Regional Watershed Monitoring Program: Surface Water Quality Temporal Trends Update 2011-2015

Environmental Monitoring and Data Management Section
Restoration and Infrastructure Division

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1. Media Summary (plain language)

Stream water quality was measured across the Toronto Region between 2011 and 2015 as part of the Toronto and Region Conservation Authority's Regional Watershed Monitoring Program. These data were recently compiled into a report adding this time period to the findings over the past 50 years of monitoring data. This long-term data set allows for the examination of changes in the concentration of several contaminants over time. Phosphorus, chloride and total suspended solids were analyzed because high concentrations can lead poor water quality conditions such as algal blooms, water void of oxygen, reduced water clarity or toxic conditions for fish and other aquatic species.

Phosphorus concentrations were highest at the mouth of the Don River watershed and lowest in the Rouge River, Duffins Creek and upper Humber River watersheds. In general, phosphorus concentrations have been declining across the region since the 1960's. Increasing chloride concentrations over the past 50 years at the majority of water quality stations are a cause for concern. Between 2011 and 2015, seven water quality stations had chloride concentrations that reached potentially lethal concentrations at some point. The concentration of suspended solids in the water declined at the majority of stations over the past 50 years with the most noticeable declines occurring between 1966-1980 and 2006-2015

While these substances are naturally occurring in the environment, high concentrations can be toxic to aquatic life and humans. Sources of these contaminants on the landscape vary. Phosphorus is input from sewage effluent or agricultural fertilizers while chloride generally comes from road salts applied during the winter season which are used for de-icing roads and parking lots. Total suspended solids measures the amount of dirt, sediment or other particles suspended in the water and affects water clarity and aquatic life that needs sunlight. Higher total suspended solids values can be caused by construction sites, untreated stormwater and extreme rain events scouring stream banks.

Many organizations are using best management practices to mitigate these impacts (e.g. improvements in sewage treatment capabilities and stormwater management, fertilizing relative to agricultural needs, banning pesticides for personal use and requiring household detergents to be phosphate-free); however, more efforts are needed because many water quality stations are not meeting the stream water quality objectives set by the province.

2. Tweets

“50 years of stream water quality monitoring shows decreases in phosphorus and increases in chloride”

“Chloride concentrations continue to rise across the jurisdiction over the past 50 years”

“Peak chloride concentrations at 7 stream water quality monitoring stations likely lethal to aquatic life”

3. Introduction

Every living thing on earth needs water to survive. Water is used for personal, recreational, and work related purposes. Good water quality is fundamental for good river health. Water quality sustains ecological processes that support fish populations, vegetation, wetlands and bird life. Protecting water quality requires monitoring to identify problems and implement corrective actions. Monitoring stream water quality helps to provide a greater understanding of the potential impacts associated with various land uses on streams and rivers.

Agriculture and urbanization are the two main land use activities that negatively affect stream water quality (Paul and Meyer 2001, TRCA 2011). Stream water quality is impaired by these land uses through the application of fertilizers to agricultural land, salting roads in the winter, discharging waste water from industries and sewage treatment plants and non-point source urban runoff. Monitoring helps water resource managers understand the impacts of various activities on water quality so that informed decisions can be made to manage and protect this valuable resource.

Since 2002, Toronto and Region Conservation Authority (TRCA) has partnered with the Ontario Ministry of the Environment and Climate Change (OMOECC) to monitor surface water quality throughout the TRCA's jurisdiction. Surface water quality samples are collected monthly at 43 sites across the jurisdiction plus several other sites on an as-needed basis. Samples are analyzed for a routine set of analytes including metals, nutrients and bacteria. In addition to routine monitoring, two sentinel sites at the mouths of the Don and Humber Rivers are also analyzed for mercury and pesticides. These data enable TRCA and other agencies to document long-term water quality trends, identify general locations of water quality problems, and determine the effectiveness of broad pollution control and watershed management programs.

This report summarizes current (2011-2015) stream water chemistry within the TRCA's jurisdiction. These data have been added to a long-term dataset and temporal trends are examined at stations with sufficient data. Stream water chemistry for the TRCA jurisdiction has been summarized previously for the periods of 1990-1996 (TRCA 1998), 1996-2002 (TRCA 2003), 2003-2007 (TRCA 2009) and 2006-2010 (TRCA 2011).

3.1 Background

The OMOECC's Provincial Water Quality Monitoring Network (PWQMN) was started in 1964 to collect surface water quality information from watercourses throughout Ontario. Through this program, water quality samples are sent to the Laboratory Services Branch of the MOECC. Over time, stations were added or discontinued in response to changing needs (OMOE 2003). The PWQMN monitored water quality throughout the Toronto region until the OMOECC substantially scaled back the PWQMN due to funding issues in the 1990s. Only the two sentinel stations continued to operate in the Toronto region (06008501402 at the mouth of the

Don River, and 06008301902 at the mouth of the Humber River). In 2002, TRCA began collecting field samples from 11 additional stations as part of the PWQMN, for a total of 13 PWQMN stations in the Toronto region. The 11 stations were sampled 8 times per year on a monthly basis during the ice-free period.

In addition to the PWQMN stations, TRCA collects water quality samples as part of the Regional Watershed Monitoring Program (RWMP). Since 2002, TRCA has monitored 23 additional stations previously part of the PWQMN. In the spring of 2009, two additional water quality stations were added to the RWMP in the Petticoat Creek and Frenchman's Bay watersheds and five stations were added to the Etobicoke Creek watershed in August 2013 for a total of 43 stations (13 PWQMN + 30 RWMP) in the TRCA region (Figure 1, Table 1). The number of stations in each watershed is roughly proportional to the size of the watershed and efforts have been made to establish one site at the outlet of each subwatershed. Station location information is provided in Appendix A. Prior to 2009, water quality samples collected by the RWMP were sent to various laboratories including Entech Inc., City of Toronto Dee Avenue Laboratory and Maxxam Analytics Inc. Between 2009 and May 2015, water quality samples were sent to the York-Durham Regional Environmental Laboratory. Starting in June 2015, water quality samples were sent to the City of Toronto Dee Avenue Laboratory (Appendix B).

From 2002-2003, water quality samples were collected approximately eight times per year from approximately April to November. In 2004, the RWMP expanded its water quality sampling to be year-round. This includes sampling the PWQMN stations during the four months not covered under the agreement with the OMOECC. From 2004-2005, winter samples were not collected if the stream was ice-covered. From 2006 onwards, an auger was used for ice-covered streams ensuring at least one water quality sample is collected per month. In June 2009, TRCA began sampling stations at the Don River (station 85014) and Humber River (station 83019) mouths on behalf of the OMOECC. In exchange, the OMOECC laboratory began to analyze the water quality at six sites (stations: 85014, 104001, 80006, 83019, 82003, 97011) year round. In addition, the RWMP also collects *Escherichia coli (E. coli)* samples from all sites (both RWMP and PWQMN) year round.

FIGURE 1: CURRENT PWQMN/RWMP WATER QUALITY MONITORING LOCATIONS 2011 - 2015

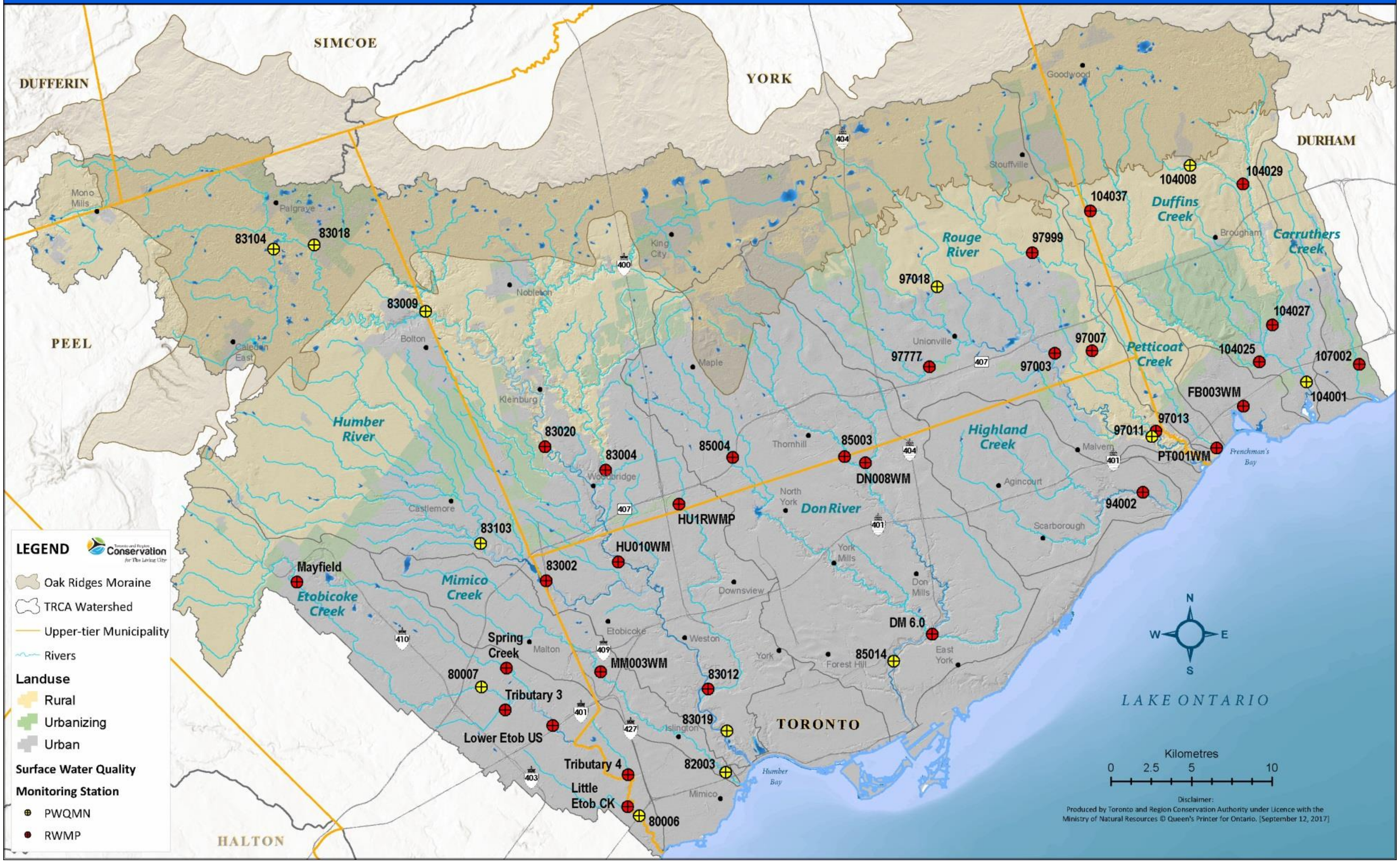


Table 1. Number of water quality sampling locations per watershed and station names

Watershed	# Stations	Stations
Etobicoke Creek	8	Mayfield, 80007*, Spring Creek, Tributary 3, Lower Etob US, Tributary 4, Little Etob CK, 80006*[M]
Mimico Creek	2	MM003WM, 82003*[M]
Humber River	11	83104*, 83018*, 83009*, 83020, 83004, 83103*, HU1RWMP, HU010WM, 83002, 83012, 83019*[M]
Don River	5	85004, 85003, DN008WM, DM6.0, 85014*[M]
Highland Creek	1	94002*[M]
Rouge River	7	97999, 97018*, 97777, 97003, 97007, 97013, 97011*
Petticoat Creek	1	PT001WM[M]
Frenchman's Bay (Pine Creek)	1	FB003WM
Duffins Creek	6	104008*, 104037, 104029, 104027, 104025, 104001*[M]
Carruthers Creek	1	107002[M]

Notes: * denotes a OMOE PWQMN station
[M] denotes a station at the mouth of the watershed or on the main tributary
Many station names have been shortened from the original 11-digit OMOE code (e.g. 06008501402 ⇒ 85014

3.2 QA/QC

Inter-laboratory QA/QC programs were run in 2012 and 2014 to ensure the results of various laboratories were comparable. Results of these analyses can be found in *"Water Quality Split Sample QA/QC Program 2012"* (TRCA 2013) and *"Water Quality Split Sample QA/QC Program 2014"* (TRCA 2015). City of Toronto was initially ranked second to York-Durham in comparability of data with OMOECC because of high detection limits for several metals (TRCA 2013); however, by 2014, City of Toronto improved detection limit capabilities for metals and now provides comparable data to OMOECC (TRCA 2015).

3.3 Indicator Analytes

Over 36 water quality analytes are monitored at each station. Only total phosphorus, chloride and total suspended solids were selected for determining temporal trends. These analytes have been used in previous reports and are assumed to have been chosen because of their known impacts on aquatic systems, availability of historical data and limited issues with changing detection limits and labs. Table 2 outlines these indicator analytes, their sources as well as their effects on the aquatic environment, and the applicable water quality guidelines for comparison.

Water quality results were compared to the Provincial Water Quality Objectives (PWQO; OMOEE 1994). The PWQO are a set of numerical and narrative criteria which serve as chemical and physical indicators representing a satisfactory level for surface waters which is protective of all forms of aquatic life and/or the protection of recreational water uses based on public health and aesthetic considerations. When PWQO were not available, other objectives such as the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG; CCME 2007) were used. A background concentration for total suspended solids (TSS) was determined to be 5 mg/L. This was based on historical regional monitoring data collected during dry weather conditions from “pristine” watercourses in the jurisdiction (drainage areas that do not include significant urban or agricultural land uses).

Table 2. Significance, sources and guidelines for key surface water parameters

Analyte	Significance	Sources (examples)	Guideline
Total Phosphorus	In excess, phosphorus can have unfavourable effects such as eutrophication (enrichment of a waterbody with nutrients). Phosphorus stimulates plant and algae productivity and biomass. Past a certain point, this can cause reduced biodiversity, changes in the dominant biota, decreases in ecologically sensitive species, increases in tolerant species, anoxia, and increases in toxins (e.g. cyanobacteria).	• Fertilizers • Animal wastes • Sanitary sewage	Interim PWQO[1]: 0.03 mg/L
Chloride	Chloride can be toxic to aquatic organisms with acute (short-term) effects at high concentrations and chronic (long-term) effects at lower concentrations.	• Road salt application • Fertilizers • Industrial discharge	CWQG: chronic 120 mg/L; acute 640 mg/L
Total Suspended Solids (TSS)	TSS represents the amount of particulate matter (e.g. silt, clay, organic and inorganic matter, etc.) suspended in water. TSS can act as a transport vector for contaminants (e.g. metals). Elevated TSS concentrations can affect aquatic organisms such as fish by reducing water clarity and inhibit the ability to find food, clogging of fish gills, and habitat changes such as smothering fish spawning and nursery areas.	• Construction sites • Farm fields • Lawns and gardens • Eroding stream channels • Road grit accumulation • Soil	CWQG: 30 mg/L (background (assumed at <5 mg/L)+ 25 mg/L for short term (<24 hour) exposure)

[1]PWQO = Provincial Water Quality Objective
[2]CWQG = Canadian Water Quality Guideline

4. Methods

4.1 Sample Collection

Monthly grab samples were collected year-round in accordance with the PWQMN sampling protocols (OMOE 2003). Samples were stored in a cooler with ice and delivered to a laboratory for analysis usually within 24 hours of sampling. Samples were collected on set dates, independent of weather conditions. Results are for total (i.e. particulate) samples rather than the dissolved (i.e. bioavailable) forms.

4.2 Data Analysis

Data were separated into 5-year periods (beginning with 2015 and working backwards) and median values for the 5-year periods were calculated. Only sites with greater than 30 samples over the 5-year period and sites with at least 4 sample periods were analyzed. Data were examined in 5-year periods because this length of time is expected to allow for inter-annual variation in precipitation and provide a better overall summary of water quality conditions. Annual water quality summaries are prepared in a separate document each year. Based on the addition of the 2011-2015 data, temporal analysis was possible for one new station for chloride (83108 in the upper Humber watershed) and two new stations for TSS (97003 and 97011 both in the Rouge watershed). Particular attention was paid to the stations at or near the watershed outlets. Watershed mouths are important sentinel sites because they incorporate the water quality of all the incoming tributaries at a single point before the water enters Lake Ontario. These sites also have the longest, most complete data records. When results were below the laboratory detection limit (i.e. trace amounts), these values were set at half of the laboratory detection limit for analysis purposes. Total phosphorus values determined using OMOECC laboratory method E3516A were used for this analysis.

To maintain consistency with previous 5-year surface water quality reports, statistical analysis procedures did not include an adjustment for flow. Consideration of flow can aid the analysis of water-quality trends because, on a day-to-day basis, most water-quality characteristics vary in response to changes in flow. In the near future, it will be possible to examine flow-weighted water quality data because there are increasingly more flow stations being established associated with surface water quality monitoring stations and there are techniques available to use flow data not immediately associated with a water quality station (Ontario Flow Assessment Tool; MNRF 2017). In addition to these tools, two programs will be starting up in the next few years to assess the effects of wet weather flows. These are further discussed in the results and discussion section.

Changes in flow appear as a source of random variation over the period of analysis. Water quality samples are typically skewed whereby most samples are similar in concentration (base/low flow) with a few samples being significantly higher than the others (storm flow). Median values are often used for skewed distributions. The median value is the numerical value separating the higher half of a sample from the lower half (i.e. 50^{th} percentile). The median is often used because the value is less influenced by extreme results compared to average values, therefore depicting what a stream experiences on a typical day.

Trends were analyzed using the Mann-Kendall test. The Mann-Kendall is a non-parametric test to describe monotonic trends. Monotonic trends occur when a population of observations shifts over time. The detection of a monotonic trend does not imply that the trend is linear, occurs in one or more discrete steps, or in any pattern (Hirsch *et al.* 1991). These analyses test only for the existence of a monotonic trend over the entire period covered by the data set and does not test for the possibility that a “change point” occurred (e.g. trend was increasing during the beginning of the period and then declining during the later stage). The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test is well-suited to data with missing values and to data that are truncated at upper and lower detection limits (Gilbert 1987). The test compares the relative magnitude of sample data rather than the data values themselves. The data values are evaluated as an ordered time series. The initial value of the Mann-Kendall statistic, S, is assumed to be zero (*e.g.*, no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by one. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by one. The net result of all such increments and decrements yields the final value of S. For example, a very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. Because of the wide range of water quality values (i.e. includes baseflow, low flow and storm events), a significance level of $p<0.05$ was used to determine if temporal trends were significant.

If there were large gaps in the chronological sequence of data (e.g. chloride data for station 83018 was missing multiple time periods in the 1980's and 1990's) the Mann-Kendall can become less appropriate and data were grouped for analysis instead of analyzing data as continuous (Step-trend analysis; Helsel and Hirsch 2002). Data were analyzed using the non-parametric Kruskal-Wallis test with the Nemenyi test as a post-hoc test using the functions kruskal.test and posthoc.kruskal.nemenyi.test provided in the Pairwise Multiple Comparison of Mean Ranks Package (PMCMR) in R. The test statistic for the Kruskal-Wallis test is the chi-square (X^2) statistic and significant differences among time periods are represented using letters (A, B, C, D, etc) where different letters denote a significant difference between time periods while time periods sharing the same letter are not significantly different. This test does not detect a trend as a continuous change over time but instead allows you to detect whether different time periods have significantly higher or lower concentrations. For chloride, only station 83018 was analyzed this way while for TSS, a Kruskal-Wallis test was used for multiple stations (83002, 83004, 85004, 85003, 94002, 97003, 97011 and 104001).

5. Results and Discussion

Results are presented using RWMP station names which are often a derivative of the (current/historic) 11-digit PWQMN name. For example, PWQMN station 06008000602 is presented as station 80006. Stations are presented by watershed from west to east and from headwaters to mouth.

It is important to note that samples were collected on varying field dates, under a variety of weather conditions and analyzed at several laboratories (see Appendix B). Water quality samples collected as part of the PWQMN/RWMP are collected independent of weather conditions. Water quality data should represent the range of water quality conditions that affect the aquatic system (e.g. streamflow conditions including snowmelt, runoff from rain events of varying magnitude and baseflow conditions during varying seasons). Because specific wet-weather events are not targeted, nutrient and contaminant concentrations presented in this report may be significantly lower than what would be measured during a storm event. The majority of wet weather flow originates from surface runoff, either from agriculture or urban areas. Urban runoff can contain high concentrations of nutrients and contaminants (e.g. sediments, road salts) which are washed off impervious surfaces such as roads and parking lots. Agricultural runoff is surface water leaving farm fields because of excessive precipitation, irrigation, or snowmelt. It can also contain high levels of pesticides, sediments, nutrients and bacteria.

There are several programs starting in the near future (2017-2019) that will merge flow data and water quality data. The first is related to the existing City of Toronto Wet Weather Flow Master Plan. This plan is an initiative to protect watersheds and infrastructure from the effects of wet weather flows and the subsequent increase in run-off. Baseline conditions were determined in 2013 using data from 2008-2012 and continued monitoring and analyses will be conducted to assess water quality following the implementation of innovative wet weather flow strategies. The second program is a potential new Urban Watershed Phosphorus Monitoring Program. This program is being developed by the OMOECC and will partner with existing urban water quantity and quality monitoring programs including the TRCA's Regional Watershed Monitoring Program. The goal of this program is to estimate current and future phosphorus loads into the Great Lakes and to assess the effectiveness of stormwater management, low-impact development practices and best management practices on reducing phosphorus loads at the subwatershed scale. The third program is the 2018 Lake Ontario Cooperative Science and Monitoring Initiative. This bi-national program will contribute data on tributary loadings to Lake Ontario under storm and baseflow conditions from streams and rivers from the Niagara region to Cobourg. Together, these programs will provide us with a better understanding of water quality related to wet weather flows and viable methods for mitigation.

5.1.1 Total Phosphorus

Phosphorus is an essential nutrient for all living organisms but it can have unfavorable effects in high concentrations. Phosphorus is associated with eutrophication – the enrichment of a waterbody with nutrients. Waterbodies with low phosphorus concentrations typically support relatively diverse and abundant aquatic life and support various water uses. However, elevated phosphorus concentrations can adversely affect aquatic ecosystems by increasing plant and algal productivity and biomass (CCME 2004). Further phosphorus additions may cause undesirable effects such as decreased biodiversity and changes in dominant biota, decline in ecologically sensitive species, increase in tolerant species, increase in plant and animal biomass, and anoxic conditions (EC 2004). When the excessive plant growth includes certain species of cyanobacteria, toxins may be produced, causing increased risk to aquatic life, livestock, and human health (CCME 2004). The PWQO for total phosphorus is 0.03 mg/L. This concentration is intended to prevent excessive plant growth in rivers and streams.

Trend analysis results for total phosphorus are presented in Table 3 and Figure 2. A decrease in total phosphorus over time ($S<0$) was found at all 13 stations and no stations had increasing trends ($S>0$). Of these stations, 6 of 13 showed statistically significant decreasing trends ($p<0.05$).

Currently, just above half of the median phosphorus values are above the PWQO of 0.03 mg/L. Station 85014, near the mouth of the Don River, had the highest median phosphorus value of 0.084 mg/L (almost three times the PWQO). Station 85014 is located downstream of the North Toronto Wastewater Treatment Plant. Despite being elevated, a concentration of 0.084 mg/L is

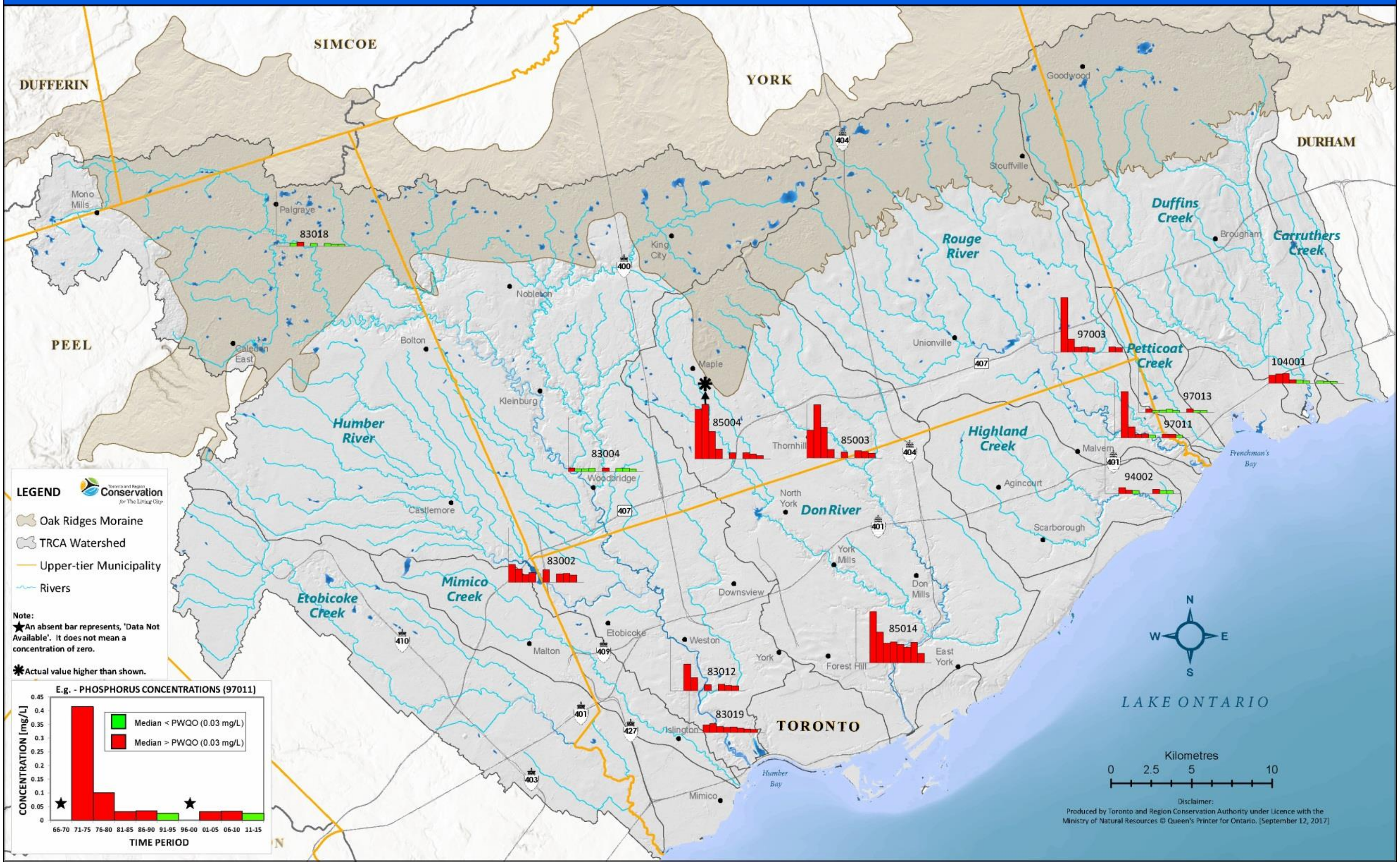
5.5 times lower than the median concentration of 0.462 mg/L for the 1976-1980 time period. The current median value (0.084 mg/L) at this station is more than half the value of the previous 2006-2010 time period of 0.186 mg/L.

Table 3. Total phosphorus trend analyses over time (bold indicates value > PWQO of 0.03 mg/L and numbers in brackets represent the number of samples over the 5-year period)

Watershed	Station	Median Total Phosphorus Concentrations in mg/L (N)										Mann-Kendall		Regression
		66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	06-10	11-15	S	*p*	R^2
Humber	83018			0.030 (54)	**0.035** (56)		0.024 (41)		0.024 (66)	0.020 (57)	0.020 (60)	-1.879	0.060	0.7933
	83002	**0.160** (52)	**0.120** (42)	**0.069** (52)	**0.090** (51)		**0.113** (41)		**0.078** (53)	**0.080** (60)	**0.068** (57)	-1.856	0.063	0.4651
	83004	**0.032** (52)	0.027 (40)	0.025 (53)	0.029 (52)		**0.034** (32)		0.030 (50)	0.030 (58)	0.023 (57)	-0.247	0.805	0.0318
	83012			**0.240** (54)	**0.121** (52)		**0.058** (31)		**0.060** (50)	**0.050** (60)	**0.047** (57)	-2.254	0.024*	0.7005
	83019[M]			**0.069** (69)	**0.080** (117)	**0.054** (176)	**0.047** (346)	**0.052** (109)	**0.041** (149)	**0.032** (73)	**0.031** (58)	-2.846	0.004*	0.8461
Don	85004	**0.510** (54)	**1.600** (42)	**0.280** (50)	**0.099** (51)		**0.064** (39)		**0.065** (40)	**0.050** (60)	**0.033** (59)	-2.846	0.004*	0.3879
	85003	**0.250** (57)	**0.480** (42)	**0.277** (54)	**0.078** (51)		**0.056** (41)		**0.065** (42)	**0.060** (60)	**0.044** (59)	-2.351	0.019*	0.5850
	85014[M]			**0.462** (65)	**0.275** (135)	**0.178** (145)	**0.190** (372)	**0.168** (99)	**0.139** (140)	**0.186** (64)	**0.084** (60)	-2.351	0.019*	0.672
Highland	94002			**0.054** (87)	**0.032** (52)	0.028 (59)			**0.040** (36)	0.030 (60)	0.027 (59)	-1.503	0.133	0.3004
Rouge	97003		**0.600** (41)	**0.145** (53)	**0.053** (60)	**0.056** (56)	**0.050** (36)			**0.060** (48)	**0.048** (59)	-1.802	0.072	0.3589
	97013		**0.032** (39)	0.020 (51)	0.024 (60)	0.029 (58)	0.018 (41)		**0.035** (41)	0.020 (48)	0.020 (59)	-0.495	0.621	0.0537
	97011		**0.415** (42)	**0.099** (52)	**0.031** (60)	**0.034** (58)	0.025 (44)		**0.031** (65)	**0.032** (44)	0.026 (59)	-1.732	0.083	0.3873
Duffins	104001[M]	**0.072** (103)	**0.086** (53)	**0.088** (70)	**0.035** (59)	0.030 (58)	0.022 (48)		0.022 (37)	0.020 (43)	0.020 (60)	-2.815	0.005*	0.6998

Notes: * = significant $p<0.05$
[M] = mouth of watercourse
Bolded values indicate exceedance of 0.03 mg/L objective
Different letters denote a significant difference

FIGURE 2: TEMPORAL CHANGES IN 5-YEAR MEDIAN PHOSPHORUS CONCENTRATION 1966 - 2015



Total phosphorus concentrations for the mouth of the Humber River (83019), Don River (85014), Highland Creek (94002), Rouge River (97011) and Duffins Creek (104001) are presented in Figure 3. All five watersheds have had decreasing phosphorus concentrations over the last several decades (Figure 4) but only the Humber, Don and Duffins watersheds had statistically significant decreasing trends ($p<0.05$) while the Rouge trend was approaching significance ($p=0.08$). The declining trend in phosphorus is likely associated with a general reduction in phosphorus use in the 1970s and specifically due to the decommissioning of several sewage treatment plants within the TRCA's jurisdiction.

Even though phosphorus levels have declined, the potential for current levels to cause harmful algal blooms and eutrophic conditions continues to be monitored. Chlorophyll *a* concentrations (a surrogate of algal density) have been monitored by the OMOECC in the Toronto and Region nearshore between 1994 and 2013 (Toronto and Region RAP 2015). Chlorophyll *a* concentrations were the highest in 2000, 2006 and 2009 but by 2012 and 2013 concentrations were more indicative of oligotrophic or mesotrophic conditions (Toronto and Region RAP 2015). Even though these changes occurred, there was no significant decline in chlorophyll *a* concentration between 1994 and 2013 and *Cladophora* problems still occur along some areas of the shoreline.

To help combat eutrophication issues such as algal blooms and anoxia, the federal government introduced a ban which almost eliminates phosphorus from household laundry, dishwasher, and dish washing detergents as well as some household cleaners (Canada Gazette 2009). The ban came into effect in July 2010 and reduces the allowable amount of phosphorus to 0.5% by weight (currently 2.2%). This will help to reduce some of the phosphorus released to watercourses but even the most advanced wastewater treatment technologies available cannot totally eliminate phosphorus releases to the environment. Although this is a step in the right direction, municipal wastewater sewers and septic systems only contribute about 14% to the national phosphorus load (Canada Gazette 2009). Additional work is needed to decrease the phosphorus contribution from agriculture which contributes 82% of the national load (although this might not be the largest contributor in the Toronto region).

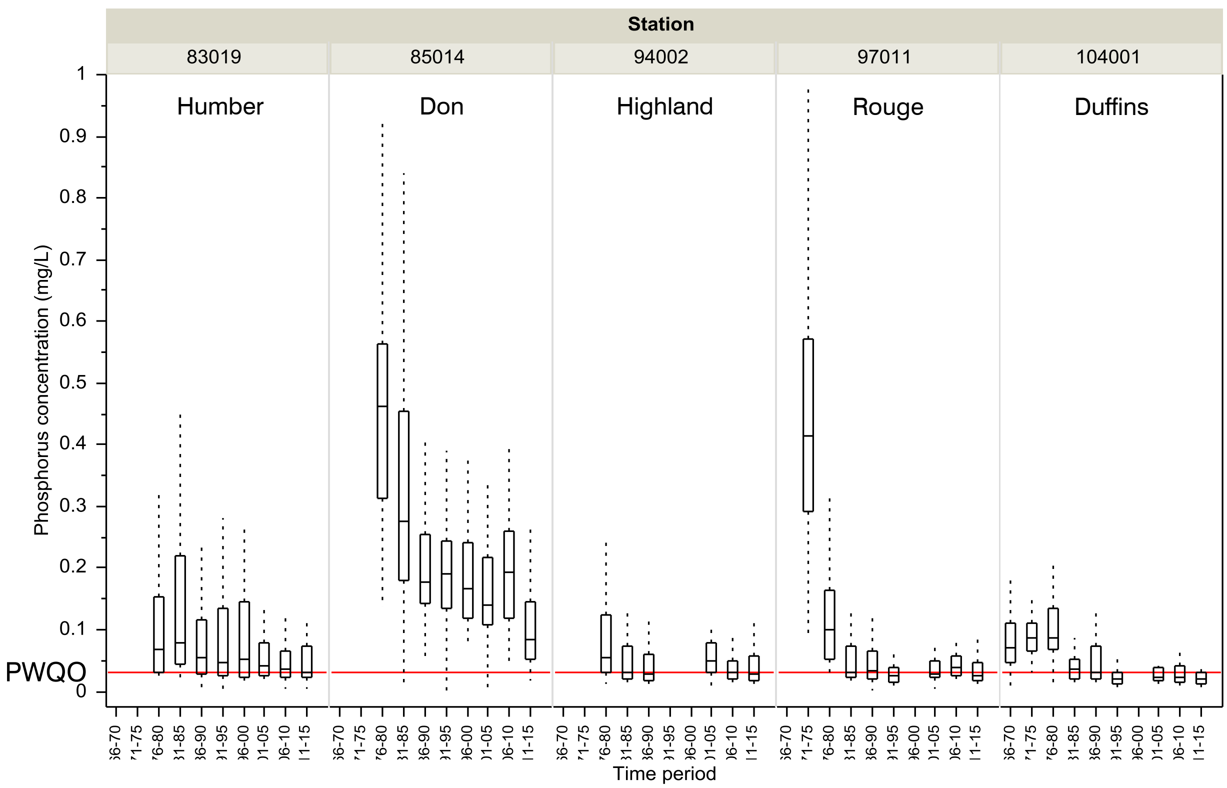


Figure 3. Total phosphorus concentrations for the mouth of the Humber River (83019), Don River (85014), Highland Creek (94002), Rouge River (97011) and Duffins Creek (104001) over time

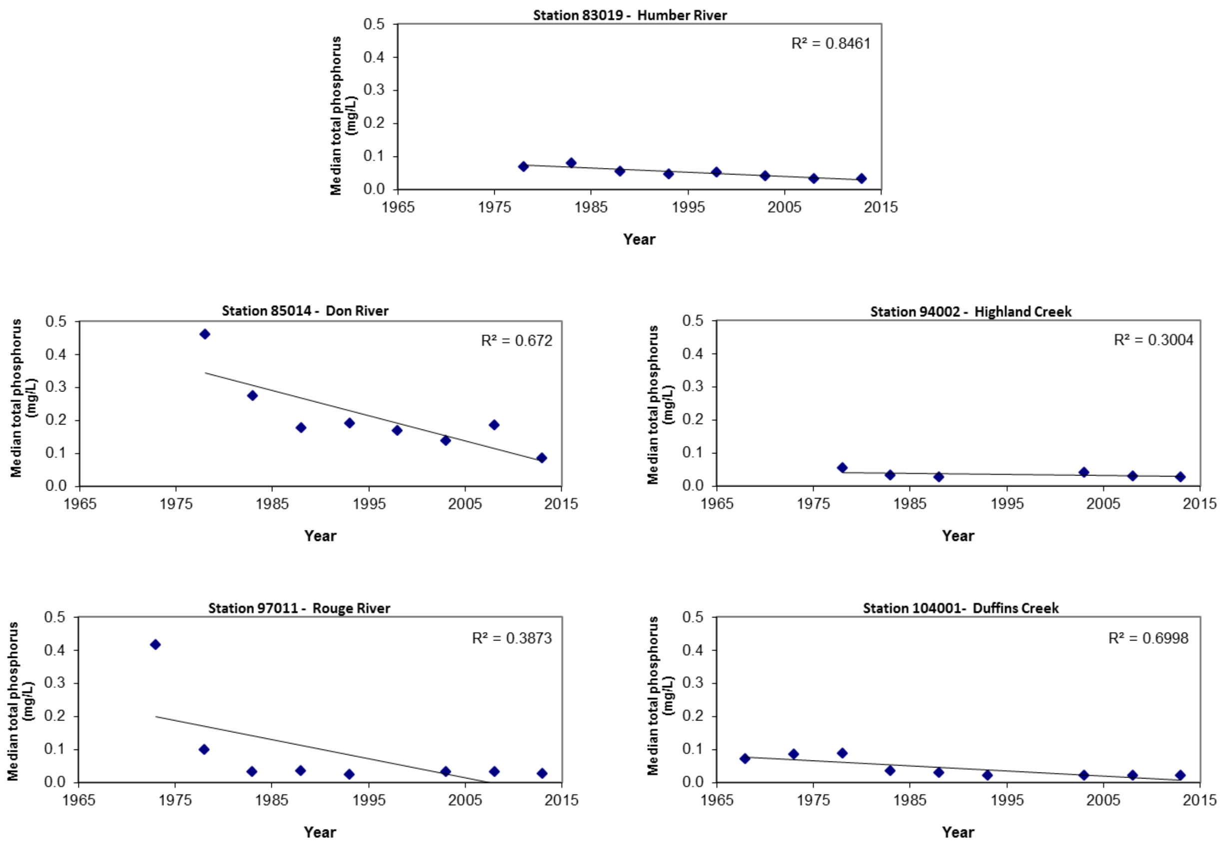


Figure 4. 5-year median total phosphorus concentrations over time at the mouths of the Humber River (83019), Don River (85014), Highland Creek (94002), Rouge River (97011), and Duffins Creek (104011)

5.1.2 Chloride

Chloride can be toxic to aquatic organisms with acute effects at high concentrations and chronic effects (e.g. growth, reproduction) at lower concentrations (OMOE 2003). Chloride in our waterways is mainly due to the use of road salts which are used as de-icing and anti-icing agents during winter road maintenance. The predominant chloride road salt is sodium chloride, which is composed of about 40% sodium and 60% chloride by weight. Additional sources of chloride include wastewater treatment, industry discharge and fertilizers (OMOE 2003). Natural background concentrations of chloride in water are generally no more than a few milligrams per litre, with some local or regional instances of higher natural salinity (EC & HC 2001). Chloride is a highly soluble and mobile ion. There are no major natural removal mechanisms (e.g. volatilization, degradation) and therefore, all chloride ions from road salts can be expected to be ultimately found in surface water. The CWQG for chloride is 120 mg/L for chronic effects and 640 mg/L for acute effects (CCME 2011).

Trend analysis data for chloride are presented in Table 4 and Figure 5. All stations (13 of 13) showed an increasing trend for chloride concentrations with 8 of the 13 stations having a statistically significant increasing trend ($p<0.05$). All stations had higher median chloride concentrations in 2011-2015 compared to 2016-2010 except for station 83012 in the lower Black Creek in the Humber which had a decline of 40 mg/L.

There were five stations with sufficient data in the Humber River watershed to determine temporal trends (Table 4). All five sites showed an increasing trend for chloride with the trends at four sites being significant (83018 in the upper Humber, 83004 on the main Humber River, 83002 on the west Humber Creek just south of the Claireville Reservoir, 83019 at the mouth of the Humber). Station 83012, located close to the mouth of the Black Creek, had the highest chloride concentrations of all stations during each time period monitored (medians: 269-459 mg/L from 1976-2015). Chloride concentrations for this station in the current time period are 2 to 8 times higher than other stations in the Humber watershed. Station 83018, in the upper reaches of the Humber River watershed, was the only station in the watershed that did not exceed the 120 mg/L objective during the current time period. It showed statistically significant increases between 1976-1980 and 2001-2005 and again from 2001-2005 to 2006-2010.

Three stations in the Don River watershed had sufficient data for trend analysis. Two stations (85003 and 85004) are located in the upper-middle portions of the watershed and one station (85014) is located at the mouth of the Don River. All three stations showed an increasing trend in median chloride concentrations over time and this increase was statistically significant for station 85014 and approaching significance for station 85003 ($p=0.072$). All of these stations have more than doubled in chloride concentration since they were first sampled. These sites are in areas which have undergone considerable urbanization over the past few decades.

All three stations in the Rouge River watershed which had adequate chloride data for trend analyses showed either a statistically significant increase (97011 on the Rouge River) or an increase approaching significance (97003, 97013 both on the Little Rouge River) in median chloride concentrations over time. Chloride concentrations on the Little Rouge River remain at about half of the concentration on the Rouge River although both continue to increase. Station 97013, in the lower portion of the Little Rouge River, is close to surpassing the threshold for chronic effects.

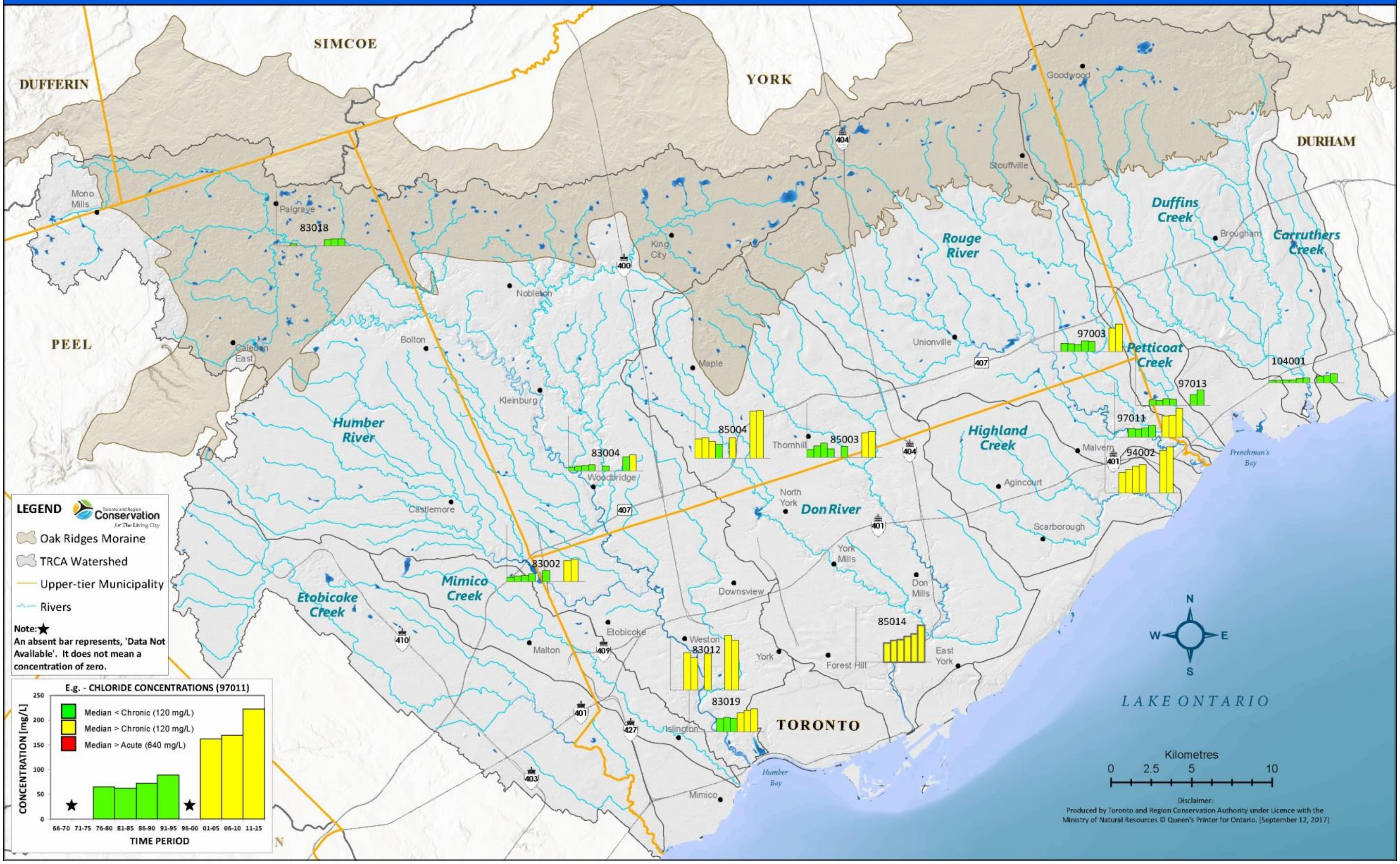
The Highland Creek and Duffins Creek each had one station with sufficient chloride data for trend analysis. Station 94002 at the mouth of Highland Creek and station 104001 at the mouth of Duffins Creek both showed a significant increasing trend in median chloride concentrations over time. Station 94002 in the Highland Creek watershed has had concentrations above the chronic effects guideline since sampling began while the Duffins Creek site has continually had the lowest median chloride concentrations of all the sites with temporal data (half the chronic effects guideline). This watershed was and continues to be mainly rural although pressures such as the 407 east expansion and urbanization remain.

Table 4. Chloride trend analyses over time (bold indicates value > CWQG of 120 mg/L and numbers in brackets represent the number of samples over the 5-year period)

Watershed	Station	Median Chloride Concentrations in mg/L (N)										Test Statistic		Regression
		66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	06-10	11-15	S or X^2	*p*	R^2
Humber	83018			16^{A} (42)					48^{B} (37)	52^{C} (57)	53^{C} (60)	X^2=119	<0.0001*	n/a
	83004	28 (52)	37 (42)	42 (45)	46 (49)	-	39 (41)	-	-	106 (60)	**124** (57)	S=2.403	0.016*	0.8483
	83002	33 (53)	41 (40)	46 (46)	59 (50)	-	83 (31)	-	-	**154** (60)	**166** (57)	S=3.004	0.003*	0.9656
	83012	-	-	**315** (53)	**269** (51)	-	**304** (31)	-	-	**459** (60)	**419** (57)	S=0.735	0.462	0.7568
	83019^{M}	-	-	-	-	102 (112)	111 (344)	104 (111)	**146** (126)	**164** (72)	**178** (60)	S=2.254	0.024*	0.8876
Don	85004	**147** (54)	**158** (42)	**130** (50)	107 (51)	-	**158** (39)	-	-	**362** (60)	**364** (59)	S=1.352	0.176	0.7595
	85003	60 (57)	90 (41)	110 (54)	66 (51)	-	87 (41)	-	-	**188** (60)	**198** (59)	S=1.802	0.072	0.7771
	85014^{M}	-	-	-	-	**148** (113)	**169** (369)	**173** (105)	**199** (122)	**218** (72)	**283** (60)	S=2.63	0.009*	0.8863
Highland	94002^{M}	-	-	**158** (87)	**178** (53)	**203** (59)	**218** (43)	-	-	**326** (59)	**356** (59)	S=2.63	0.009*	0.9868
Rouge	97003	-	62 (41)	60 (53)	53 (60)	82 (56)	80 (36)	-	-	**180** (48)	**210** (59)	S=1.802	0.072	0.8837
	97013	-	-	41 (51)	39 (58)	51 (58)	50 (41)	-	-	84 (48)	119 (59)	S=1.879	0.060	0.8841
	97011	-	-	65 (51)	63 (60)	72 (58)	89 (44)	-	**162** (44)	**170** (44)	**223** (60)	S=2.703	0.007*	0.9265
Duffins	104001^{M}	15 (103)	18 (53)	21 (70)	21 (59)	32 (58)	38 (47)	-	52 (33)	53 (43)	71 (60)	S=3.545	0.000*	0.9468

Notes: * = significant $p<0.05$ (different letters denote significant difference based on Nemenyi post-hoc)
^{M} = mouth of watercourse
Bolded values indicate exceedance of 120 mg/L objective for chronic exposure
Different letters denote a significant difference

FIGURE 5: TEMPORAL CHANGES IN 5-YEAR MEDIAN CHLORIDE CONCENTRATION 1966 - 2015



Chloride results are presented in Figures 6 and 7 for the mouths of the Humber River (83019), Don River (85014), Highland Creek (94002), Rouge River (97011) and Duffins Creek (104001). All five stations showed increasing trends in chloride concentrations. Stations at the mouth of the Humber River, Don River, Highland Creek and Rouge River had median chloride concentrations that exceeded the CWQG of 120 mg/L for chronic effects for at least three time periods. While the median value for Duffins remains below the chronic threshold, the 75th percentile for the 2011-2015 data has now surpassed the threshold for the first time in the past 50 years.

The Don River (85014) has consistently had median chloride concentrations greater than 120 mg/L since the mid-1980s. During the 2011-2015 period, this station had the highest 75th percentile of the entire TRCA jurisdiction over the past 50 years. The median concentration of chloride at the mouth of the Highland Creek has been above the 120 mg/L objective since the mid-1970s. The Humber River (83019) and Rouge River (97011) both surpassed the chronic objective in the early 2000s and concentrations continue to increase into the 2011-2015 time period. It is important to note that winter samples (when chloride concentrations are expected to be the highest due to road salting activities) were not collected during every time period. At the Duffins Creek site, winter sampling began in 1965. Winter samples were collected at the Rouge River and Highland Creek beginning in the mid-1970s and winter sampling did not start at the Humber River and Don River stations until 1990. This suggests that median chloride concentrations may have been higher than what is presented during periods when winter sampling did not occur.

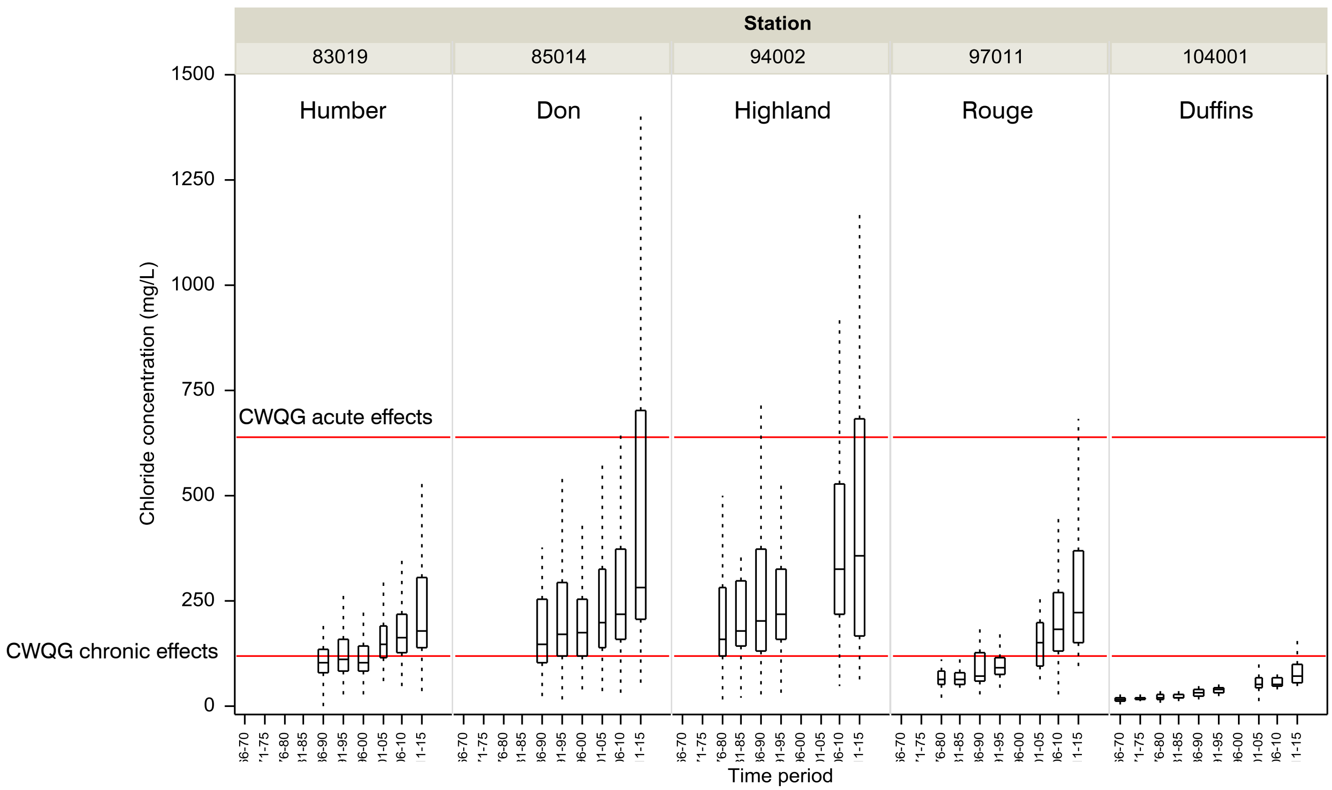


Figure 6. Chloride concentrations for the mouth of the Humber River, Don River, Highland Creek, Rouge River and Duffins Creek over time

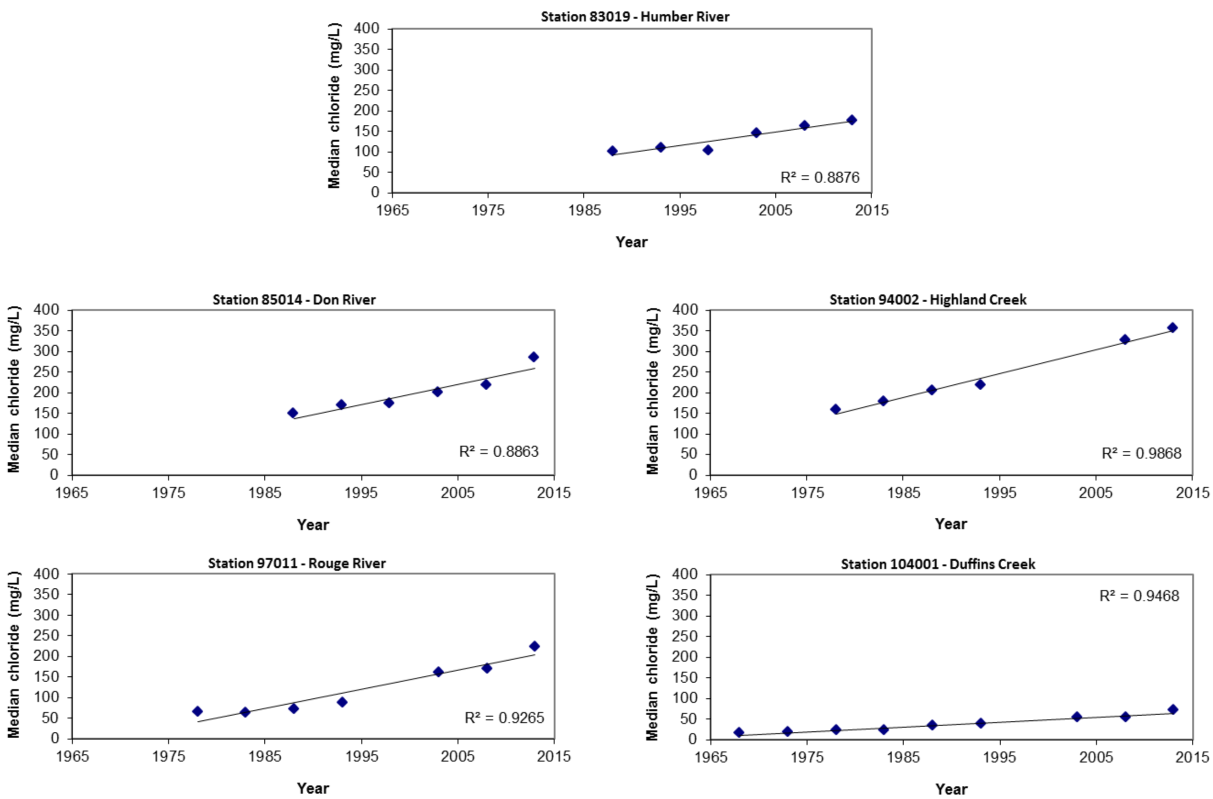


Figure 7. 5-year median chloride concentrations over time at the mouths of the Humber River (83019), Don River (85014), Highland Creek (94002), Rouge River (97011), and Duffins Creek (104011)

5.1.3 Total Suspended Solids

A total suspended solids (TSS) value represents the amount of particulate matter (e.g. silt, clay, organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms) suspended in water. Suspended sediments can act as transport vectors for contaminants (e.g. metals are charged particles that can bind with sediment) and can affect aquatic organisms. Direct negative effects on fish include clogging and abrasion of gills, behavioural effects (e.g. movement and migration), blanketing of spawning gravels and other habitat changes, the formation of physical constraints disabling proper egg and fry development, and reduced feeding (CCME 2002). Effects on benthic invertebrates include physical habitat changes, smothering of benthic communities, clogging of interstices between gravel, cobbles, and boulders affecting invertebrate microhabitat, abrasion of respiratory surfaces, and interference of food intake for filter-feeding invertebrates (CCME 2002). Recall that the CWQG contain a narrative guideline for TSS which the maximum increase of TSS should be no more than 25 mg/L from background concentrations (with TRCA using a background TSS concentration of 5 mg/L determined using data from the jurisdiction).

Trend analyses for TSS concentrations are presented in Table 5 and Figure 8. Station 83018 in the upper reaches of the Humber River and station 85014 at the mouth of the Don River both had statistically significant decreasing trends in TSS concentrations. Of particular note are the stations in the Don River. In the late 1960s and early 1970s, median TSS concentrations were in the 30-40 mg/L range. During the latest time period, concentrations in the Don River were less than 11 mg/L which is a significant improvement over the past few decades. Since untreated stormwater is the main contributor of TSS to streams in urban areas, the continued installation and improvement of stormwater infrastructure will further improve the health of the streams in the Toronto region. In rural areas, the erosion of tablelands and stream channels contribute to the TSS load. Efforts to improve riparian vegetation and reforestation may help to reduce runoff.

Stations tested for trends using the step-trend test showed variable results. Station 83002 had significantly lower concentrations in 2011-2015 than in 1966-1970. Station 83004 on the main Humber River has had slightly lower concentrations in recent years; however, post-hoc analyses showed that this difference was not significant. Stations 85004 (west Don River) and 85003 (east Don River) had significantly lower TSS concentrations in more recent time periods (2006-2010, 2011-2015) than in earlier time periods (1966-1970, 1971-1975, 1976-1980). Station 94002 had a significantly higher TSS concentration in 1976-1980 than in all other time periods where the concentration remained similar. Stations 97003 (Little Rouge River), 97011 (Rouge River) and 104001 (mouth of Duffins Creek) have generally seen declines since earlier time periods compared to more recent periods.

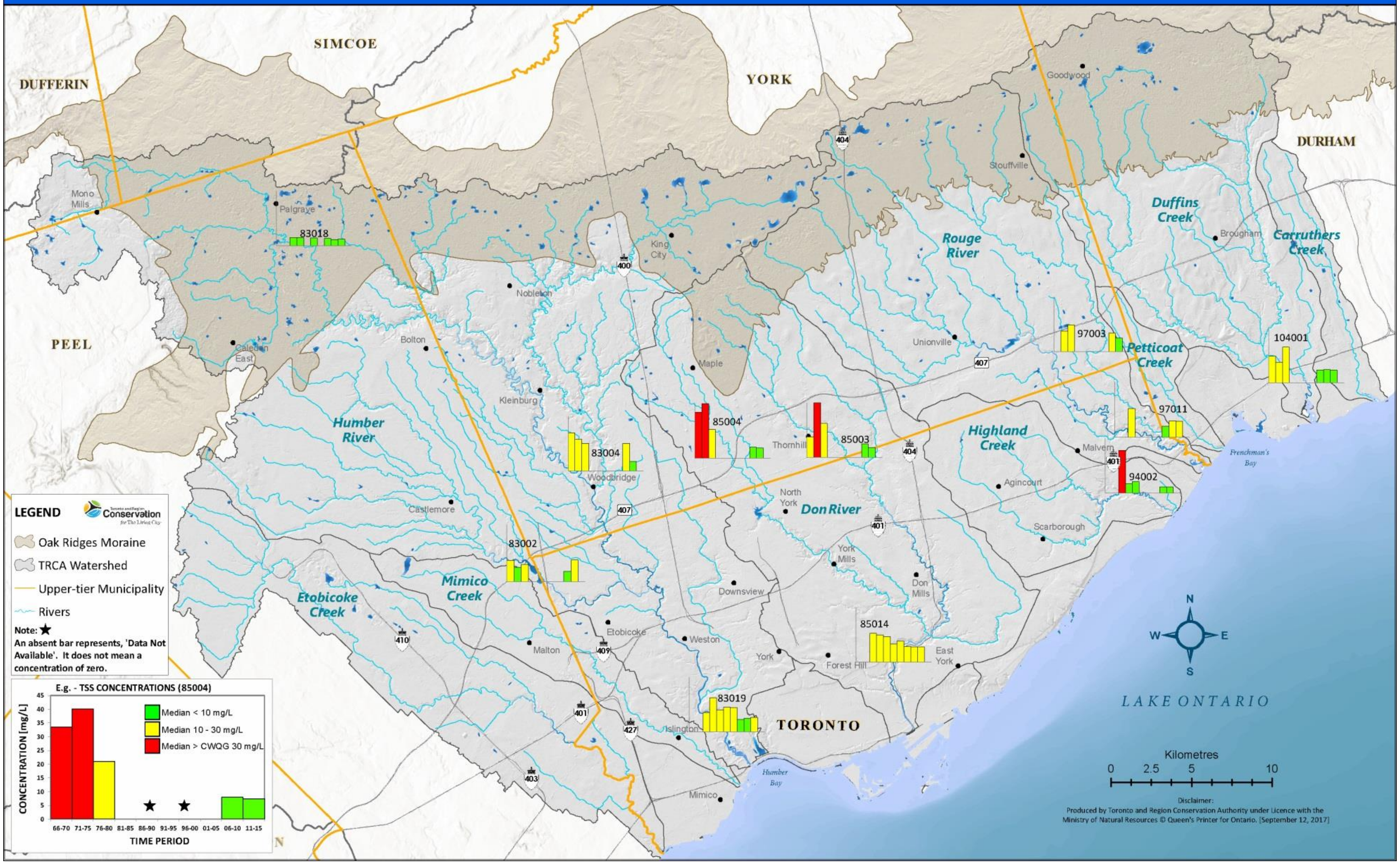
TSS results for the mouths of the Humber River, Don Diver, Highland Creek and Duffins Creek are presented in Figures 9 and 10. Highland Creek had the only time period with a median concentration greater than the CWQG derived guideline of 30 mg/L (1976-1980, 31 mg/L). The remaining stations had median values below 30 mg/L for all time periods.

Table 5. Total suspended solids (TSS) trend analyses over time (bold indicates value > CWQG of 30 mg/L and numbers in brackets represent the number of samples over the 5-year period)

Watershed	Station	Median TSS Concentrations in mg/L (N)										Mann-Kendall		Regression
		66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	06-10	11-15	S or X^2	p	R^2
Humber	83018			6.1 (52)	6.0 (50)		5.8 (41)		5.3 (43)	4.6 (55)	4.9 (59)	S=-2.25	0.024*	0.8802
	83002	28^{A} (53)	23^{AB} (39)	20^{AB} (39)						20^{AB} (58)	15.4^{B} (57)	X^2=11.3	0.023*	n/a
	83004	15 (52)	10 (38)	12 (37)						7.2 (60)	7 (57)	X^2=11.2 (post-hoc NS)	0.024* (post-hoc NS)	n/a
	83019^{M}			14.0 (67)	25.0 (116)	16.0 (179)	18.0 (345)	17.8 (110)	9.0 (126)	9.9 (69)	10.5 (60)	S=-1.11	0.266	0.4348
Don	85004	**33.5^{A}** (54)	**40.0^{A}** (41)	21.0^{A} (43)						8.0^{B} (60)	7.4^{B} (59)	X^2=72.9	<0.01*	n/a
	85003	15.0^{AB} (56)	**40.0^{A}** (41)	25.0^{A} (47)						10.0^{BC} (60)	7.3^{C} (59)	X^2=48.5	<0.01*	n/a
	85014^{M}			21.0 (65)	20.0 (133)	18.7 (144)	13.3 (359)	15.5 (103)	11.5 (121)	11.1 (68)	11.1 (60)	S=-2.97	0.003*	0.8808
Highland	94002^{M}			**31.0^{A}** (80)	6.8^{B} (50)	8.3^{B} (54)				4.5^{B} (60)	4.5^{B} (59)	X^2=81.4	<0.01*	n/a
Rouge	97003		15^{A} (37)	19.5^{A} (52)						13.5^{AB} (60)	9.8^{B} (59)	X^2=18.0	<0.01*	n/a
	97011			21^{A} (51)					8^{B} (37)	12^{AB} (56)	11.6^{AB} (59)	X^2=13.8	<0.01*	n/a
Duffins	104001^{M}	19.5^{AB} (102)	15.0^{ABCD} (50)	26.0^{A} (69)					9.1^{BD} (32)	9.0^{CD} (55)	9.3^{D} (59)	X^2=42.4	<0.01*	n/a

Notes: * = significant p<0.05 (different letters denote significant difference based on Nemenyi post-hoc)
^{M} = mouth of watercourse
Bolded values indicate exceedance of 30 mg/L objective
Different letters denote a significant difference

FIGURE 8: TEMPORAL CHANGES IN 5-YEAR MEDIAN TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATION 1966 - 2015



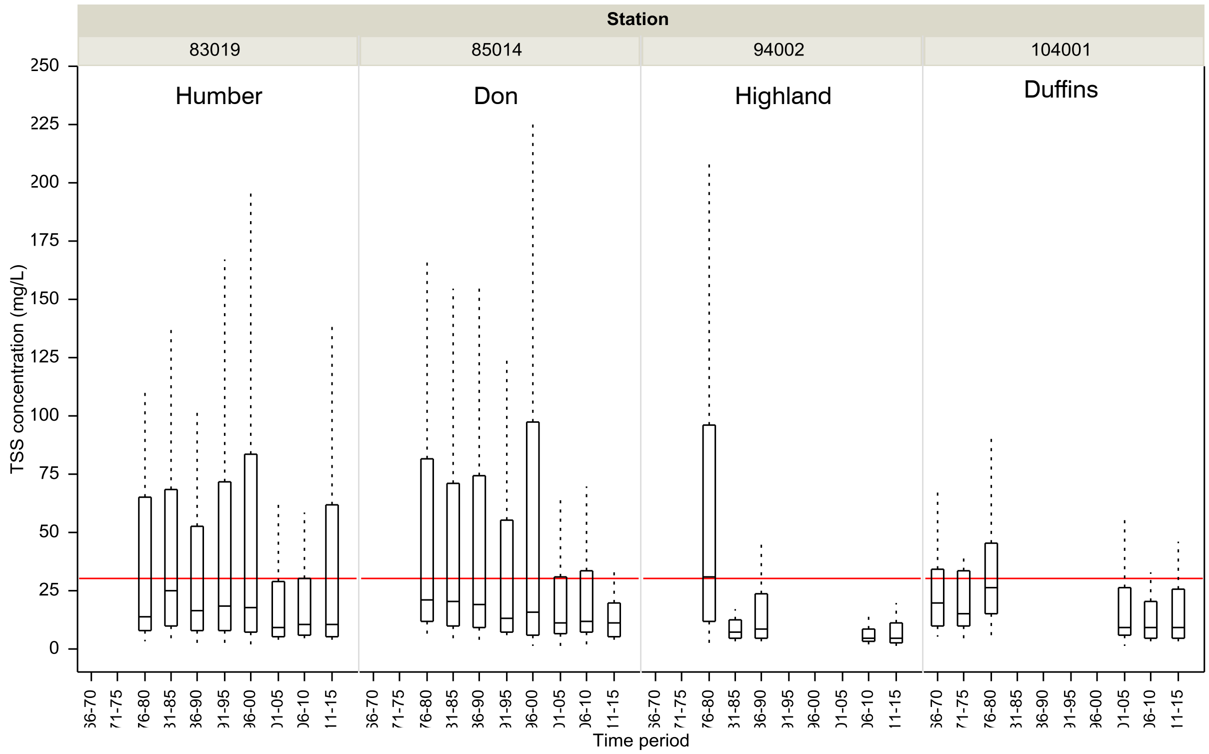


Figure 9. Total suspended solids (TSS) concentrations for the mouths of the Humber River (83019), Don River (85014), Highland Creek (94002), and Duffins Creek (104001) over time

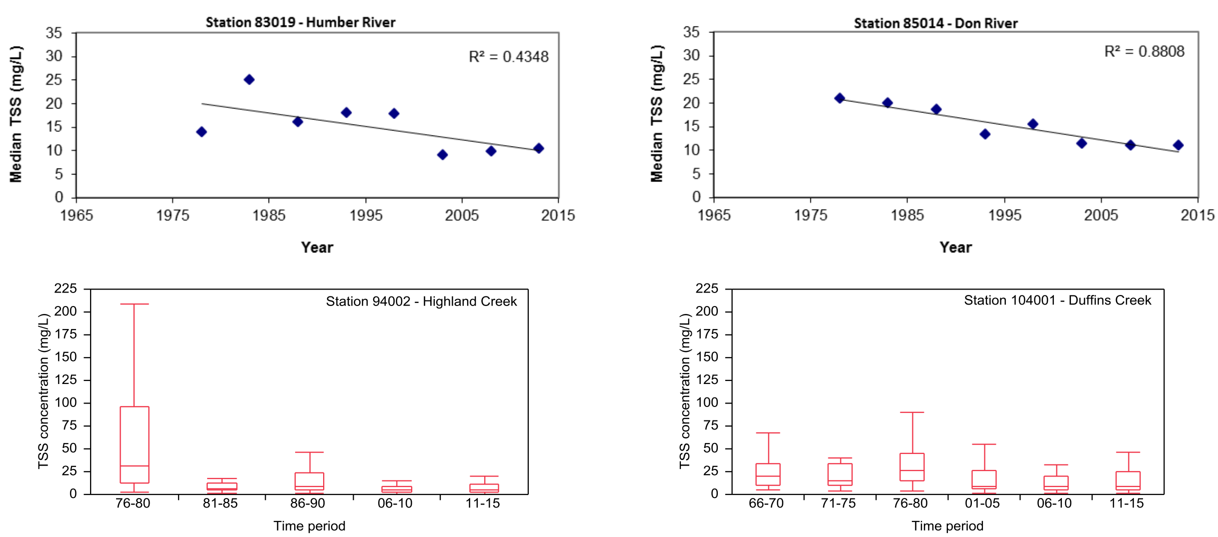


Figure 10. 5-year median total suspended solids (TSS) concentrations over time at the mouths of the Humber River (83019), Don River (85014), Highland Creek (94002) and Duffins Creek (104001)

6. Summary

Temporal trends in stream surface water quality collected through MOECC's PWQMN and TRCA's RWMP over the past 50 years show declines in total phosphorus and TSS concentrations while chloride concentrations have increased over time. These results are similar to the findings of the previous surface water quality summary report which incorporated 2006-2010 data into the long-term data set (TRCA 2011).

These reports are consistent with declines in total phosphorus seen in Lake Ontario between the 1970's and 1980's where loadings were reduced by almost a half (Stevens and Neilson 1987, Johengen *et al.* 1994). This change is in response to limiting the concentration of phosphates in detergent in the early 1970's through Canadian legislation and the signing of the Great Lakes Water Quality Agreement which limited discharges by municipal waste water treatment plants. Declines in phosphorus have also been found in streams in southern Ontario including several within the Toronto region between 1975 and 2010 (Raney and Eimers 2014). This paper suggests (although did not empirically determine) that declines in phosphorus in southern Ontario streams are due to declines in agricultural cover over the past decades.

The increase in chloride found in this report is consistent with the findings of several other papers examining data from Ontario and elsewhere (Kaushal *et al.* 2005, Todd and Kaltenecker 2012, Raney and Eimers 2014). Significant increases in chloride were found at 96% of PWQMN stream stations in southern Ontario between 1975 and 2009 based on data collected during the warm season (May to October; Todd and Keltenecker 2012). Chloride concentrations were found to be related to road density suggesting that streams with more urbanization within the catchment had higher chloride concentrations. These findings also support findings of studies using data from broader geographical areas (such as the northeastern United States) where long-term increases (1980-2000) in both rural and urban areas (Kaushal *et al.* 2005). This analysis also predicted that if chloride levels continue to increase at current rates, many surface waters in the northeastern United States would not be potable for human consumption.

The assessment of long-term water quality changes across a large area such as the Toronto region is a challenging task. Differences in the number of samples collected, parameters analyzed, analytical capabilities of laboratories completing the analysis, improvements in laboratory analysis techniques (e.g. lower detection levels) and varying stream flow complicate water quality analyses. Several of these factors confounded water quality analysis within the TRCA's jurisdiction.

Stream flow is an important variable in the analysis of water-quality trends because much of the variability in concentration is caused by variability in stream flow. For example, several high TSS concentrations were found in Duffins Creek and these were associated with precipitation prior to sampling and stream flow likely increased as a result. Using median values helps to ameliorate these effects but identifying and removing the stream flow-related variability in concentration increases the ability to detect trends in the presence of stream flow-related variability. Without flow data, we are unable to determine whether detected trends were the direct result of actual changes in water quality, or if they were an indirect result of differences in the distribution of high (or low) flow-volumes-at-sampling throughout the monitoring period. As more flow stations are added across that jurisdiction, this analysis may be possible in the near future.

Even though we are seeing declines in total phosphorus and TSS, concentrations for phosphorus continue to be greater than the acceptable PWQO and chloride concentrations continue to rise. Monitoring programs incorporating data on wet-weather flows will provide additional information to determine seasonal loadings. Non-point sources of contamination from urbanization are the largest contaminant contributing to poor water quality within the TRCA's jurisdiction. Point sources of contamination such as wastewater treatment plants also contribute to the degradation of water quality in Toronto water courses. Continued routine efforts such as the treatment of urban runoff via stormwater ponds as well as innovative actions for wastewater treatment are required to maintain and improve the water quality in the streams and rivers within the Toronto region.

7. Recommendations

The following recommendations are offered for consideration:

- Where possible, further analysis of the data should be completed which takes into account stream flow, changes in sample sizes among years and seasonality of sampling and changes in detection limits and labs

- Communicate results of this report to the municipalities to make them aware that chloride concentrations are continuing to rise and provide a means to a solution by recommending best management practices developed by the Sustainable Technologies Evaluation Program (STEP) at TRCA

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Appendix A – Surface Water Quality Site Descriptions

Watershed	Station	Alternate Name	Northing	Easting	SubWatershed	Township	Municipality	Location Description	Proprietor
Etobicoke Creek	Mayfield		4843488	595028	Etobicoke Headwaters	Brampton	Peel	Southeast of Mayfield Rd. and Hwy 10	RWMP
	Spring Creek		4838157	607990	Spring Creek	Mississauga	Peel	North of Derry Rd., upstream of Pearson International Airport	RWMP
	80007	06008000702	4836994	606440	Etobicoke West Branch	Mississauga	Peel	Northwest of Dixie Rd. and Derry Rd.	PWQMN
	Tributary 3		4835564	607921	Tributary 3	Mississauga	Peel	North of Courtneypark Dr., west of Dixie Rd.	RWMP
	Lower Etob US	Lower Etobicoke US	4834597	610862	Etobicoke Main Branch	Mississauga	Peel	North of Hwy 401, downstream of Pearson International Airport	RWMP
	Tributary 4		4831543	615546	Tributary 4	Toronto	Toronto	South of Bloor St., east of Markland Dr.	RWMP
	Little Etob CK	Little Etobicoke Creek	4829577	615520	Little Etobicoke Creek	Mississauga	Peel	West of East Mall, north of The Queensway	RWMP
	80006[M]	06008000602	4829016	616234	Lower Etobicoke Creek	Toronto	Toronto	Southwest of the QEW and Brown's Line	PWQMN
Mimico Creek	MM003WM		4837916	613849	Lower Mimico	Toronto	Toronto	Southwest of Dixon Rd. and Hwy 27, in Royal Woodbine Golf Club	RWMP
	82003[M]	06008200302	4831713	621585	Lower Mimico	Toronto	Toronto	Southwest of Park Lawn Rd. and The Queensway, Etobicoke	PWQMN
Humber River	83104	06008310402	4864112	593560	Main Humber	Caledon	Peel	Northwest of Old Church Rd. and Hwy 50, in Albion Hills CA, at blue gauge station	PWQMN
	83018	06008301802	4864366	596071	Main Humber	Caledon	Peel	Southwest of Old Church Rd. and Hwy 50, downstream Albion Hills CA	PWQMN
	83009	06008300902	4860243	602980	Main Humber	King	York	Northeast of King Rd. and Caledon-King Townline	PWQMN
	83020	06008302002	4851861	610386	Main Humber	Vaughan	York	Northeast of Rutherford Rd. and Hwy 27 at first bridge	RWMP
	83004	06008300402	4850423	614148	East Humber River	Vaughan	York	At bridge Pine Grove Rd., west of Pine Valley Dr., Woodbridge	RWMP
	83103	06008310302	4845870	606385	West Humber River	Brampton	Peel	Northwest of Hwy 7 and McVean Dr, north (upstream) of Claireville	PWQMN
	HU1RWMP		4848311	618678	Black Creek	Vaughan	York	Northwest of Steeles Ave. and Jane St.	RWMP
	HU010WM		4844739	614940	Lower Main Humber	Toronto	Toronto	Northwest of Finch Ave. and Islington Ave. in Rowntree Mills Park	RWMP
	83002	06008300202	4843562	610459	West Humber River	Toronto	Toronto	Northwest of Hwy 427 and Finch Ave. Claireville dam outlet.	RWMP
	83012	06008301202	4836845	620488	Black Creek	Toronto	Toronto	Northeast of Scarlett Rd. and St. Clair Ave.	RWMP
	83019[M]	06008301902	4834265	621663	Lower Main Humber	Toronto	Toronto	Old Mill Rd., Etobicoke	PWQMN
Don River	85004	06008500402	4851207	622014	Upper West Don	Vaughan	York	Northwest of Hwy 7 and Centre St.	RWMP
	85003	06008500302	4851256	628954	Upper East Don	Markham	York	Northwest of Steeles Ave. and Bayview Ave.	RWMP
	DN008WM		4850878	630252	German Mills Creek	Toronto	Toronto	Northeast of Cummer Ave. and Bayview Ave.	RWMP
	DM 6.0		4840251	634378	Taylor/Massey Creek	Toronto	Toronto	West of the DVP and east of Don Mills Rd.	RWMP
	85014[M]	06008501402	4838576	632000	Lower Don	Toronto	Toronto	Pottery Rd., Toronto	PWQMN
Highland Creek	94002	06009400202	4849056	647429	Main Highland Creek	Toronto	Toronto	South of Kingston Rd. and Colonel Danforth Trail	RWMP

[M] = watercourse outlet/mouth.

Appendix A – Surface Water Quality Site Descriptions (cont'd)

Watershed	Station	Alternate Name	Northing	Easting	SubWatershed	Township	Municipality	Location Description	Proprietor
Rouge River	97999	97999	4863887	640589	Little Rouge Creek	Markham	York	Northwest of Major Mackenzie Rd. and 9th Line	RWMP
	97018	06009701802	4861770	634680	Bruce Creek	Markham	York	Northwest of Major Mackenzie Dr. and Kennedy Rd.	PWQMN
	97777	97777	4856823	634214	Middle Rouge/Beaver	Markham	York	Northwest of Hwy 407 and Warden Ave.	RWMP
	97003	RG008WM/06009700302	4857669	641985	Lower Rouge Creek	Markham	York	14 Ave, W of 9 Line, Markham	RWMP
	97007	RG007WM/06009700702	4857816	644300	Little Rouge Creek	Markham	York	Reesor Rd., N of Steeles Ave., E of Markham	RWMP
	97013	06009701302	4852830	648243	Little Rouge Creek	Toronto	Toronto	Northeast of Twyn Rivers Dr.and Sheppard Ave.	RWMP
	97011	06009701102	4852511	648007	Lower Rouge River	Toronto	Toronto	Southeast of Twyn Rivers Dr. anf Sheppard Ave.	PWQMN
Duffins Creek	104008	06010400802/DuE17.5	4869299	650372	East Duffins Creek	Pickering	Durham	Northwest of Brock Rd. and 8th Concession	PWQMN
	104037	8th Concession/06010403702	4866462	644191	West Duffins Creek	Pickering	Durham	Conc 8, W of Sideline 34, W of Atha Road	RWMP
	104029	7th Concession/06010402902	4868158	653641	East Duffins Creek	Pickering	Durham	Sideline 12, N of Conc 7	RWMP
	104027	Paulyn Park/06010402702	4859419	655458	East Duffins Creek	Ajax	Durham	Rossland Rd., W of Church St.	RWMP
	104025	Brock Ridge/06010402502	4857115	654656	West Duffins Creek	Pickering	Durham	Brock Rd., N of Finch Ave.	RWMP
	104001[M]	06010400102/Annadale	4855880	657579	Lower Main Duffins	Ajax	Durham	Southwest of Bayly St. and Westney Rd.	PWQMN
Carruthers Creek	107002[M]	Shoal Point/06010700202	4856972	660850	Carruthers Creek	Ajax	Durham	Northwest of Bayly St. and Shoal Point Rd.	RWMP
Petticoat Creek	PT001WM		4851804	652005	Lower Petticoat Creek	Pickering	Durham	Petticoat Creek Conservation Area, 1100 Whites Road, Whites Rd. south of Highway 401	RWMP
Frenchman's Bay (Pine Creek)	FB003WM		4854372	653673	Pine Creek	Pickering	Durham	Liverpool Rd., south of Bayly St.	RWMP

[M] = watercourse outlet/mouth.

Appendix B. Laboratories used for water quality sample analysis

Parameter	Program	2011	2012	2013	2014	2015*
Metals	PWQMN	OMOECC[1]	OMOECC[1]	OMOECC[1]	OMOECC[1]	OMOECC[1]
	RWMP	YD	YD	YD	YD	YD/TOR
Nutrients	PWQMN	OMOECC[1]	OMOECC[1]	OMOECC[1]	OMOECC[1]	OMOECC[1]
	RWMP	YD	YD	YD	YD	YD/TOR
General	PWQMN	OMOECC[1]	OMOECC[1]	OMOECC[1]	OMOECC[1]	OMOECC[1]
	RWMP	YD	YD	YD	YD	YD/TOR
E. coli	PWQMN	OMOECC[2]	OMOECC[2]	OMOECC[2]	OMOECC[2]	OMOECC[2]
	RWMP	YD	YD	YD	YD	YD/TOR

Notes: OMOECC = Ontario Ministry of the Environment and Climate Change Rexdale Laboratory, TOR = City of Toronto Dee Laboratory; YD = York-Durham Regional Environmental Laboratory (Pickering).

[1] Most stations analyzed by OMOECC from April to November, remaining months at YD; exceptions 85014, 104001, 80006, 83019, 82003, and 97011 analyzed year round by OMOE.

[2] *E. coli* analyzed by OMOECC at stations 85014 and 83019 only; remaining PWQMN stations analyzed for *E. coli* by YD Jan-May and TOR Jun-Dec.

* If not analyzed by OMOECC, YD analyzed samples from Jan-May and TOR analyzed samples from Jun-Dec (phosphate continued to be sent to YD Jun-Dec).