

**BLACK/HARMONY/FAREWELL CREEK WATERSHED
EXISTING CONDITIONS REPORT
CHAPTER 8 - CLIMATE**

**Draft
November 2009**



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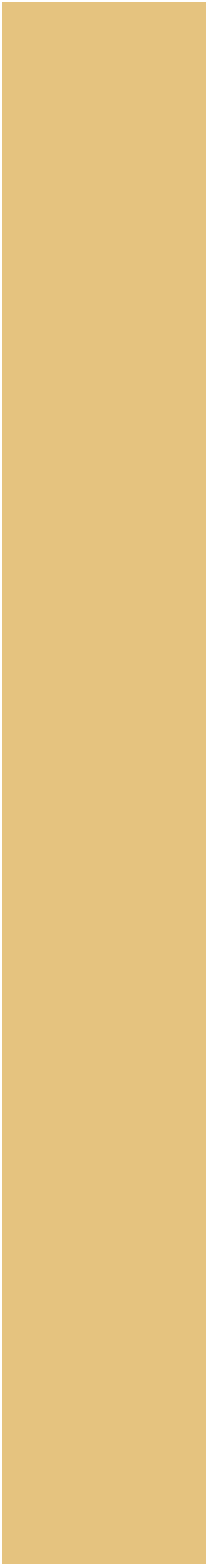
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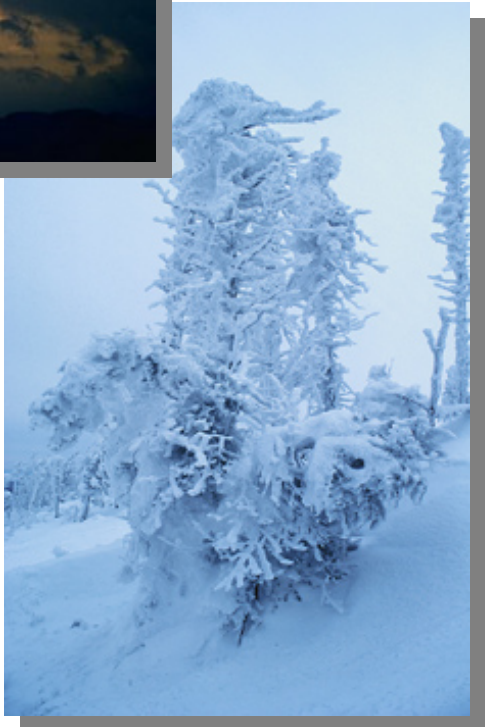
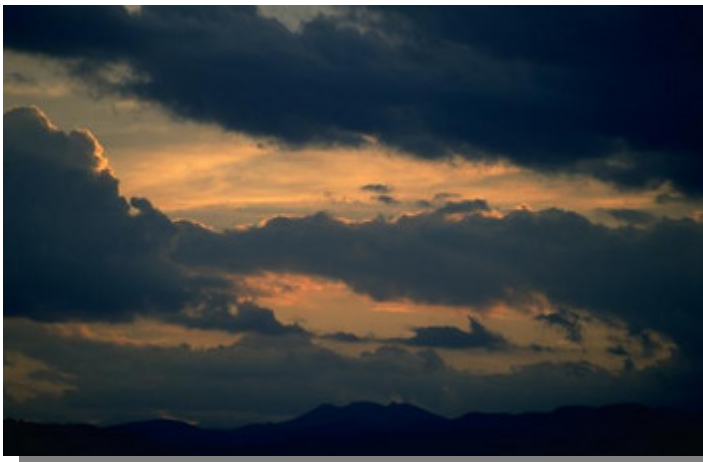
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1.0 INTRODUCTION

Climate and the monitoring of climate information are vital components to the functioning of the Conservation Authority. Climate information is used on a daily basis for flood warning and forecasting, it is also used in conjunction with other collected data to analyze long-term trends. Precipitation, temperature, solar radiation, evaporation and transpiration are some of the key elements of on-going hydrologic assessments. The purpose of this chapter is to identify the available climatic data in and around the Black/Harmony/Farewell Creek watershed.



climate information provides vital components to the functioning of the Conservation Authority'

2.0 STUDY AREA AND SCOPE

The Black/Harmony/Farewell Creek watershed is situated entirely within the Regional Municipality of Durham and covers an area of approximately 108 km² (Figure 1). The watershed drains southerly towards Lake Ontario from its headwaters which originate in the south slope till plain of the Oak Ridges Moraine. The Black/Harmony/Farewell Creek watershed is divided into 3 primary subwatersheds: Black Creek, Harmony Creek and Farewell Creek. The Harmony Creek subwatershed is further divided into 5 subwatersheds: Ritson, Wilson, Grandview, Taunton and Mitchell. This chapter focuses on the climate conditions in and around the Black/Harmony/Farewell Creek watershed.

While climate information is collected at stations within and around the Black/Harmony/Farewell Creek watershed by CLOCA and Environment Canada, the scope of this chapter goes further than only reporting on the available data. This data has been used to predict the spatial distribution of net precipitation and evapotranspiration across the watershed. In addition, a discussion of climate change is included along with its possible impacts on watershed functions.



'models help predict the spatial distribution of climate data across the watershed'



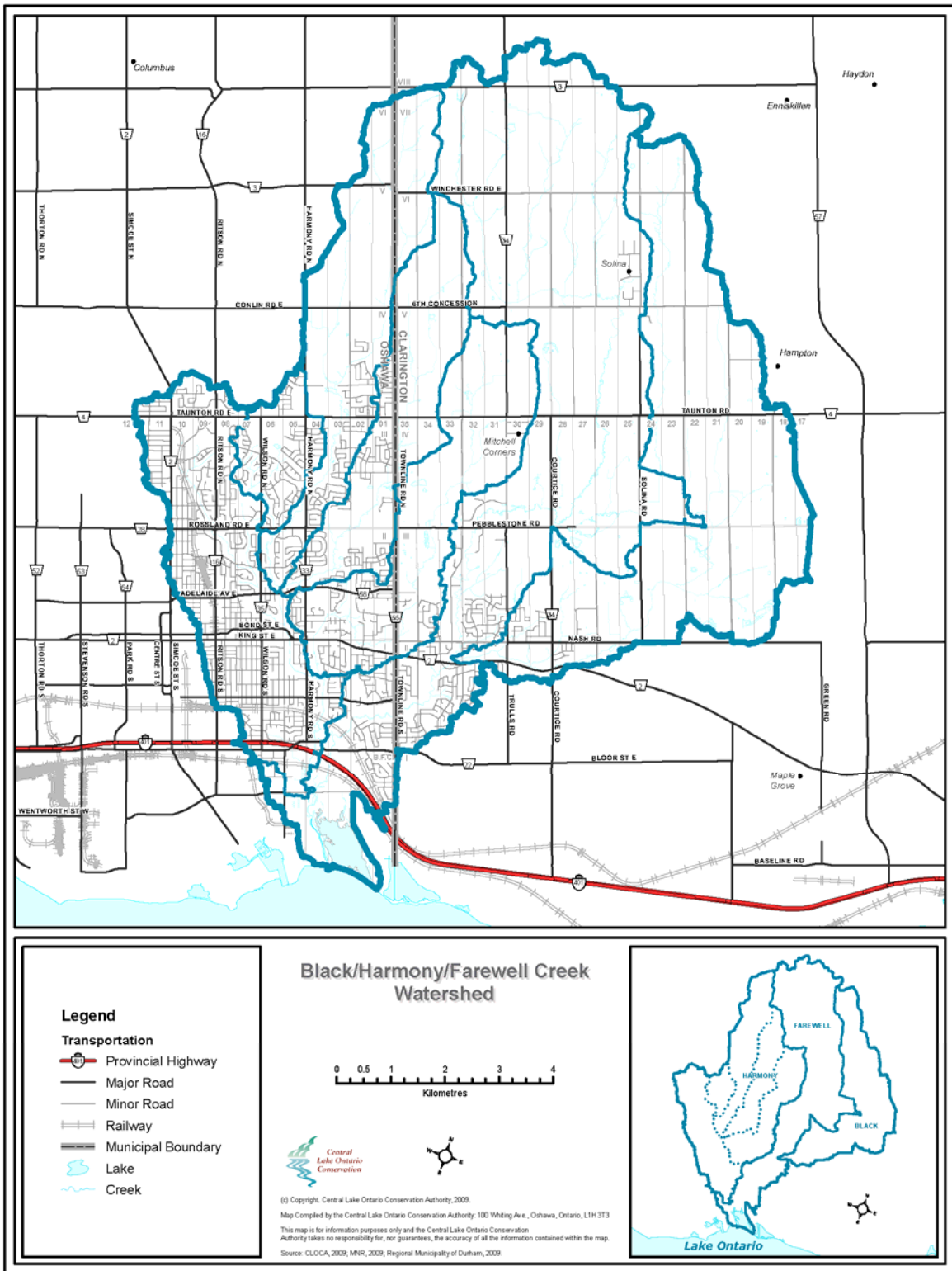


Figure 1: Black/Harmony/Farewell Creek watershed.

3.0 METHODOLOGY

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

The climate information collected from monitoring stations (daily precipitation and temperature) was used together as input into a numerical modelling tool (computer software) to distribute the net precipitation and evapotranspiration across the watershed. This is particularly important information for hydrology and water budget investigations. In addition, relevant climate change information was researched from various literature sources and related to the watershed where possible.

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

'climate data is important for hydrology and water budget investigations'



4.0 FINDINGS

The following sections describe the available climate data in the vicinity of the Black/Harmony/Farewell Creek watershed, the climatic regions and the distributed precipitation and evapotranspiration. Climate change and the potential impacts on the watershed are also discussed.

4.1 Climate Data

Climatic data are collected in and around the Black/Harmony/Farewell Creek watershed under two monitoring networks: the Environment Canada Climate Network and CLOCA's climate monitoring program. The Environment Canada Climate Network monitors daily precipitation and temperature. Environment Canada posts climate normals (averages) at http://climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html for 1971 to 2000. Climate data, primarily daily maximum and minimum temperature and precipitation are noted in Table 1 for selected Environment Canada stations in the vicinity of the Black/Harmony/Farewell Creek watershed.

Table 1: Climate normals for selected Environment Canada climate stations (source: Earthfx, 2007).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bowmanville Mostert (#6150830)													
Daily Maximum Temp (°C)	-1.9	-0.9	4.0	10.9	17.8	22.8	25.5	24.5	20.2	13.4	6.9	1.2	12.0
Daily Minimum Temp (°C)	-10.7	-9.7	-4.9	1.1	6.6	11.3	14	13.2	9.2	3.4	-0.7	-6.6	2.2
Rainfall (mm)	33.1	30.8	47.2	70	73.7	81.5	63.7	81	90.5	67.8	77.9	47.4	764.6
Snowfall (cm)	30.0	16.4	13.5	2.9	0	0	0	0	0	0.1	6.1	24.2	93.2
Precipitation (mm)	63.1	47.2	60.7	72.9	73.7	81.5	63.7	81	90.5	67.9	84.0	71.6	857.9
Burketon McLaughlin (#6151042)													
Daily Maximum Temp (°C)	-4.0	-2.8	2.4	10.0	17.5	22.1	24.9	23.9	19.1	12.3	5.1	-1.0	10.8
Daily Minimum Temp (°C)	-12.1	-10.9	-5.8	0.8	7.3	12.0	14.8	14.0	9.9	3.9	-1.5	-8.1	2.0
Rainfall (mm)	24.5	21.1	39.1	66.7	83.2	95.7	74.9	88.5	92.4	79.2	73.9	34.9	774.1
Snowfall (cm)	38.2	27.2	19.5	5.8	0.1	0	0	0	0	0.6	11.5	32.1	135
Precipitation (mm)	62.7	48.3	58.6	72.5	83.3	95.7	74.9	88.5	92.4	79.8	85.4	67.0	909
Claremont (#6151545)													
Rainfall (mm)	21.1	25.9	52.3	68.8	78.2	75.5	72.7	92.4	82.2	73.0	76.0	46.3	764.3
Snowfall (cm)	33.4	27.1	16.5	2.8	0	0	0	0	0	0.4	4.5	31.4	116.0
Precipitation (mm)	54.5	53.0	68.8	71.5	78.2	75.5	72.7	92.4	82.2	73.4	80.5	77.7	880.3
Greenwood MTRCA (#6153020)													
Rainfall (mm)	19.9	26.7	54.2	68.3	70.3	75.4	69.2	91.5	83.6	72.6	76.0	48.2	755.9
Snowfall (cm)	37.4	27.8	20.3	4.0	0	0	0	0	0	0.4	5.5	34.9	130.3
Precipitation (mm)	57.2	54.5	74.4	72.3	70.3	75.4	69.2	91.5	83.6	73.0	81.5	83.2	886.1
Leskard (#6154410)													
Rainfall (mm)	31.3	24.5	45.4	82.4	78.9	77.2	79.3	91.4	100	88.2	87.7	38.9	825.1
Snowfall (cm)	47.1	36.5	24.5	8.1	0	0	0	0	0	1.2	12.8	46.2	176.4
Precipitation (mm)	78.4	61.0	69.8	90.5	78.9	77.2	79.3	91.4	100	89.4	100.4	85.1	1001.4
Orono (#6155854)													
Daily Maximum Temp (°C)	-2.7	-1.6	3.6	11.0	18.4	23.2	26.3	24.9	20.0	13.4	6.6	0.2	11.9
Daily Minimum Temp (°C)	-11.4	-10.9	-5.6	0.8	6.6	11.3	14.4	13.5	9.3	3.5	-1.1	-7.7	1.9
Rainfall (mm)	31.2	25.1	47.0	69.7	75.6	75.1	63.7	85.7	89.6	78.1	78.1	40.2	759.1
Snowfall (cm)	32.9	25.1	15.8	3.2	0	0	0	0	0	0	7.4	29.7	114.1
Precipitation (mm)	64.1	50.2	62.8	72.9	75.6	75.1	63.7	85.7	89.6	78.1	85.5	69.9	873.2
Oshawa WPCP (#6155878)													
Daily Maximum Temp (°C)	-1.4	-0.6	4.1	10.5	17.0	21.9	25.0	24.0	19.7	13.1	7.2	1.5	11.8
Daily Minimum Temp (°C)	-9.2	-8.2	-3.8	2.0	7.6	12.4	15.5	15.2	11.2	5.2	0.7	-5.4	3.6
Rainfall (mm)	32.1	29.5	46.8	70.1	74.7	80.6	67.3	83.3	87.9	66.2	74.2	46.8	759.5
Snowfall (cm)	38.9	23.2	15.5	3.1	0	0	0	0	0	0.1	5.7	31.9	118.4
Precipitation (mm)	71.0	52.7	62.3	73.1	74.7	80.6	67.3	83.3	87.9	66.3	79.9	78.7	877.9
Tyrone (#6159048)													
Daily Maximum Temp (°C)	-3.1	-2.1	3.1	10.7	18.1	23.0	25.7	24.6	20.0	13.0	5.9	-0.1	11.6
Daily Minimum Temp (°C)	-12.3	-11.3	-6.3	0.5	6.5	11.2	14.0	13.2	9.0	3.0	-1.7	-8.1	1.5
Rainfall (mm)	33.7	29.9	48.8	74.4	75.7	80.0	76.1	88.6	93.7	77.1	82.4	44.5	804.9
Snowfall (cm)	46.6	29.6	23.3	4.8	0	0	0	0	0	0.4	9.4	34	147.9
Precipitation (mm)	80.3	59.5	72.1	79.2	75.7	80.0	76.1	88.6	93.7	77.5	91.8	78.4	952.8

'climate data is collected in the Black/Harmony/Farewell Creek watershed area by CLOCA and Environment Canada'

Figure 2 depicts the variation in average annual precipitation collected at five climate stations listed in Table 1. By depicting an average annual precipitation of 886 mm/yr, the fluctuations showing wet, dry and average years can be easily observed over the period of record as shown in Figure 2. Four of the Environment Canada stations have been decommissioned over the last 10 to 12 years including Burketon McLaughlin, Orono, Tyrone, Bowmanville Mostert (Figure 2).

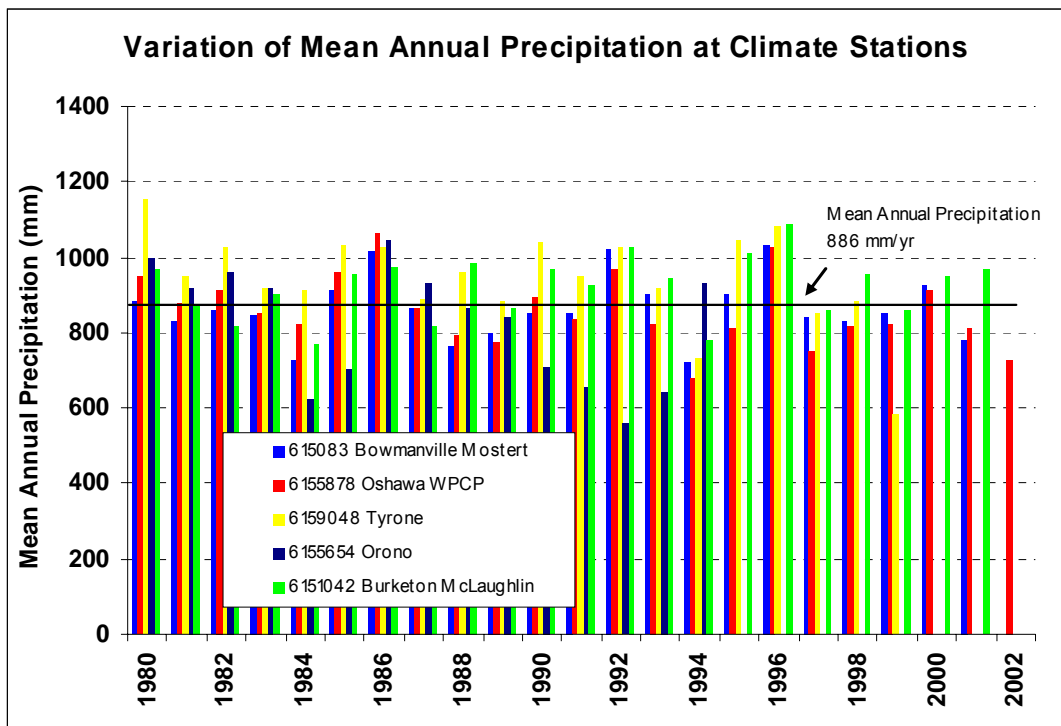


Figure 2: Variation of annual precipitation at selected climate stations with extended periods of record.

While several CLOCA monitoring stations have recently been commissioned in and around the watershed to advance the flood forecasting program, they do not yet have sufficient periods of record to be used for long-term climate assessments (Table 2). CLOCA climate stations, for the most part, collect rainfall information whereas the Environment Canada stations also account for other forms of precipitation (such as snow accumulation and collected temperature data).

Table 2: CLOCA precipitation stations within or around the Black/Harmony/Farewell Creek watershed.

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

'several CLOCA monitoring stations have recently been commissioned in and around the watershed'

4.2 Climatic Regions

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

4.3 Temperature

The average of the mean daily temperatures recorded at the Bowmanville Mostert, Burketon McLaughlin, Orono, Oshawa WPCP, and Tyrone stations (Table 1) is approximately 6.9°C. The average annual temperatures range from 6.4°C at the Burketon McLaughlin station to 7.7°C at the Oshawa WPCP station, which resides closest to Lake Ontario. This temperature range falls within the regional pattern. For instance, the mean daily temperatures for the period 1931 to 1960 range from 5.6 to 6.7°C in the Simcoe and Kawartha Lakes region northwest and north of the Black/Harmony/Farewell Creek watershed to 6.7 to 7.8°C along the Lake Ontario shore. In the Simcoe and Kawartha Lakes Region, the mean daily temperature for January (coldest month) is from -8.9 to -7.8°C. The mean daily temperature for July (warmest month) is 20°C. For the Lake Ontario shore, mean daily temperatures for January and July are -6.7 to -4.4 and 20 to 21.1°C, respectively (Brown et al., 1980).

'there are 2 climatic regions in the watershed: the Lake Ontario Shore and the South Slope'



4.4 Precipitation

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

Net precipitation across the watershed was generated from long-term climatic data detailed in Table 1 using the Precipitation-Runoff Modelling System (PRMS) numerical model. The results of the simulation are shown for the Black/Harmony/Farewell Creek watershed in Figure 3. Net precipitation is important to depict, in that it represents the amount of available water that will eventually be infiltrated, evaporated or that runs off surfaces and is expressed as;

$$\text{Net Precipitation} = \text{Evapotranspiration} + \text{Runoff} + \text{Groundwater Infiltration}$$

And also as;

$$\text{Net Precipitation} = \text{Observed Precipitation} - \text{Interception Losses}$$

The estimates for the Black/Harmony/Farewell Creek watershed simulations approximates that 751 mm/yr of precipitation reaches the ground surface as net precipitation.

It can be seen in Figure 3 that more precipitation is expected to reach the ground surface of urbanized areas where there is generally less percent interceptive natural cover, or for instance in gravel pits where there is no natural cover and all precipitation is anticipated to reach the ground surface. The effects of interception storage may be visually noted by the amount of water that is stored on water or snow-laden trees or shrubs following a precipitation event; water stored on these surfaces is eventually evaporated or sublimated back to the atmosphere.



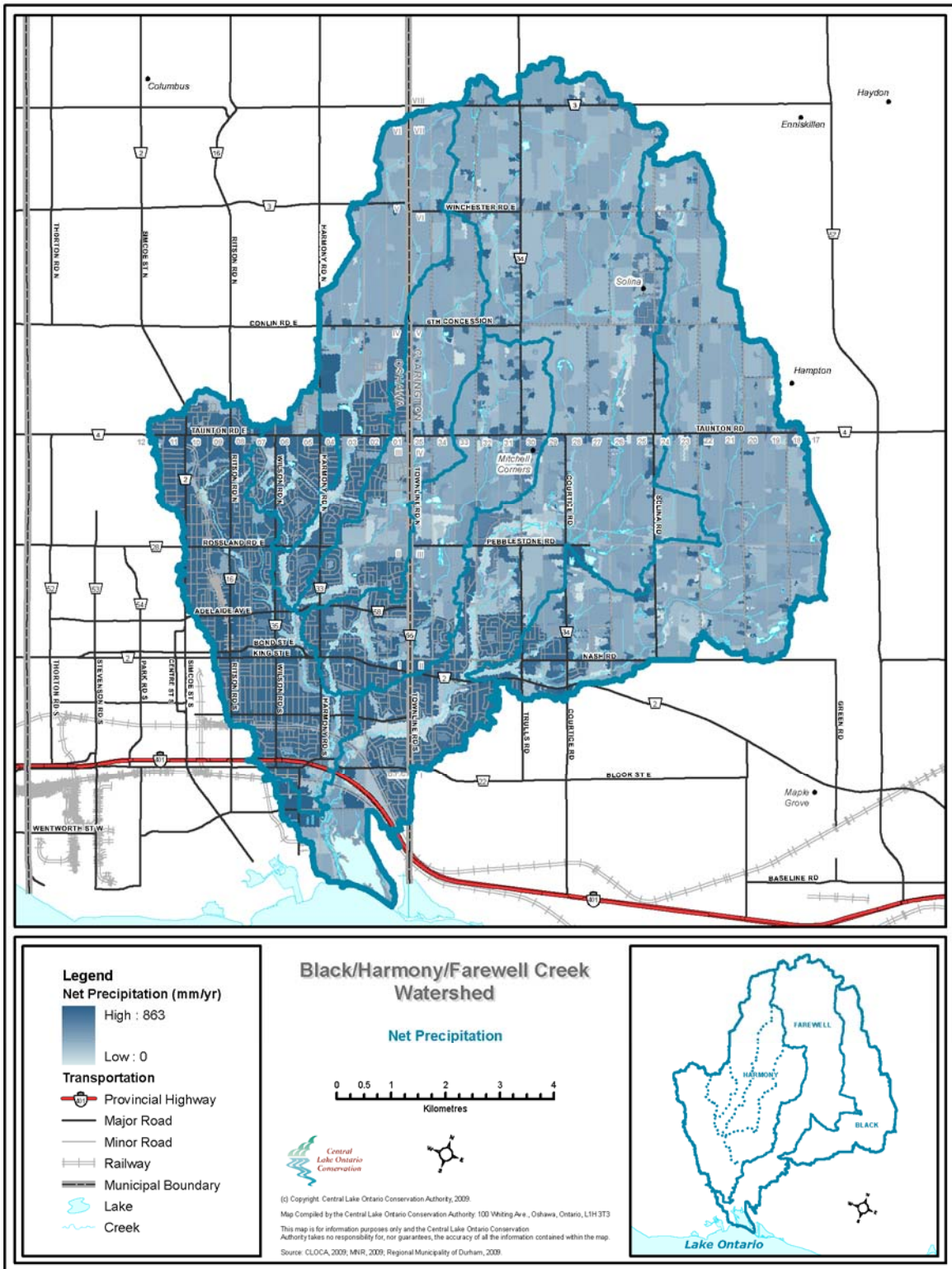


Figure 3: Net precipitation distribution (source: PRMS Model simulations (Earthfx, 2007)).

4.5 Evapotranspiration

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

The mean annual potential evapotranspiration (PET) was calculated for the Ecodistrict 553 in which the Black/Harmony/Farewell Creek watershed resides (Table 3). Ecodistrict 553 covers CLOCA's jurisdictional area as well as the Ganaraska and Trent watersheds. Ecodistricts are mapped across Canada by Agriculture and Agri-food Canada (<http://sis.agr.gc.ca/cansis/nsdb/ecostrat/district/climate.html>). Table 3 presents monthly and annual estimates of potential evapotranspiration (PET) calculated using two methodologies: the Thornthwaite and the Penman methods. Comparison with average precipitation data shows that PET exceeds available precipitation from May to August (Penman method) or June to August (Thornthwaite method). Actual evapotranspiration in those months will depend on the ability of plants to extract moisture from the soil.

Table 3: Monthly and Annual Estimated Potential Evapotranspiration for the CLOCA jurisdiction (from: Earthfx, 2007).

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

'an actual evapotranspiration rate of about 411 mm/yr is predicted for the watershed'

Estimates of long-term actual evapotranspiration (AET) generated using the Precipitation-Runoff Modelling System (PRMS) numerical model are shown for the Black/Harmony/Farewell Creek watershed in Figure 4. The estimates depicted represent the long-term average millimetres per year (mm/yr) of evapotranspiration that is predicted from all sources including intercepted and stored precipitation that is eventually evaporated. AET depends on soil type, soil water storage capacity, vegetation rooting depths, amount of interception storage based on land cover type, temperature, and solar radiation. The model estimates an evapotranspiration rate of approximately 411 mm/yr for the watershed.

Urban areas are depicted in Figure 4 as having on average lower evapotranspiration rates than the watershed average. This is largely influenced by the greater percentage of impervious surfaces in urban areas such as roadways, parking lots and rooftops. While some of the precipitation including melting snowpacks remains stored in surface depressions and is evaporated by the model, much of the precipitation is diverted from these surfaces as runoff.

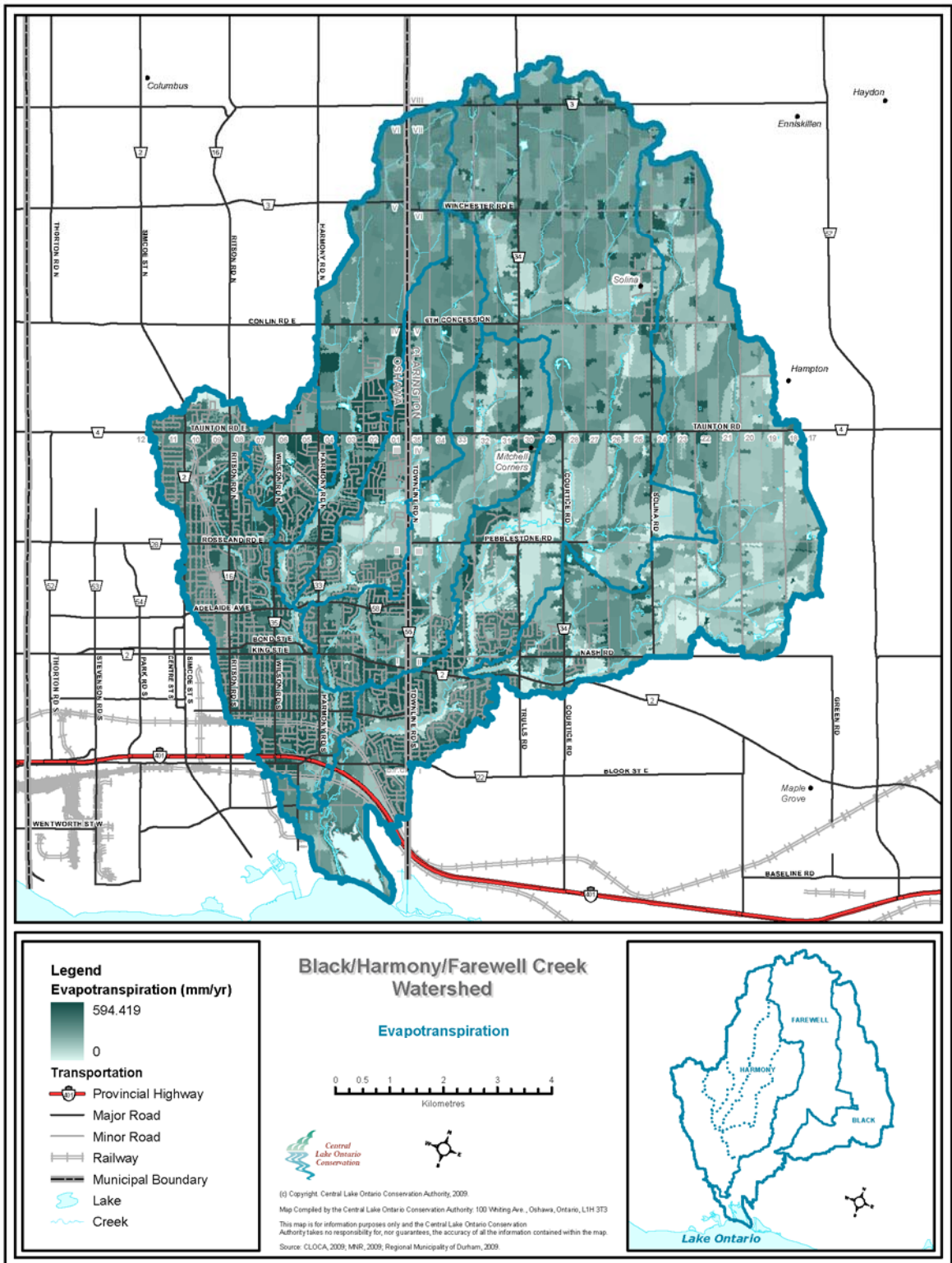


Figure 4: Evapotranspiration (source: PRMS Model simulation (Earthfx, 2007)).

4.6 Climate Change

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

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

‘our climate is controlled by the amount of energy our atmosphere allows to pass through’

Precipitation

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

Surface Runoff

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

Evapotranspiration

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

Infiltration

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

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

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

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

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



'overall, the impacts of climate change on our forests, wetlands and fish populations could be extreme'

5.0 CONCLUSIONS

This chapter has summarized the available climatic data and trends for the Black/Harmony/Farewell Creek watershed and surrounding area. This data has been applied to numerical models to distribute net precipitation and evapotranspiration over the entire watershed. The estimates provide a base for future land use change scenario testing such as an increase in impervious surfaces. However, due to the decommissioning of many of the local Environment Canada operated stations over the past several years, the spatial distribution of current climate monitoring stations has been identified as a gap locally in the support of flood forecasting and current and future local water budget modelling. Efforts are being made by CLOCA to address these gaps through the installation of local precipitation/temperature stations. CLOCA is currently investigating, in partnership, the commissioning of a centrally located comprehensive climate station to supplement the existing network.

It should be anticipated that a change in our climate, will lead to greater stresses on our cold water fisheries, a reduction in the quantity and health of wetlands, greater instability in our streams, stress on our plant and forests, and increasing the number of invasive pests. We should also be aware of the potential for a greater number of damaging natural events (extreme storms, flooding, erosion of bluffs and slope failures). While we may not be able to prevent many of these impacts, efforts must continue to limit the severity of them by minimizing our activities that produce carbon dioxide gas.



'a change in our climate will lead to greater stress on the health of the watershed'

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WHAT WE DO ON THE LAND IS MIRRORED IN THE WATER