Annual Precipitation 1890 through 2008

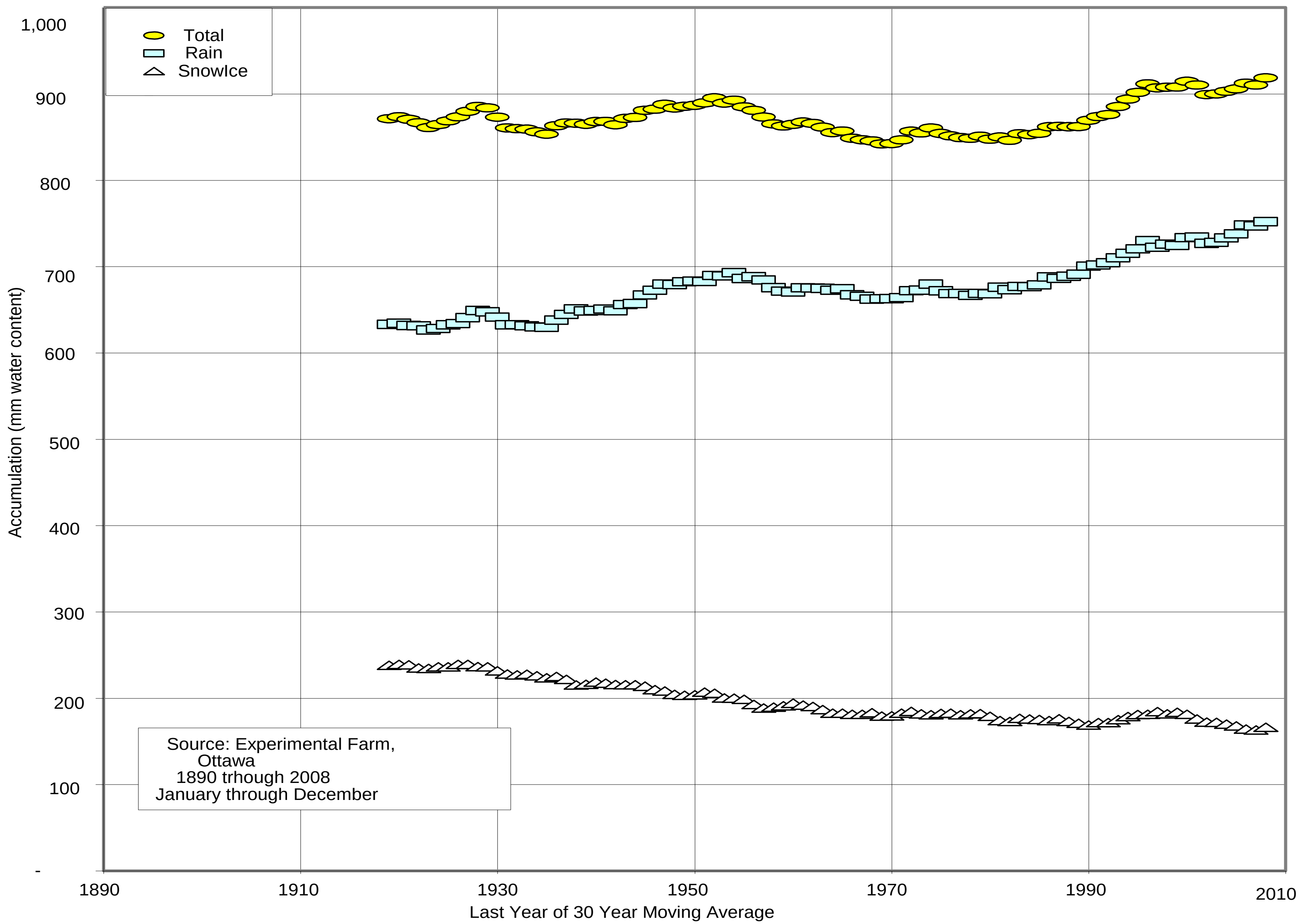


Figure 3-9 Thirty-Year Moving Average Seasonal Precipitation 1890 through 2008

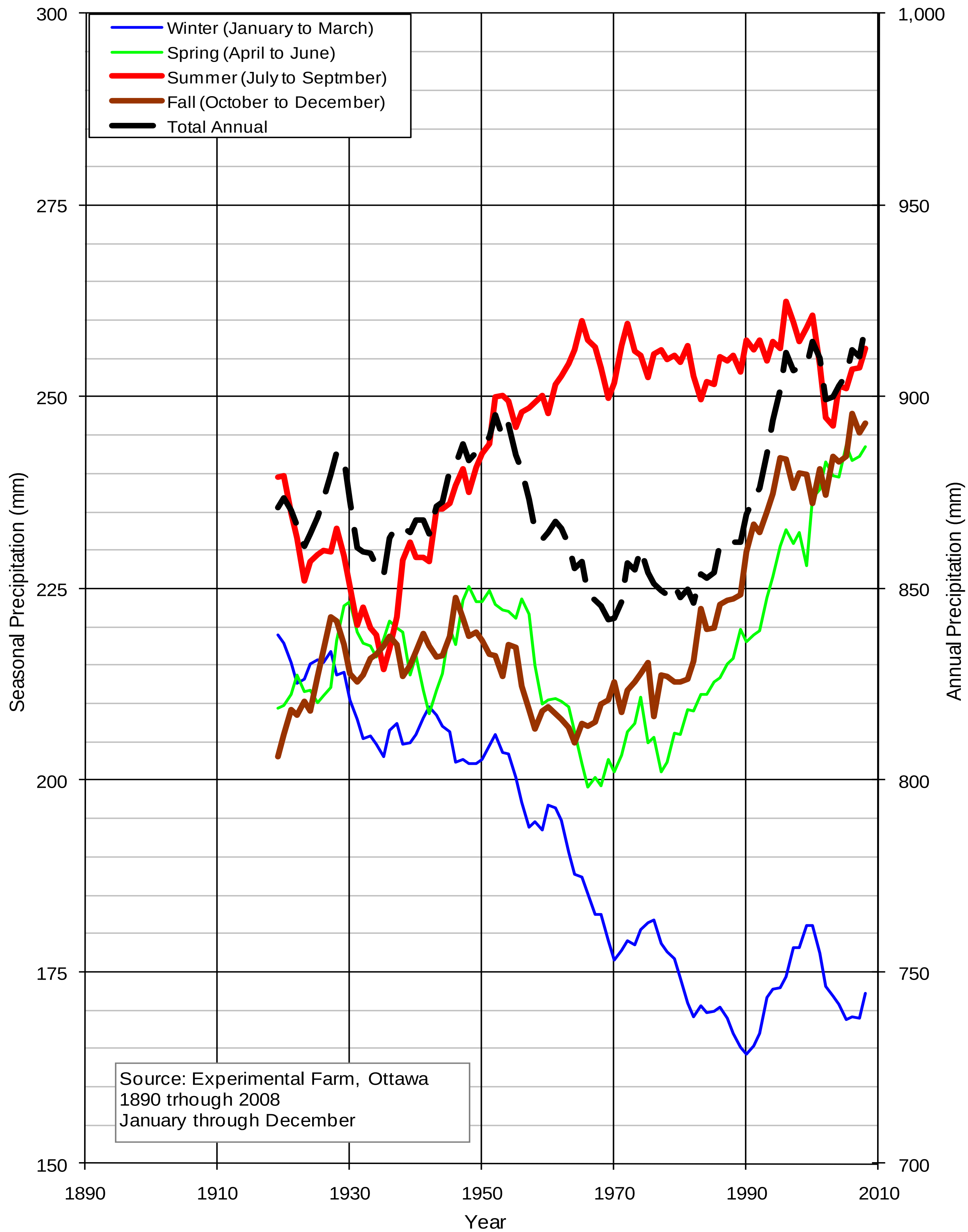


Figure 3-10 Average Monthly Total Precipitation by Period 1890 through 2008

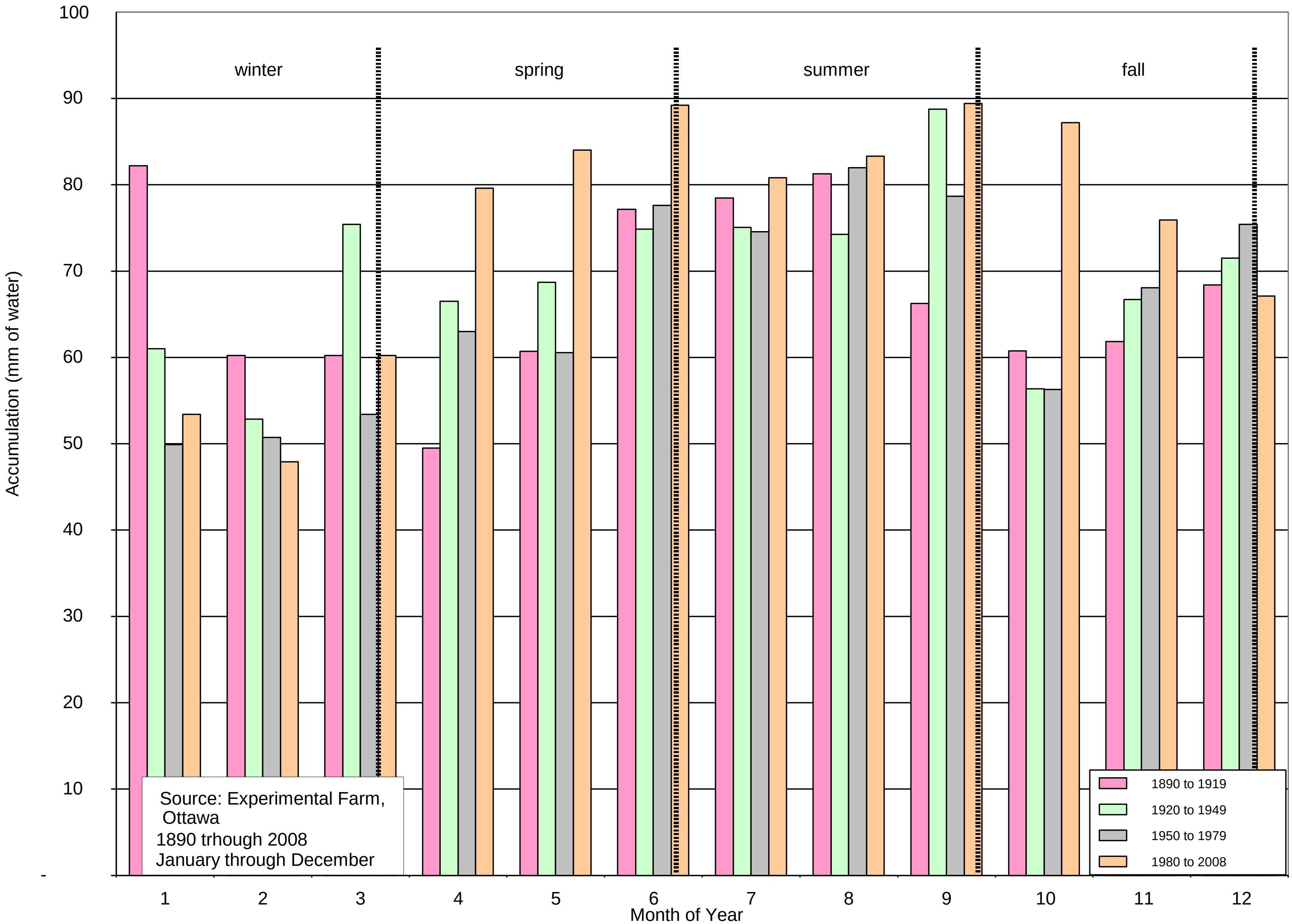


Figure 3-11 Average Monthly Rainfall by Period 1890 through 2008

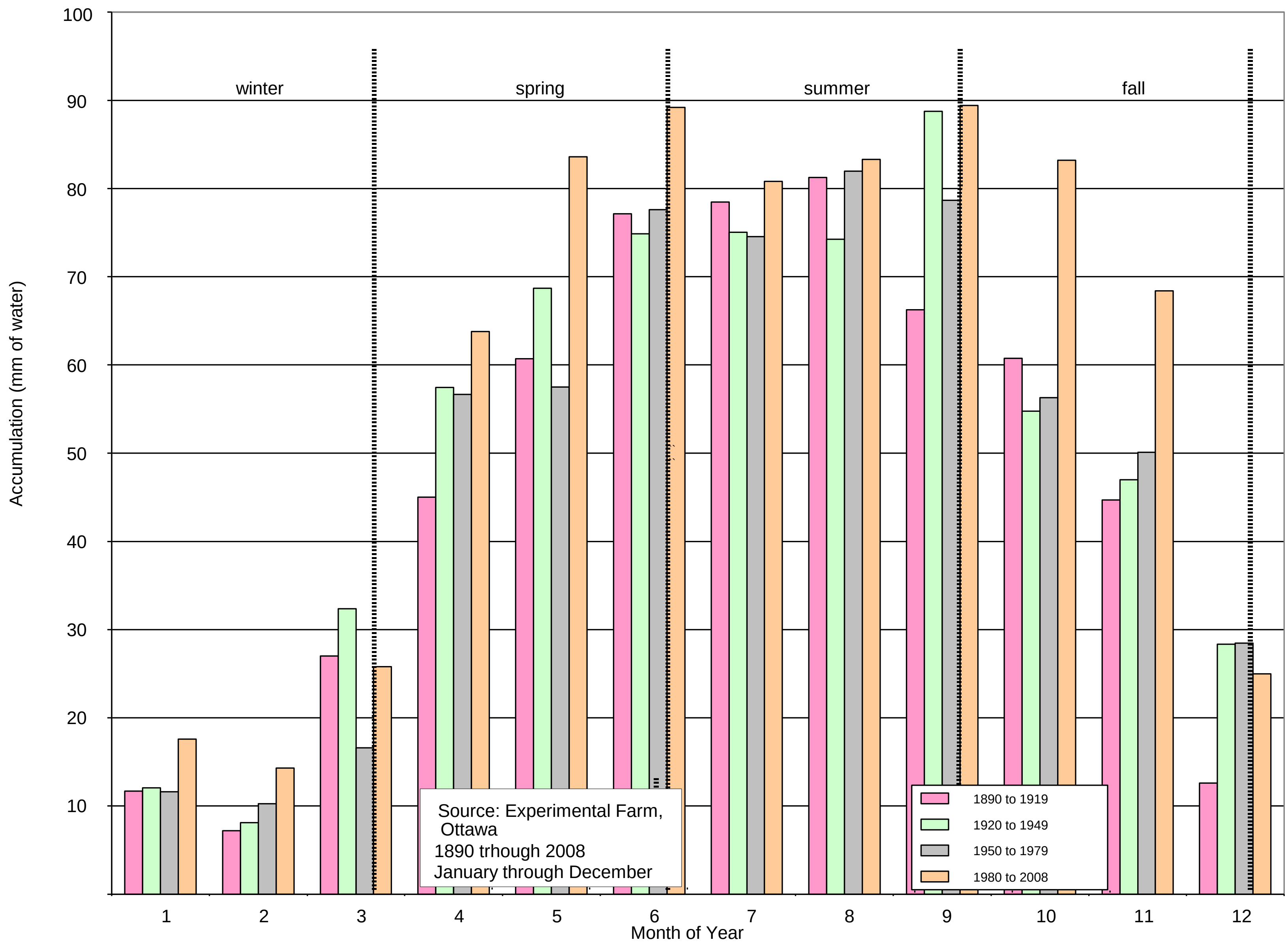
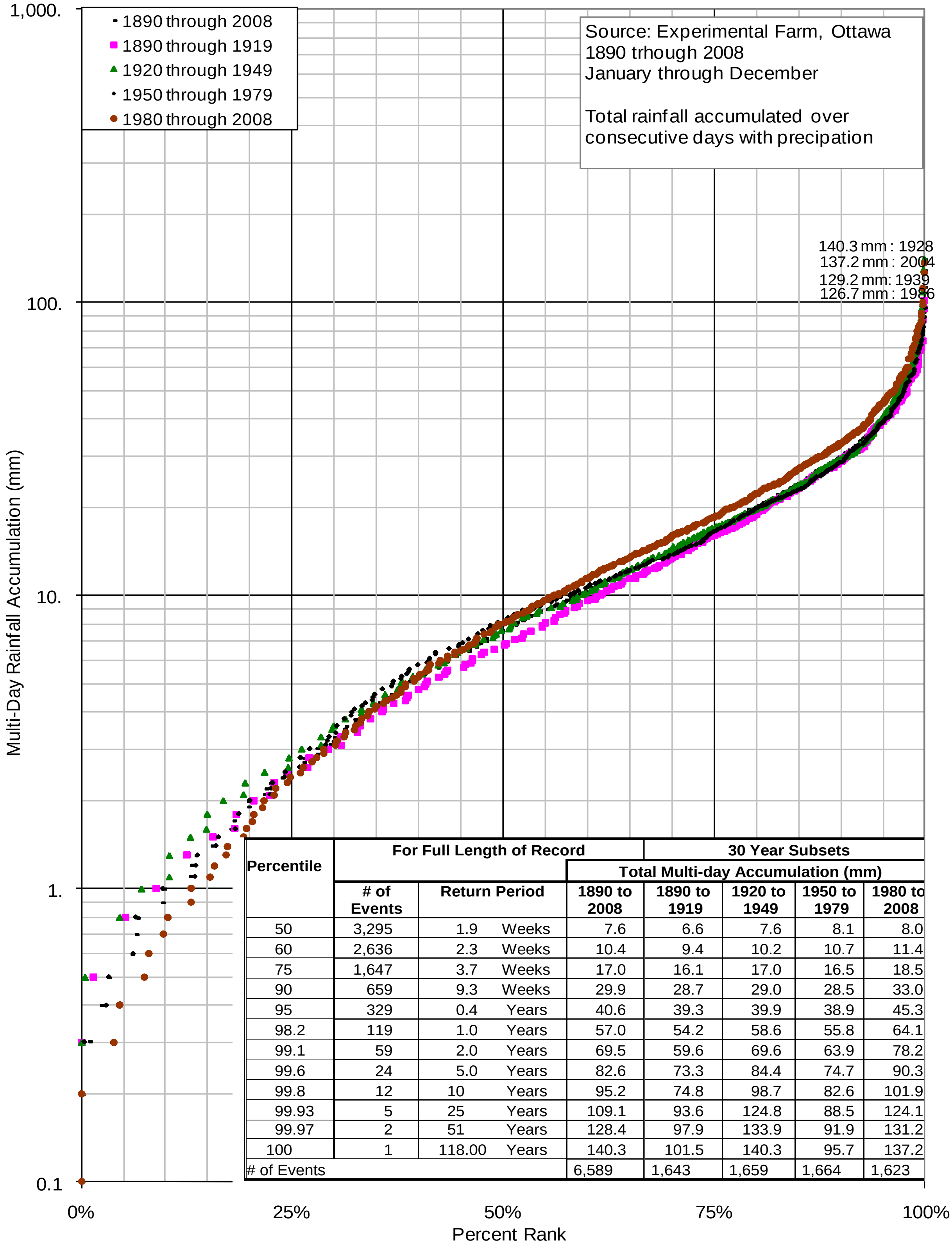


Figure 3-12 Frequency Distribution of Multi-day Precipitation Accumulation 1890 through 2008



Percentile	For Full Length of Record			30 Year Subsets				
				Total Multi-day Accumulation (mm)				
	# of Events	Return Period		1890 to 2008	1890 to 1919	1920 to 1949	1950 to 1979	1980 to 2008
50	3,295	1.9	Weeks	7.6	6.6	7.6	8.1	8.0
60	2,636	2.3	Weeks	10.4	9.4	10.2	10.7	11.4
75	1,647	3.7	Weeks	17.0	16.1	17.0	16.5	18.5
90	659	9.3	Weeks	29.9	28.7	29.0	28.5	33.0
95	329	0.4	Years	40.6	39.3	39.9	38.9	45.3
98.2	119	1.0	Years	57.0	54.2	58.6	55.8	64.1
99.1	59	2.0	Years	69.5	59.6	69.6	63.9	78.2
99.6	24	5.0	Years	82.6	73.3	84.4	74.7	90.3
99.8	12	10	Years	95.2	74.8	98.7	82.6	101.9
99.93	5	25	Years	109.1	93.6	124.8	88.5	124.1
99.97	2	51	Years	128.4	97.9	133.9	91.9	131.2
100	1	118.00	Years	140.3	101.5	140.3	95.7	137.2
# of Events				6,589	1,643	1,659	1,664	1,623

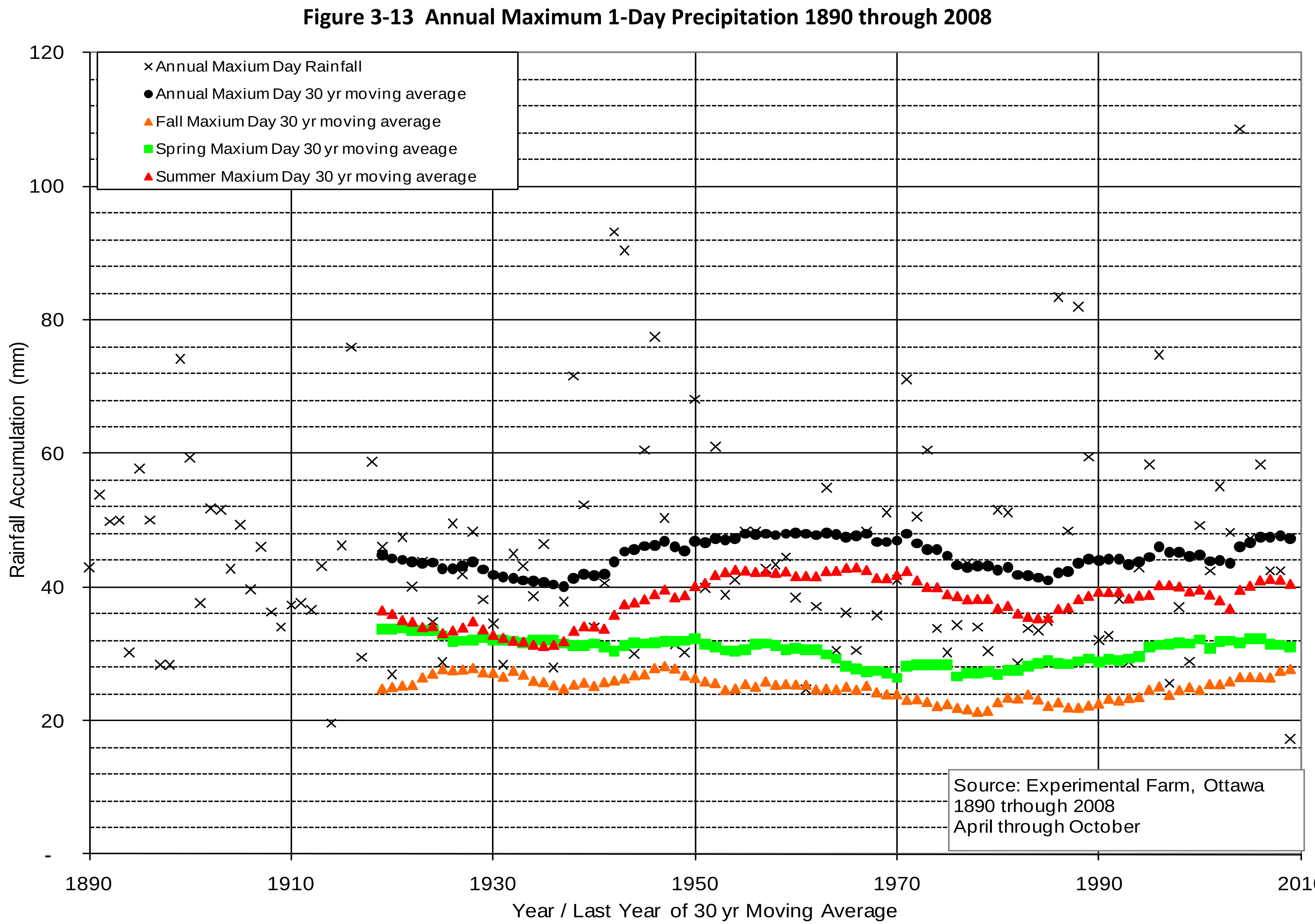


Figure 3-13 Annual Maximum 1-Day Precipitation 1890 through 2008
Annual Maxium Day Rainfall
Annual Maxium Day 30 yr moving average
Fall Maxium Day 30 yr moving average
Spring Maxium Day 30 yr moving aveage
Summer Maxium Day 30 yr moving average
Rainfall Accumulation (mm)
120
100
80
60
40
20
-
1890
1910
1930
1950
1970
1990
2010
Year / Last Year of 30 yr Moving Average
Source: Experimental Farm, Ottawa
1890 trhough 2008
April through October

Figure 3-14 Annual Maximum Average / Day Multi-day Precipitation Accumulation

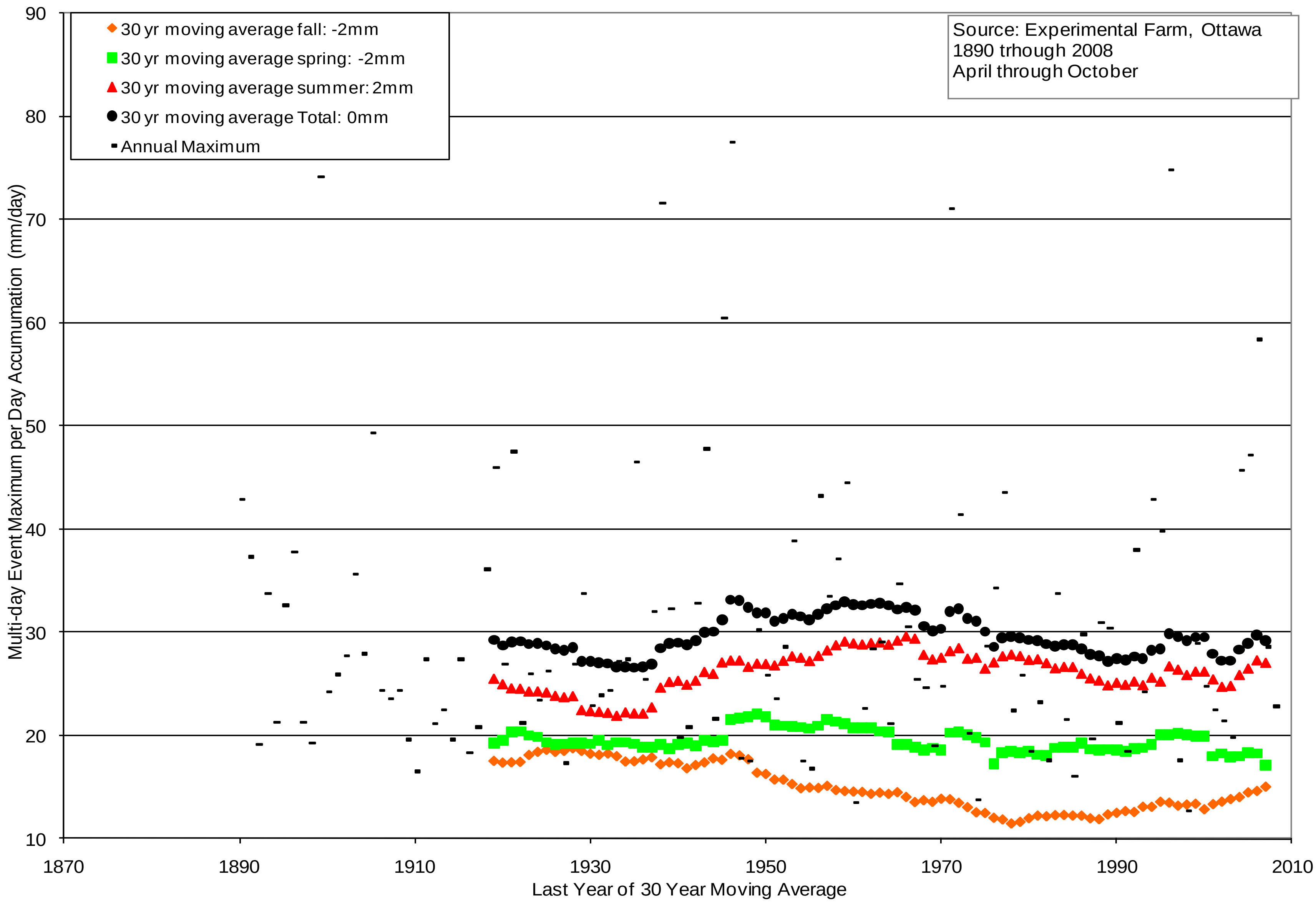
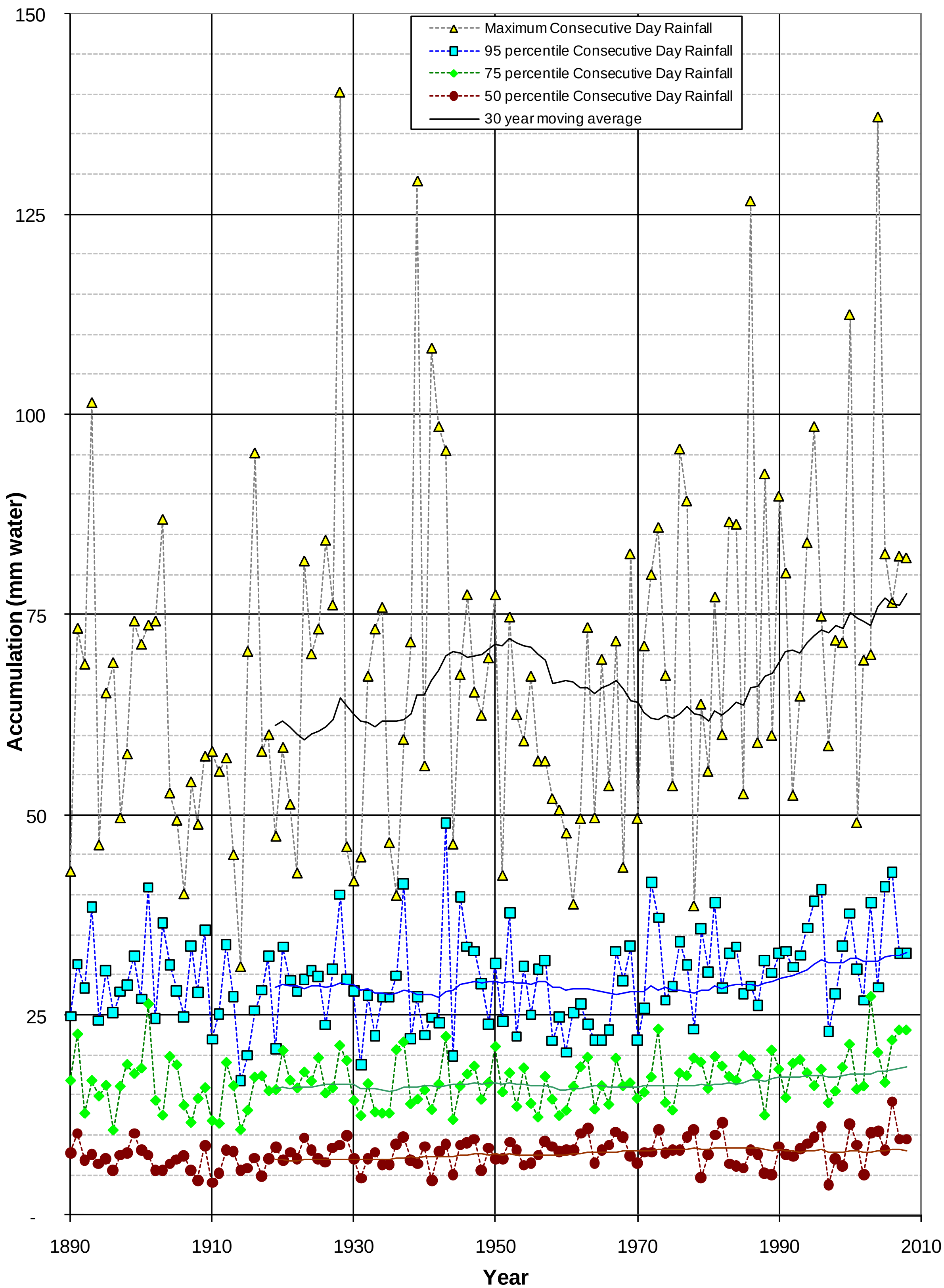


Figure 3-15 Annual and Thirty-Year Moving Average of Frequent Events 1890 through 2008



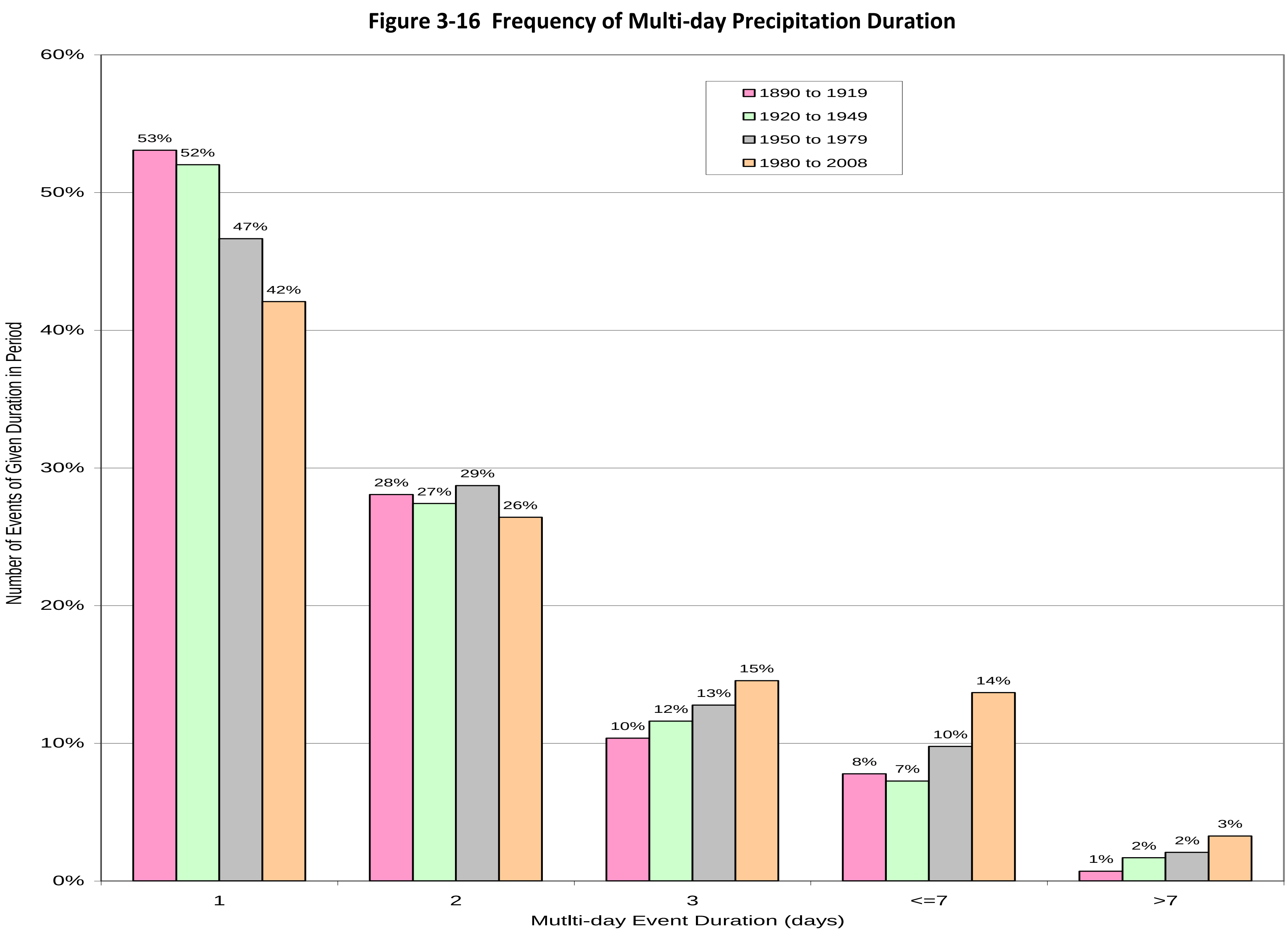


Figure 3-16 Frequency of Multi-day Precipitation Duration
1890 to 1919
1920 to 1949
1950 to 1979
1980 to 2008
Number of Events of Given Duration in Period
Mutlti-day Event Duration (days)
60%
50%
40%
30%
20%
10%
0%
1
2
3
<=7
>7
53%
52%
47%
42%
28%
27%
29%
26%
10%
12%
13%
15%
8%
7%
10%
14%
1%
2%
2%
3%

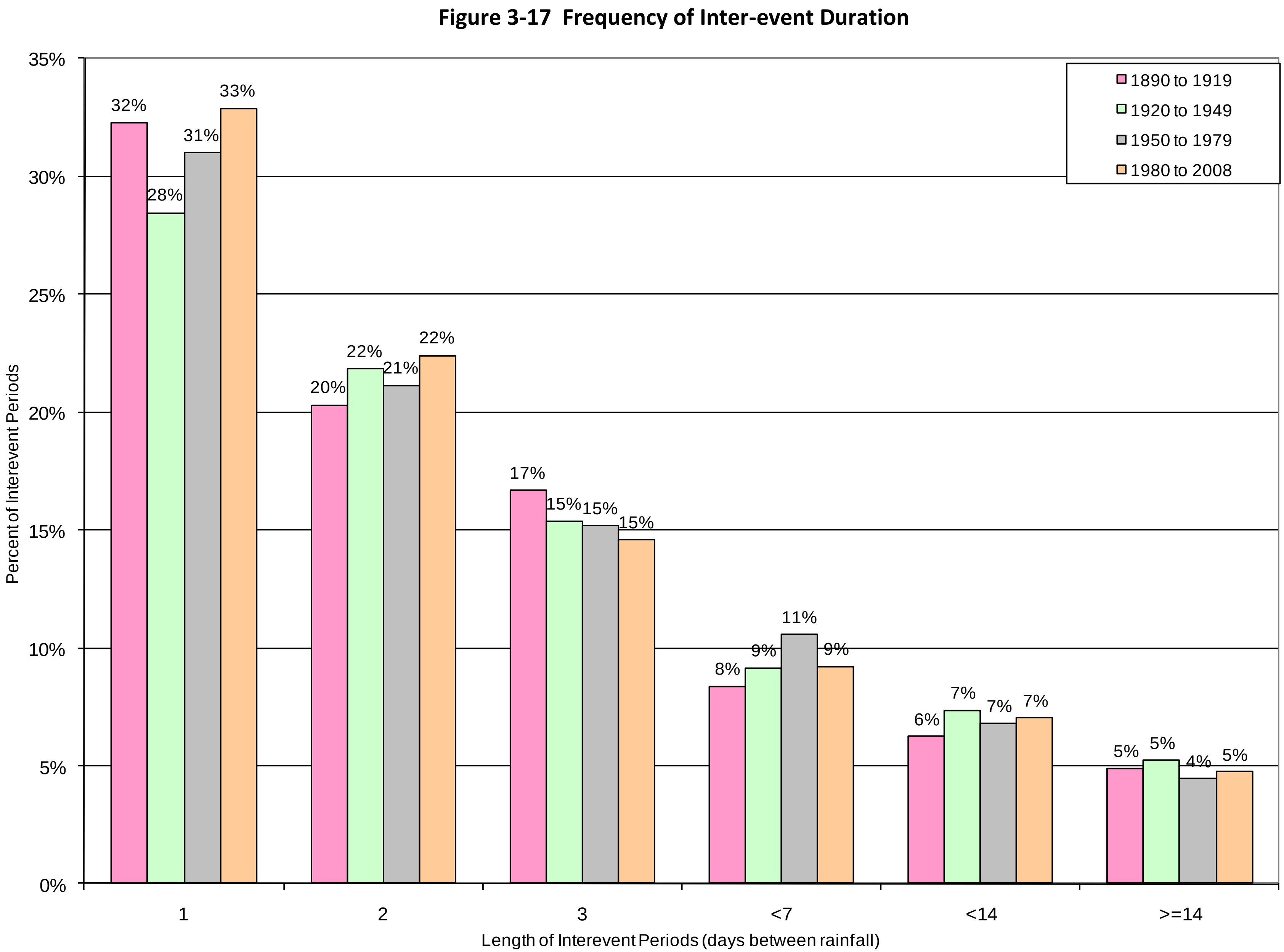
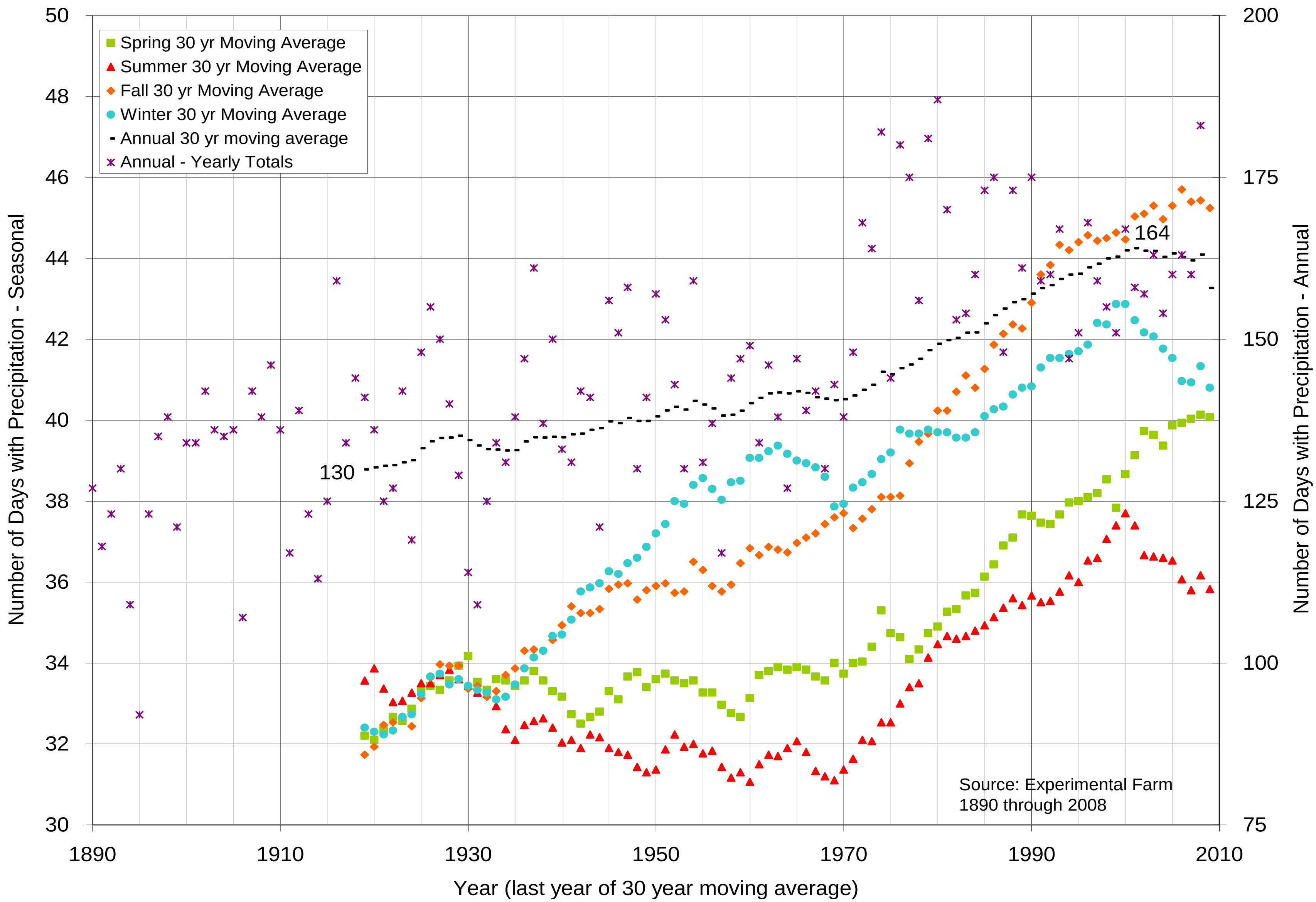


Figure 3-17 Frequency of Inter-event Duration
35%
30%
25%
20%
15%
10%
5%
0%
Percent of Interevent Periods
32%
28%
31%
33%
20%
22%
21%
22%
17%
15%
15%
15%
8%
9%
11%
9%
6%
7%
7%
7%
5%
5%
4%
5%
1890 to 1919
1920 to 1949
1950 to 1979
1980 to 2008
1
2
3
<7
<14
>=14
Length of Interevent Periods (days between rainfall)

Figure 3-18 Number of Days with Precipitation: Seasonal and Annual



3.4 Long-term Trends

It is clear that the climate in the Study Area has changed in the past 120 years.

With respect to *precipitation*, the Study Area is experiencing more days with precipitation rather than more precipitation on individual days. The available data suggest that there is an increasing trend in three important measures: multi-day accumulation of precipitation, the total number of days of precipitation (especially in spring and fall) and the duration of precipitation events. However, the two estimates of maximum daily precipitation (Figure 3-13**,** Figure 3-14**)** do not show increases over the long term. While the Study Area is experiencing more precipitation, there is not a clear indication that the intensity of precipitation events is increasing. This is partly due to the lack of long-term data required to assess whether or not actual changes in precipitation intensity at hourly intervals are occurring.

With respect to *temperatures*, while the average summer temperatures are increasing, the increases are due to higher daily minimum temperatures (i.e., cooler evenings) while the daily maximum temperatures are decreasing. The small increase in average temperature and the decrease in maximum temperature does not suggest a significant increase in the potential for afternoon thunderstorms that are typically associated with intense rainfall. However, there may be more overnight thunderstorms associated with frontal activity due to the higher minimum temperatures. This interpretation needs further study in context of synoptic weather patterns. The study of weather patterns is beyond the scope of this report.

The information shows significant variability over the length of record, even when the data is filtered using a thirty-year moving average. Therefore rainfall statistics cannot be assumed to be stationary in time but have significant uncertainty. Caution is advised in any assessment that uses a subset of data, such as a single thirty-year data set, to identify trends since the trend may relate to a local maximum or minimum that is not representative of the long-term trend. Caution is also advised in extrapolating from historical data to predict future climate trends.

4 HYDROLOGY

Hydrology is the study of the water cycle – how water circulates between the atmosphere, land and water bodies. Hydrologists study the distribution of water on the earth, its circulation through the hydrologic cycle, the physical and chemical properties of water, and the interaction between the hydrosphere and other earth systems. This Report focuses on six major aspects of hydrology: climate (covered in section 3), stream flows, groundwater, water balance, water quality, and water temperature.

4.1 Stream Flows

Stream flows are dependent on a number of natural factors, including precipitation, topography, geology and soils. They are also altered by human activities such as the construction of dams, withdrawals of ground and surface water, deforestation, changes in land use, increases in watershed imperviousness (i.e., the amount of impermeable surfaces in a watershed), and enhanced drainage; as a result of urbanization and agriculture.

4.1.1 Major Rivers and Streams

As noted at the beginning of this Report, the City of Ottawa has an extensive network of rivers and streams, with some 4,500 km of watercourses in total. These watercourses vary dramatically in size, drainage area and nature. The network of watercourses includes portions of four major rivers (the Rideau, South Nation, Mississippi and Ottawa Rivers), four major tributaries (the Carp, Jock and Castor Rivers and the Bear Brook Creek), and hundreds of smaller creeks and streams.

Table 4-1 Characteristics of the Study Area's Major Rivers and Streams

Watercourse	Length (km)	Total Drainage Area (km^2)	Drainage Area within the City (km^2)	% of Watershed within the City
Ottawa River	1,271	146,300	1,010	2%
Carp River	42	305	305	100%
Lower Madawaska	230	8,470	5	<1%
Mississippi River	169	4,059	178	4%
Rideau River	146	3,935	991	25%
Jock River	63	573	380	66%
South Nation River	175	4,184	647	15%
Castor River	60	591	371	63%
Bear Brook	74	484	277	57%

The location of these major watercourses is shown in Figure 1-1. Flows for some of these major watercourses are presented in the following sections, along with information on water quality.

4.1.2 Watershed Stream Flows

During the winter, with sub-zero average temperatures, precipitation accumulates as snow and ice. As the temperature rise in spring, this accumulation of stored water is released during the spring melt (or freshet) resulting in what is typically the highest flows for rivers and streams for the Ottawa area. As illustrated in Table 4-2, Figure 4-1 and Figure 4-2, peak flows in the spring are typically over 10 times (and in some years 100 times greater than) the flows in late summer when the lowest flows typically occur. Flows increase through the fall, and subsequently drop through the winter. Flows at the scale of a muted spring freshet can occur during unusually wet periods or due to major thunderstorms in localized developed areas.

Table 4-2 Minor Watersheds: Seasonal Flows

Watershed	Flows (m^3/s)					Seasonal Flows / Annual Average			
	Winter	Spring	Summer	Fall	Annual	Winter	Spring	Summer	Fall
Ottawa	1,180	1,970	605	1,030	1,180	100%	166%	53%	87%
Bear Brook	1.7	16.1	0.5	7.0	5.8	29%	275%	8%	120%
Carp	0.7	11.7	0.2	1.8	2.8	24%	410%	7%	62%
Castor	1.9	19.4	0.4	3.6	5.2	37%	377%	8%	70%
Jock	2.2	24.5	0.3	4.6	6.1	36%	399%	5%	75%
Rideau	26.6	133.0	8.4	30.2	41.9	63%	317%	20%	72%

Key points relating to stream flows are:

- the difference in the range of spring flows is relatively small among the minor watersheds;
- the differences in the range of late summer (August/September) flows is very large, with flows in the Jock River being especially low;
- as shown in Figure 4-2, in the wettest years, spring flows are high and relatively similar across the minor watersheds because of saturated conditions; during relatively dry years, flows are considerably less (by as much as two orders of magnitude) and there is greater differences that reflect the different characteristics of the watersheds; and
- seasonal flows in the Ottawa River are dampened by the size of the watershed and on-line storage; these factors are big enough that the timing of the Ottawa's freshet is different than the other watersheds in the Study Area.

Figure 4-1 presents the median value of the normalized monthly average flow in mm/unit area for the period of record for watersheds in the Study Area. Key points include:

- the normalized runoff is similar for each of the watersheds during the spring runoff (April) with larger differences being noted in August;
- the Ottawa River has the lowest spring flow/unit area and the highest August flow/unit area, due to both the size and northern extent of the watershed, the associated delayed spring melt, and the significant effect of storage reservoirs on the system; the result is a significant attenuation of peak and low flows;
- flows in the Rideau River show trends that are similar to the other unregulated watersheds;
- the lowest summer flows are found in the Jock and Carp Rivers with Bear Brook and the Castor River maintaining higher average flows (about double the flow volume) compared to the Jock and Carp Rivers.

Figure 4-2 and Figure 4-3 present the normalized monthly flow for April and August for the length of record for each watershed. Key points include:

- the range of spring flows, from the lowest to the highest flows on record, is relatively similar for all rivers;
- for the month of August, the highest flows on record are relatively similar reflecting significant runoff during wet years;
- the trends evident in the median years are amplified in dry years – in the driest year on record, the Jock River flows drop to 0.1 mm/unit area, almost an order of magnitude (10 times) lower than Bear Brook and the Castor River;
- the Ottawa and Rideau Rivers have much more muted responses to the dry year conditions, likely primarily due to flow augmentation from storage reservoirs on the systems; and
- the buffering of the Bear Brook and Castor River low summer flows is also likely due storage, in this case, due to the greater presence of groundwater aquifers.

Figure 4-1 Median Average Monthly Flow by Watershed by Unit Area

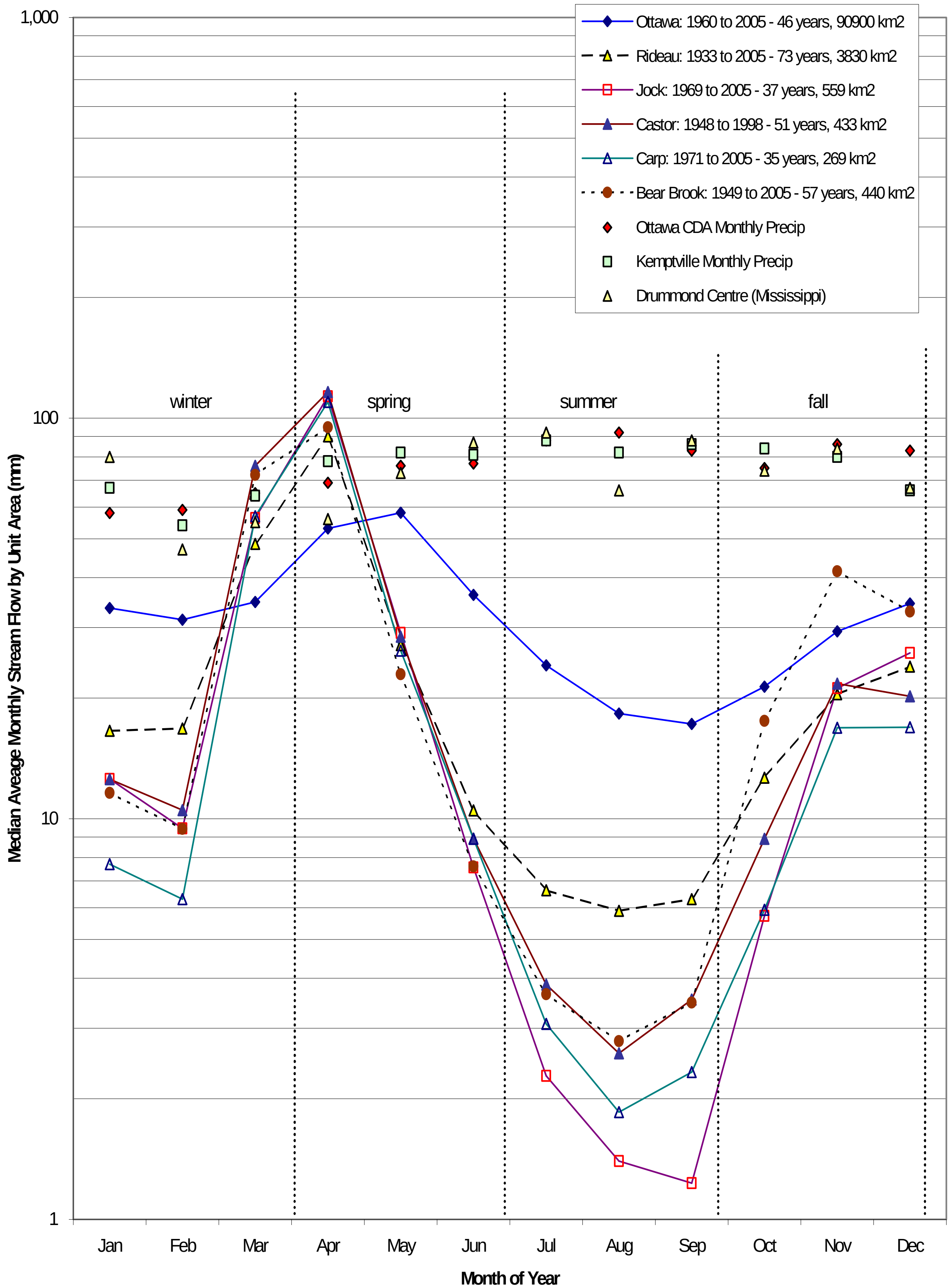


Figure 4-2 Percent Rank Distribution of April (Spring) Flows for Length of Record Minor Watersheds in Ottawa

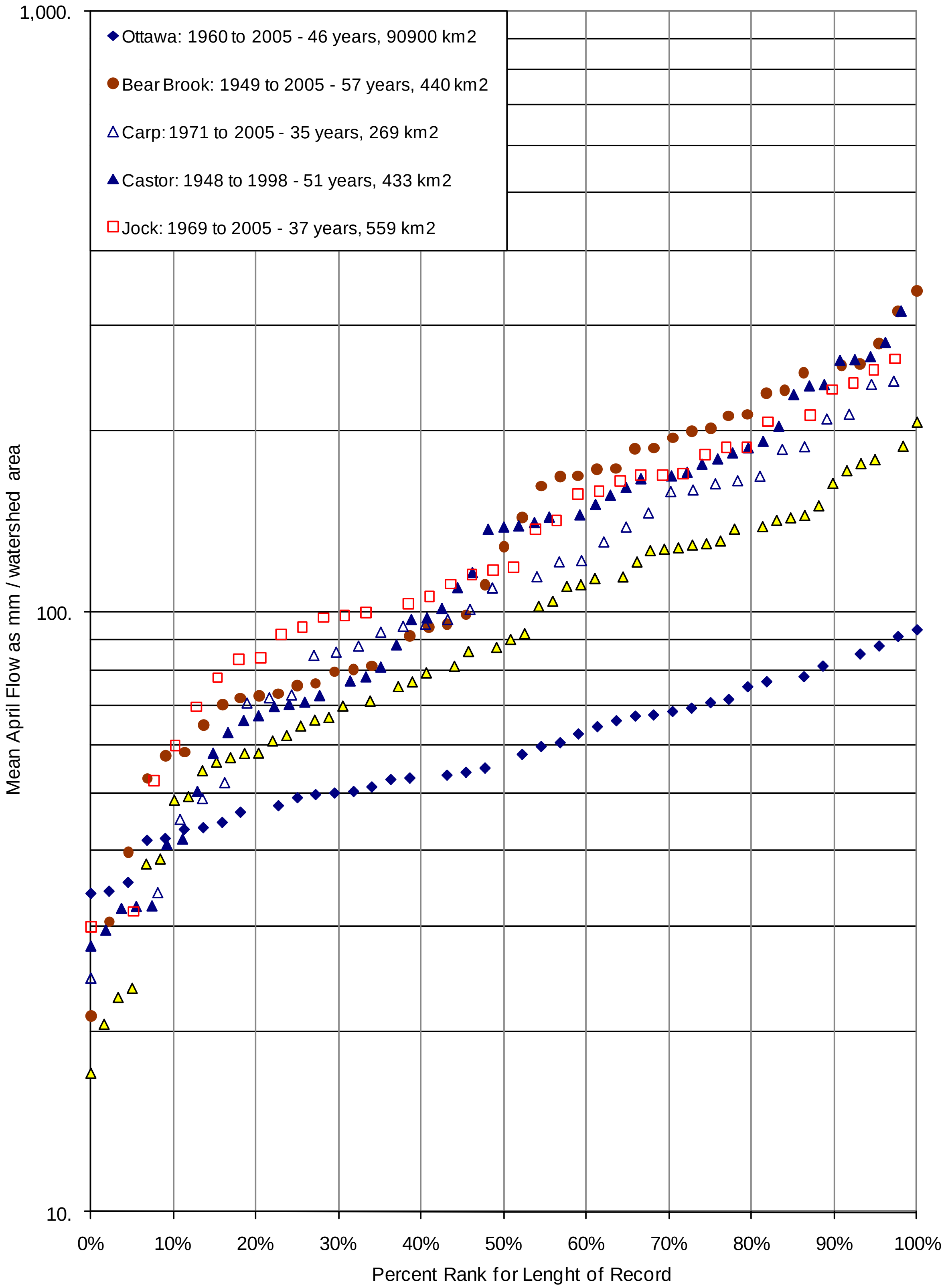
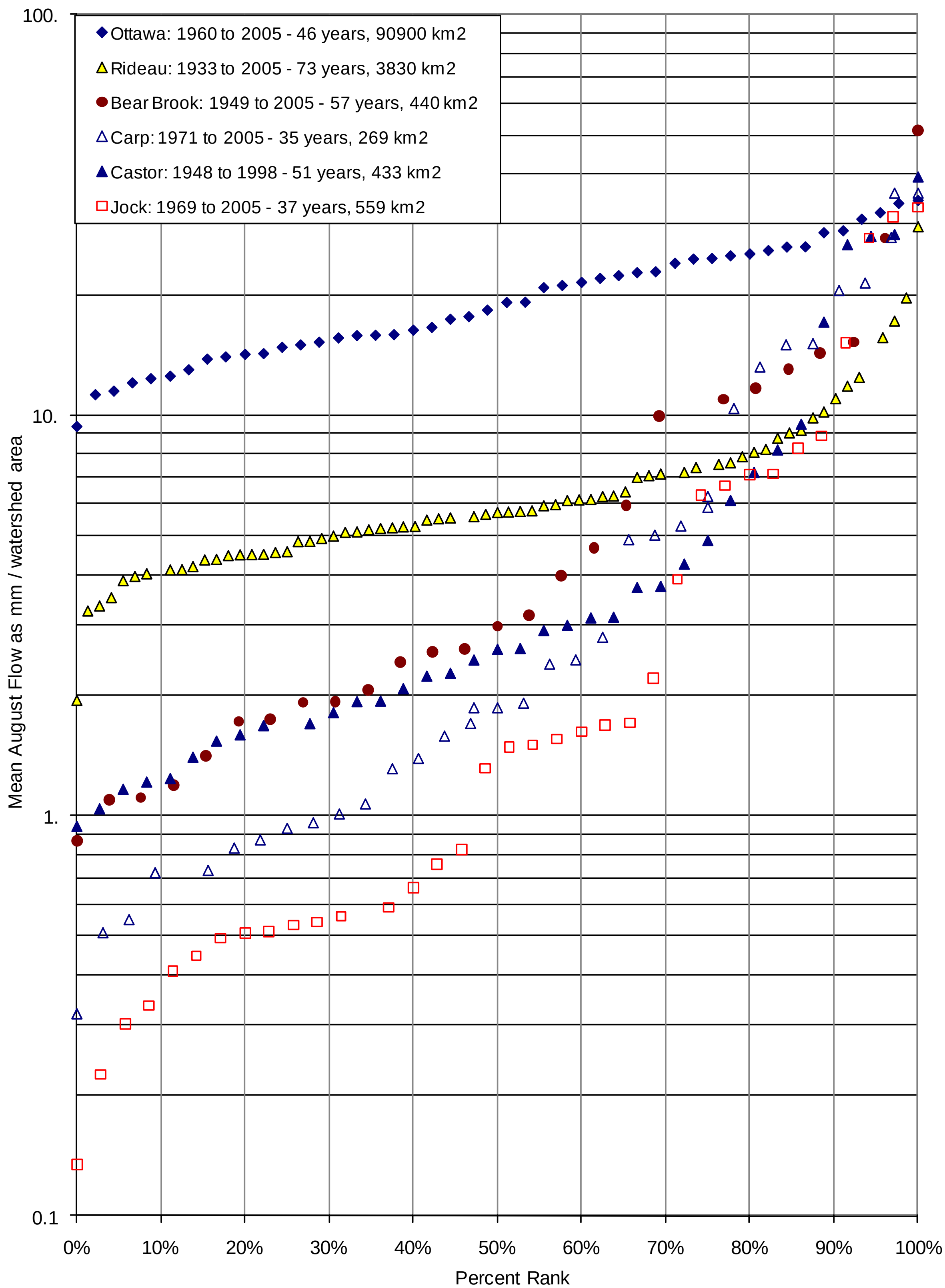


Figure 4-3 Percent Rank Distribution of Average August (Summer) Flows for Length of Record Minor Watersheds



4.2 Groundwater

With respect to groundwater, the geology of the Ottawa area can be simplified into 5 layers:[4]

- Littoral-fluvial sand (shallow aquifer).
- Champlain Sea Mud (aquitard);
- Esker (aquifer);
- Till (aquitard); and
- Fractured bedrock and stratified sediment overlaying bedrock (contact zone aquifer).

Unlike southern Ontario, the Ottawa area does not contain extensive aquifers. Throughout most of the Ottawa valley, the recharge of aquifers is limited by an impervious aquitard (or confining layer) known as the Champlain Sea silt and clay layer. Natural Resources Canada has estimated that only 10% of precipitation that falls in the Ottawa area infiltrates into the ground, the rest being lost to evapotranspiration or runoff to rivers and lakes.[5] The Study Area does have some good but localized groundwater sources in esker features, but there are only two significant eskers in the Study Area. These are:

- the esker that crosses Mud Creek in a north-south direction and then intersects the Rideau River in the Rideau watershed (see Physiography Map 4D); and
- the Vars-Winchester esker that runs north-south through Bear Brook (see Physiography Map 4F).

The relatively high flows in August in Bear Brook are due to the presence of groundwater from the Vars-Winchester esker. Other shallow surface aquifers are found in the sand plains where the depth of overburden is sufficient. The relatively good summer flows in the Castor minor watershed are likely due to the shallow sand plain aquifers.

Groundwater in the Study Area is variable with respect to both quantity and quality. Ongoing efforts to characterize the resource through the Source Water Protection Program will improve the understanding of use, withdrawals, the location of important aquifers and recharge areas, and the quality of groundwater.

---

[4] D. I. Cummings and H.A. J. Russell, 2007. Geological Survey of Canada Open File 5624 The Vars-Winchester esker aquifer, South Nation Watershed , Ontario CANQUA Fieldtrip, June 6, 2007

[5] http://geopanorama.rncan.gc.ca/ottawa/pdf/theme7_7a_e.pdf

4.3 Water Balance

Changing the units used to measure runoff from flow (m^3/s) to average runoff in terms of water accumulation per area of the watershed (mm/month) provides a representation of the water balance (Table 4-3, Table 4-4, Figure 4-1and Figure 4-2). This amount of water in mm/unit area discharged over a month can then be compared to the monthly precipitation. The difference between precipitation and runoff is the volume lost to evapotranspiration and changes in groundwater storage.

A standard assumption in the calculation of water balance is that groundwater storage is constant over the long term, assuming precipitation is also constant. There are variations year-to-year related to the variability in annual precipitation and throughout the year with respect to monthly variability in both precipitation and evapotranspiration. During extended dry periods, the flows in streams are directly related to water table levels. The change in flows and water table levels is related to the volume of groundwater storage and rate of discharge.

Table 4-3 Minor Watersheds: Normalized Median Seasonal Flows

Watershed	Flows (mm / unit area)			
	Winter	Spring	Summer	Fall
Bear Brook	9	95	2.9	41
Carp	6	110	1.9	17
Castor	11	116	2.8	22
Jock	9	112	1.3	21
Rideau	17	90	6	20
Ottawa	31	58	17	29

Table 4-4 Estimated Annual Average Evapotranspiration by Minor Watershed

Minor Watershed	Period of Record (from year-to-year)	Annual Totals			
		Precipitation*	Runoff*	Evapo-transpiration	
		(mm)	(mm/ unit area)	(mm)	% of total Precipitation
Bear Brook	1949 to 2005	876	422	454	52%
Castor River	1948 to 1998	871	396	480	55%
Jock River	1969 to 2005	907	355	521	60%
Carp River	1971 to 2005	912	337	539	62%
Rideau River	1933 to 2005	879	329	546	62%

* Average Annual over length of record

4.4 Water Quality

Water quality can be affected by many factors including temperature, hardness, alkalinity, levels of dissolved oxygen; and the presence of suspended solids, bacteria, nutrients, metals and synthetic organic compounds. Surface water quality can affect human uses (such as swimming and aesthetics) and aquatic species (including plants, invertebrates, fish and organisms that eat these species). Most surface water monitoring programs, including the City of Ottawa's, focus on key water parameters or indicators. The importance of some of these indicators of water quality is shown in Table 4-5. The water quality objectives for key water quality parameters are presented

Table 4-6. Table 4-7 provides information on the average levels of key water quality parameters in Ottawa's watersheds, minor watersheds and urban and rural creeks (small subwatersheds) for the period 1998 to 2007. Table 4-8 shows the percentage of samples for the same period that meet the water quality objectives. Maps 9A to 9F (Appendix A) show the location of baseline water quality sampling locations in 2009. Percentile Graphs of the complete data sets for selected parameters are provided in Appendix C.

4.4.1 Reference Chemistry: A Reflection of Watershed Geology

The Ottawa River has distinctly different chemistry than other rivers and streams in Ottawa, with pH and alkalinity of 7.5 and 23 respectively. (pH is a measure of the range between acid and basic solutions, 1 to 14 respectively, and alkalinity is the ability of a solution to neutralize acids). The range for pH for all other rivers in the Study Area is between 8.1 and 8.2, which reflects the greater buffering capacity of the water as measured by the alkalinity.

The low alkalinity of the Ottawa River (23) reflects the dominance of the shallow overburden and metamorphic rock of the Canadian Shield. The alkalinity in the Rideau (127) and Mississippi (98) Rivers is also limited by the geology of the Canadian Shield. Alkalinity is highest in the Castor River (222) and urban creeks (214) respectively, with the higher alkalinity reflecting the presence of sources of carbonate including limestone. The Rideau and Mississippi Rivers have relatively moderate levels of alkalinity of 127 and 98 respectively while the Bear Brook, Jock River, Carp River, and rural creeks have alkalinity of 164, 180, 194, and 192 respectively.

Table 4-5 Importance of Key Water Quality Parameters *

Parameter	Measure	Comments
Dissolved Oxygen	Concentrations	• levels are limiting factors for different organisms
Temperature	Stratification Peak range	• thermoclines act as barriers to dissolved oxygen • seasonal mixing occurs as cold and warm layers flip • maximum temperatures influence the presence of different fish species
pH	Presence of free ions	• direct relationship with alkalinity and acidity and overall buffering capacity of a system • more severe outside of the natural range of 6.5 to 9.0 • very significant in the percent of ammonia present as un-ionized ammonia – increasing portion of un-ionized ammonia with increasing pH • metals typically have increasing toxicity with decreasing pH
Alkalinity	Buffering capacity of a system	• representative of presence of carbonates, sapphires, silicates, and phosphates • toxicity of chemicals can be altered in unpredictable ways
Hardness	Presence of calcium and magnesium salts	• increasing hardness mediates the toxicity of many metals
Organic Carbon	Presence	• acts as a binding agent with some metals reducing toxicity
Nutrients	Concentration	• acceptable levels dependant on water body characteristics and target fisheries • some forms are toxic under some temperature, pH, and presence of other chemicals, for example at low levels ammonia is a nutrient and is not toxic
Suspended Solids	Concentration relative to background conditions	• affects organisms by: ○ impairing breathing due to clogging filtering capabilities ○ causing injury due to abrasion ○ restricting food availability ○ restricting movement ○ impairing egg development
Metals	Presence	• can be toxic to aquatic organisms

*** Summarized from Canadian Water Quality Guidelines**[3]

Table 4-6 Water Quality Objectives for Key Parameters

Parameter	Source	Objective	Comment
Chlorides[1]	BC	maximum 600 mg/L 30-day average 150 mg/L	Objective for the protection of aquatic life
Copper	PWQO	0.0050 mg/L	Based on hardness > 20 mg/L as $CaCO_3$, which is typical for hardness of surface waters in the Study Area
E. coli	PWQO	100 counts / 100 mL	Based on: • a recreational water quality guideline specifically intended for application by the local Medical Officer of Health to swimming and bathing beaches • minimum 5 samples per site taken within a given swimming area and collected within a month
Iron	PWQO	0.30 mg/L	
Lead	PWQO	0.001 mg/L	
Manganese	PWQO	0.05 mg/L	
Nitrates and Nitrates	PWQO	25 mg/L	
Total Kjedahl Nitrogen	PWQO	1 mg/L	
Total Phosphorous	PWQO	0.030 mg/L	Excessive weed growth in rivers and streams should be eliminated at a total phosphorus concentration below the objective
Total Suspended Solids	CCME	Increase of 25 mg/L from background levels or 10% greater than background levels when background levels exceed 250 mg/L	
Sulphates[2]	BC	100 mg/L	Objective for protection of aquatic life
Zinc	PWQO	0.020 mg/L	

1 There is currently no Canadian or Ontario objective for chlorides, although CCME is developing one. The British Columbia objective has been used in the interim.

2 There is currently no Canadian or Ontario objective for sulphates. The British Columbia objective has been used for comparison purposes.

4.4.2 Overview of Water Quality

Total Suspended Solids

The average amount of total suspended solids (TSS) in a watercourse provides additional insights on watershed characteristics and stream function. The presence of high levels of TSS can also bias the presence of other parameters, due to the adsorption of other materials to the suspended solids. The Bear Brook is the largest system with relatively high average TSS of 19 mg/L. This is comparable to the average levels of TSS found in urban creeks (17 mg/L). The levels of TSS in the Castor and Carp Rivers and rural creeks are similar to each other, at 10, 8, and 9 mg/L respectively, and in the order of ½ the levels found in the Bear Brook. Average levels of TSS in the Ottawa, Rideau, Mississippi, and Jock Rivers are lower still and range around 3 to 4 mg/L.

TSS is often used as a surrogate for parameters of concern. This is appropriate for direct stormwater runoff from surfaces such as roadways. However, this is not appropriate in all systems: the presence of TSS in natural stream systems is not a reflection of pollution but rather the natural sediment transport function of the stream that is required to maintain stream form.

Phosphorus

Phosphorus is a naturally occurring mineral that is necessary for plant growth. However, in aquatic systems, high levels of the nutrient can lead to excessive growth of aquatic plants, the creation of unsightly mats of algae, and the depletion of oxygen, which limits the ability of fish to survive. The Provincial Water Quality Objectives (PWQO) for phosphorus in rivers and streams is set in order to eliminate excessive plant growth[6].

In terms of water pollution, the main sources of phosphorus are human and animal wastes (i.e., sewage and manure), stormwater, industrial wastes, soil erosion, and fertilizers. Phosphorus is tightly bound to active calcium in neutral to alkaline soils as well as to weathered acid soils with iron and phosphorus. Unlike nitrogen, phosphorus is not subject to leaching unless there are saturated conditions or there are high levels in the soils. Due to its resistance to leaching, phosphorus tends to accumulate in the surface layers of soils. The major pathway for phosphorus to enter surface waters is overland or sheet flow erosion where the surface materials are moved across the surface the flow**.**

Average levels of total phosphorus exceed the PWQO in most of the Study Area's watercourses, with the exception of the Ottawa and Mississippi Rivers. The Ottawa and Mississippi Rivers meet the PWQO in 99% and 86% of samples taken.

[6] Water Management Policies Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment, 1994

The highest average levels of total phosphorus are found in the Carp River, Bear Brook, and in urban and rural creeks. The PWQO is met in the Carp River and Bear Brook in only 19% of samples. In urban creeks, the PWQO is met in only 28% of samples, and in rural creeks in only 38% of samples. Because of high phosphorus levels, excessive weed growth and algae blooms are observed in late summer in many of the streams and rivers in Ottawa and were identified as key concerns in the Lower Rideau Watershed Strategy [7]

The watercourse sampling sites with the highest levels of phosphorus, many of which are relatively small creeks, are listed in Table 4-11. Watercourse sampling sites having with average total phosphorus levels of 0.08 mg/L or greater, compared to the PWQO of 0.03 mg/L include stations on Cranberry, Casey, Greens, Graham, Steven, Becket's, Cody, Bilberry, Cardinal, and Flowing Creeks.

Table 4-12 lists the watercourse sampling sites with the lowest average phosphorus levels. They include seven sites along the Ottawa River, and sites on the Rideau River, Brassil's Creek and Steven Creek. (The presence of both high and low phosphorus levels in Steven Creek reflects local farm sources).

E. coli

Escherichia coli (*E. coli*) is a bacterium commonly found in the lower intestine of warm-blooded organisms and is an indicator of the presence of human sewage and animal manure. It can enter rivers and streams through direct discharge from mammals and birds, from agricultural and stormwater runoff containing animal wastes, and from sewage leaked or deliberately discharged to a watercourse.

Between 1998 and 2007, average levels of *E. coli* met the PWQO in all Ottawa watercourses except Bear Brook and urban creeks. The lowest average levels were found in the Rideau and Mississippi Rivers at 15 and 17 counts per 100 ml respectively. By contrast, the average levels in Bear Brook and in urban creeks were 112 and 147 counts per 100 ml respectively.

In terms of exceedances, 92% of samples from the Rideau and 91% of samples from the Mississippi met the PWQO for *E. coli.* Urban creeks met the PWQO in only 38% of samples. Bear Brook met the PWQO in only 57% of samples, and a similar frequency was found for the Castor River, the Carp River and rural creeks.

Watercourse sampling sites where *E. coli* levels are the highest are shown in Table 4-13. These are those with geometric means of 200 counts / 100 mL and include sites on Bilberry, Casey, Sawmill, Flowing, Watts, and Greens Creeks. One sampling station on the Ottawa River is among this group because of the presence of combined sewer overflows. Maximum values at some of these sites range as high as 10,000 counts per 100 mL.

[7] Lower Rideau Watershed Strategy, Robinson Consultants Inc Consulting Engineers Aquafor Beech Limted, 2005 r

Table 4-14 shows the watercourse sampling sites with the lowest average levels of *E. coli*. This includes five sites on the Rideau River and sites on Mud Lake, the Ottawa River, Mackay Lake and Constance Lake.

Other Parameters

As shown in Table 4-7 and Table 4-8:

- On average, levels of Total Kjedahl Nitrogen, nitrates and nitrites and sulphates generally meet the PWQO;
- Average levels of copper exceed the PWQO in Bear Brook, and the PWQO for copper is exceeded in urban creeks in 33% of samples;
- Average levels of iron exceed the PWQO in the Castor and Carp Rivers, Bear Brook and in urban and rural creeks; levels of iron exceed the PWQO in 69% of samples from the Castor River, 64% of samples from urban creeks, 45% of samples from rural creeks and 38% of samples from the Carp River and Bear Brook;
- As with iron, average levels of manganese exceed the PWQO in the Castor and Carp Rivers, Bear Brook and in urban and rural creeks; the most frequent exceedances are in the Castor River (65% of samples) and in urban creeks (61% of samples).
- Average levels of lead exceed the PWQO in all major watercourses;
- Average levels of zinc exceed the PWQO in the Castor River, although 99% of samples meet the PWQO.

Table 4-10 suggests that the levels of phosphorus, *E. coli*, copper and iron are generally rising over time in all major watercourses, although the time series is not long. The exception to this seems to be Bear Brook, in which levels of these key water quality parameters appear to be dropping.

Table 4-7 Overview Statistics: Average Parameter Values 1998 through 2007

Parameter	Ottawa	Rideau	Mississippi	Jock	Castor	Carp	Bear Brook	Urban Creeks	Rural Creeks	Objectives
Reference Chemistry										
Conductivity	76	329	233	497	787	891	833	1,265	548	
Alkalinity	23	127	98	180	222	194	164	214	192	
pH	7.5	8.1	8.1	8.2	8.2	8.1	8.1	8.1	8.1	
General Indicators										
Total Suspended Solids	3	4	4	4	10	8	19	17	9	
Total Phosphorus	0.016	**0.039**	0.024	**0.037**	**0.045**	**0.061**	**0.090**	**0.059**	**0.062**	0.03
Total Kjeldahl Nitrogen	0.356	0.628	0.494	0.791	0.667	0.732	**1.037**	0.697	0.814	1
Nitrites and Nitrates	0.1	0.4	0.1	0.5	0.8	0.5	0.6	1.1	0.5	25
Sulphate	6	11	8	18	95	56	35	80	23	100
E. coli	44	15	17	41	79	81	**112**	**147**	66	100
Chlorides	3	23	10	41	67	138	143	**240**	49	150
Selected Metals										
Copper	0.0028	0.0024	0.0020	0.0022	0.0034	0.0033	**0.0055**	0.0047	0.0029	0.005
Iron	0.243	0.162	0.187	0.181	**0.517**	**0.352**	**1.290**	**0.791**	**0.532**	0.3
Manganese	0.016	0.033	0.020	0.043	**0.080**	**0.064**	**0.081**	**0.073**	**0.112**	0.05
Lead[2]	**0.0015**	**0.0012**	**0.0011**	**0.0012**	**0.0014**	**0.0011**	**0.0015**	**0.0015**	**0.0012**	0.001
Zinc	0.0034	0.0043	0.0032	0.0035	**0.0206**	0.0047	0.0090	0.0128	0.0051	0.02

Exceedances of Objectives	

Table 4-8 Overview Statistics: Percent of Samples below (better than) Objectives 1998 through 2009

Parameter	Ottawa	Rideau	Mississippi	Jock	Castor	Carp	Bear Brook	Urban Creeks	Rural Creeks	Objectives
Phosphorus	99%	45%	86%	46%	36%	19%	19%	28%	38%	0.03
Total Kjeldahl Nitrogen	100%	98%	99%	84%	96%	94%	94%	92%	83%	1
Nitrites and Nitrates	100%	100%	100%	100%	100%	100%	100%	100%	100%	25
Sulphates	100%	100%	100%	100%	100%	100%	100%	100%	100%	100
E. coli	77%	92%	91%	76%	61%	57%	57%	38%	60%	100
Chlorides	100%	100%	100%	98%	84%	26%	26%	23%	94%	150
Copper	90%	91%	95%	92%	86%	86%	86%	67%	88%	0.005
Iron	83%	90%	93%	86%	31%	62%	62%	27%	55%	0.3
Manganese	100%	90%	99%	76%	35%	54%	54%	39%	55%	0.05
Lead[1]	78%	84%	85%	82%	82%	84%	84%	76%	82%	0.001
Zinc	99%	99%	99%	100%	99%	99%	99%	86%	98%	0.02

Good	(blue)
Fair	(yellow)
Poor	(pink)

1 Detection limit for Lead was 0.002 for some samples > PWQO

Table 4-9 Selected Statistics: Percent of Samples below (better than) Objectives 1998 through 2009

Parameter	Ottawa	Rideau	Mississippi	Jock	Castor	Carp	Bear Brook	Urban Creeks	Rural Creeks
Phosphorus	**100%**	47%	**90%**	50%	37%	27%	1%	28%	38%
E. Coli	**90%**	**94%**	**93%**	79%	61%	71%	51%	42%	64%
Copper	**95%**	**95%**	**98%**	**96%**	**92%**	**94%**	64%	74%	**94%**
Iron	**89%**	**92%**	**95%**	79%	31%	64%	15%	21%	53%
Zinc	**99%**	**98%**	**100%**	**99%**	**99%**	**99%**	**92%**	**83%**	**97%**
Good									
Fair									
Poor									

Table 4-10 Selected Statistics: Change in Percent of Samples below (better than) Objectives 1998 through 2009 compared to 1998 through 2002

Parameter	Ottawa	Rideau	Mississippi	Jock	Castor	Carp	Bear Brook	Urban Creeks	Rural Creeks
Phosphorus	-1%	-4%	-4%	-8%	-1%	**-28%**	**1844%**	-1%	0%
E. Coli	**-14%**	-2%	-2%	-4%	-1%	**-19%**	**12%**	-10%	-6%
Copper	-6%	-4%	-3%	-4%	-6%	-8%	**35%**	-10%	-7%
Iron	-7%	-2%	-2%	9%	-2%	-3%	**315%**	**30%**	4%
Zinc	0%	1%	-1%	1%	0%	0%	8%	4%	1%

Table 4-11 Top Sites Exceeding Water Quality Objectives: Phosphorus

Phosphorus (PWQO = 0.03 mg/L)				
Creek	**Location**	**Average**	**Max**	**Dominant Land Uses**
Cranberry Creek	CK43-02	0.13	0.57	60 % undeveloped, 33% agriculture
Casey Creek	CK64-02	0.10	0.27	55 % undeveloped, 30% agriculture
Greens Creek	CK21-009	0.10	0.44	(headwaters) 59% undeveloped, 34% agriculture
	CK21-002	0.08	0.35	30% undeveloped, 44% urban, 12% agriculture
	CK21-502	0.08	0.43	(Black Creek) 82% undeveloped, 14% agriculture
Graham Creek	CK8-35	0.10	6.00	42% urban, 24% agriculture, 23% undeveloped
Steven Creek	CK42-05-03	0.10	1.17	44% undeveloped, 41% agriculture
Becketts Creek	CK25-001	0.10	0.73	58% agriculture, 23% natural
Cody Creek	CK3-01	0.10	0.39	55% undeveloped 33% agriculture
Bear Brook	CK31-01	0.09	0.63	42% agriculture, 41% undeveloped
	CK31-04	0.09	0.25	50% agriculture, 35% undeveloped
Bilberry Creek	CK22-001	0.09	0.33	75% urban
Cardinal Creek	CK24-002	0.08	0.26	54% agriculture, 24% urban
Mud Lake	MUDLK-03	0.08	0.41	N/A
Flowing Creek	CK67-001	0.08	0.62	50% agriculture, 32% natural

Table 4-12 Sites with Lowest Average Phosphorus

Phosphorus (PWQO = 100 counts / 100 mL)				
Creek	**Location**	**Average**	**Max**	**Dominant Land Uses**
Ottawa River	ORS-210.10	0.014	0.057	near Ontario shore – u/s of Britannia
	ORS-430.10	0.014	0.023	near Ontario shore d/s of Kettle Island
	ORS-430.60	0.013	0.025	near Quebec shore d/s of Kettle Island
	ORS-430.30	0.013	0.034	mid channel d/s of Kettle Island
	ORS-210.30	0.013	0.020	mid channel u/s of Britannia
Brassil's Creek	CK44-02	0.013	0.033	90% undeveloped, 6% agriculture
Ottawa River	ORS-210.40	0.013	0.022	u/s of Britannia Beach – u/s of urban core
	ORS-100.20	0.012	0.021	west end of City u/s of City development
Rideau River	RRS-121B	0.011	0.011	
Steven Creek	CK42-07	0.010	0.058	undeveloped

Table 4-13 Top Sites Exceeding of Water Quality Objectives: *E. coli*

E. coli **(PWQO = 100 counts / 100 mL)**				
Creek	**Location**	**Geometric Mean**	**Max**	**Dominant Land Uses**
Bilberry Creek	CK22-001	468	10,000	75% urban
Casey Creek	CK64-02	416	10,000	55 % undeveloped, 30% agriculture
Graham Creek	CK8-01	208	10,000	42% urban, 24% agriculture, 23% undeveloped
Flowing Creek	CK67-001	277	10,000	50% agriculture, 32% natural
Sawmill Creek	CK18-Q	349	9,300	57% urban, 25% natural
	CK18-J	342	8,000	N/a
	CK18-S	365	10,000	N/a
	CK18-M	314	6,400	Na/
Ottawa River	ORS-450.40	339	1,000	N/a
Watts Creek	CK6-312	261	10,000	50% urban, 17% undeveloped, 11 % agriculture
Greens Creek	CK21-002	211	10,000	30% undeveloped, 44% urban, 12% agriculture
	CK21-003	203	10,000	42% undeveloped, 33% developed, 15% agriculture
Stillwater Creek	CK7-01	205	3,100	57% undeveloped, 23% urban, 12% agriculture
Taylor Creek	CK23-001	190	10,000	72% urban
Voyager Creek	CK35-004	199	3,900	74% urban

Table 4-14 Sites with Lowest Geometric Mean *E. coli*

E. coli **(PWQO = 100 counts / 100 mL)**				
Creek	**Location**	**Geometric Mean**	**Max**	
Rideau River	RRS-119B	12	200	Manotick
	CRS-105B	11	136	Rideau Canal at Bronson
	RRS-167B	9	194	Mooney's Bay
Mud Lake	MUDLK-03	9	370	
Ottawa River	ORS-100.20	8	104	west end of City u/s of City development
Rideau River	RRS-124B	8	520	Burritt's Rapids u/s of City
MacKay Lake	MKL-01	4	60	Urban
Constance Lake	CLL-01	3	48	
Rideau River	RRS-121A	2	2	Roger Steven Road

4.5 Water Temperature

As discussed in section 6.2 of this Report, water temperature is one of the determinant factors of aquatic communities. Water temperature in watercourses is affected by ambient air temperature, solar radiation and inputs of groundwater.

Temperatures in coldwater streams are sustained by significant inputs of groundwater that buffer the effects of ambient air temperature and solar radiation. As shown in Table 4-15, cold water fish communities require summer water temperatures that are no more than 19°C.

Table 4-15 Temperature Preferences of Adult Fishes in Ontario

Category	Temperature Range(°C)
Warm Water	Maximum > 25
Cool Water	Maximum > 19 < 25
Cold Water	Maximum < 19

Median, 80th percentile and 95th percentile water temperatures for July and August for a number of sites in the Study Area are presented in Table 4-16. Maps showing the locations of these sites are provided in Appendix A (Maps 10A to 10F July and August Water Temperatures).

From Table 4-16, it can be seen that most of the monitored sites in the Study Area fall within the cool water category, with the median, 80th and 95th percentile temperatures for July and August falling in the cool water range. Only two creeks – Hunt Club and Pinecrest -- have water temperatures suitable for coldwater fish communities. In these creeks the median, 80th, and 95th percentile summer temperatures are below 19° C.

Table 4-16 In-stream Water Temperature Ranges (July and August)

Subwatershed	# of Points	Median	80th Percentile	95th Percentile
Hunt Club Creek	1	12	13	17
Pinecrest Creek	4	13	15	18
Taylor Creek	2	16	17	20
McEwan Creek	1	16	19	22
Graham Creek	6	17	20	22
Black Rapids Creek	1	18	20	23
Leamy Creek	1	18	19	20
Shield's Creek	1	18	20	21
Sawmill Creek	11	18	21	23
Bilberry Creek	2	19	21	23
Middle Castor	1	19	21	22
Mud Creek	8	19	21	22
South Indian Creek	1	19	20	21
Barrhaven Creek	1	19	20	22
Cardinal Creek	5	19	21	23
Feedmill Creek	5	19	21	23
North Castor	1	19	21	24
Findlay Creek	2	19	21	23
Poole Creek	3	20	21	23
Shaw's Creek	1	20	22	25
McKinnon's Creek	3	20	22	24
Hobbs Drain	1	20	22	25
Monahan Creek	4	20	22	24
Stillwater Creek	3	20	22	24
Flowing Creek	5	21	23	25
Green Creek	11	21	23	25
Nichols Creek	1	21	23	24
Nepean Creek	3	21	23	25
Steven's Creek	7	21	23	25
Bear Brook	4	21	24	26
Ottawa River	13	21	22	23
King's Creek	1	22	25	27
Jock River	7	22	24	25
Mosquito Creek	2	22	24	26
Brassil's Creek	6	22	25	27
Rideau River	2	22	25	25
Central Castor	1	22	25	27
O'Keefe Drain	1	23	29	33

Temperature < 19°C	(blue)
Temperature <= 25°C	(green)
Temperature > 25°C	(red)

5 LAND USE

5.1 General Characteristics

Since its founding as Bytown in 1832, the developed area of Ottawa has grown outward from the confluence of the Rideau River and the Ottawa River. The City of Ottawa today includes a variety of land uses and built forms – a dense central core, a number of other urban and suburban areas, hamlets and villages, large swaths of agricultural land, and significant amounts of natural forest and wetlands. Table 5-1 and Table 5-2 provide a breakdown of major land use by watersheds and minor subwatersheds. Table 5-3 provides a more detailed breakdown of the land use categories for the City of Ottawa. **Note that the data in this section uses the boundary of the City of Ottawa (i.e., the land base is approximately 2,800 km^2 dependant on shoreline delineation).** This information is mapped in Maps 11A to 11F (Simplified Land Use) in Appendix A.

Major land use factors that affect environmental function in watersheds include:

- the area of land developed;
- the type of development (i.e., residential, industrial, transportation);
- the percent of land cover that is impervious;
- the percentage of natural vegetation, especially forests and wetlands; and
- sanitary and storm sewer design standards.

Highlights of the land use information include:

- **Tree, shrub and wetland cover** is the dominant land use across the City, forming 37% of the total area. This category includes forests, wetlands and other natural areas. Watersheds in which tree, shrub and wetland cover is 30% or greater include the Lower Mississippi, Carp, Green Creek, Ottawa West, Jock, Lower Rideau and Bear Brook watersheds. The watersheds with the lowest tree, shrub and wetland cover are the Lower Madawaska and Ottawa East, both with 13%.

- **Agricultural** land use is a major land use that accounts for 35% of the City's total area. In part, agricultural land use reflects the ability of soils to support agriculture. As such, farming is largely found in the relatively deep low permeability soils found in the clay and sand plains of the Lower Mississippi, Carp, Ottawa East, Jock, Lower Rideau, Bear Brook and Castor watersheds. The Castor River watershed has the highest percentage of agricultural land use at 50% and the Lower Mississippi has 47%.

- **"Developed" areas** make up 22% of the City's total area. For the purposes of this Report, "developed areas" is defined to include industrial, commercial and institutional uses, utilities, schools, recreational areas, residential areas, rights-of-way and vacant land that is zoned for development. The three watersheds with the greatest proportion of developed areas are Ottawa Central (64%), Ottawa East (47%) and Green Creek (40%). The lowest percentage of developed areas is found in the Lower Mississippi (9%) and Bear Brook (13%) watersheds.

Table 5-1 City of Ottawa 2005 Land Use by Categories (by Percent)

Major Watershed	**Minor Watershed**	**Agriculture**	**Water**	**Tree/shrub/ wetland cover**	**Industrial**	**Commercial**	**Institution**	**Utilities**	**School**	**Recreation**	**Residential**	**Right-of-Way**	**Vacant Land**	**Sub-Total Development**	**Total**
Mississippi	Lower Mississippi	47%	1%	42%	1%						4%	3%	1%	9%	100%
Mississippi Total		*47%*	*1%*	*42%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*4%*	*3%*	*1%*	*9%*	*100%*
Ottawa	Carp	34%	1%	40%	2%	1%		1%		2%	9%	5%	6%	19%	100%
	Green Creek	15%		39%	5%	2%	1%	2%		5%	10%	14%	6%	40%	100%
	Lower Madawaska	22%	50%	13%	1%			2%			3%	8%	1%	14%	100%
	Ottawa Central	13%	1%	21%	1%	5%	2%	1%	1%	12%	24%	17%	1%	64%	100%
	Ottawa East	34%	1%	13%	1%	2%	3%	1%	1%	8%	20%	12%	5%	47%	100%
	Ottawa West	25%	2%	46%		1%	2%			4%	11%	4%	5%	22%	100%
Ottawa Total		*27%*	*1%*	*35%*	*2%*	*2%*	*1%*	*1%*	*0%*	*5%*	*13%*	*8%*	*5%*	*32%*	*100%*
Rideau	Jock	35%		43%	2%					2%	6%	3%	7%	14%	100%
	Lower Rideau	32%	2%	38%	1%	1%		2%		3%	9%	6%	6%	23%	100%
Rideau Total		*33%*	*1%*	*40%*	*2%*	*1%*	*0%*	*1%*	*0%*	*3%*	*8%*	*5%*	*6%*	*19%*	*100%*
South Nation	Bear Brook	42%		41%	1%		1%			1%	5%	4%	4%	13%	100%
	Castor	50%		29%	3%					1%	7%	3%	5%	15%	100%
South Nation Total		*47%*	*0%*	*34%*	*2%*	*0%*	*1%*	*0%*	*0%*	*1%*	*6%*	*4%*	*5%*	*14%*	*100%*
Total		**35%**	**1%**	**37%**	**2%**	**1%**	**1%**	**1%**	**0%**	**3%**	**9%**	**6%**	**5%**	**22%**	**100%**
Dominant Land Use			**Subdominant Land Use**												

Table 5-2 City of Ottawa 2005 Land Use by Categories (km^2)

Major	Minor	Agriculture	Water	Tree / Shrub / Wetland Cover	Industrial	Commercial	Institution	Utilities	School	Recreation	Residential	Right-of-Way	Vacant Land	Sub-Total Development	Total
Mississippi	Lower Mississippi	84	1	75	3						7	5	2	16	**178**
Mississippi Total		*84*	*1*	*75*	*3*	*0*	*0*	*0*	*0*	*0*	*7*	*5*	*2*	*16*	***178***
Ottawa	Carp	104	2	122	7	2	1	2	0	6	27	14	19	58	**305**
	Green Creek	17		45	6	3	1	2	1	6	12	16	7	46	**116**
	Lower Madawaska	1	3	1										1	**5**
	Ottawa Central	14	2	23	1	6	2	1	1	13	26	19	1	70	**110**
	Ottawa East	54	1	20	1	3	5	2	1	13	32	19	8	75	**159**
	Ottawa West	79	7	144	2	2	6	1		12	34	12	15	70	**315**
Ottawa Total		*270*	*15*	*354*	*17*	*16*	*14*	*8*	*4*	*50*	*130*	*81*	*50*	*321*	***1,010***
Rideau	Jock	134	2	163	9	1	1	2		7	22	13	27	54	**380**
	Lower Rideau	193	12	232	7	7	3	9	1	20	57	34	35	138	**611**
Rideau Total		*327*	*14*	*395*	*16*	*7*	*4*	*11*	*2*	*26*	*79*	*47*	*63*	*192*	***991***
South Nation	Bear Brook	115	1	114	3		2	1		4	15	10	11	36	**277**
	Castor	186	1	107	10	1	1	1	0	4	26	13	19	57	**371**
South Nation Total		*301*	*2*	*221*	*13*	*2*	*3*	*2*	*0*	*8*	*41*	*23*	*30*	*92*	***647***
Total		**982**	**32**	**1,046**	**49**	**26**	**22**	**21**	**6**	**84**	**257**	**157**	**145**	**621**	**2,826**

Table 5-3 Breakdown of Land Use Categories by Sub-components

Land Use Description	Categories									
	Commercial	Tree / Shrub / Wetland Cover	Industrial	Institution	Recreation	Residential	Right-of-Way	School	Utilities	Total
Active recreation					48%					2%
Active recreation on school property					4%					
Apartments						3%				
Communications									7%	
Community shopping centre	13%									
Elementary school								55%		
Forest		64%								40%
Hospital, rehabilitation, nursing home				10%						
Idle and shrub land		20%								13%
Industrial			41%							1%
Industrial condominium			4%							
Mobile homes										
Office	41%									1%
Open space							11%			1%
Other commercial	41%						0%			1%
Other institution				90%						1%
Passive recreation					47%					2%
Passive recreation on school property					1%					
Pits and quarries			55%							2%
Post-secondary residence										
Post-secondary school								13%		
Regional shopping centre	3%									
Row and town homes						7%				1%
Secondary school								32%		
Semi-detached residential						2%				
Single-detached residential						88%				14%
Street							89%			8%
Transportation									62%	1%
Utility									31%	
Vacant building	1%									
Wetland		16%								10%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 5-4 Sources and Limitations of Land Use Information

Description	Sources / Interpretation	Comment / Limitations
Wetlands	Evaluated Wetlands – MNR	Not all wetlands have been evaluated.
	Surficial Geology Organic Materials – OGS	Does not incorporate surface vegetation or current hydrologic conditions
	SOLRIS [(1)]	Interpretation from a number of sources with limited field truthing / validation. Sources include evaluated wetlands, soils, surficial geology, topography, aerial photography.
Wooded Areas (rural area)	Natural Environment Systems Strategy (NESS) City of Ottawa	Underlying information based on 1978 Forest Resource Inventory, with updated forest area delineation in 1990's and limited fieldwork.
	SOLRIS Phase 1 wooded area theme	Updated forest delineation (2002 aerial photography including contiguous wooded areas where trees are greater than 2 m in height and 60% cover.
	Differences between NESS and SOLRIS	SOLRIS wooded area incorporates where development and regrowth has occurred since 1990's. NESS includes wooded areas in wetlands that may be less than the 2 m / 60% cover criteria while playing an important ecological role that may not be recognized in the SOLRIS interpretation.
Wooded Areas (Urban area)	City of Ottawa 1:2,000 scale mapping	High accuracy. The information is an assemblage over a number of years, some more current than others are.
	SOLRIS	Interpreted from aerial photography. Lower accuracy than 1:2,000 mapping. Single year – 2002.
Impervious Area	City of Ottawa 1:2,000 scale mapping for urban area and selected villages during the period 2001 through 2005	High accuracy. The information is an assemblage over a number of years, some more current than others are.
	SOLRIS	Interpreted from aerial photography. Lower accuracy than 1:2,000 mapping. Single year – 2002.
Storm sewer catchments	City of Ottawa	2007 interpretation of existing pipe, road, and topography information. Additional work required on connectivity and relation to stormwater facilities.

(1) SOLRIS - Southern Ontario Land Resource Information System, MNR

5.2 Impervious Cover

As noted above, the type of cover can have a major influence on watersheds and watershed function. There are great differences between watersheds that have predominantly natural cover, those that are predominantly rural, and those that are predominantly urban. The impact of urbanization on watersheds and watercourses is well recognized. Urbanization creates extensive impervious areas with reduced tree cover. The change from pervious areas (forest, wetlands, meadows or agricultural lands) to impervious areas (roads, parking lots and rooftops) dramatically affects the hydrologic cycle. Watercourses in urban areas typically suffer from increased volume and frequency of flow that lead to increased erosion, loss of aquatic habitat and impairment of water quality. These problems increase in severity with increasing imperviousness.

Useful information on cover is produced by the Southern Ontario Land Resource Information System (SOLRIS). SOLRIS is a landscape-level inventory of natural, rural and urban areas. It follows a standardized approach for ecosystem description, inventory and interpretation known as Ecological Land Classification (ELC) for southern Ontario. **Note that this section – unlike section 5.1 – uses as its geographic scope the entire watersheds of the Jock, Bear Brook, Castor and Ottawa East minor watersheds for a total area of 3,554 km^2.**

Table 5-5 shows the breakdown of cover by watershed and minor watershed. The percentage of impervious cover by watersheds, minor watersheds and subwatersheds is presented in Table 5-6. Table 5-7 provides detailed information on the components that make up impervious cover (i.e., buildings, roads and sidewalks on a Study Area-wide basis. Maps 12Ato 12F (Land Cover) in Appendix A illustrate the SOLRIS information. Discussion of natural cover (forests and wetlands) is presented in section 6 of this Report.

From the SOLRIS data, highlights of cover include:

- Only 9% of the total Study Area's area is impervious (defined for this Report as "built up impervious" plus "transportation"). This is relatively low compared to many municipalities in southern Ontario, which typically have 14% or more imperviousness.

- The minor watersheds with the highest percentage of impervious cover are Ottawa Central (49%), Green Creek (23%) and Ottawa East (20%).

- Some subwatersheds are more densely developed. The highest percentage of impervious cover is found in Cyrville Drain subwatershed (49%) in the Green Creek minor watershed, the central core area of Ottawa (47%) in the Ottawa Central minor subwatershed, and an area tributary to the Rideau River downstream of Mooney's Bay (45%).

- Except for the Lower Rideau at 12%, imperviousness is low at all other minor watersheds (i.e., 7% or less).

Table 5-5 SOLRIS Cover by Subwatershed (%)

Watershed	Minor Watershed	General								Treed	Wetland		%age of Total Area
		Hedge Rows	Extraction	Transportation	Built-Up Area Pervious	Built-Up Area Impervious	Water Open	Undifferentiated	Sub-Total Open General	Sub-Total Treed	Provincially Significant	Other Wetlands	
Ottawa	Lower Madawaska	1%		2%	1%	2%	50%	37%	**93%**	7%		3%	**0%**
	Ottawa West			3%	2%	4%	1%	39%	**50%**	44%	7%	19%	**9%**
	Carp	1%	1%	4%	3%	3%		47%	**58%**	38%	4%	19%	**8%**
	Ottawa Central			18%	7%	31%	1%	22%	**78%**	18%	3%	10%	**3%**
	Green Creek			8%	3%	15%		35%	**63%**	26%	11%	18%	**3%**
	Ottawa East			7%	3%	13%	0%	48%	**72%**	25%	1%	9%	**7%**
Sub-total Ottawa		*0%*	*0%*	*6%*	*3%*	*9%*	*1%*	*41%*	***62%***	*34%*	*5%*	*16%*	***31%***
Mississippi	Lower Mississippi	1%		2%	1%		1%	57%	**62%**	35%	7%	16%	**5%**
Sub-total Mississippi		*1%*	*0%*	*2%*	*1%*	*0%*	*1%*	*57%*	***62%***	*35%*	*7%*	*16%*	***5%***
South Nation	Bear Brook			2%		3%		46%	**53%**	41%	3%	19%	**13%**
	Castor	1%	2%	3%	1%	3%		63%	**72%**	23%	3%	16%	**16%**
Sub-total South Nation		*1%*	*1%*	*3%*	*1%*	*3%*	*0%*	*55%*	***63%***	*31%*	*3%*	*17%*	***30%***
Lower Rideau	Jock	1%	1%	2%	1%	2%		42%	**49%**	36%	9%	33%	**16%**
	Lower Rideau	1%	1%	5%	2%	7%	1%	43%	**60%**	33%	9%	21%	**18%**
Sub-total Lower Rideau		*1%*	*1%*	*4%*	*2%*	*5%*	*1%*	*43%*	***55%***	*35%*	*9%*	*26%*	***34%***
Totals		**1%**	**1%**	**4%**	**2%**	**5%**	**1%**	**47%**	**60%**	**33%**	**6%**	**20%**	**100%**

Highest Imperviousness ("Transportation" + "Built-up Impervious") (shaded cells)

Table 5-6 Percent Impervious Area in Subwatersheds with Developed Areas

Watershed	Minor Watershed	Subwatershed	Percent Impervious
Ottawa	Ottawa West	Kizell Drain / Watt's Creek	17%
		Shirley's Brook	6%
	Carp	Poole Creek	11%
		Feedmill Creek	4%
		Carp u/s reach	19%
	Ottawa Central	Stillwater Creek	10%
		Graham Creek	17%
		Ottawa Central	10%
		Ottawa Britannia Bay	33%
		Pinecrest Creek	35%
		City Core West	42%
		Rideau Canal	42%
		City Core East	**47%**
	Green Creek	Ramsay Creek	3%
		McEwan Creek	22%
		Green Creek headwaters	2%
		Mather Award Drain	38%
		Green Creek mid reach	28%
		Cyrville Drain	**49%**
		Mud Creek (GrCk)	10%
		Green Creek d/s reach	19%
	Ottawa East	Ottawa East of Core 1	44%
		Ottawa East of Core 2	27%
		Voyager Creek	29%
		Bilberry Creek	37%
		Taylor Creek	38%
		Cardinal Creek	7%
		Ottawa East 1	4%
		Ottawa East 2	8%
South Nation	Bear Brook	Bear Brook headwaters	2%
		McKinnon's Creek	4%
	Castor	North Castor Findlay Creek	5%
		North Castor Shield's Creek	5%
Rideau	Jock	Van Gaal West Main	4%
		Jock mid reach	3%
		Monahan Drain	7%
		Jock d/s reach	7%
	Lower Rideau	Rideau Mooney's - Billing's Reach Trib	**45%**
		Rideau Mooney's - Billing's Reach	29%
		Nepean Creek	37%
		Rideau d/s reach	39%
		Hunt Club Creek	19%

Watershed	Minor Watershed	Subwatershed	Percent Impervious
		Rideau Jock River to Mooney's	13%
		Black Rapids Creek	4%
		Mosquito Creek	3%
		Barrhaven Creek	20%
		Sawmill Creek	27%

>= 25%	
< 25%, > 10%	
< 10%, > 5%	
< 5%	

Table 5-7 City-wide Impervious Cover by Detailed Land Use

Category	Land Use	**Pervious**	Impervious Surface Cover									
			Total	**Buildings**	Driveways	Laneways	Parking Lots: Paved	Parking Lots: Unpaved	Pathways	Roads	Runways	Sidewalks
Commercial	Community shopping centre	26%	**74%**	27%			**44%**			2%		1%
	Office	53%	47%	17%	1%		23%	1%		3%		1%
	Other commercial	54%	46%	16%	1%		24%	3%		1%		
	Regional shopping centre	34%	66%	37%			23%			4%		1%
	Vacant building	59%	41%	17%	4%		18%					1%
Commercial Total		49%	51%	19%	1%		26%	2%		2%		1%
Industrial	Industrial	69%	31%	11%			12%	6%		1%		
	Industrial condominium	28%	72%	32%			36%	2%			1%	
	Pits and quarries	98%	2%							1%		
Industrial Total		83%	17%	6%			7%	3%		1%		
Institution	Hospital, rehab.,nursing home	59%	41%	16%	1%	2%	16%	1%		4%		1%
	Other institution	87%	13%	4%			5%	1%		2%		
Institution Total		84%	16%	5%			6%	1%		2%		
Recreation	Active recreation	96%	4%	1%			1%					
	Active recreation: school property	96%	4%	1%			2%					
	Passive recreation	97%	3%							1%		1%
	Passive rec: school property	99%	1%									
Recreation Total		97%	3%	1%			1%			1%		
Residential	Apartments	49%	51%	28%	5%		16%			1%		1%
	Mobile homes	86%	14%	5%	2%	1%				5%		
	Post-secondary residence	46%	54%	**40%**	3%		4%			2%		5%
	Row and town homes	56%	44%	27%	4%		6%			5%		1%
	Semi-detached residential	62%	38%	29%	8%		1%					
	Single-detached residential	88%	12%	9%	3%							
Residential Total		84%	16%	11%	3%		1%					
Right-of-Way	Open space	99%	1%							1%		
	Street	62%	38%		3%					**33%**		2%
Right-of-Way Total		66%	34%		3%					30%		1%
School	Elementary school	55%	45%	25%	1%		15%	1%		1%		2%
	Post-secondary school	41%	59%	29%	2%		15%			6%		6%
	Secondary school	49%	51%	25%	1%	1%	20%	1%		2%		1%
School Total		51%	49%	25%	1%		17%	1%		2%		2%
Utilities	Communications	98%	2%	1%								
	Transportation	74%	26%	2%			6%	2%		5%	10%	
	Utility	93%	7%	1%			3%	1%		2%		
Utilities Total		81%	19%	2%			5%	1%		4%	6%	

5.3 Stormwater Management

In urban areas, effective management of stormwater is critical for the protection of life, property and aquatic habitat. (Drainage in agricultural areas is addressed in section 5.4). The approach to managing stormwater has evolved considerably over time. Where once the emphasis was on efficient removal of stormwater from urban areas, today's stormwater management uses a more balanced approach that considers the protection of natural systems and associated fish habitat as well as people and property. The evolution of stormwater management practices reflects the growing scientific understanding of how rivers and streams function, the use of integrated planning processes, and improved technologies to mitigate the consequences of urbanization.

Stormwater management infrastructure varies across the City and reflects the policies in place when development occurred. This infrastructure includes:

- ***Combined sewers*** are found in older parts of the City. In these, stormwater and sanitary flows are conveyed in the same pipe. Most of the flows are intercepted and conveyed to the wastewater treatment plant. Flows greater than the capacity of the interceptor overflow to the Ottawa River. Ongoing initiatives continue to reduce the frequency and volume of combined sewer overflows.

- ***Partially separated sewers*** are found in areas foundation drains were and in some cases still are connected to sanitary sewers. These have a higher frequency of failure due to excessive flows resulting in basement flooding and discharge of bacterial to local receiving waters

- ***Storm sewers*** that are completely separate from sanitary sewers are found in areas developed after 1961. These are designed with a range of assumptions including the size of design storm, typically from a 1 year to a 5 year return period. Only since 1985 have guidelines recommended that flows into stormsewers be restricted to prevent pipe surcharging when events exceed the design capacity.

- Over 140 ***stormwater management facilities*** including wet and dry ponds provide storage and in some cases treatment of stormwater before it is discharged to watercourses.

Key milestones in the evolution of the City's stormwater management practices and policies are listed in Table 5-8. Map 13 (Stormwater Management) in Appendix A delineates storm sewer catchments. These are categorized in terms of sewer system type: combined, partially separated and separated, with separated systems further categorized by age (pre and post-1985) and by type of stormwater management pond (quality or quantity control).

Table 5-8 Key Milestones in Stormwater Management

Year	Milestone	Design/ Observation
1897	Construction of first sewers	Combined sanitary and storm sewers.
1915	Rideau River Interceptor Collector	Diversion of flows to Ottawa River from Rideau River. Recommendation for separate storm sewers and treatment of the dirty first flush of stormwater.
1950	Implementation of separate sewer policy	Sanitary sewers also service weeping tiles to maintain 'flushing flows. Storm sewers not constructed in all areas.
1954	Hurricane Hazel	Resulting loss of life and property damage lead to Ontario policies and funding for flood plain mapping.
1960	Commissioning of interceptor sewer and wastewater treatment plant	Interceptor captures up to 2 ½ dry weather sanitary flow and diverts it to the treatment plant. Excess flows continue to overflow to receiving waters – Ottawa and Rideau Rivers.
1961	Implementation of fully separated sewers	Weeping tile flows are removed from sanitary and discharged to storm sewers. Storm sewer design flow return periods vary by municipality and size of catchment. Frequency of basement flooding from surcharged sanitary sewers leads to disconnection of weeping tiles. Remedial work is ongoing.
1970	Rideau River urban beaches closed by Ministry of Health	Bacterial water quality becomes a major issue in Ottawa.
1983	Completion of Rideau River Stormwater Management Study	Implementation of stormwater ponds for water quality as well as quantity.
1985	Ontario Master Drainage Plan Guidelines	Stormwater management guidelines require the design of overland flow routes (major system) for flows in excess of pipe capacity (minor system). However, restriction of flows into pipes to design capacity is not consistently pursued.
1989	Scarborough Golf Course Erosion Court Case	Erosion of golf course lands due to upstream development leads to the development of natural channel practices that address both flow and erosion process in stream systems.
1989	MOE Ottawa requires a watershed approach for rigorous stormwater treatment	MOE Treatment Policy • 100 FC/100 mL • 100 EC/100 mL • 25 mg/L ss • effluent criteria on C of A • 4 violations / season
1995	MOE Procedure F-5-5	Defines requirements for combined sewer overflow (CSO) control requirements
1995	Regional Wastewater Master Plan	Recommends storage to reduce CSOs, as previously identified by City of Ottawa
2006	Council endorsement of Lower Rideau Watershed Strategy	The strategy identifies the need to protect tributaries and take a watershed approach, moving from the dominant priority of bacteria.
2006	City initiates development of comprehensive Stormwater Management Strategy	Underway.
2010	Real-time-control of Combined Sewer Overflows	Implemented as part of CSO control recommendations of Ottawa River Action Plan

5.4 Agriculture

5.4.1 Drainage

Agriculture requires optimal soil moisture levels for the various phases of a crop's life cycle. Soil moisture is a function of climate, topography, surficial geology and soils. Topography and the role and extent of surficial geology and soils are discussed in Section 2 of this report. Relevant mapping in Appendix A includes:

- Depth of overburden and permeability of geological deposits (Maps 6A to 6F);
- Agricultural capability of soils (Maps 7A to 7F); and
- Hydrologic soil groups or the potential for runoff (Maps 8A to 8F).

Most of the agriculture that takes place in the Study Area is located on relatively flat areas with deep layers of low permeability overburden. These areas of low permeability overburden have restricted or poor drainage because of the predominance of clay and till soils.

As shown in Table 5-9, most (84%) active agriculture areas, based on the 2005 City of Ottawa Land Use Survey, are located on soils with a soil capability class of 2 or 3. Fully 80% of these areas on class 2 or 3 soils have restricted drainage or poorly drained soils (i.e., fall into Hydrologic Soil Groups C or D). Because these poorly drained soils maintain both water and nutrients, they are generally the most fertile soils in the Study Area.

Table 5-9 Soil Capability and Drainage in Active Agriculture Areas

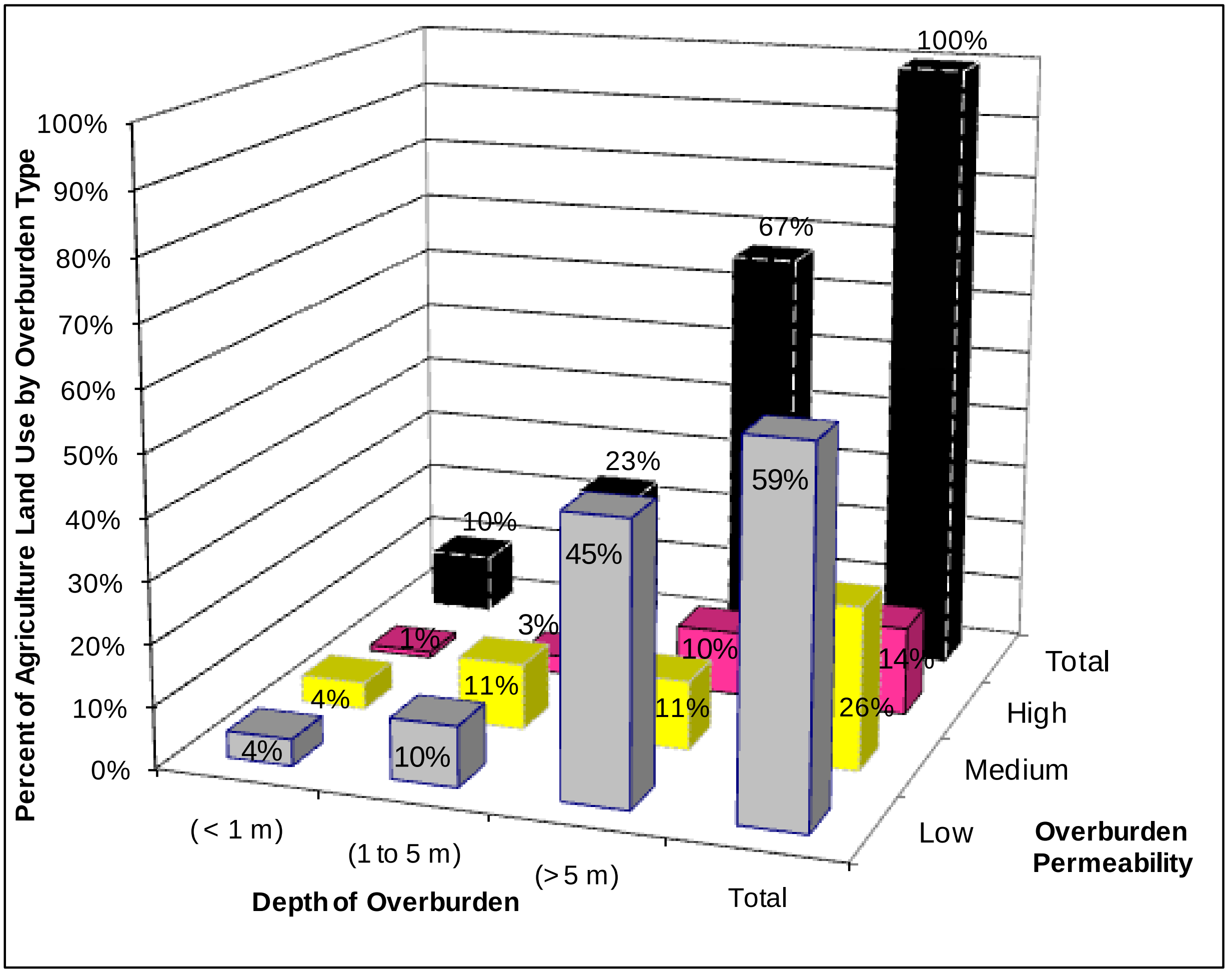
Hydrologic Soil Group	Soil Capability							Total
	1	2	3	4	5	6	7	
A	0%	1%	1%	5%	0%	0%	0%	6%
B	1%	9%	6%	1%	0%	5%	1%	23%
C	0%	14%	9%	0%	1%	0%	0%	25%
D	0%	13%	32%	0%	0%	0%	0%	46%
Total	2%	36%	48%	5%	2%	6%	1%	100%

Enhancements to drainage are often required to meet the optimal soils moisture content. The two major modifications are:

- tile drainage of the fields, which enhances drainage of the soils through subsurface drains; and
- municipal drains, which enhance conveyance of flows away from fields through maintained channels.

Tile drainage is particularly important in reducing soil moisture levels following the spring freshet. This allows earlier working of the fields in an area of limited frost-free growing periods.

Figure 5-1 Agricultural Land Use and Depth and Permeability of Overburden



The density of tile drainage across the Study Area is shown in Map 14 (Density of Tile Drainage) and the density of municipal drains is shown in Map 15 (Density of Municipal Drains) in Appendix A. Information on municipal and tile drainage by watersheds and minor watersheds is presented in Table 5-10. The relationship of tile drainage to surficial geology is presented in Table 5-11.

Table 5-10 Municipal and Tile Drains by Watershed and Minor Watershed and Farm Areas

Watershed	Minor Watershed	Length (Km)		Drains/ Streams (Km/Km)	Area (Km2) Tile Drains	% Farm Area *	% Crop Land *
		Streams	Municipal Drains				
Mississippi	Lower Mississippi	274		0.00	34	32%	55%
Mississippi Total		*274*	*0*	*0.00*	*34*	*32%*	*55%*
Ottawa	Carp	433	30	0.07	48	33%	54%
	Green Creek	188	6	0.03	25	144%	178%
	Lower Madawaska	6		0.00		14%	27%
	Ottawa Central	80		0.00	9	56%	69%
	Ottawa East	465	53	0.11	23	19%	26%
	Ottawa West	616	11	0.02	18	17%	36%
Ottawa Total		*1,787*	*100*	*0.06*	*124*	*30%*	*48%*
Rideau	Jock	700	245	0.35	62	25%	41%
	Lower Rideau	1,006	186	0.18	78	34%	53%
Rideau Total		*1,706*	*431*	*0.25*	*140*	*29%*	*47%*
South Nation	Bear Brook	1,067	464	0.43	49	24%	33%
	Castor	1,069	680	0.64	124	37%	49%
South Nation Total		*2,137*	*1144*	*0.54*	*172*	*32%*	*43%*
Grand Total		**5,904**	**1675**	**0.25**	**471**	**32%**	**47%**
* 2001 Census Data							

Drainage of agricultural land has an impact on hydrology. Tile drains remove excess water from the upper layer of the soil faster than evaporation alone would remove the water and they lower the groundwater table to below optimal root depths. The removal of excess water results in less surface ponding-surface storage and a reduction in the duration of saturated soil conditions. The related result is likely an increase in total runoff volume, due to the reduced storage, and associated increased peak flows. However, the tile drains are typically only active where there are significant volumes of water as a result of high volume rainfall events and winter and spring snow melts. Tile drains are typically inactive during summer months when high evapotranspiration minimizes excess water in the upper layers of the soils.

With the subsurface drainage, surface wash off of sediment directly to receiving streams may be reduced. However, phosphorus in the surface layers of soil may build up because of its bonding with soil particles; this may increase the phosphorus loading to watercourses during large rainfall events when surface sediment transport occurs.

Table 5-11 Relationship of Tile Drainage to Surficial Geology

Tile Drains and Underlying Surficial Geology						
Watershed	**Minor Watershed**	**Clay, Silt, Till**	**Organic**	**Bedrock**	**Sand & Gravel**	**Total**
Mississippi	Lower Mississippi	84%	1%	4%	11%	100%
Ottawa	Lower Madawaska	99%			1%	100%
	Ottawa West	78%	2%	8%	12%	100%
	Carp	85%	1%	7%	7%	100%
	Ottawa Central	79%	1%	7%	13%	100%
	Green Creek	70%	1%	2%	27%	100%
	Ottawa East	93%	1%	3%	3%	100%
South Nation	Bear Brook	78%	4%		18%	100%
	Castor	88%	4%		8%	100%
Rideau	Jock	86%	3%	3%	9%	100%
	Lower Rideau	80%	2%	2%	16%	100%
Totals		**84%**	**3%**	**2%**	**11%**	**100%**

5.4.2 Level and Nature of Agricultural Activity

The Census of Agriculture for the Eastern Ontario Subwatersheds provides extensive information on farming in the Study Area. A number of key parameters relating to farming activities were selected for analysis. These include area in agricultural operation, area in cropland, number of cattle, poultry and livestock units per unit area and annual nitrogen production per unit area. The density of farming activities for watersheds and minor watersheds for the years 2001 and 2006 is shown in Table 5-12, Table 5-13, Figure 5-2 and Figure 5-3, and Maps 16A to 16F (Farming) in Appendix A. (More detail on farming activities on a subwatershed basis is provided in Table 14 and Table 15 in Appendix B). The change in density of these farming activities between 2001 and 2006 is shown in Table 5-14.

Highlights of this information include:

- The minor watersheds with the greatest amount of agricultural activity per square kilometre in 2001 were the Lower Mississippi, Castor, Ottawa East and Carp watersheds. In each of these 50% or more of the land base was used for agriculture. These were also the watersheds with the greatest percentage of cropland, and with the Jock, the highest number of livestock units.

- The subwatersheds with the greatest amount of agricultural activity per square kilometre (see Table 5-13) are the mid-reach of the Carp River, the York and Fifth Concession Drains, Mud Creek (Rideau), and the downstream portion of the Lower Mississippi. The greatest percentage of cropland is found in the York and Fifth Concession Drains, Mud Creek (Rideau) and the Main Castor. The highest number of livestock units per square kilometre is found in the York and Fifth Concession Drains, Cheney Drain, and Main Castor.

- A comparison of agricultural activity in 2001 with that in 2006 shows that there was a minor drop in the overall density of agriculture in the minor watersheds (i.e., the amount of operations per kilometre squared), but a significant drop in Ottawa East, which fell from 54 ha/km^2 to 42 ha/km^2. There was also a notable drop in the production of poultry, in the Ottawa East watershed. In contrast to the general minor decline in agricultural operations across the Study Area, there was an increase in the Lower Madawaska.

- At the subwatershed level, there are strong changes between 2001 and 2006 that reflect the external forces that influence farm production. There are significant decreases in the density of farming operations, but also shifts across the Study Area with respect to where the most intense activity takes place.

- The minor watersheds with the least amount of agricultural activity in 2001 were Green Creek and Ottawa Central, with only 15% of the land base used for agriculture. By 2006, this had dropped significantly to 12%.

Table 5-12 Farming Activities by Minor Watershed: Density in 2001

Watershed	Minor Watershed	Area (Km2)	Area Operated (ha/km2)	Cropland Area (ha/km2)	Cattle (#/km2)	Poultry (#/km2)	Livestock Units (#/km2)	Nitrogen Production (kg/yr/km2)
Mississippi	Lower Mississippi	184	59	34	30	7	22	973
Mississippi Total		*184*	*59*	*34*	*30*	*7*	*22*	*973*
Ottawa	Carp	305	49	30	19	6	15	727
	Green Creek	111	15	12	2		2	83
	Lower Madawaska	5	30	15	13	1	10	472
	Ottawa Central	110	15	12	2		2	83
	Ottawa East	226	54	40	21	576	20	1,075
	Ottawa West	317	33	16	13	2	10	433
Ottawa Total		*1,075*	*38*	*24*	*14*	*124*	*12*	*580*
Rideau	Jock	573	43	26	19	3	15	727
	Lower Rideau	647	35	23	13	23	10	498
Rideau Total		*1,221*	*39*	*24*	*16*	*13*	*12*	*605*
South Nation	Bear Brook	484	42	31	19	89	16	843
	Castor	591	56	43	25	51	23	1,195
South Nation Total		*1,075*	*50*	*37*	*22*	*68*	*20*	*1,036*
Total		**3,554**	**43**	**29**	**18**	**63**	**15**	**747**
Distribution	>= 75 percentile		**42**	**31**	**19**	**12**	**15**	**765**
	> 50 < 75 percentile		**41**	**25**	**15**	**2**	**12**	**549**
	> 25 < 50 percentile		**34**	**18**	**11**	**1**	**9**	**402**

Table 5-13 Farming Activities by Minor Watershed: Density in 2006

Watershed	Minor Watershed	Area (km2)	Area Operated (ha/km2)	Cropland Area (ha/km2)	Cattle (#/km2)	Poultry (#/km2)	Livestock Units (#/km2)	Nitrogen Production (kg/yr/km2)
Mississippi	Lower Mississippi	184	57	33	20	2	16	750
Mississippi Total		*184*	*57*	*33*	*20*	*2*	*16*	*750*
Ottawa	Carp	305	41	25	17	42	13	595
	Green Creek	111	12	8	1	2	1	57
	Lower Madawaska	5	36	19	15	2	12	492
	Ottawa Central	110	12	8	1	2	1	57
	Ottawa East	226	42	31	18	1	15	781
	Ottawa West	317	32	17	12	1	9	382
Ottawa Total		*1,075*	*32*	*20*	*13*	*13*	*10*	*460*
Rideau	Jock	573	42	26	15	1	12	549
	Lower Rideau	647	37	25	11	21	9	422
Rideau Total		*1,221*	*39*	*26*	*13*	*12*	*10*	*482*
South Nation	Bear Brook	484	42	31	19	64	15	808
	Castor	591	59	46	25	4	20	1,052
South Nation Total		*1,075*	*51*	*39*	*22*	*31*	*18*	*942*
Total		**3,554**	**42**	**29**	**16**	**17**	**13**	**628**
Distribution	>= 75 percentile		**52**	**32**	**20**	**37**	**18**	**908**
	> 50 < 75 percentile		**42**	**26**	**19**	**6**	**15**	**727**
	> 25 < 50 percentile		**32**	**15**	**13**	**2**	**10**	**453**

Table 5-14 Farming Activities by Minor Watershed: Difference in Density between 2001 and 2006

Watershed	Minor Watershed	Area (km2)	Area Operated (ha/km2)	Cropland Area (ha/km2)	Cattle (#/km2)	Poultry (#/km2)	Livestock Units (#/km2)	Nitrogen Production (kg/yr/km2)
Mississippi		184	-2	0	-10	-5	-6	-224
Mississippi Total		*184*	*-2*	*0*	*-10*	*-5*	*-6*	*-224*
Ottawa	Carp	305	-8	-5	-2	+36	-2	- 132
	Green Creek	111	-3	-4	0	(2)	-1	- 27
	Lower Madawaska	5	+6	+4	+2	0	+1	+20
	Ottawa Central	110	-3	-4	0	+2	-1	- 27
	Ottawa East	226	-13	-9	-3	-575	-5	- 293
	Ottawa West	317	-2	+1	-1	-1	-1	- 51
Ottawa Total		*1,075*	*-6*	*-4*	*-2*	*-111*	*-2*	*-120*
Rideau	Jock	573	-1	-1	-4	-2	-	- 178
	Lower Rideau	647	+1	+3	-2	-1	-1	- 75
Rideau Total		*1,221*	*0*	*+1*	*-3*	*-2*	*-2*	*- 123*
South Nation	Bear Brook	484	0	0	0	-25	-1	-35
	Castor	591	+2	+3	-1	-47	-3	- 142
South Nation Total		*1,075*	*+1*	*+2*	*0*	*-37*	*-2*	*-94*
Total		**3,554**	**2**	**0**	**2**	**46**	**2**	**119**

Figure 5-2 Farming Activities by Minor Watershed 2001

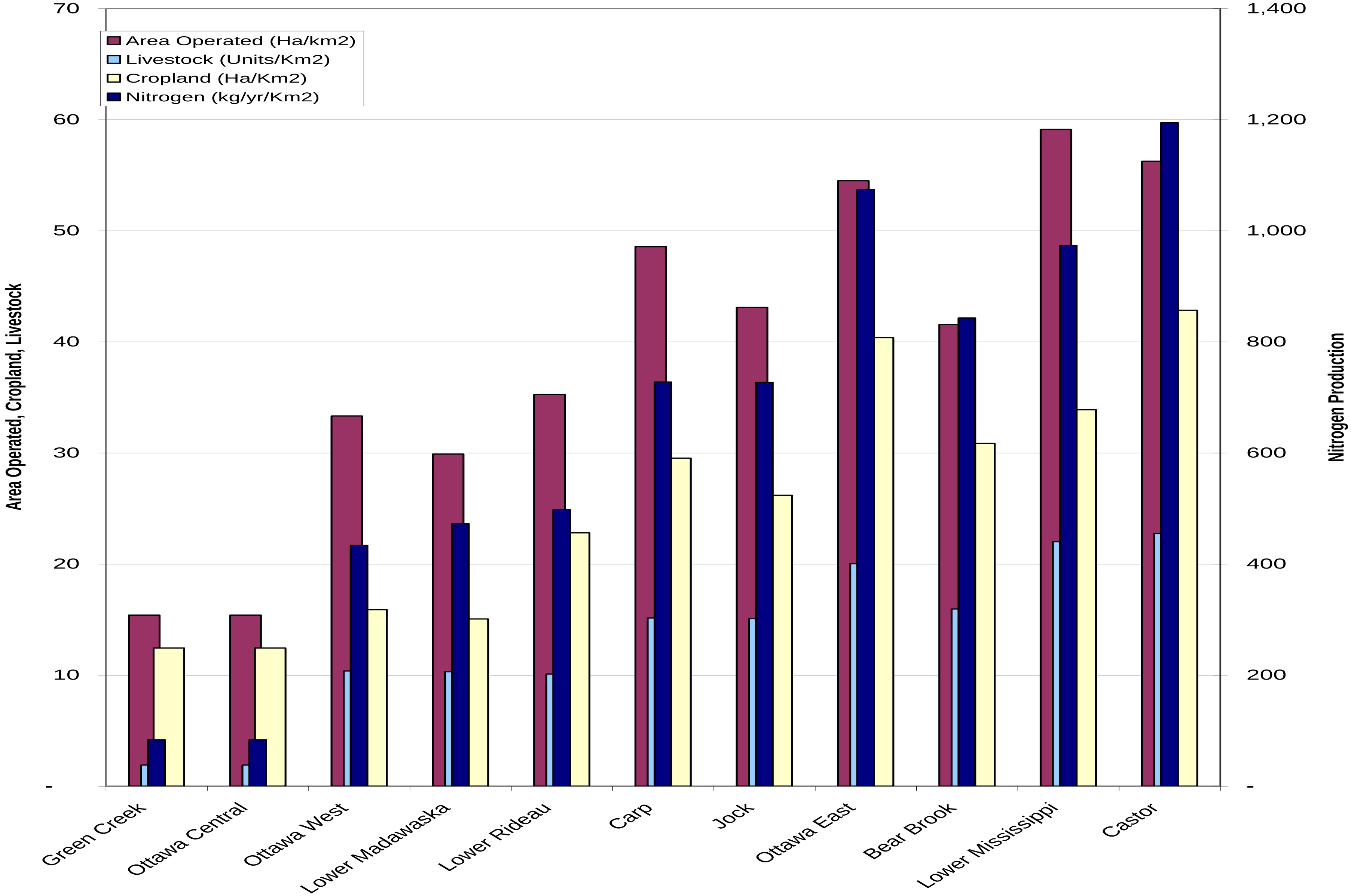


Figure 5-3 Farming Activities by Minor Watershed 2006

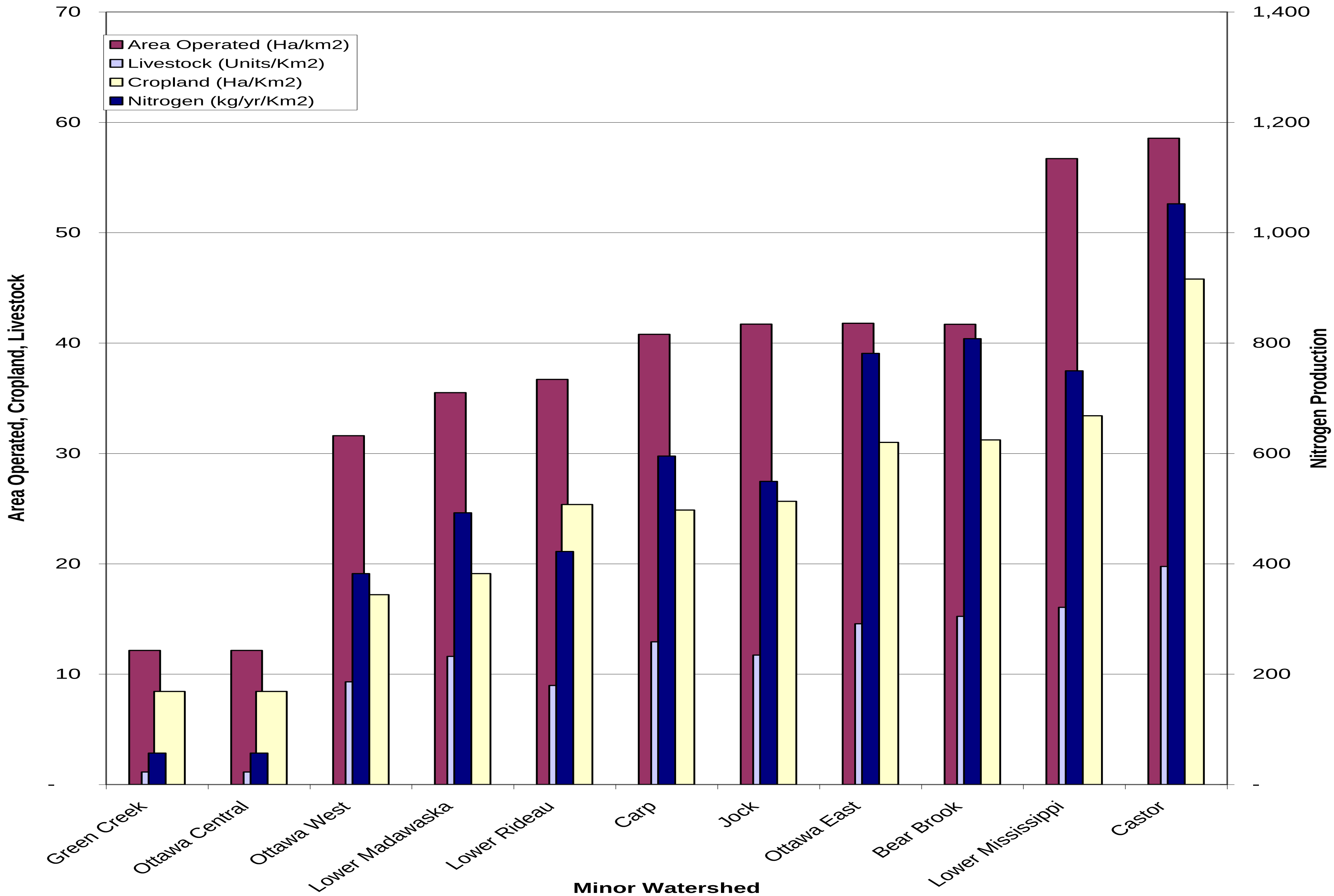


Table 5-15 Top Twelve Subwatersheds for Farming Activities 2001 and 2006

Rank	Farming Operations		Cropland		Livestock Units		Nitrogen Production	
	Subwatershed	Ha/ Km^2	Subwatershed	Ha/ Km^2	Subwatershed	Units/ Km^2	Subwatershed	Kg/ Km^2/yr
2001								
1	Cheney Drain	89	Cheney Drain	77	Cheney Drain	41	Cheney Drain	2,274
2	Mississippi d/s reach	80	Main Castor u/s	62	Main Castor u/s	39	Main Castor u/s	2,175
3	Main Castor u/s	79	**Beckett's Creek**	**60**	York & Fifth Conc. Drains	34	**Beckett's Creek**	**1,895**
4	**Cardinal Creek**	**75**	**Cardinal Creek**	**57**	**Beckett's Creek**	**33**	York & Fifth Conc. Drains	1,735
5	**Beckett's Creek**	**75**	Van Gaal West Main	55	Cody Creek d/s	27	Leamy Creek	1,392
6	Carp mid 1	71	Leamy Creek	55	Carp mid 1	26	Van Gaal West Main	1,392
7	Leamy Creek	70	Jock mid reach	55	Leamy Creek	25	Jock mid reach	1,392
8	Van Gaal West Main	70	York & Fifth Conc. Drains	54	Van Gaal West Main	25	Bear Brook mid 2	1,250
9	Jock mid reach	70	Mississippi d/s reach	51	Jock mid reach	25	Shaw's Creek	1,233
10	Cody Creek d/s	68	Main Castor d/s	45	Mississippi d/s reach	25	North Indian Creek	1,226
11	York & Fifth Conc. Drains	67	Shaw's Creek	43	Shaw's Creek	25	Main Castor d/s	1,211
12	Hobb's Drain	61	Carp mid 1	43	North Indian Creek	23	Carp mid 1	1,207
2006								
1	Carp mid 1	84	York & Fifth Conc. Drains	66	York & Fifth Conc. Drains	33	Cheney Drain	1,793
2	York & Fifth Conc. Drains	78	Cheney Drain	64	Cheney Drain	32	York & Fifth Conc. Drains	1,786
3	Mud Creek (Rdu)	77	Mud Creek (Rdu)	64	Main Castor d/s	28	Main Castor u/s	1,532
4	Mississippi d/s reach	74	Main Castor d/s	57	Main Castor u/s	28	Main Castor d/s	1,518
5	Cheney Drain	73	Main Castor u/s	51	Carp mid 1	27	**Bear Brook mid 2**	1,372
6	Main Castor d/s	70	Mississippi d/s reach	49	**Bear Brook mid 2**	26	Carp mid 1	1,227
7	***Flowing Creek***	***65***	Carp mid 1	49	***Flowing Creek***	***23***	North Indian Creek	1,195
8	Cody Creek d/s	63	**Central Castor**	**46**	North Indian Creek	22	Mississippi d/s reach	1,100
9	Main Castor u/s	63	*North Castor d/s reach*	46	Mississippi d/s reach	21	***Flowing Creek***	***1,090***
10	*North Castor d/s reach*	62	***Flowing Creek***	***46***	**Central Castor**	**21**	**Central Castor**	**1,085**
11	**Central Castor**	**61**	**Bear Brook mid 2**	43	Carp d/s reach	20	**Beckett's Creek**	1,067
12	**Bear Brook mid 2**	60	Lower Castor	40	**Beckett's Creek**	19	**Shaw's Creek**	1,027

(Data Source: Statistics Canada 2001 and 2006 Census of Agriculture Data (Catalogue No. 97C0003 / 22C0006)

6 TERRESTRIAL AND AQUATIC ECOLOGY

6.1 Terrestrial Ecology

6.1.1 Wooded Areas

Most of the Study Area's original forests were cut for lumber or cleared for farmland in the 1800s and early 1900s. Like other parts of southern Ontario, this has left a patchwork of wooded areas often located in valleys or wetlands that were not easily developed.

Notably, there has been significant re-growth forest in areas where farming was ultimately not feasible or where the lands were marginal farmlands (i.e., were a low soil capability class). This re-growth is evident in aerial photography (see Figure 6-1). The result today is that 90% of the Study Area's forests are located in areas other than preferred agricultural lands, that is, in areas where the surficial geology has medium to high permeability (Figure 6-2). Forest cover in the Study Area is shown on Maps 17A to 17F (Wooded Areas) in Appendix A.

Environment Canada has developed targets for forest cover in watersheds in the Great Lakes Basin. [8] These targets are intended to guide decision-making relating to the protection and restoration of habitat that is needed to support a healthy well functioning ecosystem. The landscape-scale targets are:

- 30% forest cover on a watershed basis;
- 10% of the watershed should be forest cover 100 m or further from the forest edge; and
- 5% of the watershed should be forest cover 200 m or further from the forest edge.

It should be noted that these targets are on a watershed basis. It is understood that variations will occur on a subwatershed scale.

Forest Cover

Forest cover in the Study Area is just over the 30% forest cover target. The re-growth noted above that is occurring in some areas is offset in other areas by development. Forest cover for the minor watersheds is shown in Table 6-1and forest cover for the subwatersheds is shown in Table 6 in Appendix B. Key points relating to forest cover include:

- the Study Area meets the 30% target for forest cover;
- all minor watersheds except the Lower Madawaska, Ottawa Central, Green Creek, Ottawa East and Castor meet the 30% target for forest cover;

[8] Environment Canada, 2004. How Much Habitat Is Enough? Available at: http://www.on.ec.gc.ca/wildlife/factsheets/fs_habitat-e.html

- the Jock minor watershed has the highest forest cover at 42%;
- the Lower Madawaska minor watershed has the lowest forest cover at 6%; and
- forest cover in the Ottawa Central, Green Creek and Ottawa East reflects the amount of urban development and agriculture in these minor watersheds.

However, it should be understood that not all of the forested area in the Study Area is designated as “natural environment” and is therefore protected to some degree. Of the 30% that is wooded area, over 13% is designated “residential” and includes vacant land for future development. A further 3% is designated “agricultural”. The net wooded areas that are not affected by rural development, either subdivision or village, is in the order of 25% of the City’s land cover.

Interior Forest

Total forest cover is not the only important metric. Larger areas of forest support ‘interior forest species’. The support of the interior species is impaired by forest fragmentation and incursions. Cut lines for roads and other easements as well as pocket developments in forests provide access routes for non-indigenous species that have a strong negative impact on interior forest species. Key points relating to interior forest are:

- at 8%, the Study Area is below the 10% target for interior forest cover that is 100 m from the forest edge;
- at 3%, the Study Area is below the 5% target for interior forest cover that is 200 m or more from the forest edge;
- the Bear Brook minor watershed meets the target for interior forest cover that is 100 m from the forest edge; and
- the Jock minor watershed meets the target for interior forest cover that is 100 m from the forest edge and that for interior forest cover that is 200 m or more from the forest edge.

Although the City meets or exceeds the Environment Canada targets for overall forest cover, it should be noted that:

- **rural development affects up to 16% of the forest cover;**
- **although there is extensive deep (interior) forest in the Bear Brook and Jock minor watersheds, elsewhere interior forest cover is limited (< 2%) and very fragmented; and**
- **interior habitat is significantly below target levels.**

Figure 6-1 Wooded Area Re-growth 1965 to 2008

Figure 6-2 Woodland Cover and Depth and Permeability of Overburden

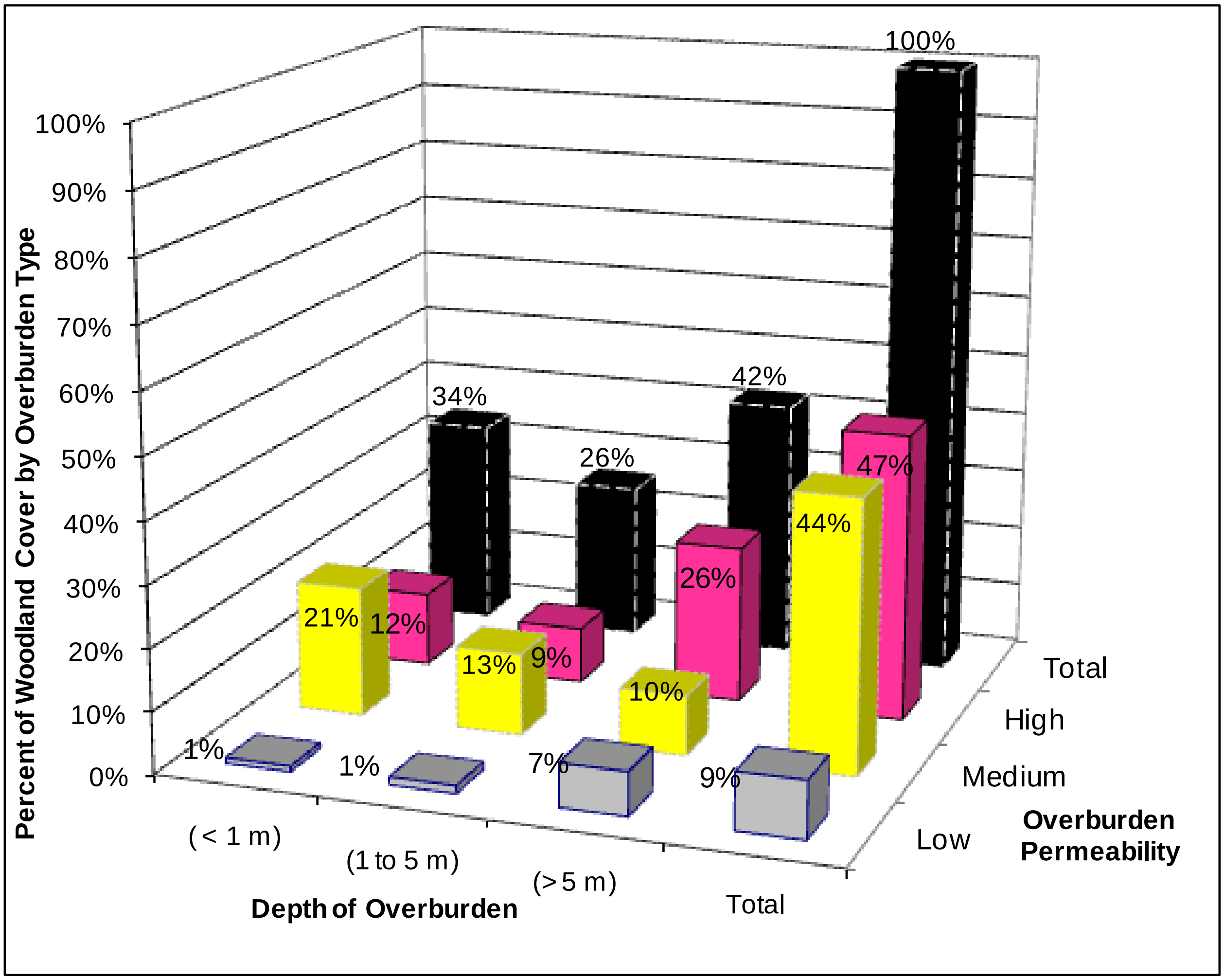


Table 6-1 Woodland Cover, Watersheds and Minor Watersheds*

Watershed	Minor Watershed	Total Area (Km2)	Cover (% of watershed)		
			Wooded Area		
			Total	100 m Interior	200 m Interior
Mississippi	Lower Mississippi	184	31%	7%	2%
Mississippi Total		*184*	*31%*	*7%*	*2%*
Ottawa	Lower Madawaska	5	6%	2%	
	Ottawa West	317	**38%**	7%	1%
	Carp	305	34%	8%	2%
	Ottawa Central	110	17%	3%	1%
	Green Creek	111	23%	3%	
	Ottawa East	265	24%	4%	1%
Ottawa Total		*1,113*	*30%*	*6%*	*1%*
South Nation	Bear Brook	484	**39%**	11%	4%
	Castor	591	22%	4%	1%
South Nation Total		*1,075*	*30%*	*7%*	*2%*
Rideau	Jock	573	**42%**	14%	6%
	Lower Rideau	647	33%	9%	3%
Rideau Total		*1,221*	*37%*	*12%*	*5%*
Total		**3,592**	**32%**	**8%**	**3%**

* Shading indicates where Environment Canada targets are met

Table 6-2 Deep Interior Forest Statistics by Minor Watershed

Watershed	Minor Watershed	Area (Km2)	Wooded Area 200m Interior for Patches > 1 Ha						
			Total Area		Patches				
			Km2	% Cover	Max (Ha)	#	# > 200 Ha	Average (Ha)	Median (Ha)
Mississippi	Lower Mississippi	184	4.0	2%	69	23		17	8
Mississippi Total		*184*	*4.0*	*0%*	*69*	*23*		*17*	*8*
Ottawa	Ottawa West	317	4.6	1%	77	44		10	4
	Carp	305	6.4	2%	101	38		17	7
	Ottawa Central	110	0.7	1%	20	7		10	9
	Green Creek	111	0.4	0%	20	5		8	6
	Ottawa East	265	2.4	1%	31	24		10	6
Ottawa Total		*1,108*	*14.5*	*1%*	*101*	*118*		*12*	*6*
South Nation	Bear Brook	484	17.8	4%	178	80		22	9
	Castor	591	5.6	1%	120	32		17	10
South Nation Total		*1,075*	*23.3*	*2%*	*178*	*112*		*21*	*9*
Rideau	Jock	573	35.7	6%	470	105	5	34	9
	Lower Rideau	647	20.4	3%	448	85	2	24	7
Rideau Total		*1,221*	*56.2*	*5%*	*470*	*190*	*7*	*30*	*8*
Total		**3,587**	**97.9**	**3%**	**470**	**443**	**7**	**22**	**7**

* Shading indicates where Environment Canada targets are met

Table 6-3 Distribution of Deep Interior Wooded Areas by Watershed

Watershed	Deep Interior (>1 Ha)					Wooded Area		
	Max Area (Ha)	Number			Total Area (Ha)	Max Area (Ha)	Number with Deep Interior	Total Area (Ha)
		> 200 Ha	> 100 Ha	Total				
Mississippi	187		1	28	703	472	85	7,245
Ottawa	187		2	131	3,171	944	16	35,868
Rideau	470	8	14	196	8,243	4,835		273,377
South Nation	178		8	125	5,102	1,139		35,495

6.1.2 Wetlands

Like forests, in the Study Area wetlands tend to be found in areas of relatively high permeability. Some 80% of the Provincially Significant Wetlands in the Study Area are located in areas with high permeability and 44% are in areas with bedrock near the surface. Only 5% of the wetlands are found in areas with low permeability where the majority of farming activities occur (see Figure 6-3).

As with forests, Environment Canada has developed targets for wetlands in watersheds in the Great Lakes Basin. [9] The landscape-scale targets are:

- 10% of a watershed should be comprised of wetlands; and
- 6% of any subwatershed should be comprised of wetlands.

The location of wetlands in the Study Area is shown in Maps 12A to 12F (Land Cover) in Appendix A where they are differentiated by type (i.e., swamp, fen, bog and marsh). Table 6-4 shows the distribution of wetlands by watershed and minor watershed. Key points include:

- the Study Area far exceeds the 10% target for wetlands with 20% estimated coverage[10];
- all minor watersheds except the Lower Madawaska meet the 10% target for wetlands;
- 6% of the Study Area is comprised of Provincially Significant wetlands;
- the highest coverage of Provincially Significant wetlands is found in Green Creek (11%), the Jock (9%), the Lower Rideau (9%) minor watersheds; and
- the lowest coverage of Provincially Significant wetlands is found in the Lower Madawaska (0%) and Ottawa East (1%).

---

[9] Environment Canada, 2004. How Much Habitat Is Enough? Available at: http://www.on.ec.gc.ca/wildlife/factsheets/fs_habitat-e.html

[10] Wetland cover was developed from Combined NRVIS Evaluated Wetlands and modeling and interpretation of unevaluated wetlands from DEM, soils, orthos and satellite imagery.

Figure 6-3 Wetland Cover and Depth and Permeability of Overburden

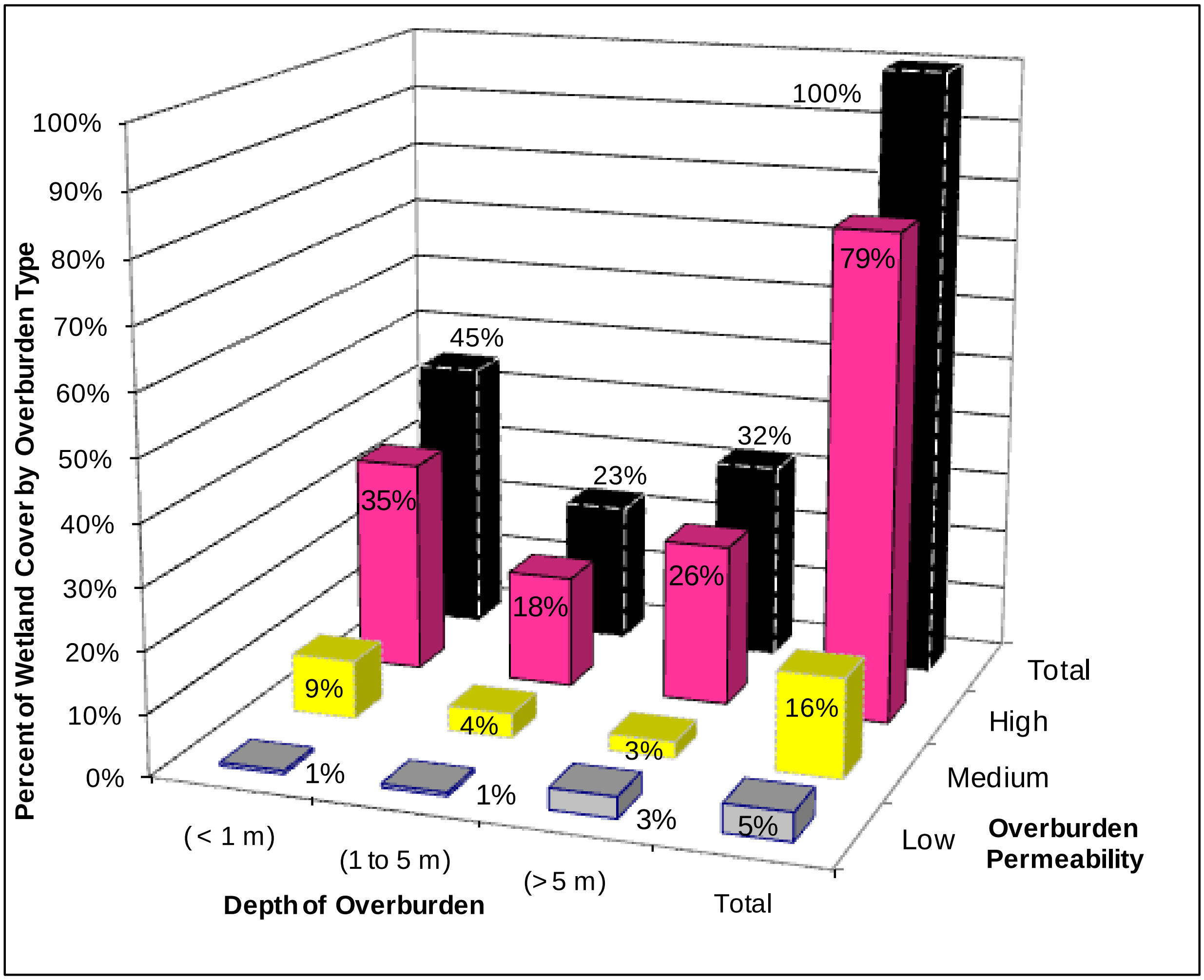


Table 6-4 Wetland Cover, Watersheds and Minor Watersheds*

Watershed	Minor Watershed	Total Area (Km2)	Cover (% of watershed) Wetland Provincially Significant	Cover (% of watershed) Wetland Total Estimated[11]
Mississippi	Lower Mississippi	184	7%	16%
Mississippi Total		*184*	*7%*	*16%*
Ottawa	Lower Madawaska	5		3%
	Ottawa West	317	7%	19%
	Carp	305	4%	19%
	Ottawa Central	110	3%	10%
	Green Creek	111	11%	18%
	Ottawa East	265	1%	9%
Ottawa Total		*1,113*	*5%*	*16%*
South Nation	Bear Brook	484	3%	19%
	Castor	591	3%	16%
South Nation Total		*1,075*	*3%*	*17%*
Rideau	Jock	573	9%	33%
	Lower Rideau	647	9%	21%
Rideau Total		*1,221*	*9%*	*26%*
Total		**3,592**	**6%**	**20%**

* Shading indicates where Environment Canada targets are met

11 Ontario Ministry of Natural Resources, Southern Ontario Resource Information System, 2003

6.2 Aquatic Habitat

Freshwater aquatic habitat is dependent on a number of factors. The complexity of aquatic ecosystems is illustrated in Figure 6-4 that shows the many flow, chemical, biotic, energy and habitat factors that contribute to water resource integrity[12]. Another view of this is presented in Figure 6-5, in which aquatic resources are affected by habitat (and external stressors). In this model, the underlying environmental components (climate, topography and geology) are modified by land use and management practices to yielding the characteristics of the water column and physical structure that define aquatic habitat. The water column and physical structures that affect habitat are summarized in Table 6-5.

Table 6-5 Water Column and Physical Structure Factors Affecting Habitat

Water Column	Physical Structure
• temperature • fertility (nutrients) • chemical variables • food sources • flow regime	• flow regime • bed materials / composition • geometry • riparian zone • connectivity

6.2.1 Water Column

Water temperature in streams is a dominant factor in determining aquatic resource potential and limits the potential aquatic community (see Table 6-6). It is influenced by groundwater, ambient air temperature and sunlight. The amount of groundwater contributing to baseflow is a function of the surficial geology and is typically reduced in urban areas where recharge of aquifers is lessened due to the change from pervious to impervious cover. Groundwater temperatures are unaffected by ambient air temperature and sunlight, and are typically relatively cold. Significant groundwater sources are required to maintain cold-water aquatic habitat. The amount of sunlight may be buffered by canopy of riparian vegetation and adjacent tree cover beyond the riparian zone.

Maps 10A to 10F provide information on August Average Stream Temperatures for the Study Area and the minor watersheds. Temperatures vary considerably and there is little pattern discernable at the mapping scale used, except for the cooling effect of esker features (e.g. on Mud Creek).

[12] Rankin (1991) as modified from Karr et al., 1986

Table 6-6 Temperature Preferences of Adult Fishes in Ontario

Category	Temperature Range(° C)
Warm Water	Maximum > 25
Cool Water	Maximum > 19 < 25
Cold Water	Maximum < 19

Nutrients are the controlling factor in the fertility of aquatic systems in terms of aquatic vegetation growth and associated oxygen levels. The saturation levels of oxygen decrease with an increase in temperature and the oxygen demand increases with the presence of decaying plant matter. The most oxygen-rich environments are coldwater streams with low nutrient levels. One important measure of nutrients in streams is total phosphorus. As noted in section 4, average levels of total phosphorus exceed the Provincial Water Quality Objective (PWQO) in most of the Study Area's watercourses, with the exception of the Ottawa and Mississippi Rivers. The Ottawa and Mississippi Rivers meet the PWQO in 99% and 86% of samples taken. The highest average levels of total phosphorus are found in the Carp River, Bear Brook, and in urban and rural creeks. The PWQO is met in the Carp River and Bear Brook in only 19% of samples. In urban creeks, the PWQO is met in only 28% of samples, and in rural creeks it is met in only 38% of samples. Because of high phosphorus levels, excessive weed growth and algae blooms are observed in late summer in many of the streams and rivers in Ottawa

Chemical variables include water quality parameters that include substances that can impair or are toxic to aquatic life. They also include parameters that reflect the buffering capacity of a system including alkalinity and pH. Details on water chemistry in Ottawa's rivers and streams are presented in section 4.3.

The availability of food sources and access to life cycle habitat through connectivity through the system are critical to overall functioning. The food sources and life cycle habitat includes the need for headwater streams including intermittent streams, both of which play key roles in the food chain, spawning habitat, and other functions.[13,14]

Flow regime includes the range, timing and frequency of flows and is influenced by climate, land use, geology, topography, groundwater contributions and other factors. This is discussed in section 4.1.

---

[13] Meyer, Judy L; et al, The Contribution Of Headwater Streams To Biodiversity In River Networks, 2007 February
[14] Richardson, John S. et al, A Synthesis of the Ecology of Headwater Streams and their Riparian Zones in Temperate Forests, 2007

6.2.2 Physical Structure

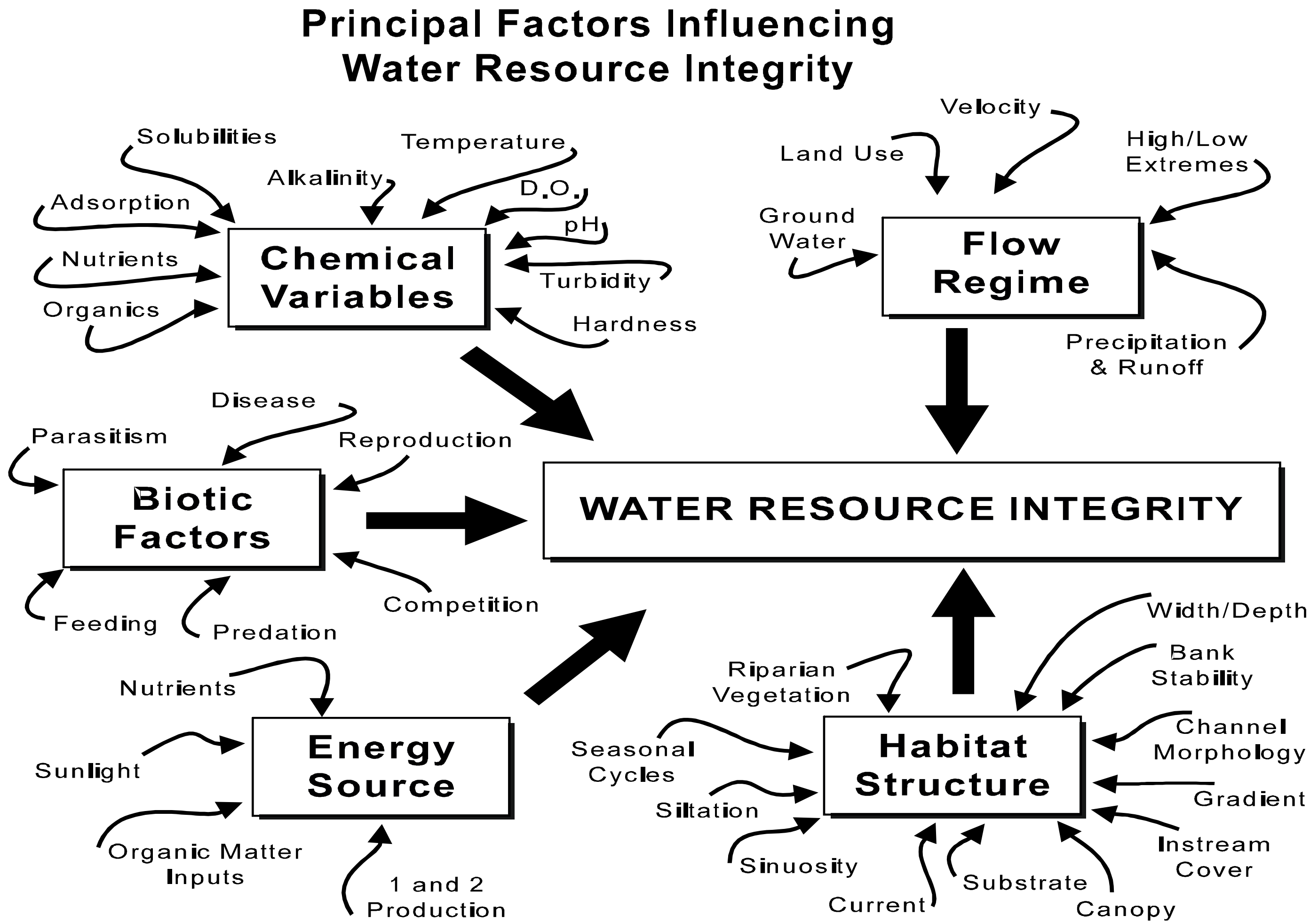
Perfect conditions in the water column alone do not create sufficient conditions for healthy aquatic communities. Physical structure is also a critical component of aquatic habitat. In addition to factors relating to the water column, healthy communities of benthic invertebrates and fish depend on the physical structure of streams to provide the places where they can spawn, shelter and find food. Each species has different requirements for different parts of its life cycle. Cobbles are needed for some species for spawning; other species need deep pools for loafing or protection from predators. Aquatic community composition is different in clay, bedrock, and cobbled streambeds.

The physical structure of a stream is a function of stream flow, the transport of sediment, the gradient of the section (reach) of the stream or river, the bed and bank materials and the adjacent riparian zone. The geometry of a reach – the slope, riffle-pool sequence, sinuosity, and cross-section – depends on the interactions of the flows of water and sediment with bedrock, soils and vegetation over time. Connectivity from large river systems through to headwater streams is needed for successful spawning and rearing of fish and to provide food, protection from predators and genetic variability. This is true for all fisheries, not just cold-water fisheries.

Changes in flows of water, slope, sediment quality, or sediment particle size will result in changes to the other factors and over time will affect the geometry of the reach. During periods of adjustment in the geometry, the reach will be ‘in transition’ and show signs of ‘instability’. Many streams in the Study Area have areas of instability due to changes in land use. Adjustments to land use changes often take decades. The historic loss of forest cover is a land use change that affects stream flows and which likely contributes to ongoing adjustments. The addition of municipal drains affects the drainage function in a watershed, and therefore stream flows and sediment transport, leading to instability. (Note that instability can be increased erosion or increased deposition.) This can be compounded by the straightening of a rivers and streams, which works against the natural tendency of watercourse to adopt a dynamic, sinuous shape. The readjustment from a straightened form can be partially offset in some areas where the drains are big enough that they do not attain critical thresholds that lead to erosion and instability. With field wash-off during the spring freshet, rural streams may receive more sediment than they can handle, leading to deposition of sediment. This may require maintenance over the long term and may limit aquatic habitat function.

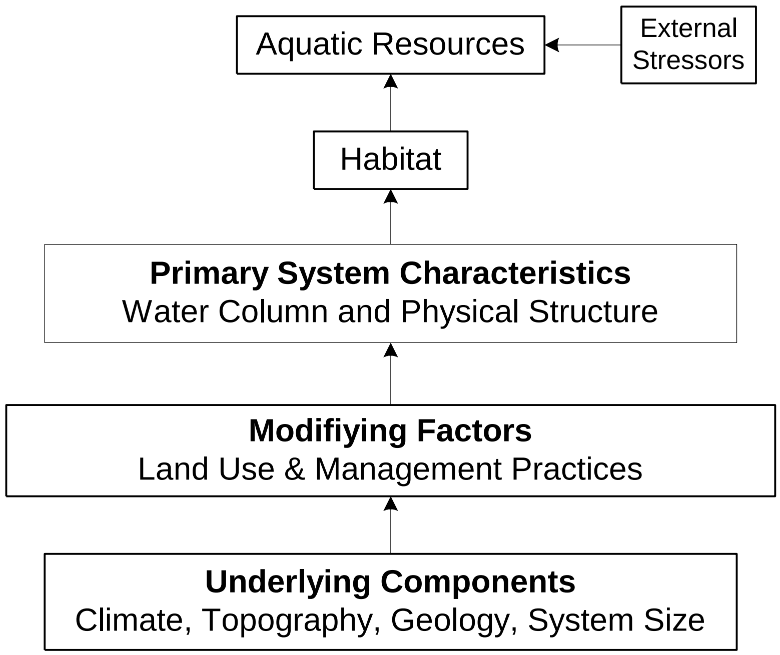
The physical structure of a stream is in a state of constant change with the movement of water and sediment. The rate and frequency of change is a function of the hydrology/flow regime. Changes in land use and associated management practices affect the flow regime, sediment transport, and habitat. As with changes in the water column, changes in physical structure affect the ability of different aquatic communities to use that habitat.

Figure 6-4 Principle Factors Influencing Water Resource Integrity



Source: EPA Nonpoint Source Watershed Workshop, E.T. Rankin, 1991

Figure 6-5 Factors Affecting Aquatic Resources



7 HIGHLIGHTS OF WATERSHED FUNCTION

While the Study Area is complex and varied in terms of topography, geology, soils, hydrology, water quality, vegetative cover and land use, a number of important interrelationships exist. This section of the Report explores these interrelationships that tell us how the natural (and human-altered) systems function.

7.1 Geology, Groundwater, Land Cover, Land Use

The surficial and bedrock geology, together with topography, are the determining factors in groundwater function, land cover (in terms of natural vegetation and wetlands) and land use. The Study Area is dominated by three major types of surficial deposits – limestone plains, clay plains and sand plains – that together comprise 82% of the area.

- **Limestone plains** such as those found in the Upper Jock River are defined by the underlying limestone bedrock. Soils on the limestone plains are typically of medium permeability, and extensive wetlands are found. The working assumption is that the wetlands are perched water tables, sitting on the aquitard of limestone bedrock. While the overburden is permeable, where wetlands are established the downward movement of water is limited by the bedrock. The soils in the limestone plains are not productive in terms of agriculture. Because of this, there has been fairly extensive re-establishment of wooded areas.

- The **clay plains** such as those found in the Ottawa East minor watershed are associated with mixed and variable sedimentary bedrock. Soils are of low permeability and function as an aquitard for downward movement of water. As such they limit infiltration of water to lower layers of permeable materials that may support groundwater storage and by so doing, limit the risk of contamination of underlying groundwater supplies that may be fed by other pathways.

  The soils on the clay plains support agriculture by retaining nutrients and water that support the productivity of crops. Most of the agriculture in the Study Area takes place on relatively flat areas with deep layers of low permeability overburden. These areas of low permeability overburden typically have restricted or poor drainage because of the predominance of clay and till soils. Most (84%) of the active agriculture areas are located on soils with a soil capability class of 2 or 3. Fully 80% of these areas on class 2 or 3 soils have restricted drainage or poorly drained soils (i.e., fall into Hydrologic Soil Groups C or D). Because these poorly drained soils maintain both water and nutrients, they are generally the most fertile soils in the Study Area. They also typically require enhanced drainage though the use of tile or municipal drains (see section 7.7.2). The poor drainage characteristics are mitigated through the installation of tile drains that support optimum root depth for crops. Because of the high agriculture capability of the soils in the clay plains, land use is dominated by agriculture with limited woodland cover scattered across the landscape.

- The **sand plains** such as those found in the southern portion of Bear Brook are associated with shale bedrock. Soils are highly permeable and there are very few wetlands found due to the generally good drainage (i.e., few areas have aquitards that prevent the downward flow of water and there are few locations where the water table reaches the surface). While the sand plains provide ready infiltration, groundwater storage is limited by the depth of the sand deposits. The groundwater storage function of the sand plains supports late summer flows; however, the ready infiltration increases the risk of groundwater contamination by any surface spills or other sources of contaminants.

- **Eskers** are a minor surface deposit in terms of area, but are important surficial deposits in terms of groundwater function. There are two significant eskers in Ottawa – the Var-Winchester Esker and the Flowing Creek-Mud Creek -Rideau Esker – that provide significant local storage that supports both drinking water supplies and influences local stream flows and stream water temperature through the summer months.

Figure 7.1 illustrates the relationship between geology, groundwater resources and baseflow in a schematic way.

7.2 Permeability of Overburden and Seasonal Trends in Flows

The presence of deep, high permeability overburden allows precipitation to infiltrate into the ground to recharge groundwater and also supports the subsurface flow of groundwater into stream systems (baseflow). In areas with low permeability overburden (such as the clay plains), the rate of infiltration of precipitation is reduced, groundwater storage is limited and discharges are equality constrained, resulting in low flow of groundwater to streams and rivers.

Analysis of the average monthly flows for Bear Brook, Castor, Jock, Carp, Rideau, and Ottawa Rivers compared the robustness of the late summer flows to the presence of deep permeable overburden. Only 9% of the Carp River and 7% of the Jock River has deep (more than 5 metres) high permeability overburden. By contrast, 48% of the Bear Brook and the 24% of the Castor River is covered by deep, highly permeable overburden. The analysis of monthly flows clearly illustrates that during the driest years, the Carp and Jock Rivers have much lower August flows than Bear Brook and the Castor River (see Figure 4-1 and Figure 4-3). Note that the flows have been converted to mm/month based on watershed area. This allows the direct comparison of outflow from the watershed to the monthly precipitation.

Table 7-1 Characteristic August Flows: Typical, Wet, and Dry Years

Watershed	% Deep Permeable Materials	Flow (m3/s)					% of Typical Flows			
		Typical (Median)	Wet		Dry		Wet		Dry	
			Max	95%	5%	Min	Max	95%	5%	Min
Bear Brook	48%	3.0	51.3	27.6	1.1	0.9	1,731%	932%	37%	29%
Castor	24%	2.6	39.2	27.8	1.2	0.9	1,507%	1,071%	45%	36%
Rideau (1)	21%	5.7	29.4	15.6	3.9	1.9	517%	273%	68%	34%
Carp	9%	1.9	35.7	21.3	0.5	0.3	1,930%	1,151%	30%	17%
Jock	7%	1.5	33.1	27.7	0.3	0.1	2,226%	1,865%	20%	9%

(1) Assessment of permeable materials is only for lower reach and the Rideau summer flows are controlled.

7.3 Geology and Surface Water Chemistry

In the Study Area, stream chemistry is influenced by the nature of the bedrock and surficial geology in a watershed. This is seen clearly with pH and alkalinity. The Ottawa River has distinctly different chemistry than other rivers and streams in Ottawa, with alkalinity of 23 and pH of 7.5. The low alkalinity of the Ottawa River reflects the dominance of the shallow overburden and metamorphic rock of the Canadian Shield. The alkalinity in the Rideau and Mississippi Rivers is also limited by the geology of the Canadian Shield. Alkalinity is highest in the Castor River and urban creeks, which reflects the presence of sources of carbonate including limestone.

The range for pH for all other rivers in the Study Area is between 8.1 and 8.2, which reflects the greater buffering capacity of the water as measured by the alkalinity.

Figure 7-1 Characteristics Relating to the Dominant Physiographic Units in the Study Area

	LIMESTONE PLAINS	CLAY PLAINS	SAND PLAINS	
BASEFLOW	Limited	Very Limited	Significant	BASEFLOW
GROUNDWATER RESOURCES	Limited	Very Limited	Significant	GROUNDWATER RESOURCES
WETLANDS	Extensive	Limited	Very Limited	WETLANDS
DOMINANT SOILS	Medium Permeability	Low Permeability	High Permeability	DOMINANT SOILS
DOMINANT SURFICIAL DEPOSITS	Limestone	Clay	Sand	DOMINANT SURFICIAL DEPOSITS
BEDROCK	Mixed Sedimentary Rock (mostly Limestone)	Mixed and Variable Sedimentary Rock	Shale	BEDROCK

7.4 Watershed Response to Alterations in Drainage

7.4.1 Alterations in Drainage in Developed Areas

Drainage of lands has been enhanced throughout the Study Area in developed areas (urban areas) and along. The most significant change in hydrology occurs in highly urbanized areas. Here, the increase in impervious surfaces (such as roads, parking lots and roofs) and the reduction in the depth of pervious top soils lead to a reduction in infiltration of precipitation and an increase in overland runoff. Evapo-transpiration may be reduced with the loss of forest cover and the associated reduced loss of groundwater through transpiration.

To address this change in hydrology, municipalities develop stormwater management systems that include sewers to collect and transport runoff, stormwater management facilities to hold and treat runoff, and in some places roadside ditches. While the goal of current stormwater management is to replicate "pre-development" flows, typically streams and rivers in urban areas have higher peak flows and higher volumes of flow during precipitation events compared to watercourses in undeveloped areas. Higher volumes and flows in urban channels result in enlargement of the channel cross-section with decreased stream structure including the thalweg, riffles, and pools

7.4.2 Alterations in Drainage in Agricultural Areas

Agriculture typically takes place in areas with poorly drained soils (Section5.4.1). Tile drains and municipal drains are used to enhance drainage of these soils. This allows optimal groundwater tables and soil moisture for root development of crops and for access to fields by equipment.

Drainage of agricultural land has an impact on hydrology. Tile drains remove excess water from the upper layer of the soil faster than evaporation alone would remove the water and they lower the groundwater table to below optimal root depths. The removal of excess water results in less surface ponding / surface storage with an associated reduction in the duration of saturated soil conditions. The related result is likely an increase in total runoff volume, due to the reduced storage and reduced evaporation, with the associated increased peak flows. However, the tile drains are typically only active where there are significant volumes of water as a result of high volume rainfall events and winter and spring snow melts. Tile drains are typically inactive during summer months when high evapo-transpiration minimizes excess water in the upper layers of the soils.

With the subsurface drainage, surface wash off of sediment directly to receiving streams may be reduced. However, phosphorus in the surface layers of soil may build up because of its bonding with soil particles; this may increase the phosphorus loading to watercourses during large rainfall events when surface sediment transport occurs.

7.5 Water Quality and Land Use

Land use practices, both urban and rural, can have profound effects on water quality in rivers and streams. The analysis in section 4.4 shows that agricultural practices affect the water quality of rivers such as Bear Brook, which has the highest average values for phosphorus and nitrogen. The source of the high levels for copper and iron are not clear and may be related to the local geology. Only 19% of samples taken in Bear Brook between 1998 and 2007 met the Provincial Water Quality Objective (PWQO) for phosphorus.

Urban creeks show the highest values for *E.coli* and chlorides. Only 38% of samples taken between 1998 and 2007 met the PWQO for *E. coli*; only 23% met the PWQO for chlorides, and only 27% met the PWQO for iron.

7.6 Alterations in Vegetation Cover and Hydrology

Evapo-transpiration is the movement of water back into the atmosphere through both evaporation from water surfaces and transpiration of water from vegetation. In natural landscapes, evapo-transpiration is a major component of the hydrologic cycle; the removal of forests results in a reduction in evapo-transpiration. If the new land use is agricultural, the net effect may be an increase in infiltration into the ground. Where the new land use is urban, with its increase in imperviousness, the net effect will be a dramatic increase in surface runoff with its attendant impact on streams and rivers (low base flows, high peak flows and high volumes of flow during precipitation events).

7.7 Influences on Aquatic Habitat

Hydrology is the fundamental component in creating and maintaining aquatic habitat. The flow regime is greatly influenced by the underlying surficial geology, drainage system characteristics, and adjacent land use (especially the extent of vegetative and impervious cover). The surficial geology supports base flows and influences the temperature regime of rivers and streams. The extent of vegetation and imperviousness combined with the surficial geology and topology influences the amount (and quality) of runoff resulting from different rainfall events and watershed flows. The interaction of watershed flows with the stream form drives the erosion processes and sediment transport both of which create and modify habitat structures including the thalweg (deepest portion of the channel), riffles, and pools.

8 RECOMMENDATIONS

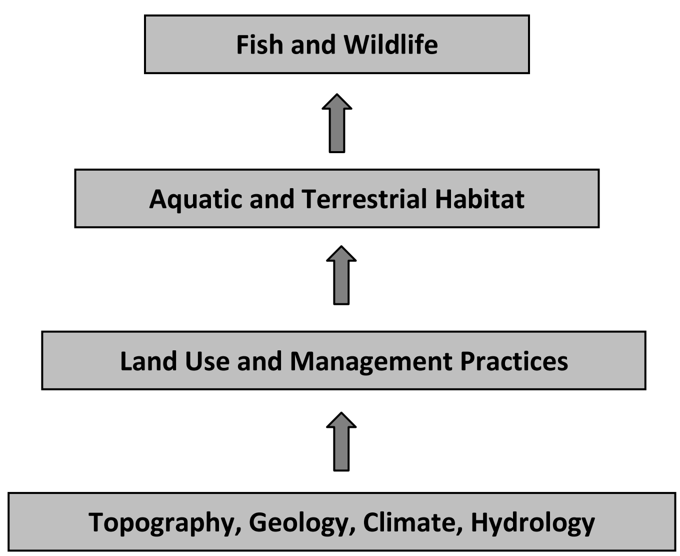
As evidenced in this Report, the City produces or has access to a rich array of data and information on its watershed resources. In particular, there is extensive information available on key environmental components that allow us to characterize the form of the watersheds. There is also a significant amount of information available on the current condition of the watersheds. However, there is less information available – and less understanding – of how the watersheds function.

Key functions provided by watersheds include:

- *hydrological functions* (such as the collection, storage and release of water);
- *ecological functions* (such as the cycling of nutrients and energy and the provision of habitat for flora and fauna, composition and associated variations of aquatic communities across the City); and
- *human-centred functions* (such as the provision of ground and surface water for human use, the assimilation of waste, and the provision of recreational opportunities).

A key desired end-point of ecological function is the ability to support self-sustaining communities of species, both within the terrestrial and aquatic environments. This requires sufficient habitats of sufficient quality to support the life cycles of fish and wildlife species. Habitat is influenced by natural factors (such as topography, geology, climate and hydrology) and human land use and management practices.

Figure 8-1 Influences on Aquatic and Terrestrial Communities



8.1 Terrestrial System Work

Develop wooded areas characteristics and associated habitat potential

The Provincial Policy Statement (PPS 2005) and the Official Plan often require assessments of proposed development or infrastructure projects to address the question, "Is there a significant impact on the terrestrial ecosystem values and functions?" The ability of the City, proponents and other review agencies to answer this question is often limited, in large part due to the lack of current data, consistent definitions, and a consistent methodology. The change in habitat potential could be estimated based on the proposed changes to tree cover from a proposed development or infrastructure project. To do this, the following information is needed:

- Updating the delineation of wooded areas: The City has established a practice of taking citywide aerial photography every three years. This should include the delineation and updating of forest, scrub land, and 'wet areas' with each cycle of citywide aerial photography.

- Field Verification of vegetation composition: The most recent ground based vegetation inventory from MNR dates back to 1978. MNR has a vegetation inventory sampling program that requires two years of field work following established protocols. From this, predictive vegetation mapping and habitat potential could be synthesised.

- Deriving citywide vegetation cover and habitat potential: MNR has developed models that predict vegetation cover and habitat potential. The model uses field data collected at a scale consistent with aerial photograph interpretation and has been calibrated and verified for St. Lawrence Islands National Park and adjacent areas. The modelling approach incorporates other factors including topography, soils, soil moisture etc. Habitat potential is derived from preference for different species for different assemblages of vegetation. It is anticipated that MNR will be carrying out this work in the City of Ottawa.

8.2 Aquatic System Work

The Provincial Policy Statement (PPS 2005) requires the ecological function of aquatic environments to be addressed in tandem with terrestrial environments. Understanding the ecological function of the aquatic environment requires a characterization of the aquatic system including what is living in streams and rivers, how that differs in different areas of the City and how the different aquatic conditions affects management decisions. The Water Environment Protection Baseline Monitoring Program has been updated to provide biological (benthic organisms and fish communities) and flow monitoring information across the City, in addition to the established water quality monitoring program. The design of the Baseline Monitoring

Program has been adapted to reflect the importance of physiography and surficial geology as illustrated in the Characterization Report. Additional work is required to:

- improve the understanding of the physical structure of streams and its importance to habitat function and life within that habitat; and
- explore how to protect and manage small streams.

Improve understanding of physical structure of streams and habitat function

As outlined in the aquatic resources section of the Characterization Report, the physical conditions of streams is largely overlooked in terms of stormwater management. Changes in flows as a result of changes in land use can affect the structure of aquatic habitat. The effects of this can be different in different parts of the City and reflect among other factors the underlying surficial deposits (whether the stream is located on a limestone, clay or sand plain). To improve understanding of the relationship between the physical structure and habitat function, the City should provide guidance on standard practices for information needs and assessment methods for stream structure with supporting case studies for typical streams in Ottawa.

Protecting and managing small streams

Small streams, although they may appear insignificant, are important to the function of watersheds, and are often at risk from filling in, burying and relocation. To provide direction on the protection and management of these watercourses, the City should develop a City of Ottawa Standard of Practices for the Protection and Management of Small Streams based on case studies of recent projects and natural channel guidelines issued elsewhere. The Standard of Practice would identify different classes of projects including:

- <u>Natural channel design for greenfields sites:</u> how to design optimal natural channels as land use changes from rural/agriculture to urban;
- <u>Realignment:</u> when, where, why, and how to realign channels to maintain or enhance natural function while protecting infrastructure and high value property;
- <u>Hardened shoreline solutions:</u> where and when 'hard' solutions are required and what approaches are recommended; and
- <u>Do nothing:</u> when to leave the channel alone.

8.3 Best Management Practices Work

Best Management Practices (BMPs) are design, construction, and maintenance practices that reduce the quantity of stormwater runoff, minimize its impact, prevent erosion, reduce pollutant loading and capture pollutants. BMPs in rural areas include such practices as improving manure storage and properly disposing of milk house waste; in urban areas, BMPs include such practices as cleaning out catchbasins and treating stormwater in ponds. The City should conduct a structured citywide assessment (urban and rural) in order to:

- determine what types of BMPs have been applied and where;
- assess the effectiveness of the applied BMPs; and
- identify priority areas for increased application of BMPs.

8.4 Information Base and Reporting

At a foundational level, the Characterization Report establishes the context for assessing terrestrial and aquatic ecological values and functions in the broader ecosystem context of topology, geology, land use, and climate. It also provides a snapshot of environmental conditions and trends as of the time of writing (2010). In the future, further work should be done to improve the City's environmental information base and its reporting. These improvements could include the following.

Improvements to reporting

The Characterization Report should be updated, in whole or in part, at regular five-year intervals. Improvements to components of the report, as suggested in this document, should be reported on as they are completed. The City should develop a framework for reporting on various components of the environment. Reporting should also support the reporting on key indicators carried out through the Water Environment Strategy.

Refine and document analyses in Characterization Report

The analytic processes used in the development of the Characterization Report and the lessons learned should be reviewed, refined, and documented to enable the long term maintenance and sharing of methodologies.

Improve information base, analysis, and understanding

There are significant gaps in the level of information and assessments presented in the document. Future proposed areas of work include:

- Terrestrial inventory, vegetation mapping and habitat potential;
- Aquatic system characterization, habitat function and the protection of small streams;
- Refinement of the definition of valley lands and escarpments;

- Development of risk mapping for Leda clays and slopes;
- Refinements to components of hydrology;
- Assessment of need for, use of and effectiveness of Best Management Practices;
- Data collection, management and dissemination; and
- On-going updates and improvements to the underlying data sets consistent with the need of assessing the ecological function.

Data Collection, Management and Dissemination

Environmental data is routinely collected for a wide range of projects taking place in the City. With the exception of the work carried out by the Water Environment Protection group, there is a lack of data collection protocols, capture of the data into corporate databases, and review of data. The net result is that the data is not available for use by other departments, agencies, and organizations. To address this, the following initiatives are proposed.

Data capture

The City should:

- adopt the data collection protocols established by the Water Environment Protection group and the Province as corporate standards, with additional protocols if required;
- identify a person or group to be the custodians of each data set with the responsibility of receiving, reviewing, and consolidating the data into corporate or provincial databases from other sources;
- make the corporate and provincial databases accessible to all with a business function need for the data;
- report annually on the data collected to set a context for reference to others (i.e., be the first to interpret the data);
- publish the data under open data concepts upon completion of the annual report; and
- use the annual reports and input received to update priority areas and issues for study.

As an example, discussions with MNR have resulted in a tentative plan to define data collection needs for Environmental Impact Studies in terms of the Ecological Land Classification protocols developed by MNR. The data would be submitted to MNR who would review and load it into the Provincial Database. The City would receive the updated version of the database as part of a regular refresh of the City's copy of Provincial Data. The effect of the changes would be assessed in context of the citywide terrestrial cover and habitat potential map discussed in other sections of this paper. .

Data updates from external sources

The City should systematically publish data to and download data from the Land Information Ontario data warehouse. The province maintains a number of data sets that are fundamental to the City information needs. A complete list should be established, with systematic downloading for all data sets.

Data dissemination

- Disseminating data to partner agencies: While the City has downloaded data from the Land Information Ontario data warehouse, there is no consistent approach and there is a lack of resources and coordination. This is also true for our partner agencies. With the recognition of the watershed scale of some studies, (e.g., Source Water Protection) and the close working relationship with the Conservation Authorities, it is proposed that the City act as a local node for our conservation partners in maintaining readily accessible data sets not just for the City but for the areas covered by the source water programs. The City standards will provide consistency across the 3 conservation and 2 source water jurisdictions – leading to a commonality of standards for data collection and dissemination among our partners.

- Disseminating data to the Consultant and Development Industry: Given the intention to use the *Characterization of Ottawa's Watersheds* as a foundation document, a subset of the information base should made available to anyone completing a study that uses the Report as a base reference. The subset of information should include the study area and an appropriate area extending beyond it.

8.5 Proposed Candidate Reference Subwatersheds

A key challenge of environmental monitoring is to understand how complex systems function. The development of this Report has provided substantial insight into some aspects of watershed function. To aid in future monitoring and assessment, a number of candidate reference subwatersheds with dominant characteristics were identified (see Table 8-2). These candidate subwatersheds with their dominant characteristics provide benchmarks against which ecological function in other similar subwatersheds can be compared in the future.

The candidate subwatersheds reflect the following typology of dominant characteristics:

- Urban/Suburban subwatersheds (developed and developing);
- Agricultural subwatersheds (cropland, livestock and mixed); and
- Non-Clay Plain subwatersheds (sand plain, limestone plain, and rock outcrop/Canadian shield.

Table 8-1 Candidate Subwatersheds: Farming (2006)

Subwatershed	Area Operated (Ha/Km2)	Cropland (Ha/Km2)	Livestock (Units/Km2)
	2006	2006	2006
Bear Brook headwaters	30	23	7
Beckett's Creek	49	37	19
Brassil's Creek	24	9	5
Cardinal Creek	47	37	17
Casey Creek	49	28	16
Central Castor	61	46	21
Cranberry Creek	41	25	12
Flowing Creek	65	46	23
McKinnon's Creek	36	27	10
Mud Creek (Rideau)	77	64	18
South Indian Creek	35	28	10

Table 8-2 Candidate Reference Subwatersheds with Dominant Characteristics

Land Use		Subwatershed	Characteristics
Dominant	**Sub-category**		
Urban / Suburban	Developed	Sawmill Creek	Upstream area has deep groundwater aquifer and wetland areas, lower half is clay plain Development from the 1950 through to present Extensive valley system with riparian cover, lots of local blockages
		Bilberry Creek	Deep valley system armoured in 1980s Largely developed in the 70s and 80s Clay plain, predating most stormwater quality ponds
		Taylor Creek	Clay plain with escarpment feature at end of residential development Downstream channel through urban natural feature Potential good flow monitoring at storm dry pond weir
		Pinecrest Creek	Clay plain, old urban area, fully developed Recent stream restoration works
		Barrhaven Creek	UV disinfection with over attenuation of frequent events to protect downstream 500 m canopied natural channel Ongoing flow and water quality monitoring of pond
	Developing	Shirley's Brook	Rock outcroppings headwaters and central / downstream clay plain
		Cardinal Creek	Upper areas dominated by agriculture Urban development in a portion of the mid-subwatershed Lower subwatershed dominated by deep valley system and karst features
		Mosquito Creek	Headwaters in deep high permeability to variable permeability areas Central and lower watershed dominated by clay plains with development occurring
Agriculture	Cropland	Mud Creek	Clay plains with significant esker feature crossing the subwatershed
		Flowing Creek	Headwater in limestone plain then sand plain, farming in clay plain in lower subwatershed
	Livestock	Becket's Creek	Dominated by Clay plains in headwaters with some sand plains High level of livestock in 2001 has dropped of in 2006
	Mixed	Central Castor	Deep permeable overburden in headwaters with central clay plain with low to medium/ variable permeability

Land Use		Subwatershed	Characteristics
Dominant	**Sub-category**		
Other Non-Clay Plain Physiographic Units	Sand Plain	South Indian Creek Bear Brook Headwaters	Most uniform sand plain subwatershed. 56% tree cover Dominated by sand plan. Some agriculture
	Limestone Plain	Brassil's Creek	Dominated by Limestone plain, with some peat and muck areas. 19% Provincially Significant wetland
	Rock Outcropping / Canadian Shield	Casey Creek	Headwaters in Canadian shield wetlands, shallow till rock ridges Downstream are flows through clay plains

Table 8-3 Candidate Reference Subwatersheds with Dominant Characteristics (Summary Statistics)

Minor Watershed	Subwatershed	Physiographic Units	Farming Activity (2006)			Urban		Deep Overburden / Permeability (%age of watershed)			Environmental (%age of watershed)			Monitoring To Date					Comments
			Area Operated (Ha/Km2)	Cropland (Ha/Km2)	Livestock Units	Impervious (%)	Development *	Deep High/ Total High	Total Medium and Variable	Deep Low/ Total Low	Trees	Provincially Significant Wetland	SOLRIS Wetland	Flow	Baseline (#points)	Inputs (# of years)	Biology (#of Years)	Morphology	
Lower Rideau	Barrhaven Creek	Clay Plain				20	D		30	50/70	5%	0%	1%	Y					Monitored SWM Pond over period of development (1992 through early 2000s). 500 m d/s canopied natural channel
Ottawa	Bilberry Creek	Clay Plain				40	D	8/10	16	68/74	11%	4%	6%	2					No treatment, high impervious
Ottawa	Pinecrest Creek	Clay Plain Limestone Plain Sand Plain				35	D	16/18	36	25/46	5%	0%	2%		1	1	1	Y	Mixed old and new urban area. High imperviousness with limited stormwater management. Restored creek.
Lower Rideau	Sawmill Creek	Sand Plain Clay Plain				27	D	42/44	25	16/30	24%	0%	14%	5	5	1+	1+		Many studies. Urban watershed with upstream aquifer/ wetland.
Ottawa	Taylor	Clay Plain				42	D	2/	13	71/83					1				Downstream creek through UNA. Easy flow monitoring location. High impervious area.
Ottawa	Cardinal Creek	Clay Plain Till Plain Limestone Plain	47	37	17		F	1/1	20	53/78	16%	0%	6%	2	1	1	1		1992 Fisheries study by Niblett. Urban and agriculture. Development pressures
Ottawa	Shirley's Brook	Clay Plain Shallow Till-Rock Ridges Limestone Plain					F	0/9	64	1/27	44%	10%	20%		2				Development pressures. Rock ridges. High forest cover and significant wetland area.
Ottawa	Beckett's Creek	Clay Plains Sand Plains Limestone Plains	49	37	19			15/17	49	28/34	26%	0%	8%	Y					Significant agriculture in both livestock and crop.
Jock	Flowing Creek	Clay Plain Sand Plain Limestone Plain	65	46	23			15/32	33	31/35	29%	5%	17%		1	1			High agriculture with deep permeable tree coved overburden in headwaters.
Castor	Central Castor	Sand Plain Clay Plain Peat & Muck	61	46	21			33/38	25	26/37	27%	7%	17%						Sand plain in headwaters, clay plain agricultural area. Notable forest and wetland cover.
Lower Rideau	Mud Creek (Rideau)	Clay Plains Sand Plains Esker	77	64	18			25/25	27	16/30	21%	0%	12%		2	1		Y	Significant farming, cropland
Bear Brook	McKinnon's Creek	Clay Plain Sand Plain	36	27	10			16/16	14	64/70	12%	0%	5%			1			Development pressures
Ottawa	Casey Creek	Shallow Till-Rock Ridges Clay Plain	49	28	16			1/7	62	13/30	42%	9%	18%		1				Headwaters in Canadian shield wetlands, shallow till rock ridges
Bear Brook	Bear Brook headwaters	Sand Plains Peat & Muck	30	23	7			70/	7	22/22	47%	0%	20%			1	1		High permeability, high tree cover
Bear Brook	South Indian Creek	Sand Plain	35	28	10			74/79	5	15/16	56%	1%	23%						High forest cover and deep permeable overburden
Lower Rideau	Cranberry Creek	Sand Plain Peat and Muck Clay Plain	41	25	12			42/49	28	23/23	51%	17%	39%		1	1	1		Fisheries 1992 High forest and wetland cover
Lower Rideau	Brassil's Creek	Limestone Plain Peat and Muck	24	9	5			0/29	68		51%	19%	38%		1	1	1		Dominated by Limestone plain, high forest and wetland cover

F – Future, D – Developed, Livestock units based on estimates of nitrogen production, shading denotes dominant characteristic

9 INFORMATION SOURCES

Files:

1. Topography: 1988 Ontario Base Mapping 1:10,000 Digital Elevation Model

2. Stream Network: Ontario Ministry of Natural Resources, Water Resources Information Project

3. Road network: Surveys and Mapping, City of Ottawa

4. Subwatersheds: Environmental Sustainability, City of Ottawa

5. Slopes, Valleys, and Escarpments: Environmental Sustainability, City of Ottawa, derived from Digital Elevation Model with reference to 2010 Natural Heritage Reference Manual.

6. Bedrock Geology: 2001 from Urban Geology of Canada's National Capital Area, Geological Survey of Canada, NRCAN

7. Bedrock Elevation: 2001 from Urban Geology of Canada's National Capital Area, Geological Survey of Canada, NRCAN

8. The Physiography of Southern Ontario: Chapman and Putman, 3rd ed. 1984 Ministry of Natural Resources

9. Surficial Geology (Quaternary Geological Units): 2003, Ontario Geological Survey, Ministry of Northern Development and Mines

10. Soils: 2008, Ontario Ministry of Agriculture and Rural Affairs

11. Temperature and Rainfall: 1890 through 2008, Environment Canada, 2008a, Environment Canada Meteorological Services, Ottawa CDA Weather Station (Experimental Farm)

12. Stream flows: 2008, Environment Canada, Water Survey of Canada online data

13. Water Quality: 2009, Water Environment Protection Program, City of Ottawa

10\. Evaluated Wetlands: 2008, Ontario Ministry of Natural Resources, Kemptville District

11\. Woodlands: 2007 Southern Ontario Land Resources Information, Phase 1

12\. Vegetated Areas: Natural Environment Systems Strategy, Region of Ottawa Carleton

14. Land Use: City of Ottawa Detailed Land Use, 2005, City of Ottawa

15. Land Cover, 2007 Southern Ontario Land Resources Information V2.

16. Impervious Cover: City of Ottawa, Surveys and Mapping 1:2,000 mapping

17. Stormwater Management Facilities: Stormwater Treatment Unit, City of Ottawa

18. Storm Sewers: Capital Planning / Strategic Asset Management Unit, City of Ottawa

19. Constructed (Municipal) Drains: Ontario Ministry of Agriculture, Food and Rural Affairs

20. Agricultural Information: 2001 and 2006 Census of Agriculture Data for Eastern Ontario Sub-Watersheds (Catalogue No.: 97C0003 / 22C0006)

APPENDIX A: MAPS

Map 1A - Topography: Study Area
Map 1B - Topography: Carp River, Lower Mississippi and Ottawa West
Map 1C - Topography: Jock River
Map 1D - Topography: Rideau River, Ottawa Central
Map 1E - Topography: Castor River
Map 1F - Topography: Bear Brook, Green Creek, Ottawa East

Map 2A - Slope: Study Area
Map 2B - Slope: Carp River, Lower Mississippi and Ottawa West
Map 2C - Slope: Jock River
Map 2D - Slope: Rideau River, Ottawa Central
Map 2E - Slope: Castor River
Map 2F - Slope: Bear Brook, Green Creek, Ottawa East

Map 3A - Bedrock Elevation by Watersheds and Minor Watersheds
Map 3B - Bedrock Geology by Watersheds and Minor Watersheds

Map 4A - Physiographic Units: Study Area
Map 4B - Physiographic Units: Carp River, Lower Mississippi and Ottawa West
Map 4C - Physiographic Units: Jock River
Map 4D - Physiographic Units: Rideau River, Ottawa Central
Map 4E - Physiographic Units: Castor River
Map 4F - Physiographic Units: Bear Brook, Green Creek, Ottawa East

Map 5A - Surficial Geology: Study Area
Map 5B - Surficial Geology: Carp River, Lower Mississippi and Ottawa West
Map 5C - Surficial Geology: Jock River
Map 5D - Surficial Geology: Rideau River, Ottawa Central
Map 5E - Surficial Geology: Castor River
Map 5F - Surficial Geology: Bear Brook, Green Creek, Ottawa East

Map 6A - Depth of Overburden and Permeability of Surficial Geology: Study Area
Map 6B - Depth of Overburden and Permeability of Surficial Geology: Carp River, Lower Mississippi and Ottawa West
Map 6C - Depth of Overburden and Permeability of Surficial Geology: Jock River
Map 6D - Depth of Overburden and Permeability of Surficial Geology: Rideau River, Ottawa Central

APPENDIX B: TABLES OF SUBWATERSHED CHARACTERISTICS

APPENDIX C: WATER QUALITY