2013 Surface Water Quality Summary

Regional Watershed Monitoring Program

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Watershed Monitoring and Reporting Section
Restoration Services Division

Toronto and Region Conservation for The Living City

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1. Introduction

Since 2002, the Toronto and Region Conservation Authority (TRCA) has monitored stream water quality at selected locations within the watersheds of the greater Toronto region on a monthly basis. These activities have been undertaken as part of TRCA's Regional Watershed Monitoring Program (RWMP) in partnership with the Ontario Ministry of the Environment (OMOE). The data collected are shared with partner municipalities and other external agencies. The results are also used for planning, implementation and reporting activities including the development of watershed plans and report cards as well as watershed characterization reports in support of source water protection planning.

This report presents selected results of the 2013 surface water quality sampling, as well as five years of results from 2009 to 2013, conducted in support of the Provincial Water Quality Monitoring Network (PWQMN), RWMP, and special projects. It provides a general overview and description of the range of water quality conditions across the TRCA jurisdiction during 2013. This report and associated data can assist in identifying areas of concern, elevated levels of contaminants, and can be used to affirm both poor and good water quality in different land use areas. However, the 2013 results should be interpreted with caution since water quality samples were collected independent of precipitation, and one year of data is insufficient to represent normal conditions at stations and watersheds. The 2009 to 2013 data provided sufficient sample size per station to represent water quality conditions as the impact of intra-annual variation was reduced.

2. Methods

In 2013, surface water quality samples were collected at 46 stations (Figure 1) throughout the TRCA's jurisdiction (the City of Toronto's wet weather stations are displayed for informative purposes in Figure 1). Sample collection and laboratory analysis were carried out through several partnerships which are outlined below:

- 13 stations were sampled by TRCA under the OMOE's PWQMN;
- 25 stations were sampled by TRCA for the RWMP, including:
    - 5 new stations (Tributary 3, Spring Creek, Lower Etob US, Little Etob Ck, and Tributary 4) established in Etobicoke Creek watershed to monitor:
        - the Little Etobicoke Creek, Spring Creek, and other tributaries of Etobicoke Creek,
        - upstream and downstream of Pearson International Airport, and
        - runoff from Markland Wood Golf Club;
- 3 Duffins Creek stations (104028, 104026 and 104023) were sampled in support of the Seaton/Duffins Heights Development Monitoring Project;

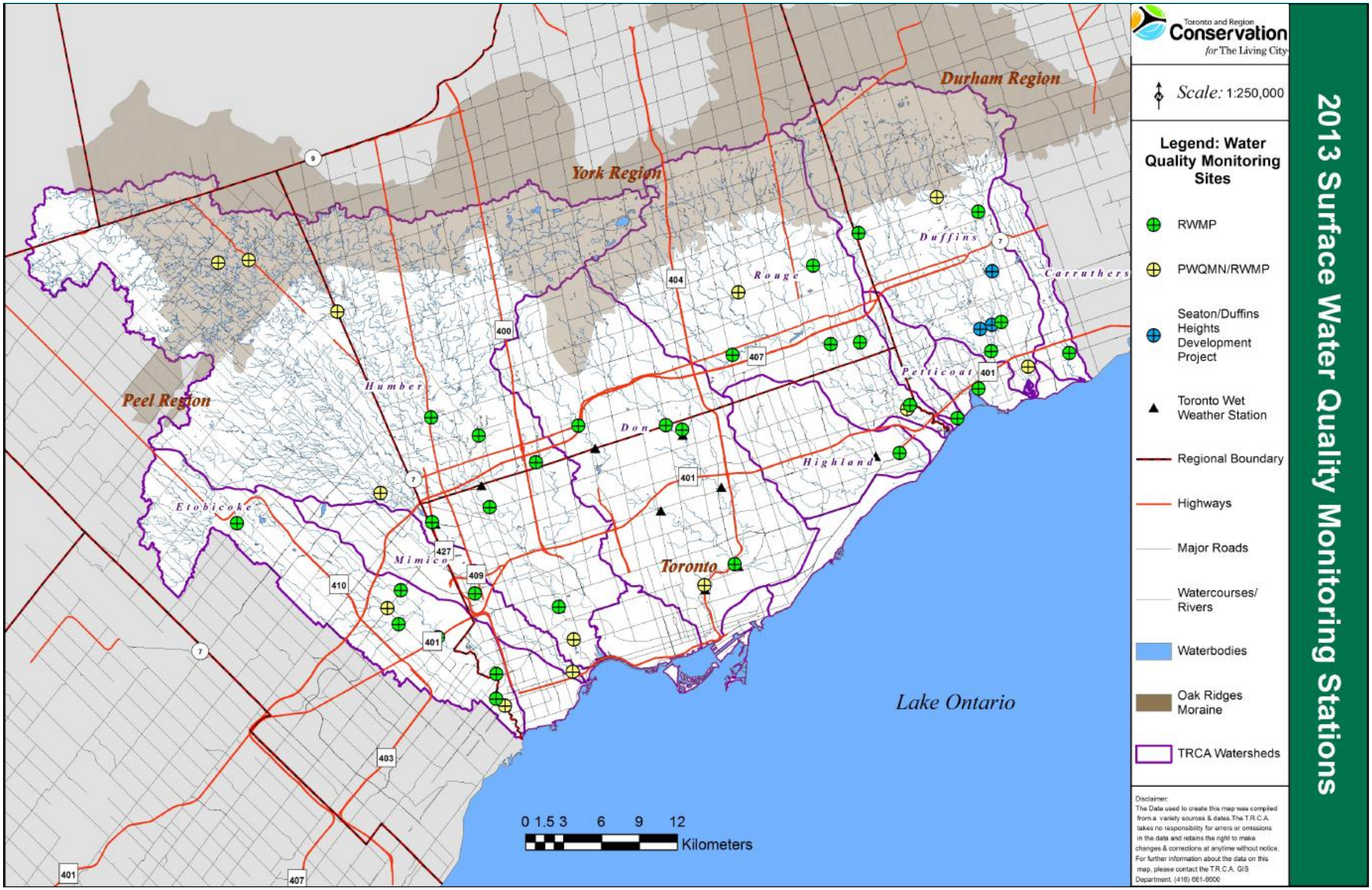


Figure 1. 2013 TRCA surface water quality monitoring stations

Monthly samples were collected using in-stream “grab” techniques following the OMOE PWQMN protocol (OMOE 2003) and also included in-situ measurements (e.g. water temperature, pH, and dissolved oxygen) collected using a hand-held YSI meter (Model 600QS). Water quality samples were collected throughout the year, typically in the third week of each month, irrespective of precipitation. Samples from the 13 stations that were part of the PWQMN partnership were submitted to the OMOE Rexdale Laboratory. The remaining samples from stations or months (e.g. January to March, and December) not included in the PWQMN were submitted to the York-Durham Regional Environmental Laboratory in order to augment water quality data from these stations, and to maintain a year-round dataset (Table 1).

Table 1. 2013 TRCA surface water quality stations, associated laboratories and Environment Canada precipitation stations

Station	Watershed	UTM Coordinates		Environment Canada Precipitation Station	Laboratory		
		Northing	Easting		Jan-Mar	Apr-Nov	Dec
Mayfield	Etobicoke Creek	4843488	595028	Pearson	YD	YD	YD
80007	Etobicoke Creek	4836994	606440	Pearson	YD	OMOE	YD
Tributary 3	Etobicoke Creek	4835477	607825	Pearson	YD	YD	YD
Spring	Etobicoke Creek	4838157	607990	Pearson	YD	YD	YD
Lower Etob	Etobicoke Creek	4834442	610933	Pearson	YD	YD	YD
Little Etob	Etobicoke Creek	4829577	615520	Pearson	YD	YD	YD
Tributary 4	Etobicoke Creek	4831543	615546	Pearson	YD	YD	YD
80006	Etobicoke Creek	4829016	616234	Pearson	OMOE	OMOE	OMOE
MM003WM	Mimico Creek	4837916	613849	Pearson	YD	YD	YD
82003	Mimico Creek	4831713	621585	Pearson	OMOE	OMOE	OMOE
83104	Humber River	4864112	593560	Pearson	YD	OMOE	YD
83018	Humber River	4864366	596071	Pearson	YD	OMOE	YD
83009	Humber River	4860243	602980	Pearson	YD	OMOE	YD
83103	Humber River	4845870	606385	Pearson	YD	OMOE	YD
83020	Humber River	4851861	610386	Pearson	YD	YD	YD
83002	Humber River	4843562	610459	Pearson	YD	YD	YD
83004	Humber River	4850423	614148	Pearson	YD	YD	YD
HU010WM	Humber River	4844739	614940	Pearson	YD	YD	YD
HU1RWMP	Humber River	4848311	618678	Pearson	YD	YD	YD
83012	Humber River	4836845	620488	Pearson	YD	YD	YD
83019	Humber River	4834265	621663	Pearson	OMOE	OMOE	OMOE
85004	Don River	4851207	622014	Buttonville	YD	YD	YD
85003	Don River	4851256	628954	Buttonville	YD	YD	YD
DN008WM	Don River	4850878	630252	Buttonville	YD	YD	YD
85014	Don River	4838576	632000	Buttonville	OMOE	OMOE	OMOE

Station	Watershed	UTM Coordinates		Environment Canada Precipitation Station	Laboratory		
		Northing	Easting		Jan-Mar	Apr-Nov	Dec
DM 6.0	Don River	4840251	634378	Buttonville	YD	YD	YD
94002	Highland Creek	4849056	647429	Buttonville	YD	YD	YD
97777	Rouge River	4856823	634214	Buttonville	YD	YD	YD
97018	Rouge River	4861770	634680	Buttonville	YD	OMOE	YD
97999	Rouge River	4863887	640589	Buttonville	YD	YD	YD
97003	Rouge River	4857814	644266	Buttonville	YD	YD	YD
97007	Rouge River	4857816	644300	Buttonville	YD	YD	YD
97011	Rouge River	4852511	648007	Buttonville	OMOE	OMOE	OMOE
97013	Rouge River	4852830	648243	Buttonville	YD	YD	YD
PT001WM	Petticoat Creek	4851804	652005	Buttonville	YD	YD	YD
FB003WM	Frenchman's Bay	4854372	653673	Buttonville	YD	YD	YD
104008	Duffins Creek	4869299	650372	Buttonville	YD	OMOE	YD
104037	Duffins Creek	4866462	644191	Buttonville	YD	YD	YD
104029	Duffins Creek	4868158	653641	Buttonville	YD	YD	YD
104023	Duffins Creek	4858867	653796	Buttonville	YD	YD	YD
104025	Duffins Creek	4857115	654656	Buttonville	YD	YD	YD
104026	Duffins Creek	4859199	654730	Buttonville	YD	YD	YD
104028	Duffins Creek	4863433	654742	Buttonville	YD	YD	YD
104027	Duffins Creek	4859419	655458	Buttonville	YD	YD	YD
104001	Duffins Creek	4855880	657579	Buttonville	OMOE	OMOE	OMOE
107002	Carruthers Creek	4856972	660850	Buttonville	YD	YD	YD

OMOE: OMOE Rexdale Laboratory; YD: York-Durham Regional Environmental Laboratory

The two laboratories analyzed a standard suite of nutrients, metals, microbiological, and conventional water quality parameters (Table 2). The 16 parameters in boldface are those that were selected for discussion in this report and include all the PWQMN recommended indicator parameters as well as additional forms of nitrogen (ammonia, nitrate, nitrite, and total Kjeldahl nitrogen), *Escherichia coli*, and several metals. These parameters provide a quick but comprehensive indication of the water quality at each station. Elevated concentrations of these parameters may point to natural and/or anthropogenic sources within the watershed.

Table 2. Standard suite of water quality parameters analyzed by York-Durham and OMOE laboratories. The results of the 16 parameters in boldface are discussed in this report

General Chemistry	Nutrients	Metals	Microbiological
Alkalinity	**Ammonia**	**Aluminium**	***Escherichia coli***
Biochemical Oxygen Demand	***Nitrate/Nitrite**	**Arsenic**	
Calcium	**Nitrogen, Total Kjeldahl**	Barium	
***Chloride**	Phosphate	Beryllium	
Conductivity	***Total Phosphorus**	Cadmium	
Dissolved Oxygen		Chromium	
Hardness		Cobalt	
Magnesium		***Copper**	
pH		**Iron**	
Potassium		***Lead**	
Sodium		Manganese	
Total Dissolved Solids		Molybdenum	
***Total Suspended Solids**		**Nickel**	
Turbidity		Strontium	
Water Temperature		Vanadium	
		***Zinc**	

Note: additional parameters may be analyzed on a site or project specific basis.
*PWQMN recommended indicator parameters

The results of each parameter were compared to the Provincial Water Quality Objectives (PWQO) guidelines where applicable. The PWQOs are a set of numerical and narrative ambient surface water quality criteria that represent a desirable level of water quality. These guidelines were developed to protect all forms of aquatic life and all aspects of their aquatic life cycles during indefinite exposure to the water as well as protecting recreational water usage based on public health considerations and aesthetics (OMOEE 1994). When PWQO guidelines were not available, other objectives such as Canadian Water Quality Guidelines (CWQG) (CCME 2007) and Recommended Water Quality Guidelines for the Protection of Aquatic Life under the Canadian Environmental Sustainability Indicators (CESI) Initiative (EC 2012) were used. All laboratory results that were reported as less than the minimum detection limit (MDL) were set to the MDL value for the purposes of interpretation. Surface water quality data are maintained in a relational SQL database that is part of the TRCA's corporate database web applications.

Water quality laboratory results for 2013, as well as from 2009 to 2013, for each analyte were presented in box plots which summarize the distribution of values for each parameter over the course of the year

(Figure 2). The use of box plots displays the range of results where the majority (50%) of results are located within the box section. The ends of the boxes represent the 25th and 75th quartiles and the difference between the quartiles is the interquartile range. The line across the middle of the box identifies the median sample value. Box plot graphs use median values because annual mean values can be skewed by one or two high values. The "whiskers" above and below the box represent the range of data plus or minus 1.5 times the interquartile range, excluding extreme values. Water quality stations are arranged along the x-axis of each graph from upstream to downstream (left to right) and grouped into watersheds which are arranged from west to east.

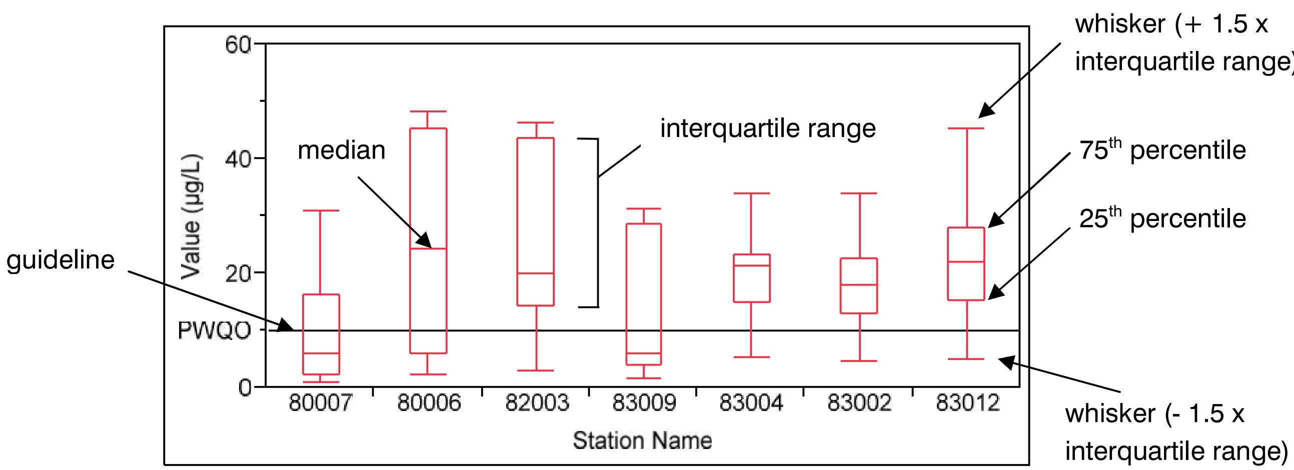


Figure 2. Box plot graphic example

The boxplots of stations are comparable to one another, and stations were grouped by watershed to permit comparison of watersheds. The 2013 data represented conditions in 2013 whereas the 2009 to 2013 data provided an examination of long-term patterns. The five-year data were presented in two formats: as boxplots per station and boxplots per month. The five-year monthly boxplots were tested for differences in water quality parameters between months using an analysis of variance (ANOVA) and Tukey's tests, where *p* values less than 0.05 indicating significance.

Daily and monthly precipitation data were downloaded from the Environment Canada National Climate Data and Information Archive website (http://climate.weather.gc.ca/). Precipitation data from meteorological stations at Pearson International and Buttonville Airports were attributed to TRCA water quality stations based on which airport was closer to the stations (Table 1). Data from Pearson were attributed to 21 water quality stations in the Etobicoke, Mimico, and Humber watersheds. Buttonville precipitation data were attributed to 25 stations in the Don, Highland, Rouge, Petticoat, Duffins, and Carruthers watersheds, as well as the Frenchman's Bay area. For a general overview of precipitation in the TRCA jurisdiction, the Pearson and Buttonville data were averaged. When determining from these data whether samples were collected during precipitation events, both precipitation on the day of sampling as well as the day prior to sampling were used. Precipitation on the day prior to sampling is relevant because runoff from a precipitation event can take as much as 72 hours to flow through TRCA watersheds (TRCA 2008).

Road density values for 2013 were provided by TRCA's GIS department. Road density is a proxy for urbanization, and is calculated as the number of kilometres of roads in a catchment divided by the number of square kilometres of the catchment (km/km^2). Higher road densities indicate more impervious surfaces and therefore stations in catchments with high road densities may experience more stormwater runoff, which contributes to the degradation of poor water quality.

Precipitation and road density data were tested for relationships with water quality parameters. Regression analysis determined the strength of the relationship at a significance level of 0.05. The Mann-Kendall trend test was used to detect temporal trends in precipitation data over time with a significance level of 0.05. Precipitation data from 2013 and from 2009 to 2013 were explored with multivariate analyses to reveal which stations were characterized by elevated concentrations of analytes.

Stream conditions were recorded at the time of sampling to help characterize the sample with respect to flow response to recent or occurring precipitation. These field notes (Appendix A) as well as 2013 precipitation data from Pearson International and Buttonville Airports (subsection 3.1 Precipitation) were included in this report to provide context to assist with interpretation of results.

The results of 2013 data were intended to provide a general characterization of TRCA surface water quality conditions. Due to the small annual sample size (n=12) for each station, only one or two high values (e.g. storm events) are required to skew results upwards. Therefore, one year of data cannot be assumed to represent normal conditions in the TRCA jurisdiction. The 2013 results should be considered a general overview of conditions and description of ranges of water quality parameters at stations across the jurisdiction.

For more informative interpretation of results the OMOE recommends a minimum sample size of 30 samples per station (or 2.5 years of monthly data) to reduce the influence of unusual conditions such as spills, extreme runoff events, and drought (OMOEE 2003). TRCA water quality data from 2009 to 2013 provided sufficient sample size to characterize conditions at stations, watersheds, and across the jurisdiction, and can be considered representative of typical conditions within the jurisdiction.

2.1 Seasonal Variation

The 16 water quality parameters from 41 stations from 2009 to 2013 were displayed in box plots from January to December in order to explore monthly or seasonal patterns. Sampling began at five stations in Etobicoke Creek watershed (Tributary 3, Spring Creek, Lower Etob US, Little Etob CK, and Tributary 4) in 2013, therefore only 41 stations had been consistently sampled since 2009. An ANOVA was used to detect significant differences between months and the Tukey's test specified between which months the significant differences were. The Tukey's test results were presented in tables where months were grouped into columns if their values were similar. Months in the same column were not significantly different whereas months allocated to different columns were significantly different. Note that the box plots displayed median values whereas the ANOVA and Tukey's test detected differences based on mean values and the variation of the data around that mean.

3. Results & Discussion

3.1 Precipitation

The jurisdictional precipitation data discussed in this section was an average of Environment Canada's Pearson and Buttonville Airport meteorological stations. The total amount of precipitation recorded in 2013 was 985.8 mm, which was 135.8 mm above the 12-year average of 850 mm (Figure 3). In the last 12 years, only 2008 experienced higher precipitation with a total of 1029.7 mm being recorded.

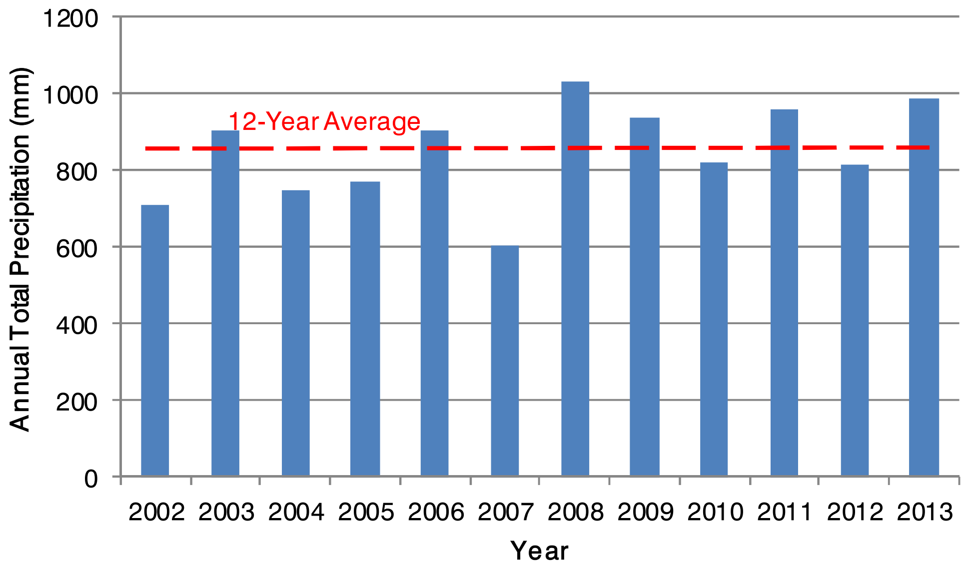


Figure 3. Annual precipitation for the TRCA jurisdiction from 2002 to 2013. The data is an average of Environment Canada's Pearson and Buttonville Airport meteorological stations

To reduce the influence of annual variability in order to detect longer term trends, the 5-year moving averages of rainfall, snowfall, and total precipitation were analyzed (Figure 4). The data point for each year in the graph was an average of the previous five years. For example, the rainfall, snowfall, and total precipitation values displayed in Figure 4 for the year 2002 were an average of values from 1998-2002.

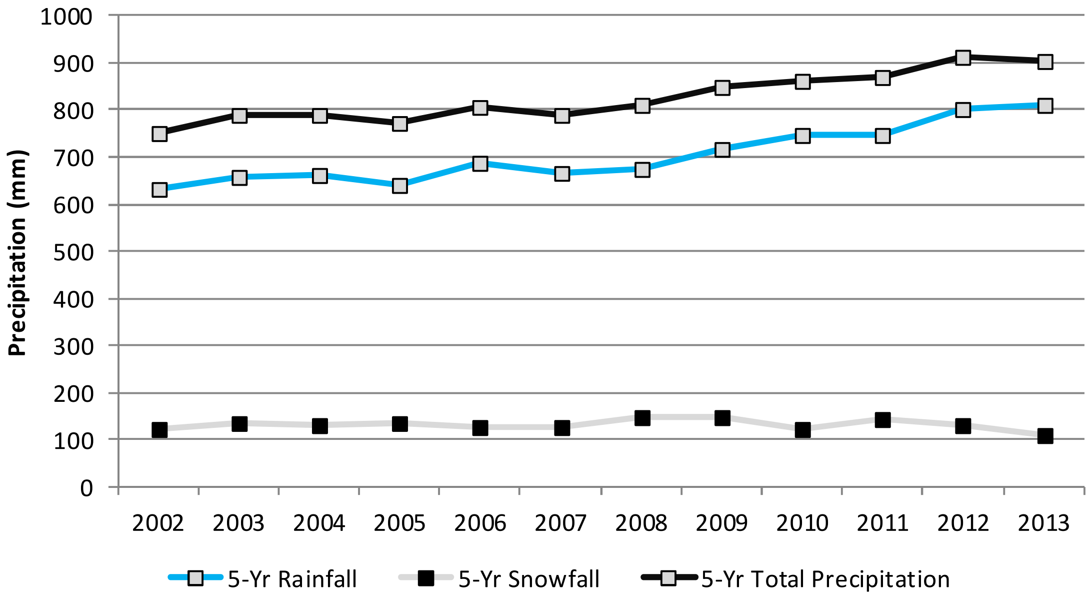


Figure 4. Five year moving averages for rainfall, snowfall, and total precipitation from 2002 to 2013

The 5-year rainfall and total precipitation moving averages demonstrated significant increasing trends, as detected by the Mann-Kendall temporal trend test (p value<0.001). The 5-year snowfall moving averages did not demonstrate a trend but appeared to be relatively constant. Rainfall had a strong positive relationship with total precipitation ($R^2=0.85$, $p<0.0001$) but snowfall did not. Snowfall did demonstrate an inverse relationship with temperature ($R^2=0.51$, $p<0.0001$). These relationships would appear to be obvious: that higher total precipitation would increase rainfall and that snowfall would increase as temperatures decreased. However, it is interesting to note that higher snowfall was very dependent upon colder temperatures and independent from total precipitation.

Figure 5 displays 2013 monthly precipitation and monthly 12-year precipitation averages. Precipitation recorded in March and November, 2013, was much lower than the 12-year averages. Precipitation in July, June, February, April, and January, 2013, was much higher than the 12-year averages, in some cases more than 150% higher. Stations may exhibit elevated concentrations of water quality analytes and pollutants as a result of high precipitation.

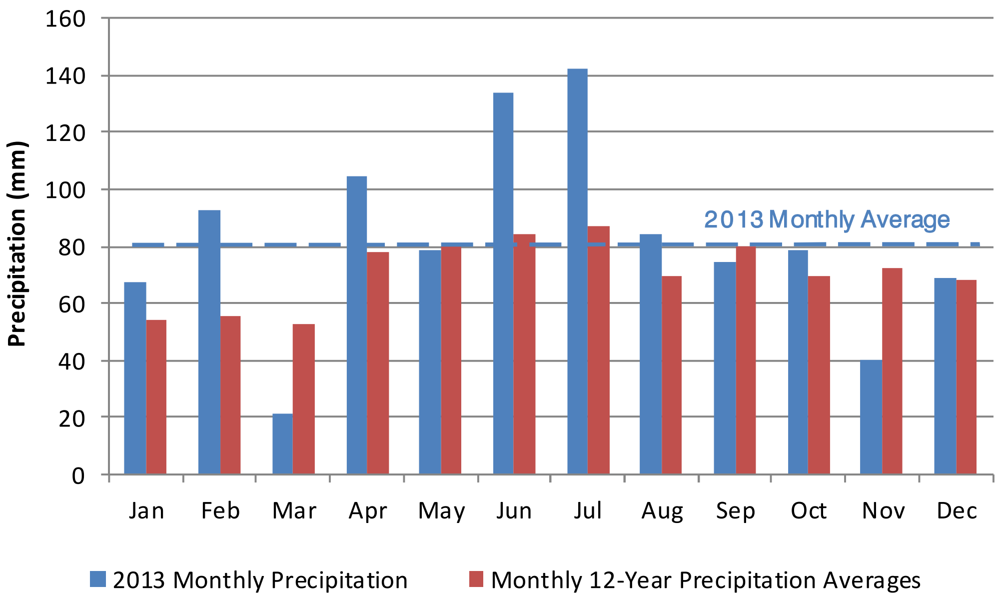


Figure 5. Monthly precipitation for 2013 compared to monthly 12-year precipitation averages

Stations were sampled independent of precipitation; however, it was noted on field sheets if there was precipitation at the time of sampling (Appendix B). Additionally, Environment Canada precipitation data from the day of and the day prior to sampling were used to calculate the percentage of wet and dry sampling events (Table 3). Based on field records, 23.4% of samples were collected during precipitation events whereas using Environment Canada data, 59.2% of samples were collected on the day of, or the day after, precipitation events. These results were very dissimilar because field records did not include precipitation the day before sampling and reflected conditions at the time of sampling,

Table 3 presents wet and dry sampling events from 2009 to 2013 based on Environment Canada's Pearson and Buttonville Airport weather station data. The annual total number of sampling events ranged from 433 in 2009 to 600 in 2013. Annual wet sampling events ranged from 51.8% in 2012 to 70.9% in 2011, with an average over the five years of 61.2%. Dry events ranged from 29.1% in 2011 to 48.2% in 2012 and over the five years averaged 38.8%.

Table 3. Wet and dry sampling events based on Environment Canada's Pearson and Buttonville Airports, from 2009 to 2013

Year	Wet Events	Dry Events	Total Events	Wet Event Percentage	Dry Event Percentage
2013	355	245	600	59.2	40.8
2012	255	237	492	51.8	48.2
2011	349	143	492	70.9	29.1
2010	300	156	456	65.8	34.2
2009	252	181	433	58.2	41.8
Average	302.2	192.4		61.18	38.82

From 2002 to 2013 snowfall ranged from 50.4 (2006) to 253 cm (2008) and the average was 130.9 cm (Figure 6). The 151.6 cm of snow recorded in 2013, almost twice the 76.9 cm recorded in 2012, was the third highest recorded since 2002, and was higher than the 12-year average. Snow may reduce the amount of contaminants being washed into aquatic systems however other analytes may display increased concentrations in the winter. For example, chloride levels would be expected to be higher in months with snowfall due to the use of road salt. Some water quality stations may have elevated concentrations of chloride as a result of frequent applications of road salt due to the high snowfall in 2013.

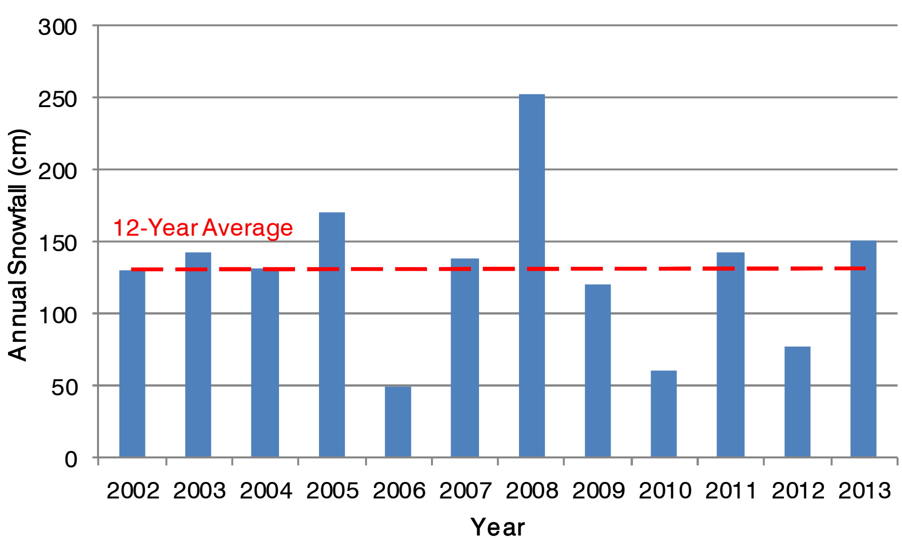


Figure 6. Annual snowfall from 2002 to 2013

3.2 Exploration of Water Quality Data

A principal components analysis (PCA) maps stations with respect to their water quality analyte concentrations. Stations which appear at or near a parameter arrow are characterized by higher levels of that parameter. Therefore, stations situated near the termination of a parameter arrow were characterized by high concentrations of that parameter, and can be considered to be an area of concern. Stations which are situated far apart from other stations are dissimilar, whereas stations situated close together are very similar, in terms of the analytes which characterize them. Additionally, parameters are positively correlated if their arrows are close together and inversely correlated if their arrows point in opposite directions. Arrows which are close to the x or y axes exert influence over that axis. PCAs were performed for the 2013 as well as the 2009 to 2013 data.

The 2013 water quality data consisted of 46 stations and 16 parameter values per month. Parameters were averaged for the year for each station. Each station had 12 monthly values for each analyte so it was possible that one or two high values may have skewed the averages. For this reason, the 2013 results were considered representative of the conditions in 2013 but did not represent long-term conditions. The 2009 to 2013 data had sufficient sample size to represent long-term station, watershed, and jurisdiction conditions because a few high analyte values would have less of an influence.

Prior to performing a PCA, the data would be tested for correlated analytes, especially when a large number are involved. Since only 16 analytes were included in this analysis, correlated analytes were not removed although it was expected *a priori* that a few analytes would be correlated. For example, the various forms of nitrogen (ammonia, nitrate, nitrite, and TKN) and some of the metals might be correlated. Finally, since the intent of the PCA was to 'map' water quality stations in the context of which analytes characterize which stations, none of the 16 analytes were removed from the analysis.

Analyte arrows which were very close to each other are considered correlated with each other. Iron and phosphorus, and TKN and *E. coli* were highly correlated (Figure 7). Arsenic was inversely correlated to aluminium and TSS and lead was inversely correlated to iron and phosphorus due to their arrows being very close together. The two axes of the biplot are interpreted by the parameter arrows closest to each axis. The primary (horizontal) axis was influenced by metals, beginning on the left of the biplot with high levels of nickel, zinc, and copper, and moving towards the right half of the biplot, higher lead values. The secondary (vertical) axis represented high pH values towards the top half of the biplot and high nitrate levels in the lower half. Stations situated closer to the origin of the two axes had lower concentrations of most analytes whereas stations situated towards the termination of an arrow were characterized by elevated levels of that parameter.

Stations with elevated parameter concentrations were from the Don River, Humber River, Mimico Creek, Etobicoke Creek, Rouge River, Petticoat Creek, and Frenchman's Bay watersheds. Stations in Duffins Creek, Carruthers Creek, and Highland Creek watersheds did not exhibit high analyte levels in 2013.

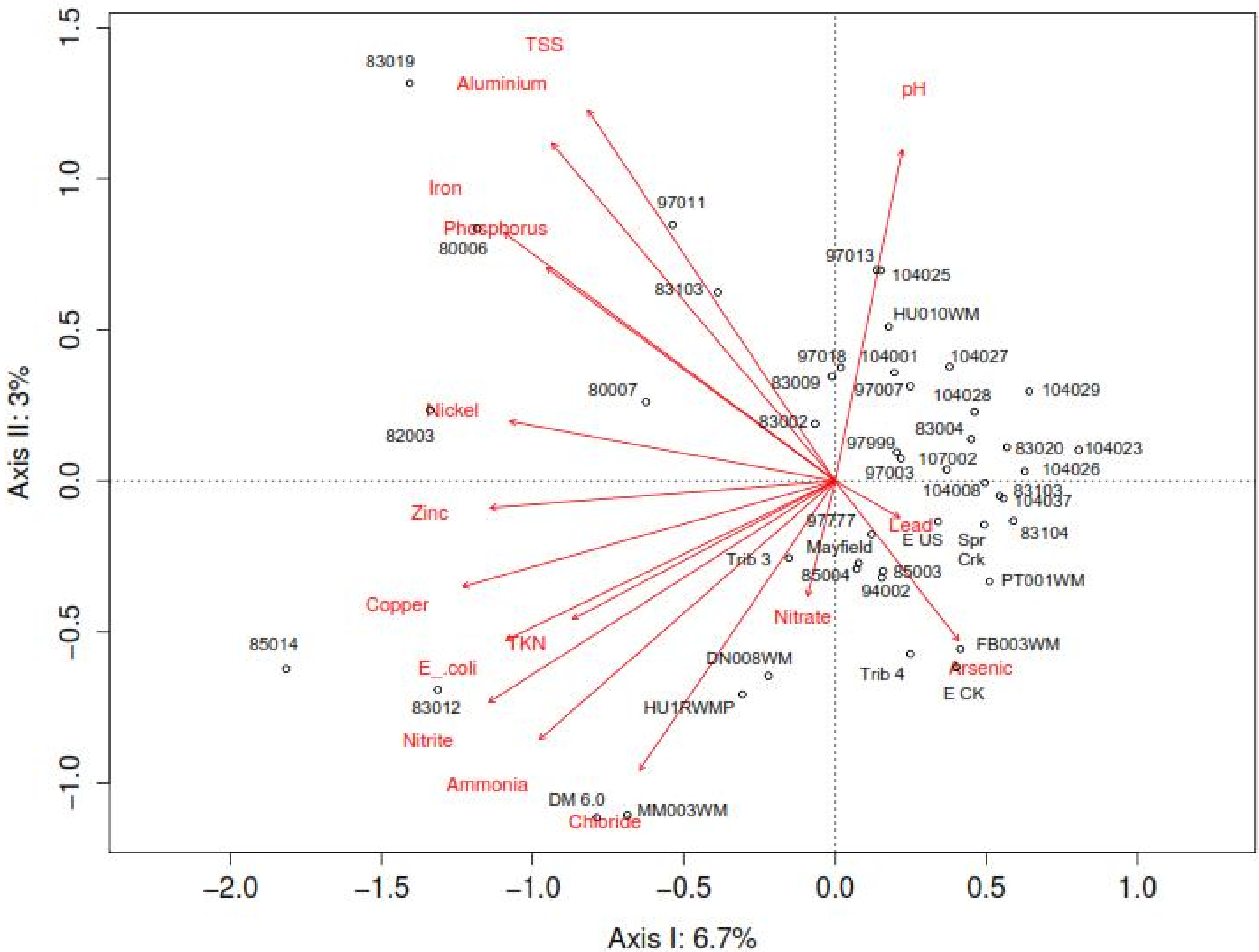


Figure 7. Biplot of PCA results for 46 stations and 16 water quality analytes in 2013

From the PCA biplot, stations which demonstrated elevated parameter concentrations were listed in Table 4. Stations situated beyond parameter arrows were described as having very high concentrations, stations situated at the termination of parameter arrows were described as having high concentrations, and those situated approximately half way up an arrow as moderately high. Two stations displayed very high concentrations for a few analytes. Station 85014 displayed very high levels of copper and *E. coli* and station 83019 had very high levels of iron and aluminium. Stations which displayed high concentrations of various analytes were 80006, 82003, 83012, DM 6.0, MM003WM, L Etob CK, FB003WM, 97013, and 104025. Stations 97011, 83103, 80007, HU1RWMP, and DN008WM displayed moderately high concentrations of different analytes.

Table 4. Stations which displayed high concentrations of various water quality parameters in 2013

Very High Concentrations	
Station	**Parameter**
85014	Copper
	E. coli
	TKN
83019	Aluminium
	TSS
	Iron
	Phosphorus
High Concentrations	
Station	**Parameter**
80006	Phosphorus
	Iron
82003	Nickel
83012	E. coli
	TKN
	Nitrite
DM 6.0	Chloride
MM003WM	Chloride
L Etob CK	Arsenic
FB003WM	Arsenic
97013	pH
104025	pH
Moderately High Concentrations	
Station	**Parameter**
97011	TSS
83103	TSS
80007	Iron
	Phosphorus
	Nickel
HU1RWMP	Chloride
	Nitrate
DN008WM	Chloride
	Nitrate

These stations with elevated concentrations represented the mid and low Etobicoke Creek, Mimico Creek, the lower half of the Humber River, and Don River, the low Rouge River, Frenchman's Bay, and the low Duffins Creek watersheds (Figure 8). These areas of concern were representative of conditions in 2013.

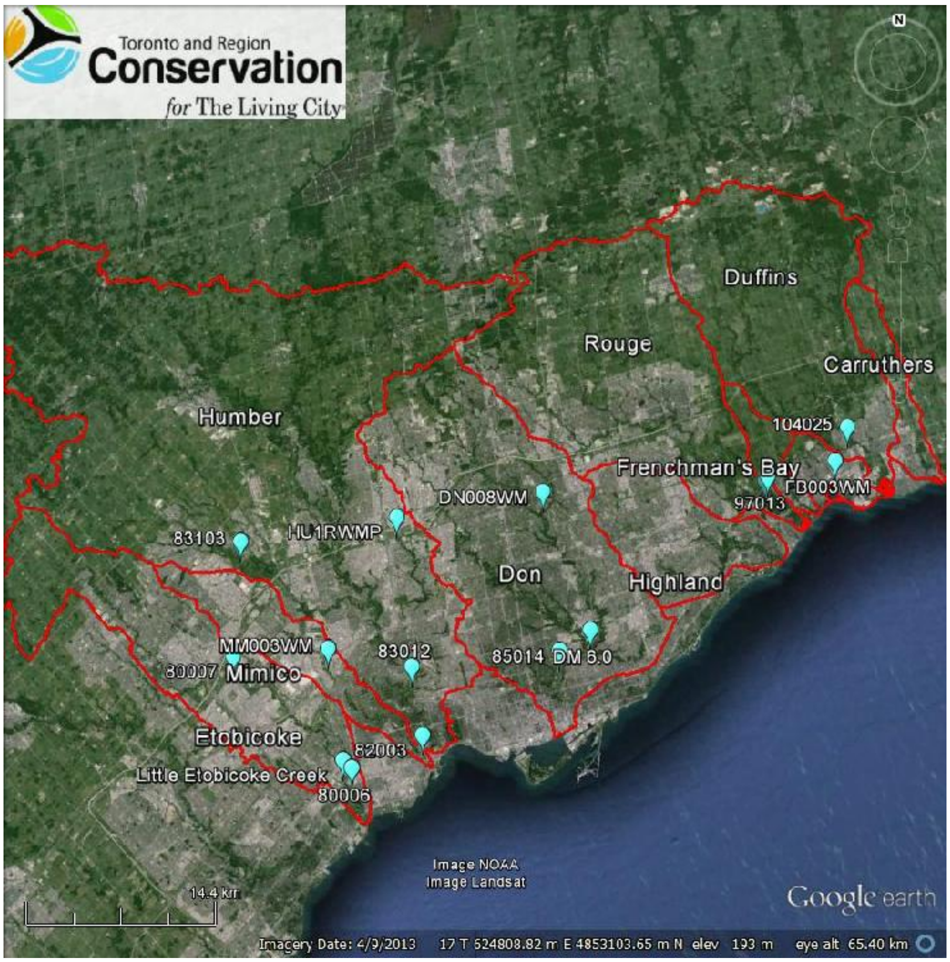


Figure 8. Locations of stations which displayed elevated concentrations of one or more analytes in 2013

To represent long-term conditions, five years of data were used (n = 60) so that the influence of high values from unusual conditions, typically increased runoff from storm events, were reduced. This five-year period of data included 41 stations and mean monthly values for 16 analytes (Appendix C).

The PCA results for 2009 to 203 data were displayed in a biplot (Figure 9). The primary axis represented an increasing gradient of copper, zinc, and phosphorus levels from left to right. The secondary axis was not as well defined, but was influenced by nitrate, lead, and pH values. Lead and aluminium, TSS and arsenic, zinc and copper, and nitrite and ammonia were highly correlated as evidenced by how close together their arrows were. Station 85014 demonstrated substantially elevated concentrations of zinc and copper. Other stations with high analyte levels were DM 6.0 with high levels of nitrate and chloride, 83012 with chloride, 82003 with phosphorus, 83019 with aluminium, lead, and TSS, and 97011 with aluminium and lead.

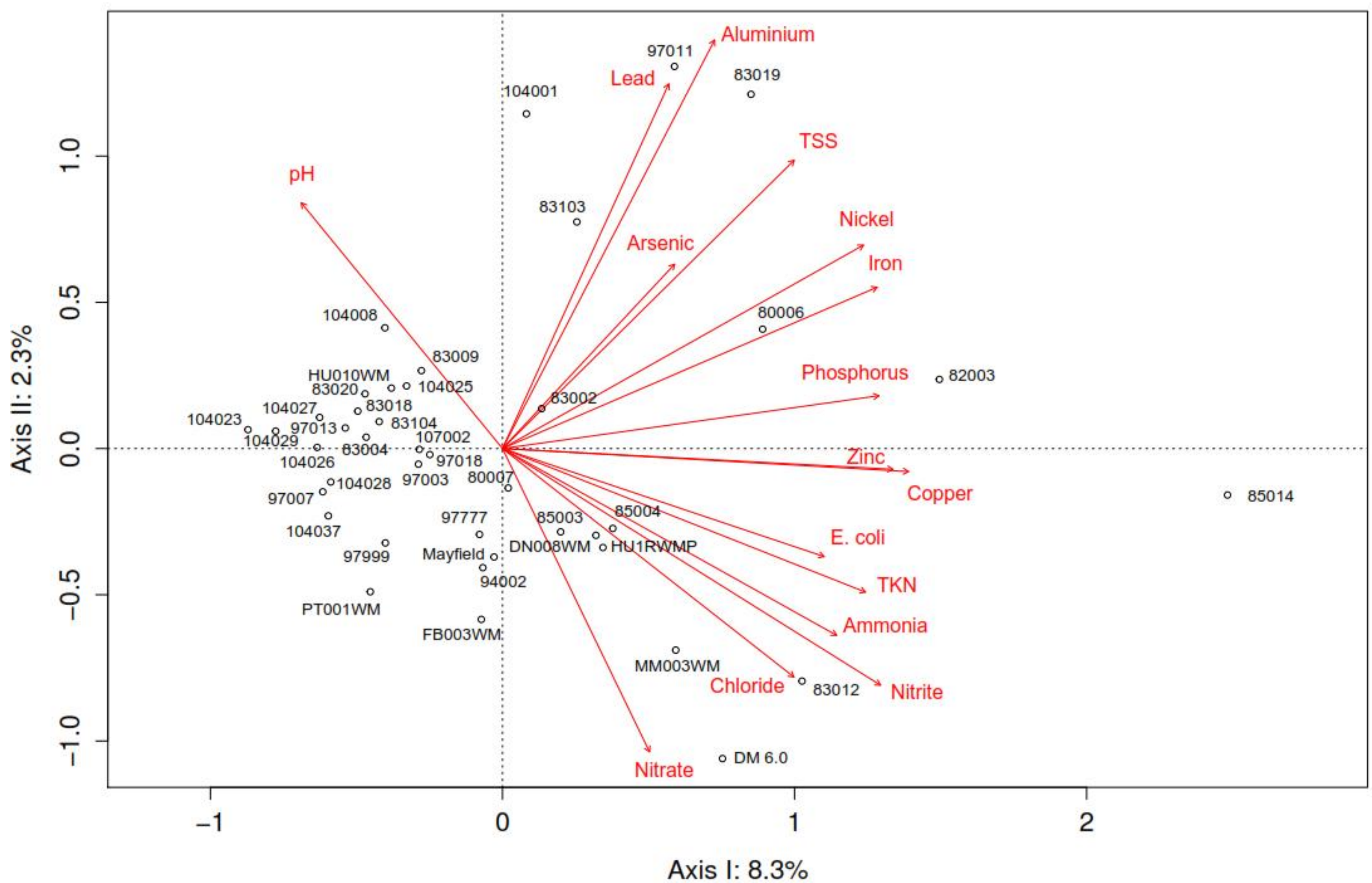


Figure 9. Biplot of PCA results for 41 stations and 16 analytes from 2009-2013

From Figure 9, stations with elevated analyte levels were categorized into very high, high, and moderately high concentrations (Table 5).

Table 5. Stations which displayed high levels of various water quality parameters from 2009-2013

Very High Concentrations	
Station	**Parameter**
85014	Copper
	Zinc
High Concentrations	
Station	**Parameter**
DM 6.0	Nitrate
	Chloride
83012	Chloride
82003	Phosphorus
83019	Aluminium
	Lead
	TSS
97011	Aluminium
	Lead
104001	pH
	Lead
	Aluminium
MM003WM	Nitrate
	Chloride
Moderately High Concentrations	
Station	**Parameter**
HU1RWMP	Chloride
	Nitrite
	Ammonia
	Nitrate
DN008WM	Chloride
	Nitrite
	Ammonia
	Nitrate
85004	Chloride
	Nitrite
	Ammonia
	Nitrate
80006	Iron
	Nickel
83103	Lead
	pH

Station 85014 stood out as having displayed very elevated concentrations of copper and zinc, as well as high concentrations of phosphorus, *E. coli*, and TKN. Stations which displayed high levels of different contaminants were DM 6.0, 83012, 82003, 83019, 97011, 104001, and MM003WM. Stations with moderately high concentrations were HU1RWMP, DN008WM, 85004, 80006, and 83103.

Over five years, the areas of concern represented by these stations were the low Etobicoke Creek, Mimico Creek, the lower half of the Humber River, Don River, the low Rouge River, and the lower Duffins Creek watersheds (Figure 10). These areas of concern have consistent chronic long-term water quality issues.

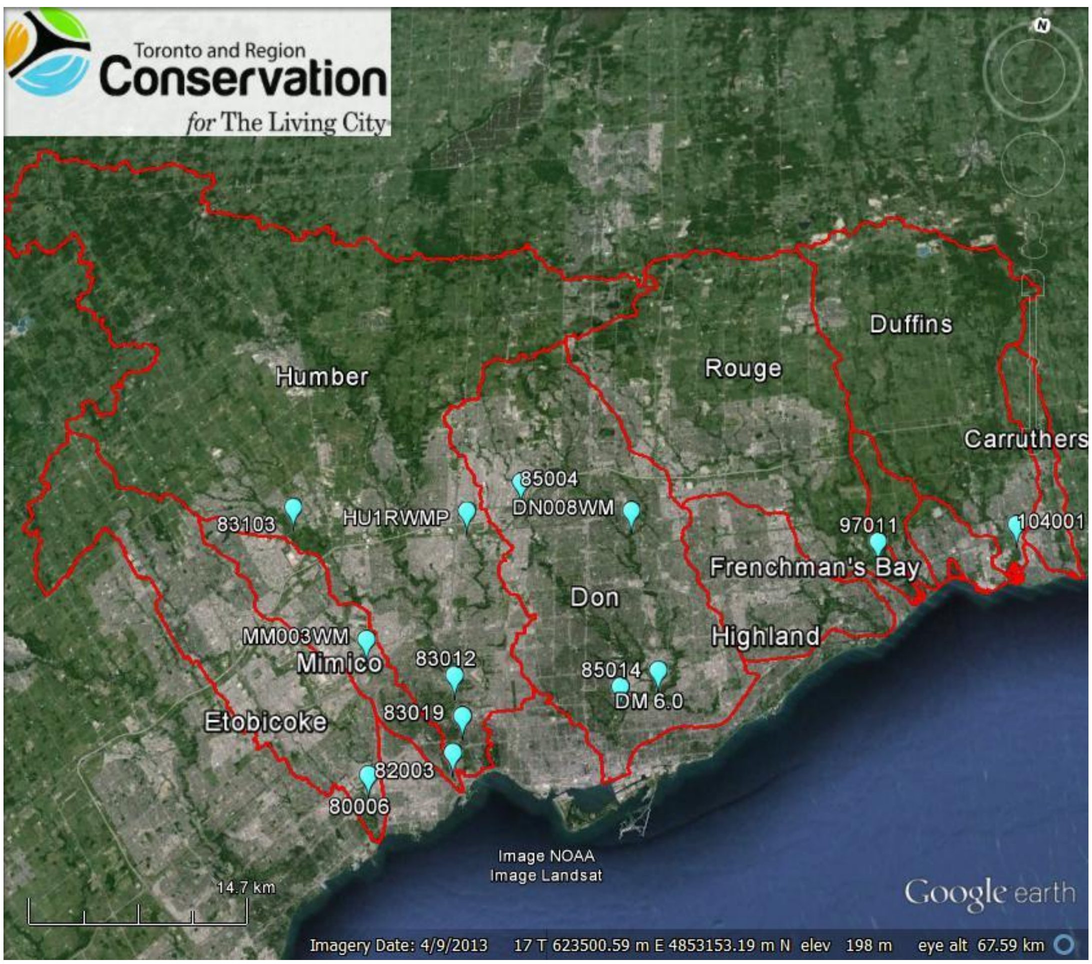


Figure 10. Stations which displayed elevated concentrations from 2009-2013

3.3 General Chemistry Parameters

Each water quality parameter from 2013 was analyzed and discussed in context of per station and per watershed 2013 data. The five-year data from 2009 to 2013 data were displayed in box plots per station and box plots per month, the latter of which were tested for differences between months. Any significant, or close to significant, relationships with precipitation and road density were discussed. The general chemistry parameters analyzed in this section are chloride, total suspended solids (TSS) and pH.

3.3.1 Chloride

Chloride does not readily absorb onto mineral surfaces, and thus concentrations can be high in surface water and shallow aquifers, the latter releasing chloride throughout the year (CCME, 2011). It can be toxic to aquatic organisms with acute toxic effects at high concentrations and chronic effects (on growth and reproduction) at lower concentrations (OMOE, 2003). CWQG have two guidelines for chloride: acute, or short-term, and chronic, or long-term. The short-term guideline is 640 mg/L and the long-term guideline is 120 mg/L. A primary source of chloride is the application of road salt in winter months. There is a strong relationship ($p<0.0001$) between road density and chloride: stations with higher road density values tended to have elevated chloride concentrations (Figure 11). Also, stations that received high amounts of snowfall may display elevated chloride levels as a result of the use of road salt.

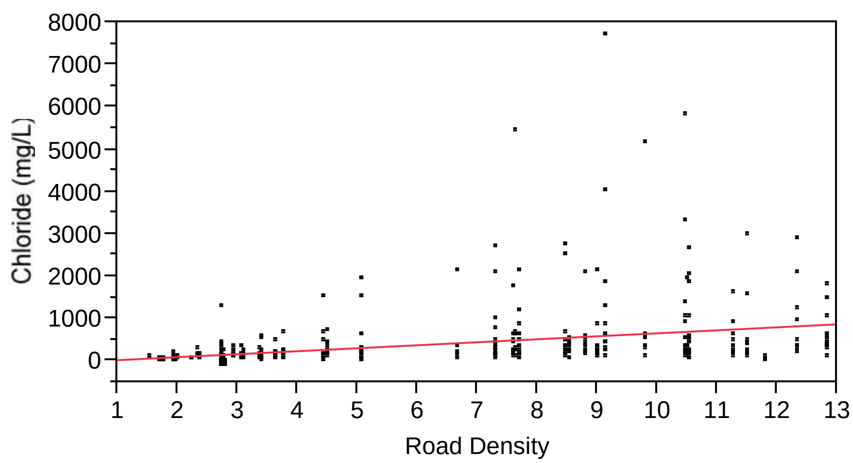


Figure 11. Results of regression analysis of 2013 chloride and road density values at 46 stations

Chloride concentrations appeared higher at stations in urbanized areas (Figure 12). There was a pattern in most watersheds of chloride levels being lower at northern stations (beginning on the left side of the boxplot graph), and increasing towards the southern stations typically situated in more urbanized areas (on the right side).

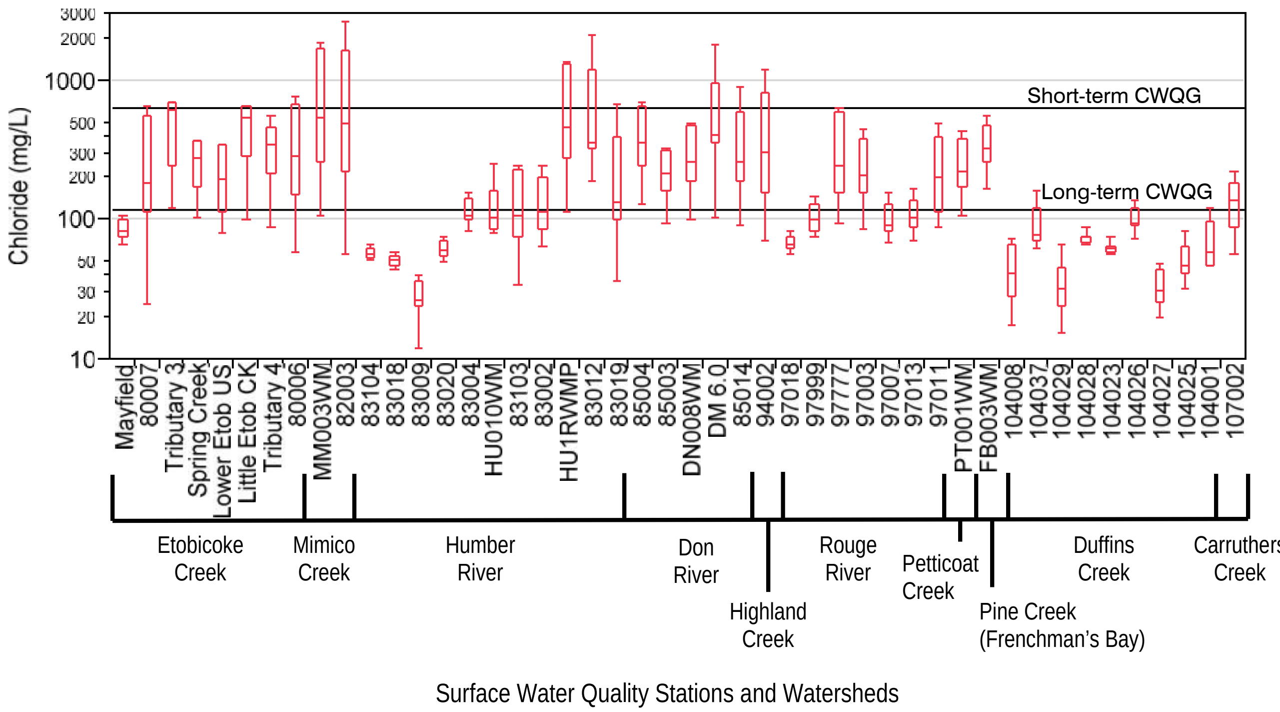


Figure 12. 2013 chloride concentrations (mg/L) at 46 stations within TRCA jurisdiction (CWQG: long-term 120 mg/L (chronic) and short-term 640 mg/L (acute); CCME 2011)

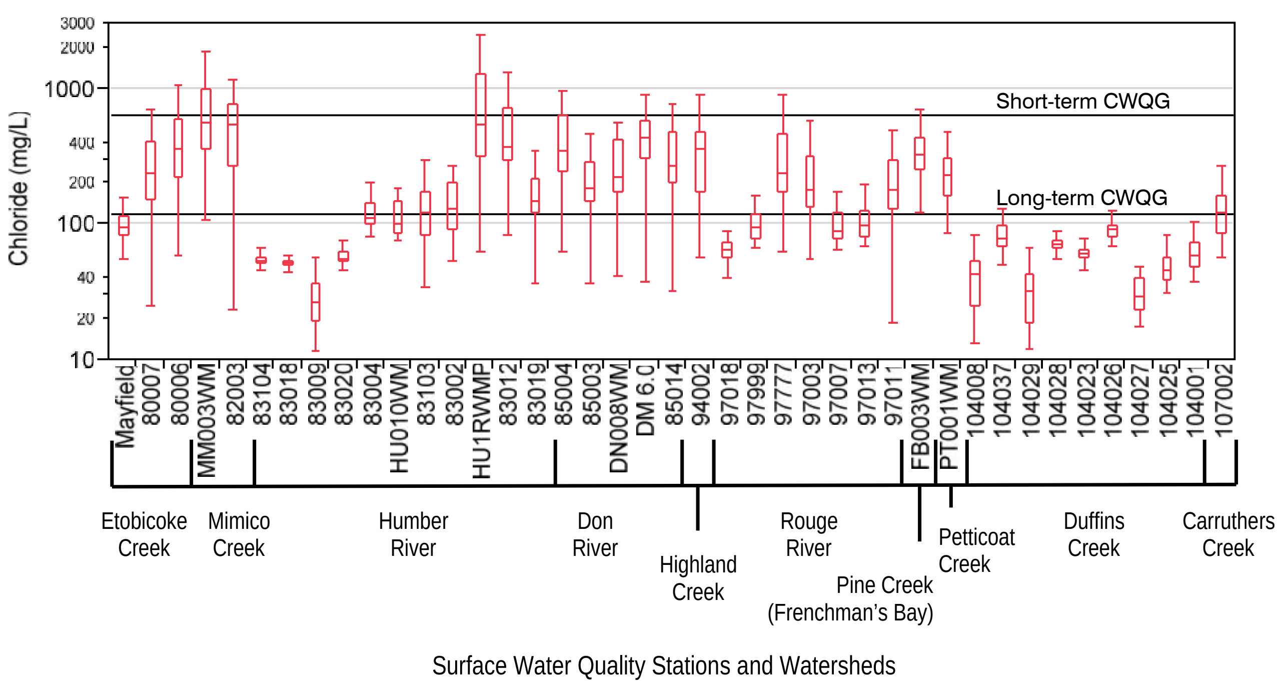


Figure 13. 2009-2013 chloride concentrations (mg/L) at 41 stations from 2009 to 2013 (CWQG: long-term 120 mg/L (chronic) and short-term 640 mg/L (acute); CCME 2011)

No stations in 2013 displayed a median chloride value which exceeded the short-term CWQG of 640 mg/L. Ten stations (Etobicoke Creek: Tributary 3, Little Etob CK, 80006; Mimico Creek: MM003WM, 82003; Humber River: HU1RWMP, 83012; Don River: 85004, DM 6.0; and Highland Creek: 94002) had 75th percentile chloride values which exceeded the short-term CWQG. In 2012, there were five stations, and in 2011 nine stations, which exceeded this threshold. The higher snowfall in 2013 may account for why there were more stations in exceedance of 640 mg/L compared to 2012, when the snowfall was approximately half of the 2013 amount. It would be expected that greater amounts of road salt were applied in 2013 than in 2012.

Similar to 2012, in 2013, 50% of stations had median chloride values which surpassed the long-term CWQG guideline of 120 mg/L for chronic exposure. Many of those stations (Etobicoke Creek: 80007, 80006; Mimico Creek: MM003WM, 82003; Humber River: HU1RWMP, 83012, 83019; and Highland Creek: 94002) exhibited the greatest interquartile ranges in chloride concentrations.

Figure 13 presents chloride concentrations from 2009 to 2013 for 41 stations. Compared to the 2013 box plots, the interquartile ranges were narrower whereas the lower whiskers were longer, representing samples with low chloride concentrations. No stations displayed median values above the short-term CWQG. Stations MM003WM, 82003, and HU1RWMP had the highest median values which ranged between 500-600 mg/L. There were 20 stations with median values below the long-term 120 mg/L CWQG, and 21 stations with median values above the long-term CWQG. Less urbanized areas/watersheds, such as the upper Humber River, the upper Rouge River, and Duffins Creek and Carruthers Creek watersheds, displayed lower chloride levels. Etobicoke Creek, Mimico Creek, Don River, and mid and low Rouge River displayed elevated chloride concentrations.

Elevated chloride values at most of these stations have been documented consistently since 2009 and are likely a result of the surrounding land-uses (i.e. urban, industrial, commercial, residential, etc.) which increase road density. The application of salt on roads and parking lots in winter months is direct consequence of urbanization and is linked to increased chloride levels. Stations that displayed the highest concentrations of chloride were in highly urbanized areas of watersheds such as Etobicoke Creek, Mimico Creek, the lower Humber River, Don River, Highland Creek, and the mid and lower Rouge River. The stations that displayed the lowest concentrations were situated in less urbanized areas of the healthier watersheds (the upper Humber River, Duffins Creek, and Carruthers Creek.

Station 83009 located in the upper Humber River watershed recorded the lowest median concentration of chloride in 2011, which is likely a result of low road density. Duffins Creek, which is the least urbanized watershed, exhibited the lowest chloride concentrations and the median values did not exceed the long-term CWQG of 120 mg/L.

Results from analysis of chloride data from 2009 to 2013 displayed a pattern of elevated concentrations in winter months and low concentrations towards the end of summer and early autumn (Figure 14). An ANOVA detected significant differences between months ($p<0.0001$). Tukey's test results are displayed in Figure 14, represented as circles to the right side of the box plots. Significant differences between months are displayed as circles which do not overlap one another. However, as Figure 14 shows, it can be difficult to determine which months are different from other months. To make differences clearer, Tukey's test results are also presented in tabular format (Table 6. Results of Tukey's test for monthly chloride concentrations (mg/L) from 2009 to 2013. Here months are listed in ascending order of mean analyte values. Months which are not different from each other are grouped into the same column. Each month is displayed in only one row but one or more columns. A month is not significantly different from the other months in its column(s), which is why those months were grouped into one column. Months are significantly different from any months that are not in the same column(s). For example, in Table 6. Results of Tukey's test for monthly chloride concentrations (mg/L) from 2009 to 2013, chloride values from January were not different from February, but January and February were different from all other months. Values from April were only different from January and February, but not different from any other months.

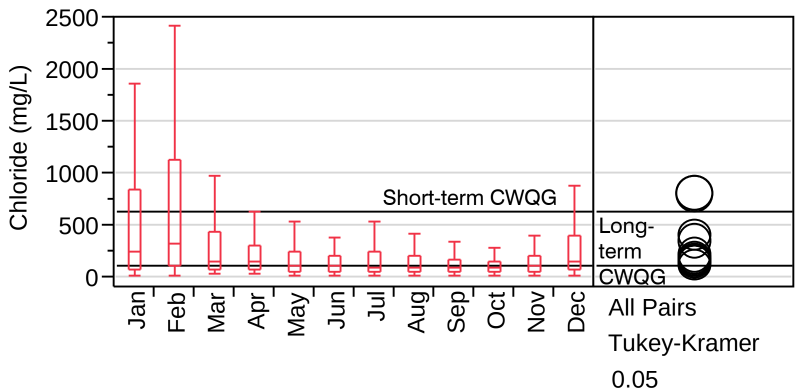


Figure 14. Box plots of monthly chloride concentrations (mg/L) at 41 stations from 2009 to 2013

Table 6. Results of Tukey's test for monthly chloride concentrations (mg/L) from 2009 to 2013

Columns			
1	2	3	4
Jan			
Feb			
	Dec		
	Mar	Mar	
	Apr	Apr	Apr
		May	May
		Jul	Jul
		Jun	Jun
		Nov	Nov
		Aug	Aug
		Sep	Sep
			Oct

January and February displayed the highest mean chloride levels which were significantly higher than the other months. December had the second highest levels which were significantly different from all other months except March and April. October was significantly lower than January, February, December, and March. There were no significant differences between mean chloride concentrations in March, April, May, July, June, November, August, and September.

This analysis exemplified the influence of road salt on chloride concentrations at water quality stations. Elevated chloride levels track winter months very closely. Chloride began to increase in November and December, peaked in January and February, and declined in March and April, in unison with snowfall patterns.

Mean monthly chloride concentrations range from a low of 127.2 mg/L in October to 815.4 mg/L in January. The total of the 12 mean monthly values was 3737.9 mg/L. The TRCA jurisdiction received an average of 3737.9 mg/L per year between 2009 and 2013. The non-winter months from May to November averaged 159.8 mg/L per month. In a scenario where no road salt was applied in winter months or where no snowfall occurred in the jurisdiction, the non-winter chloride average over 12 months would total 1917.9 mg/L, or 51% of the actual annual average. It appears as though 50% of chloride in TRCA aquatic systems washed into streams during five months (December to April), due to the application of road salt.

Road salt contributes to chloride levels from May to November as well. Chloride concentrations can persist into and throughout the summer in groundwater, residue from snow dumps, stormwater management ponds, and ditches. Spring, summer, and fall precipitation events can flush chloride from these reserves into streams and elevate concentrations to chronic levels.

3.3.2 Total Suspended Solids

An important facet of water quality is turbidity: the cloudiness of water due to suspended particles. Turbidity can be caused by stormwater runoff, erosion, increased stream flow, as well as by construction and agriculture. Higher turbidity can increase the likelihood that bacteria (which can attach to the particles) are present, block light from penetrating to lower depths which would negatively affect the species dependent upon such light, reduce the absorption of oxygen by fish gills, and impair stream aesthetics. Suspended particles may cause abrasion on fish gills, and reduce as well as impair spawning habitat. Toxic organics and metals often adhere to suspended solids and may become available to benthic fauna when the solids settle (CCME, 2007). Total suspended solids (TSS) are a measure of suspended particles, and precipitation, stream flow, erosion, and agricultural or urban land uses can increase TSS. The lowest and least variable TSS values tend to occur at stations which have more natural land cover.

Median TSS values remained below the TRCA interpretation of the CWQG of 30 mg/L, however the median value of one station (Rouge River: 97011) exceeded the guideline (Figure 15). In 2012, the 75th percentile TSS values of 4 stations (82003, 83020, 83103, and HU1RWMP) exceeded the CWQG.

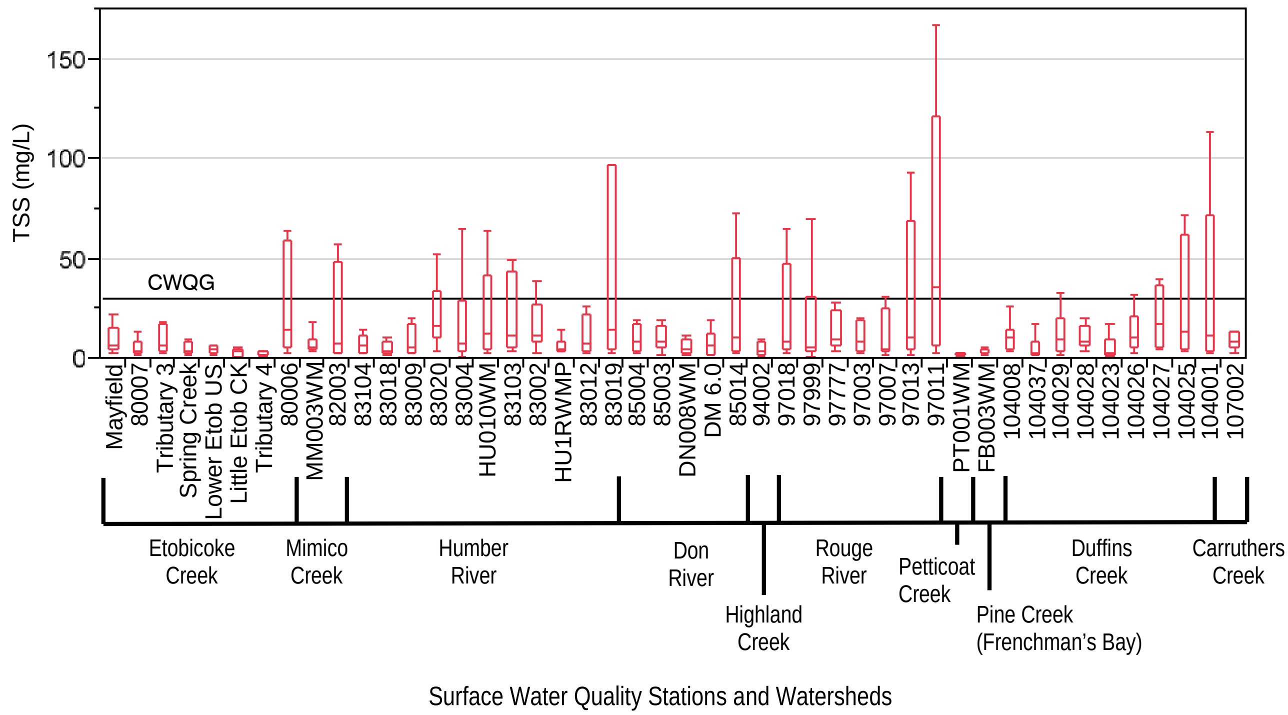


Figure 15. 2013 TSS concentrations (mg/L) at 46 stations within TRCA jurisdiction (CWQG: 30 mg/L)

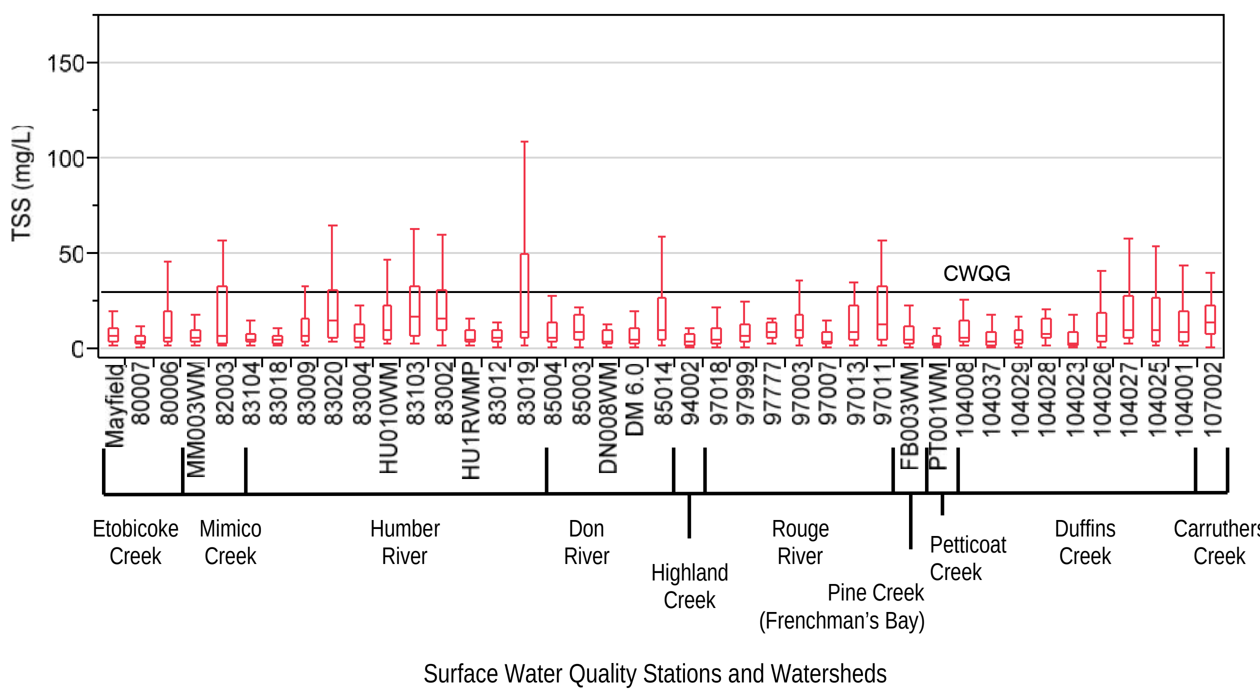


Figure 16. TSS concentrations (mg/L) at 41 stations from 2009 to 2013 (CWQG: 30 mg/L)

In 2013, 14 stations (Etobicoke Creek: 80006; Mimico Creek: 82003; Humber River: 83020, HU1RWMP, 83103, 83019; Don River: 85014; Rouge River: 97018, 97999, 97013, 97011; Duffins Creek: 104027, 104025, and 104001) displayed 75th percentiles above the guideline. Many of these stations were sampled the day after a powerful storm on July 8, 2013, deluged the western portion of the TRCA jurisdiction with up to 126.0 mm of rain in just a few hours. The TSS values (195 to 615 mg/L) collected on July 9, 2013, from eight sites in the Humber, Etobicoke, Mimico, and Don watersheds ranged from 195 to 615 mg/L and were in the top 40 highest values of the year. The July 8 storm delivered moderate amounts of precipitation to the eastern TRCA watersheds, such that the highest TSS values from Duffins Creek stations were recorded on May 22 and November 18, 2013.

Lower precipitation in 2012 and higher precipitation in 2013 may have contributed to the differences in TSS values between the two years. The unusually high 75th percentile TSS values at station 97011 were approximately three times higher than the highest 2012 values at station 82003.

Box plots for data from 2009 to 2013 are presented in Figure 16. No stations had median values in excess of the CWQG of 30 mg/L. Stations 82003, 83020, 83103, 83002, 83019, and 97011 displayed 75th percentiles above the CWQG. Station 83019 had the greatest interquartile range. Stations situated in the low portion of their watershed displayed elevated concentrations of TSS. The Rouge River and Duffins Creek watersheds exhibited the lowest TSS values of all the watersheds.

Box plots of data from 2009 to 2013 display higher mean monthly TSS levels from March to July compared to the remainder of the year (Figure 17). An ANOVA detected significant differences between months ($p<0.0001$). The Tukey's test detected significant differences in TSS concentrations between various months (Table 7). Mean TSS levels in March were significantly higher than all other months except for June, July, and May. June and July were significantly different from all months except March. May was significantly higher than August and December.

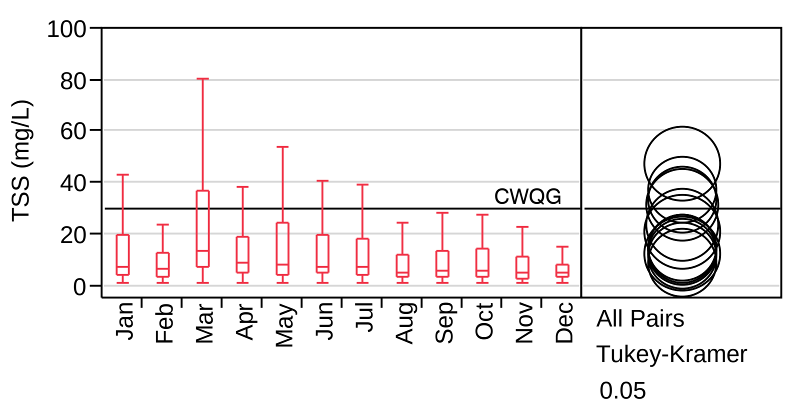


Figure 17. Box plots of monthly TSS concentrations (mg/L) at 41 stations from 2009 to 2013

Table 7. Results of Tukey's test for monthly TSS concentrations (mg/L) from 2009 to 2013

Columns			
1	2	3	4
Mar			
Jun	Jun		
Jul	Jul		
May	May	May	
	Apr	Apr	Apr
	Jan	Jan	Jan
		Oct	Oct
		Sep	Sep
		Nov	Nov
		Feb	Feb
			Aug
			Dec

Elevated TSS values from March to July reflect the influence of snow melt in March and increased precipitation from April to July (refer to Figure 5). Precipitation and increased stream flow can increase the process of erosion which results in higher TSS concentrations.

3.3.3 pH

pH is a measure of the acidity, neutrality, or alkalinity of water. Fluctuations in pH can affect fish communities directly and indirectly by facilitating the release of organic and metal contaminants bonded to sediments. The pH of water also affects the toxicity of ammonia. Nutrient cycling, the discharge of industrial effluent, and spills can result in pH fluctuations. pH had a positive relationship with precipitation ($p<0.0001$), meaning that higher precipitation, particularly stormwater runoff, contributed to higher pH values (Figure 18).

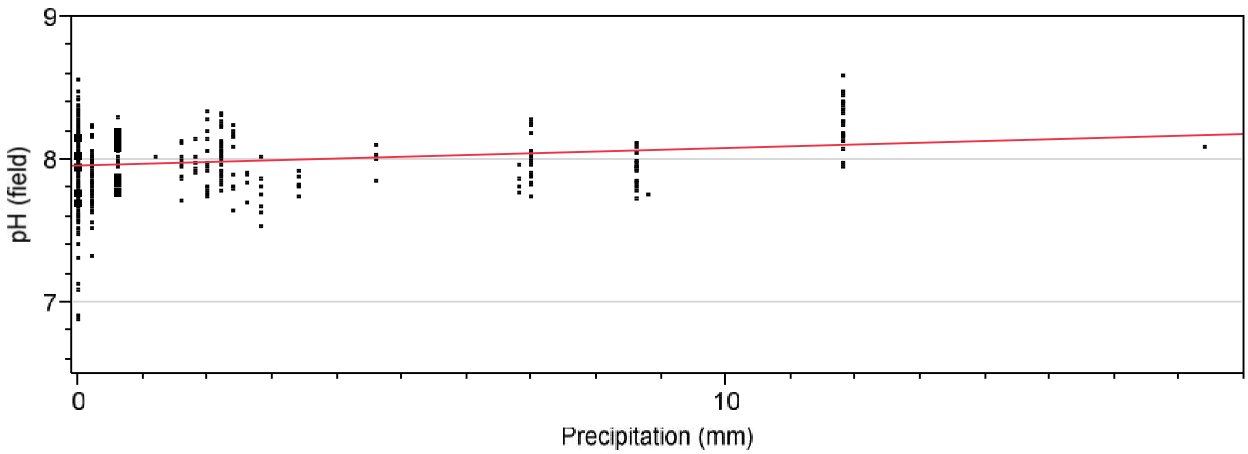


Figure 18. Results of 2013 pH values regressed against precipitation at 46 stations within TRCA jurisdiction

Median pH values were within PWQO range of 6.5 to 8.5 for all stations (Figure 19). The five year pH data presented in box plots demonstrated median values close to a pH of 8 for all stations (Figure 20). No station had 75th percentiles above the PWQO of 8.5. Stations 97003, 97007, 97013, and 97011 exhibited the highest median values. MM003WM, 85004, DN008WM, and 85014 were the stations with the lowest median values.

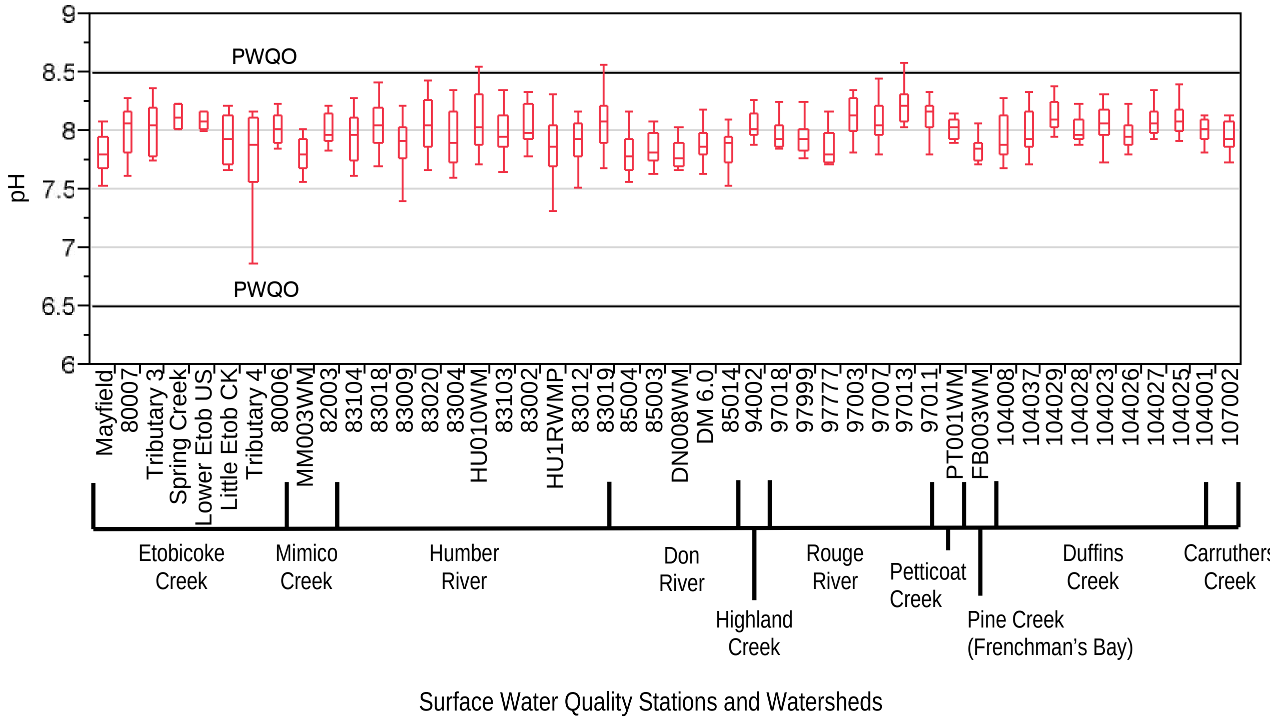


Figure 19. 2013 pH values at 46 stations within TRCA jurisdiction (PWQO: 6.5 - 8.5 pH)

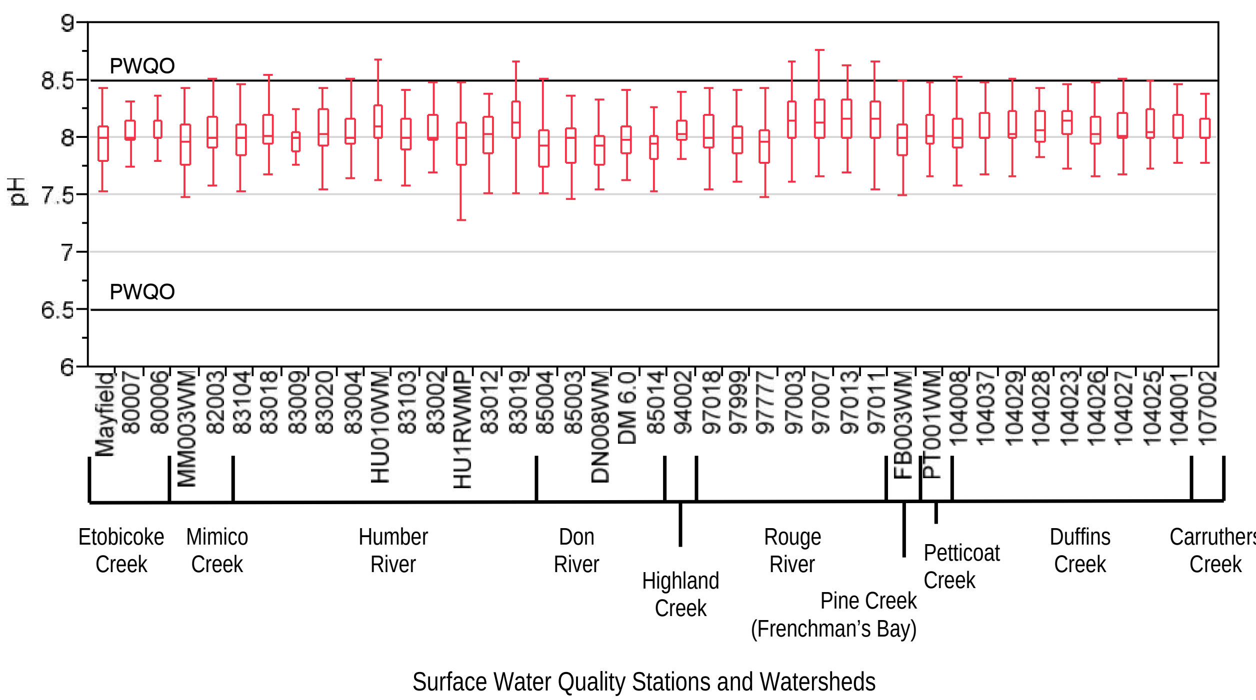


Figure 20. pH values at 41 stations from 2009 to 2013 (PWQO: 6.5 - 8.5 pH)

The median monthly pH values did not vary much from 8.0, however the interquartile ranges and whiskers displayed more variation (Figure 21). An ANOVA detected significant differences (p<0.0001) and the Tukey's test determined which months were different (Table 8). Mean monthly pH concentrations were significantly higher in April than all months except March. March was significantly different from November and January. January was significantly different from April, May, and February.

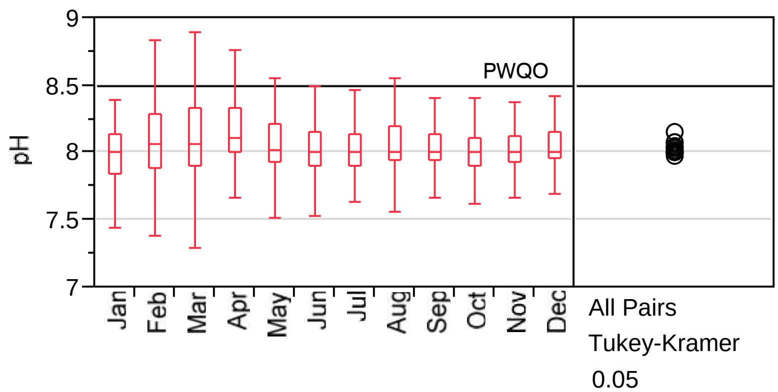


Figure 21. Box plots of monthly pH concentrations at 41 stations from 2009 to 2013

Table 8. Results of Tukey's test for monthly pH concentrations from 2009 to 2013

Columns			
1	2	3	4
Apr			
Mar	Mar		
	Feb	Feb	
	May	May	May
	Dec	Dec	Dec
	Aug	Aug	Aug
	Sep	Sep	Sep
	Jun	Jun	Jun
	Jul	Jul	Jul
	Oct	Oct	Oct
		Nov	Nov
			Jan

The monthly mean and median values, interquartile ranges, and whisker extents appeared to be influenced by conditions from February to April. During that period there were greater interquartile and whisker ranges, and mean and median values were higher. Since pH values were influenced by precipitation, it is likely the snow melt and higher precipitation from February to April contributed to higher pH values.

3.4 Metals

Metals occur naturally in the environment, usually in low concentrations. Industrial processes and increased stormwater runoff in urban areas can dramatically alter the distribution and increase the concentrations of metals. High concentrations of metals can be toxic, cause disruptions to aquatic ecosystems, and decrease the suitability of a waterbody to support aquatic life and supply water for domestic uses.

3.4.1 Aluminium

Since over 8% of the earth's crust is comprised of aluminium, the amount of aluminium in the environment from natural sources exceeds that from agriculture, industry, and other anthropogenic sources. Acidic precipitation, poorly buffered soils, and rapid spring snowmelts can increase concentrations of aluminium in streams (Wetzel, 2001). Currently, there are no PWQO, CWQG or CESI guidelines which define the amount of allowable total aluminum for the protection of aquatic life.

Stations in urbanized areas within all watersheds demonstrated relatively higher levels of aluminium (Figure 22). Similar to 2012, station 83103 displayed the highest median aluminium value, and stations in Etobicoke Creek: 80006; Mimico Creek: 82003; Humber River: 83103, 83019; and Rouge River: 97011 had the greatest interquartile ranges.

Box plots of aluminium data from 2009 to 2013 displayed the majority of stations with limited interquartile ranges well below 500 μg/L (Figure 23). A few stations in the low portion of the watershed (85014, 83019, 82003, 8006, and 97011) exhibited much greater interquartile ranges from 600 to 1700 μg/L. However, the modest median values at these stations imply that, over the five years, the majority of monthly samples had typically low aluminium levels, but several had very elevated aluminium concentrations. The reduced annual variability in the five year box plots clearly illustrated which stations experienced chronic elevated aluminium concentrations.

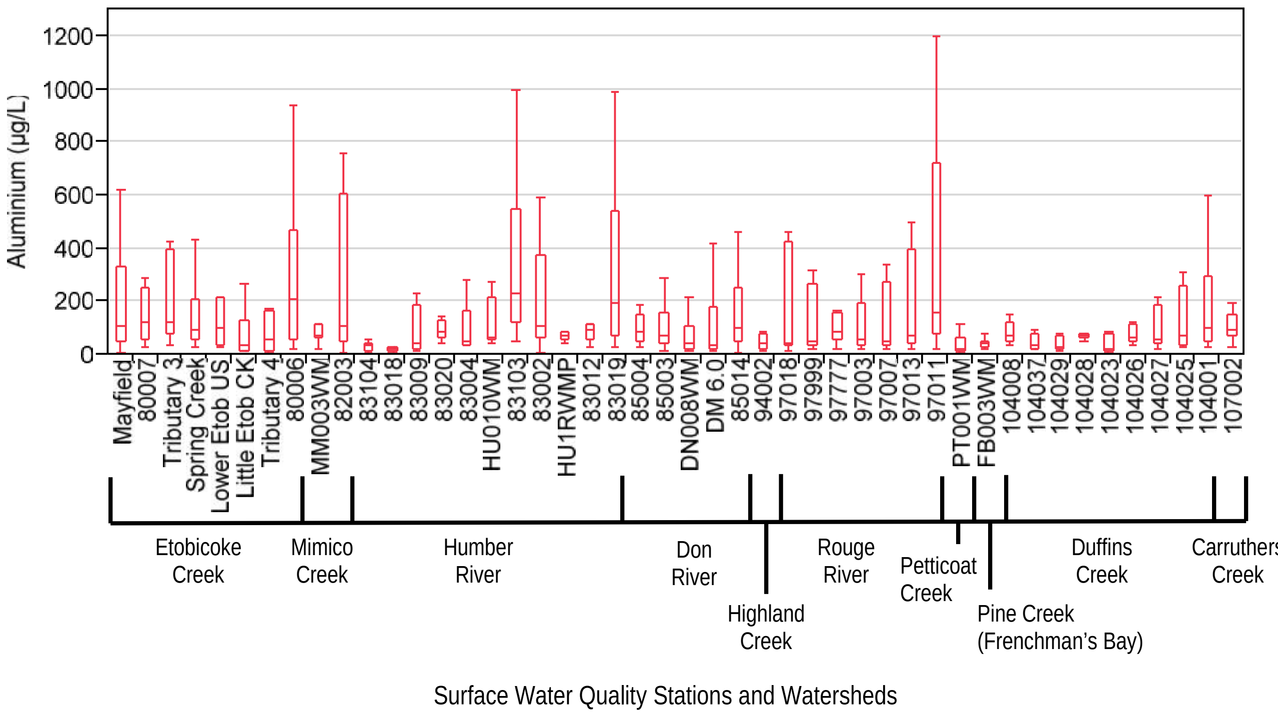


Figure 22. 2013 aluminum concentrations (µg/L) at 46 stations within TRCA jurisdiction

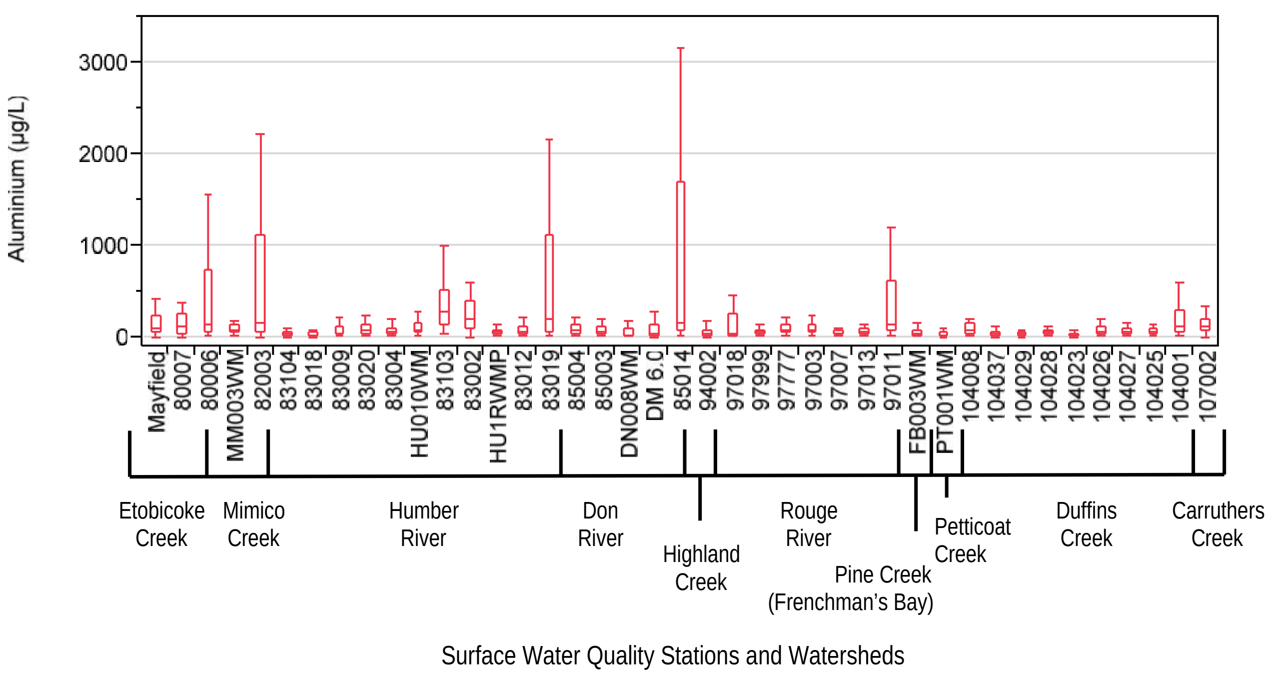


Figure 23. Aluminum concentrations (µg/L) at 41 stations from 2009 to 2013

Many of those six stations, as well as others, were sampled on July 9, 2013, the day after the record-breaking thunderstorm, and displayed the highest aluminium values of the year. Stations sampled on May 22, 2013 also had high aluminium values. These high aluminium values increased the interquartile range of the boxplots of those stations, often dwarfing the ranges of stations which were not sampled after a large precipitation event. Although it may seem contradictory, a regression analysis determined that aluminium has an inverse relationship with precipitation ($p<0.0001$): concentrations of aluminium decrease when precipitation increased (Figure 24). This result is based on precipitation data on the day of sampling, whereas the elevated levels recorded on July 9 were mobilized by the rainfall from the previous day.

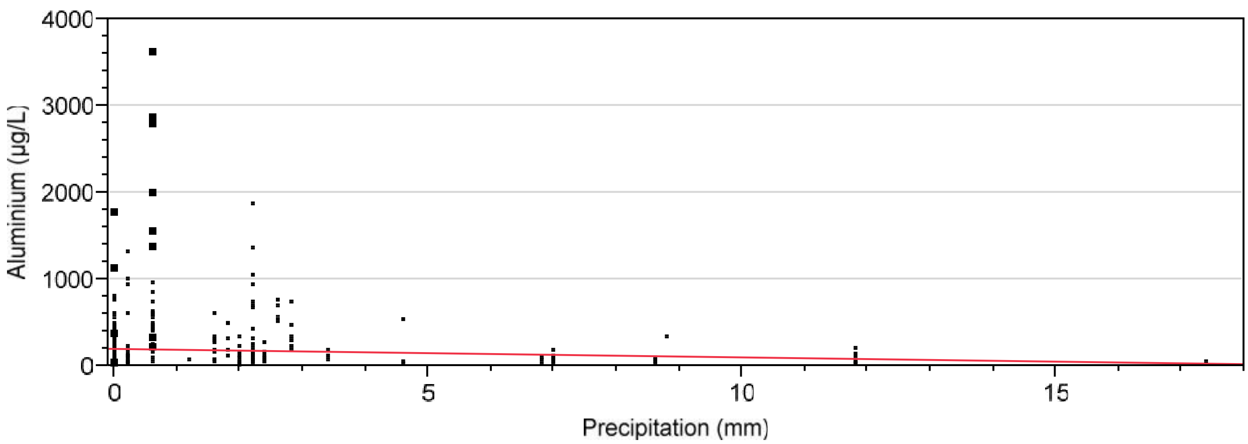


Figure 24. Results of 2013 aluminum concentrations (µg/L) regressed against precipitation at 46 stations within TRCA jurisdiction

The monthly box plots for aluminium displayed higher median values, greater interquartile and whisker ranges from March to July and October to November (Figure 25). The mean monthly aluminium values ranged from 103.7 µg/L in February to 17,726.2 µg/L in May (Table 9). An ANOVA did not detect any significant differences between monthly aluminium concentrations. Nonetheless, it can be suggested that aluminium levels were influenced by winter conditions, spring snow melt, and rainfall. Aluminium concentrations were lowest from December to February and highest from March to June.

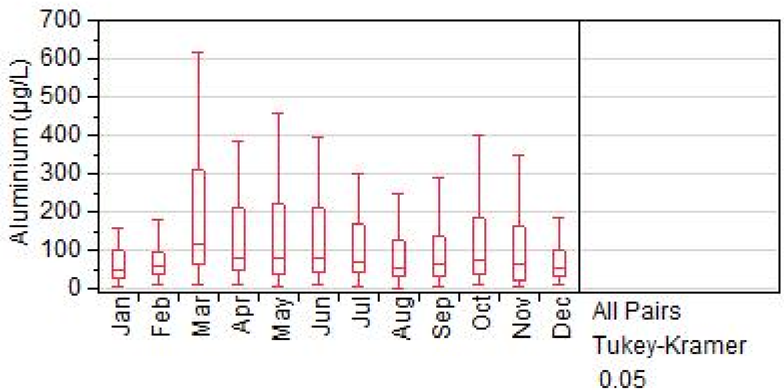


Figure 25. Box plots of monthly aluminium (µg/L) concentrations at 41 stations from 2009 to 2013

Table 9. Results of Tukey's test for monthly aluminium (µg/L) concentrations from 2009 to 2013

Column
May
Mar
Apr
Jul
Oct
Jun
Aug
Sep
Dec
Nov
Jan
Feb

3.4.2 Arsenic

The weathering of rocks and soils, and smelting and refining industries are sources of arsenic. Arsenic is an odourless, tasteless, and toxic metal, for which the PWQO is 5 µg/L. Arsenic data presented in this report represents 36 stations since not all stations were analyzed regularly for this parameter by OMOE. Arsenic values at all 36 stations in 2013 (Figure 26) were well below the PWQO of 5 µg/L. Station Tributary 4 (Etobicoke Creek) had the highest median value, and other Etobicoke Creek stations (Mayfield, Tributary 3, Little Etob CK) also displayed high concentrations.

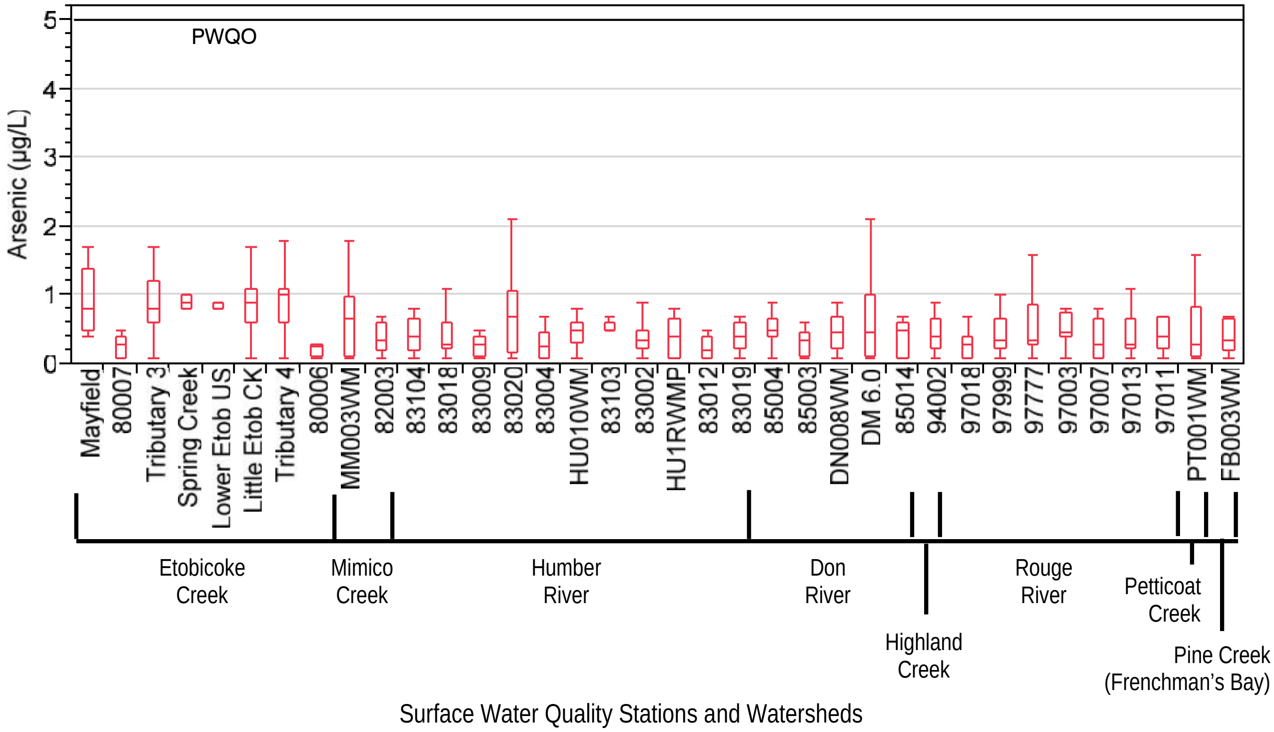


Figure 26. 2013 arsenic concentrations (µg/L) at 36 stations within TRCA jurisdiction (PWQO: 5 µg/L)

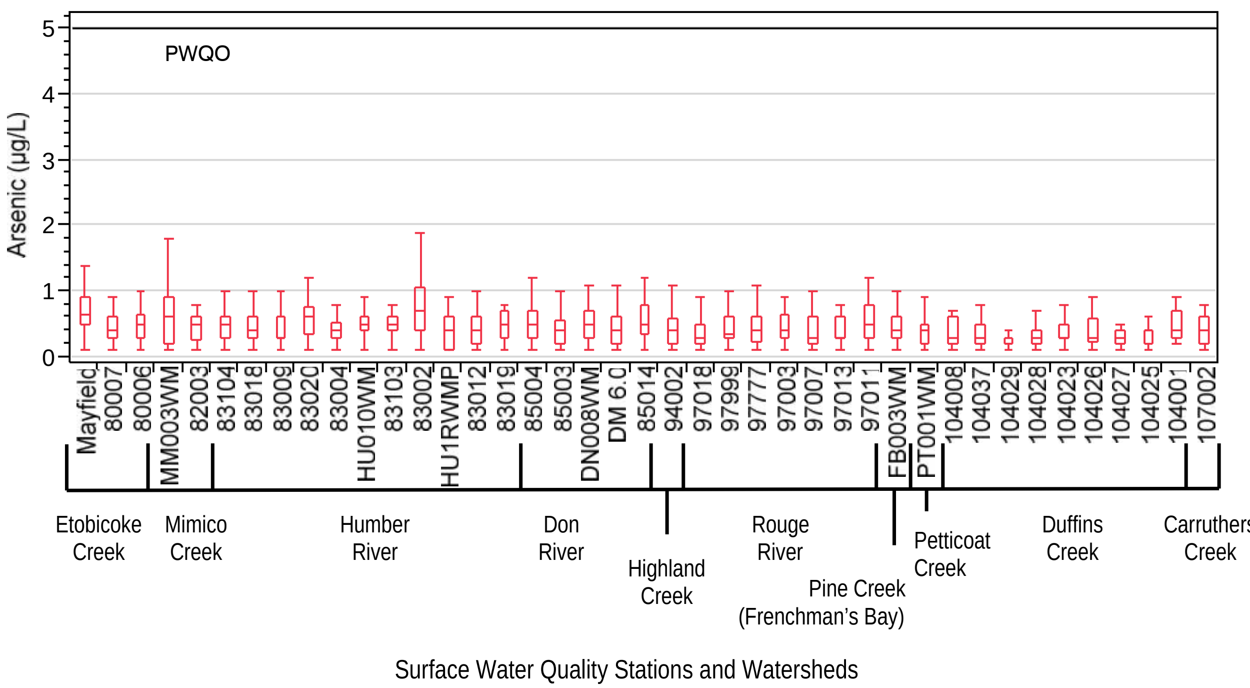


Figure 27. Arsenic concentrations (µg/L) at 41 stations from 2009 to 2013 (PWQO: 5 µg/L)

Stations with the greatest interquartile ranges were Mayfield (Etobicoke Creek), MM003WM (Mimico Creek), 83020 (Humber River), DM 6.0 (Don River). All stations demonstrated five-year arsenic levels ranging from zero to two µg/L, substantially below the PWQO of 5 µg/L (Figure 27). Station 83002 had the highest median value, and 83002, MM003WM, and Mayfield had the highest 75th percentiles.

The monthly box plots for five years of arsenic data exhibited lower concentrations in the winter months and elevated concentrations from April to November (Figure 28). Median arsenic levels were highest in June and July and the lowest in February and December. From April to October the interquartile and whisker ranges were greater compared to winter months. Mean arsenic values were highest in July and lowest in January, March, February, and December (Table 10).

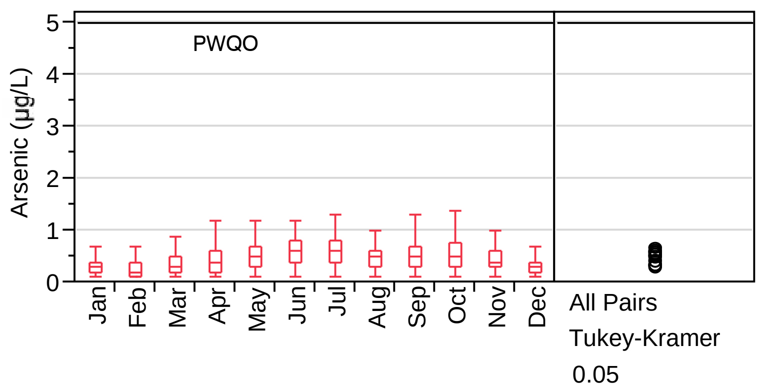


Figure 28. Box plots of monthly arsenic values (µg/L) at 41 stations concentrations from 2009 to 2013 (PWQO: 5 µg/L)

Table 10. Results of Tukey's test for monthly arsenic (µg/L) concentrations from 2009 to 2013

Columns				
1	2	3	4	5
Jul				
Oct	Oct			
Jun	Jun			
May	May	May		
Sep	Sep	Sep		
	Aug	Aug		
	Nov	Nov	Nov	
		Apr	Apr	Apr
			Jan	Jan
			Mar	Mar
				Feb
				Dec

An ANOVA detected significant differences in arsenic concentrations between months ($p<0.0001$). The Tukey's test determined that arsenic levels in July were significantly higher than levels in August, November, April, January, March, February, and December. October and June were significantly higher than April, January, March, February, and December. May, September, and August were significantly higher than February and December. November was significantly higher than February and December, and significantly lower than July.

3.4.3 Copper

Copper is a trace metal whose elevated concentrations are associated with urbanization. It may readily bind to soil particles (particularly organic matter) and is therefore relatively immobile. Anthropogenic sources of copper include textile manufacturing, paints, electrical conductors, plumbing fixtures and pipes, wood preservatives, pesticides, fungicides, and sewage treatment plant effluent (OMOE, 2003). Copper has an almost significant inverse relationship with precipitation ($p<0.07$) (Figure 29), using precipitation from the day of sampling.

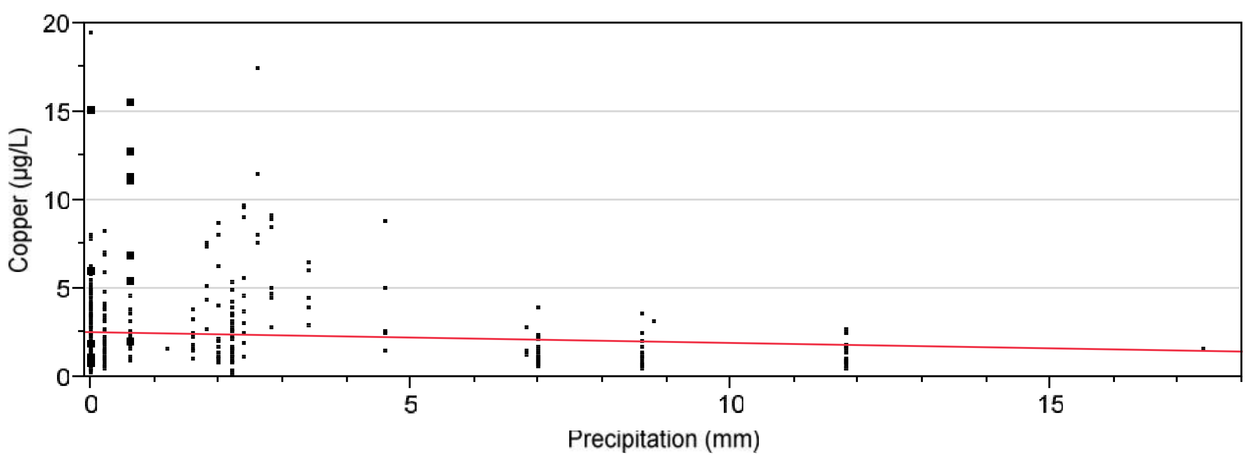


Figure 29. Results of 2013 copper concentrations (µg/L) regressed against precipitation at 46 stations within TRCA jurisdiction

Copper levels appeared to increase towards the urbanized lower watershed areas while stations in relatively less urbanized watersheds (Duffins Creek) or at upper watershed locations displayed lower copper values (Figure 30). Stations 82003 (Mimico Creek) and 80006 (Etobicoke Creek) had median values above the PWQO of 5 µg/L, as well as the greatest interquartile range, similar to previous years.

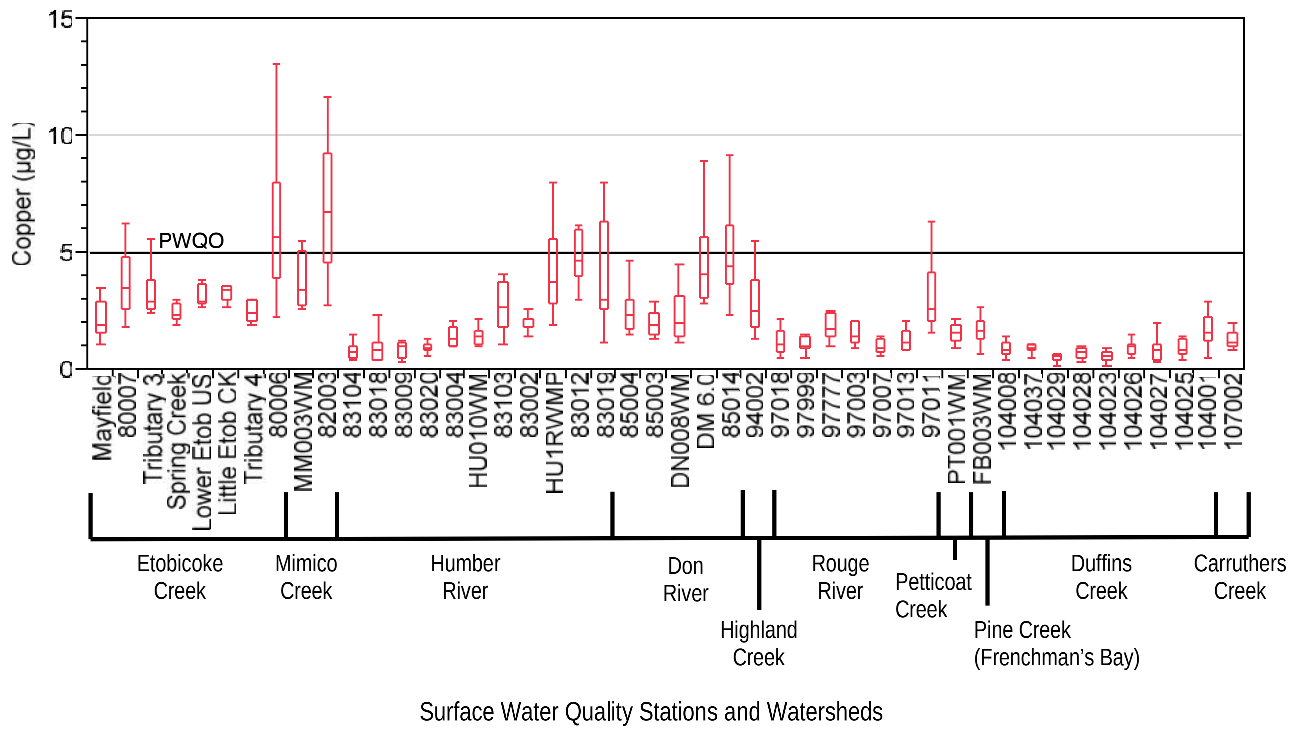


Figure 30. 2013 copper concentrations (µg/L) at 46 stations within TRCA jurisdiction (PWQO: 5 µg/L)

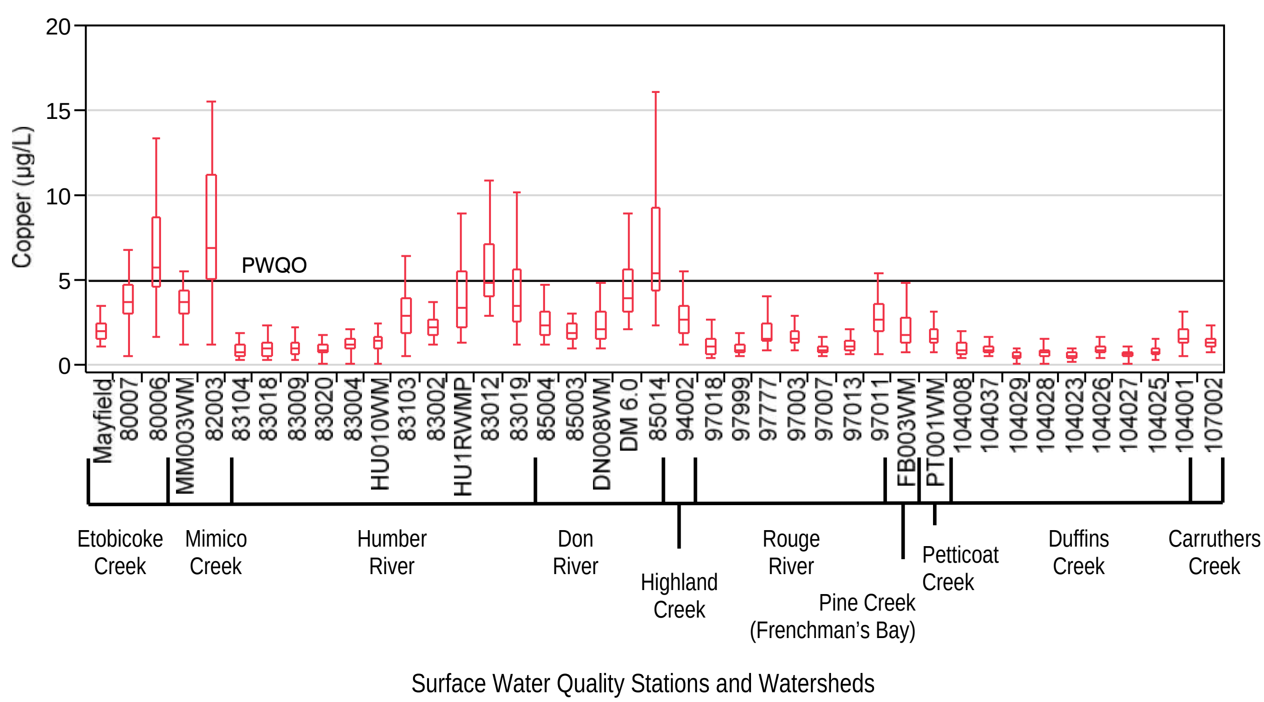


Figure 31. Copper concentrations (µg/L) at 41 stations from 2009 to 2013

There were eight stations (Etobicoke Creek: 80006; Mimico Creek: MM003WM, 82003; Humber River: HU1RWMP, 83012, 83019; and Don River: DM 6.0, 85014) with 75th percentiles above the PWQO. Many of the highest copper values were recorded on July 9, 2013, the day after an unusually strong storm; however, overall the 2013 results are similar to 2012 results.

Box plots of the five-year copper data exhibit a similar pattern to the 2013 box plots (Figure 31). The Etobicoke, Mimico, Humber and Don watersheds exhibited increased copper concentrations at stations situated low in the watershed. The stations with the highest median values and greatest interquartile ranges were 82003, 80006, 85014, 83012, 83019, DM 6.0, and HU1RWMP. The upper Humber River, the mid and upper Rouge River, and Duffins Creek and Carruthers Creek watersheds displayed the lowest copper concentrations.

Monthly copper box plots displayed lower values from August to December and higher values from February to May (Figure 32). Median values were highest from March to May and lowest in August and from November to January. Interquartile and whisker ranges were greatest from February to April. Mean copper concentrations were highest in February, June, April, and March and lowest in August and November (Table 11). An ANOVA detected significant differences in copper levels between months ($p<0.0001$). The Tukey's test determined that copper values in February and June were significantly higher than August and November. April was significantly higher than November.

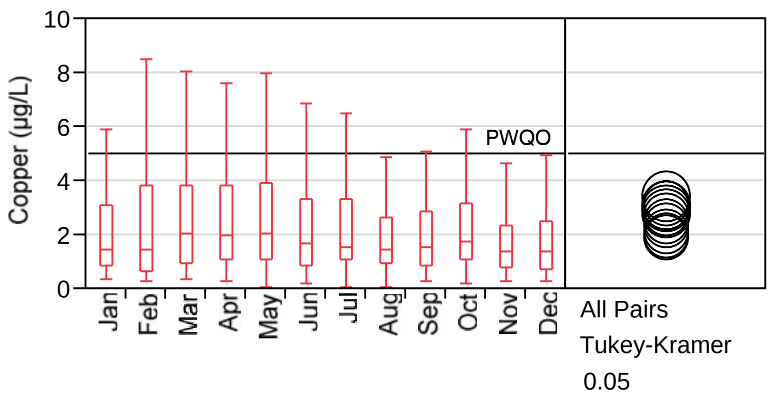


Figure 32. Box plots of monthly copper (µg/L) concentrations at 41 stations from 2009 to 2013

Table 11. Results of Tukey's test for monthly copper (μg/L) concentrations from 2009 to 2013

Columns			
1	2	3	4
Feb			
Jun	Jun		
Apr	Apr	Apr	
Mar	Mar	Mar	Mar
May	May	May	May
Jan	Jan	Jan	Jan
Jul	Jul	Jul	Jul
Oct	Oct	Oct	Oct
Sep	Sep	Sep	Sep
	Dec	Dec	Dec
		Aug	Aug
			Nov

3.4.4 Iron

The median iron values of 10 stations in 2013 exceeded the PWQO of 300 μg/L (Figure 33). In 2012, there were 10 stations and in 2011 there were 13 stations. These stations (Etobicoke Creek: Tributary 3; Humber River: 83009, 83002, HU1RWMP, 83012, 83019; and Don River: 85004, 85003, DN008WM, 85014) are predominantly located in urbanized areas of watersheds. In 2013, 34 out of 46 stations (78%) displayed 75th percentiles above the PWQO; in 2012 there were 24 out of 41 stations (58%). This increase demonstrates the slightly higher iron concentrations recorded in 2013. More stations (Etobicoke Creek: 80006; Mimico Creek: 82003; Humber River: 83103, 83019; and Rouge River: 97018, 97011) demonstrated greater interquartile ranges than in 2012. Stations sampled after the powerful July 8, 2013, storm recorded the highest iron concentrations of the year, and contributed to the number of stations which exceeded the PWQO. Precipitation tends to increase runoff which may increase iron concentrations given the fact that iron has an affinity to bind to sediment particles.

Station 80006 is located within two kilometres of an industrial warehouse complex that may be a source of iron contamination in Etobicoke Creek. Stations 80006 and 82003 are situated downstream of the Pearson International Airport in a highly developed area. Urban surface runoff is likely the cause of elevated iron concentrations in the surface water of Etobicoke and Mimico Creek watersheds.

From 2009 to 2013, median iron concentrations were close to the PWQO of 300 μg/L (Figure 34). There were 21 stations with median values below, and 12 stations above, the PWQO. The stations with the highest median values were DN008WM, 83002, 83012, HU1RWMP, and 107002. The greatest interquartile ranges were exhibited by stations 83019, 82003, and 83103. Stations in urbanized areas lower in the watershed appeared to display elevated iron concentrations. The Rouge River, except for station 97011, and Duffins Creek watersheds had consistently low iron levels.

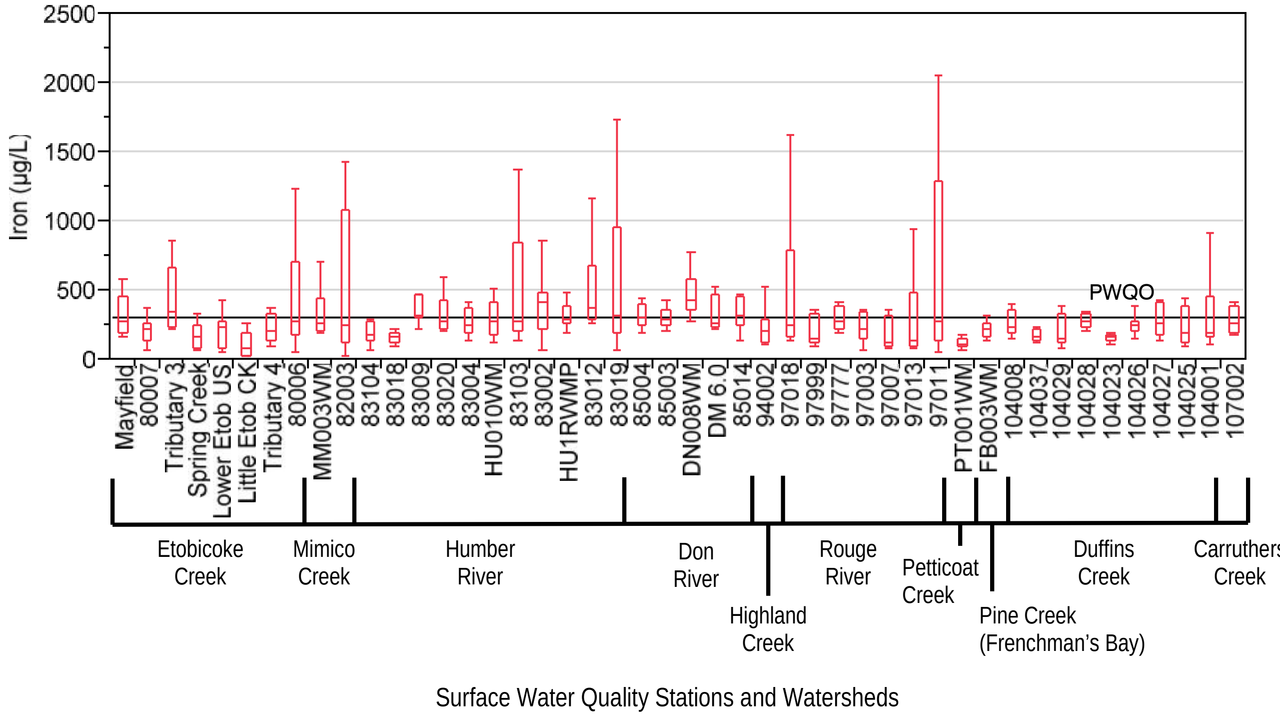


Figure 33. 2013 iron concentrations (µg/L) at 46 stations within TRCA jurisdiction (PWQO: 300 µg/L)

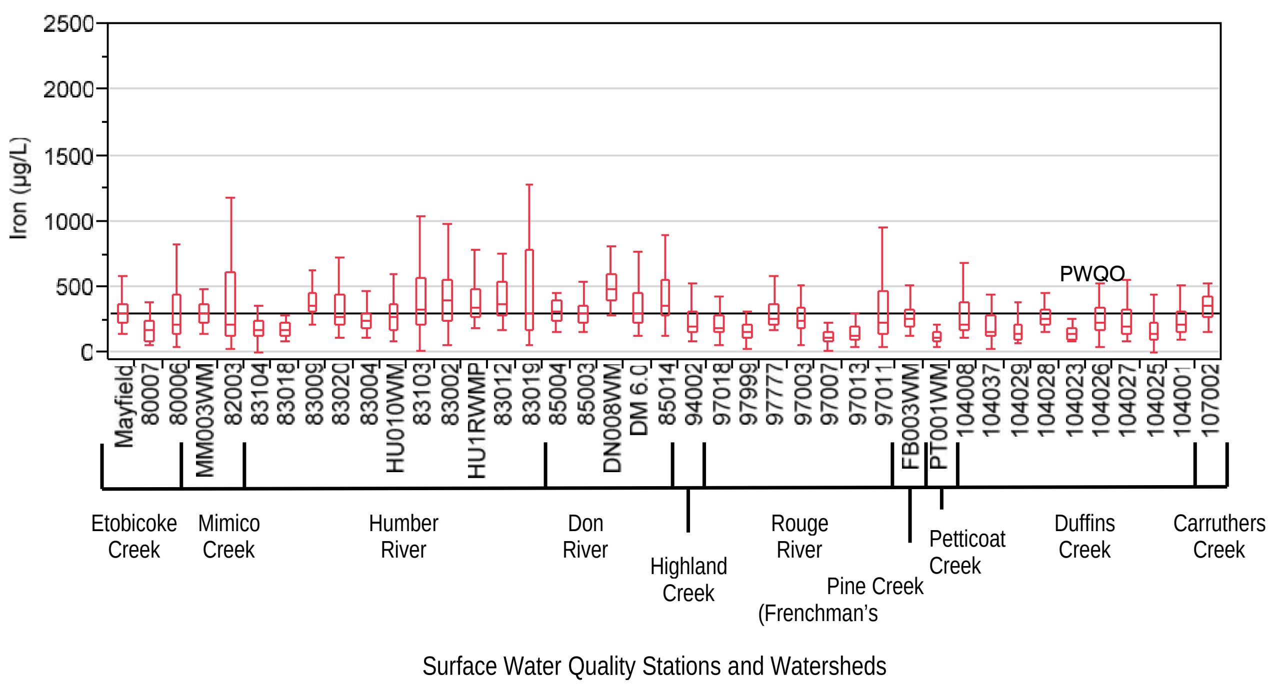


Figure 34. Iron concentrations (µg/L) at 41 stations from 2009 to 2013 (PWQO: 300 µg/L)

Monthly median iron concentrations were highest in March and lowest from July to September (Figure 35). Mean values were highest in June and March and lowest in September and August (Table 12). An ANOVA detected significant differences in iron concentrations between months (*p*<0.0001). The Tukey's test found that iron levels in June were significantly higher than January, December, October, November, February, September, and August. March was significantly higher than December, October, November, February, September, and August.

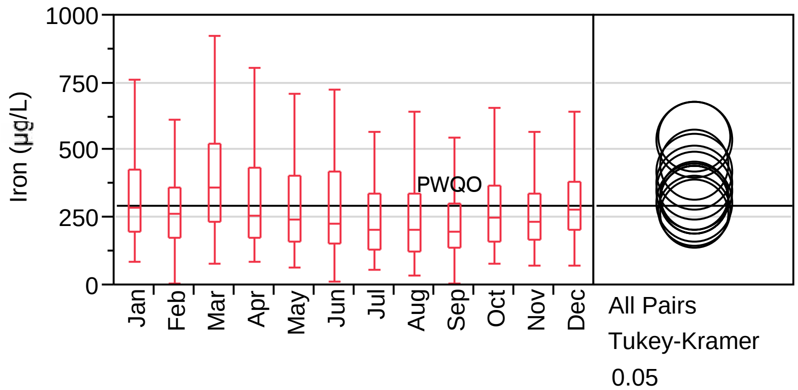


Figure 35. Box plots of monthly iron (µg/L) at 41 stations concentrations from 2009 to 2013

Table 12. Results of Tukey's test for monthly iron (µg/L) concentrations from 2009 to 2013

Columns		
1	2	3
Jun		
Mar	Mar	
Jul	Jul	Jul
May	May	May
Apr	Apr	Apr
	Jan	Jan
		Dec
		Oct
		Nov
		Feb
		Sep
		Aug

3.4.5 Lead

The lead results represented 36 stations whose samples were analyzed by the York-Durham Regional Environmental laboratory. OMOE lead results were excluded because the OMOE reporting detection limit (RDL) of 11 µg/L is much higher than the RDL of York-Durham (5 µg/L) and the PWQO of 5 µg/L.

All 36 stations displayed lead concentrations well below the PWQO (Figure 36). Station Tributary 3 (Etobicoke Creek) had the highest median value, and stations Tributary 3, 83104 (Humber River), and 97003 (Rouge River) displayed the greatest interquartile range. For all other stations median lead values and interquartile ranges were below 1 µg/L.

The box plots for the five-year data represented 36 stations (Figure 37). All median values were substantially below the PWQO of 5 µg/L. The station with the highest median value was MM003WM, and stations 97018 and 83019 displayed the greatest interquartile range and highest 75^{th} percentiles.

Median lead concentrations were highest in March, June, September, and October, and interquartile and whisker ranges were greatest in October (Figure 38). Median values were lowest in February, April, May, July, August, November, and December. October and August displayed the highest mean lead concentrations and December, February, and May had the lowest (Table 13). No significant differences were detected in lead values between months.

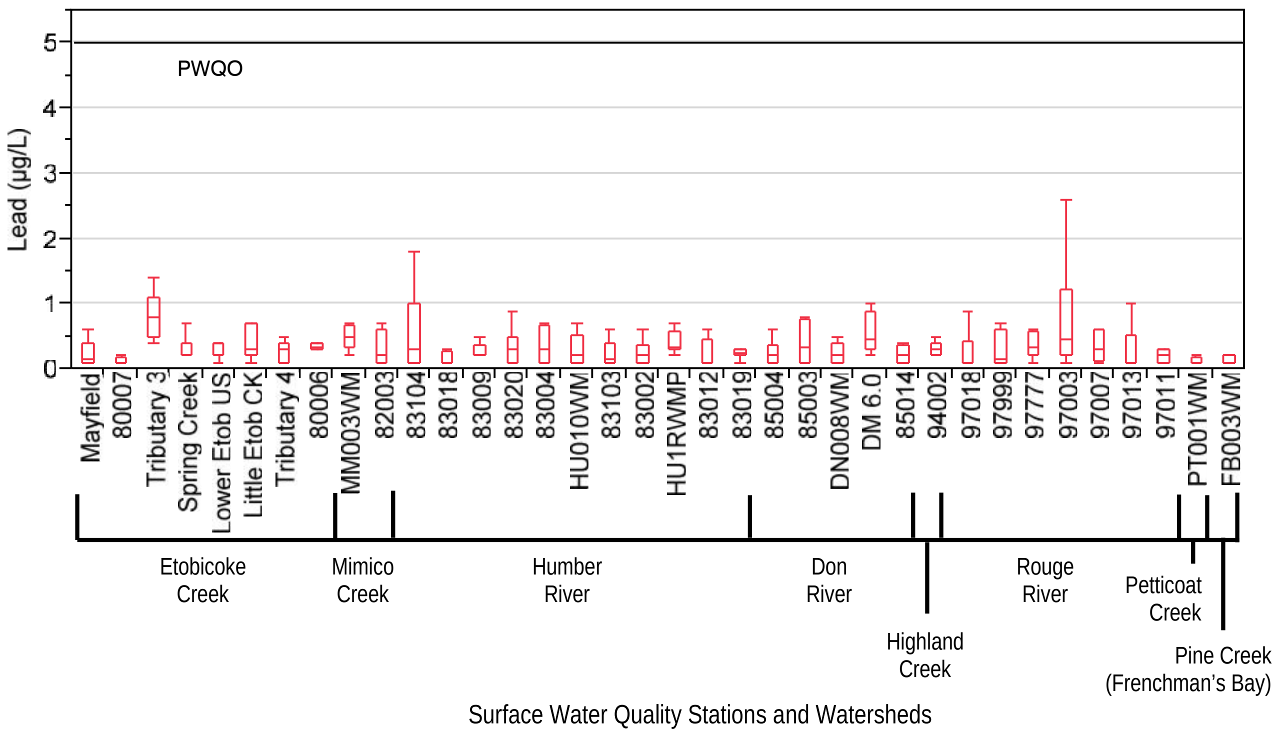


Figure 36. 2013 lead concentrations (µg/L) at 36 stations within TRCA jurisdiction (PWQO: 5 µg/L)

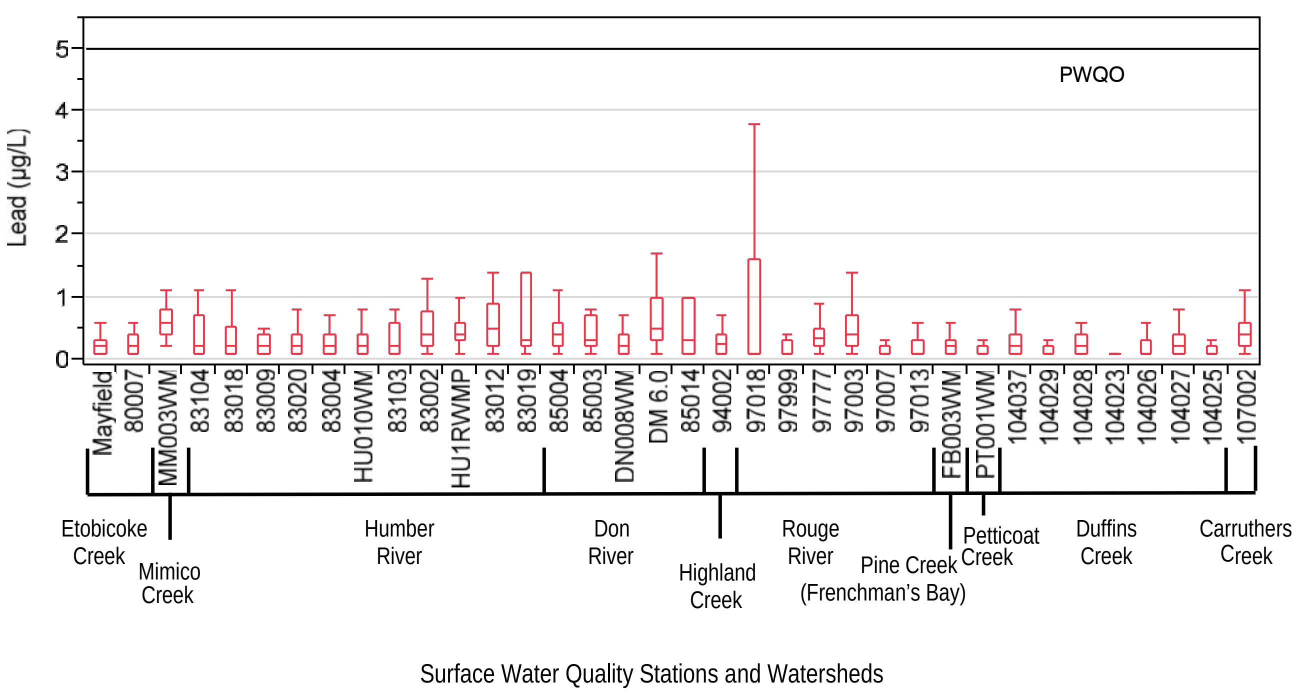


Figure 37. Lead concentrations (µg/L) at 36 stations from 2009 to 2013 (PWQO: 5 µg/L)

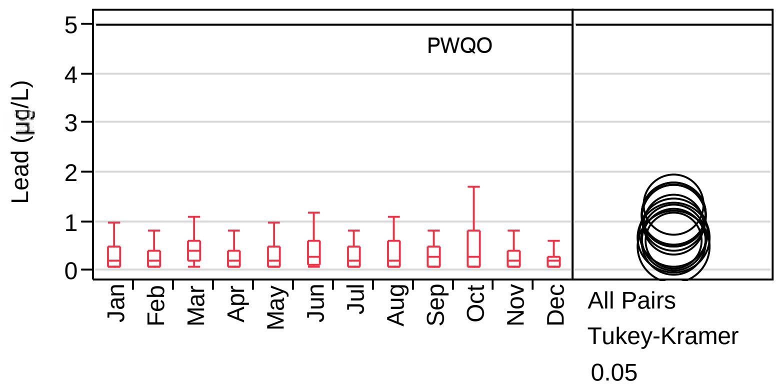


Figure 38. Box plots of monthly lead (µg/L) concentrations at 36 stations from 2009 to 2013 (PWQO: 5 µg/L)

Table 13. Results of Tukey's test for monthly lead (µg/L) concentrations from 2009 to 2013

Column
Oct
Aug
Sep
Jul
Jun
Nov
Jan
Mar
Apr
Dec
Feb
May

3.4.6 Nickel

Several stations (Etobicoke Creek: 80006; Mimico Creek: 82003; Humber River: 83019; Don River: 85014; Rouge River: 97011; and Duffins Creek: 104001) had median values of 2.0 µg/L. These median values are a result of substituting nickel values which were below the OMOE method detection limit (MDL) with the 2.0 µg/L MDL value for nickel. This is considered a conservative technique since the nickel concentrations were sufficiently low such that the OMOE laboratory process could not confidently measure them. It is likely that the nickel concentrations of these stations were lower than 2.0 µg/L.

Nickel results from all stations were well below the PWQO of 25 µg/L (Figure 39). For a clearer picture of the nickel concentrations at each station, the nickel results were plotted without the PWQO (Figure 40). The highest median value was less than 2 µg/L at station 83102 (Humber River). More stations in 2013 had greater interquartile ranges than in 2012; it is likely that precipitation contributed to the increased ranges.

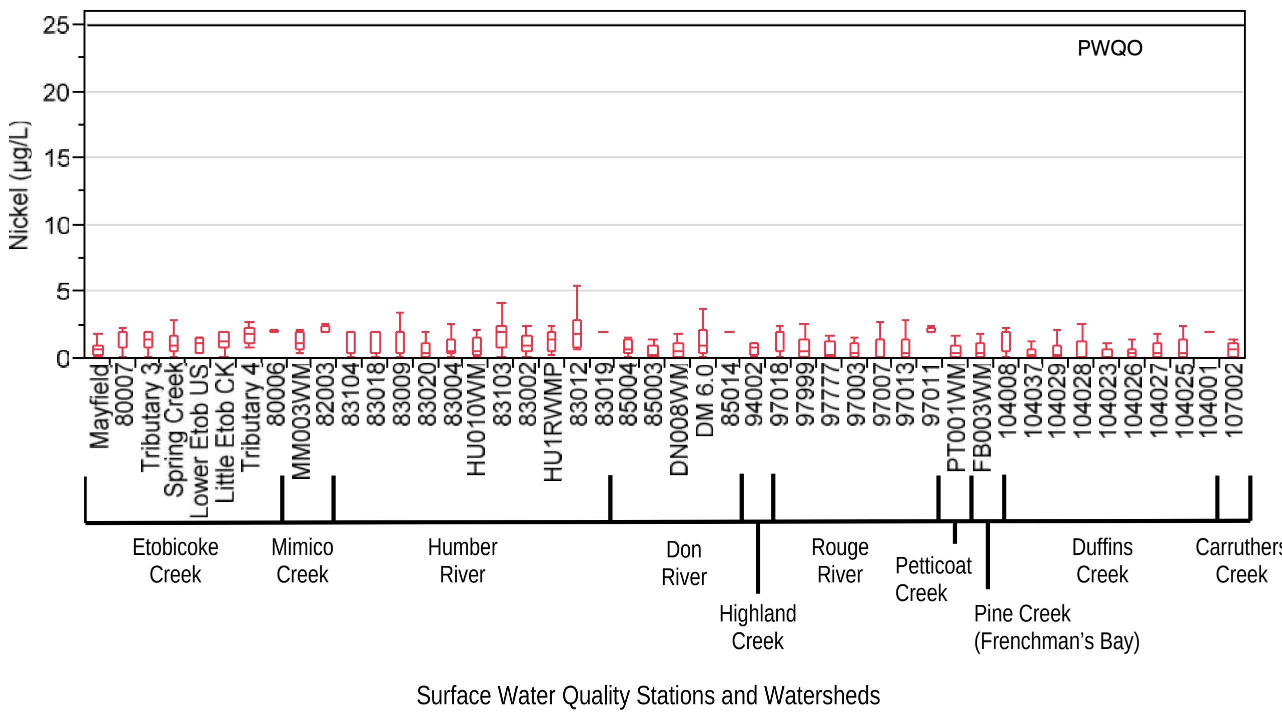


Figure 39. 2013 nickel concentrations (µg/L) at 46 stations within TRCA jurisdiction (PWQO: 25 µg/L)

The five-year nickel box plots demonstrated a trend for Etobicoke Creek, Mimico Creek, Humber River, and Don River: increasing nickel concentrations towards stations in the lower portion of the watershed (Figure 41). No stations displayed median values, 75th percentiles, or whiskers which exceeded 6 µg/L, far short of the PWQO of 25 µg/L. The highest median values were from stations 80006, 82003, 83019, 85014, 97011, and 104001. These values were influenced by the substitution of the OMOE MDL of 2.0 µg/L for trace nickel amounts. Stations 82003 and 83012 exhibited the highest 75th percentiles. Duffins Creek had the most consistently low nickel concentrations.

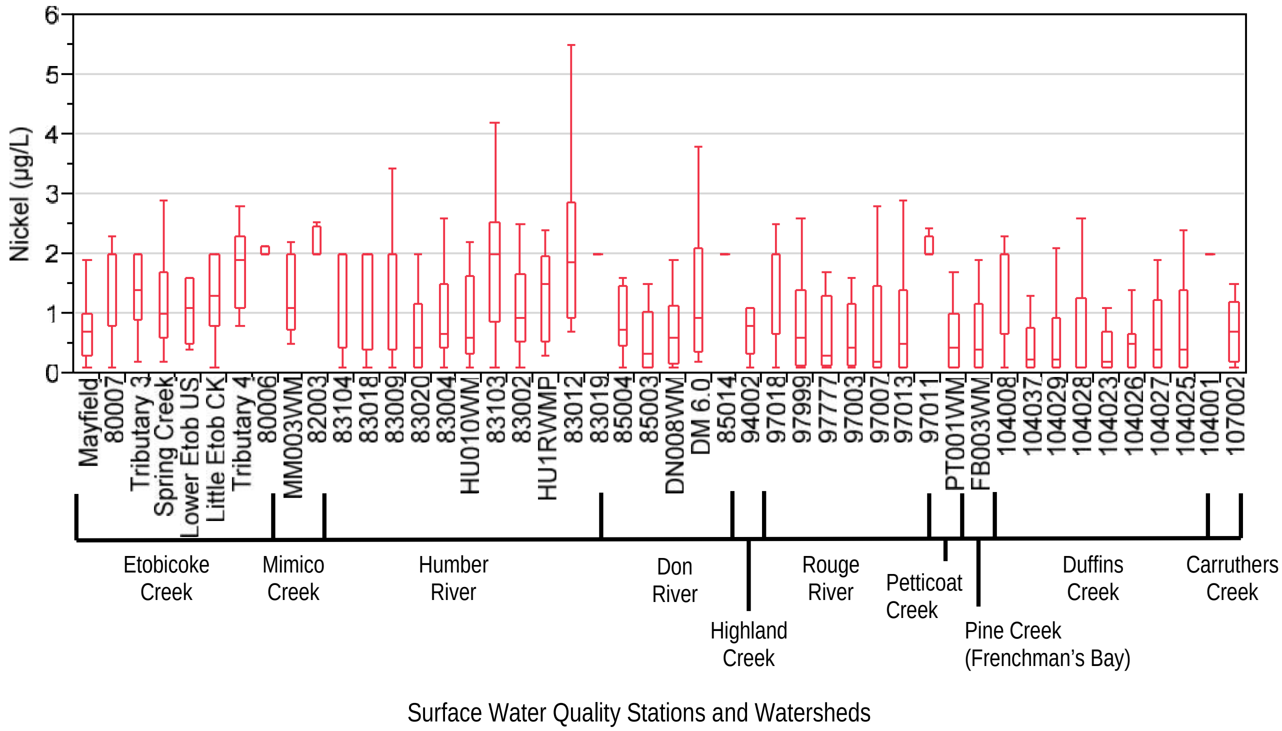


Figure 40. 2013 nickel concentrations (µg/L) at 46 stations within TRCA jurisdiction

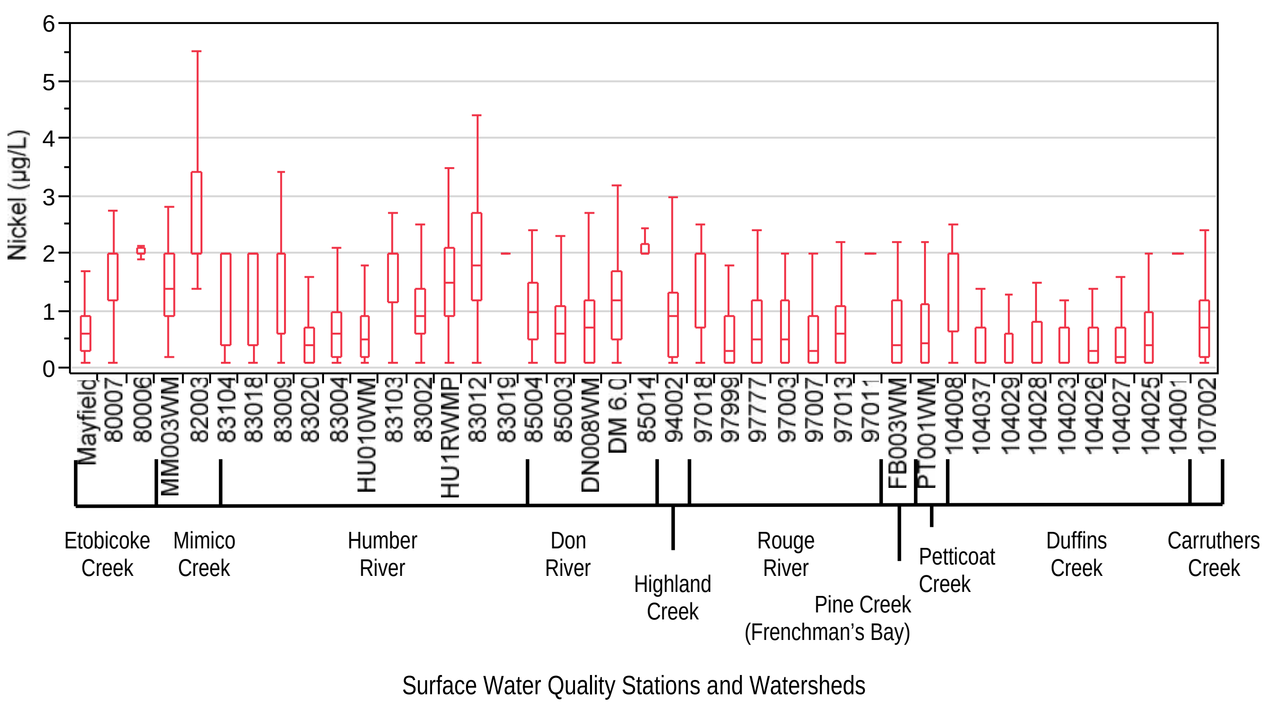


Figure 41. Nickel concentrations (µg/L) at 41 stations from 2009 to 2013

Many of the highest nickel results were recorded from sampling the day after the powerful July 8, 2013, storm, however, a regression analysis, using precipitation on the day of sampling, determined that nickel has an inverse relationship with precipitation (p<0.0001) (Figure 42).

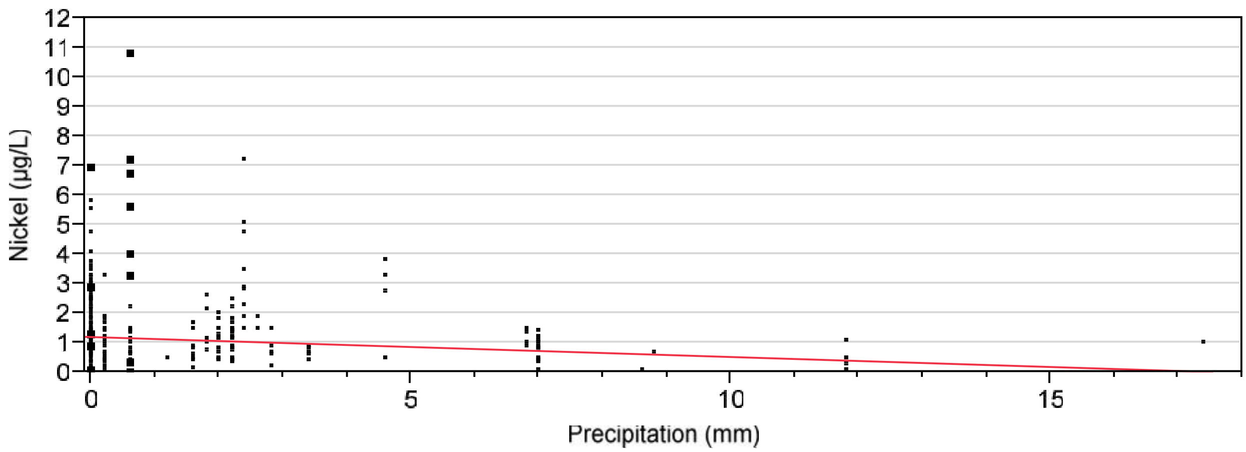


Figure 42. Results of 2013 nickel concentrations (µg/L) regressed with precipitation at 46 stations within TRCA jurisdiction

Monthly nickel concentrations were elevated from April to October (Figure 43). Median values were highest from May to September and lowest in February and November. Interquartile ranges were greatest in April, June, July, October, and November. An ANOVA detected significant differences in nickel concentrations between months (p<0.0001). Tukey's test results detected that nickel levels in June, September, and December were significantly higher than January, March, November, and February (Table 14). August, July, and May were significantly higher than March, November, and February. Finally, April was significantly higher than February. Mean nickel values ranged from 0.8 to 1.4 (µg/L).

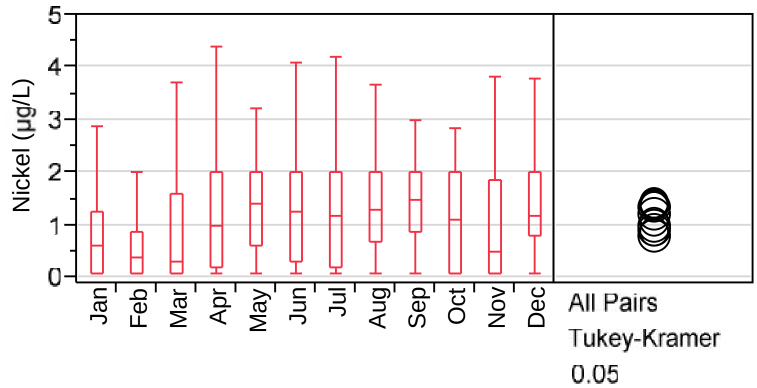


Figure 43. Box plots of monthly nickel (µg/L) concentrations at 41 stations from 2009 to 2013

Table 14. Results of Tukey's test for monthly nickel (µg/L) concentrations from 2009 to 2013

Columns			
1	2	3	4
Jun			
Sep			
Dec			
Aug	Aug		
Jul	Jul		
May	May		
Apr	Apr	Apr	
Oct	Oct	Oct	Oct
	Jan	Jan	Jan
		Mar	Mar
		Nov	Nov
			Feb

3.4.7 Zinc

Similar to other metals, the natural process of weathering makes zinc available in ecosystems. Zinc is also released from anthropogenic sources such as municipal wastewater, wood combustion, iron and steel production and waste incineration (OMOEE, 2003). There were three stations (Etobicoke Creek: 80006; Mimico Creek: 82003; and Don River: 85014) which displayed median values in excess of the PWQO in 2013 (Figure 44); but in 2012 there no stations which exceeded the PWQO. In addition to these three stations, MM003WM (Mimico Creek), 83012, 83019 (Humber River), and 97011 (Rouge River) also had 75th percentiles above the PWQO; in 2012, only four stations had 75th percentiles above the PWQO.

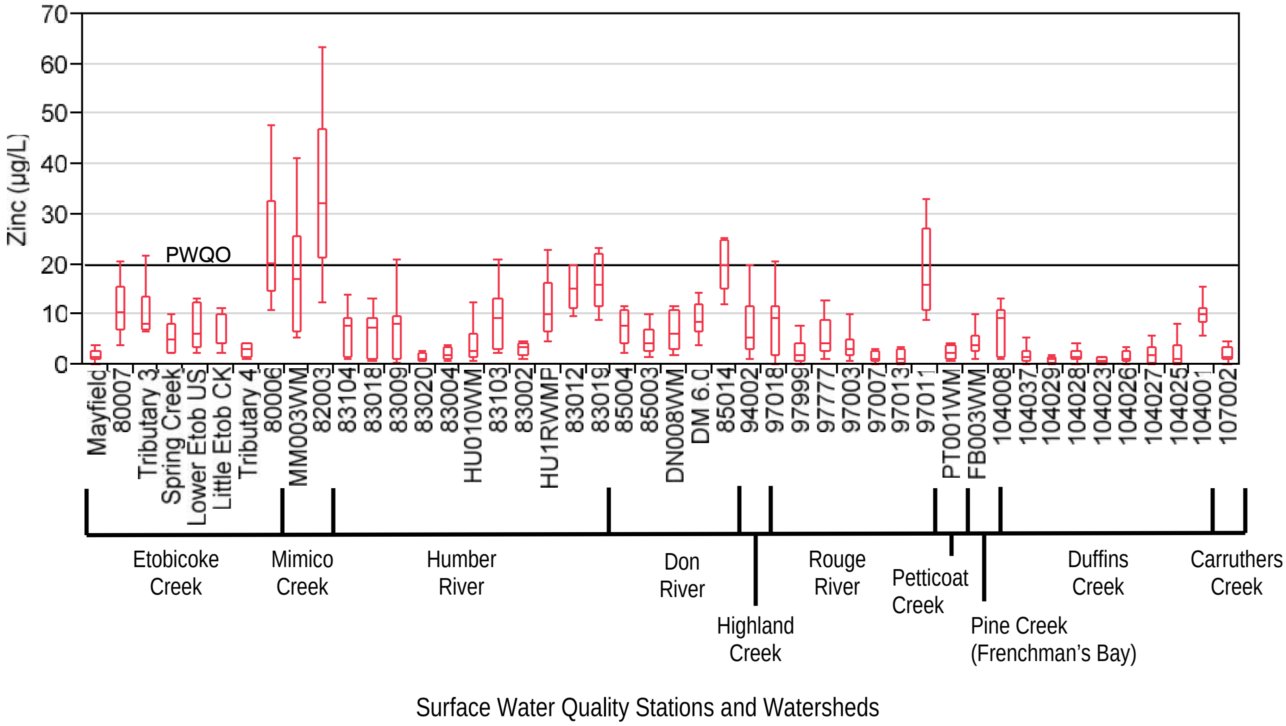


Figure 44. 2013 zinc concentrations (µg/L) at 46 stations within TRCA jurisdiction (PWQO: 20 µg/L)

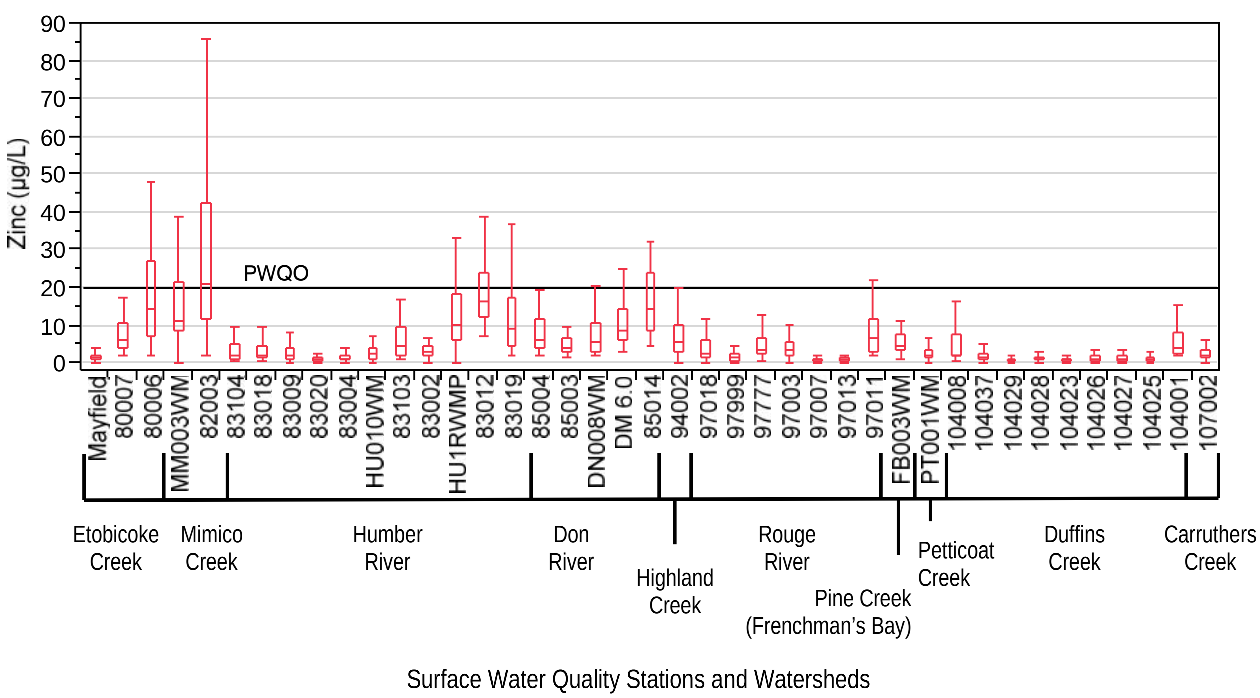


Figure 45. Zinc concentrations (µg/L) at 41 stations from 2009 to 2013 (PWQO: 20 µg/L)

The range of zinc concentrations at stations situated in the lower Etobicoke and Mimico watersheds stand out from the other stations, and urban surface runoff is the likely cause. Stations 80006 and 82003 are situated downstream of the Pearson International Airport in a highly urbanized area. Precipitation contributed to the increased zinc values, as many of the year's highest zinc concentrations were recorded the day after the powerful storm on July 8, 2013.

From 2009 to 2013, station 82003 was the only station with median zinc values over the PWQO of 20 μg/L, and also exhibited the greatest interquartile range (Figure 45). Stations 80006, MM003WM, 82003, 83012, and 85014 displayed 75th percentiles in exceedance of the PWQO. The majority of watersheds demonstrated a pattern of increasing zinc concentrations towards the lower portion of the watershed. The lower Etobicoke Creek, Mimico Creek, and the lower Humber River and Don River are areas which displayed elevated zinc levels. The upper Humber River and Duffins Creek exhibited low zinc levels.

Monthly median zinc concentrations were similar throughout the year, but interquartile and whisker ranges were greater in January, February, and June, and July (Figure 46). An ANOVA detected significant differences in zinc levels between months (p<0.0001). Tukey's test results demonstrated that zinc concentrations in February were significantly higher than October and August (Table 15). February, January, and June were significantly higher than August. The highest mean zinc values were in February and January and the lowest were in May, December, and September.

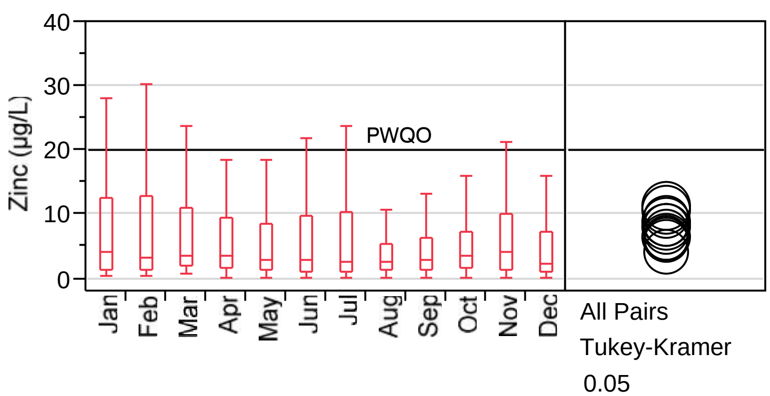


Figure 46. Box plots of monthly zinc (μg/L) at 41 stations concentrations from 2009 to 2013

Table 15. Results of Tukey's test for monthly zinc (µg/L) concentrations from 2009 to 2013

Columns		
1	2	3
Feb		
Jan	Jan	
Jun	Jun	
Apr	Apr	Apr
Jul	Jul	Jul
Mar	Mar	Mar
Nov	Nov	Nov
May	May	May
Dec	Dec	Dec
Sep	Sep	Sep
	Oct	Oct
		Aug

3.5 Bacteria

Escherichia coli is a relatively harmless bacterium which is commonly found in the digestive systems of warm-blooded animals. Although it represents only 0.1% of gut flora in humans, it is exponentially more abundant than most pathogenic bacteria. Rather than attempting to detect presence and abundance of scarce/rare pathogenic bacteria, due its abundance *E. coli* is utilized as an indicator of harmful pathogens. If *E. coli* levels are low, then the assumption is that pathogenic bacteria levels would be correspondingly low as well. High levels of *E. coli* are indicative of recent human and/or animal fecal contamination and raw sewage loading. *E. coli* levels may increase in urbanized areas due to inadequately designed combined sewer systems, illegal connections between storm and sanitary sewers, and precipitation events that overflow those sewer systems (CCME, 2003). Municipalities use *E. coli* analyses to ensure that drinking water and recreational bathing waters are safe. However, WM&R monitoring of *E. coli* levels in TRCA streams was designed to measure and track long-term watershed health.

The station with the highest median value, which was greater than 1000 colony forming units (CFU)/100 mg/L, was DM 6.0, similar to 2012 (Figure 47). In 2013, 18 out of 46 stations (39%), and in 2012 only nine out of 41 stations (22%), displayed 75th percentiles that exceeded 1000 CFU/100 mg/L in 2013. There were 31 out of 46 stations (67%), and in 2012, 23 out of 41 stations (56%), which displayed median *E. coli* values in excess of the PWQO of 100 CFU/100mL. Many stations (Etobicoke Creek: Mayfield; Humber River: 83104, 83018, 83009, 83103, 8300; Rouge River: 97007, 97013; and Duffins Creek: 104008, 104023) demonstrated very broad interquartile ranges, much wider than 2012. A few of the higher *E. coli* values were recorded after the powerful July 8, 2013, storm. The comparatively higher *E. coli* concentrations and broader interquartile ranges in 2013 may have resulted from increased precipitation.

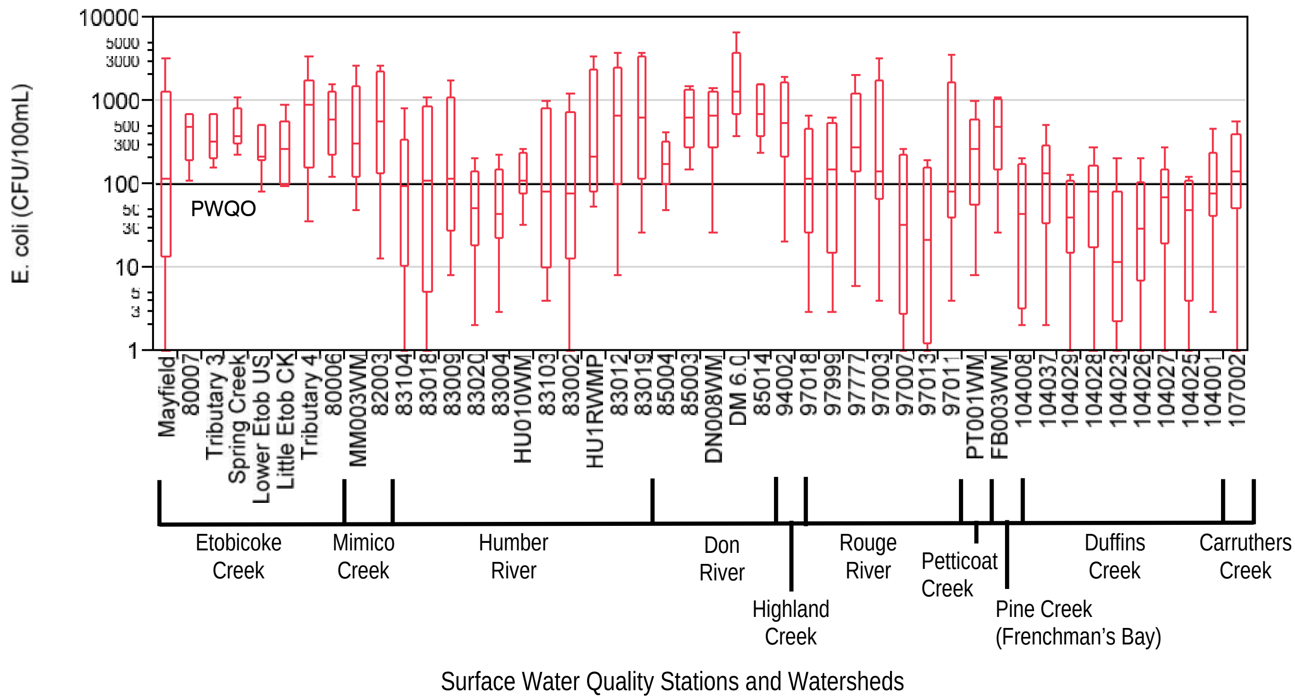


Figure 47. 2013 Escherichia coli concentrations (CFU/100mL) at 46 stations within TRCA jurisdiction (PWQO: 100 CFU/100 mL)

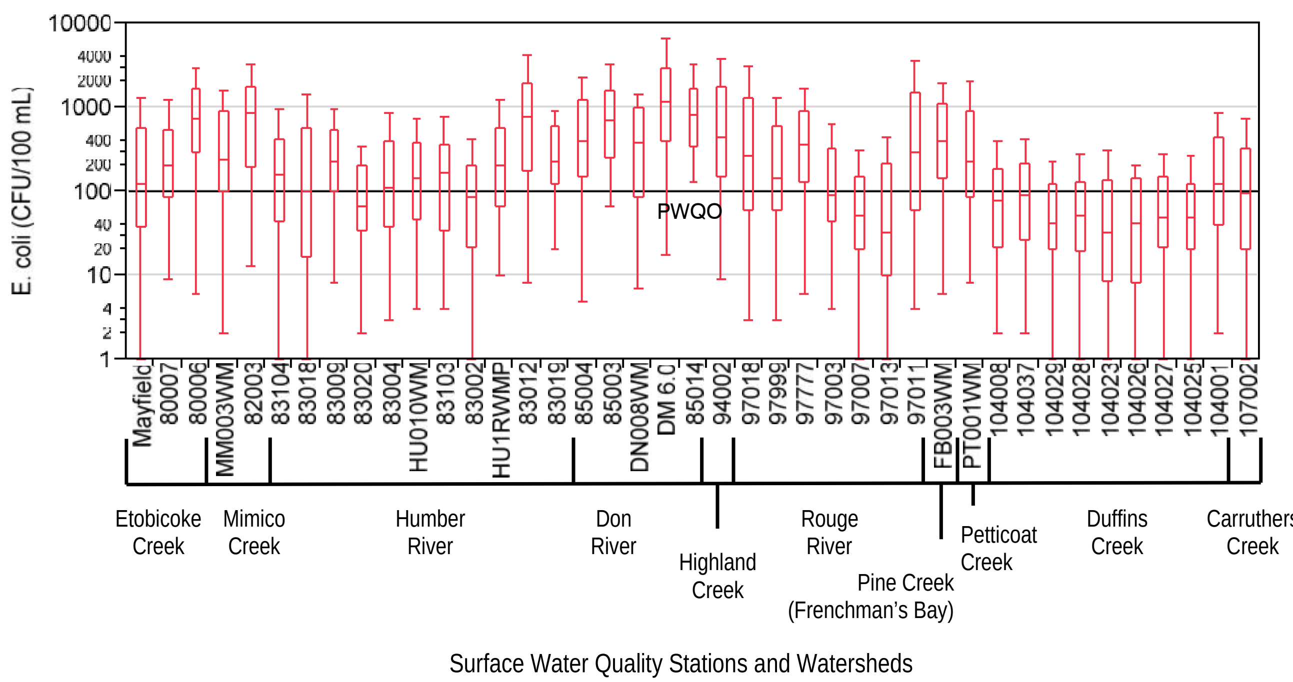


Figure 48. Escherichia coli concentrations (CFU/100mL) at 41 stations from 2009 to 2013 (PWQO: 100 CFU/100 mL)

These results underline areas which were highlighted year after year. Areas of concern include Etobicoke Creek, Mimico Creek, the lower Humber River, the Don River, Highland Creek, station 97777 and the lower Rouge River, and station FB003WM in Pine Creek (Frenchman's Bay). Several stations (Etobicoke Creek: 80006; Mimico Creek: 82003; Humber River: 83012; Don River: DM 6.0, 85014; and Highland Creek: 94002) have exhibited consistently high median *E. coli* values in the past few years.

Station DM 6.0 is located on a heavily urbanized tributary (Taylor Massey Creek) of the Don River that is serviced by combined sewers. Also, illegal sewage cross connections to stormwater sewers may have contributed elevated levels. Station 85014 is located downstream of DM 6.0 as well as approximately 1.5 km downstream of the North Toronto Wastewater Treatment Plant which may contribute to elevated *E. coli* concentrations in the lower Don River. Station 83012 is located on a highly urbanized tributary in the Humber River watershed that is serviced by combined sewers with large portions of the channel hardened with concrete banks. These conditions appear to result in an influx of contaminants from upstream urban areas, which have little opportunity to be filtered or absorbed due to the lack of riparian zone vegetation as they travel downstream. The elevated *E. coli* median value documented at station 94002 is likely a result of the watershed being completely urbanized.

The box plots for five-years of *E. coli* data displayed a similar pattern to the 2013 box plots (Figure 48). In Etobicoke Creek and Mimico Creek, stations lower in the watershed tended to display higher *E. coli* levels. However, most stations and watersheds exhibited elevated concentrations except for Duffins Creek. Of the 41 stations, 27 demonstrated median values in excess of the PWQO, and 14 had median values below the PWQO. Etobicoke Creek, Mimico Creek, Don River, and Frenchman's Bay displayed elevated *E. coli* levels and Duffins Creek displayed the lowest levels.

Monthly *E. coli* concentrations were lower in March, April, November, and December and higher from May to October (Figure 49). Monthly mean *E. coli* values ranged from 528.1 in April to 1557.8 in June (Table 16). An ANOVA detected significant differences in *E. coli* levels between months (p<0.0169). Results from the Tukey's test show that *E. coli* levels in June were significantly higher than April. There were no significant differences between the other months.

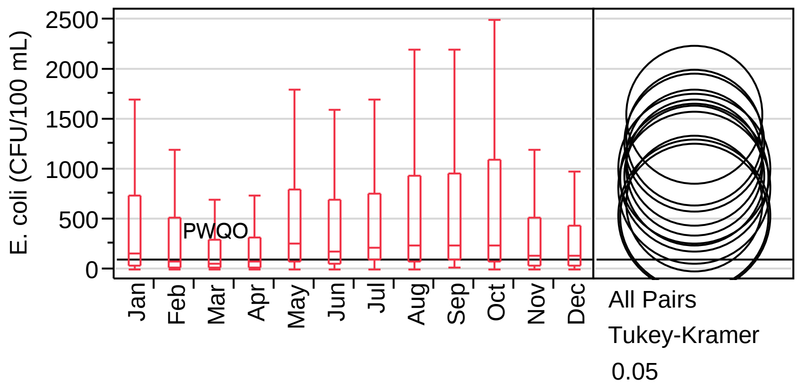


Figure 49. Box plots of monthly E. coli (CFU/100 m/L) concentrations at 41 stations from 2009 to 2013 (PWQO: 100 CFU/100 mL)

Table 16. Results of Tukey's test for monthly E. coli (CFU/100 m/L) concentrations from 2009 to 2013

Columns	
1	2
Jun	
Aug	Aug
Sep	Sep
Dec	Dec
Oct	Oct
Mar	Mar
Jul	Jul
May	May
Jan	Jan
Nov	Nov
Feb	Feb
	Apr

3.6 Nutrients

Nitrogen and phosphorus are critical to plant and animal life and their concentrations determine the productivity of aquatic systems. If there is substantial phosphorus loading into aquatic systems, nitrogen becomes the growth limiting nutrient.

Nitrogen occurs in various forms such as nitrate, nitrite, and ammonia. Nitrate is the most common form of nitrogen entering freshwater systems and is assimilated by plants. Upon the decomposition of plant matter, nitrate is converted to ammonia, an energy-efficient source of nitrogen for plants. Bacteria convert ammonia into nitrate, nitrite, and nitrogen. Nitrite is easily converted and rarely accumulates unless organic pollution is high (Wetzel, 2001). Total Kjeldahl nitrogen (TKN) is a quantitative determination of nitrogen and ammonia that is required in the analysis of sewage treatment plant effluent.

Anthropogenic sources of nitrogen and phosphorous such as agricultural fertilizer, animal wastes and municipal sewage that leaches into aquatic systems provide unusually high concentrations of these nutrients. This over-nutrition, or eutrophication, of aquatic environments can promote excessive plant and algae growth. Eutrophic lakes can be characterized by algal blooms which reduce recreational use and deplete oxygen levels to the detriment of other biota, especially fish. Excessive growth of aquatic plants in streams can cause dissolved oxygen concentrations to decrease during the night to levels that may not sustain certain aquatic species, as well as reduce the aesthetic appeal of the stream.

3.6.1 Ammonia

Currently, there are no PWQO, CWQG or CESI guidelines which define the amount of allowable total ammonia for the protection of aquatic life. The highest median ammonia values were recorded at 83012 (Humber River) and 85014 (Don River), which have consistently displayed elevated ammonia concentrations over the years (Figure 50). Higher ammonia levels at station 85014 can be attributed to combined sewer systems, the proximity of the North Toronto Wastewater Treatment Plant upstream which discharges effluent into the lower Don River, as well as illegal cross connections that discharge effluent directly into stormwater sewers and into the Don River. The highest ammonia values and greater interquartile ranges were recorded in the Mimico Creek and the Don River watersheds, followed by the lower Humber River and Etobicoke Creek watersheds.

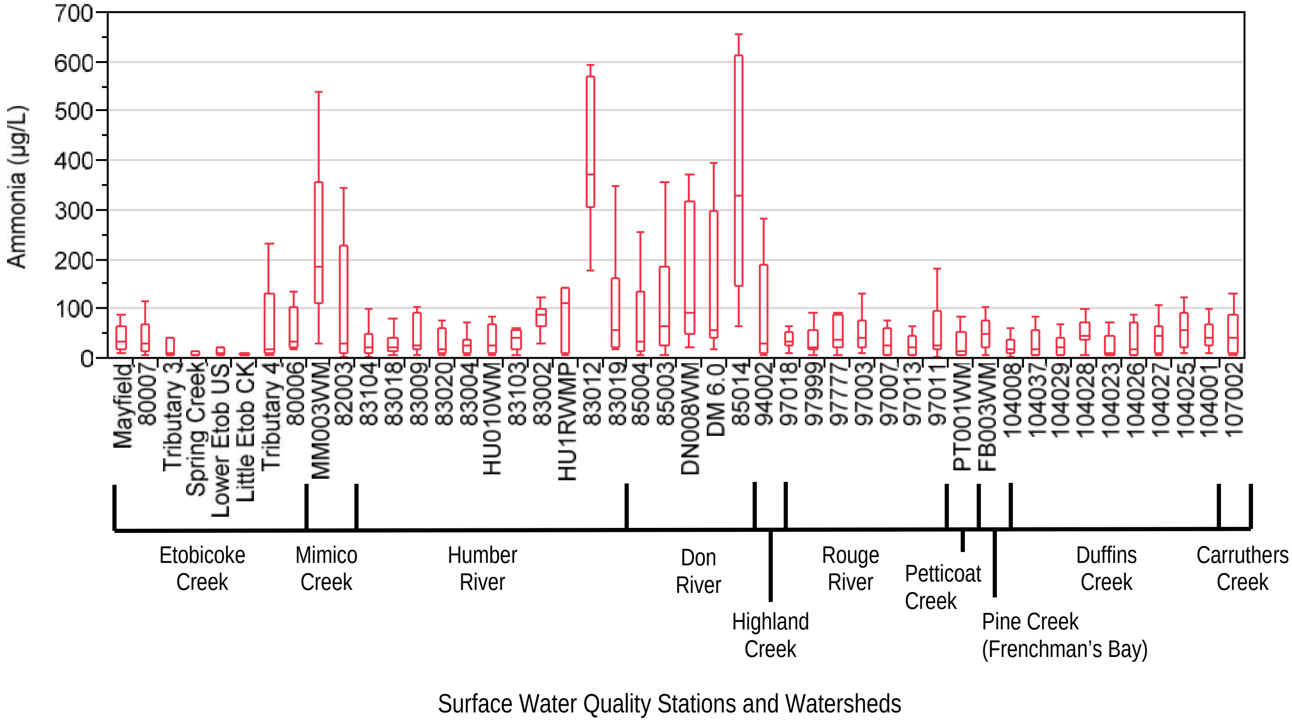
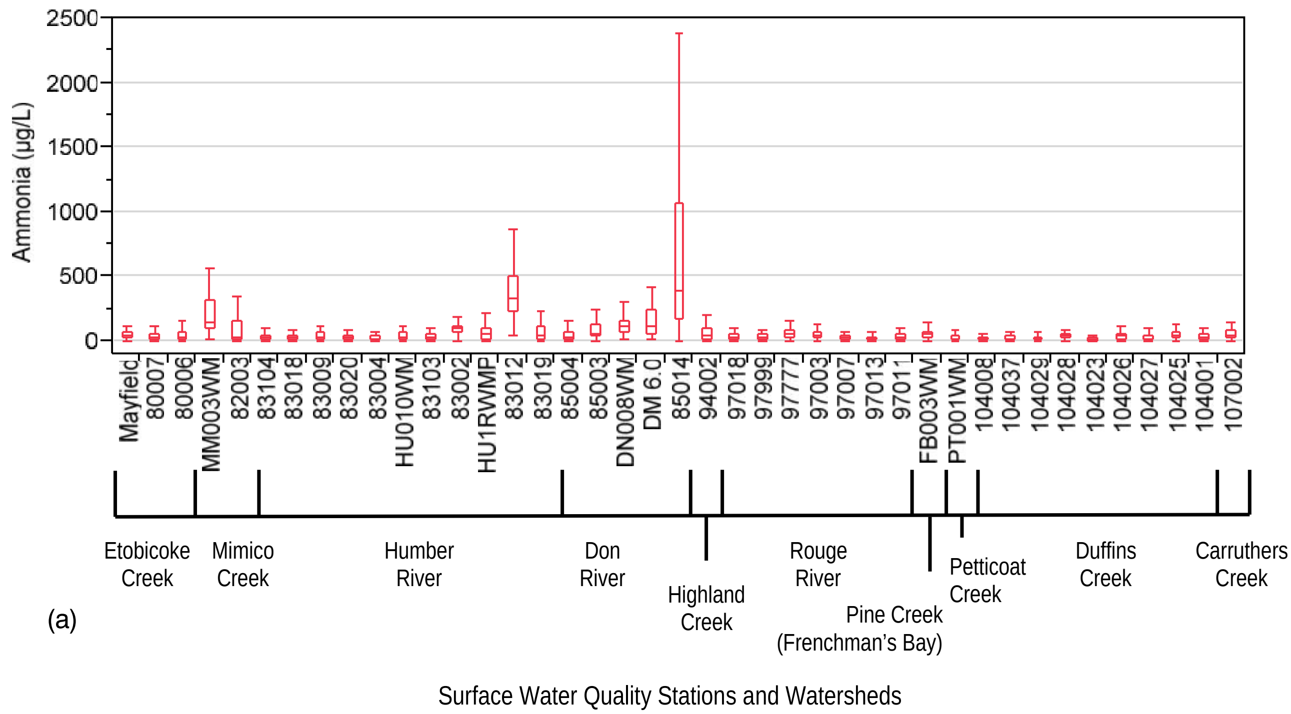


Figure 50. 2013 ammonia concentrations (µg/L) at 46 stations within TRCA jurisdiction

The box plots for ammonia data from 2009 to 2013 are presented in two formats: Figure 51 (a) displays box plots along a linear y-axis whereas 46 (b) displays box plots along a logarithmic y-axis. In Figure 51 (a), stations with elevated ammonia concentrations are apparent, and in Figure 51 (b) stations with moderate ammonia levels are displayed in detail. Station 85014 had the highest median values, the greatest interquartile range, and the highest whisker. Stations 83012 and MM003WM were second and third, respectively, for those same criteria. Station 85014 was the only station with 75th percentiles above 1000 µg/L. There were four stations with median values above 100 µg/L and the remaining 37 stations had median values below 100 µg/L. Mimico Creek and Don River watersheds displayed the highest ammonia levels, and the upper Humber River, Rouge River, Petticoat Creek, and Duffins Creek had the lowest levels.



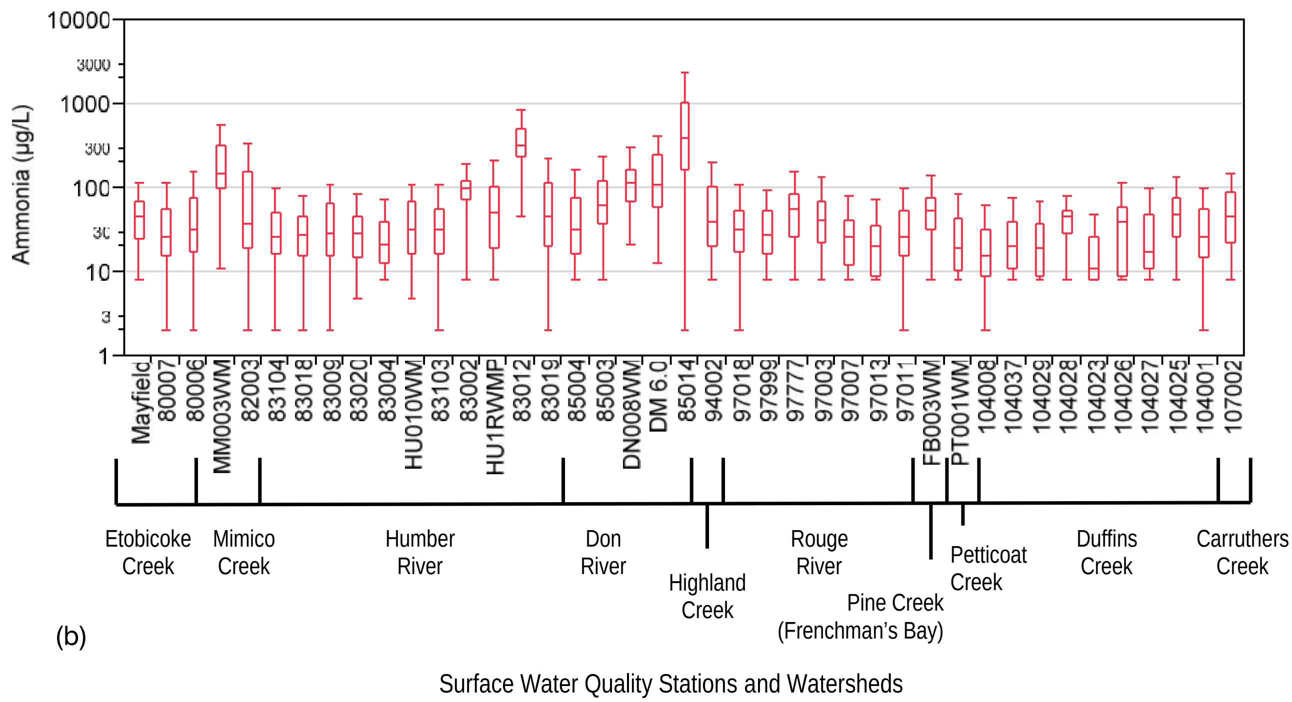


Figure 51. Ammonia concentrations (µg /L) at 41 stations from 2009 to 2013: (a) box plots with linear y-axis, and (b) box plots with logarithmic y-axis

Monthly median ammonia values appeared elevated and interquartile ranges were greater during winter months (Figure 52). Median values were lowest in April and October. An ANOVA detected significant differences in ammonia concentrations between months ($p<0.0001$). The Tukey's test detected that ammonia levels in January were significantly higher than May, March, June, August, November, July, September, April, and October (Table 17). December was significantly higher than March, June, August, November, July, September, April, and October. February was significantly higher than June, August, November, July, September, April, and October.

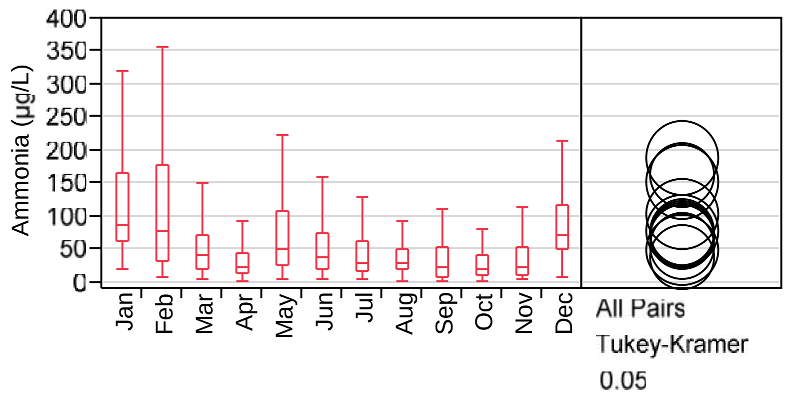


Figure 52. Box plots of monthly ammonia (µg/L) concentrations at 41 stations from 2009 to 2013

Table 17. Results of Tukey's test for ammonia (µg/L) concentrations from 2009 to 2013

Columns			
1	2	3	4
Jan			
Dec	Dec		
Feb	Feb	Feb	
	May	May	May
		Mar	Mar
			Jun
			Aug
			Nov
			Jul
			Sep
			Apr
			Oct

The pattern exhibited in Figure 52 of higher ammonia concentrations in winter is controlled by processes in which ammonia is removed from or contributed to the water column. A primary source of ammonia is the decomposition of organic material in stream sediments, whereas fish excrement contributes much less. These processes contribute ammonia to the water column year round. Plant growth and nitrification are two processes which remove ammonia from water. Plant growth, including algal photosynthesis, requires ammonia which is removed from water. Bacterial nitrification is the process whereby ammonia is oxidized in two steps: ammonia is first converted to nitrite and then to nitrate. These processes remove ammonia from water but only in non-winter months (Wetzel 2001). Higher ammonia concentrations in the winter months reflect the shutdown of plant growth and nitrification due to low temperatures, whereas the supply of ammonia continues.

3.6.2 Nitrate

There were no stations with median nitrate values above the CESI of 2.93 mg/L (Figure 53). Similar to previous years, station DM 6.0 (Don River) had the highest median value. DM 6.0 is situated in a highly urbanized watershed and receives input from combined sewers and illegal cross connections. Station Mayfield (Etobicoke Creek) was the only station with 75th percentiles in excess of the CESI guideline. Stations Mayfield and 83020 (Humber River) displayed the greatest interquartile range: both these stations have substantial agricultural lands in their catchments.

Station DM 6.0 displayed the highest median values from 2009 to 2013 (Figure 54). Station Mayfield displayed the greatest interquartile range, the highest 75th percentiles (equalling the CESI guideline), and the highest whisker. The mid and upper Etobicoke Creek, lower Humber River and Don River, Rouge River, and Frenchman's Bay displayed elevated nitrate levels. Mimico Creek, the upper Humber River, and Duffins Creek (except for stations 104037 and 104028) exhibited the lowest levels.

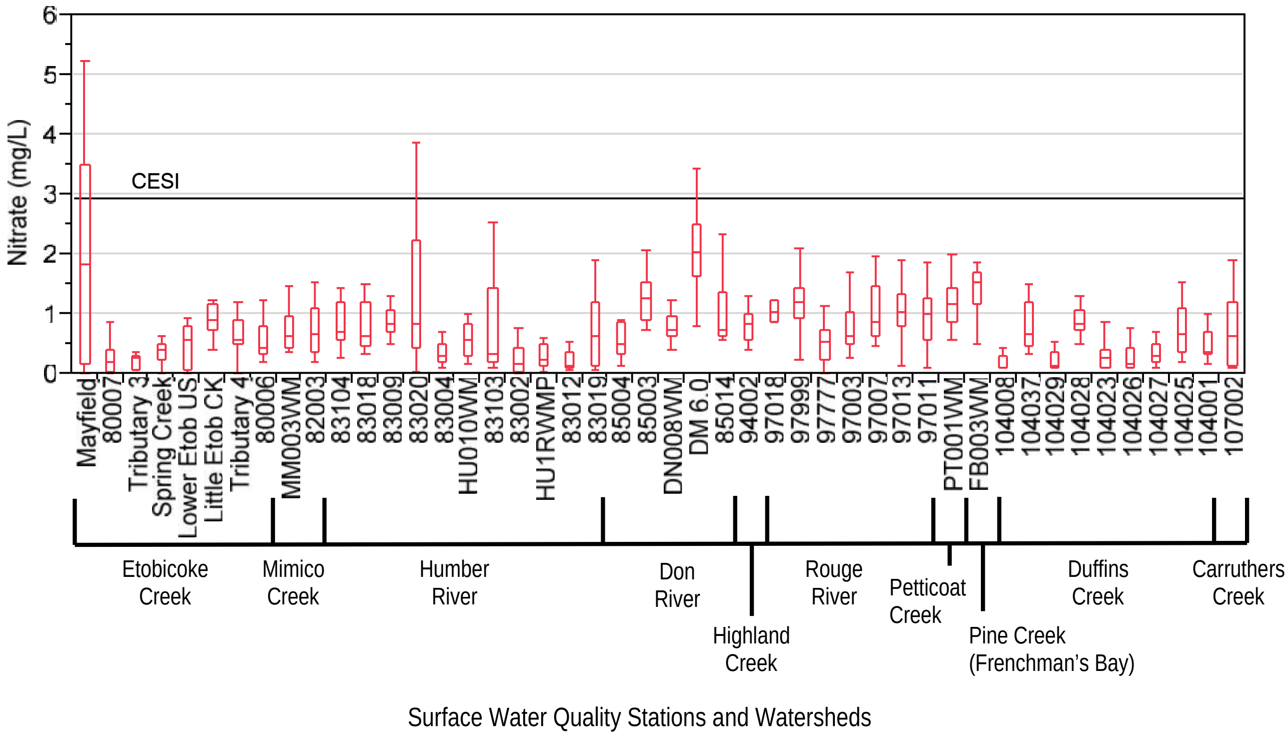


Figure 53. 2013 nitrate concentrations (mg/L) at 46 stations within TRCA jurisdiction (EC: 2.93 mg/L)

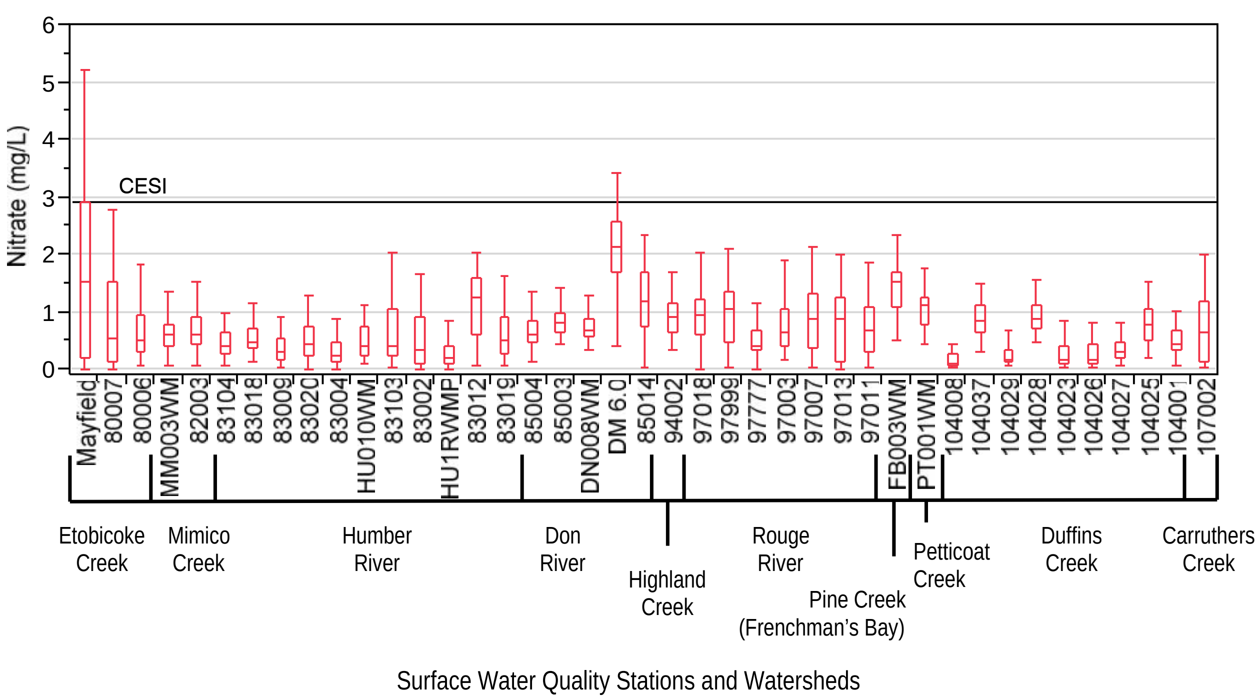


Figure 54. Nitrate concentrations (mg/L) at 41 stations from 2009 to 2013 (EC: 2.93 mg/L)

Monthly nitrate concentrations displayed a clear pattern of elevated levels from December to March and lower levels from May to October (Figure 55). This pattern was supported by monthly mean nitrate values: December, January, February, and March had the highest mean values and June, September, August, and July had the lowest (Table 18). An ANOVA detected significant differences in nitrate concentrations between months ($p<0.0001$). Results from the Tukey's test specified which months were significantly different. Nitrate concentrations in December, February, January, and March were significantly higher than all other months. April was significantly higher than November, May, October, June, September, August, and July. November was significantly higher than May, October, June, September, August, and July. May and October were significantly higher than June, September, August, and July.

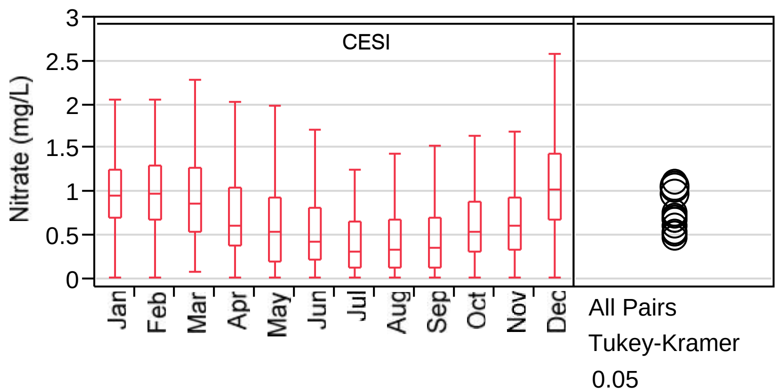


Figure 55. Box plots of monthly nitrate (mg/L) concentrations at 41 stations from 2009 to 2013 (EC: 2.93 mg/L)

Table 18. Results of Tukey's test for monthly nitrate (mg/L) concentrations from 2009 to 2013

Columns				
1	2	3	4	5
Dec				
Feb				
Jan				
Mar				
	Apr			
	Nov	Nov		
	May	May	May	
	Oct	Oct	Oct	
	Jun	Jun	Jun	Jun
		Sep	Sep	Sep
			Aug	Aug
				Jul

3.6.3 Nitrite

Nitrite levels appeared slightly lower in 2013 compared to 2012. Stations 83012 (Humber River) and 85014 (Don River) had 75th percentile values in excess of the CWQG, as well as displaying the highest median values which were below the CWQG (Figure 56). In 2012, there were four stations with 75th percentiles above the CWQG. Stations 80007 (Etobicoke Creek), MM003WM and 82003 (Mimico Creek), 83012 (Humber River), and DM 6.0 and 85014 (Don River) displayed the greatest interquartile ranges of nitrite, which was similar to previous years. Generally, nitrite concentrations appeared to increase with urbanization.

Box plots of the five-year nitrite data displayed similar patterns to the 2013 box plots (Figure 57). Etobicoke Creek, the lower Humber River, and Don River watersheds exhibit increasing nitrite concentrations in stations in the low portion of the watershed. Stations 85014 and 83012 displayed the highest median values, in excess of the CWQG, the highest 75th percentiles and whiskers, and the greatest interquartile ranges. Mimico Creek and Don River watersheds have consistently elevated nitrite concentrations. The upper Humber River and Duffins Creek displayed consistently low nitrite levels.

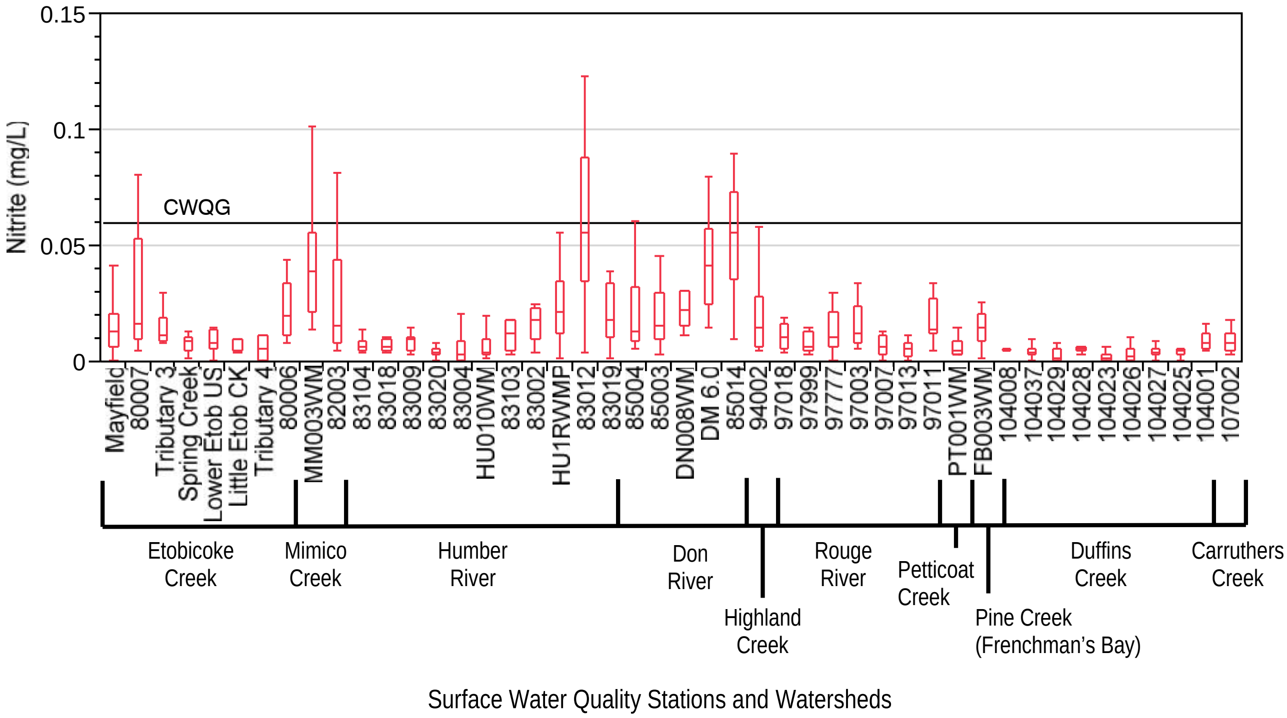


Figure 56. 2013 nitrite concentrations (mg/L) at 46 stations within TRCA jurisdiction (CWQG: 0.06 mg/L)

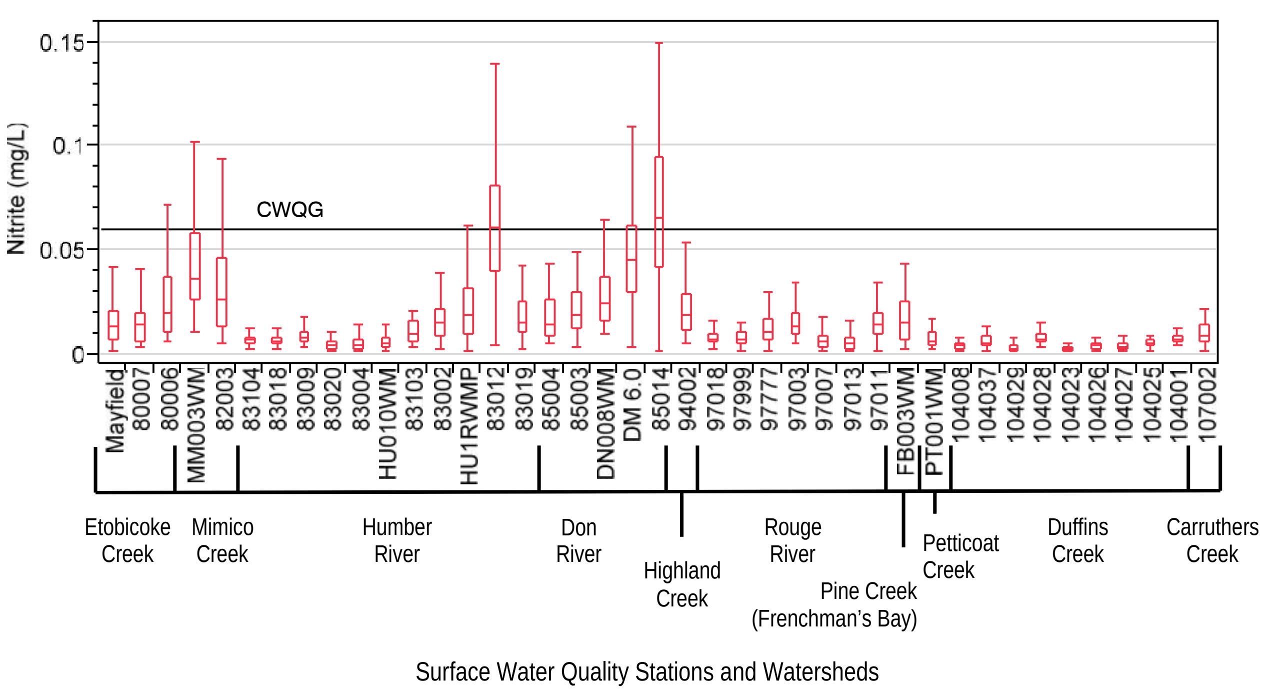


Figure 57. Nitrite concentrations (mg/L) at 41 stations from 2009 to 2013 (CWQG: 0.06 mg/L)

Median monthly nitrite concentrations appeared elevated and interquartile ranges were greater in January and February, and also in May and June (Figure 58). April, July, August, and September displayed the lowest median values. The highest mean nitrite values (0.03 mg/L) occurred in January and the lowest (0.01 mg/L) in December, September, April, November, and August (Table 19). An ANOVA detected significant differences in nitrite levels between months (p<0.0001). The Tukey's test determined that nitrite concentrations in January were significantly higher than July, March, October, December, September, April, November, and August. February, June, and May were significantly higher than December, September, April, November, and August.

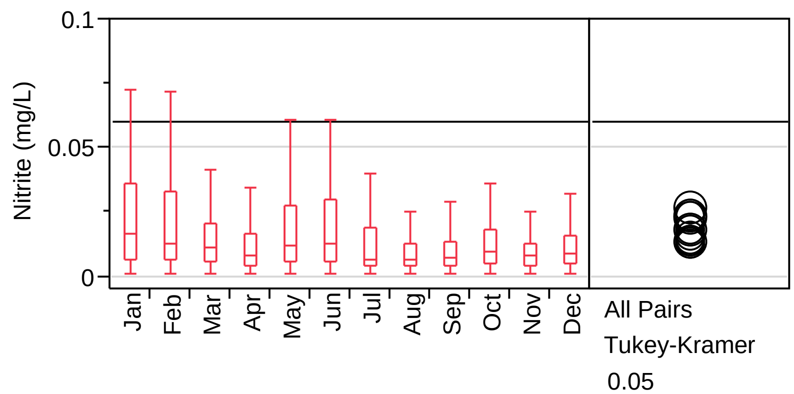


Figure 58. Box plots of monthly nitrite (mg/L) concentrations at 41 stations from 2009 to 2013 (CWQG: 0.06 mg/L)

Table 19. Results of Tukey's test for monthly nitrite (mg/L) concentrations from 2009 to 2013

Columns		
1	2	3
Jan		
Feb	Feb	
Jun	Jun	
May	May	
	Jul	Jul
	Mar	Mar
	Oct	Oct
		Dec
		Sep
		Apr
		Nov
		Aug

3.6.4 Total Kjeldahl Nitrogen

Similar to 2012, station 85014 (Don River) demonstrated the highest median TKN value, the highest 75th percentile values, and the greatest interquartile range (Figure 59). Generally, TKN levels increased at stations situated lower in the watershed and in urbanized areas.

The five-year box plots of TKN data patterns similar to the 2013 box plots (Figure 60). Station 85014 displayed elevated TKN concentrations: the median value was the highest, and the only one above 1 mg/L, the 75th percentile was above 2 mg/L, and the interquartile range was greatest. Stations in the upper Etobicoke Creek and Mimico Creek watersheds had higher TKN levels compared to the lower portion of the watersheds whereas in the Humber River TKN values increased from the upper to mid watershed. The upper Humber River and Duffins Creek displayed consistently low levels.

Median monthly TKN concentrations were lower during the winter months and highest in May and June (Figure 61). The mean TKN values ranged from 0.5 mg/L in February, October, April, December, August, and November, to 0.7 mg/L in May and June (Table 20). There were significant differences in TKN levels between months as determined by an ANOVA ($p<0.0001$). Results from the Tukey's test demonstrate that TKN concentrations in May were significantly higher than July, January, September, February, October, April, December, August, and November. June was significantly higher than February, October, April, December, August, and November.

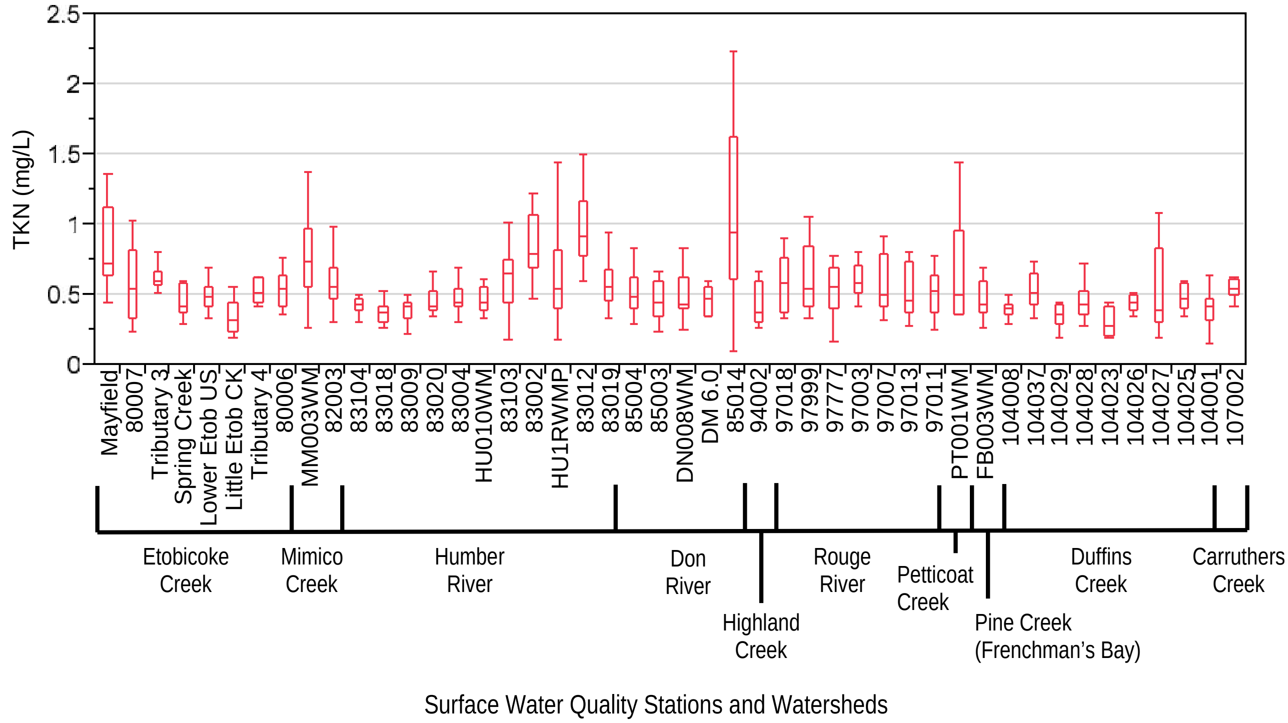


Figure 59. 2013 TKN concentrations (mg/L) at 46 stations within TRCA jurisdiction

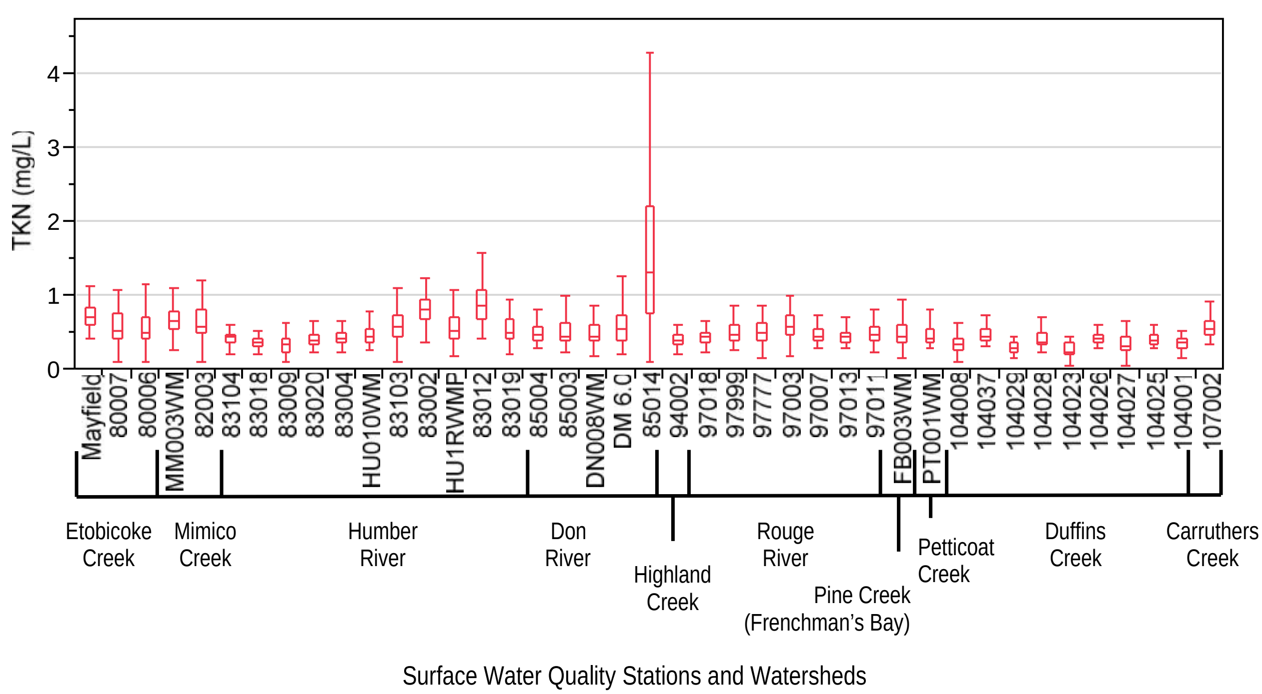


Figure 60. TKN concentrations (mg/L) at 41 stations from 2009 to 2013

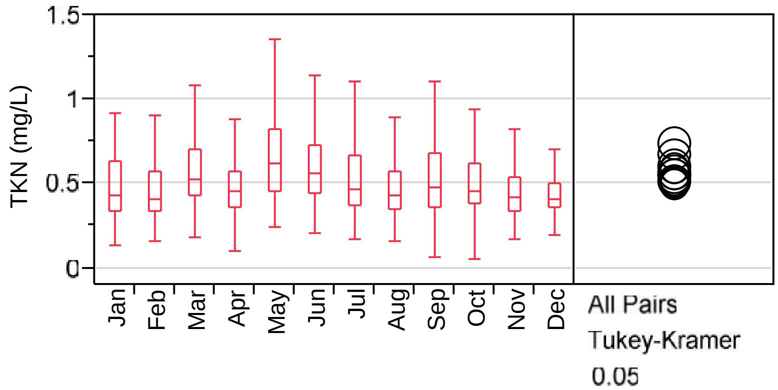


Figure 61. Box plots of monthly TKN (mg/L) concentrations at 41 stations from 2009 to 2013

Table 20. Results of Tukey's test for monthly TKN (mg/L) concentrations from 2009 to 2013

Columns		
1	2	3
May		
Jun	Jun	
Mar	Mar	Mar
	Jul	Jul
	Jan	Jan
	Sep	Sep
		Feb
		Oct
		Apr
		Dec
		Aug
		Nov

3.6.5 Phosphorus

Phosphorus readily binds to sediment particles and increases in phosphorus concentrations are typically associated with storm events and elevated levels of turbidity. Stations 83002 (Humber River) and 85014 (Don River) displayed the highest median levels of phosphorus (Figure 62). Median levels exceeded the PWQO of 0.03 mg/L at 23 out of 46 stations (50%). The majority of these stations were located in the mid to low Humber River, Don River, and Rouge River. In 2013, 44 out of 46 stations had 75th percentiles above the PWQO more than previous years. The Rouge River watershed demonstrated the most consistently elevated phosphorus concentrations.

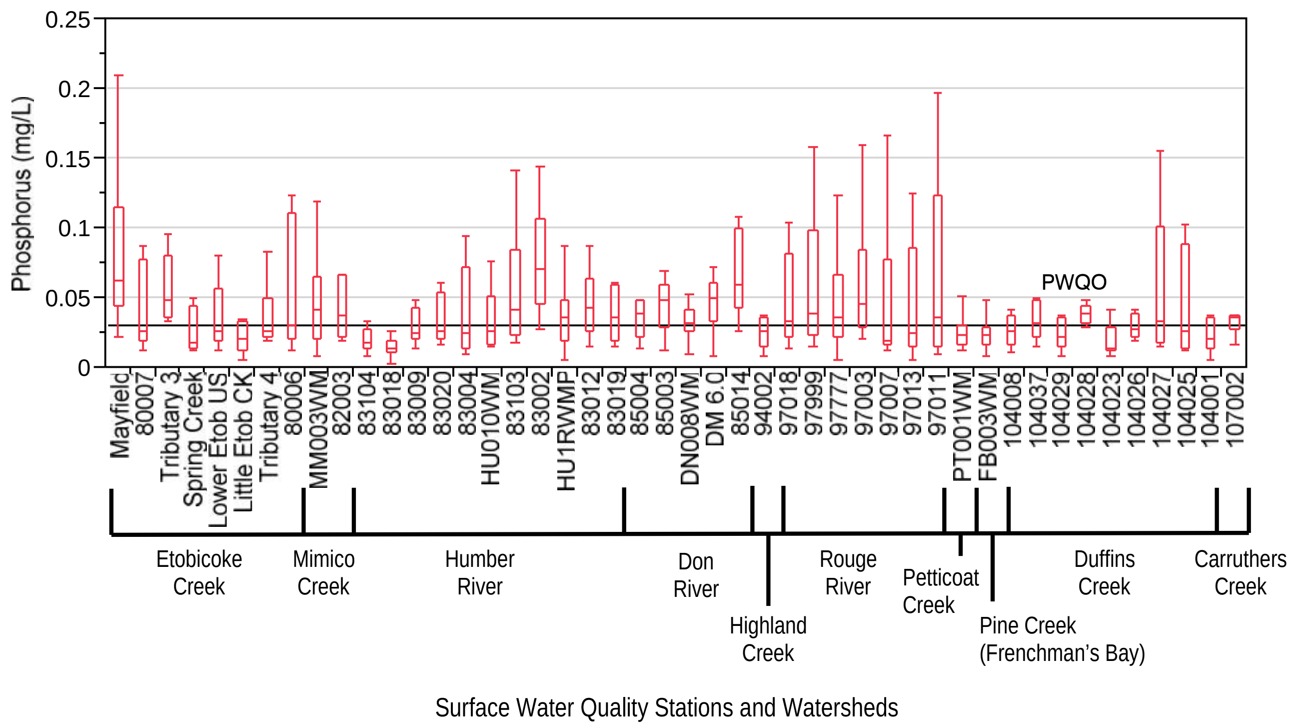


Figure 62. 2013 total phosphorus concentrations (mg/L) at 46 stations within TRCA jurisdiction (PWQO: 0.03 mg/L)

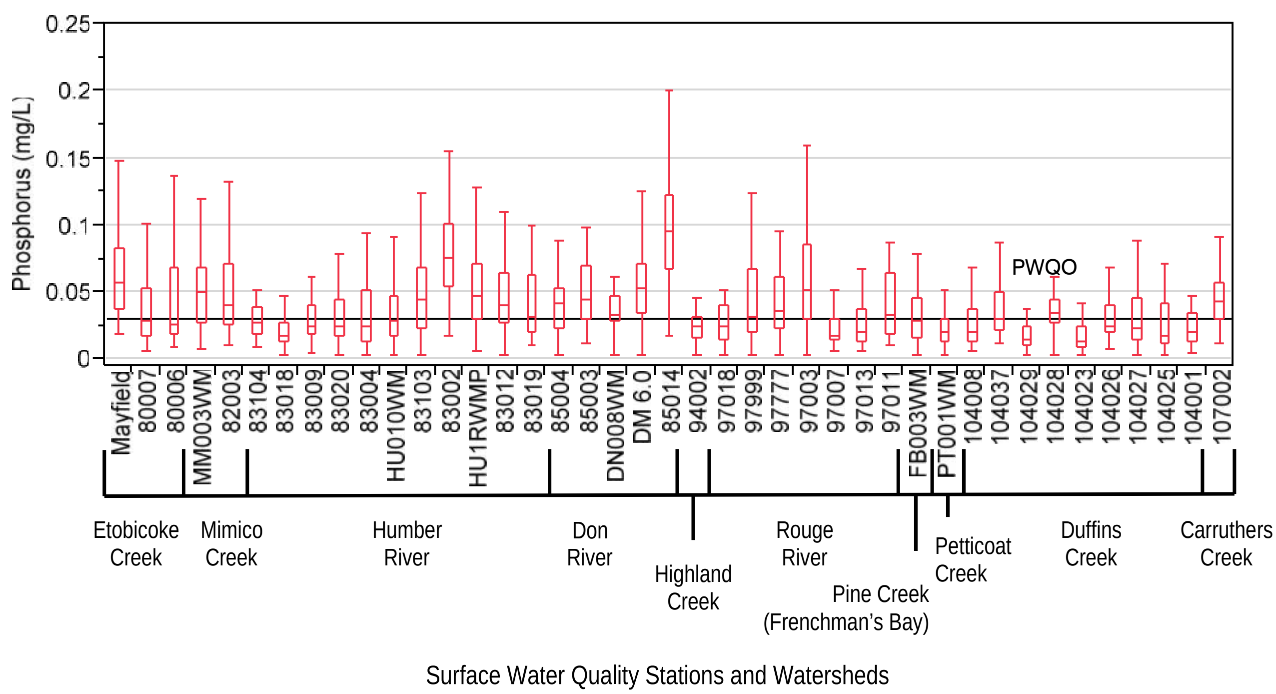


Figure 63. Total phosphorus concentrations (mg/L) at 41 stations from 2009 to 2013 (PWQO: 0.03 mg/L)

Station 85014 displayed the highest median values and 75th percentiles, and the greatest interquartile range (Figure 63). Stations 83002, Mayfield, DM 6.0, and 97003 also exhibited elevated median values, 75th percentiles, and great interquartile ranges. The upper and mid Etobicoke Creek and Mimico Creek, the mid Humber River, and the lower Don River displayed high phosphorus levels. The upper Humber River, Highland Creek, Petticoat Creek, and Duffins Creek exhibited low levels. Phosphorus had an almost significant inverse relationship with precipitation ($p<0.07$) (Figure 64).

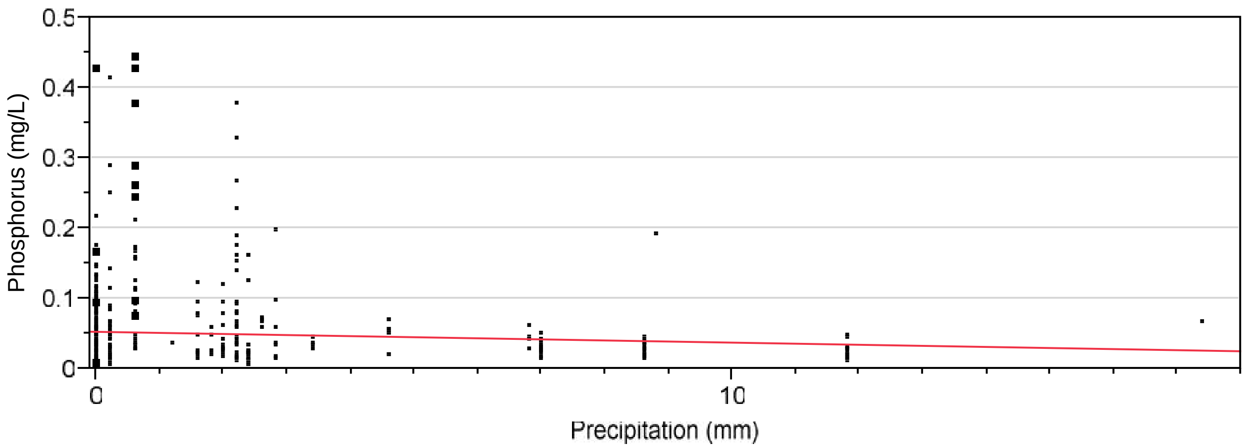


Figure 64. Results of 2013 total phosphorus concentrations (mg/L) regressed against precipitation at 46 stations within TRCA jurisdiction

Monthly median phosphorus concentrations were elevated in March, May, June, and July and were lowest in February and December (Figure 65). March and May exhibited the greatest interquartile ranges. Significant differences were detected by an ANOVA ($p<0.0001$). Results from the Tukey's test demonstrate that phosphorus levels in March and June were significantly higher than October, January, April, September, August, November, February, and December (Table 21). July was significantly higher than September, August, November, February, and December. May was significantly higher than August, November, February, and December. Mean phosphorus values ranged from 0.03 to 0.09 mg/L.

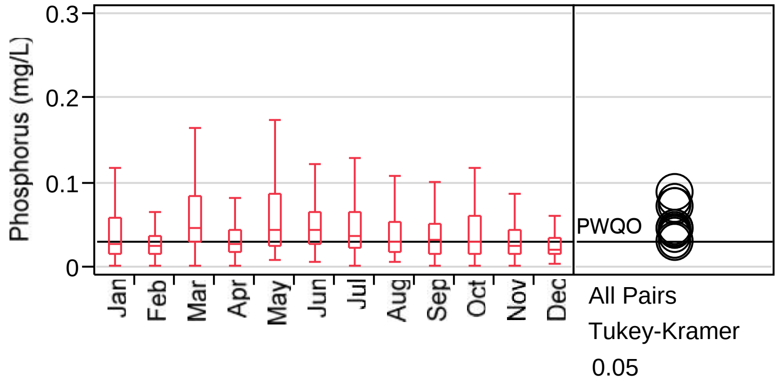


Figure 65. Box plots of monthly phosphorus (mg/L) concentrations at 41 stations from 2009 to 2013 (PWQO: 0.03 mg/L)

Table 21. Results of Tukey's test for monthly phosphorus (mg/L) concentrations from 2009 to 2013

Columns			
1	2	3	4
Mar			
Jun			
Jul	Jul		
May	May	May	
	Oct	Oct	Oct
	Jan	Jan	Jan
	Apr	Apr	Apr
		Sep	Sep
			Aug
			Nov
			Feb
			Dec

3.7 The July 8, 2013, Thunderstorm

On July 8, 2013, the Greater Toronto Area (GTA) faced two separate but back-to-back storm cells which slowed and stalled over the GTA. In two hours, the storms delivered more rain than the Environment Canada Toronto Pearson weather station usually received in the entire month of July. The Toronto Pearson station received 126.0 mm of rain, breaking the previous record of 121.4 mm of rain which Hurricane Hazel delivered on October 15, 1954. The storm also set records for 30-minute and 1, 2, 6, and 12-hour rainfall amounts at Toronto Pearson (Environment Canada 2013).

There was extensive flooding in areas in the Etobicoke Creek, Mimico Creek, Humber River, and Don River watersheds. Very high water levels and very turbid water typified conditions at the 13 stations sampled on July 9, 2013 (Figure 66).

Figure 66. Conditions at Etobicoke Creek, in Brampton, and Mimico Creek on July 9, 2013 (courtesy of TRCA)

Water samples were collected on July 9, 2013, from 13 out of 46 RWMP water quality stations; the remaining 33 stations were sampled on July 20, 23, and 24, 2013. The data from July 9 were tested for differences from the data collected later in July. The box plot results of t-tests were arranged by those parameters that exhibited elevated levels on July 9, 2013 (Figure 67) and those that exhibited lower levels (Figure 68). This analysis serves as an example of the effect of torrential rainfall on water quality at TRCA stations.

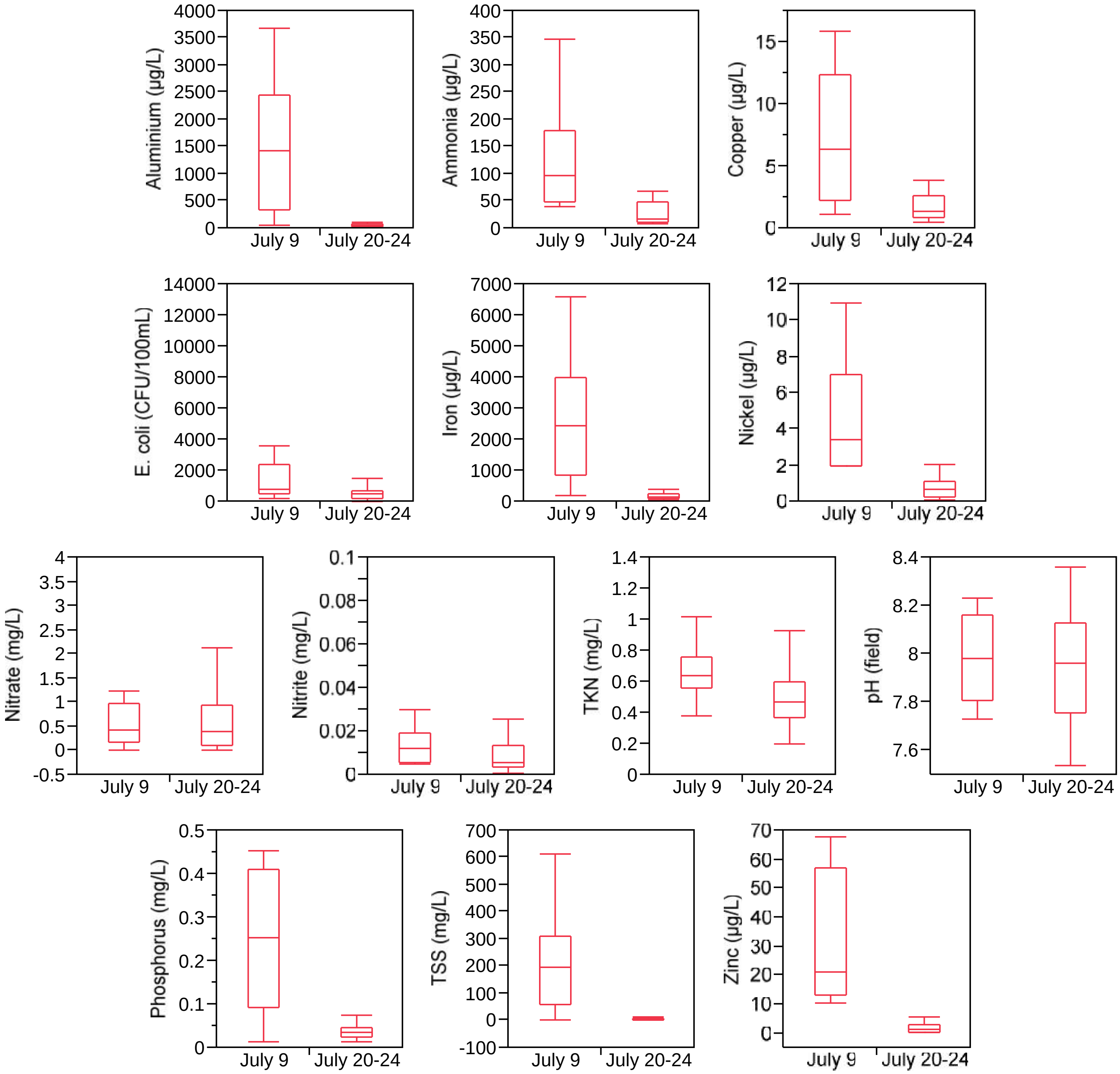


Figure 67. Boxplot results of 13 water quality parameters which displayed elevated concentrations on July 9, 2013

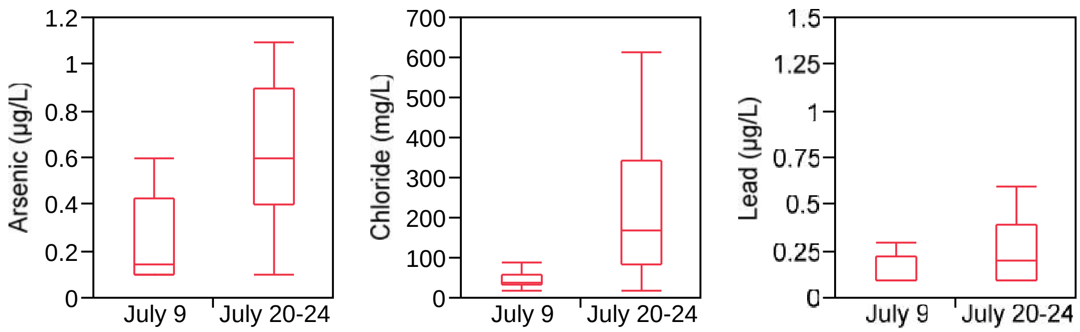


Figure 68. Boxplot results of 3 water quality parameters which did not display elevated concentrations on July 9, 2013

Of the 16 parameters discussed in this report, 13 parameters displayed elevated levels and 3 displayed lower levels on July 9, 2013. Of the 13 parameters with elevated levels, 5 parameters displayed insignificant increases and the other 8 were significantly higher (Table 22). The nitrogen constituents displayed elevated levels, however only ammonia was significantly higher. Two parameters, *E. coli* and TKN, were very close to demonstrating significant increases with *p* values of 0.08. Of the 3 parameters which exhibited lower levels on July 8, 2013, arsenic and chloride were significantly lower but lead was not (Table 23).

Table 22. t-test results for 13 water quality parameters sampled on July 9 and July 20, 23, and 24, 2013

Parameter	*p* value
Aluminium	0.0001
Copper	0.0001
E. coli	0.08
Iron	0.0001
Nickel	0.0001
Nitrate	0.6822
Nitrite	0.27
TKN	0.0845
pH	0.6944
Phosphorus	0.0001
TSS	0.0001
Zinc	0.0001
Ammonia	0.002

Table 23. t-test results for 3 water quality parameters sampled on July 9 and July 20, 23, and 24, 2013

Parameter	*p* value
Arsenic	0.0005
Chloride	0.0013
Lead	0.1125

It may have been expected that more than 8 of the 16 parameters would be significantly elevated by the record-breaking storm. However, different precipitation levels and sampling lag time after the storm may account for why there were significant increases in only 8 parameters. Many stations sampled on July 9, 2013, were situated in areas which received very high precipitation, such as those stations in close proximity to Pearson International Airport. The 4 stations in the Rouge River and Duffins Creek watersheds were spared the record-breaking deluge and most likely received a more typical amount of rainfall. Thus, the July 9 data encompassed stations which received a range of rainfall, not just stations which received record-breaking rainfall. For example, Table 24 presents July 8, 2013, rainfall amounts at weather stations from Hamilton to Oshawa which ranged from 4.2 to 126.0 mm (Environment Canada 2014). Weather stations in the TRCA jurisdiction are in bold face and their precipitation amounts ranged from 51.5 to 126.0 mm. Note that Table 24 does not include precipitation data for the eastern TRCA watersheds (Petticoat Creek, Frenchman's Bay, Duffins Creek, and Carruthers Creek).

Table 24. Rainfall amounts on July 8, 2013, from various Environment Canada weather stations, from west to east. The stations in bold face are in the TRCA jurisdiction

Weather Station	Rainfall (mm)
Hamilton	4.2
Oakville	4.2
Toronto Pearson	**126.0**
Downsview	**65.8**
Richmond Hill	**19.8**
Toronto City	**96.8**
Toronto Island	**85.5**
East York	**51.5**
Oshawa	4.8

Stations were sampled 14 to 21 hours after the storm ended. It is possible that there were pulses of contaminants prior to, during, or after stations were sampled on July 9. For example, contaminants on impervious surfaces and agricultural fields may be immediately washed away by storm runoff, whereas contaminants in sewers and water treatment plants may be washed away only if and when sufficient rainfall over flows those systems. Finally, six stations sampled on July 9, 2013, were located in the headwaters of watersheds and the remaining seven stations were in the lower portion of watersheds. The localized intensity of the storm as well as the time required for stormwater runoff to flow down through the watersheds may have influenced the levels of water quality parameters at different stations. Precipitation can influence concentrations of water quality analytes. The long-term RWMP was designed to sample surface water quality irrespective of precipitation events, thus monitoring results will not reflect peak concentrations of analytes during or after storms.

4. Summary and Recommendations

This report represents a summary assessment and characterization of 16 water quality parameters collected throughout 2013. Sampling was performed irrespective of precipitation, and it was expected that levels of many of the parameters presented in this report would be higher when mobilized by storm events. Data from stations sampled the day after a record-breaking rainstorm proved this expectation to be true. The overall higher precipitation in 2013 may have contributed to elevated levels of water quality parameters compared to 2012.

Generally, water quality stations situated in urbanized areas displayed high chloride, metals, *E. coli*, and phosphorus concentrations. Similar to previous years, areas of concern in 2013 were Mimico Creek, the mid and low Don River, and the lower portions of Etobicoke Creek, Humber River, and Rouge River.

The Etobicoke Creek watershed exhibited high chloride and *E. coli* values, with the Mayfield station also displaying high nitrate, TKN, and phosphorus values. The Mimico Creek watershed was characterized by high chloride, TSS, *E. coli*, copper, and zinc levels. The upper Humber River watershed exhibited better water quality than the mid and low portion. The mid and low Humber River was characterized by high chloride, nitrite, TKN, *E. coli*, iron, and nickel concentrations. The Don River displayed elevated chloride, TSS, *E. coli*, ammonia, nitrate, nitrite, TKN, and iron levels. The Rouge River watershed exhibited high *E. coli*, aluminium, and phosphorus levels, with the lower portion also having elevated chloride and TSS. Petticoat Creek and Frenchman's Bay were characterized by high chloride and *E. coli* levels.

Less urbanized and/or upper portions of watersheds did not display high concentrations of most water quality parameters, but some still had high phosphorus levels. Overall, Duffins Creek had the best water quality, followed by the upper Humber River and Carruthers Creek.

The water quality parameters with the most numerous occurrences of high concentrations were iron, *E. coli*, nickel, TSS, chloride, copper, zinc, arsenic, nitrite, aluminium, ammonia, and phosphorus. Factors that contribute to impaired water quality are urbanized areas, road density, agricultural areas, compromised sewage systems, and stormwater runoff. The cumulative influence of these factors degrades water quality at stations situated lower in watersheds.

Water quality samples were collected the day after the July 8, 2013, record-breaking storm. The impact of up to 126.0 mm of rain delivered in only two hours was pronounced. Eight parameters demonstrated significantly higher concentrations and two demonstrated significantly lower concentrations. Aluminium, ammonia, copper, iron, nickel, phosphorus, TSS, and zinc displayed elevated levels compared to stations sampled on July 20, 23, and 24, 2013. *E. coli* and TKN concentrations were close to being significantly higher (p=0.08). Nitrate, nitrite, and pH levels appeared higher on July 9 but were not significantly higher. Arsenic and chloride demonstrated significantly lower concentrations on July 9, whereas lead appeared decreased but was not significantly lower.

The stations sampled on July 9 received different precipitation amounts across the TRCA jurisdiction, with the eastern watersheds receiving lower amounts of rainfall. Contaminants originating on impervious surfaces and agricultural lands may have been washed into aquatic systems by storm runoff more quickly compared to other contaminants. Stations were sampled 14 to 21 hours after the storm ended and it is possible that there were pulses of contaminants prior to, during, and after stations were sampled on July 9.

In 2013, five stations were added to Etobicoke Creek to fill data gaps in this watershed. These stations were included in the 2013 data analysis but were not included in the five year analysis. Newly established stations will be included long-term data assessments once they have been sampled for five years.

One year of data (n=12) may be skewed by one or two high samples whereas five years of monthly water quality data provides sufficient sample size (n=60) such that the influence of a few high samples will be reduced. Annual data represents the conditions for that year whereas five-year data represents long-term conditions at stations, in watersheds, and across the jurisdiction. Annual surface water quality reports should compare the annual water quality results to the most recent five-year period in order to compare the most recent year to long-term patterns.

There may be value in grouping historical data in three to five year periods for comparison purposes. For example, the RWMP began sampling in 2001, therefore 2001-2005 and 2006-2010 represent the first and second five-year period, respectively. When 2015 water quality data are available, the third period 2011-2015 will be complete. Having three five-year periods of water quality data would facilitate the beginning of investigating long-term trends and patterns where the effects of seasonality and interannual variation are reduced.

Seasonal trends in water quality parameters should be investigated further. This report began examination of this issue by plotting box plots for five years of monthly data, from which some seasonal effects were elucidated. Further analysis could use a longer period of data, for example using data from 2001 to 2013 would provide 12 years of data. Analyte data for a specific month or season could be regressed against rainfall and snowfall to further investigate seasonal relationships between precipitation and contaminant levels.

In support of TRCA's The Living City Report Card, the CCME's Water Quality Index (WQI) scores and grades were calculated for each watershed. The WQI calculator measures the frequency and amplitude of analyte values which exceed the guidelines. The WQI should be calculated each year for inclusion in annual surface water quality reports. The WQI uses a slightly different set of water quality parameters, a four-year period of data, and produces one score or grade which represents the watershed for that period, which differs from analyses normally used in annual reports. The WQI is useful in scoring/grading analyte exceedances in a top down manner which characterizes each watershed and the jurisdiction.

Sites which were frequently cited as having substantial water quality issues over the years should be analyzed for temporal trends from 2001 to the current year. It would be interesting to know if analyte concentrations increased over the years or are simply high each year in comparison to other TRCA sites.

The RWMP samples water quality stations typically in the third week of each month independent of precipitation. Additional sampling of both dry and wet events for select stations may provide new information regarding the range of concentrations which are influenced by precipitation. Also, the availability, frequency, and distribution of TRCA rain gauge data should be investigated in order to have finer resolution precipitation data for not only RWMP water quality stations, but also for all other sites or stations which are monitored by RWMP.

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Appendix A
2013 Water Quality Stream Conditions from Field Notes

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80006	Partially Frozen	Turbid, High, rain/snow event	Turbid, Slightly High	Slightly Turbid, Slightly High	Clear	Clear	Turbid, Very High	Clear	Clear	Turbid Slightly	High Slightly	Frozen Partly
80007	Partially Frozen	Partly Frozen, Clear	Clear	Clear, Normal	Clear	Clear	Clear	Normal	Slightly Turbid	Clear	Clear	Clear
82003	Frozen	Turbid, High, rain/snow event	Clear	Slightly Turbid, High	Slightly High	Clear	Turbid, High	Clear	Clear	Clear	Clear	Frozen
83002	Clear, Normal	Clear	Slightly Turbid, Slightly High	Turbid, Slightly High	Clear	Clear	Turbid, Flooded, Unable to measure depth & hyd head as samples taken from top of bridge	Clear, Low	Slightly Turbid	Clear	Clear	Frozen Partly
83004	Clear, Normal	Clear	Turbid	Slightly Turbid, Slightly High	Clear	Slightly Turbid	Clear	Clear	Slightly Turbid	Clear, Religious Offerings	High Slightly	Frozen Partly
83009	Partially Frozen	Clear	Clear	Turbid, High	Clear	Turbid, High	Turbid, Flooded	Clear, Very Low	Clear	Clear	Clear	Frozen
83012	Partially Frozen	Turbid, High, rain/snow event	Clear	Turbid, High	Clear	Clear	Turbid, High	Clear	Clear	Clear	Clear	Frozen
83018	Partially Frozen	Frozen	Clear	Clear, Normal	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
83019	Frozen	Turbid, High, rain/snow event	Turbid, High	Slightly Turbid, High	Slightly Turbid	Clear	Clear	Clear	Clear	Clear	Clear	Frozen

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
83020	Partially Frozen	Clear	High	Turbid, High	Clear, Slightly High	Clear	Turbid, Very High, Unable to measure depth & hyd head as samples taken from top of bridge	Clear	Clear	Clear	Clear	Frozen Slightly, Clear
83103	Partially Frozen	Partly Frozen, Clear	Slightly Turbid, Slightly High	Slightly Turbid	Clear, Low	Clear, Slightly High	Clear	Clear	Clear	Clear	Turbid, High	Frozen
83104	Frozen	Frozen	Clear	Clear	Clear	Clear	Clear	Clear, Low	Clear	Clear	Turbid, High	Frozen
85003	Partially Frozen	Slightly Turbid, High, rain/snow event	Slightly Turbid, Slightly High	Slightly High	Clear	Clear	Clear	Clear, Low	Clear	Clear, Religious Offerings	Turbid, High	Frozen
85004	Partially Frozen	Clear, rain/snow event	Turbid, High	Slightly Turbid, Slightly High	Clear	Clear	Turbid, Flooded	Clear, Low, Religious Offerings	Clear	Clear, Religious Offerings	Turbid, High	Open Partially
85014	Partially Frozen	Turbid, High, rain/snow event	Clear	Slightly Turbid	Clear	Clear	Clear	Clear, Low	Clear	Clear	Turbid, High	Frozen
94002	Partially Frozen	Clear	Clear	Turbid, Slightly High	Clear	Clear	Turbid, Slightly High	Clear, Low	Clear	Clear	Turbid, High	Clear
97003	Partially Frozen	Clear	Slightly Turbid	Clear, Normal	Turbid, High due to rain event	Clear	Clear, Low	Clear, Low	Clear	Clear	Turbid, High	Frozen Slightly
97007	Partially Frozen	Partly Frozen, Clear	Slightly Turbid, High	Clear, Normal	Turbid, High due to rain event	Clear	Clear	Clear, Low	Clear	Clear	Turbid, High	Frozen
97011	Lots of slush moving down-stream	Turbid	Turbid, High	Religious Offering	Turbid, High due to rain event	Clear	Clear	Turbid (cloudy, fine clay)	Clear	Clear	Clear	Frozen Partly

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
97013	Partially Frozen	Frozen	Turbid, High	Slightly Turbid, Slightly High	Turbid, High due to rain event	Clear	Clear	Clear	Clear	Clear	Clear	Frozen Partly
97018	Partially Frozen	Partly Frozen, Clear	Slightly Turbid	Clear, Normal	Turbid, High due to rain event	Clear, Low, beaver dam possibly gone	Clear	Clear, Low	Clear	Clear	Turbid Slightly, High, Beaver Dam Upstream	Frozen
97777	Partially Frozen	Clear	Slightly Turbid	Clear, Normal	Turbid, High, rain event	Turbid, High	Clear	Clear, Low	Slightly Turbid	Clear	Clear	Frozen Partly
97999	Frozen	Frozen	Slightly Turbid	Clear, Normal	Turbid, High due to rain event	Turbid, Very High	Clear	Normal	Clear	Clear	Clear	Frozen Partly
104001	Partially Frozen	Clear	Slightly Turbid, Slightly High	Slightly Turbid	Turbid, High due to rain event	Clear	Clear, Normal	Clear	Clear	Clear	Turbid, High	Frozen
104008	Partially Frozen	Partly Frozen, Clear	Clear	Clear, Normal	Turbid, High due to rain event	Clear	Clear, Normal	Clear, Low	Clear	Clear	Turbid, High, Beaver Dam Upstream	Frozen
104023	Partially Frozen	Frozen	Clear, Slightly High	Clear, Normal	Slightly Turbid, Slightly High	Clear	Clear	Clear	Clear	Clear	Turbid, High	Frozen
104025	Partially Frozen	Frozen	Slightly Turbid, Slightly High	Slightly Turbid, High	Turbid, High due to rain event	Clear	Clear	Clear	Clear	Clear	Turbid, High	Frozen
104026	Frozen	Frozen	Clear, High	Clear, Normal	Slightly High	Clear	Clear	Clear, Low	Clear	Clear	Turbid Slightly, High	Frozen

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
104027	Partially Frozen	Frozen	Slightly Turbid, High	Slightly Turbid, High	Turbid, High due to rain event, Religious Offering, Flowers	Clear	Turbid, Flooded, sample taken DS due to restricted access (fallen trees), Unable to measure depth & hyd head	Clear	Clear	Clear	Clear	Frozen
104028	Frozen	Partly Frozen, Clear	Clear, Slightly High	Slightly High	Clear, Slightly High	Clear	Turbid, Flooded, Unable to measure depth & hyd head as samples taken from top of bridge	Clear, Low	Clear	Clear	Clear	Frozen
104029	Frozen	Partly Frozen, Clear	Clear	Slightly High	Slightly Turbid, Slightly High	Clear	Turbid, Flooded, sample taken DS due to restricted access (fallen trees), Unable to measure depth & hyd head	Clear	Clear	Clear, Religious Offerings	Clear	Frozen
104037	Frozen	Frozen	Clear	Clear, Normal	Turbid, High due to rain event	Clear	Clear	Clear, Low, Religious Offerings	Slightly Turbid	Clear	Turbid Slightly	Frozen Partly
107002	Frozen	Clear	Turbid, High	Clear, Normal	Turbid, High due to rain event	Slightly Turbid	Clear	Clear	Slightly Turbid	Clear	Clear	Frozen
DM 6.0	Frozen	Slightly Turbid, High, rain/snow event	Clear	Slightly Turbid, Slightly High	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
DN008WM	Partially Frozen	High, rain/snow event	Clear, Normal	Clear, Normal	Clear	Clear	Clear	Clear	Clear	Wet Event, Slightly Turbid	Clear	Frozen
FB003WM	Frozen	Clear	Clear	Slightly High	Slightly Turbid, Slightly High	Clear	Turbid, Flooded, Wet event, Staff Gauge > 1000 mm	Clear, Dry Event	Slightly Turbid	Dry Event, Clear	Turbid Slightly	Frozen

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HU010WM	Clear, Normal	Clear	Slightly Turbid	Turbid, High	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
HU1RWMP	Clear, Normal	Clear	Clear	Clear, Normal	Clear	Clear	Clear	Clear, Low	Clear	Clear	High	Frozen
Little Etob CK	NS	NS	NS	NS	NS	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
Lower Etob US	NS	NS	NS	NS	NS	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
Mayfield	Partially Frozen	Religious Offering, Partly Frozen, Clear	High	Slightly High	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
MM003WM	Partially Frozen	Clear	Clear	Clear, Normal	Slightly Turbid, Slightly High	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
PT001WM	Partially Frozen	Clear	Clear, High	Clear, Normal	Slightly High	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
Spring Creek	NS	NS	NS	NS	NS	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
Tributary 3	NS	NS	NS	NS	NS	Clear	Clear	Clear	Clear	Clear	Clear	Frozen
Tributary 4	NS	NS	NS	NS	NS	Clear	Clear	Clear	Clear	Clear	Clear	Frozen

Appendix B
Stations Sampled in 2013 during Precipitation Events.

Samples were considered collected during precipitation events if field notes indicated precipitation at the time of sampling. “P” indicates samples collected during precipitation events and “NS” indicates stations or months not sampled.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Precipitation Samples	No Precipitation Samples
97777			P		P						P		3	9
97999			P		P						P		3	9
06008000602		P		P									2	10
06008000702													0	12
06008200302		P		P	P								3	9
06008300202			P	P									2	10
06008300402			P	P									2	10
06008300902				P							P		2	10
06008301202		P		P									2	10
06008301802													0	12
06008301902		P		P									2	10
06008302002			P	P	P						P		4	8
06008310302			P			P							2	10
06008310402													0	12
06008500302		P		P									2	10
06008500402		P		P									2	10
06008501402		P											1	11
06009400202				P		P					P		3	9
06009700302			P		P						P		3	9
06009700702			P		P						P		3	9
06009701102		P	P		P						P		4	8
06009701302				P	P						P		3	9
06009701802			P		P						P		3	9
06010400102			P	P	P						P		4	8
06010400802					P						P		2	10
06010402302					P						P		2	10
06010402502			P	P	P						P		4	8
06010402602					P						P		2	10
06010402702			P	P	P						P		4	8
06010402802			P	P	P						P		4	8

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Precipitation Samples	No Precipitation Samples
06010402902				P	P						P		3	9
06010403702					P						P		2	10
06010700202			P		P						P		3	9
DM 6.0		P		P									2	9
DN008WM		P											1	11
FB003WM				P	P						P		3	9
HU010WM			P			P							2	10
HU1RWMP			P			P							2	10
Little Etob CK	NS	NS	NS	NS	NS								0	7
Lower Etob US	NS	NS	NS	NS	NS								0	7
Mayfield			P	P			P	P		P			5	7
MM003WM					P								1	11
PT001WM					P						P		2	10
Spring Creek	NS	NS	NS	NS	NS								0	7
Tributary 3	NS	NS	NS	NS	NS								0	7
Tributary 4	NS	NS	NS	NS	NS								0	7
											Total:		100	427

Appendix C

	Mean Monthly Analyte Values															
Month	Chloride	TSS	pH	Aluminium	Arsenic	Copper	Iron	Lead	Nickel	Zinc	E. coli	Ammonia	Nitrate	Nitrite	TKN	Phosphorus
Jan	815.4	21	8	115.4	0.3	2.8	353.8	0.8	1	10.7	813.6	189	1	0.03	0.6	0.05
Feb	804.6	12.4	8.1	103.7	0.3	3.5	304.5	0.6	0.8	11.3	533.8	152	1.1	0.02	0.5	0.03
Mar	360.1	47.7	8.1	10124.6	0.3	3.1	539.6	0.7	0.9	8.1	1009.5	76.8	1	0.02	0.6	0.09
Apr	222.3	23.8	8.2	7355	0.4	3.1	380	0.7	1.2	8.9	528.1	49.6	0.8	0.01	0.5	0.05
May	189.4	31.5	8	17726.2	0.6	3	423.2	0.5	1.4	6.6	922.2	104.2	0.7	0.02	0.7	0.07
Jun	164.8	37.4	8	4802.8	0.6	3.2	552.8	1.1	1.4	9.6	1557.8	76.4	0.6	0.02	0.7	0.08
Jul	170.1	33.4	8	6325.7	0.7	2.8	448.5	1.1	1.4	8.5	938.7	69.2	0.5	0.02	0.6	0.07
Aug	157.2	11.8	8	4471.1	0.5	2	266.9	1.2	1.4	4.2	1320.4	74.1	0.5	0.01	0.5	0.04
Sep	146.7	14.4	8	3720.5	0.5	2.4	274.3	1.1	1.4	6.2	1269.2	56	0.5	0.01	0.6	0.04
Oct	127.2	14.8	8	5199.1	0.6	2.5	318.9	1.3	1.1	5.9	1024.4	39.4	0.7	0.02	0.5	0.05
Nov	163.4	13.4	8	1891	0.5	1.9	318.4	0.9	0.9	7.4	659.4	72.4	0.7	0.01	0.5	0.04
Dec	416.8	9.2	8	3296.6	0.3	2.2	333.1	0.6	1.4	6.5	1117.9	162.8	1.1	0.01	0.5	0.03