Jackman Monitoring Station

Bowmanville East Monitoring Station

BOWMANVILLE/SOPER CREEK WATERSHED EXISTING CONDITIONS REPORT CHAPTER 15 - WATER QUANTITY

Central Lake Ontario Conservation

DURHAM REGION

FINAL - December 2011

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1.0 INTRODUCTION

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

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

The purpose of this chapter is to report on the existing monitoring and modelling of water quantity conditions within the Bowmanville/Soper Creek watershed and to provide mapping of natural hazards around wetlands and watercourses. The term 'natural hazards' is used to identify features of the landscape that have the potential to negatively impact public safety, including unstable slopes, erosion and flooding.

Legislation and Policies

The Central Lake Ontario Conservation Authority (CLOCA) administers Ontario Regulation 42/06 Regulation of Development, Interference with Wetlands and Alteration to Shorelines and Watercourses. The natural hazards component of this regulation serves to:

- minimize the risk to loss of life and property damage as a result of flooding;
- direct development away from natural hazard prone land (i.e. flooding, erosion); and
- determine whether or not in the opinion of the Authority, the development proposal will affect the control of flooding, pollution, or the conservation of land.

The reader is referred to Chapter 4 - Land Use and Policy Framework for more information on the regulation.

2.0 STUDY AREA AND SCOPE

The Bowmanville/Soper Creek watershed is situated entirely within the Regional Municipality of Durham and covers an area of approximately 170 km^2 (Figure 1). The watershed drains southerly towards Lake Ontario from its headwaters in the Oak Ridges Moraine. The Bowmanville/Soper Creek watershed consists of 2 primary subwatersheds: Bowmanville Creek and Soper Creek, whose tributaries join together prior to outletting to Lake Ontario.

Bowmanville Creek watershed is comprised of the following 5 subwatersheds: Hampton, Haydon, Tyrone, Bowmanville Main, and Bowmanville Marsh. Soper Creek watershed is further divided into the following 4 subwatersheds: Mackie, Soper North, Soper Main, and Soper East.

This chapter focuses on the quantity of surface water found within the watershed and each subwatershed. Descriptions provided primarily focus on the results of existing modeling. In addition, components of CLOCA's water monitoring network within the watershed are described. Information from the network provides valuable information in support of modeling activities. In addition, landscape features within the watershed that are prone to riverine hazards including unstable slopes, erosion and flooding are identified.

Hampton Conservation Area Monitoring Station

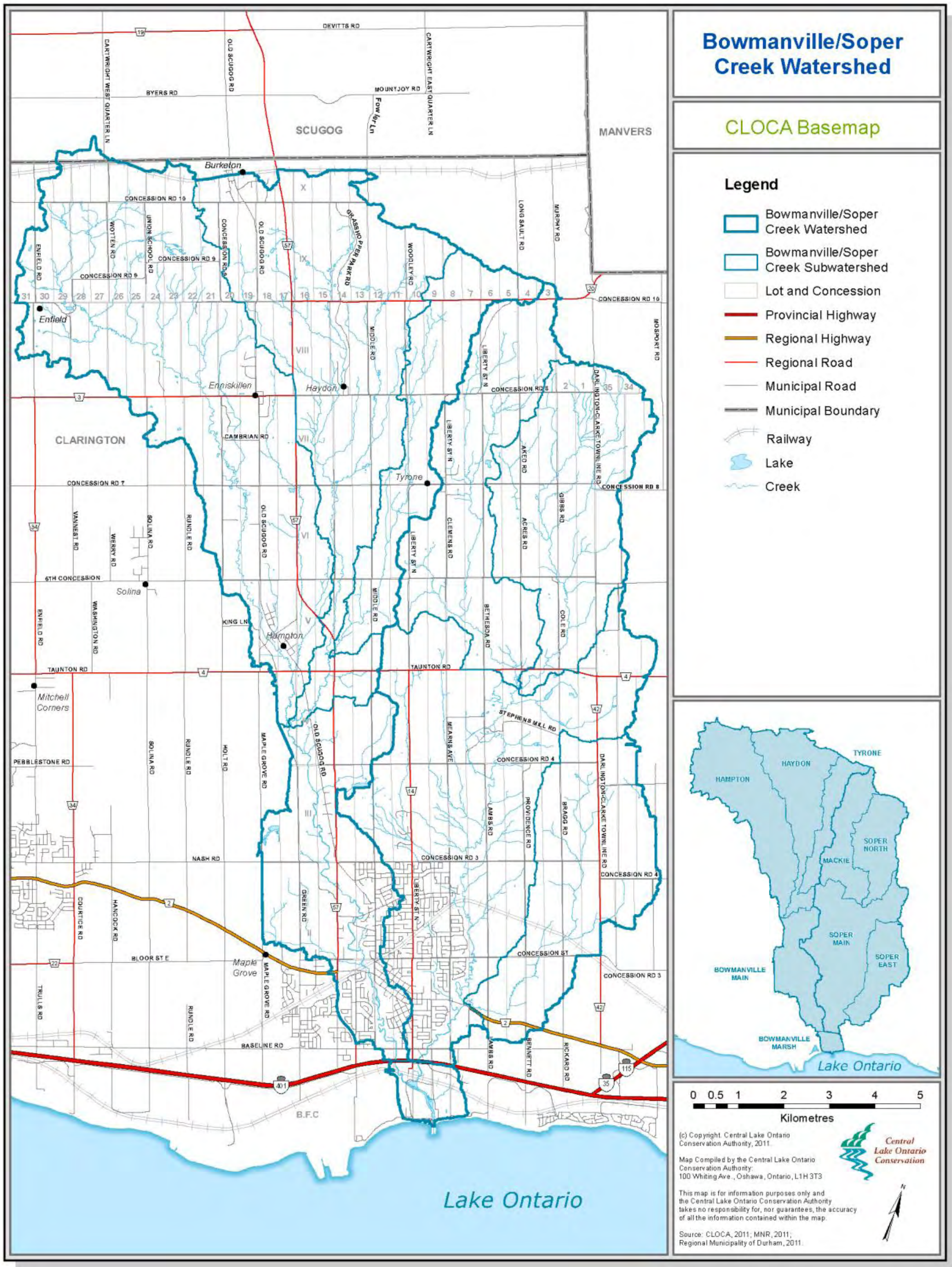


Figure 1: Bowmanville/Soper Creek watershed.

3.0 METHODOLOGY

3.1 Modeling

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

3.1.1 Hydrology – Event Modeling

Hydrology is the study of water on earth, specifically its distribution and cycle. The main hydrology model for the Bowmanville/Soper Creek watershed was created by CLOCA in Visual Otthymo 2, and was completed in December 2007 (Revised May 2010). Visual Otthymo is a single event hydrologic model meaning that simulations are created from a single storm event. This hydrologic model does not consider the movement of groundwater, it is specifically a surface water model.

The hydrology modeling of surface water for Bowmanville/Soper Creek watershed has been completed in 2 stages. The first stage (Stage 1) involved creating an existing 2005 land use model and the associated parameters for Visual Otthymo. The second stage involves editing the parameters within the existing 2005 land use model, to create a future land use model, and comparing the two models based on their input parameters and resulting peak flows. The results of Stage 1 are documented in this chapter and are intended to provide the existing condition peak flows within the watershed.

A peak flow is the highest rate (cubic metres per second) at which stormwater runs off the ground during a specific storm event. The hydrologic model calculates the peak flows at designated nodes within the watershed for a variety of simulated storm events. Peak flows are affected by landuse, soil type and condition, and topography. The peak flows that are obtained from the hydrologic model are used as inputs for the hydraulic model, which in turn, is used to generate the floodplain. An increase in peak flows, will result in an increase in the floodplain elevation, which could lead to a wider floodplain.

Under the existing condition scenario the Bowmanville/Soper Creek watershed was divided into 42 catchments. Catchment delineation was chosen based on road crossings and the merging of smaller tributaries. The catchments were determined based on Digital Elevation Model (DEM) mapping. Catchments with 20% or more total imperviousness are modeled as urban while all others were modeled as rural.

The rural catchments were modeled using the Nashyd command. Within this command, the Curve Number (CN) parameter reflects the soil types, topography, vegetation cover and land use of each subwatershed. Model parameters were determined independently of the model using GIS queries, topographic mapping and published values. Published values were obtained from the Ministry of Transportation Highway Drainage Design Standards, the Ministry of the Environment Stormwater Management Planning and Design Manual as well as other sources that are described in the Hydrologic Modeling for Bowmanville/Soper Creeks Documentation prepared by CLOCA (2010).

The urban catchments were modeled using the Standhyd command. The CN and the Initial Abstraction (Ia) values were used for the pervious areas of the units and the Ximp (directly connected impervious area) and Timp (total impervious area) values are used to define the amount of imperviousness within each urban unit. To determine the appropriate rainfall distribution for the watershed, a storm with a uniform rainfall intensity of 25 mm/hr, lasting 100 hours was simulated over the watershed. The resulting hydrograph will show the time at which the entire watershed is contributing to the peak flow. The Regional Storm (Hurricane Hazel), 1954 was used to compute the regulatory flows and flood elevations. The Regional Storm was applied to the Existing condition scenario. CN values were increased to reflect Antecedent Moisture Condition III for the regional storm event.

3.1.2 Hydrology – Transient Modeling

While Visual Otthymo is a single event hydrologic model used to predict peak flows, the United States Geological Survey's transient numerical model Precipitation-Runoff Modeling System (PRMS) has been applied to the watershed by CLOCA as part of water budgeting activities, consistent with the model developed for the Source Water Protection program (Earthfx, 2011). A transient model simulates runoff over days, months and years based primarily on daily average precipitation data recorded at local gauge stations. The reader is referred to Chapter 9 - Water Budget for more detail regarding the PRMS model application. This model has been constructed for a myriad of uses including water budget investigations, estimate land development impacts, water supply investigations, fisheries and aquatics management, and water use reviews. This model was, in-part, calibrated using the draft existing groundwater flow model developed in 2007 for the Source Water Protection Program.

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

3.1.3 Hydraulic Modeling

Hydraulics is the study of water in motion. The hydraulic models described below compute water surface profiles for creek systems. Hydraulic modeling is undertaken primarily to establish areas of potential riverine flooding hazards within the watershed. The current hydraulic models was created by Aquafor Beech Limited in HEC-GeoRAS and was completed in 2009 (revised May 2010). HEC-GeoRAS, Hydraulics Engineering Centre, Geo (Geographical), River Analysis System, is a set of tools used for processing geospatial input and output data for the hydraulics modeling. Identified areas of possible flooding hazards are assessed with areas of slope instability; stream erosion, and the shifting tendencies of meandering riverine systems. These features are used to generate an environmental hazard protection limit commonly referred to as 'hazard limits'.

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

3.2 Monitoring

CLOCA maintains a network of monitoring stations that monitor water quantity parameters including rainfall and stream water level. These stations are permanent gauges that record information on a set interval. Some gauges can be downloaded remotely and others require information to be retrieved on site. Within the Bowmanville/Soper Creek watershed there are 5 water level station, it is described in Table 1.

Table 1: Bowmanville/Soper Creek watershed flow measuring stations.

Station	Description	Period of Record (Flow)	Parameters
Prec4	Long Sault CA	2003 - Current	Precipitation
Prec 6	Clarington Fire Station	2009 - Current	Precipitation, air temperature
Hampton	Hampton CA	2003 - Current	Precipitation, water level, water temperature, discharge, air temperature
Bow-EB	Bowmanville Creek at Taunton Road	2006 - Current	Water level, discharge, water temperature
02HD023	Soper Creek at Taunton Road West	2005 - Current	Water level, discharge, water temperature
Sop-EB	Soper Creek at Taunton Road East	2006 - Current	Water level, discharge, water temperature
02HD006	Bowmanville Creek at Bowmanville	1959 - Current	Water level, discharge
Prec7	Clarington Works Yard	2009 - Current	Precipitation

CLOCA also maintains a baseflow monitoring network. The baseflow monitoring network was established in 2002 and consists of 138 stations jurisdiction wide, 23 of which are in the Bowmanville/Soper Creek watershed. These stations are monitored manually during the summer months after 3 consecutive days with no rainfall.

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 values may not always sum to the expected total.

4.0 FINDINGS

4.1 Bowmanville/Soper Creek Watershed

4.1.1 Modeling

4.1.1.1 Hydrology - Event Modeling

The results of the hydrologic model were used to examine peak flows within the watershed, subwatershed and catchments. A map showing the locations of the key reference nodes and the catchments is shown in Figure 2.

The results from the hydrologic model were compared to several past studies; the comparison is shown Table 2.

Table 2: Hydrologic model results comparison.

Node	Description	Regional Storm Peak Flow (cms)	
		CLOCA 2007	Past Study
Master Drainage Plan for West Branch of Soper Creek, Marshall Macklan Monaghan (1991)			
85	West Soper Detention Pond Outlet	39.3	27
88	Downstream of West Soper Detention Pond Outlet at Mearns	42.8	33.5
Northwest Bowmanville Master Drainage Study, GM Sernas & Associates (1996)			
23	Bowmanville Creek, West Branch, Third Conc	434.3	606.5
28	Bowmanville Creek, West Branch, Jackman Rd	440.5	606.0
34	Bowmanville Creek, West Branch, Highway 2	460.2	641.5
39	Bowmanville Creek, West Branch, Bowmanville Harbour	464.4	642.5
Stormwater Management Report for Northeast Bowmanville Detention Pond, GM Sernas & Associates (1991)			
74	Northeast Bowmanville Detention Pond	7.8	9.08

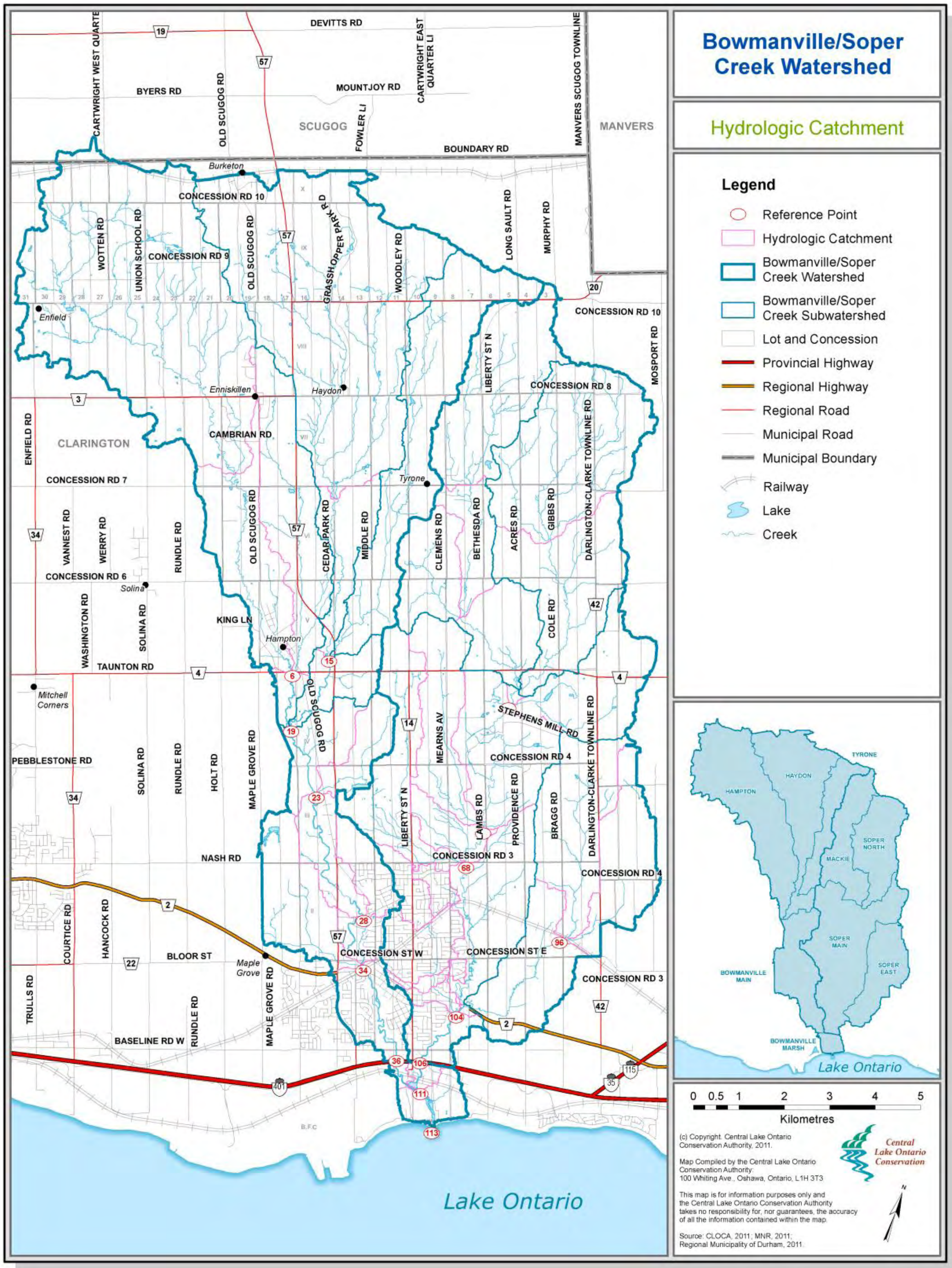


Figure 2: Catchments & hydrologic reference nodes within the Bowmanville/Soper Creek watershed.

A review of Table 2 indicates that there is a very small difference in the flows from the 1991 MDP for the West Branch of Soper and the 1991 SWM Report for the Northeast Bowmanville Detention Pond. There is, however, a large difference in the peak flows from the 1996 Northwest Bowmanville MDS. The large difference in peak flows prompted a review of other watersheds and the relationship between drainage area and peak flows. Table 3 shows the other watersheds within CLOCA, their drainage areas and peak flows.

Table 3: Drainage area and peak flows of other watersheds

Watershed	Drainage Area (ha)	Peak Flow (cms)	Peak Flow / Drainage Area
Bowmanville/Soper	16,984	974	0.057
Lynde	13,103	937	0.072
Oshawa	12,026	842	0.070
Black/Harmony/Farewell	10,736	711	0.066

A review of Table 3 indicates that the peak flows per hectare for Bowmanville and Soper Creeks are slightly lower when compared to the other watersheds within CLOCA. However, the Bowmanville and Soper Creek watersheds are significantly less urbanized than both the Oshawa and Lynde Creeks, which will affect peak flows.

To ensure that the entire watershed is contributing to the peak flow, a long duration constant intensity storm was applied to the model; the watershed hydrograph rose steadily and began to level off around the 30^{th} hour. At approximately the 18^{th} hour the flow had reached 95% of its peak. This indicates that a storm distribution with a 24 hour duration would be appropriate for the Bowmanville and Soper Creeks watershed. A 12 hour Chicago and a 24 hour SCS distribution will be used for the 2, 5, 10, 25, 50 and 100 year return period storms for both the existing and future land use scenarios. The hydrograph at the mouth of the watershed for the 100 year storm event is shown in Figure 3.

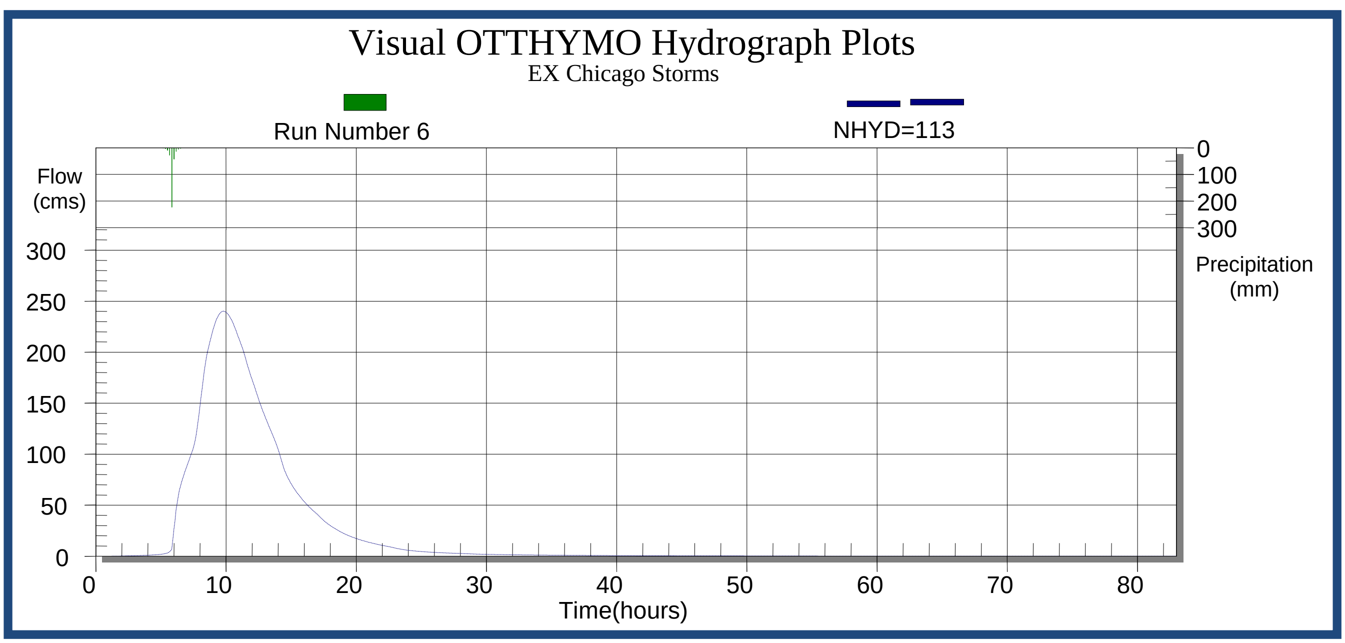


Figure 3: Bowmanville/Soper creek hydrograph: Chicago 100-year storm.

4.1.1.2 Hydrology – Transient Modelling

The distribution of long-term average annual watershed runoff in mm/year is shown in Figure 4. Note that the higher runoff values are reflected in the urban areas with higher imperviousness. Areas of less permeable surficial soils generally reflect higher runoff, as does the degree of slope, land cover and the amount of precipitation intercepted. Many stream corridors are predicted to have low runoff potential based on the extent of riparian cover, related rates of evapotranspiration and interception, and soil types. The long-term average annual runoff is estimated at approximately 190mm/year for the Bowmanville and Soper watershed (Earthfx, 2011).

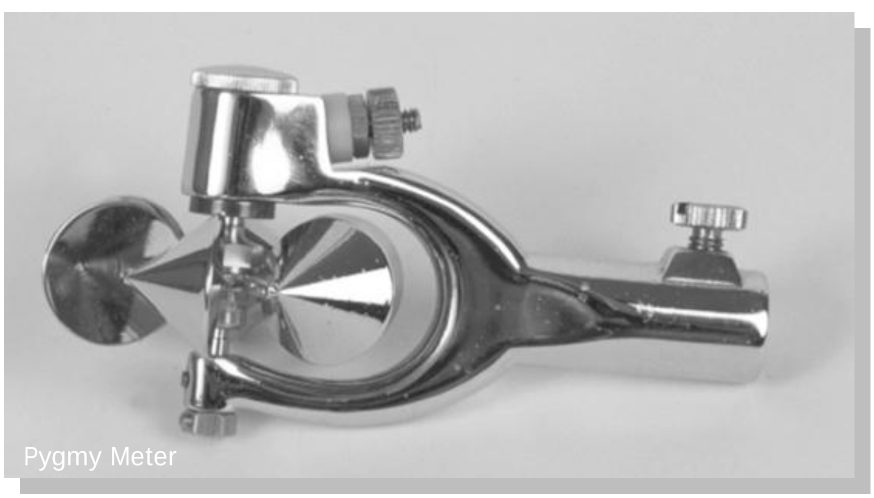
4.1.1.3 Hydraulic Modelling and Generic Regulation Limits

The 'Generic Regulation limits' include the identified areas of flooding hazards generated by the 2010 hydraulic model and the 2010 calculated erosion hazard lands and wetlands limits, all are shown in Figure 5. These limits are used by CLOCA as part of administering Ontario Regulation 42/06: Regulation of Development, Interference with Wetlands and Alteration to Shorelines and Watercourses. More information regarding this Regulation is provided in Chapter 4: Land Use and Policy.

4.1.2 Monitoring

CLOCA's monitoring network is shown on Figure 6. The information collected from the stream gauges can be used to identify trends and averages for each of the gauge locations. There are 4 subwatersheds where stream gauges have not been installed and as such, the same level and detail of information is not available for these "unguaged" subwatersheds.

The information collected through CLOCA's baseflow monitoring network (Figure 7) has been formatted and summarized to allow for the identification of trends and relationships for each site. Baseflow measurements are obtained manually after three consecutive days of dry weather. The average baseflow measurement for each site, for the period of record (2002 to 2010), has been determined and is shown in Figure 7: Baseflow stations with average flow in the Bowmanville/Soper Creek watershed. In addition, the relationship between baseflow sites is currently being examined in an effort to identify stream reaches which are gaining groundwater (groundwater discharge) or are losing stream flow to groundwater (groundwater recharge).


Pygmy Meter

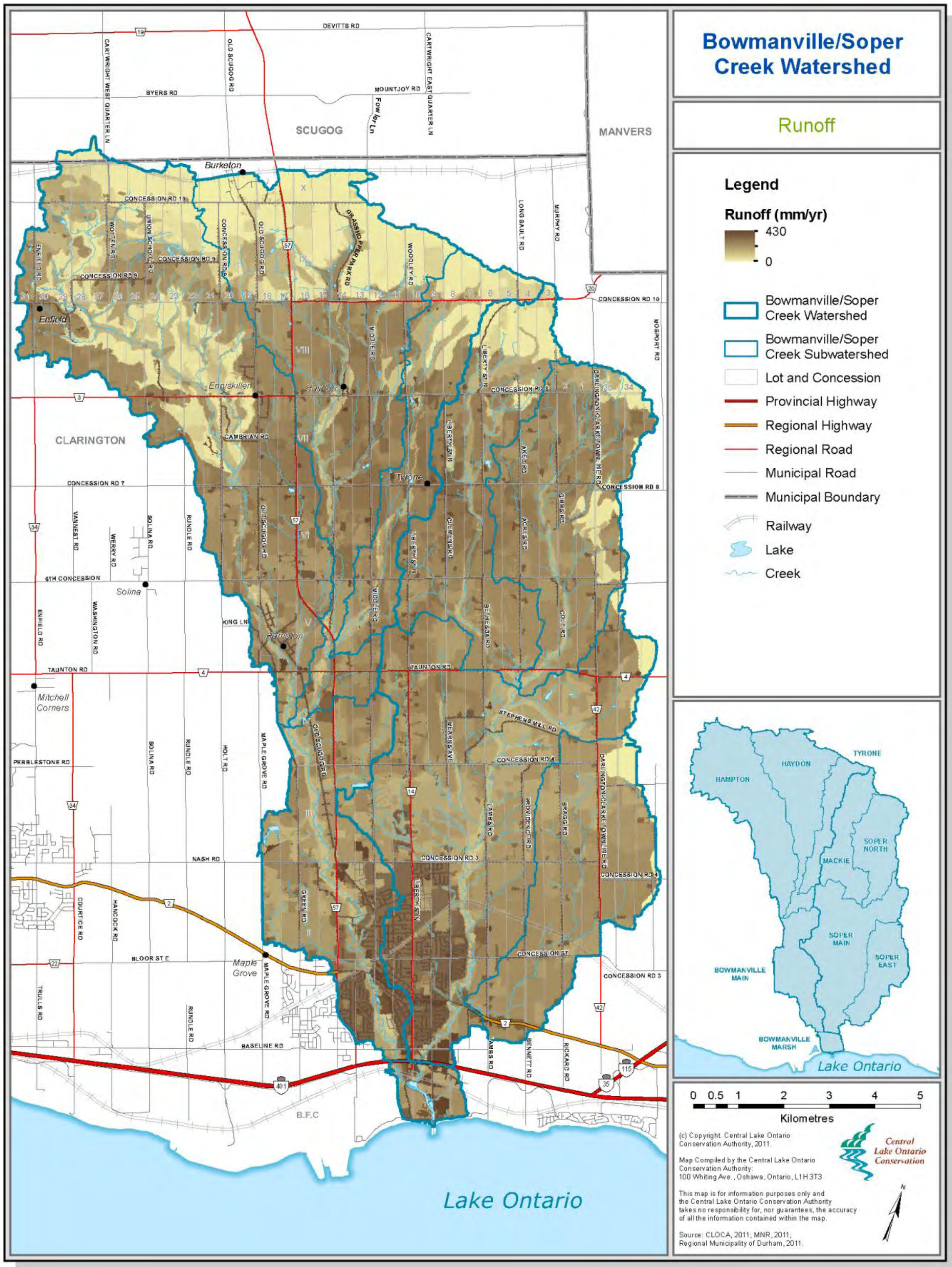


Figure 4: Runoff in the Bowmanville/Soper Creek watershed (data extracted from Earthfx, 2007).

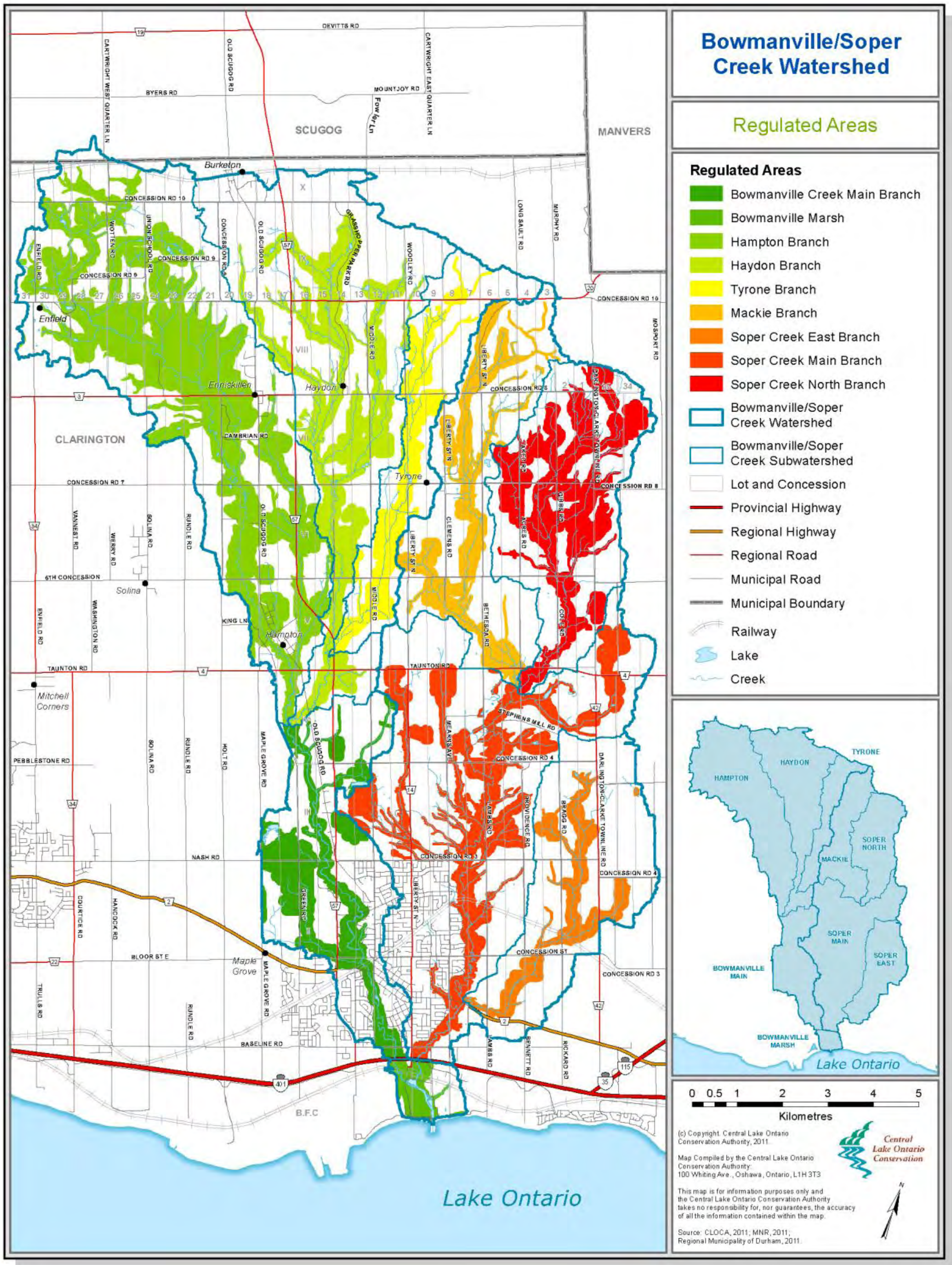


Figure 5: Generic Regulation limits for the Bowmanville/Soper Creek watershed by subwatershed.

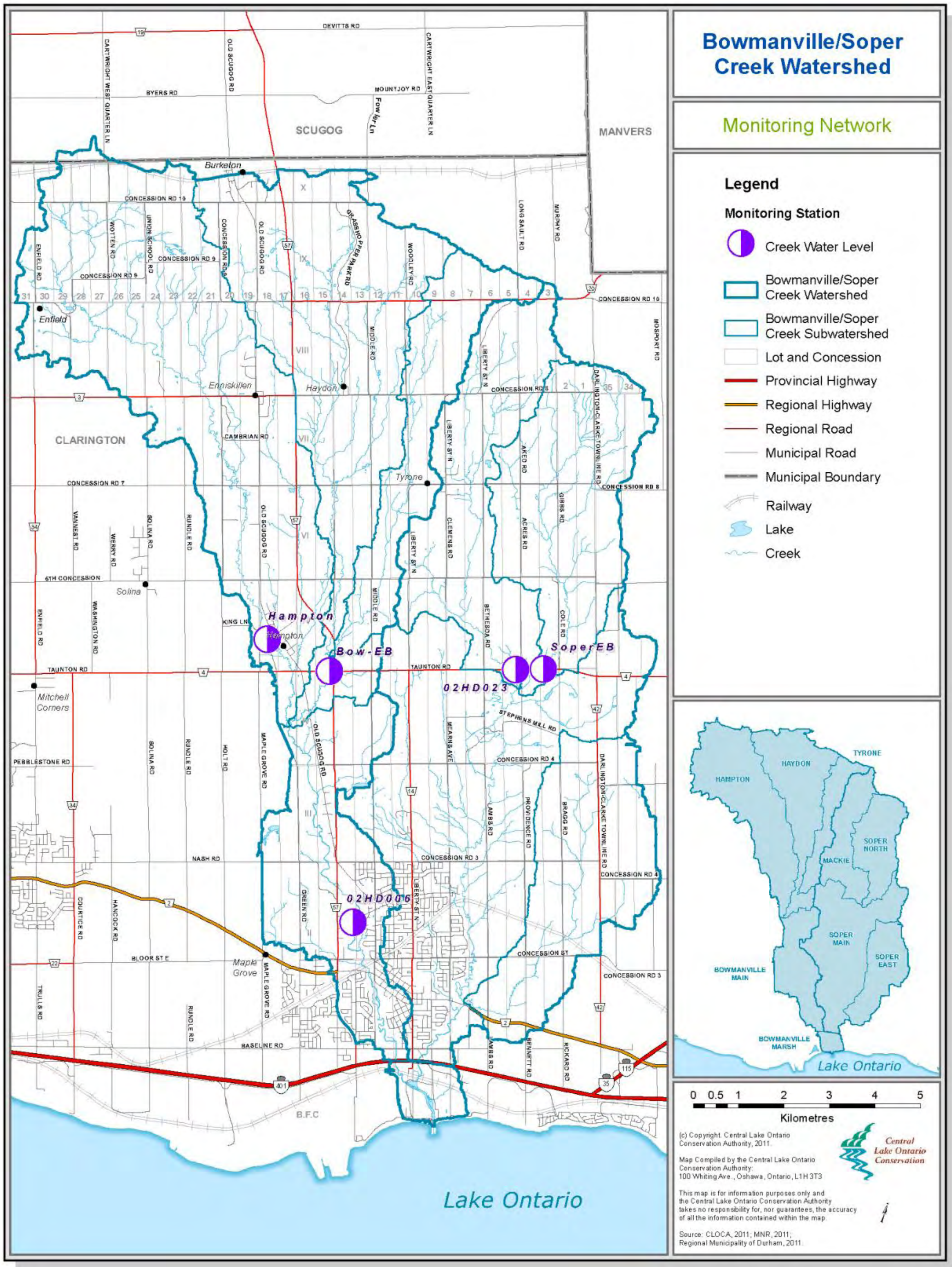


Figure 6: CLOCA's water monitoring network in the Bowmanville/Soper Creek watershed.

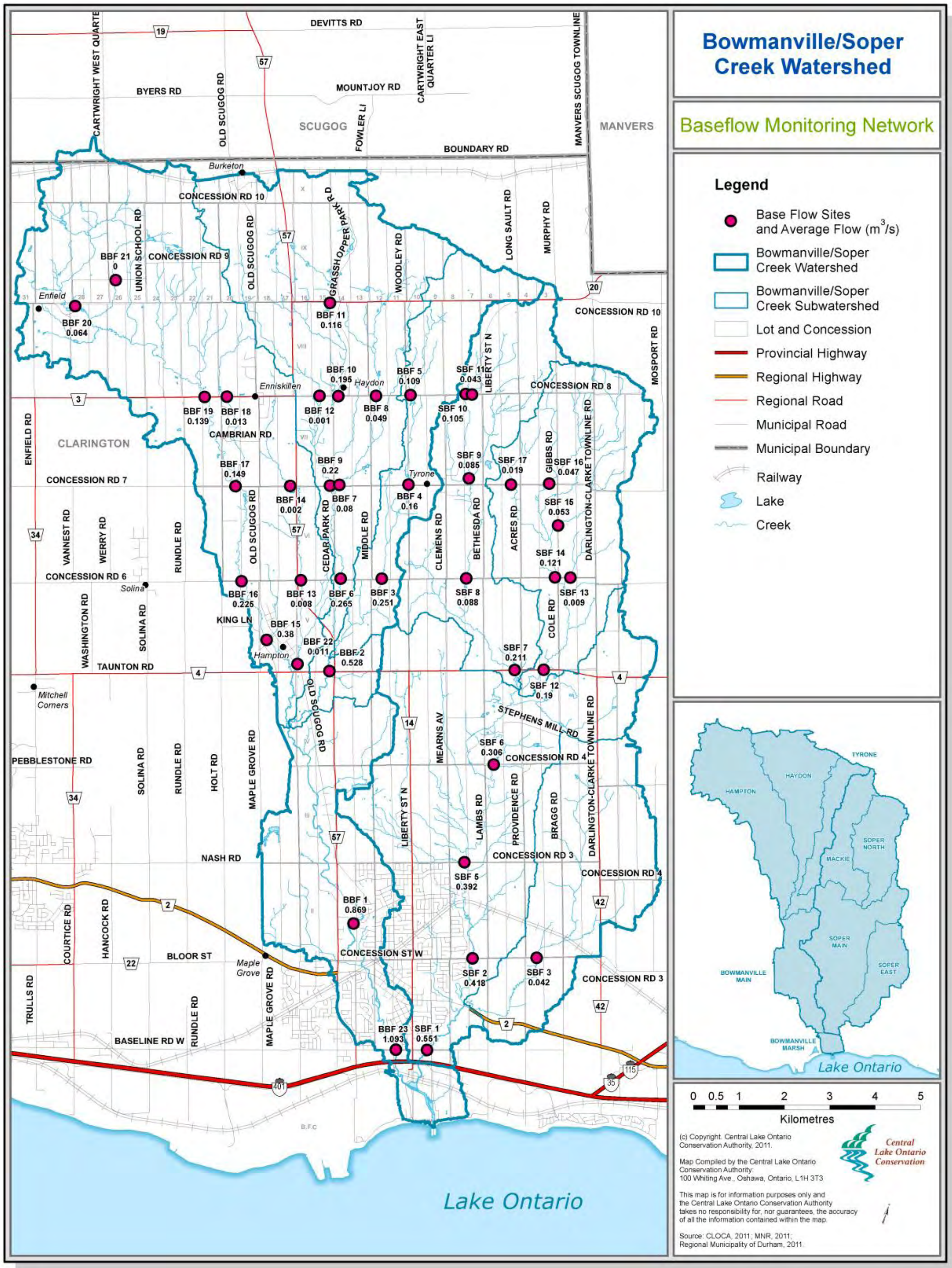


Figure 7: Baseflow stations with average flow in the Bowmanville/Soper Creek watershed.

4.2 Subwatershed Findings

4.2.1 Bowmanville Subwatershed

4.2.1.1 Hampton Subwatershed

Hydrology – Event Modeling

The Hampton subwatershed has 4 catchments (Figure 2). There are 2 reference nodes, the node locations were chosen based on road crossings and the merging of smaller tributaries. The reference nodes and the associated peak flows are presented in the table below.

Table 4: Hampton subwatershed reference nodes.

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
9	Mouth of Hampton Branch	179.46
6	Taunton Road	177.20

Hydrology – Transient Modeling

The distribution of long-term averaged annual watershed runoff in mm/year is shown in Figure 8 for the subwatershed. This subwatershed has a low imperviousness value, thus producing lower rates of runoff. The long-term average annual runoff is estimated at approximately 150mm/year for the subwatershed which is slightly lower than the watershed average of 190mm/year.

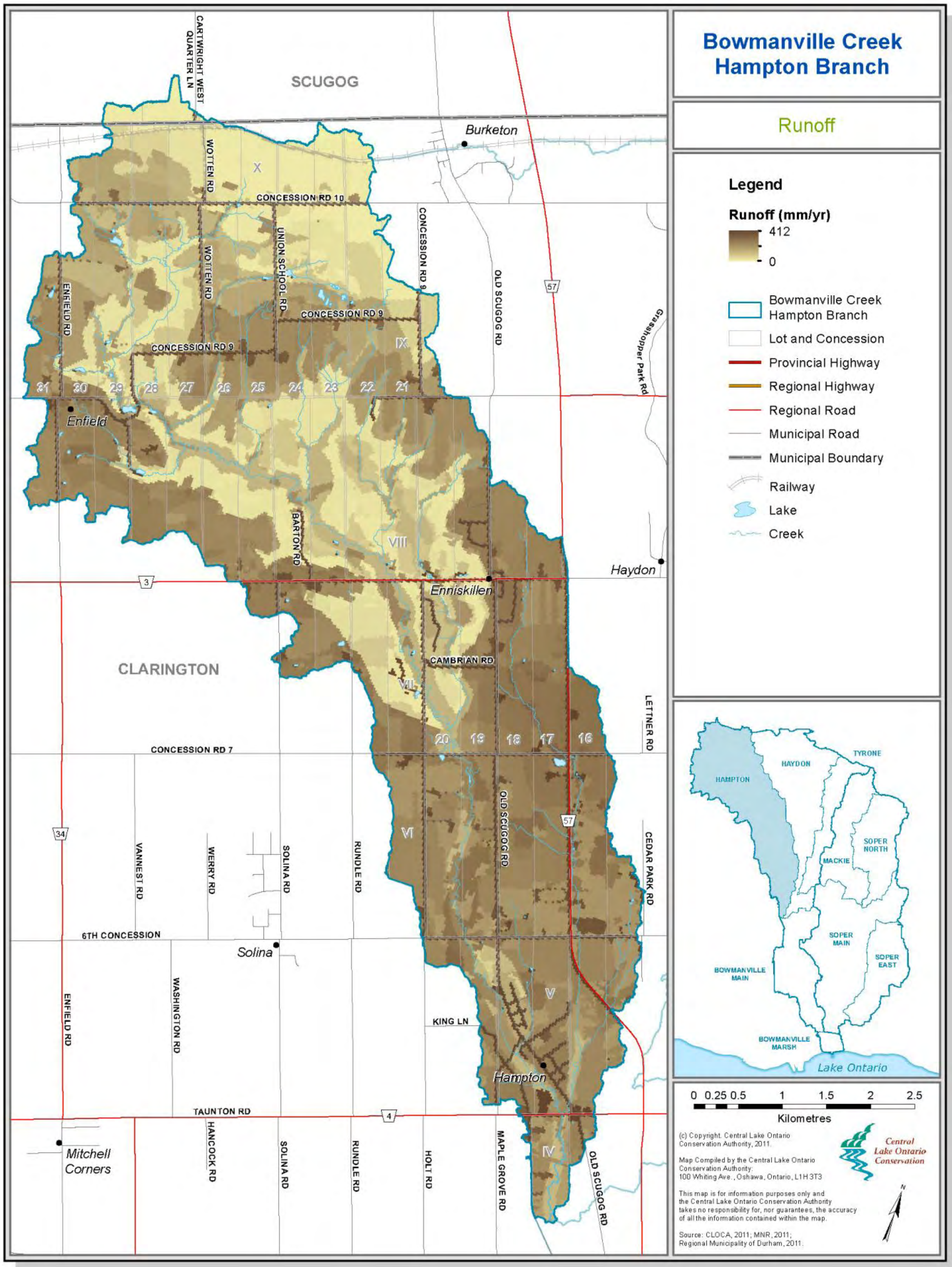


Figure 8: Runoff in the Hampton subwatershed (data extracted from Earthfx, 2007).

Monitoring

The Hampton subwatershed contains one creek flow monitoring station, it is located on Mill Street in Hampton (Hampton) and is shown on Figure 6. The average stream flow for this station is presented in the table below and the average monthly stream flow for this station is presented in Figure 9.

Table 5: Hampton subwatershed average annual stream flow.

Station	Description	Average Annual Stream Flow (m^3/s)
Hampton	Hampton, Mill Street	1.08

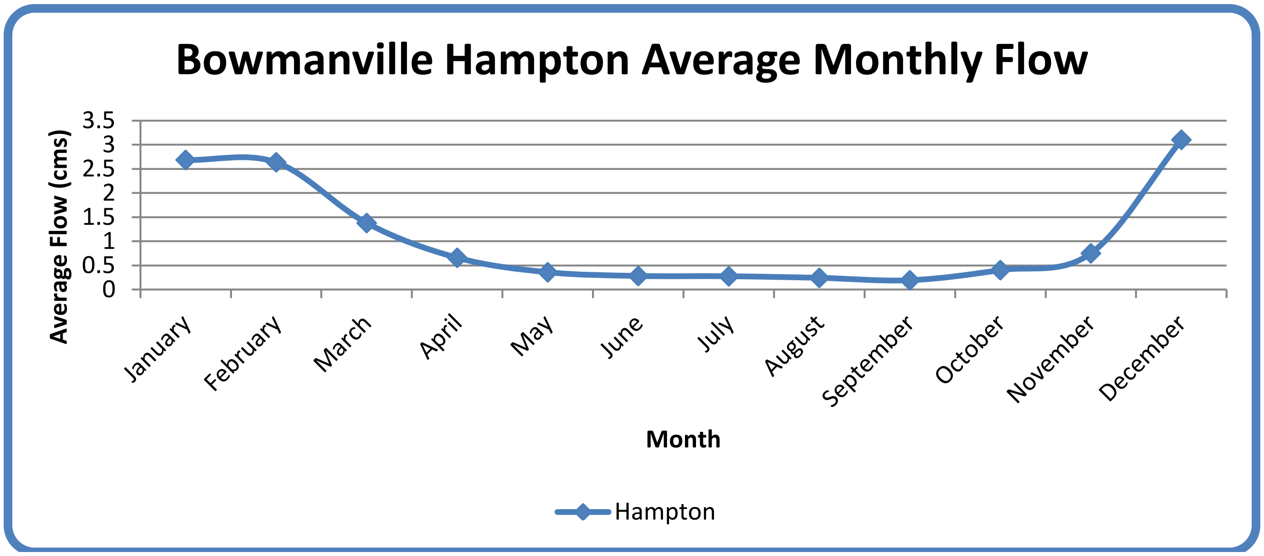


Figure 9: Average monthly streamflow for the Hampton subwatershed gauge station.

The Hampton subwatershed has 10 baseflow stations (Figure 10). The average baseflow values for this subwatershed range from 0 to 0.38 cubic meters per second.

Mill Street Bridge, Hampton

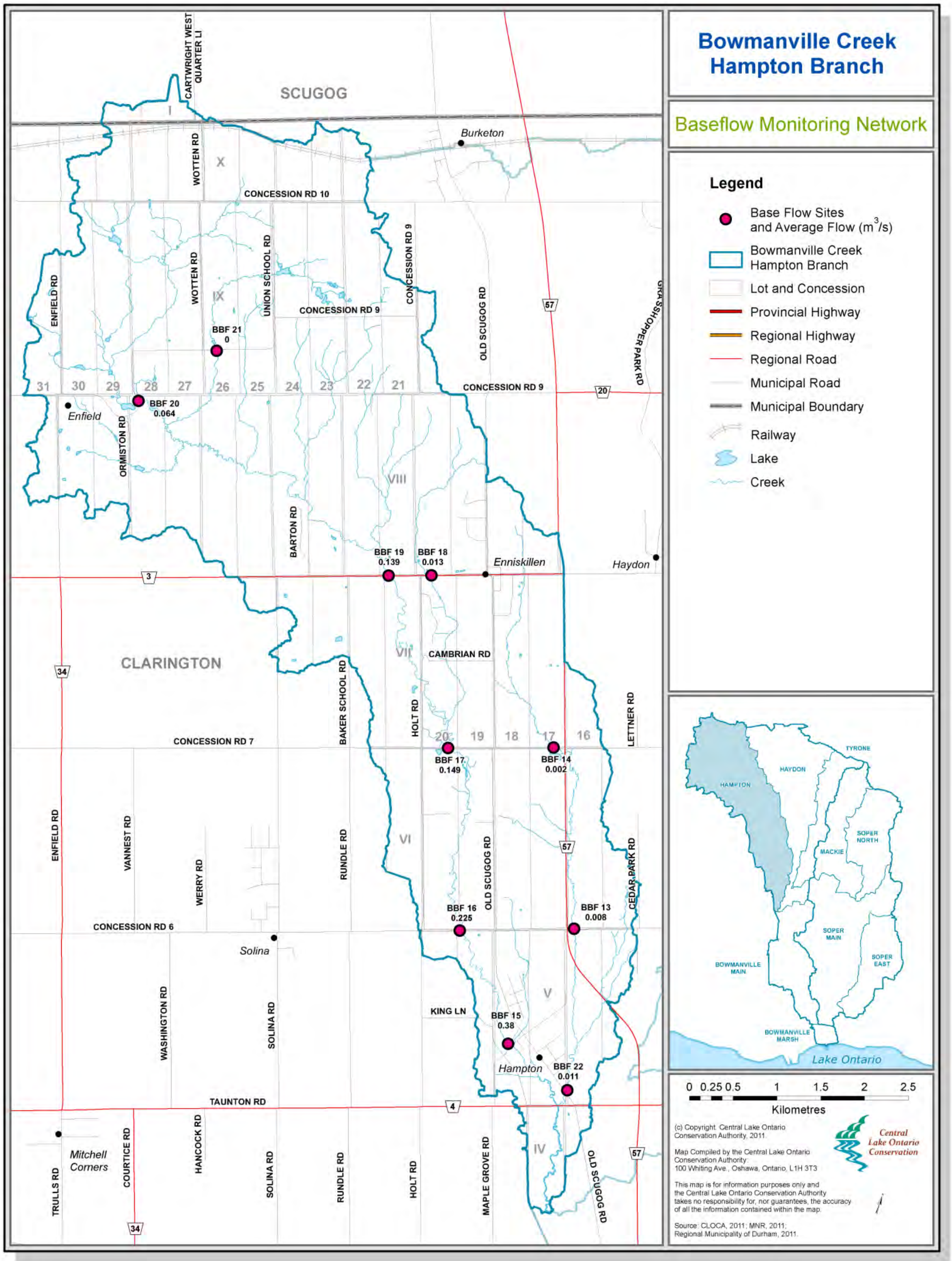


Figure 10: Baseflow stations and average flow for the Hampton subwatershed.

4.2.1.2 Haydon Subwatershed

Hydrology - Event Modeling

The Haydon subwatershed contains 3 catchments and 1 reference node (Figure 2). The reference node and the associated peak flow are presented in the table below.

Table 6: Haydon subwatershed reference nodes.

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
17	Mouth of Haydon	242.2

Hydrology – Transient Modelling

The distribution of long-term average annual watershed runoff in mm/year is shown in Figure 11 for the subwatershed. The runoff value is very low for this subwatershed, reflecting the low imperviousness of the subwatershed. The long-term average annual runoff is estimated at approximately 143mm/year for the subwatershed, which is the lowest value within the watershed (watershed average is 190mm/year).


Haydon Subwatershed

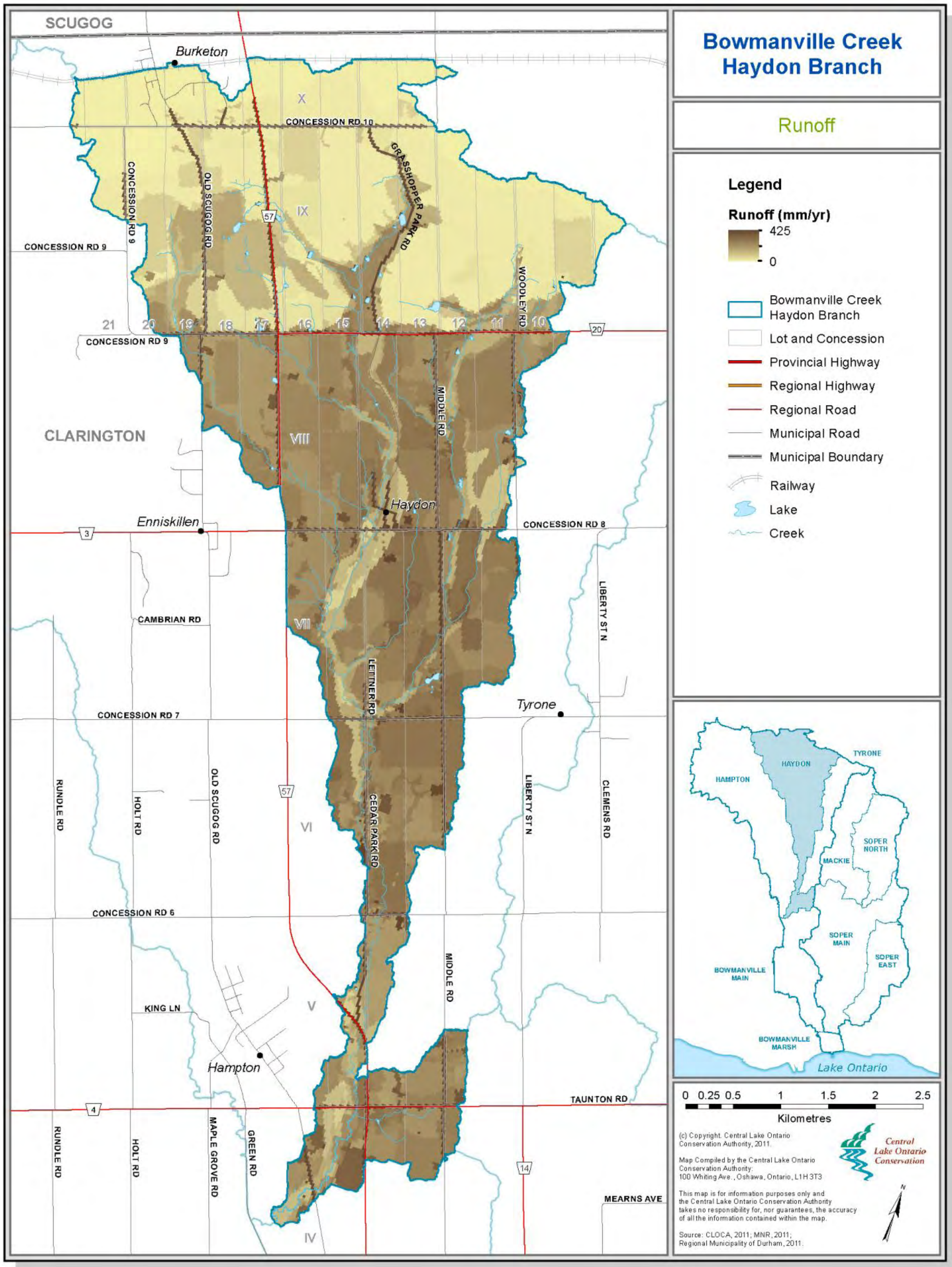


Figure 11: Runoff in the Haydon subwatershed (data extracted from Earthfx, 2007).

Monitoring

The Haydon subwatershed contains one creek flow monitoring station, it is located on Taunton Road, just east of Hampton (Bow-EB) and is shown on Figure 6. The average stream flow for this station is presented in the table below and the average monthly stream flow for this station is presented in Figure 12.

Table 7: Haydon subwatershed average stream flow.

Station	Description	Average Stream Flow (m^3/s)
Bow-EB	Taunton Road	1.20

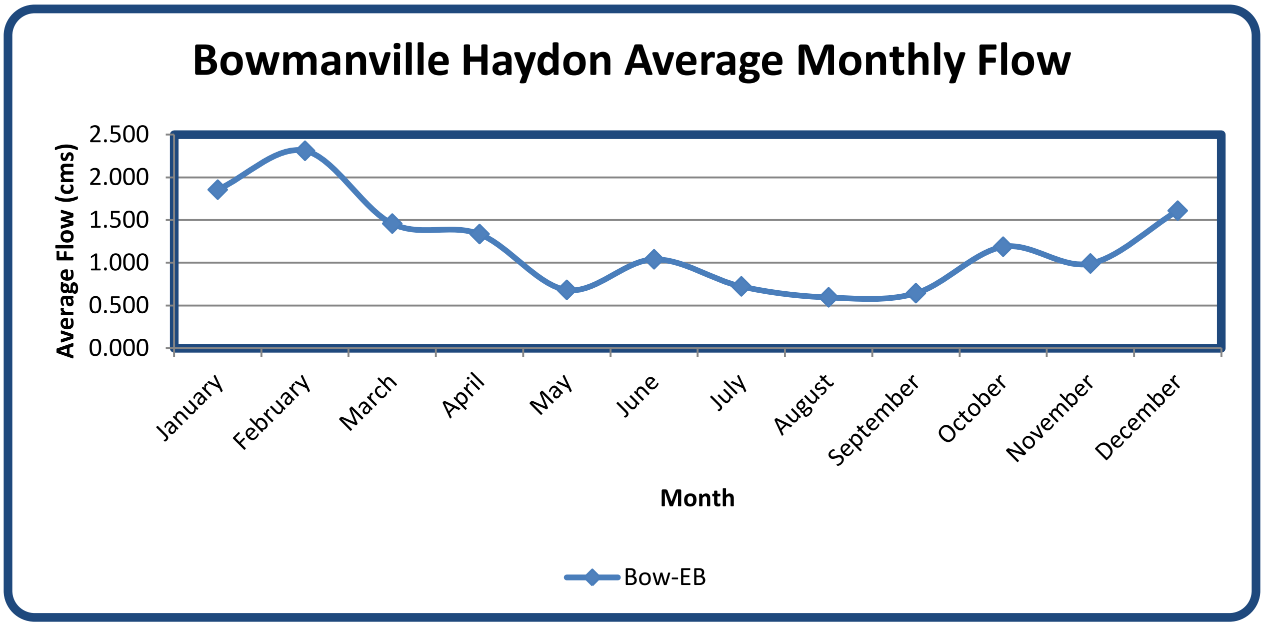


Figure 12: Average monthly streamflow for the Haydon subwatershed gauge station.

The Haydon subwatershed has 8 baseflow stations (Figure 13). The average baseflow values for this subwatershed range from 0 to 0.53 cubic meters per second.

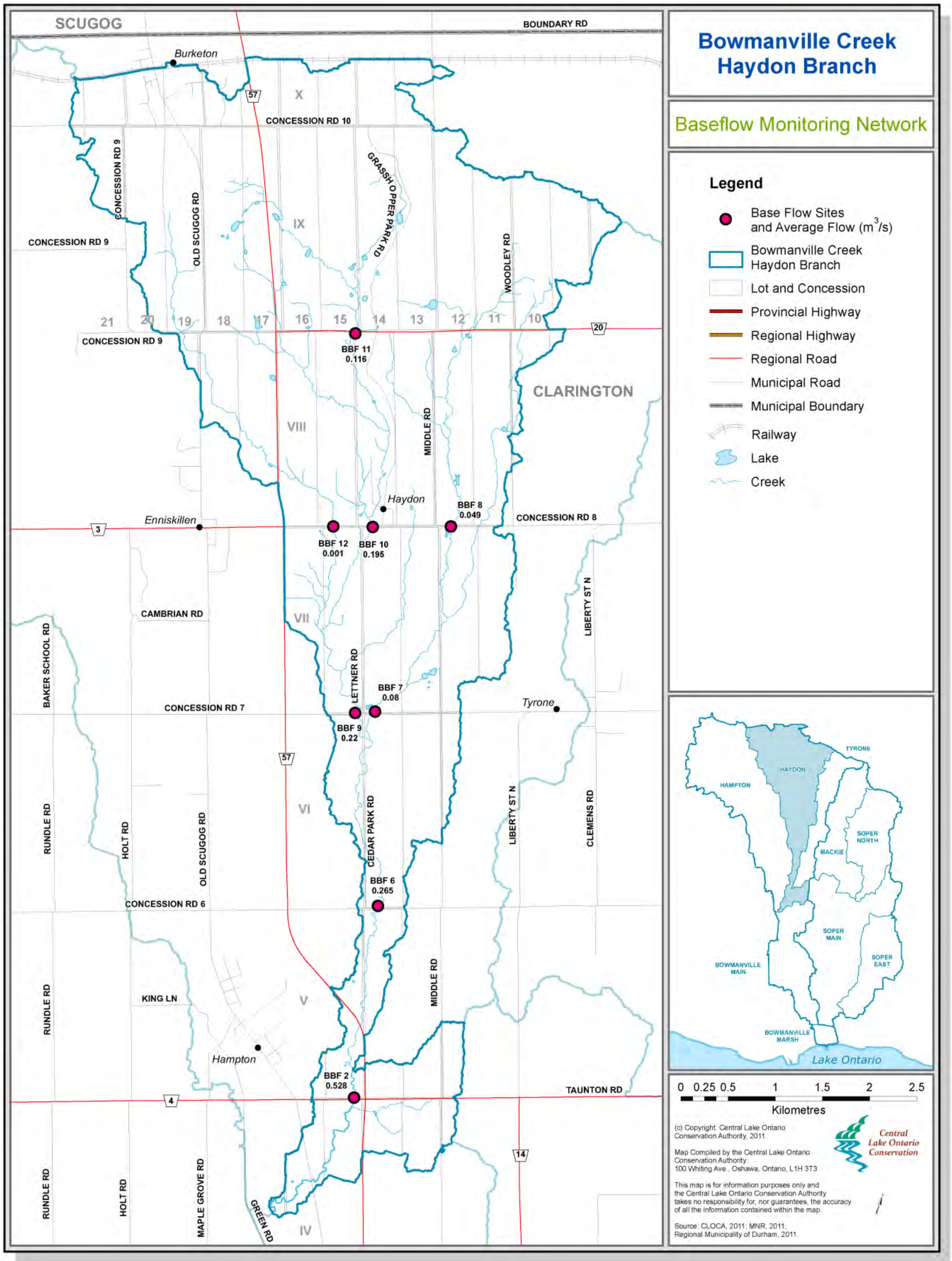


Figure 13: Baseflow stations and average flow for the Haydon subwatershed

4.2.1.3 Tyrone Subwatershed

Hydrology – Event Modeling

The Tyrone subwatershed has 1 catchment and 1 reference node (Figure 2). The reference nodes and the associated peak flows are presented in Table 8.

Table 8: Tyrone subwatershed reference nodes.

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
18	Mouth of Tyrone	15.21

Hydrology – Transient Modeling

The distribution of long-term averaged annual watershed runoff in mm/year is shown in Figure 14 for the subwatershed. Low runoff values are observed within this watershed. The long-term average annual runoff is estimated at approximately 151mm/year for the subwatershed which is slightly less than watershed average of 190mm/year.

Monitoring

The Tyrone subwatershed has no flow monitoring stations and 3 baseflow stations (Figure 15). The baseflow measurements within this subwatershed range in value from 0.11 to 0.25 cubic metres per second.

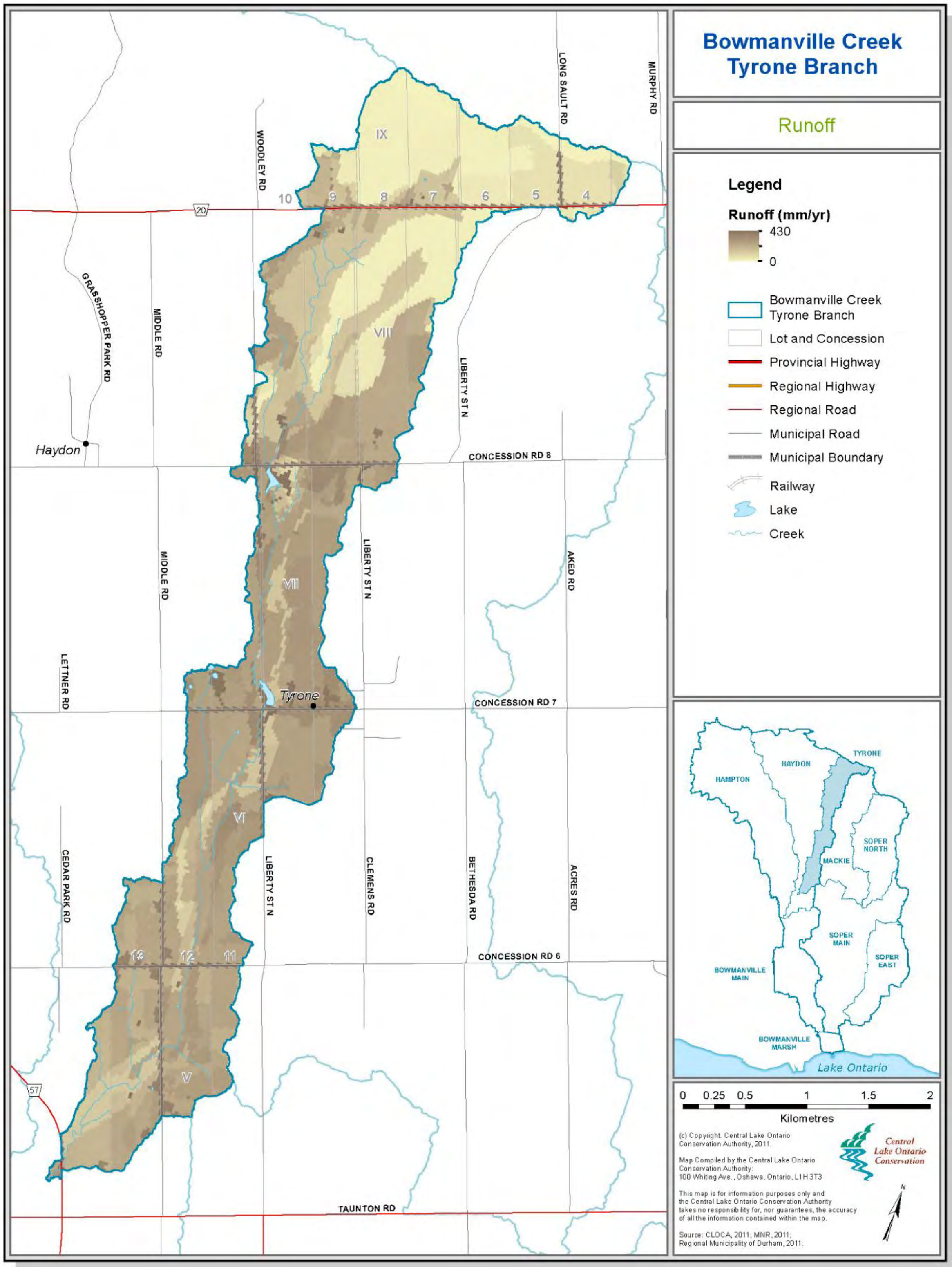


Figure 14: Runoff in the Tyrone subwatershed (data extracted from Earthfx, 2007).

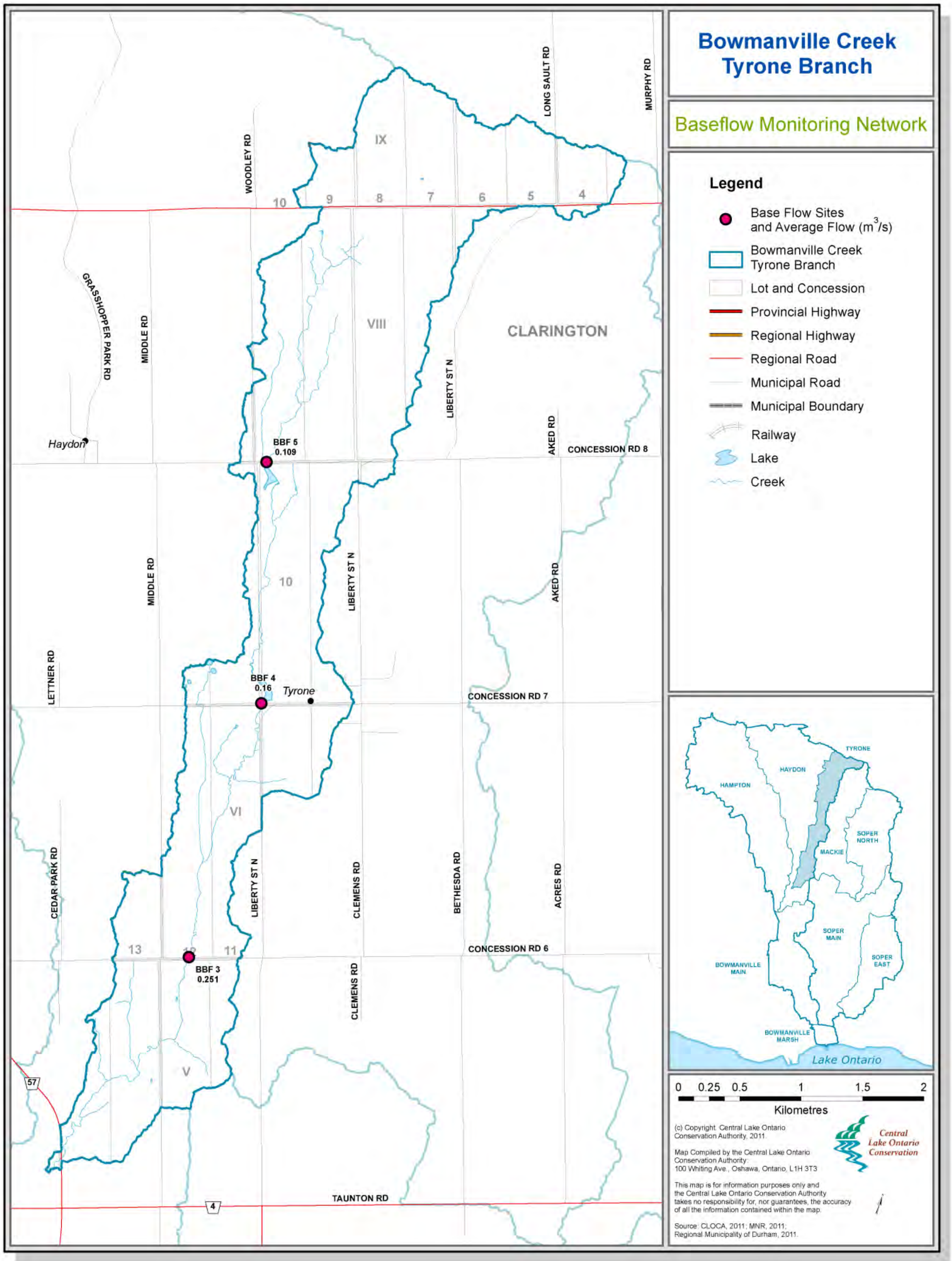


Figure 15: Baseflow stations and average flow in the Tyrone subwatershed.

4.2.1.4 Bowmanville Main Subwatershed

Hydrology – Event Modeling

The Bowmanville Main subwatershed contains 7 catchments and 4 reference nodes (Figure 2). The reference nodes and the associated peak flows are presented in the table below.

Table 9: Bowmanville Main subwatershed reference nodes.

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
36	Mouth of Bowmanville Main (401)	462.75
34	Upstream of Highway 2	460.22
28	Longworth Drive	440.46
19	After the confluence of Hampton and Haydon	416.20

Hydrology – Transient Modeling

The distribution of long-term average annual watershed runoff in mm/year is shown in Figure 16 for the subwatershed. Higher runoff values are reflected in this subwatershed, as it is contains a significant amount of urban residential area. The long-term average annual runoff is estimated at approximately 207mm/year for the subwatershed which higher than watershed average of 190mm/year for the watershed.

Bowmanville Main Subwatershed

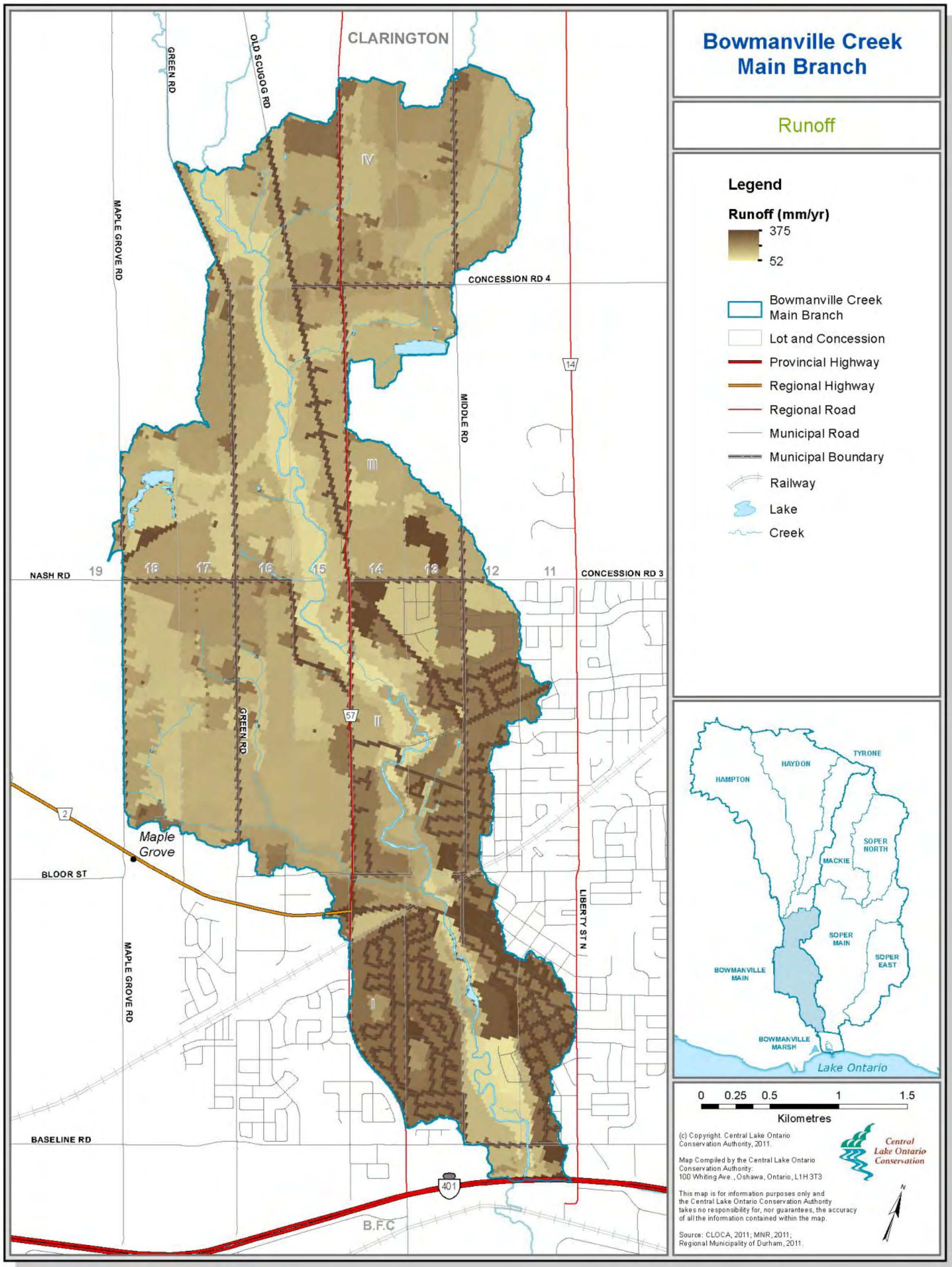


Figure 16: Runoff in the Bowmanville Main subwatershed (data extracted from Earthfx, 2007).

Monitoring

The Bowmanville Main subwatershed has one monitoring stations, it is located on Jackman Road and is shown on Figure 6. The average stream flow for this station is presented in the table below and the average monthly stream flow for this station is presented in Figure 17.

Table 10: Bowmanville Main subwatershed average stream flow.

Station	Description	Average Stream Flow (m^3/s)
02HD006	Jackman Road	1.31

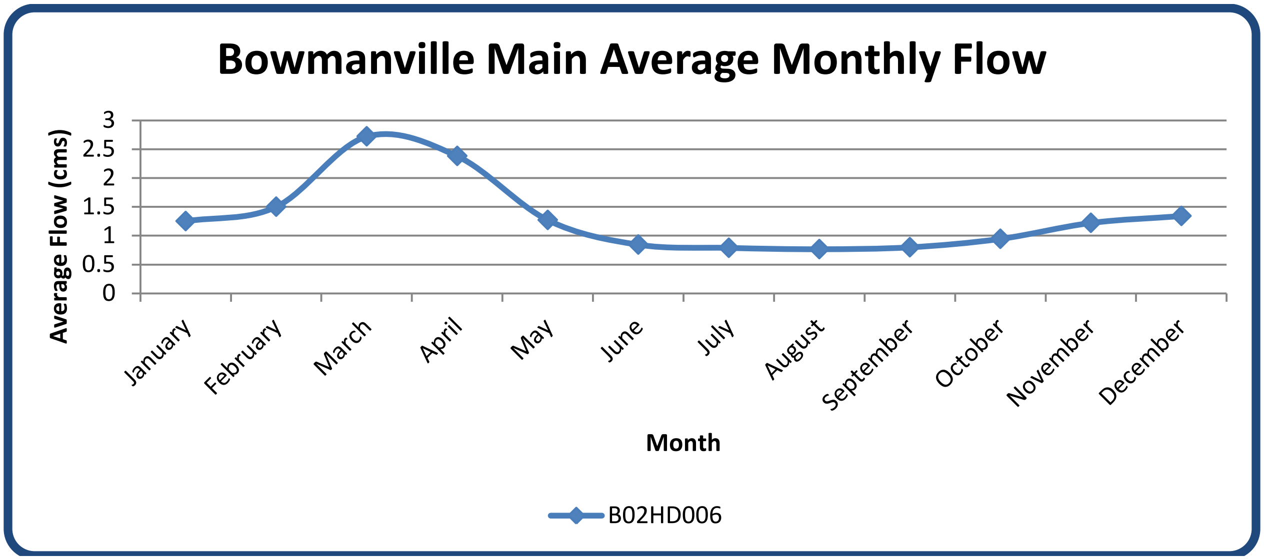


Figure 17: Average monthly streamflow for the Bowmanville Main subwatershed gauge station.

The Bowmanville Main subwatershed has 2 baseflow stations (Figure 18). The baseflow measurements within this subwatershed range in value from 0.87 to 1.09 cubic metres per second.

Baseflow station Bowmanville Creek

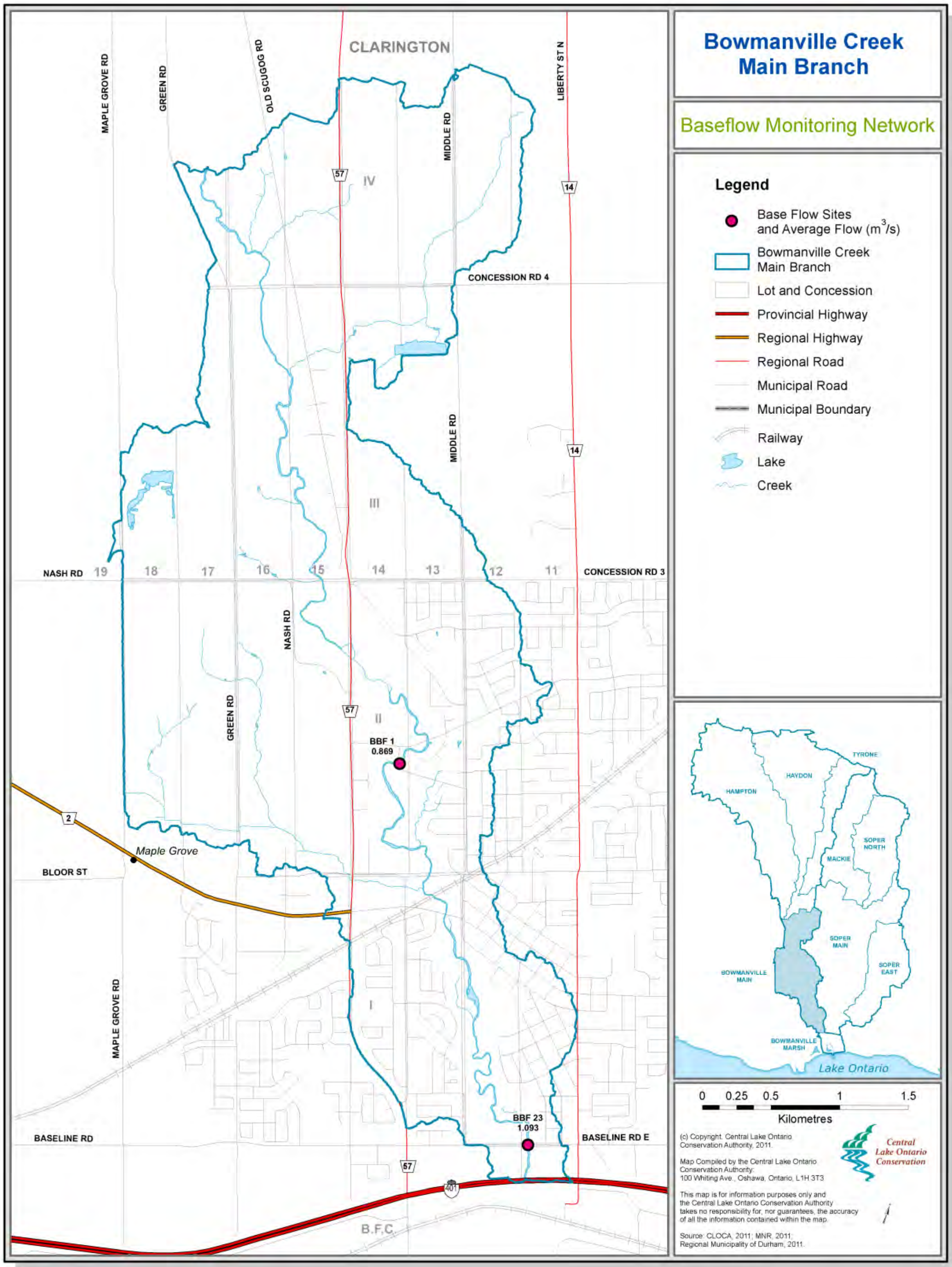


Figure 18: Baseflow stations and average flow in the Bowmanville Main subwatershed.

4.2.1.5 Bowmanville Marsh Subwatershed

Hydrology – Event Modeling

The Bowmanville Marsh subwatershed contains 3 catchments and 1 reference node (Figure 2). The reference nodes and the associated peak flows are presented the table below.

Table 11: Bowmanville Marsh subwatershed reference nodes.

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
113	Mouth – Lake Ontario	972.05

Hydrology – Transient Modeling

The distribution of long-term average annual runoff in mm/year is shown in Figure 19 for the subwatershed. Higher runoff rates are experienced in this subwatershed, as there is significant industrial/commercial and urban residential landuse. The long-term average annual runoff is estimated at approximately 225mm/year for the subwatershed which is the highest value in the watershed (watershed average of 190mm/year).

Monitoring

The Bowmanville Marsh subwatershed does not have any flow monitoring stations or baseflow stations.

Bowmanville Marsh Subwatershed

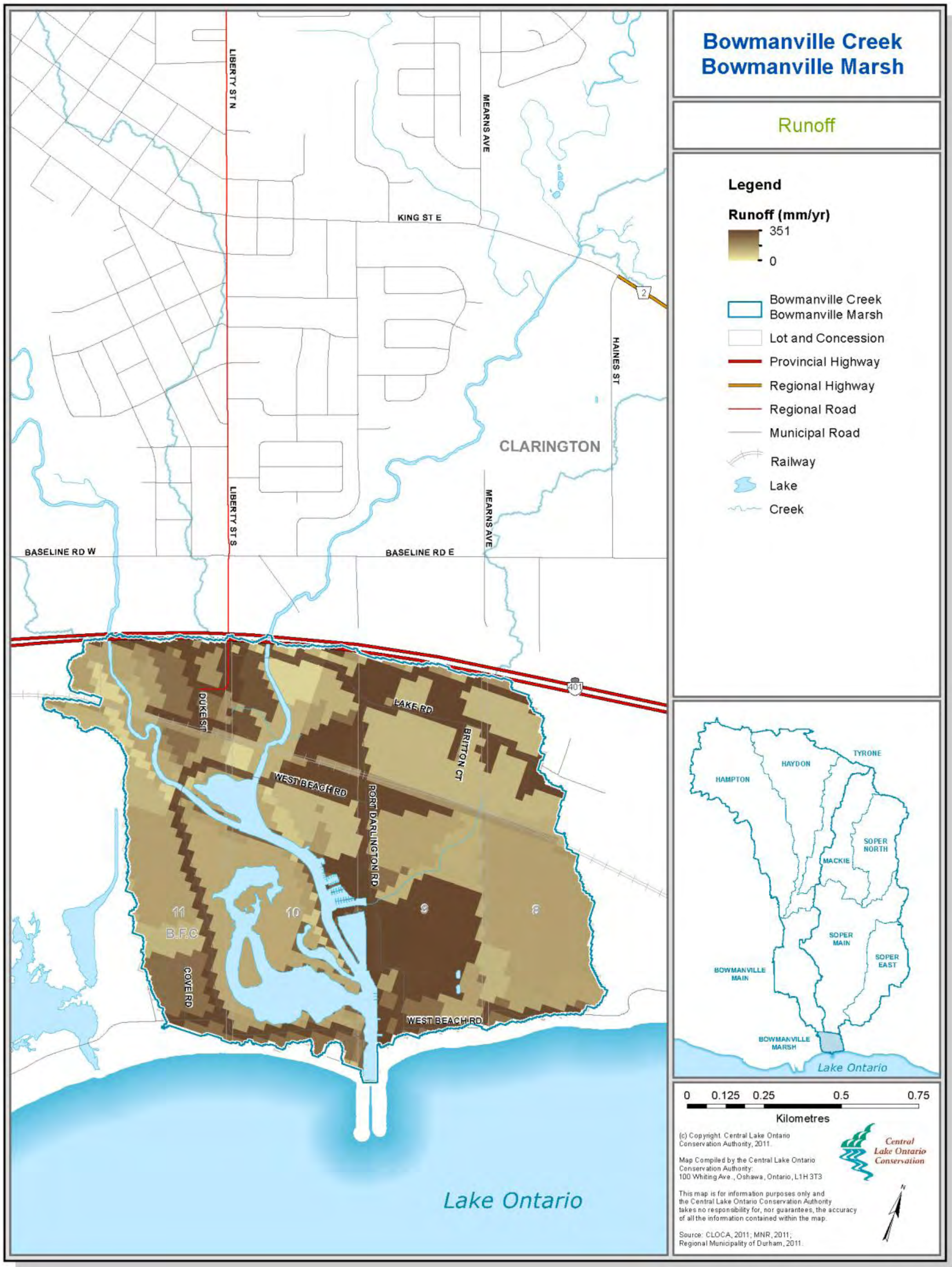


Figure 19: Runoff in the Bowmanville Marsh subwatershed (data extracted from Earthfx, 2007).

4.2.2 Soper Creek Subwatershed

4.2.2.1 Mackie Subwatershed

Hydrology – Event Modeling

The Mackie subwatershed contains 4 catchments and 1 reference node (Figure 2). The reference nodes and the associated peak flows are presented in the table below.

Table 12: Mackie subwatershed reference notes

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
48	Mouth of Mackie	114.52

Hydrology – Transient Modeling

The distribution of long-term average annual runoff in mm/year is shown in Figure 20 for the subwatershed. The Mackie subwatershed exhibits a low runoff rate, the long-term average annual runoff is estimated at approximately 172mm/year for the subwatershed which is below the watershed average of 190mm/year.

Soper Creek

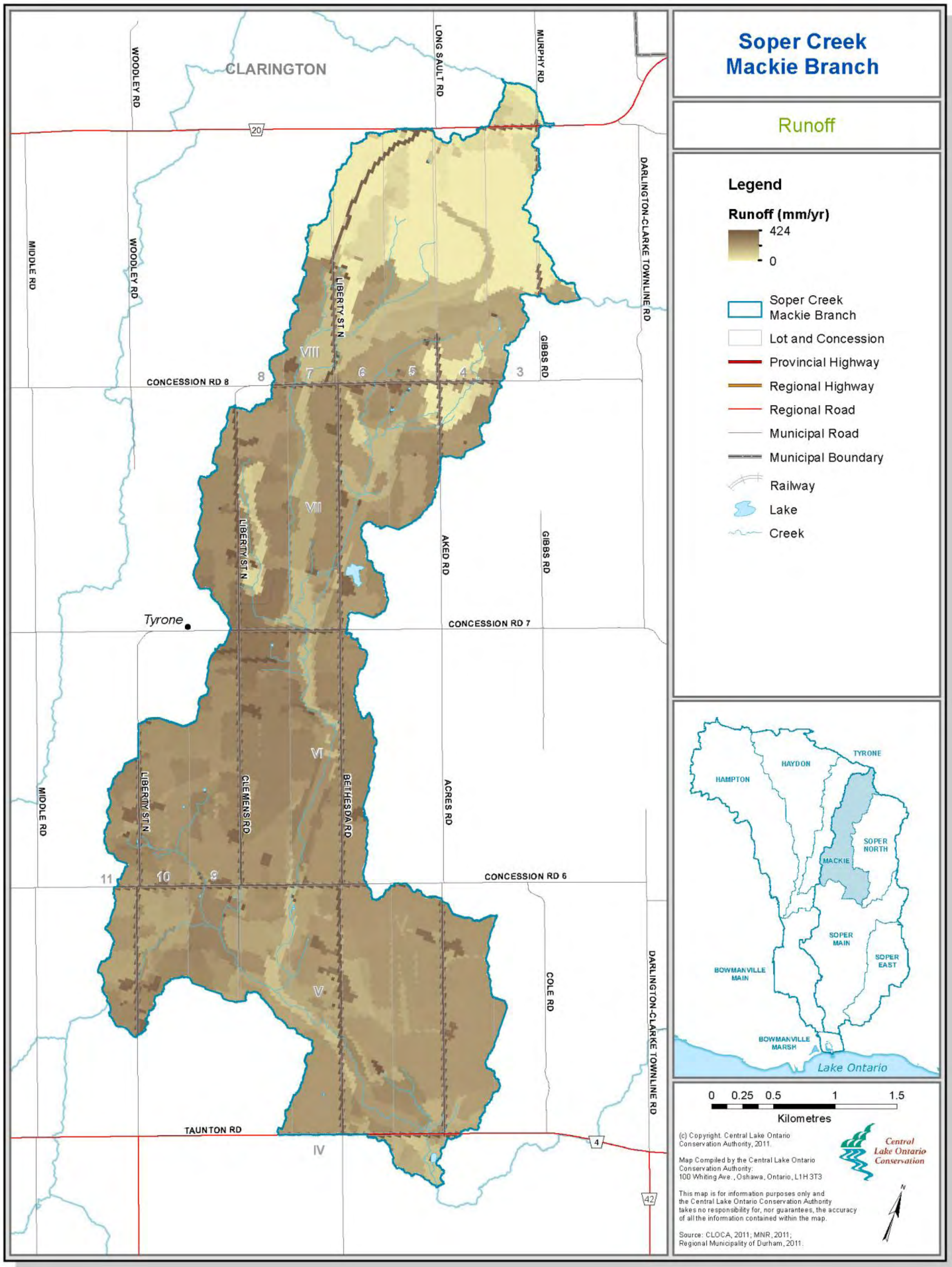


Figure 20: Runoff in the Mackie subwatershed (data extracted from Earthfx, 2007).

Monitoring
The Mackie subwatershed has one flow monitoring stations located on Taunton Road (02HD023) and is shown on Figure 6. The average stream flow for this station is presented in the table below and the average monthly stream flow for this station is presented in Figure 21.

Table 13: Mackie subwatershed average stream flow.

Station	Description	Average Stream Flow (m^3/s)
02HD023	Taunton Road	0.28

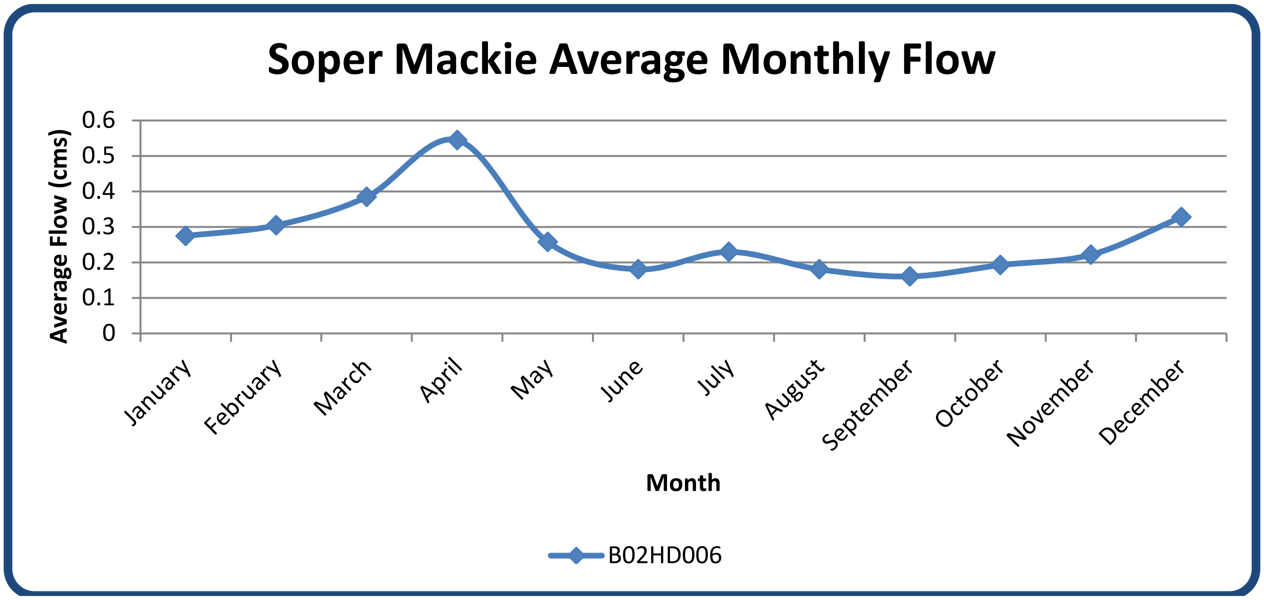


Figure 21: Average monthly streamflow for the Mackie subwatershed gauge station.

The Mackie subwatershed has 5 baseflow stations (Figure 22). The baseflow measurements within this subwatershed range in value from 0.04 to 0.21 cubic metres per second.

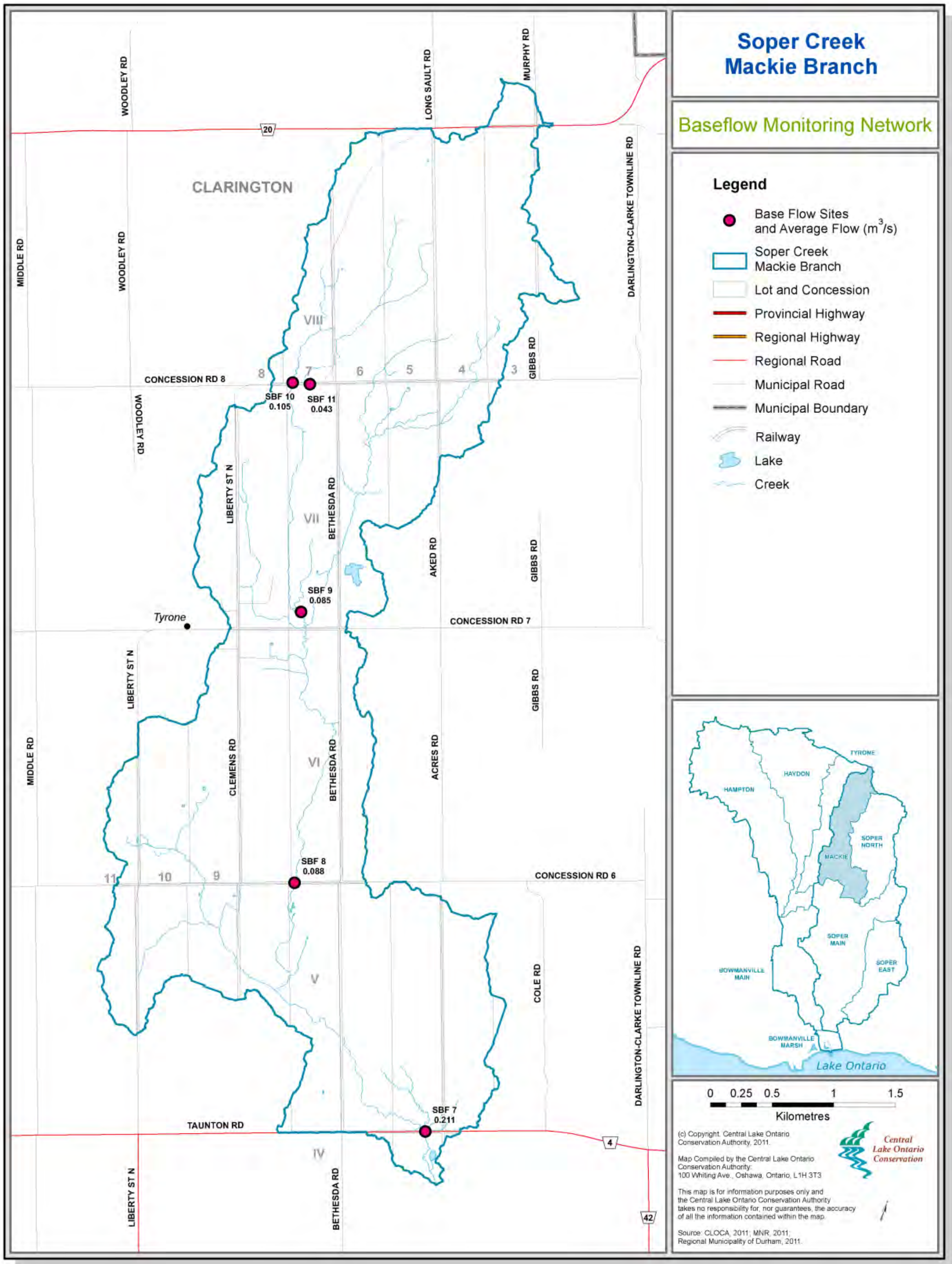


Figure 22: Baseflow stations, average flow and recharge in the Mackie subwatershed

4.2.2.2 Soper North Subwatershed

Hydrology – Event Modeling

The Soper North subwatershed contains 2 catchments and 1 reference node (Figure 2). The reference nodes and the associated peak flows are presented in the table below.

Table 14: Soper North subwatershed reference nodes

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
52	Mouth of Soper North	125.37

Hydrology – Transient Modeling

The distribution of long-term average annual runoff in mm/year is shown in Figure 23 for the subwatershed. The Soper North subwatershed is predominantly rural, and thus displays low rates of runoff. The long-term average annual runoff is estimated at approximately 173mm/year for the subwatershed which is slightly lower than the watershed average of 190mm/year.

Soper Creek, East Branch Monitoring Station, Soper North Subwatershed

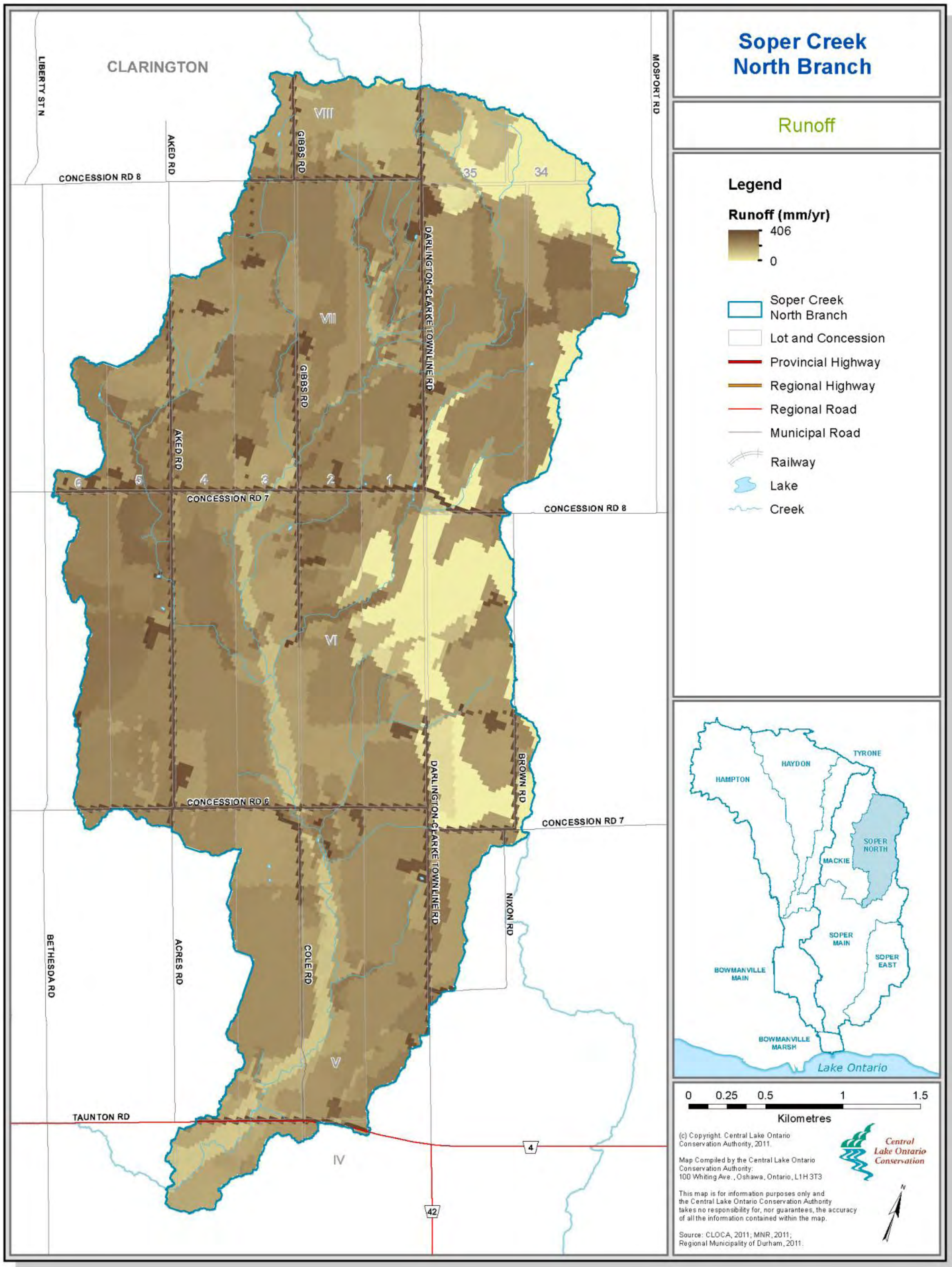


Figure 23: Runoff in the Soper North subwatershed (data extracted from Earthfx, 2007).

Monitoring
The Soper North subwatershed has one flow monitoring stations located on Taunton Road (Sop-EB) and is shown on Figure 6. The average stream flow for this station is presented in the table below and the average monthly stream flow for this station is presented in Figure 24.

Table 15: Soper North subwatershed average stream flow.

Station	Description	Average Stream Flow (m^3/s)
Sop-EB	Taunton Road	0.51

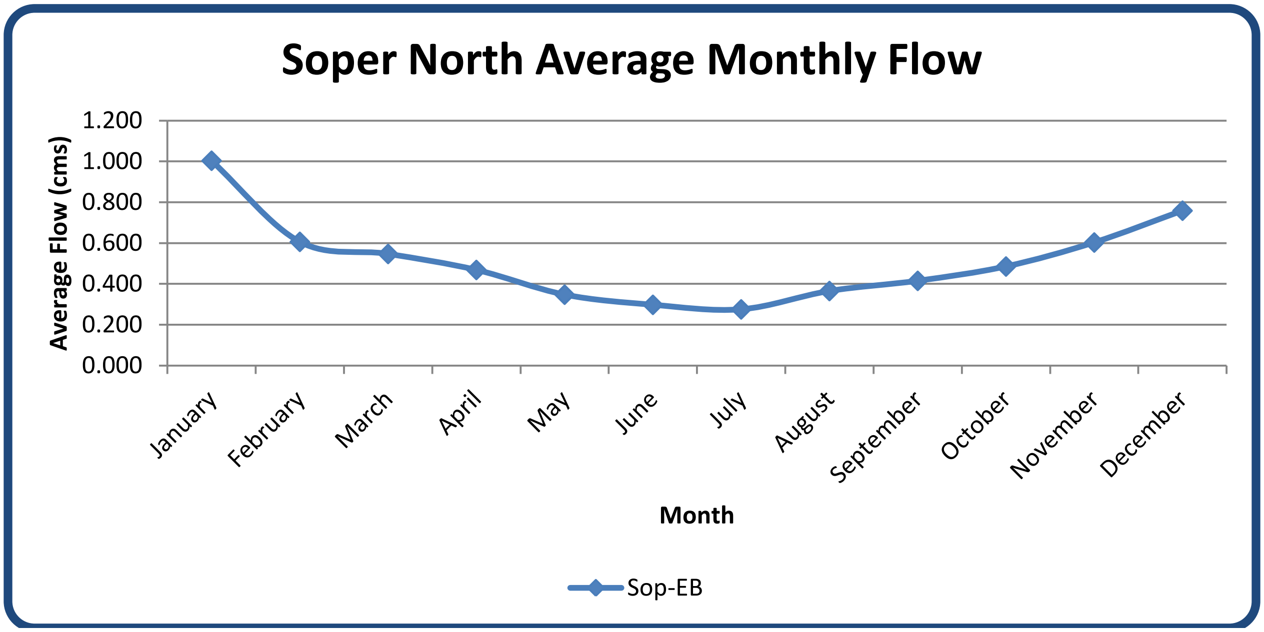


Figure 24: Average monthly streamflow for the Soper North subwatershed gauge station.

The Soper North subwatershed has 6 baseflow stations (Figure 25). The baseflow measurements within this subwatershed range in value from 0.01 to 0.19 cubic metres per second.

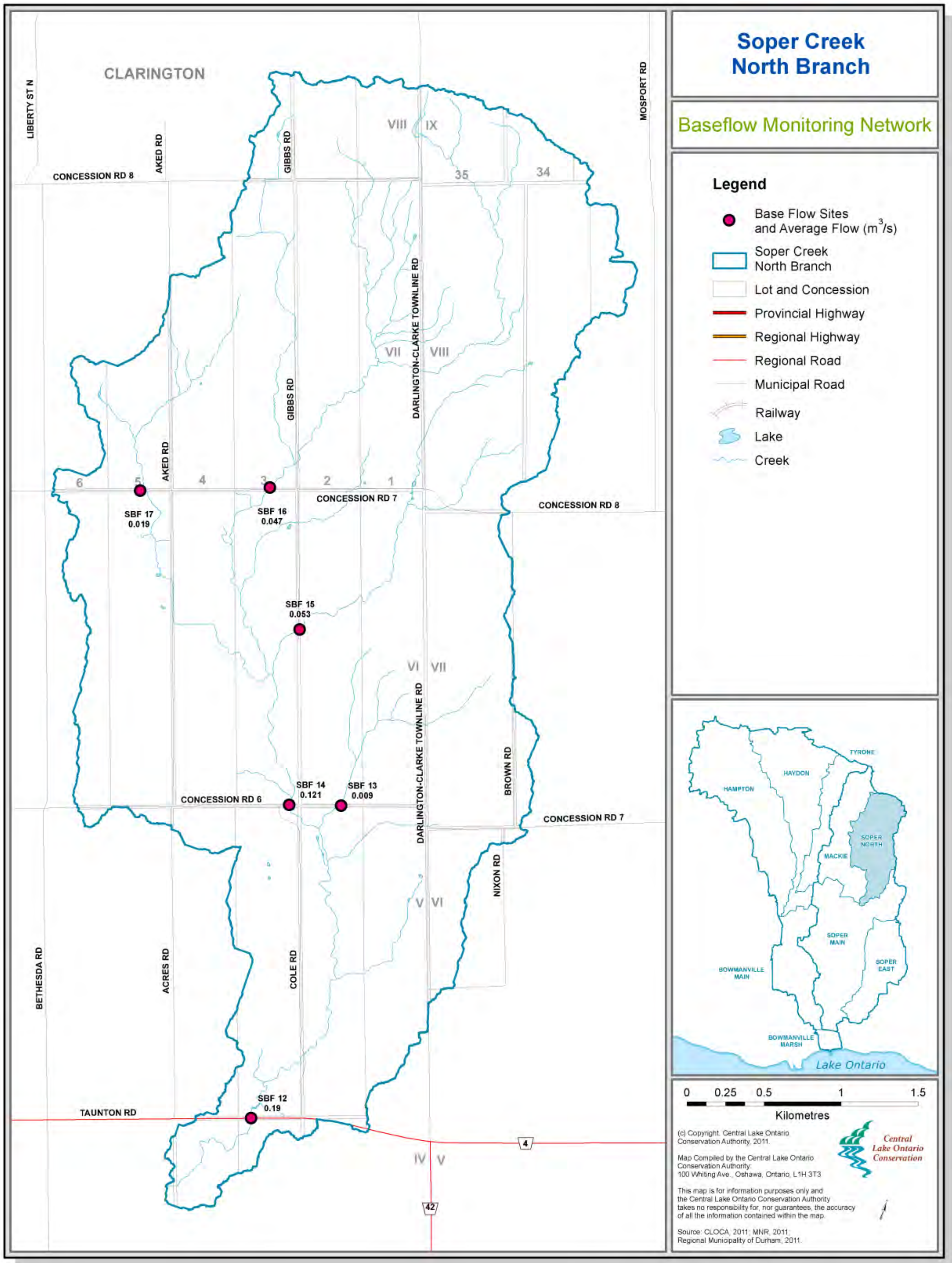


Figure 25: Baseflow stations, average flow and recharge in the Soper North subwatershed

4.2.2.3 Soper Main Subwatershed

Hydrology – Event Modeling

The Soper Main subwatershed contains 15 catchments and 2 reference nodes (Figure 2). The reference nodes and the associated peak flows are presented in the table below.

Table 16: Soper Main subwatershed reference nodes

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
106	Mouth of Soper Main (401)	510.28
100	Upstream of Highway 2	504.08

Hydrology – Transient Modeling

The distribution of long-term average annual runoff in mm/year is shown in Figure 26 for the subwatershed. The Soper Main subwatershed contains a significant amount of urban resisdential landuse, and thus displays high rates of runoff. The long-term average annual runoff is estimated at approximately 197mm/year for the subwatershed which is slightly higher than the watershed average of 190mm/year.

Monitoring

The Soper Main subwatershed does not have any flow monitoring stations, but has 4 baseflow stations (Figure 27). The baseflow measurements within this subwatershed range in value from 0.31 to 0.55 cubic metres per second.

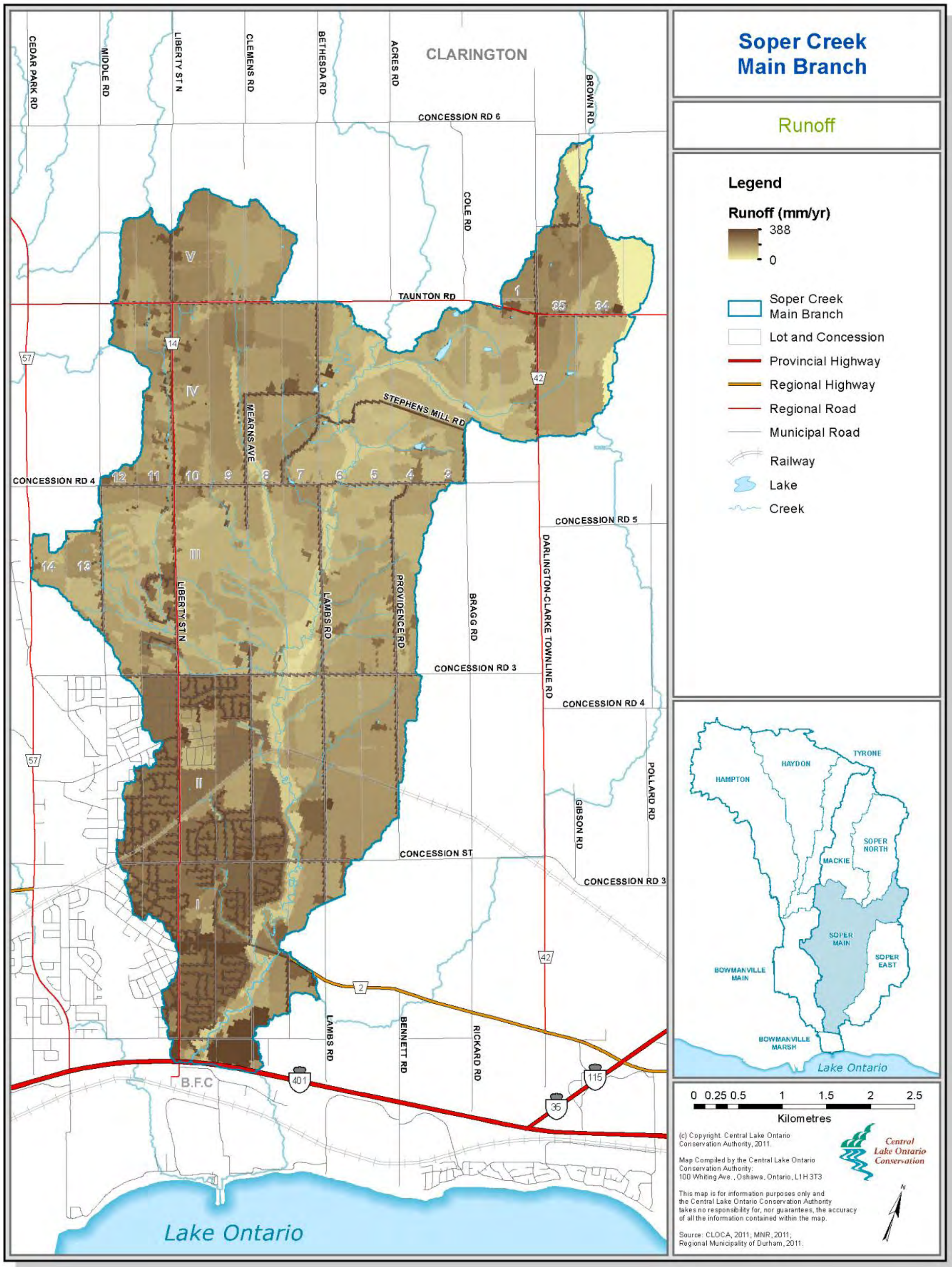


Figure 26: Runoff in the Soper Main subwatershed (data extracted from Earthfx, 2007).

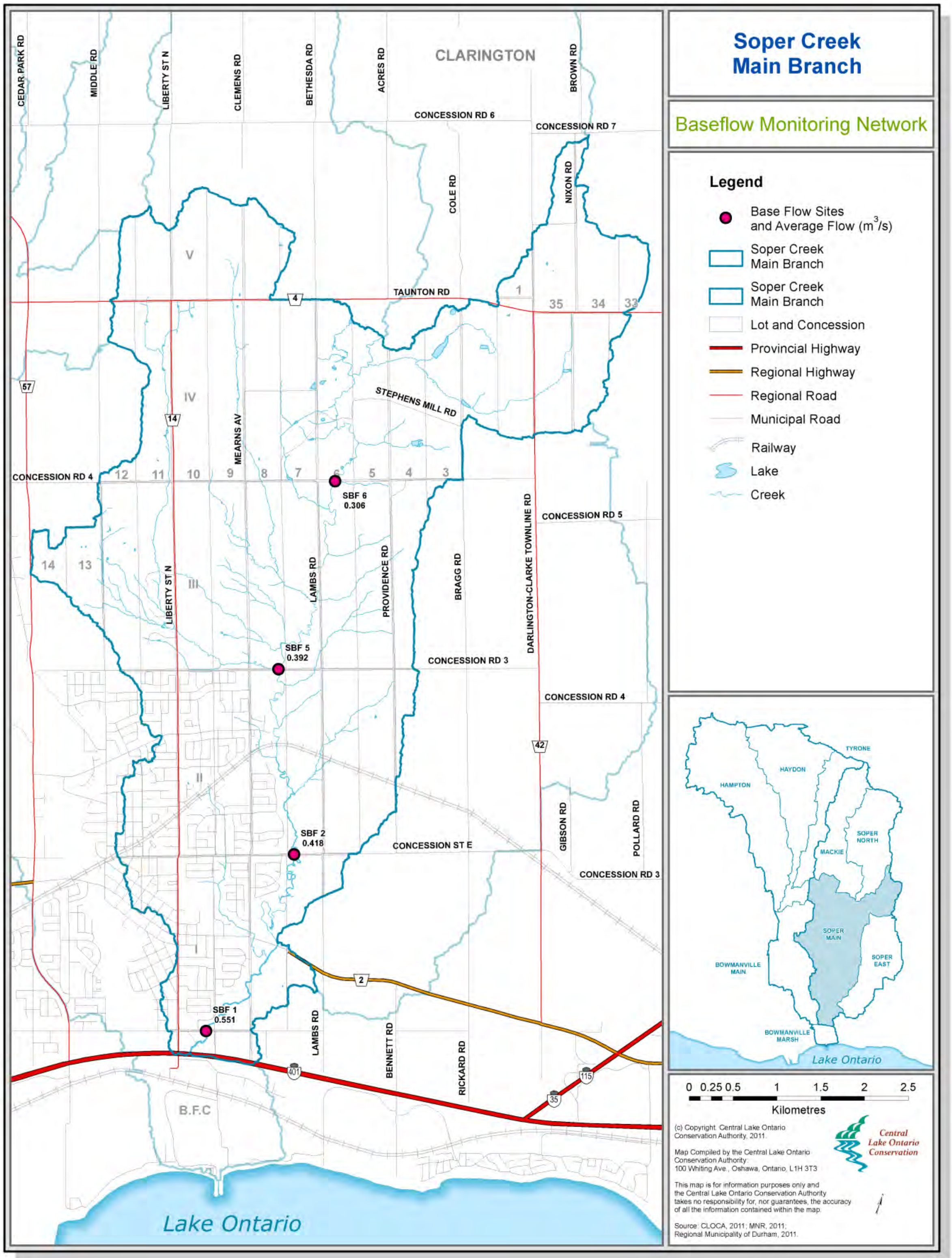


Figure 27: Baseflow stations, average flow and recharge in the Soper Main subwatershed

4.2.2.4 Soper East Subwatershed

Hydrology – Event Modeling

The Soper East subwatershed contains 3 catchments and 2 reference nodes (Figure 2). The reference nodes and the associated peak flows are presented in the table below.

Table 17: Soper East subwatershed reference nodes

Reference Node (NHYD)	Description	Peak Flow (cms) Regional Storm
98	Mouth – Soper East	107.81
96	Bragg Road	75.17

Hydrology – Transient Modeling

The distribution of long-term average annual runoff in mm/year is shown in Figure 28 for the subwatershed. The Soper East subwatershed is predominantly rural, and thus displays low rates of runoff. The long-term average annual runoff is estimated at approximately 169mm/year for the subwatershed which is slightly lower than the watershed average of 190mm/year.

Monitoring

The Soper East subwatershed does not have any flow monitoring stations and has 1 baseflow stations (Figure 29). The average baseflow measurement at this station is 0.04 cubic metres per second.

Soper East Subwatershed

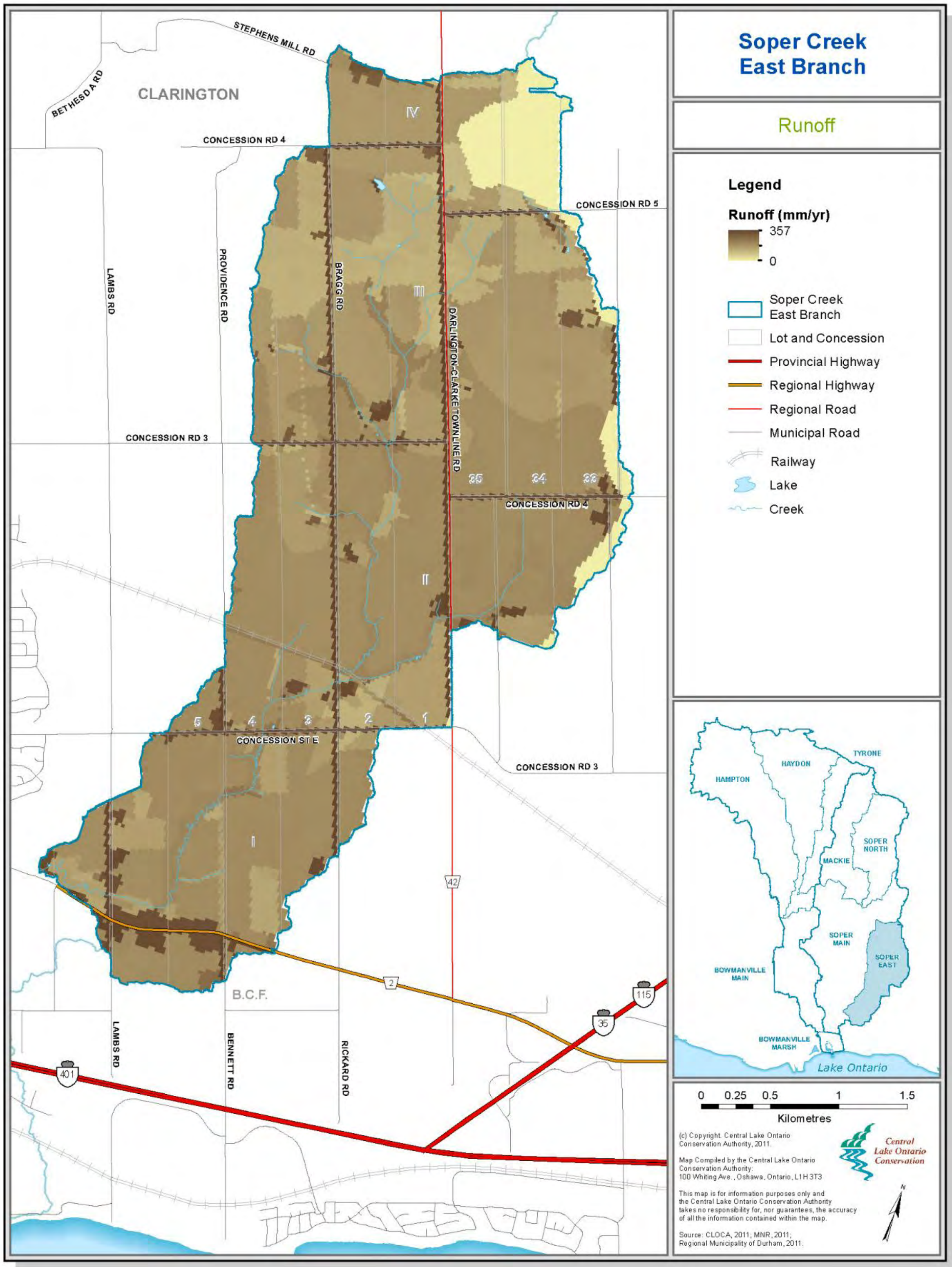


Figure 28: Runoff in the Soper East subwatershed (data extracted from Earthfx, 2007).

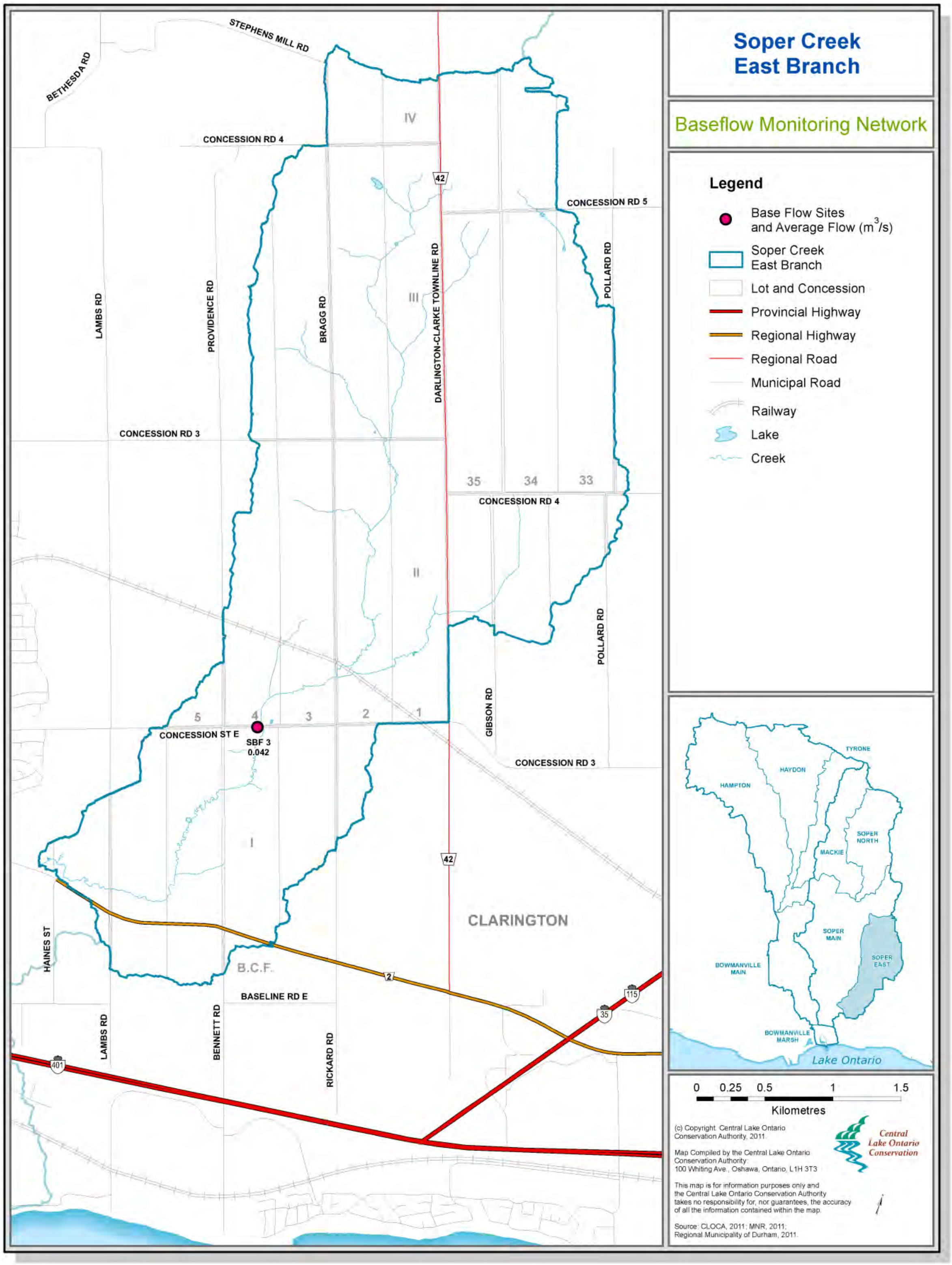


Figure 29: Baseflow stations, average flow and recharge in the Soper East subwatershed

5.0 CONCLUSIONS

Monitoring and modeling surface water quantity are key activities in gaining an understanding of the surface water flow within the watershed. A stream flow monitoring network has been established within the Bowmanville/Soper Creek watershed along with an extensive baseflow monitoring program. The peak and transient runoff for the watershed and each subwatershed has been modeled using various software applications. The 'Generic Regulation limits' include the identified areas of flooding hazards generated by the 2010 hydraulic model, updates are currently in progress and are expected to be completed by the spring of 2011.

This monitoring network, coupled with low flow investigations and detailed hydrologic and hydraulic models, provides a good base from which to manage the water resources of the Bowmanville/Soper Creek watershed.

Good Year Dam, Bowmanville Main Subwatershed

6.0 REFERENCES

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WHAT WE DO ON THE LAND IS MIRRORED IN THE WATER