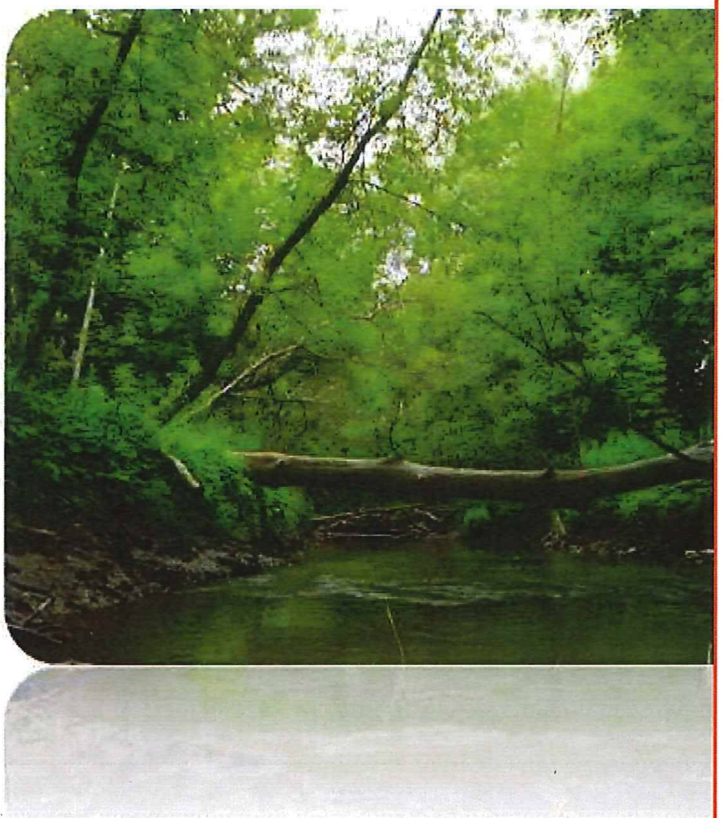

WATERSHED PLANNING
& ENGINEERING

January 2019

2017/2018 TRIBUTARY MONITORING FOR COOTES PARADISE

To support the Hamilton Harbour Remedial Action Plan

Hamilton Conservation Authority
Healthy Streams...Healthy Communities

Table of Contents

1. Background

This monitoring program aims to understand water quality contributions from creeks flowing into Cootes Paradise Marsh and ultimately, Hamilton Harbour. Establishing non-point sources of water quality inputs to the marsh, such as contributions from creeks and tributaries, is an important step in reaching the delisting objectives at a representative station located in the marsh. Once the relative sources of inputs are assessed, any needed remedial efforts in these tributaries that support delisting Hamilton Harbour can be determined.

The Hamilton Conservation Authority (HCA) has been involved with this water quality monitoring program in partnership with the Hamilton Harbour Remedial Action Plan (HHRAP), Ministry of the Environment, Conservation and Parks (MECP), and the City of Hamilton since spring of 2014. The monitoring program has been adapted from a previous sampling program undertaken by the Royal Botanical Gardens (RBG).

This program aims to explore water quality conditions in the sub-watersheds of Lower Spencer Creek, Chedoke Creek, Borers Creek, Ancaster Creek, and Sulphur Creek; their drainage areas can be seen on Figure 1-1.

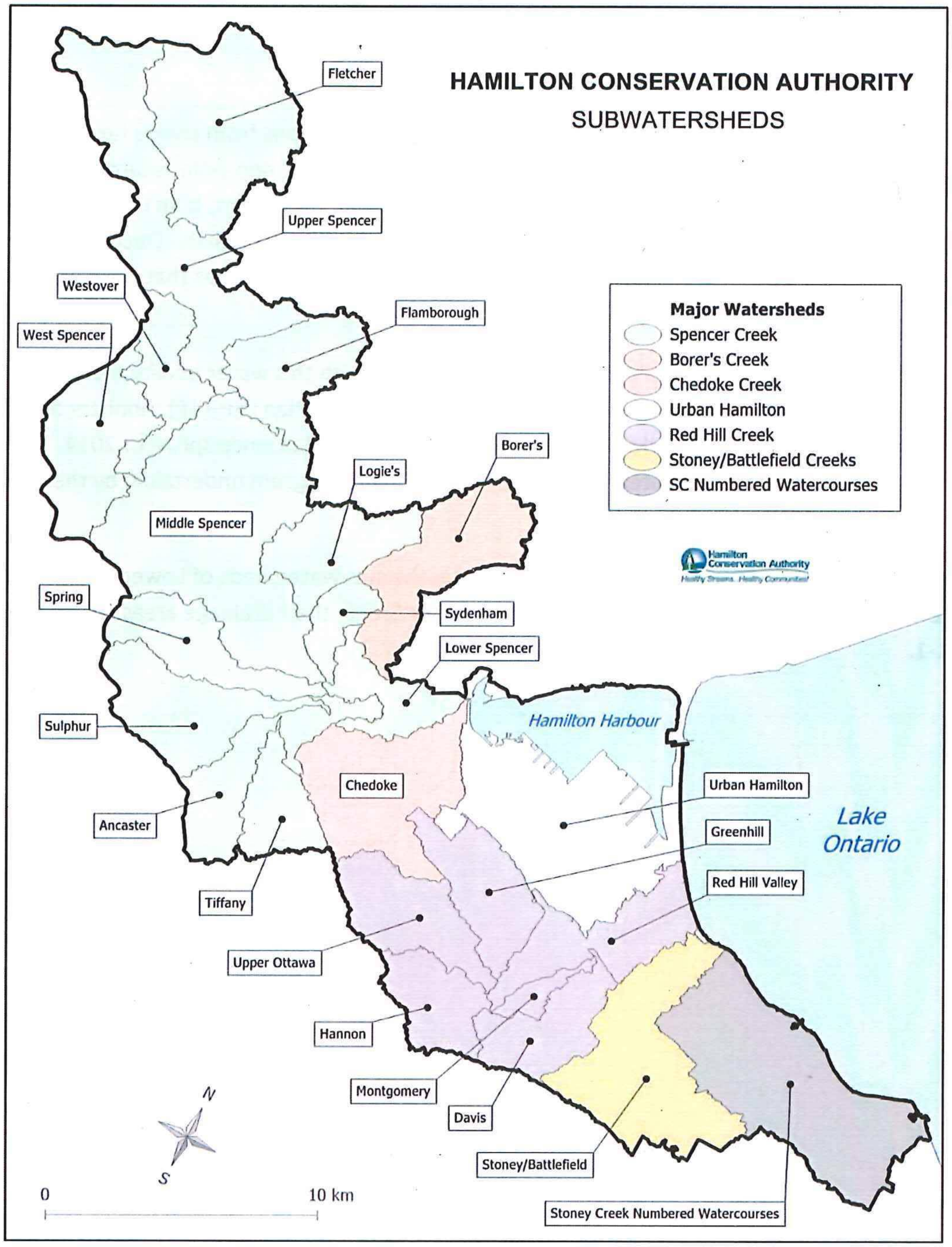

Figure 1-1: Hamilton Subwatersheds Surrounding Hamilton Harbour

2. Water Quality Monitoring Program

2.1 Program Objective

The project objective is to identify important contributions, as well as trends in contributions, to Cootes Paradise water quality from the creeks discharging into the marsh. This will also provide information to support where mitigation activities can best be applied to benefit the overall water quality within Cootes Paradise. As well, as part of a separate project for the Hamilton Harbour Remedial Action Plan (HHRAP), a nutrient loadings model is being developed for Cootes Paradise by the University of Toronto. This model could benefit from data collected by this monitoring program. The data will be shared with the Hamilton Harbour Remedial Action Plan office and/or technical committees associated with the HHRAP.

2.2 Previous Program Development

HCA assumed sampling responsibilities from RBG for the Lower Spencer Creek, Chedoke Creek, and Borers Creek grab sampling sites, to continue long term data analysis for these locations. These sites are known as CP-7, CP-11, and CP-18.1 (See Figure 2-1) and are located immediately upstream of the locations where they drain into the Cootes Paradise Marsh.

In addition, in 2014 the monitoring program was expanded to include four new grab sample sites to help characterize the water quality contributions coming from the Ancaster Creek sub-watershed (AC-1, AC-2, AC-3, and AC-4), which has relatively little water quality and flow data near the lower reaches of the sub-watershed boundaries.

In 2015, the monitoring program was further expanded to include an automated storm event sample site AC-1, using an ISCO automated composite sampler. However, storm event sampling at AC-1 was not undertaken in the winter months.

In 2016 the sampling period was lengthened to be year-round at all seven stations. Year round monitoring allowed for an enhanced view of water quality conditions throughout a wide variety of climate conditions.

2.3 Changes to the Water Quality Monitoring Program in 2017/18

Two more automated storm event sample sites were added by April 2017 (in Spencer Creek at Highway 5 and Spencer Creek at Market Street). In addition, a fourth automated storm event sample site was installed in November 2017 (in Ancaster Creek at Rousseaux Street). See Figure 2-2 for locations of the four automated storm event sample sites. Expanding storm event sampling will deepen the understanding of how land uses and conditions affect water quality during storm events.

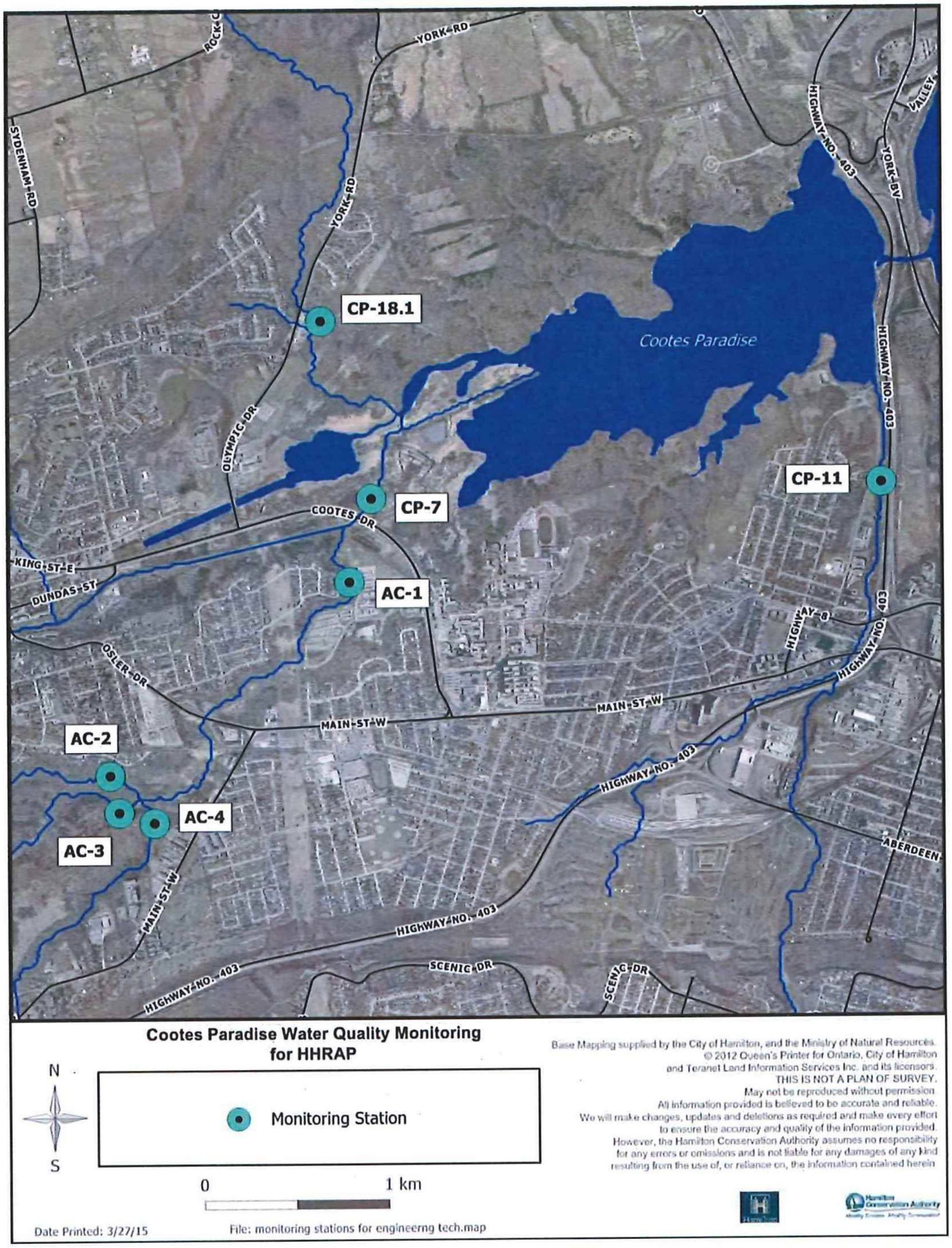

Figure 2-1: Water Quality Sampling Locations

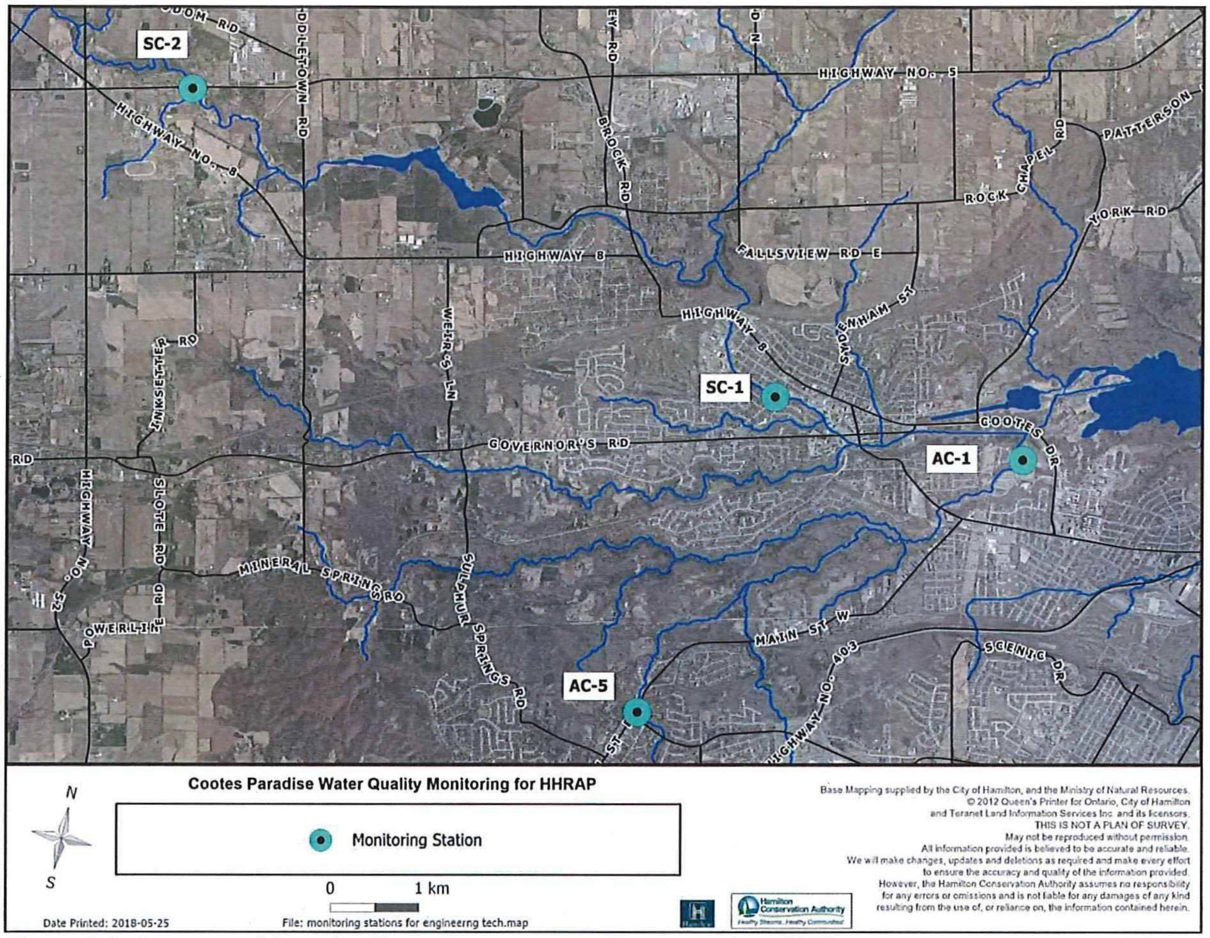

Figure 2-2: Automated Sampler Sites.

2.4 Description of Grab Sample Locations

Site AC-1 is on the main branch of Ancaster Creek just upstream of the confluence with Spencer Creek. This location is ideal to capture the nutrient and sediment contributions from the Ancaster Creek sub-watershed and its tributaries before entering Spencer Creek. Predominant land uses for the Ancaster Creek sub-watershed are residential, woodland with some light agricultural in the headwaters.

Site AC-2 is located on Sulphur Creek before the confluence with Ancaster Creek. Main land uses for the Sulphur Creek sub-watershed are woodland and residential with some agricultural in the upper headwaters.

Site AC-3 is located on the main branch of Ancaster Creek upstream of the confluence with Sulphur Creek.

Site AC-4 is located on an unnamed watercourse just upstream of the confluence with Ancaster Creek and has a relatively small drainage area which is mainly residential.

Site CP-7 is located on Lower Spencer Creek and is aimed at capturing inputs from the entire Spencer Creek Watershed and its tributaries including Ancaster Creek. Its dominant land uses are agricultural in the upper and middle reaches and residential in the lower reach below the escarpment.

Site CP-11 is located on Chedoke Creek before it drains in-to Cootes Paradise marsh. The Chedoke Creek sub-watershed is mostly residential land use with some industrial and a municipal golf course. Long reaches of the creek are piped and culverted with virtually no naturalized habitat.

Site CP-18.1 is located on Borers Creek just downstream of York Road in Dundas, upstream of the confluence with Spencer Creek. The Borers Creek sub-watershed dominant land uses are agricultural and residential.

2.5 Description of Automated Storm Event Sample Locations

Site AC-1 is on the main branch of Ancaster Creek just upstream of the confluence with Spencer Creek. This site is located at the same place bi-weekly grab samples are retrieved. Level weighted composite samples are made using a depth logger attached to the intake of the ISCO sampler. Difficulties obtaining reliable data from the ISCO Bubbler Flow Module prevented the continuous monitoring of flows throughout the sample period; however a depth logger was installed at the intake in place of the bubbler. Maintenance will be conducted to the intake and bubbler unit in 2018 in order to ensure the quality and accuracy of data and samples collected. At various points throughout the sample season, flows are manually measured at site AC-1 using a Marsh McBirney flow meter in order to establish a rating curve to estimate flows and thus loadings coming from Ancaster Creek before the confluence with Spencer Creek.

Site AC-5 is located on Ancaster Creek at the corner of Rousseaux Street and Wilson Street and is the furthest upstream site on Ancaster Creek. Land uses upstream of this site are residential, woodland, a golf course, and some light agricultural at the headwaters. Discharge weighted composite samples are made using data obtained from the Water Survey of Canada (WSC) gauge located at this site which provides water level data and a rating curve to determine discharge. This site is ideal to capture nutrients and sediments near the headwaters of Ancaster Creek, before other tributaries enter further downstream.

Site SC-1 is located on Spencer Creek at Market Street, downstream of the escarpment. Land uses upstream of this site include residential, industrial – aggregate mining, agricultural, and natural conservation land. This site is beneficial in capturing nutrient and sediment data from Spencer Creek downstream of the various tributaries which combine with the creek as it flows down the escarpment and before it receives inputs from the more urban tributaries that enter further downstream. Discharge weighted composite samples are made using data obtained for the WSC gauge that is also located at this site.

Site SC-2 is located on Spencer Creek at Highway 5 above the escarpment and upstream of SC-1. A WSC gauge is also located at this site and is used to develop discharge weighted composite samples for each event. The main land uses upstream of this site are rural residential, agricultural, and natural forested and wetland areas. Samples obtained at this site are beneficial in capturing runoff inputs from mainly agricultural land uses before the creek enters more urban development downstream.

2.6 Sampling Methodology

The 2017 water quality grab sample monitoring program occurred on alternate weeks from April 2017 to March 2018. Surface grab samples were taken during daylight hours with same day drop off for analysis at the City of Hamilton Regional Environmental Lab. Levels of phosphorus, *E. coli*, various nitrogen compounds, and suspended solids were measured. In addition, temperature, pH, conductivity, turbidity, and dissolved oxygen are measured on site by HCA staff at each sample site using a YSI 6600. A visual inspection of storm water outfalls in the area will also be completed if storm water conditions are suspected.

Chlorophyll-a is measured in an accredited laboratory once every three years (samples in 2013 and 2016 were analyzed for Chlorophyll-a). Chlorophyll-a is next scheduled to be measured in 2019.

Once lab analysis results are provided and reviewed, all individual grab samples with concentrations exceeding the water quality objectives are identified (for each sample location and each water quality parameter). Grab samples impacted by storm water conditions (wet events) are determined by reviewing precipitation data recorded at the Environment Canada precipitation monitoring station at Hamilton Airport Climate ID 6153193. If more than 4 mm of rainfall occurs within the 24 hours prior to sampling, that sample is classified as a wet event sample, while all other samples are classified as a dry event or baseflow sample.

Annual and seasonal average overall grab sample concentrations are identified (for each sample location and each water quality parameter). Also, these average concentrations are further analyzed to determine the annual and seasonal average sample concentrations for wet events and dry events.

Furthermore, long-term trends in the overall, wet event and baseflow (dry) average grab sample concentration are determined (for each sample location and each water quality parameter).

The four automated storm event sample locations capture water quality information specifically during storm events. The ISCO automated sampler is triggered prior to a storm event to take a 1 L sample every hour from the time of initiation. With 24 sample bottles in the ISCO carousel, it will be possible to capture a 24 hour time period of the storm and its effect on the water quality at each watercourse site. A level or discharge weighted composite sample is obtained.

2.7 Water Quality Objectives

Samples were analyzed for the water quality parameters listed in Table 2-1. Objectives to ensure that water quality is satisfactory for aquatic life were based on Provincial Water Quality Objectives (PWQO, MOE 1999), Canadian Water Quality Guidelines (CWQG) outlined by the Canadian Council of Ministers of the Environment (2001) and HHRAP interim water quality objective (RAP office 2012). A description of each parameter is provided below.

Table 2-1: Water quality parameters and their desired objective

Parameter	Units	Target/Objective	Reference
Unionized Ammonia	mg/L	0.02 mg/L	HHRAP/PWQO
Nitrate as N	mg/L	3 mg/L	CWQG
Nitrite as N	mg/L	0.06 mg/L	CWQG
o-Phosphate as P	mg/L	n/a	
Total Phosphorous	mg/L	0.03 mg/L	PWQO
Total Suspended Solids	mg/L	25 mg/L	HHRAP
Volatile Suspended Solids	mg/L	n/a	
Escherichia coli	CFU/100mL	100 CFU/100mL	PWQO

Total Phosphorous

Total Phosphorous (TP) is commonly found in fertilizers, manure and organic wastes in sewage and industrial effluent. It is an essential nutrient for aquatic plants, but in excess can cause eutrophication and algae blooms. Soil erosion is a main contributor of TP in surface waters, as phosphorous tends to attach to soil particles.

Unionized Ammonia

Ammonia is the preferred nitrogen containing nutrient for plant growth, yet it can also cause algal blooms and can be acutely toxic to fish in high concentrations. In water, ammonia occurs in two forms; ionized and unionized ammonia. This difference is important to know because NH_3, un-ionized ammonia, is the form more toxic to fish. Both water temperature and pH control which form of ammonia is predominant at any given time in an aquatic system.

Nitrate

Nitrates are an essential nutrient for regulating plant life but can cause degraded water quality in excess concentrations. The target concentration for nitrates in this study is based on the Canadian Water

Quality Guideline (CWQG) of 3.0 mg/L of nitrate as N. Typically nitrate concentrations tend to be low during base-flow conditions; however runoff from fertilizer, waste water treatment plants, and storm sewer outfalls can bring the concentration of nitrates up to and beyond the target for water quality.

Nitrite

For this study, we've adopted the Canadian Water Quality Guideline (CWQG) target of 0.06 mg/L as N.

Total Suspended Solids

Targeted concentrations of Total Suspended Solids (TSS) vary depending on the system being monitored. TSS thresholds are established by understanding the underlying background levels of a site which may or may not have clear flow during base-flow conditions. Storm events move sediment downstream and therefore TSS values are expected to be much higher during these events. Since background levels of TSS is unavailable for the majority of the sites sampled, the Hamilton Harbour Remedial Action Plan interim target of 25 mg/L was used as the target for TSS (RAP office 2012).

Volatile Suspended Solids

Volatile Suspended Solids (VSS) represent the organic portion of TSS. There is no current target set for Volatile Suspended Solids for the HHRAP or PWQO's. However understanding the make-up of solids (organic vs. inorganic) can help us in determining appropriate remedial actions.

Escherichia coli

E. coli is well known to have harmful effects on human health when found in the environment at certain concentrations. There are strict guidelines for *E. coli* targets for drinking and recreational purposes. Since there is little to no background data for the majority of the sites, we will be comparing the geometric mean concentration from each site to the PWQO of 100 CFU/100 mL (MOE 1999), the target for recreational purposes.

2.8 Adopted Analysis Seasons

For analysis, HCA has adopted the following start and end dates for the four seasons.

Table 2-2: HCA Adopted Seasons

Season	Start Date	End Date
Spring	Middle of March	End of June
Summer	Beginning of July	Middle of September
Fall	Middle of September	End of December
Winter	Beginning of January	Middle of March

3. 2017-2018 Water Quality Results – Grab Samples

The sampling period reported in this document covers April 2017 – March 2018. A total of 26 biweekly grab samples were taken at each location. Due to the timing of rain events and the set schedule, 5 out of 26 samples (19%) were taken during wet event conditions.

3.1 Rainfall Data

Table 3.1-1 displays the 2017/2018 grab sample days, the previous 24 hour rainfall amounts, and whether or not the grab sample was classified as wet event or dry event (baseflows).

Table 3.1-1: Rainfall totals on grab sample dates at all sampling locations in 2017/18

Dates	Previous 24 hr. Rainfall (mm)	Classification
April 12, 2017	2.2	DRY
April 27, 2017	2.2	DRY
May 11, 2017	0	DRY
May 24, 2017	7.4	WET
June 7, 2017	11.4	WET
June 21, 2017	2.4	DRY
July 5, 2017	0	DRY
July 19, 2017	0	DRY
July 27, 2017	15.2	WET
August 16, 2017	2.2	DRY
August 30, 2017	0	DRY
September 15, 2017	0	DRY
September 27, 2017	1	DRY
October 11, 2017	7.4	WET
October 25, 2017	6.2	WET
November 8, 2017	0	DRY
November 22, 2017	0	DRY
December 6, 2017	0	DRY
December 20, 2017	0	DRY
January 3, 2018	0	DRY
January 17, 2018	0.2	DRY
February 13, 2018	0	DRY
February 14, 2018	0	DRY
February 28, 2018	0	DRY
March 14, 2018	0	DRY
March 28, 2018	3.6	DRY

3.2 Total Phosphorus

Total Phosphorus (TP) grab sample concentrations for the 2017/18 season are summarized in Table 3.2-1. Results in red text indicate an exceedance of the PWQO of 0.03 mg/L.

Table 3.2-2 lists the proportion of the grab samples that exceeded the PWQO for each site, broken down individually for wet event samples, dry event samples, and all samples. For example, for AC-2, 19.0% of dry event grab samples exceeded 0.03 mg/L.

Elevated TP concentrations were observed at all sites, indicating TP impairment throughout the watershed. Exceedances were common throughout the sampling year. CP-11 experienced very high TP concentrations, with all of the grab samples significantly exceeding the PWQO. Site AC-4, a creek with less flow than the other locations which feeds into Ancaster Creek, routinely exceeds the PWQO as well. The other Ancaster sites, AC-1, AC-2, and AC-3 experience lower TP concentrations and exceedances, with total exceedances of 31%, 23.1%, and 38.5% respectively. CP-7 and CP-18.1 had TP concentrations that exceed the objective for over half of the total grab samples collected (64% and 73% respectively). Site AC-2 had the best water quality out of all locations; this particular sample site is located within a vegetated floodplain.

At individual sites, samples taken during wet events tended to have concentrations exceeding the PWQO more often than dry event (baseflow) samples. This is expected to be due to increased surface runoff and surface / channel erosion during wet events contributing to elevated amounts of TP in the creeks. The exceptions were CP-11 and CP-18.1, where the wet event and dry event exceedances of the PWQO were similar. The greatest difference in the proportion of wet event versus dry event grab samples that exceeded the objective was at AC-1 and AC-3, where 80% of wet event samples exceeded but only 19 to 29 % of dry event samples exceeded the objective. Also, of the total samples collected across all the sites during the 5 wet events, 82.9% exceeded the PWQO; whereas of all the samples collected at all the sites during the 21 dry events, 47.2% exceeded the objective.

Table 3.2-1: Total Phosphorus Concentrations (mg/L) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classification	24 hr. Precip. (mm)
4/12/2017	0.023	0.026	0.021	0.025	0.042	1.050	0.035	DRY	2.2
4/27/2017	0.015	0.021	0.015	0.024	0.029	0.130	0.023	DRY	2.2
5/11/2017	0.018	0.029	0.016	0.021	0.028	0.294	0.022	DRY	0
5/24/2017	0.014	0.028	0.024	0.047	0.024	0.283	0.028	WET	7.4
6/7/2017	0.032	0.025	0.040	0.032	0.040	0.454	0.063	WET	11.4
6/21/2017	0.121	0.130	0.064	0.063	0.069	0.293	0.074	DRY	2.4
7/5/2017	0.040	0.048	0.049	0.046	0.044	0.466	0.042	DRY	0
7/19/2017	0.045	0.044	0.038	0.065	0.057	0.359	0.037	DRY	0
7/27/2017	0.047	0.040	0.039	0.044	0.054	0.484	0.040	WET	15.2
8/16/2017	0.025	0.015	0.028	0.028	0.057	0.540	0.044	DRY	2.2
8/30/2017	0.016	0.022	0.024	0.032	0.036	0.630	0.046	DRY	0
9/15/2017	0.024	0.020	0.028	0.042	0.050	0.740	0.047	DRY	0
9/27/2017	0.029	0.016	0.046	0.059	0.045	0.709	0.054	DRY	1
10/11/2017	0.044	0.030	0.046	0.080	0.054	0.742	0.052	WET	7.4
10/25/2017	0.033	0.024	0.042	0.069	0.050	0.485	0.050	WET	6.2
11/8/2017	0.025	0.020	0.028	0.047	0.035	0.278	0.040	DRY	0
11/22/2017	0.022	0.020	0.020	0.043	0.041	0.495	0.041	DRY	0
12/6/2017	0.018	0.013	0.018	0.039	0.026	0.377	0.026	DRY	0
12/20/2017	0.018	0.017	0.017	0.033	0.023	0.276	0.025	DRY	0
1/3/2018	0.016	0.017	0.018	---	---	---	0.023	DRY	0
1/17/2018	0.029	0.022	0.039	0.050	0.053	0.202	0.059	DRY	0.2
2/13/2018	0.025	0.029	0.032	0.052	0.028	0.708	0.032	DRY	0
2/14/2018	0.024	0.025	0.023	0.046	0.021	0.496	0.031	DRY	0
2/28/2018	0.067	0.089	0.047	0.066	0.041	0.276	0.063	DRY	0
3/14/2018	0.026	0.028	0.026	0.043	0.029	0.696	0.025	DRY	0
3/28/2018	0.020	0.025	0.018	0.031	0.016	0.951	0.054	DRY	3.6
Dry Events (mean)	0.030	0.032	0.029	0.042	0.038	0.506	0.0403		
Wet Events (mean)	0.034	0.029	0.038	0.054	0.044	0.490	0.0466		
Total Mean	0.031	0.032	0.031	0.045	0.040	0.497	0.0414		

Table 3.2-2: Proportion of Grab Samples that Exceeded the PWQO

Site	Total Exceedance	Dry Exceedance	Wet Exceedance
AC-1 Ancaster Ck upstream of Spencer Ck	30.8%	19.0%	80.0%
AC-2 Sulphur Ck	23.1%	19.0%	40.0%
AC-3 Ancaster Ck upstream of Sulphur Ck	38.5%	28.6%	80.0%
AC-4 unnamed trib. of Ancaster Ck	84%	80%	100.0%
CP-7 Spencer Ck	64%	60%	80.0%
CP-11 Chedoke Ck	100.0%	100.0%	100.0%
CP-18.1 Borers Ck	73.1%	71.4%	80.0%

An analysis of average TP concentrations was also conducted. Figure 3.2-1 shows the TP average concentrations for wet event, baseflow (dry) event, and total grab samples. Figure 3.2-2 shows the same information for site CP-11. The separation of this data was done due to the large difference in TP values between CP-11 and the other sites.

Each site experienced total average TP concentrations above the PWQO of 0.03 mg/L. That said, AC-1, AC-2, and AC-3 also have wet, dry, and total averages that are near the PWQO. Sites AC-1 and AC-3 are the only sites with dry day sample averages at or below the target objective.

Site CP-11 has the highest TP averages, by a significant margin. Site AC-4 has the second highest total TP average. AC-4 has a relatively small drainage area compared to AC-2 and AC-3 that originates about 2.5 kilometers upstream of the sample location and the land use is mostly urban residential, in particular a number of apartment buildings.

CP-7 and CP-18.1 average TP concentrations exceed the objective for dry event, wet event, and total samples.

Based on these figures it can be seen that on average TP is typically higher for wet event samples, with the exception of sites AC-2 and CP-11 which experienced lower average TP concentrations during wet events.

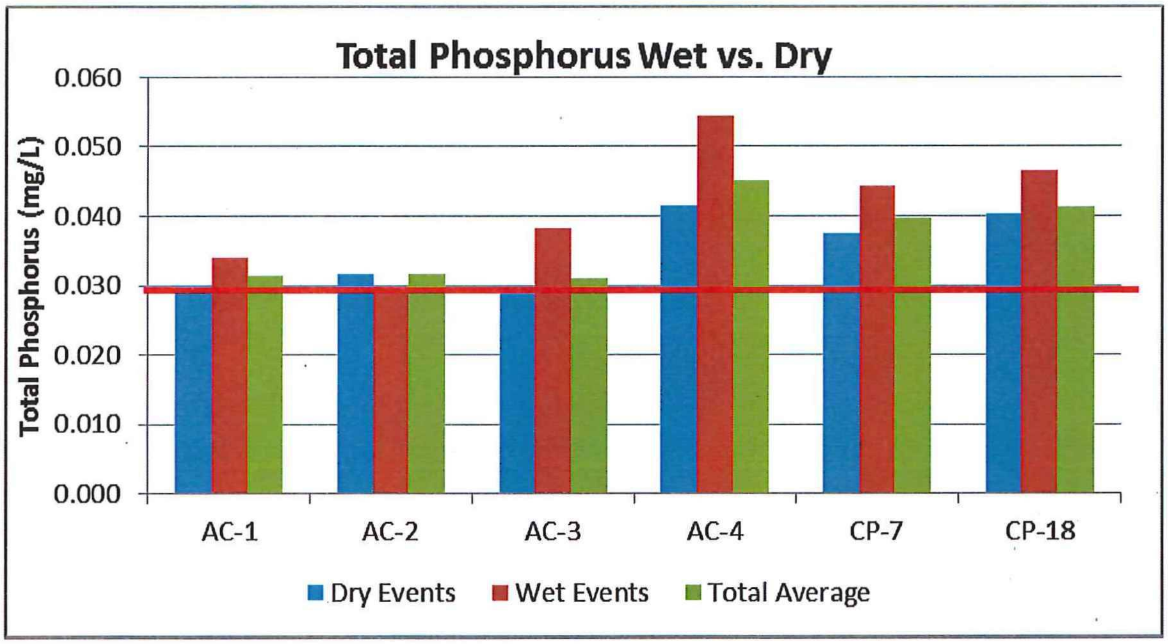

Figure 3.2-1: Total Phosphorus Average Concentration at each site for wet event, dry event, and total *grab samples*

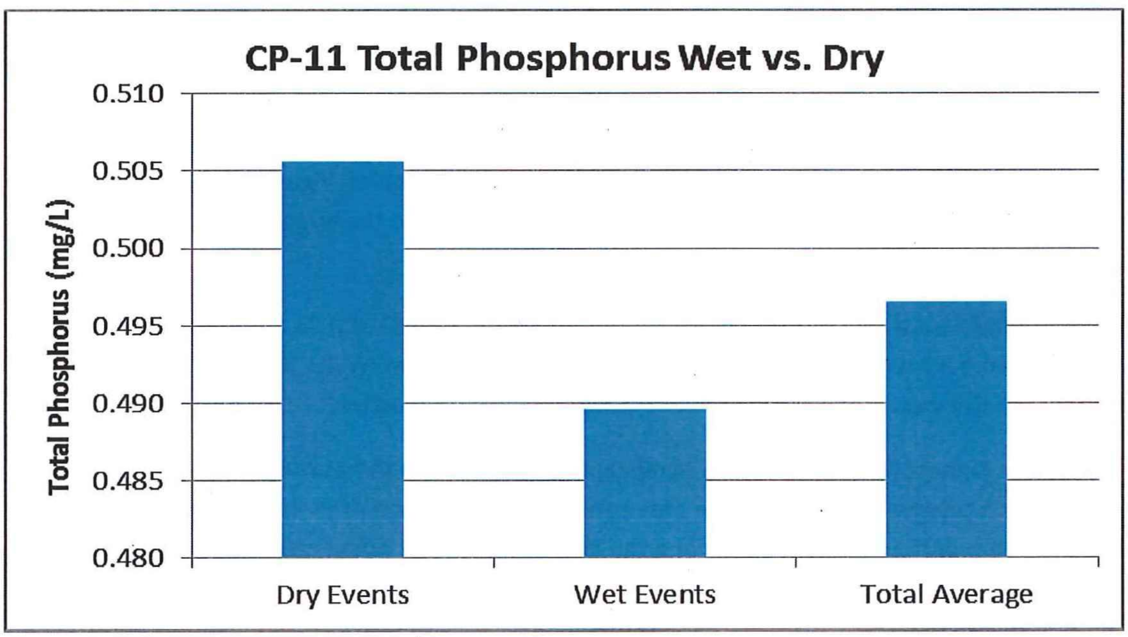

Figure 3.2-2: CP-11 Total Phosphorus Average Concentration for wet event, dry event, and total grab samples

Figure 3.2-3 below shows the seasonal relationship of grab samples taken on wet versus dry events (baseflows) for each site (except CP-11). No winter wet event samples were obtained due to timing of sampling days.

It was expected that for all seasons the TP average concentrations would typically be higher for wet events, due to increased runoff and erosion contributing to elevated amounts of TP in the creeks; however for some creeks, some seasonal TP average concentrations were lower for wet events.

Sites AC-1, AC-2, and CP-7 experienced higher averages for dry event samples in spring than wet event averages, while sites AC-3, AC-4, and CP-18.1 experienced higher spring wet event averages than spring dry event averages. This may have been a result of grab samples being collected during snowmelt events, which were wrongly identified as dry event samples due to the lack of rainfall.

For the summer season, the only site to have a higher baseflow average TP concentration was CP-18.1, all the other sites had a greater wet event average. The average concentration for wet event samples in summer exceeded the PWQO at all sites. The summer months also had the highest occurrence of exceedances.

For the fall season, all sites experienced higher TP average concentrations for wet event samples.

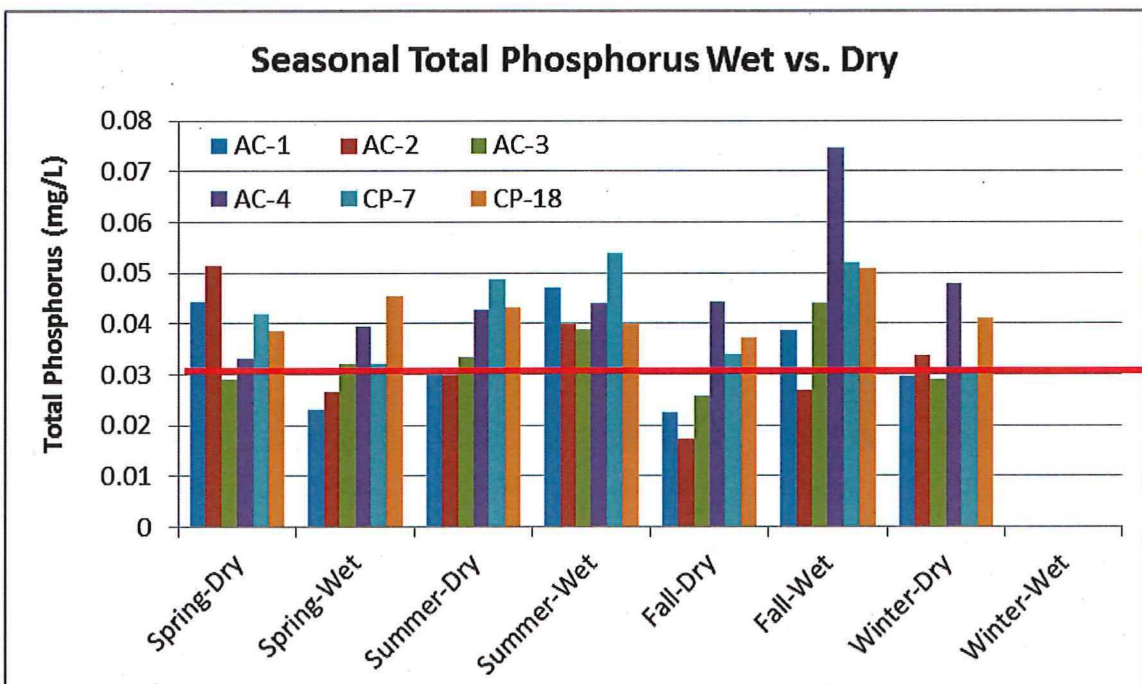

Figure 3.2-3: Total Phosphorus Seasonal Average Concentrations at each site for wet and dry event grab samples

For individual sites, the average TP concentrations for wet event samples in the fall were predominantly the highest of any seasonal average (wet or dry event), with the major exception being AC-1 and AC-2. The spring wet event average TP concentrations were predominantly the lowest of any seasonal wet event average. Dry event (baseflow) seasonal average TP concentrations were predominantly the highest in the spring or summer and lowest in the fall.

Interestingly, the fall season produced both the highest wet event average concentrations as well as the lowest dry event concentrations, typically. Also, the spring season often produced both the highest dry event average concentrations as well as the lowest wet event concentrations.

Figure 3.2-4 shows the TP seasonal average concentration for each site (except CP-11), when considering all samples. Sites AC-1, AC-2, AC-4, and CP-7 all experience considerable variability in TP averages over the seasons. Sites CP-18.1 and AC-3 do not experience much variation. AC-4, CP-7, and CP-18.1 all have TP seasonal averages that exceed the objective for all seasons. AC-1, AC-2, and AC-3 seasonal average TP concentrations are generally near the PWQO.

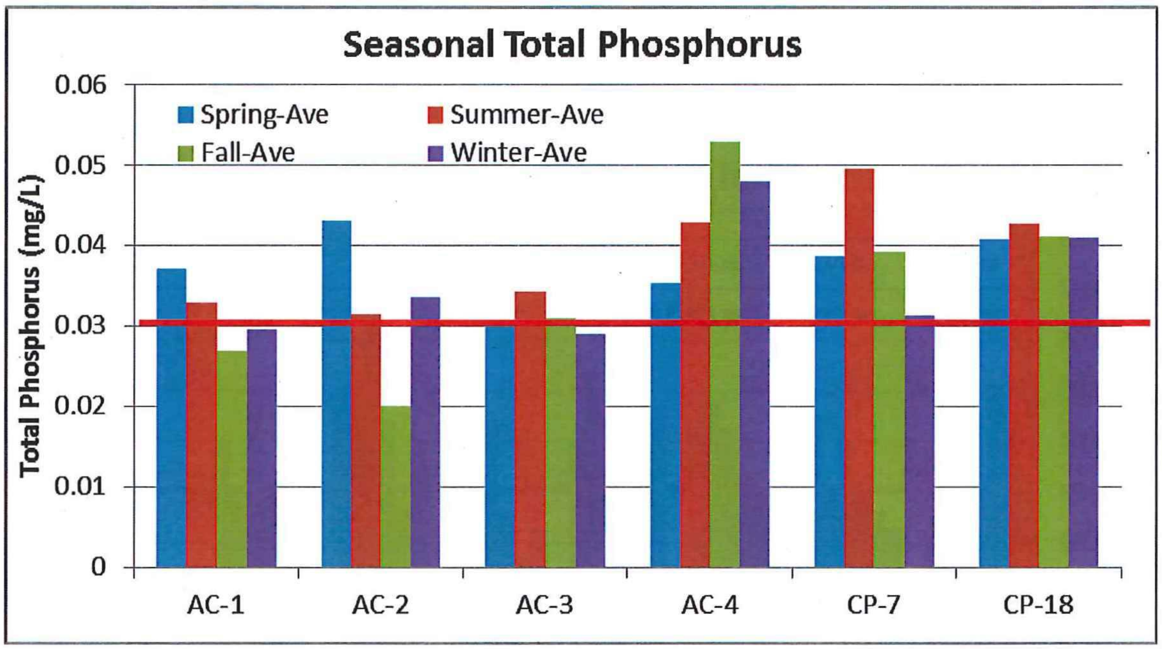

Figure 3.2-4: Total Phosphorus Seasonal Average Concentrations at each site for total grab samples

Figure 3.2-5 shows site CP-11 seasonal TP averages for wet and dry samples. This site is displayed on its own graph due to the order of magnitude difference in TP values compared to the other sites. During the spring and summer, dry event (baseflow) averages were higher than wet event averages. During the fall season the wet event averages were higher. There were no wet winter samples captured during this sampling period.

TP seasonal average concentrations, when considering all samples, were highest in the summer and winter.

For CP-11, as for the other sites, the fall wet event average TP concentrations were the highest of any seasonal average (wet or dry event). Again, the average TP concentrations for wet event samples in the spring were the lowest of any seasonal wet event average. Baseflow average TP concentrations were predominantly the highest of any seasonal dry event average in the winter or summer but again lowest in the fall.

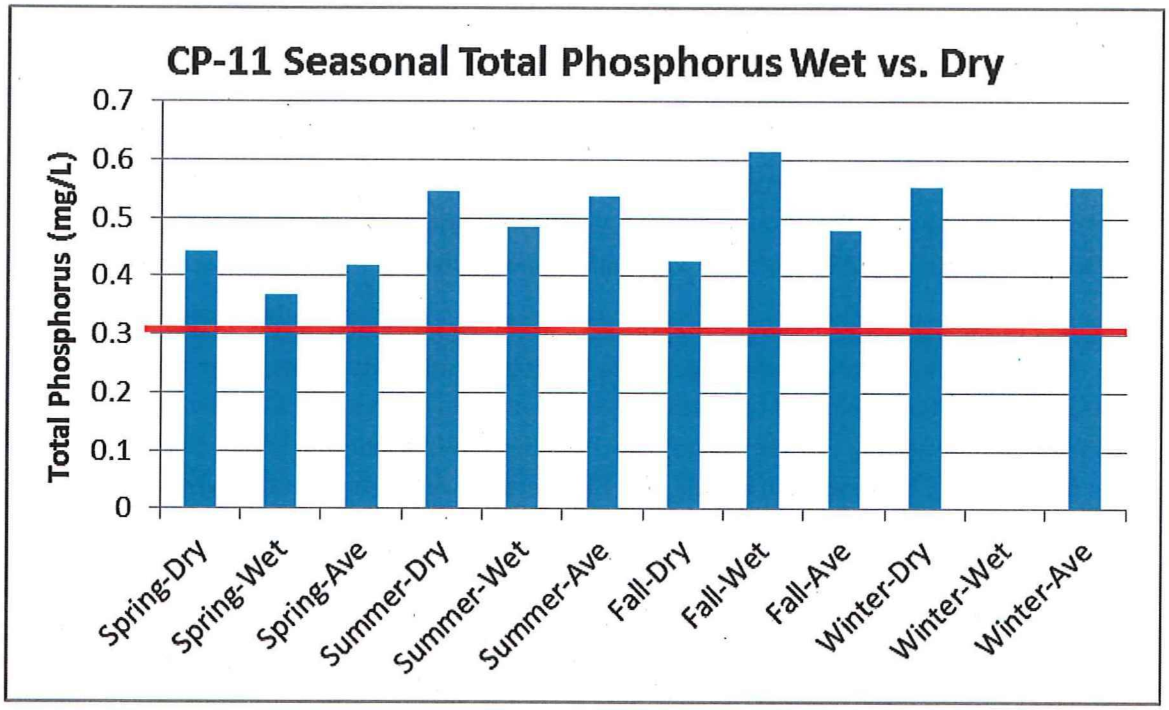

Figure 3.2-5: CP-11 Total Phosphorus Seasonal Average Concentrations for wet and dry event grab samples

3.3 Total Suspended Solids

Total Suspended Solids (TSS) grab sample concentrations for the 2017/18 season are summarized in Table 3.3-1. Results in red text indicate an exceedance of the water quality objective of 25 mg/L. Table 3.3-2 lists the proportion of the grab samples that exceeded the water quality objective for each site, broken down individually for wet event samples, dry event (baseflow) samples, and all samples.

A relatively small proportion of TSS grab samples had concentrations exceeding the HHRAP interim water quality objective for the sample year. For sites AC-3, CP-7, and CP-18.1, no grab samples exceeded the interim objective. Site CP-11 had the highest number of exceedances (6, representing less than 25% of samples), all of which were classified as baseflow (dry) samples and which typically occurred in the summer season. Site AC-2 had 5 exceedances (representing less than 20% of samples), and were also predominantly dry event, summer season grab samples.

Figure 3.3-1 shows the average concentrations for TSS for wet event, dry event, and all samples. There were no sites where the average concentration (wet event, dry event, or total) exceeded the objective. CP-18.1 had the lowest average TSS concentrations. Sites CP-11 and AC-2 both have the highest total average TSS concentrations (17.99 mg/L and 16.9 mg/L respectively).

At the majority of sites, average TSS concentrations for baseflow events were higher than wet event averages. This finding is contrary to what is generally expected during wet events, when runoff and channel erosion would be anticipated to increase TSS concentrations. This sampling year the largest wet event rainfall amount was only 15.2 mm, which may have been insufficient to produce much runoff into or erosion of the creeks. This may help explain why TSS averages were higher for dry events.

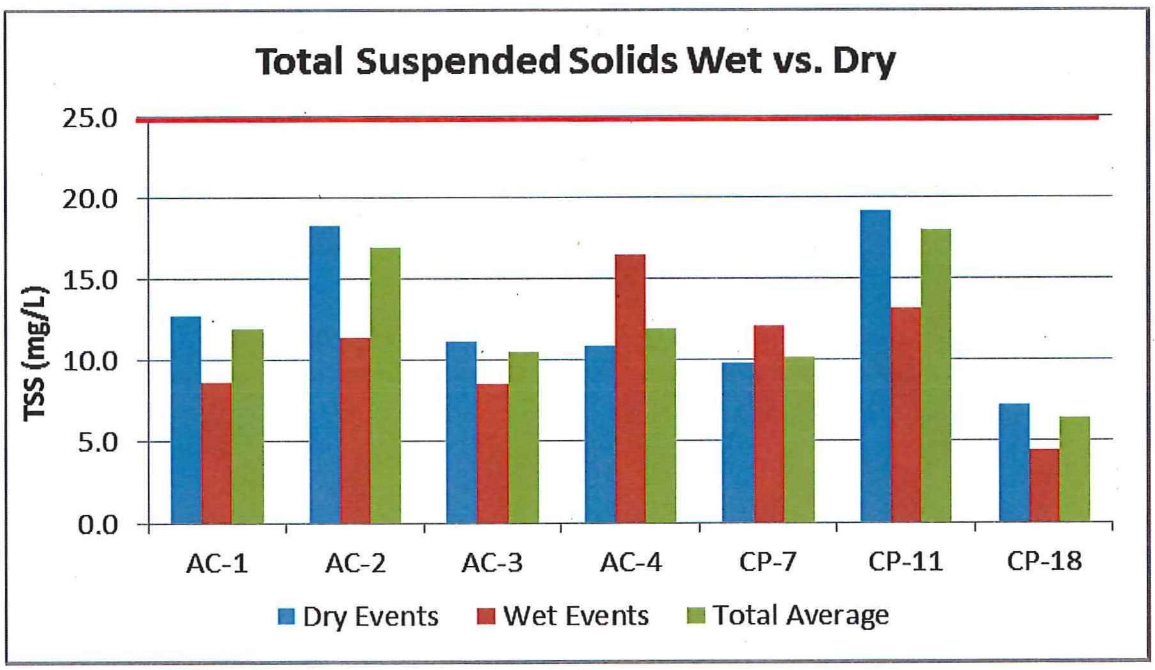

Figure 3.3-1: Total Suspended Solids Average Concentration at each site for wet event, dry event, & total grab samples

Table 3.3-1: Total Suspended Solids Concentrations (mg/L) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classification	24 hr. Precip. (mm)
4/12/2017	8.2	14.9	6.7	<4	11.2	13.5	<4	DRY	2.2
4/27/2017	5.7	14.7	3.9	5.9	5.0	9.1	<4	DRY	2.2
5/11/2017	7.0	19.3	5.4	9.7	5.6	5.0	<4	DRY	0
5/24/2017	3	5.3	7.4	42.8	<4	10.2	<4	WET	7.4
6/7/2017	4.3	7.9	4.6	2.4	9.6	12.0	9.6	WET	11.4
6/21/2017	60.0	74.7	16.0	14.8	22.5	18.7	12.0	DRY	2.4
7/5/2017	17.1	25.8	18.7	12.3	10.4	41.3	4.4	DRY	0
7/19/2017	27.1	35.7	13.1	26.8	19.2	28.9	3.2	DRY	0
7/27/2017	23.0	25.7	11.3	6.0	17.8	24.4	2.6	WET	15.2
8/16/2017	6.2	4.2	8.0	5.1	13.8	42.0	4.4	DRY	2.2
8/30/2017	3.6	8.2	8.4	4.4	11.6	42.8	5.8	DRY	0
9/15/2017	4.9	4.6	5.4	2.9	16.0	29.0	4.7	DRY	0
9/27/2017	5.0	3.2	16.5	3.8	15.8	32.3	10.2	DRY	1
10/11/2017	8.3	10.2	8.8	14.8	10.9	10.5	3.1	WET	7.4
10/25/2017	4.4	7.9	10.6	<3	10.0	8.8	2.4	WET	6.2
11/8/2017	<4	5.2	<4	<4	6.7	5.9	<4	DRY	0
11/22/2017	5.0	11.1	<3	5.5	4.6	11.5	2.9	DRY	0
12/6/2017	3.6	5.2	<3	3.2	<4	8.8	<3	DRY	0
12/20/2017	6.0	9.9	4.4	6.0	3.9	13.2	<3	DRY	0
1/3/2018	<3	9.6	<3	---	---	---	<3	DRY	0
1/17/2018	5.9	11.2	15.2	11.2	8.0	6.0	<4	DRY	0.2
2/13/2018	11.6	21.6	20.8	21.6	9.6	19.2	<3	DRY	0
2/14/2018	10.0	12.4	6.4	8.4	4.8	13.6	<3	DRY	0
2/28/2018	41.0	69.2	24.1	30.3	7.1	9.7	12.0	DRY	0
3/14/2018	9.2	10.7	11.1	12.7	6.6	12.7	<4	DRY	0
3/28/2018	5.6	12.2	5.2	11.1	3.2	20.6	12.6	DRY	3.6
Dry Events (mean)	12.8	18.3	11.1	10.9	9.8	19.2	7.2		
Wet Events (mean)	8.6	11.4	8.5	16.5	12.1	13.2	4.4		
Total Mean	11.90	16.9	10.54	11.90	10.17	17.99	6.42		

Table 3.3-2: Proportion of Grab Samples that Exceeded the Total Suspended Solids Objective

Site	Total Exceedance	Dry Exceedance	Wet Exceedance
AC-1 Ancaster Ck upstream of Spencer Ck	11.5	14.3	0.0
AC-2 Sulphur Ck	19.2	19.0	20.0
AC-3 Ancaster Ck upstream of Sulphur Ck	0.0	0.0	0.0
AC-4 unnamed trib. of Ancaster Ck	11.5	9.5	20.0
CP-7 Spencer Ck	0.0	0.0	0.0
CP-11 Chedoke Ck	23.1	28.6	0.0
CP-18.1 Borers Ck	0.0	0.0	0.0

Figure 3.3-2 shows the seasonal average TSS concentrations for the wet and dry event (baseflow) grab samples. Figure 3.3-3 shows the seasonal average TSS concentration for all grab samples, for each site.

At the majority of sites, the seasonal average TSS concentrations (wet event, dry event, and total) were below the objective of 25mg/L. Only two sites had average seasonal concentrations exceeding the objective (for CP-11 baseflow samples in the summer and total samples in the summer, as well as AC-2 dry event samples in the spring, summer dry events, and wet event samples in the summer). In contrast, the lowest total sample seasonal average was at CP-18.1 in the summer.

For some sites, the TSS average concentrations were consistently higher for dry events (AC-2, AC-3, CP-11, and CP-18.1). For other sites, some seasons had TSS average concentrations that were higher for wet events, while other seasons had TSS averages that were lower for wet events.

For individual sites, there was no consistent season of highest or lowest average TSS concentrations.

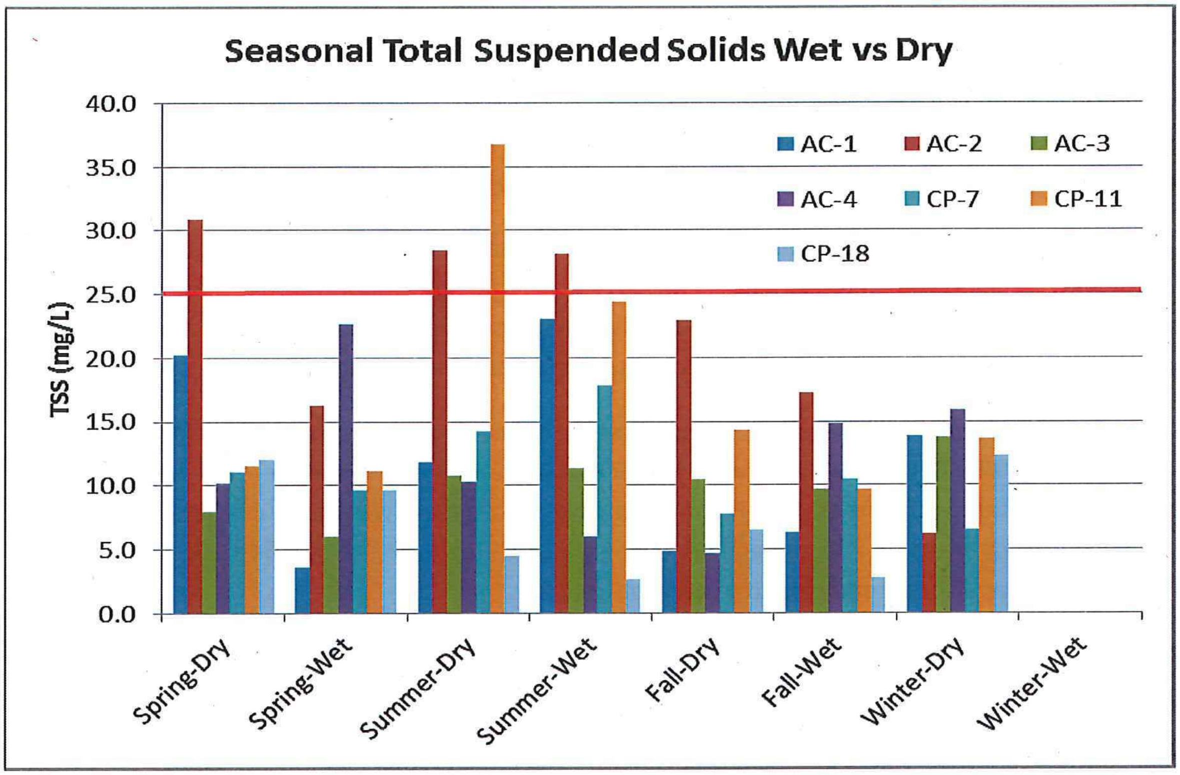

Figure 3.3-2: Total Suspended Solids Seasonal Average Concentrations at each site for wet and dry event grab samples

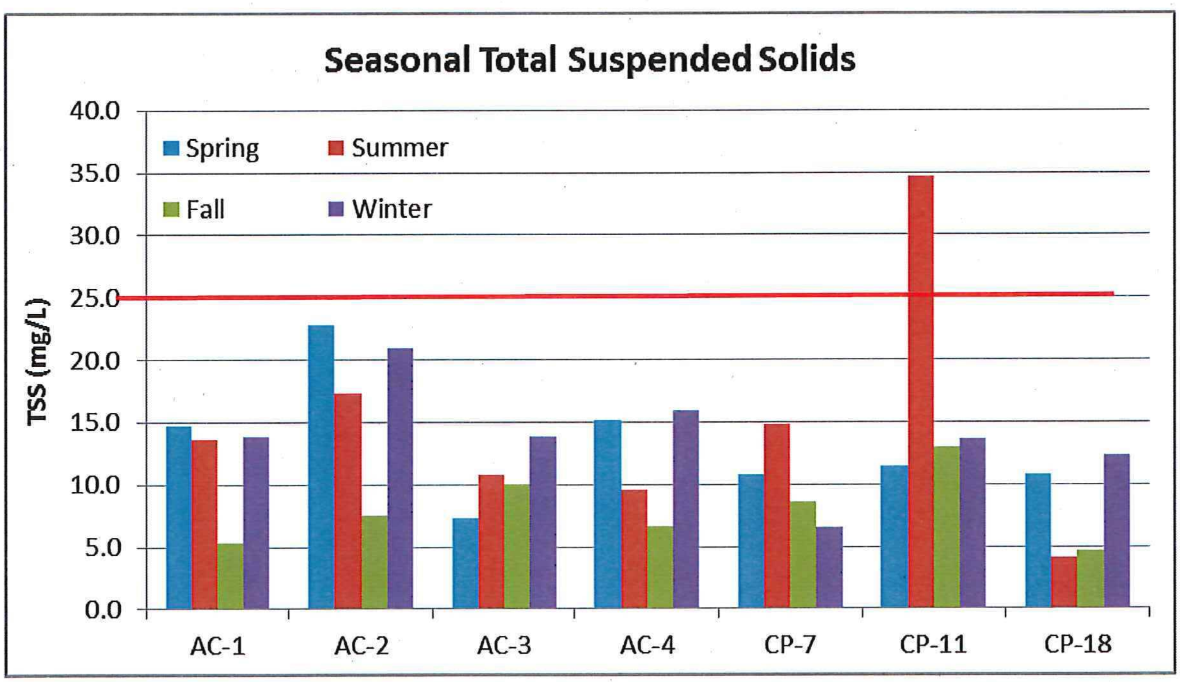

Figure 3.3-3: Total Suspended Solids Seasonal Average Concentrations at each site for total grab samples

3.4 Volatile Suspended Solids

Volatile Suspended Solids (VSS) concentrations from grab samples collected in the 2017/18 season can be seen in Table 3.4-1. VSS represents the organic portion of TSS, such as plant matter and animal waste. There is no VSS HHRAP interim water quality objective for this parameter at this time.

Figure 3.4-1 shows the breakdown of TSS into inorganic and organic solids for each site. For the majority of sites, with the exception of CP-11 and CP-18.1, TSS is predominantly inorganic suspended solids. However, at site CP-11 TSS is mostly VSS. CP-18.1 has an almost even split of organic and inorganic suspended material, while site AC-2 has the lowest concentration of organic suspended solids.

Figure 3.4-2 summarizes the average VSS concentrations for wet event, dry event (baseflow), and total samples, at each site. CP-11 had significantly higher concentrations of VSS and therefore organic materials, compared to the other sites. For this sampling season there was not much variability in the average concentrations for wet event and dry event samples. However, the baseflow average concentrations were consistently found to be slightly higher.

Figure 3.4-3 shows the seasonal average VSS concentrations for the wet and dry event grab samples. Figure 3.4-4 shows the seasonal average VSS concentration for the total grab samples.

Site CP-11 was left off of Figure 3.4-3 in order to better show the relationships at the other sites due to CP-11's higher VSS concentrations. CP-11 had the highest VSS concentrations for dry event samples in the summer and the lowest averages for dry events in the spring as well as wet event samples in the fall. For the other sites, CP-18.1 average concentrations for dry event or baseflows in winter are the highest and AC-1 average concentrations for wet events in the spring are the lowest. For individual sites, the average VSS concentrations were highest for wet events in the summer or dry events in the winter.

For this sampling season there was not much variability in the average concentrations for total samples between the seasons, except for CP-11.

Table 3.4-1: Volatile Suspended Solids Concentrations (mg/L) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classification	24 hr. Precip. (mm)
4/12/2017	1.4	2.3	1.8	<4	2.8	10.7	<4	DRY	2.2
4/27/2017	1.3	1.6	1.3	2.3	2.3	4.1	<4	DRY	2.2
5/11/2017	2.3	2.0	1.3	2.3	2.3	4.5	<4	DRY	0
5/24/2017	<3	1.6	1.6	4.2	<4	9.3	<4	WET	7.4
6/7/2017	1.3	2.0	1.7	1.4	3.2	11.7	3.6	WET	11.4
6/21/2017	7.2	7.3	3.0	2.0	3.2	9.3	2.9	DRY	2.4
7/5/2017	3.2	3.4	3.4	3.3	2.9	27.3	1.9	DRY	0
7/19/2017	3.5	4.1	2.9	4.3	4.3	21.2	2.0	DRY	0
7/27/2017	4.0	3.4	2.7	1.7	3.2	18.5	1.4	WET	15.2
8/16/2017	3.3	2.3	2.7	2.9	4.8	34.0	2.9	DRY	2.2
8/30/2017	1.2	1.4	1.6	1.4	1.4	32.8	1.8	DRY	0
9/15/2017	1.4	1.1	1.1	1.1	2.3	22.0	1.4	DRY	0
9/27/2017	1.5	1.8	2.8	<0.8	3.5	24.3	2.4	DRY	1
10/11/2017	1.3	2.0	2.0	2.0	2.6	7.7	1.5	WET	7.4
10/25/2017	1.6	<0.8	3.4	<3	1.6	5.0	1.6	WET	6.2
11/8/2017	<4	1.4	<4	<4	4.4	3.9	<4	DRY	0
11/22/2017	2.2	2.2	<3	2.5	2.2	7.0	1.7	DRY	0
12/6/2017	1.6	1.2	<3	0.8	<4	5.2	<3	DRY	0
12/20/2017	2.6	2.9	2.2	2.0	2.2	5.4	<3	DRY	0
1/3/2018	<3	4.0	<3	---	---	---	<3	DRY	0
1/17/2018	2.5	2.4	2.8	2.4	2.5	3.0	<4	DRY	0.2
2/13/2018	2.4	2.8	3.6	4.4	2.0	12.4	<3	DRY	0
2/14/2018	3.2	2.8	2.4	3.2	2.0	10.8	<3	DRY	0
2/28/2018	4.5	5.6	5.6	4.6	<0.8	5.1	3.3	DRY	0
3/14/2018	3.6	3.0	4.5	3.4	3.5	8.1	<4	DRY	0
3/28/2018	2.4	2.3	2.0	2.5	1.4	15.9	5.7	DRY	3.6
Dry Events (mean)	2.7	2.8	2.6	2.7	2.8	13.4	2.6		
Wet Events (mean)	2	2	2	2	3	10	2		
Total Mean	2.6	2.7	2.6	2.6	2.8	12.8	2.4		

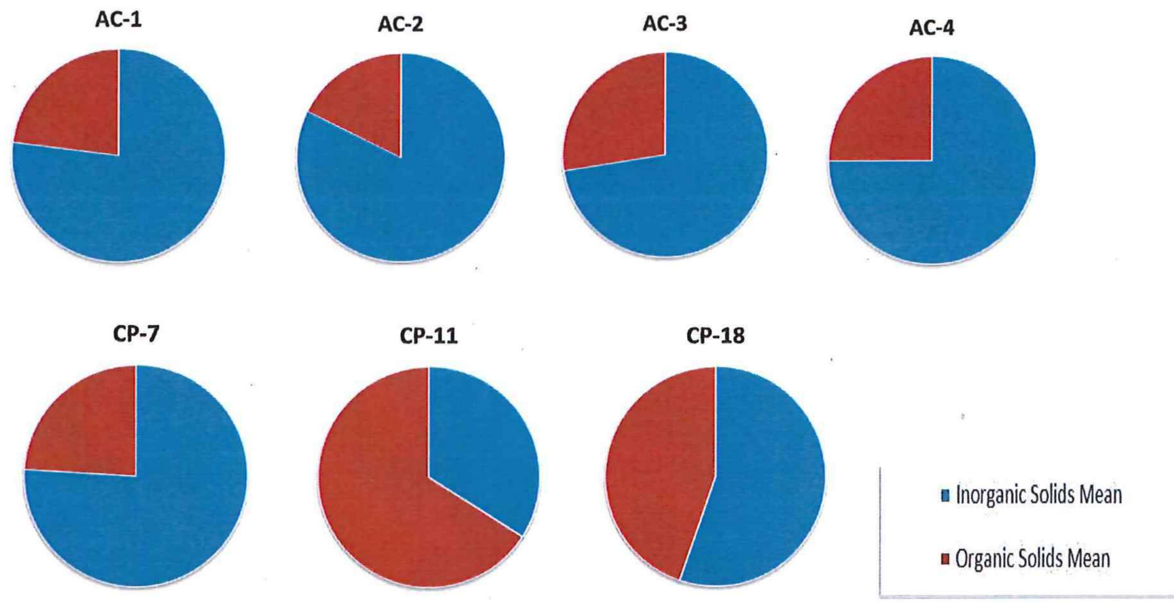

Figure 3.4-1: TSS Breakdown into Inorganic and Organic Solids at each site.

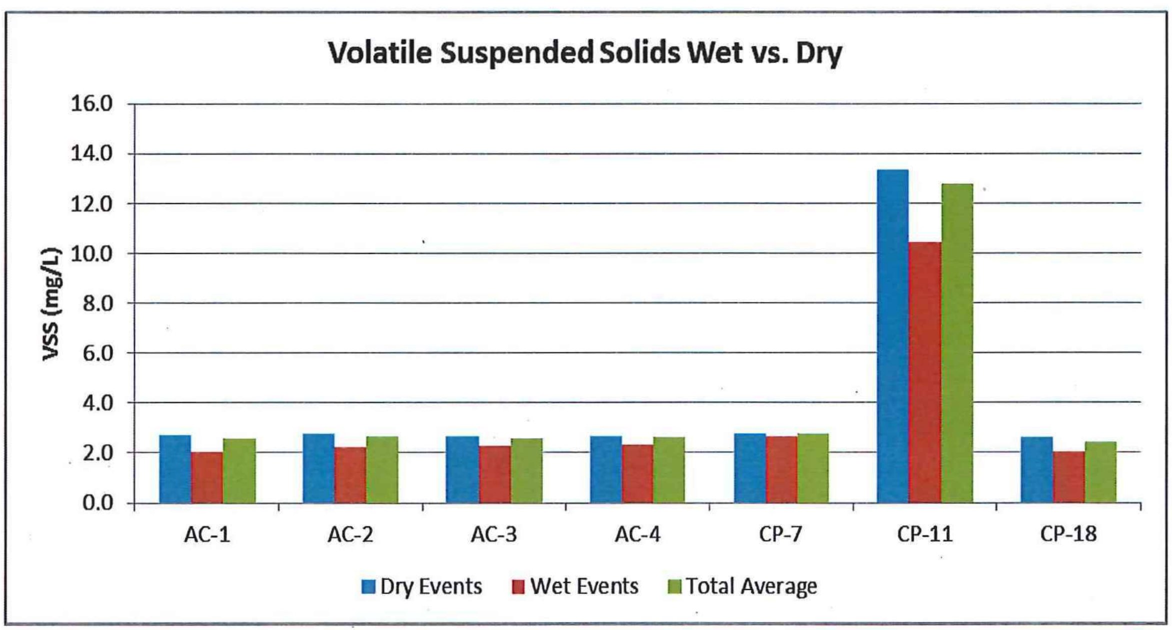

Figure 3.4-2: Volatile Suspended Solids Average Concentration at each site for wet event, dry event, & total grab samples

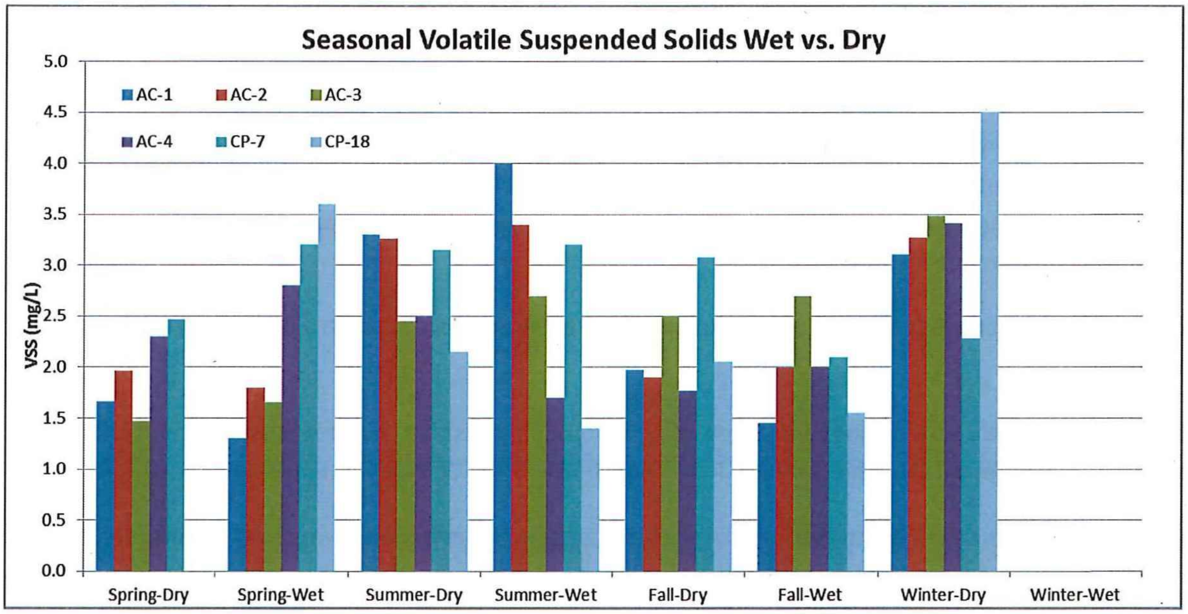

Figure 3.4-3: Volatile Suspended Solids Seasonal Average Concentrations at each site for wet and dry event grab samples

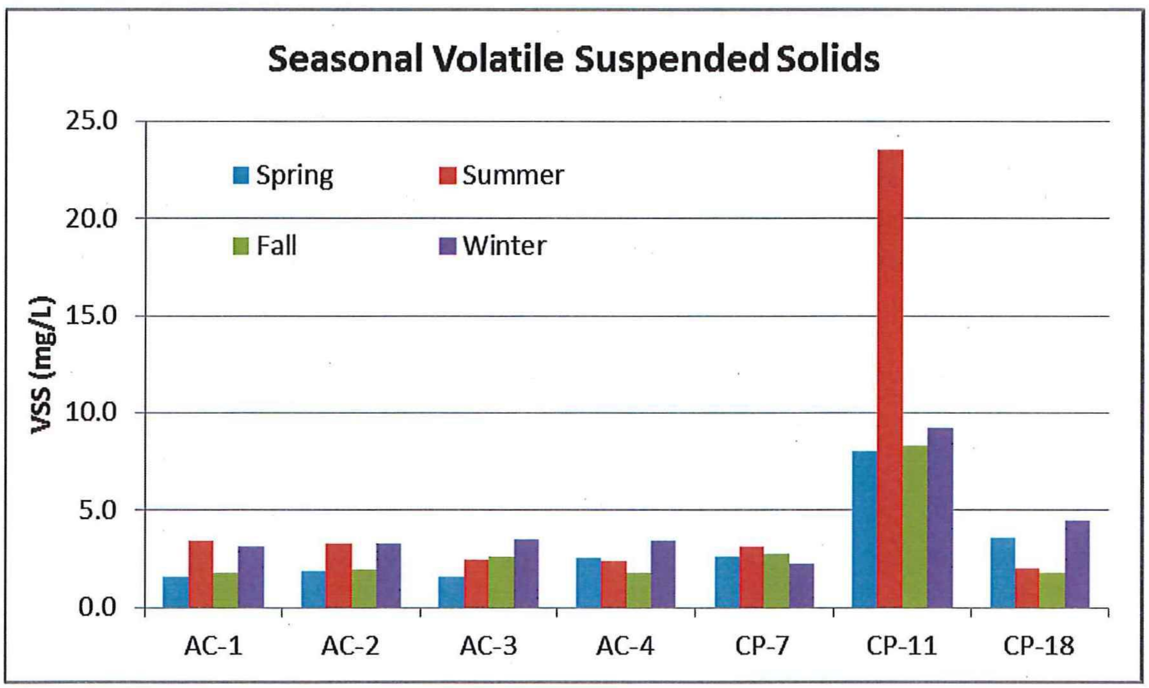

Figure 3.4-4: Volatile Suspended Solids Seasonal Average Concentrations at each site for total grab samples

3.5 Unionized Ammonia

Unionized ammonia grab sample concentrations for the 2017/18 season are summarized in Table 3.5-1. The concentrations were estimated using a formula to derive unionized ammonia from temperature, pH, and total ammonia concentration. Results marked in red reflect exceedances of the HHRAP water quality objective and PWQO of 0.02 mg/L. Blanks occurred when total ammonia concentrations were below the minimum detection limit.

For the 2017/18 sampling season, unionized ammonia does not appear to be a parameter of concern at most sites.

The majority of grab sample concentrations were below the objective. Grab sample concentrations only exceeded the water quality objective at CP-11, with three of the 26 samples exceeding 0.02 mg/L.

Figure 3.5-1 shows the average unionized ammonia concentration for wet event, dry events, and total samples. There were no sites where the average concentration (wet event, dry event, or total) exceeded the objective. For this sampling season there was not much variability in the average concentrations for wet event and dry event (baseflow) samples, expect for CP-11. CP-11 has the highest concentration of unionized ammonia (by a significant margin) with the highest average occurring for wet event samples.

At individual sites, the average concentration for dry events tended to be higher than for wet event samples. The exceptions were CP-11 and CP-7, where the wet event average concentrations were higher.

Figure 3.5-2 shows the seasonal average concentrations for total grab samples. There were no sites where any season had an average concentration for total samples that exceeded the objective. For the majority of sites, summer consistently had the highest average concentrations of unionized ammonia, while for CP-11 and CP-18.1 the fall had the greatest seasonal average concentrations.

Table 3.5-1: Unionized Ammonia Concentrations (mg/L) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classification	24 hr. Precip. (mm)
4/12/2017	>0.00014	>0.00017	0.00016	0.0001	>0.00026	0.03253	0.00332	DRY	2.2
4/27/2017	>0.00020	>0.00019	>0.00017	>0.00021	0.0007	0.0036	0.0004	DRY	2.2
5/11/2017	>0.00015	>0.00014	>0.00014	>0.00019	0.0006	0.0089	>0.00041	DRY	0
5/24/2017	0.0003	>0.0002	0.0002	>0.00024	0.0006	0.0026	0.0003	WET	7.4
6/7/2017	>0.00024	>0.00025	>0.00022	>0.0002	>0.00034	0.0065	>0.00039	WET	11.4
6/21/2017	0.0027	0.0024	0.0014	0.0012	0.0027	0.0067	0.0013	DRY	2.4
7/5/2017	0.0016	0.0008	0.0008	0.0006	0.0020	0.0038	0.0010	DRY	0
7/19/2017	0.00086	0.00035	0.00042	0.00049	0.00134	0.00048	0.00034	DRY	0
7/27/2017	0.0010	0.0004	0.0005	0.0006	0.00135	0.0101	0.0008	WET	15.2
8/16/2017	0.0005	0.0005	0.0007	>0.00036	0.0009	0.0069	>0.00015	DRY	2.2
8/30/2017	0.0007	>0.00009	0.0001	0.0002	0.0013	0.0236	0.0003	DRY	0
9/15/2017	0.0066	>0.00029	0.0004	0.0002	0.0024	0.0155	0.0007	DRY	0
9/27/2017	0.0009	>0.00042	0.0007	>0.0002	0.0022	0.0291	0.0034	DRY	1
10/11/2017	0.0011	>0.00038	0.0006	0.0003	0.0022	0.0349	>0.0003	WET	7.4
10/25/201	0.0002	>0.00007	0.0001	0.0001	0.0013	0.0156	>0.00029	WET	6.2
11/8/2017	0.0001	0.00003	0.0000	0.0001	0.0001	0.0017	>0.00008	DRY	0
11/22/2017	0.0002	0.0001	0.0002	0.0003	0.0004	0.0157	>0.0002	DRY	0
12/6/2017	0.0000	0.0001	>0.00006	0.0001	0.0001	0.0050	>0.00008	DRY	0
12/20/2017	0.0003	0.0002	>0.00005	0.0003	0.0010	0.0019	>0.00032	DRY	0
1/3/2018	0.00003	0.00003	0.00002	n/a	n/a	n/a	n/a	DRY	0
1/17/2018	n/a	0.00000	n/a	n/a	n/a	n/a	n/a	DRY	0.2
2/13/2018	n/a	n/a	n/a	n/a	n/a	n/a	n/a	DRY	0
2/14/2018	n/a	n/a	n/a	n/a	n/a	n/a	n/a	DRY	0
2/28/2018	n/a	n/a	n/a	n/a	n/a	n/a	n/a	DRY	0
3/14/2018	0.00187	0.0002	>0.00009	0.0006	0.0002	0.0030	>0.00018	DRY	0
3/28/2018	>0.00011	>0.00011	>0.00008	0.0004	0.00016	0.0144	0.00026	DRY	3.6
Dry Events (mean)	0.0013	0.0005	0.0005	0.0004	0.0011	0.0100	0.0010		
Wet Events (mean)	0.0006	0.0004	0.0003	0.0004	0.0014	0.0139	0.0006		
Total Mean	0.0011	0.0005	0.0005	0.0004	0.0012	0.0110	0.0009		

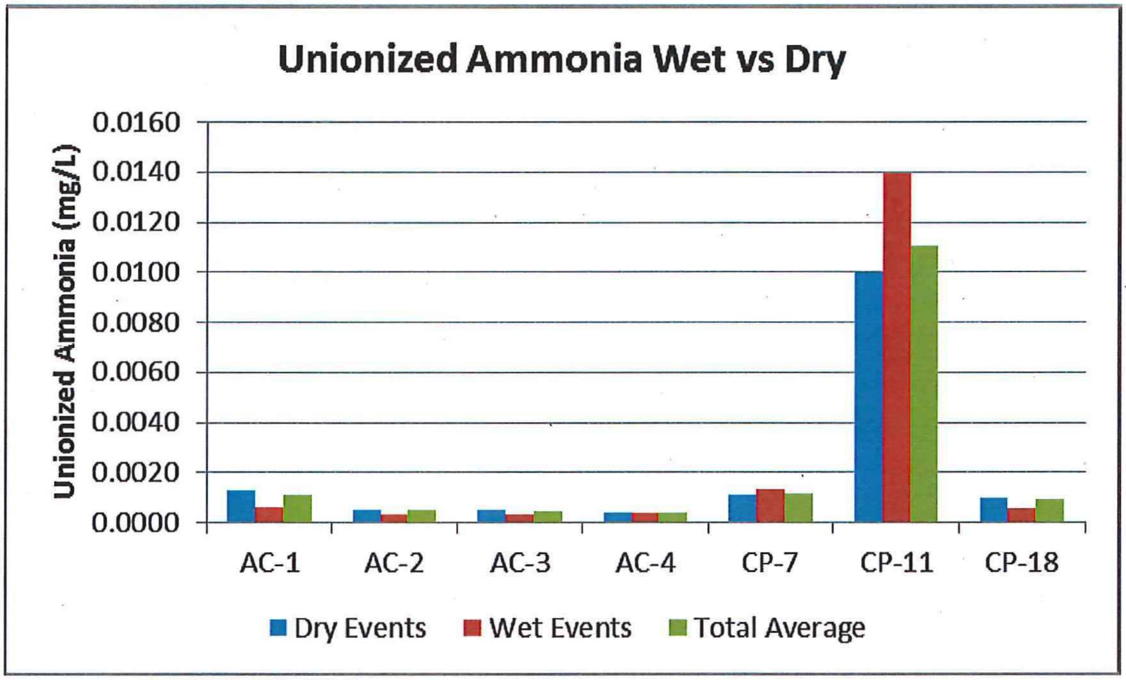

Figure 3.5-1: Unionized Ammonia Average Concentration at each site for wet event, dry event, & total grab samples

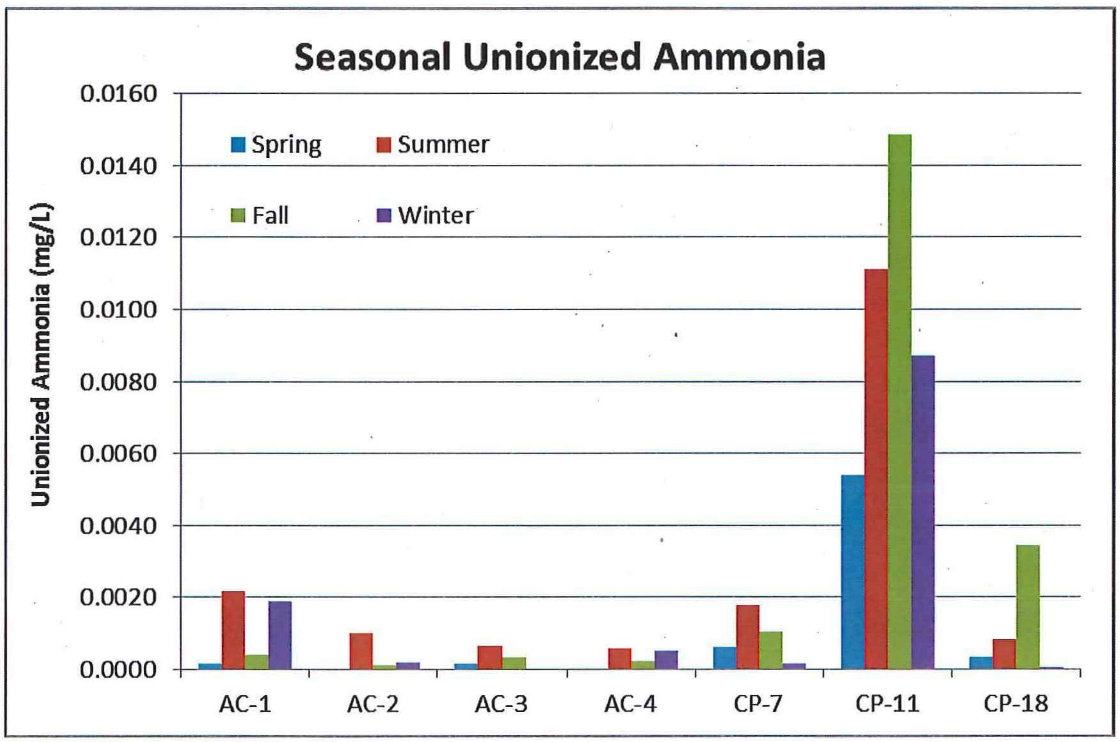

Figure 3.5-2: Unionized Ammonia Seasonal Average Concentrations at each site for total grab samples

3.6 Nitrate

Nitrate grab sample concentrations for the 2017/18 season are summarized in Table 3.6-1. Results marked in red reflect exceedances of the CWQG of 3 mg/L as N.

For the 2017/18 sampling season, nitrate does not appear to be a parameter of concern, as no samples at any sites exceeded the objective.

Figure 3.6-1 shows the average nitrate concentration for wet event, dry event (baseflow), and total samples. There were no sites where the average concentration (wet event, dry event, or total) exceeded the objective. CP-11 had the highest nitrate concentrations (by a significant margin), followed by AC-3. AC-2 reported the lowest average nitrate concentrations. Nitrate average concentrations were consistently higher for baseflow samples than for wet events.

Figure 3.6-2 shows the seasonal average nitrate concentrations for wet events and dry events, while Figure 3.6.3 shows the average concentrations for total grab samples at each site. There were no sites where any season had an average concentration (dry event, wet event, or total samples) that exceeded the objective. For the majority of sites, winter consistently had the highest average concentrations. Of interest to note is that at site CP-7 and CP-18.1, the winter nitrate concentrations are significantly greater when compared to the other seasons.

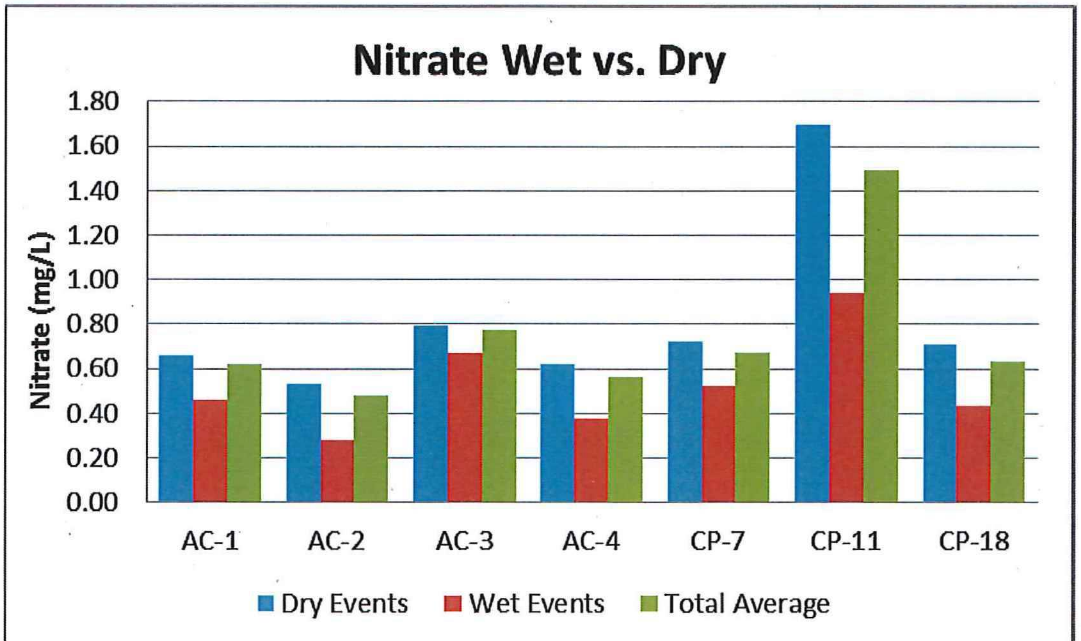

Figure 3.6-1: Nitrate Average Concentration at each site for wet event, dry event, & total grab samples

Table 3.6-1: Nitrate Concentrations (mg/L) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classification	24 hr. Precip. (mm)
4/12/2017	0.52	0.37	0.66	0.8	0.57	<0.05	0.79	DRY	2.2
4/27/2017	0.44	0.30	0.63	0.48	0.58	1.48	0.38	DRY	2.2
5/11/2017	0.50	0.29	0.70	0.49	0.47	1.27	0.32	DRY	0
5/24/2017	0.41	0.15	0.67	0.25	0.53	0.76	0.28	WET	7.4
6/7/2017	0.52	0.26	0.69	<0.05	0.79	0.68	1.10	WET	11.4
6/21/2017	1.81	1.53	0.91	0.69	0.76	<0.1	0.18	DRY	2.4
7/5/2017	0.63	0.41	0.89	<0.05	0.54	0.22	0.46	DRY	0
7/19/2017	0.6	0.44	0.83	0.41	0.51	0.17	0.18	DRY	0
7/27/2017	0.62	0.45	0.84	0.57	0.56	0.77	0.22	WET	15.2
8/16/2017	0.56	0.42	0.70	<0.1	0.39	0.84	0.19	DRY	2.2
8/30/2017	0.48	0.35	0.72	<0.1	0.41	0.99	<0.1	DRY	0
9/15/2017	0.51	0.44	0.72	0.1	0.4	1.36	<0.1	DRY	0
9/27/2017	0.26	0.26	0.53	<0.1	0.42	0.99	<0.1	DRY	1
10/11/2017	0.42	0.31	0.66	0.32	0.50	<0.1	0.13	WET	7.4
10/25/2017	0.32	0.24	0.49	0.36	0.24	1.56	<0.05	WET	6.2
11/8/2017	0.38	0.22	0.55	0.4	0.35	2.50	0.11	DRY	0
11/22/2017	0.54	0.42	0.75	0.58	0.72	2.36	0.57	DRY	0
12/6/2017	0.48	0.37	0.60	0.55	0.79	2.31	0.49	DRY	0
12/20/2017	0.61	0.46	0.76	0.65	0.86	2.58	0.79	DRY	0
1/3/2018	0.74	0.65	0.88	---	---	---	0.59	DRY	0
1/17/2017	1.04	0.86	1.31	1.03	2.08	2.96	2.03	DRY	0.2
2/13/2018	0.74	0.68	1.03	0.76	0.54	0.86	0.71	DRY	0
2/14/2018	0.80	0.68	0.97	0.76	1.08	2.05	1.47	DRY	0
2/28/2018	0.88	0.75	0.99	1.00	1.03	2.68	1.7	DRY	0
3/14/2018	0.66	0.58	0.81	0.67	0.89	1.96	0.92	DRY	0
3/28/2018	0.63	0.51	0.79	0.32	0.80	1.48	0.37	DRY	3.6
Dry Events (mean)	0.63	0.49	0.75	0.58	0.67	1.66	0.58		
Wet Events (mean)	0.46	0.28	0.67	0.38	0.52	0.94	0.43		
Total Mean	0.59	0.44	0.74	0.51	0.62	1.40	0.52		

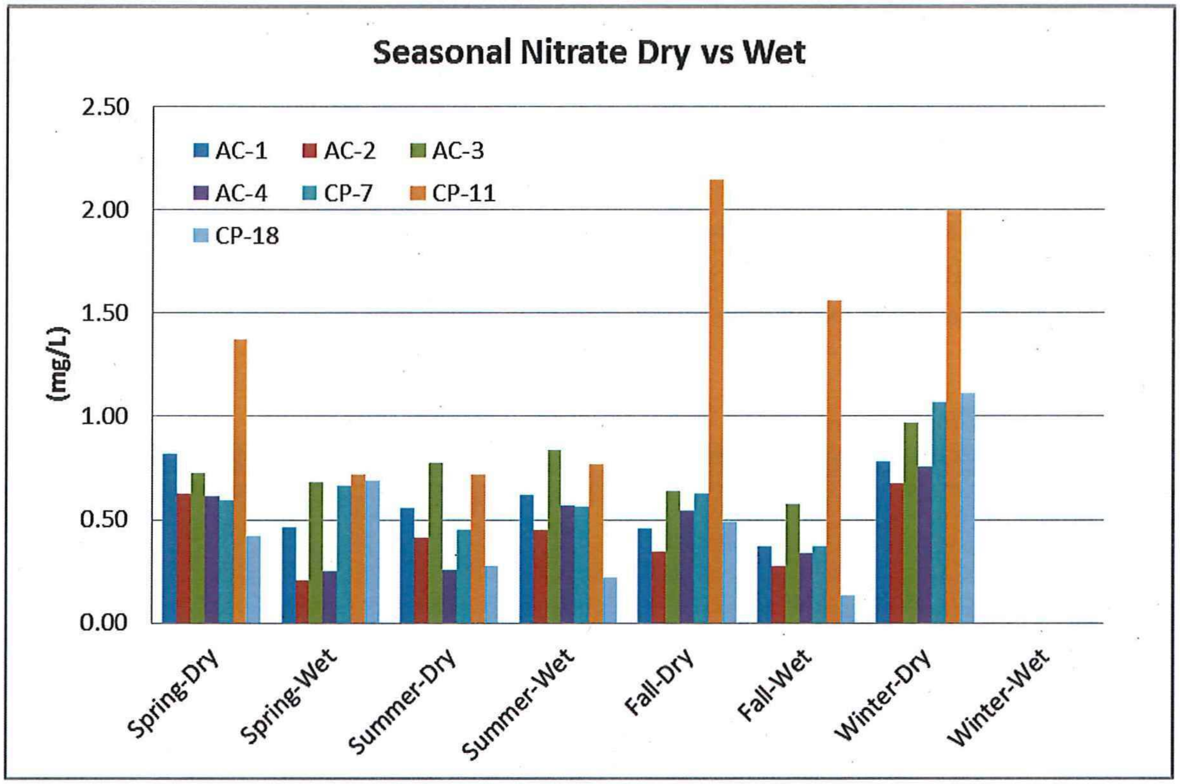

Figure 3.6-2: Nitrate Seasonal Average Concentrations at each site for wet and dry event grab samples

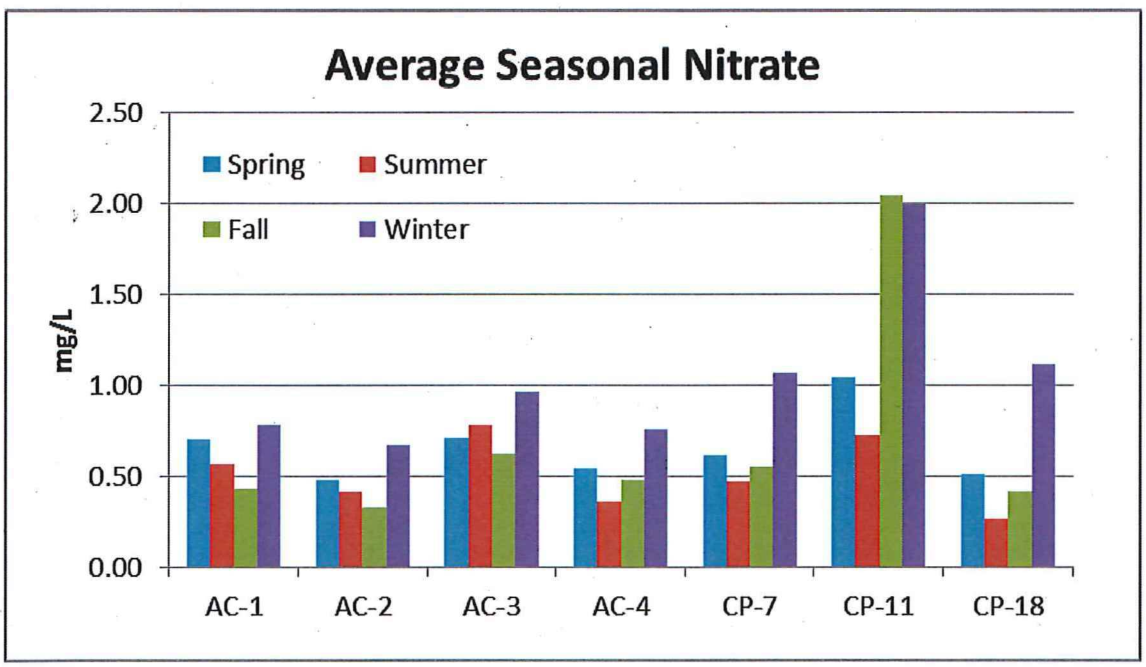

Figure 3.6-3: Nitrate Seasonal Average Concentrations at each site for total grab samples

3.7 Nitrite

Nitrite grab sample concentrations for the 2017/18 season are summarized in Table 3.7-1. Results marked in red reflect exceedances of the CWQG of 0.06 mg/L. For most sites, nitrite concentrations were predominantly below the laboratory minimum detection limit. Due to this fact, average and seasonal breakdowns were not completed. Nitrite does not appear to be a parameter of concern at most sites, except CP-11. Site CP-11 was the only site with any considerable amount of exceedances, with the majority of elevated levels occurring in the spring, summer, and winter. Again, due to the number of samples below the minimum detection limit, CP-11 average and seasonal breakdowns were not completed.

Table 3.7-1: Nitrite Concentrations (mg/L) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classification	24 hr. Precip. (mm)
4/12/2017	<0.05	<0.05	<0.05	<0.05	<0.05	0.9	<0.05	DRY	2.2
4/27/2017	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	DRY	2.2
5/11/2017	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	DRY	0
5/24/2017	<0.05	<0.05	<0.05	<0.05	<0.05	0.26	<0.05	WET	7.4
6/7/2017	<0.05	<0.05	<0.05	<0.05	<0.05	0.16	<0.05	WET	11.4
6/21/2017	<0.1	0.23	<0.1	<0.1	<0.1	<0.1	<0.1	DRY	2.4
7/5/2017	<0.05	<0.05	<0.05	<0.05	<0.05	0.16	<0.05	DRY	0
7/19/2017	0.05	<0.05	0.08	<0.05	<0.05	0.07	<0.05	DRY	0
7/27/2017	<0.05	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	WET	15.2
8/16/2017	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	DRY	2.2
8/30/2017	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	DRY	0
9/15/2017	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	DRY	0
9/27/2017	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	<0.1	DRY	1
10/11/2017	<0.1	<0.1	0.32	<0.1	<0.1	<0.1	<0.1	WET	7.4
10/25/2017	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	WET	6.2
11/8/2017	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	DRY	0
11/22/2017	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	DRY	0
12/6/2017	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	DRY	0
12/20/2017	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	DRY	0
1/3/2018	<0.05	<0.05	<0.05	---	---	---	<0.05	DRY	0
1/17/2018	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	DRY	0.2
2/13/2018	<0.01	<0.05	<0.05	<0.05	<0.05	0.06	<0.06	DRY	0
2/14/2018	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	<0.05	DRY	0
2/28/2018	<0.05	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	DRY	0
3/14/2018	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	DRY	0
3/28/2018	0.32	<0.05	<0.05	<0.05	<0.05	0.15	<0.05	DRY	3.6

3.8 Escherichia coli

E. coil grab sample concentrations for the 2017/18 season are summarized in Table 3.8-1. Results in red text indicate an exceedance of the water quality objective of 100 CFU/100 mL. Table 3.8-2 lists the proportion of the grab samples that exceeded the objective for each site, broken down individually for wet event samples, dry event (baseflow) samples, and all samples.

Elevated *E. coli* concentrations were observed at all sites, indicating impairment throughout the watershed. CP-11 experienced very high *E. coli* concentrations, with all the grab samples significantly exceeding the PWQO. At sites AC-1, AC-3, and AC-4, all, to almost all, samples collected outside of the mid-April to end of May period exceeded the objective, with over 70% of all grab samples exceeding the objective. At sites AC-2, CP-7, and CP-18.1 the majority of the exceedances occurred in the summer and fall seasons, with 40 to 55% of all samples exceeding the objective.

At all sites, 80 to 100% of wet event samples were above the objective. Grab sample concentrations for wet events generally exceeded the PWQO more often than dry event samples. This is expected to be due to increased surface runoff during wet events contributing to elevated amounts of *E. coli* in the creeks. The exception was AC-4, where a higher number of dry day exceedances occurred.

For baseflow (dry) event samples, the proportion of samples exceeding the objective varied considerably by site. For AC-1, AC-4, and CP-11 over 75% of dry event samples exceeded 100 CFU/100 mL, for AC-3 and CP-7, 50 to 70% exceeded, and for AC-2 and CP-18.1, less than 33% of dry event samples exceeded.

The greatest difference in the proportion of wet event versus baseflow (dry) grab samples that exceeded the objective was at the CP-18.1 and AC-2, where 100 and 80% of wet event samples exceeded the objective, but only 29 and 33 % of dry event samples exceeded.

Table 3.8-1: Escherichia coli Concentrations (CFU/100mL.) for Grab Samples

Dates	AC-1 Ancaster Ck upstream of Spencer Ck	AC-2 Sulphur Ck	AC-3 Ancaster Ck upstream of Sulphur Ck	AC-4 unnamed trib. of Ancaster Ck	CP-7 Spencer Ck	CP-11 Chedoke Ck	CP-18.1 Borers Ck	Classifi-cation	24 hr. Precip. (mm)
4/12/2017	40	10	20	70	50	660000	10	DRY	2.2
4/27/2017	20	20	30	50	70	420	40	DRY	2.2
5/11/2017	30	50	30	30	40	5000	20	DRY	0
5/24/2017	90	20	210	50	80	41000	330	WET	7.4
6/7/2017	760	230	620	200	630	440000	630	WET	11.4
6/21/2017	2900	2180	3000	1250	2100	40000	750	DRY	2.4
7/5/2017	290	220	390	160	300	4000	160	DRY	0
7/19/2017	560	250	410	290	320	800	50	WET	0
7/27/2017	520	340	530	450	930	2680	120	WET	15.2
8/16/2017	1300	330	360	740	400	3400	110	DRY	2.2
8/30/2017	510	240	450	330	310	670	150	DRY	0
9/15/2017	420	120	300	550	280	1120	40	DRY	0
9/27/2017	180	970	590	1600	850	200	<10	DRY	1
10/11/2017	740	260	670	470	720	1540000	100	WET	7.4
10/25/2017	270	170	280	330	470	210000	210	WET	6.2
11/8/2017	2400	<100	100	100	100	6400	100	DRY	0
11/22/2017	460	30	170	120	80	1810000	20	DRY	0
12/6/2017	130	50	120	230	1070	83000	20	DRY	0
12/20/2017	480	30	440	110	90	2600	100	DRY	0
1/3/2018	400	<10	540	---	---	---	40	DRY	0
1/17/2018	150	30	480	120	140	12400	10	DRY	0.2
2/13/2018	160	30	90	340	<10	11000	60	DRY	0
2/14/2018	70	30	80	420	40	109000	50	DRY	0
2/28/2018	30	20	20	170	20	37000	10	DRY	0
3/14/2018	120	20	70	560	10	210000	10	DRY	0
3/28/2018	180	20	310	260	60	420000	170	DRY	3.6
Dry Events (Geomean)	211	65	171	227	131	14626	47		
Wet Events (Geomean)	476	204	462	300	566	446736	278		
Total Geomean	244	82	210	231	175	19471	64		

Table 3.8-2: Proportion of Grab Samples that Exceeded the *E. coli Objective*

Site	Total Exceedance	Dry Exceedance	Wet Exceedance
AC-1 Ancaster Ck upstream of Spencer Ck	76.9	76.2	80.0
AC-2 Sulphur Ck	42.3	33.3	80.0
AC-3 Ancaster Ck upstream of Sulphur Ck	73.1	66.7	100.0
AC-4 unnamed trib. of Ancaster Ck	84.0	85.0	80.0
CP-7 Spencer Ck	56.0	47.6	80.0
CP-11 Chedoke Ck	100.0	100.0	100.0
CP-18.1 Borers Ck	46.2	28.6	100.0

An analysis of the geometric mean *E. coli* concentration was also completed. Figure 3.8-1 below shows the *E. coli* geometric mean concentration for wet event, dry event, and total samples. Figure 3.8-2 shows the same information for site CP-11. This is done due to the large difference in values of CP-11 compared to the other sites.

The majority of sites had geometric mean *E. coli* concentrations for wet event, dry event (baseflow), and total samples that were all above the target of 100 CFU/100 mL. That said, at AC-2, and CP-18.1 only the average concentration for wet event samples exceeded the objective, with dry event and overall averages being below the objective.

The average concentration for wet event samples was typically considerably greater than that for baseflow samples.

Site CP-11 again had the highest average concentrations (by a significant margin). Sites AC-2 and CP-18.1 are the only sites with an average concentration for total samples below the objective of 100 CFU/100 mL.

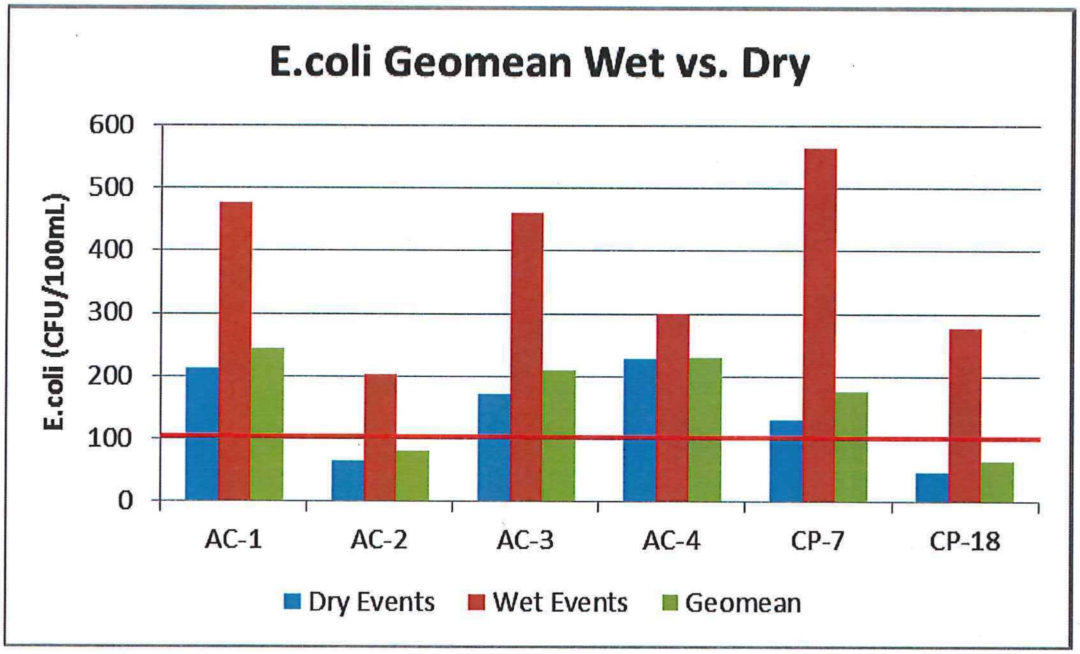

Figure 3.8-1: E. coli geometric mean concentration at each site for wet event, dry event, and total *grab samples.*

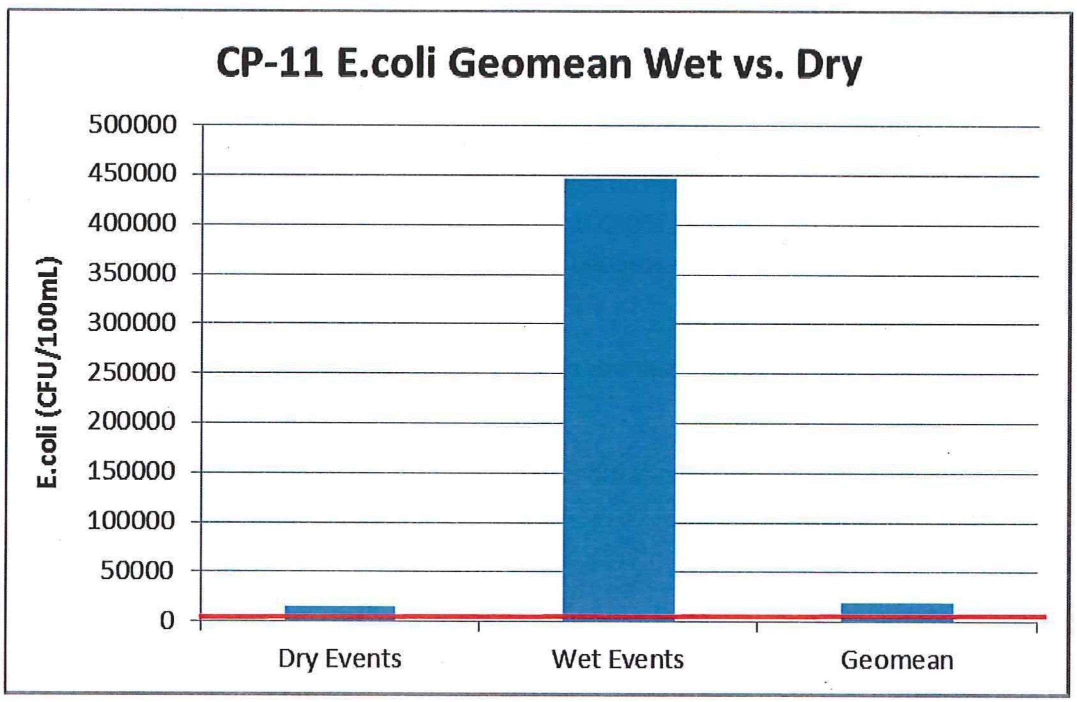

Figure 3.8-2: CP-11 E. coli geometric mean concentration for wet event, dry event, and total grab samples

Figure 3.8-3 below shows the seasonal relationship of grab samples taken on wet versus dry events for each site (except CP-11). No winter wet event samples were obtained due to timing of sampling days.

The average concentrations for wet event samples in the summer were the highest of any season at most sites. CP-11 had the highest value, followed by CP-7.

The lowest average concentrations typically occurred for dry events in the spring and winter. For dry event (baseflow) samples in the winter, sites AC-1, AC-3, and AC-4, are the only sites to exceed the objective. For dry event samples in the spring, only sites AC-4 and CP-7 exceeded (slightly) the PWQO. Interestingly, for wet event samples in the spring, many sites had an average concentration much greater than the objective (except for AC-2 and AC-4).

As expected, in the majority of instances the seasonal averages for wet events were greater than the corresponding seasonal average for baseflow samples.

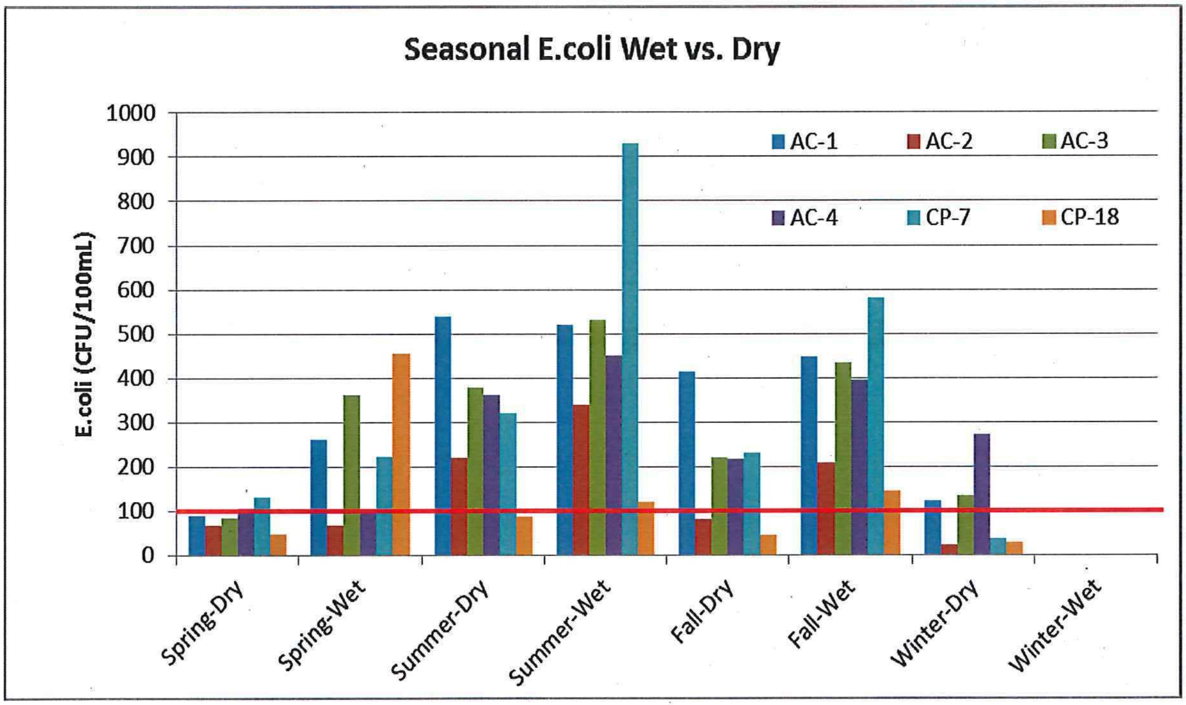

Figure 3.8-3: E. coli seasonal geometric mean concentration at each site for wet and dry event grab samples

Figure 3.8-4 shows the *E. coli* seasonal average concentrations for each site (except CP-11), when considering all samples. Figure 3.8-5 shows the *E. coli* seasonal average concentrations for CP-11, when considering all samples. In general, at most sites the seasonal average concentration when considering all samples was significantly greater in the summer and fall, and considerably less in the spring and even more so in the winter. The figure also indicates that summer had the highest grab sample overall concentrations at the majority of sites. Interestingly, for site CP-11 it was the winter and fall seasons with the highest total average *E. coli* concentrations, and the summer season with the lowest value.

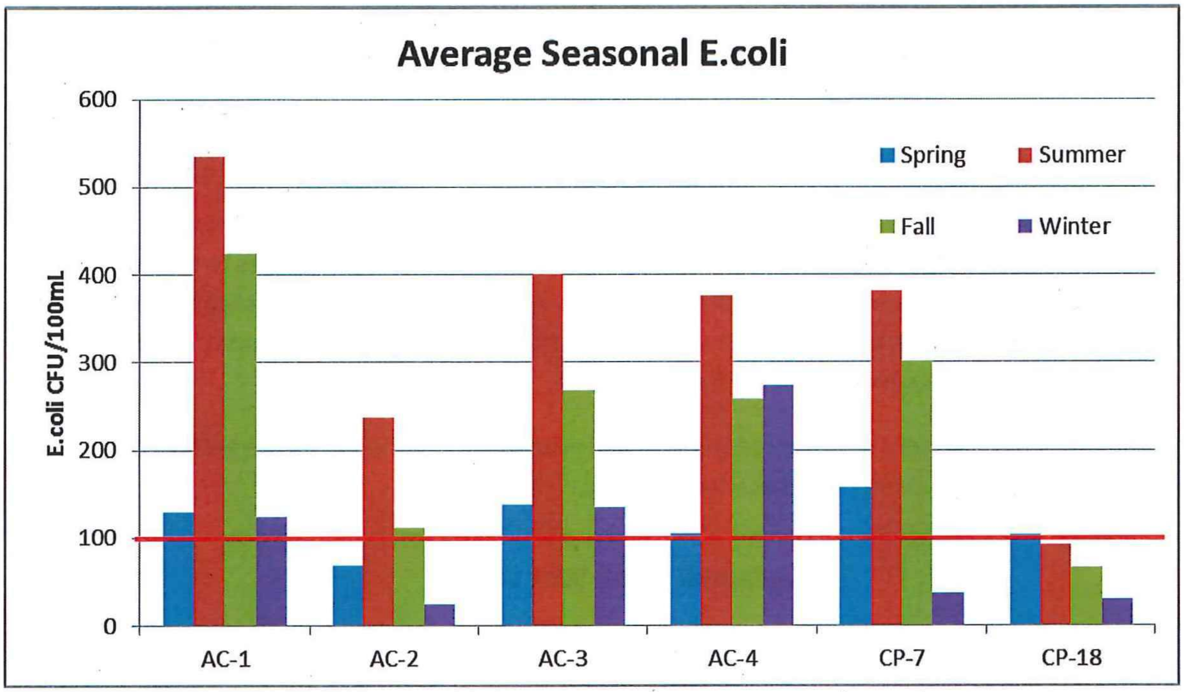

Figure 3.8-4: E. coli seasonal geometric mean concentration at each site for total grab samples

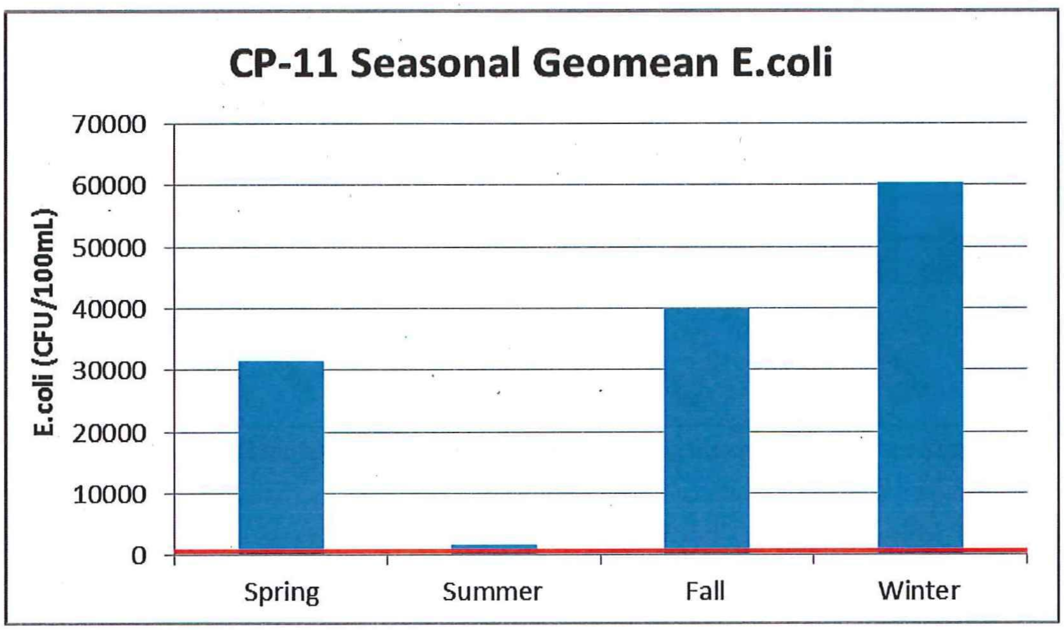

Figure 3.8-5: CP-11 E. coli Seasonal geometric mean concentration for total grab samples

4. 2017-2018 Water Quality Results – Automated Storm Event Samples

In addition to the grab samples detailed above, the sampling program also includes automatic storm event sampling (using an ISCO sampler) to determine the impairment to water quality during significant storm events. Eight storm events were targeted by the automated samplers. For some storm events, particular sites did not obtain samples, typically due to a technical difficulty relating to power supply or blockages in the intake line.

4.1 Storm Event Sample Results

Table 4.2-1 shows the concentrations for key water quality parameters for the eight storm events captured in 2017/2018 using the automated samplers at AC-1, AC-5, SC-1, and SC-2. The table also summarizes the rainfall totals associated with each storm event. Text in red indicates concentrations which exceed the guidelines/objectives.

For TP and *E. coli*, all storm event samples collected at the available stations exceeded the PWQO. For TSS, roughly half of the samples collected across all the storm events and stations exceeded the HHRAP objective. For nitrate, there were no exceedances, suggesting that it is not a parameter of concern during large storm runoff events.

Of the stations, AC-1 (at the downstream end of Ancaster Creek) had the greatest concentrations (by a significant margin) of TP, *E. coli*, and TSS for the majority of storm events collected. SC-2 (Spencer Creek above the Escarpment) typically had the lowest concentrations of *E. coli* and TSS for the storm events collected. SC-1 (Spencer Creek below the Escarpment and located within the town of Dundas) typically had the lowest concentrations of TP for the storm events collected.

A review was made with regards to changes in water quality within Spencer Creek between SC-2 (above the Escarpment) and SC-1 (below the Escarpment). In general, there was no significant change in TP moving downstream in Spencer Creek, except for the largest two storm events. For these events (April 21 and Aug 12), there was a decrease in TP concentrations moving downstream in Spencer Creek. Contrastingly, there was an increase in *E. coli* concentrations, as well as a small increase in TSS concentrations, moving downstream in Spencer Creek for many of the storm events.

Also of interest, the storm event concentrations for TP, *E. coli*, and TSS generated from Ancaster Creek were all significantly greater than that from Spencer Creek.

Table 4.2-1: Storm Event Sample Concentrations for Key Parameters.

Date	Site	Parameter				
		TP (mg/L)	Nitrate (mg/L)	E. coli (CFU/100mL)	TSS (mg/L)	VSS (mg/L)
4/4/2017 18.2 mm	AC-1	---	---	---	---	---
	SC-1	0.048	1.08	0	16.5	4.2
	SC-2	---	---	---	---	---
4/21/2017 51 mm	AC-1	---	---	---	---	---
	SC-1	0.347	0.68	1200	196	21.8
	SC-2	0.403	0.72	900	106	17
5/5/2017 21.6 mm	AC-1	2.49	0.5	1080	2510	118
	SC-1	0.115	0.63	490	45	9
	SC-2	0.1	0.55	310	22	6
8/12/2017 33.8	AC-1	0.352	0.5	---	335	30
	SC-1	0.078	0.44	---	26	7.2
	SC-2	0.109	0.52	---	25.3	6.3
10/24/2017 16.4 m	AC-1	---	---	---	---	---
	SC-1	0.046	0.46	1850	4.1	3.4
	SC-2	0.049	0.53	450	4.9	4.3
11/2/2017 23 mm	AC-1	0.174	0.53	2200	123	14
	SC-1	0.047	0.41	380	13	4
	SC-2	0.052	0.61	250	5	2.5
11/18/2017 21 mm	AC-1	0.12	0.44	300	82.1	9.2
	SC-1	0.048	0.53	200	12	4.7
	SC-2	0.046	0.62	100	9.4	3.3
	AC-5	0.132	0.74	700	24.4	8.5
2/20/2018 15.6 mm	AC-1	---	---	---	---	---
	SC-1	0.201	1.26	200	96.8	14.1
	SC-2	0.224	1.03	100	34.5	7.2
	AC-5	---	---	---	---	---
2/21/2018 21.4 mm	AC-1	---	---	---	---	---
	SC-1	---	---	---	---	---
	SC-2	---	---	---	---	---
	AC-5	0.247	0.72	640	89.4	17.5

Table 4.2-2 compares the routine grab sample averages (wet event and total samples) to the storm event sample averages at site AC-1. This is the only site that currently has both types of sampling.

For key water quality parameters (TP, *E. coli*, TSS), average concentrations for storm events were substantially greater than grab sample average concentrations (either for wet events or total samples). In addition, for TP, the storm event average at AC-1 was significantly greater than the PWQO while the grab sample averages only slightly exceeded the objective. For *E. coli*, both the storm event and grab sample averages considerably exceeded the PWQO. For TSS, the average for storm events significantly exceeded the HHRAP objective however the routine grab sample averages were below the objective.

These findings may indicate that, at AC-1 at least, significant storm events can greatly increase the amount of sediments, nutrients, and bacteria being transported downstream. However, additional years of sampling of intense rain events, as well as possible large snowmelt events is needed to gain a further understanding of how intensity affects water quality in the creeks. It also shows the difference in the ability of the two methods to provide information on the actual amount of nutrients being measured. Consistent with previous MECP monitoring of the tributaries, continuous measurements have been shown to provide better estimates of the event given the ability to measure peak flows and concentrations.

Table 4.2-2: Site AC-1 Routine Grab versus Event Sample Comparison.

AC-1 Routine Grab vs. Event Sample Comparison					
	TP (mg/L)	Nitrate (mg/L)	E. coli (CFU/100mL)	TSS (mg/L)	VSS (mg/L)
Storm Event Average	0.784	0.493	893.3	762.5	42.8
Routine Grab Wet Event Average	0.034	0.46	476	8.6	2
Routine Grab Total Samples Average	0.031	0.619	244.2	11.9	2.6

5. Discussion Summary

The data collected during the 2017/2018 year-round sampling program has provided further insight into the overall water quality contributions from creeks entering Cootes Paradise.

5.1 Overall Findings by Water Quality Parameter

Table 5.1-1 summarizes the average concentrations for key water quality parameters at each site, separately considering the average for all dry event samples, wet event samples and all samples collected. Red text indicates exceedance of the PWQO, CWQG or HHRAP objective for that water quality parameter. The site locations are re-iterated in Section 5.2 below for reference.

Table 5.1-1: Average Concentrations (for Dry Events, Wet Events, and Total Samples) for Key Water Quality Parameters at All Sites.

Parameter	Dry or Wet Event	Average Concentration						
		AC-1	AC-2	AC-3	AC-4	CP-7	CP-18	CP-11
TP (mg/L)	Dry (21 events)	0.030	0.032	0.029	0.042	0.038	0.040	0.506
	Wet (5 events)	0.034	0.029	0.038	0.054	0.044	0.047	0.490
	Total (26 events)	0.031	0.032	0.031	0.045	0.040	0.041	0.497
TSS (mg/L)	Dry Events	12.77	18.27	11.14	10.87	9.77	7.22	19.19
	Wet Events	8.60	11.40	8.54	16.50	12.08	4.44	13.18
	Total Average	11.90	16.95	10.55	11.90	10.17	6.42	17.99
Nitrate (mg/L)	Dry (21 events)	0.66	0.53	0.80	0.62	0.72	0.71	1.70
	Wet (5 events)	0.46	0.28	0.67	0.38	0.52	0.433	0.943
	Total (26 events)	0.619	0.477	0.772	0.560	0.672	0.635	1.492
E. coli (CFU/100mL)	Dry (21 events)	210.9	65.0	170.7	227.0	131.3	46.7	14626.2
	Wet (5 events)	476.0	204.0	462.0	300.0	566.0	278.0	446736.0
	Total (26 events)	244.2	81.5	209.8	230.6	175.0	63.9	19471.0

All sites had samples exceeding the TP objective, with the proportion of exceedances varying from about 25% (AC-2) to 100% (CP-11). In addition, at the sites the average TP concentrations for dry events, wet events, and total samples typically exceeded the objective. All sites had an average total sample TP concentration higher than the target of 0.03 mg/L, although AC-1, AC-2, and AC-3 averages were just above the objective. All sites except for AC-2 had an average wet event concentration greater than the objective. Site AC-3 was the only site that did not exceed the objective for dry event (baseflow) samples. In general, wet event samples had significantly higher average concentrations than dry event samples, except at AC-2 and CP-11.

For E. coli, all sites had samples exceeding the objective, with the proportion of exceedances varying from about 40% (AC-2) to 100% (CP-11). In addition, as for TP, the average E. coli concentrations for dry events, wet events, and total samples typically exceeded the objective. All sites had an average wet event concentration higher than 100 CFU/100mL. Most sites also had an average E. coli concentration for total samples and dry event samples that was higher than the objective, with the exceptions being AC-2 and CP-18.1. At all sites, wet event samples had significantly higher average concentrations than dry event samples

In general, TSS was not a water quality parameter of concern. Only a small number of samples at a few sites exceeded the objective (at AC-1, AC-2, CP-11, and AC-4). Also, at all sites the average concentrations were all below 25 mg/L. For the majority of sites (except AC-4 and CP-7), TSS concentrations were higher for dry event (baseflow) samples. This trend is interesting as TSS has been typically observed to be higher during wet events, due to increased runoff and erosion contributing increased sediments into the watercourses.

In addition, nitrate, unionized ammonia, and nitrite were also not generally found to be of concern. The exception was nitrite at CP-11. Site CP-11 was the only site with any considerable amount of exceedances in nitrite, with the majority of elevated levels occurring in the spring, summer, and winter.

Samples were also analyzed for concentrations of orthophosphate. Results were not provided above because all samples have routinely reported concentrations below the minimum detection limit.

5.2 Overall Findings by Sampling Site

The beginning of 2017 sampling seasons was marked by high water levels in Lake Ontario, and as a result higher water levels in Cootes Paradise. These higher water levels were observed in Chedoke and Spencer Creeks via backflow, where the mouth of these creeks could not properly flow into the marsh. This has the potential to have impacted some of the sample concentrations found at sites CP-11, CP-7, and AC-1. However, the magnitude of this impact could not be quantified, and as such the sampled concentrations have been presented unaltered.

Site CP-11 (at the downstream end of Chedoke Creek) continues to be the most impaired location. This site is located downstream of a number of combined sewer overflow (CSO) locations, which can discharge raw sewage into the creek during some high flow events. The proximity to CSO's, combined with the urban nature of this watershed are possible reasons why this location is experiencing poor water quality. CP-11 had average concentrations that were significantly higher than any other site for each water quality parameters, with the exception of TSS average for wet events (where CP-11 was second highest). That said, the main parameters of concern for CP-11 were determined to be TP and *E. coli*, due to the number of exceedances of the objectives and the large amount by which these objectives were exceeded. The average concentrations for TP and *E. coli* were all significantly above the objectives (for dry events, wet events, and total samples). In addition, CP-11 experienced routine exceedances for nitrite (most exceedances occurred during the winter and spring), while all other sites predominantly had concentrations below lab detection limits. Contrastingly, for TSS, concentrations were predominantly below the HHRAP objective (6 exceedances of 26 samples). Of interest to note, wet event grab samples for TP, TSS, and VSS indicated a possible dilution effect, as dry event samples tended to have higher concentrations.

Site AC-4 (a small unnamed tributary of Ancaster Creek) had water quality of concern primarily for TP and *E. coli*. That said, it should be noted that this creek contributes considerably less flow than the other locations, which is expected to result in limited relative loading amounts to Cootes Paradise. The average concentrations for TP and *E. coli* were all above the PWQOs (for dry events, wet events, and total samples). AC-4 routinely exceeded the TP objective, and almost 85% of all grab samples exceeded the *E. coli* objective.

For Site CP-7 (at the downstream end of Spencer Creek, and including the contributions from Ancaster Creek) the main parameters of concern were TP and *E. coli*. The average concentrations (for dry events, wet events, and total samples) for TP and *E. coli* were all higher than the PWQOs. About 65% of samples exceeded the TP objective, including 80% of wet event samples. For *E. coli*, 55% of samples exceeded 100 CFU/100 mL, including 80% of wet event samples. Wet events produced greater values in terms of TP and *E. coli*. CP-7 had the highest *E. coli* average concentration for wet events, compared to sites other than CP-11. Of interest, CP-7 had no samples exceeding the TSS HHRAP objective.

Site AC-1 (at the downstream end of Ancaster Creek, before the confluence with Spencer Creek) showed water quality concerns primarily for E.coli. The average concentrations for *E. coli* were all above the 100 CFU/100 mL (for dry events, wet events, and total samples). About 75% of samples exceeded the *E. coli* objective, including 80% of wet event samples. Also, almost all samples outside of the mid-April to end of May period exceeded 100 CFU/100 mL. Wet events produced considerably greater *E. coli* values, compared to dry event (baseflow) samples. AC-1 had the highest *E. coli* average concentration when considering all samples, compared to sites other than CP-11. For TP, the average concentrations (for wet events and total samples) were just above 0.03 mg/L, while the dry event average was at the objective. This site had the greatest difference in the proportion of wet event versus dry event grab samples that exceeded the TP objective, where 80% of wet event samples exceeded but only 19% of dry event samples exceeded the objective.

For this sampling year CP-7 had higher TP and nitrate concentrations and AC-1 had higher TSS and *E. coli* concentrations. This may imply that TSS and *E. coli* are being diluted once they enter Spencer Creek, while upstream of the confluence with Ancaster Creek, Spencer could be experiencing considerably higher loadings of TP and nitrate.

For Site AC-2 (at the downstream end of Sulphur Creek before the confluence with Ancaster Creek) the water quality results were fairly good, with *E. coli* during wet events being the only concern. AC-2 was one of only two sites (along with CP-18.1) with an average *E. coli* concentration for total samples below 100 CFU/100 mL. That said, the average concentration for wet events was twice the objective. Interestingly, about 40% of the total samples exceeded the objective. Also of interest to note, one of the greatest differences in the proportion of wet event versus baseflow grab samples that exceeded the *E.*

coli objective was at the AC-2, where 80% of wet event samples exceeded the objective, but only 33 % of dry event samples exceeded. The average TP concentrations were all near the objective, with the total sample average being the only one just above 0.03 mg/L. Only about 25% of samples exceeded the TP objective, including 40% of wet event samples. AC-2 was one of two sites (along with CP-11) where the average TP concentration for dry events was greater than for wet events. Regarding TSS, although the number of exceedances were relatively low and the average concentrations were all well below the objective, AC-2 had the second highest average TSS concentration for total samples (the highest was CP-11). AC-2 had 5 exceedances (representing less than 20% of samples), that were predominantly dry event, summer season grab samples.

Site AC-3 (in the main branch of Ancaster Creek, before the confluence with Sulphur Creek) showed water quality concerns primarily regarding *E.coli*. The average concentrations for *E. coli* were all above 100 CFU/100 mL (for dry events, wet events, and total samples). Interestingly all samples outside of the periods of mid-February to mid-March and mid-April to end of May exceeded the *E. coli* objective. In all, about 75% of samples exceeded the *E. coli* objective, including 100% of wet event samples. The average TP concentrations were all near 0.03 mg/L, with the total sample and wet events averages being just above the objective. AC-3 was the only site with a dry event TP average below 0.03 mg/L. Approximately 40% of samples exceeded the TP objective, including 80% of wet event samples. This site has the second largest difference in the proportion of wet event versus dry event grab samples that exceeded the TP objective, where 80% of wet event samples exceeded but only 29 % of dry event samples exceeded the objective. For TSS, AC-3 had no exceedances of the objective.

Site CP-18.1 (at the downstream end of Borers Creek) showed water quality concerns primarily regarding TP and *E. coli* during wet events. The average concentrations (for dry events, wet events, and total samples) for TP were all slightly above the objective. In all, about 75% of samples exceeded the TP objective, including 80% of wet event samples. Interestingly, the average TP concentrations were similar when considering only dry events or only wet events. For *E. coli*, CP-18.1 had the lowest average concentration for dry event and total samples of any site, and was one of only two sites (along with AC-2) below the objective of 100 CFU/100 mL. That said, the average concentration for wet events exceeded the objective. Interestingly, about 45% of the total samples exceeded the objective, while 100% of wet event samples exceeded. The greatest difference in the proportion of wet event versus baseflow grab samples that exceeded the *E. coli* objective was at the CP-18.1. CP-18.1 had no samples exceed the TSS objective, and had the lowest average TSS concentration.

5.3 Overall Findings by Season

From a seasonal perspective, some water quality parameters showed clear seasonality across the sites, while for other parameters seasonal concentration trends varied amongst the sites. For *E. coli*, the summer season predominantly had the highest average concentrations at the sites, except for CP-11 (winter). In addition, winter season predominantly had the lowest *E. coli* seasonal average concentrations at the sites, except for CP-11 (summer) and AC-4 (spring). For TP and TSS, no clear highest or lowest season was consistently observed at the majority of sites.

The season with the highest average concentration(s) for the key water quality parameter(s) of concern was determined for each site. At CP-11, the highest seasonal average concentrations for TP and *E. coli* when considering all samples occurred in the winter season. At AC-4, the highest total average concentrations for TP and *E. coli* occurred in the fall and summer (respectively). At CP-7, AC-1, AC-2, and AC-3 the highest averages for *E. coli* always occurred in the summer. At CP-18.1, all the seasons had similar average TP concentrations.

6. Long Term Trends

Using HCA data as well as historical records obtained from the RBG for sites CP-7, CP-11, and CP-18.1 long-term trends were reviewed for total phosphorus, total suspended solids, nitrate, and *E. coli*.

The figures provide each monitoring year's average concentrations for *E. coli*, nitrate, TSS, and TP. Red lines on each graph indicate the PWQO/CWQG/HHRAP objective. For recent monitoring years (2016 – 2017), samples were collected April to March, therefore, for example the 2016 annual average concentration was calculated from samples collected April 2016 to March 2017. The Green vertical bar represents the delineation between RBG and HCA sampling.

It should be noted that the number of wet event samples collected each year varied considerably. Furthermore, there is significant variability in the magnitude of wet events collected each year, which as per the storm event automated sample results previously presented, can result in significant changes in average concentrations (wet event and total samples). Also, as the monitoring program has evolved, the total number of samples collected each year has increased, including the fact that in 2016 the monitoring program was extended to year-round, increasing the number of samples collected for each monitoring year. Winter sampling may have an effect on average concentrations, as initial data indicates that winter season concentrations are sometimes significantly different from other seasons.

As a result of all of the above, caution is recommended regarding the suggested trends in total sample annual average concentrations. Furthermore, although data is presented, trends for wet events were not assessed. This is due to the significant fluctuations in wet event annual averages and a relatively low number of wet event grab samples often collected in a given monitoring year.

That said, there is a higher level of confidence on the suggested trends regarding dry event (baseflow) average concentrations.

6.1 Site CP-7 (Spencer Creek)

Historical data is available for site CP-7, located in Spencer Creek near the outlet to Cootes Paradise (and including the contributions from Ancaster Creek). Figure 6.1-1 show each year's average concentration (considering all samples collected), for *E. coli*, nitrate, TSS, and TP. Figure 6.1-2 show each year's average concentration (for dry event and wet event samples), for *E. coli*, nitrate, TSS, and TP.

An improving trend over time, or no trend, is suggested for the parameters of interest for dry event and total samples average concentrations. *E. coli* annual average concentrations (dry event and total samples) suggest a decreasing trend over time. For TP, TSS, and nitrate, annual average concentrations (dry event and total samples) suggest slight decreasing trends.

For *E. coli* and TP almost all of the annual average concentrations are well above the PWQOs (for dry event, wet event, and total samples).

For TSS, some of the annual average concentrations are above the HHRAP objective, while some are below. A larger proportion of the annual average concentrations for wet events are above the objective while more annual dry event averages are below the objective.

For nitrate, the annual average concentrations are all well below the CWQG.

For TP, TSS, and *E. coli*, wet event annual averages experience more variation than dry events. This is likely due to the variation in intensity and number of wet event samples that are collected each year. In addition, wet event annual average concentrations are typically higher than for dry event averages. Nitrate concentrations do not appear to vary significantly between dry and wet event averages.

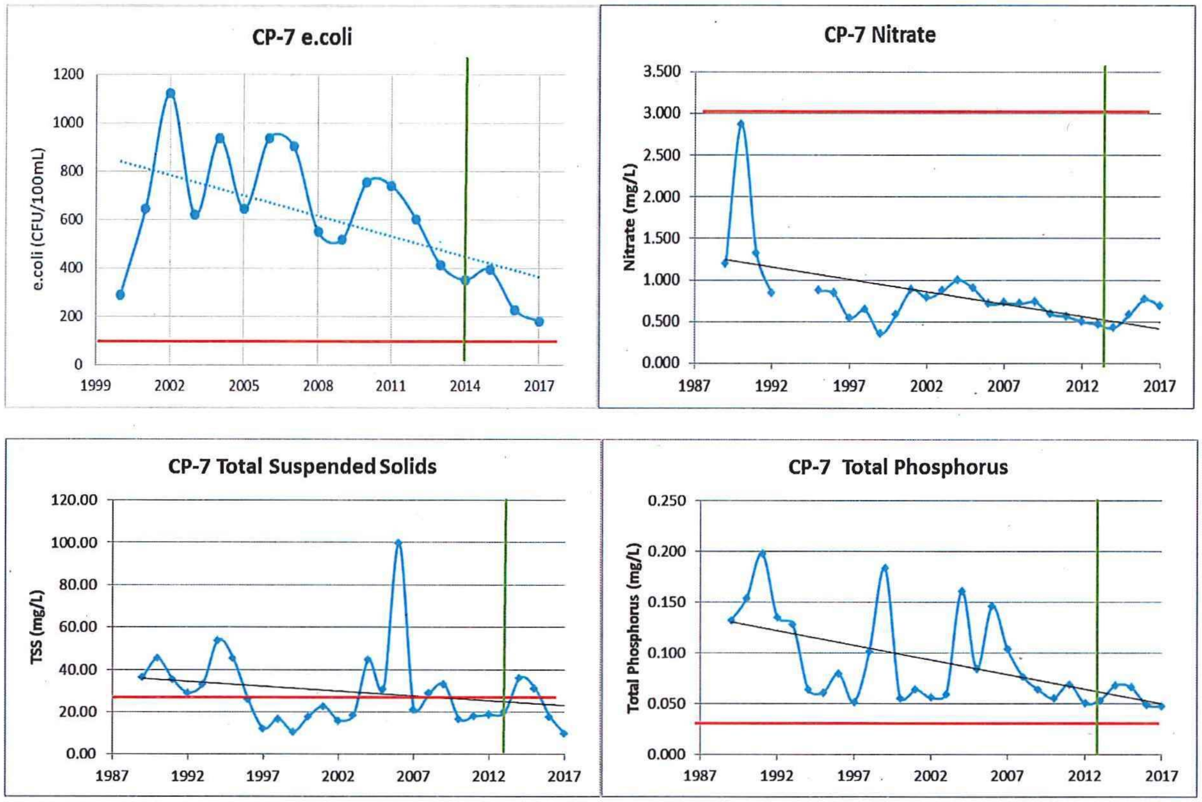

Figure 6.1-1: CP-7 Annual Total Average Concentrations

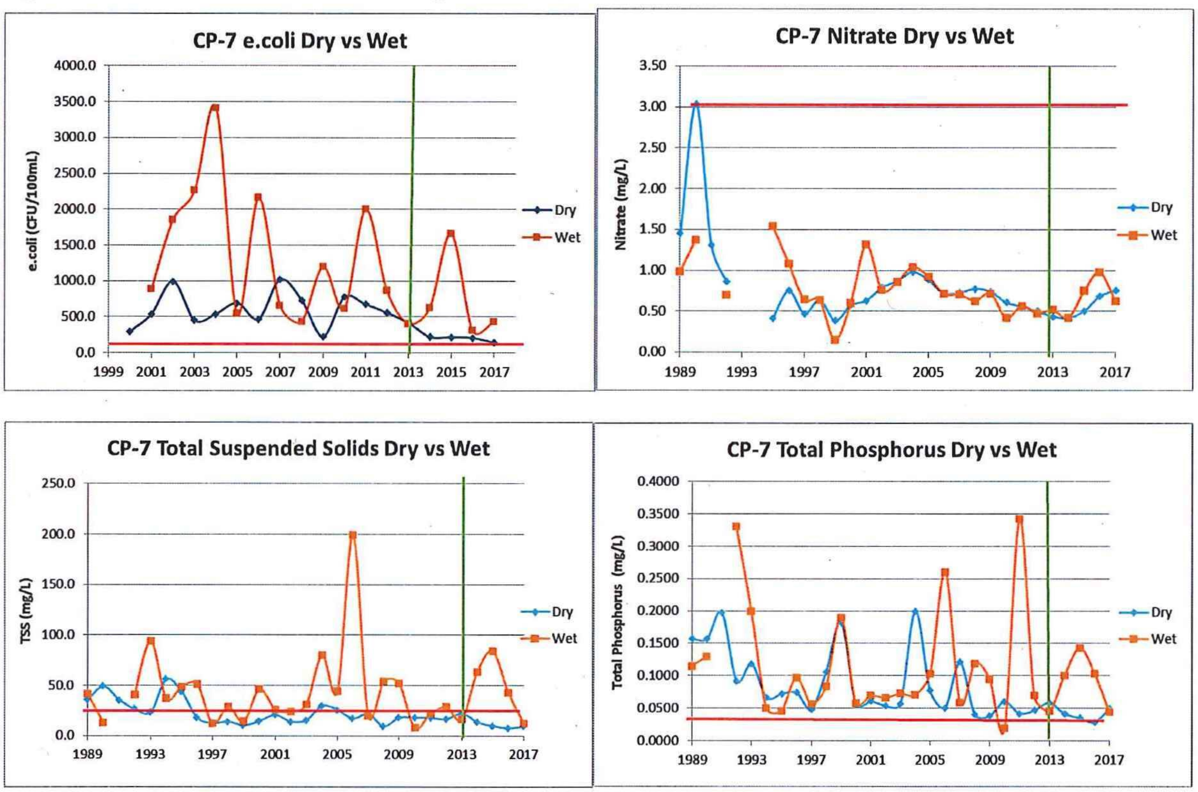

Figure 6.1-2: CP-7 Annual Wet Event and Dry Event Average Concentrations

6.2 CP-11 (Chedoke Creek)

Historical data is available for site CP-11, located in Chedoke Creek near the outlet to Cootes Paradise. Figure 6.2-1 show each year's average concentration (considering all samples collected), for *E. coli*, nitrate, TSS, and TP. Figure 6.2-2 show each year's average concentration (for dry event and wet event samples), for *E. coli*, nitrate, TSS, and TP.

Trends in annual average concentration were assessed separately for the period prior to 2014 and the period after 2014 due to a significant increase in average TP and *E. coli* concentrations starting in 2014. Potential reasons for this considerable increase in average concentrations continue to be reviewed.

For the period after 2014, it is acknowledged that additional data is required to confirm the suggested trends, due to the limited number of data points currently available.

For monitoring years prior to 2014, it is suggested that there has been a slight improving trend over time for most parameters of interest (dry event and total samples). However, *E. coli* annual average concentrations (for total samples) appear to have a slight increasing trend in concentration over time.

For monitoring years after 2014, it is suggested that *E. coli* annual average concentrations (for total samples) has an improving trend over time. For TP, annual average concentrations (for total samples) seems to have no definitive trend over time, while a slight increasing trend is suggested for dry event averages. For TSS, annual average concentrations (for total samples) there appears to be a decreasing trend over time, however it is suggested that for dry event averages there is no definitive trend. Nitrate annual average concentrations (total samples and dry event) seem to have an increasing trend over time.

For monitoring years prior to 2014, TSS annual average concentrations were sometimes above and sometimes below the objectives. The majority of years with TSS averages below the objective have occurred in recent years. For *E. coli* and TP, annual average concentrations were consistently above the objective. For nitrate, the annual average concentrations are all well below the objective.

For monitoring years after 2014, the same findings as prior to 2014 were observed.

For all parameters, wet event annual average concentrations vary more year to year than dry event averages. In addition, wet event annual average concentrations are typically higher than dry event averages for all water quality parameters except nitrate. For nitrate, dry event averages are typically higher than wet event averages.

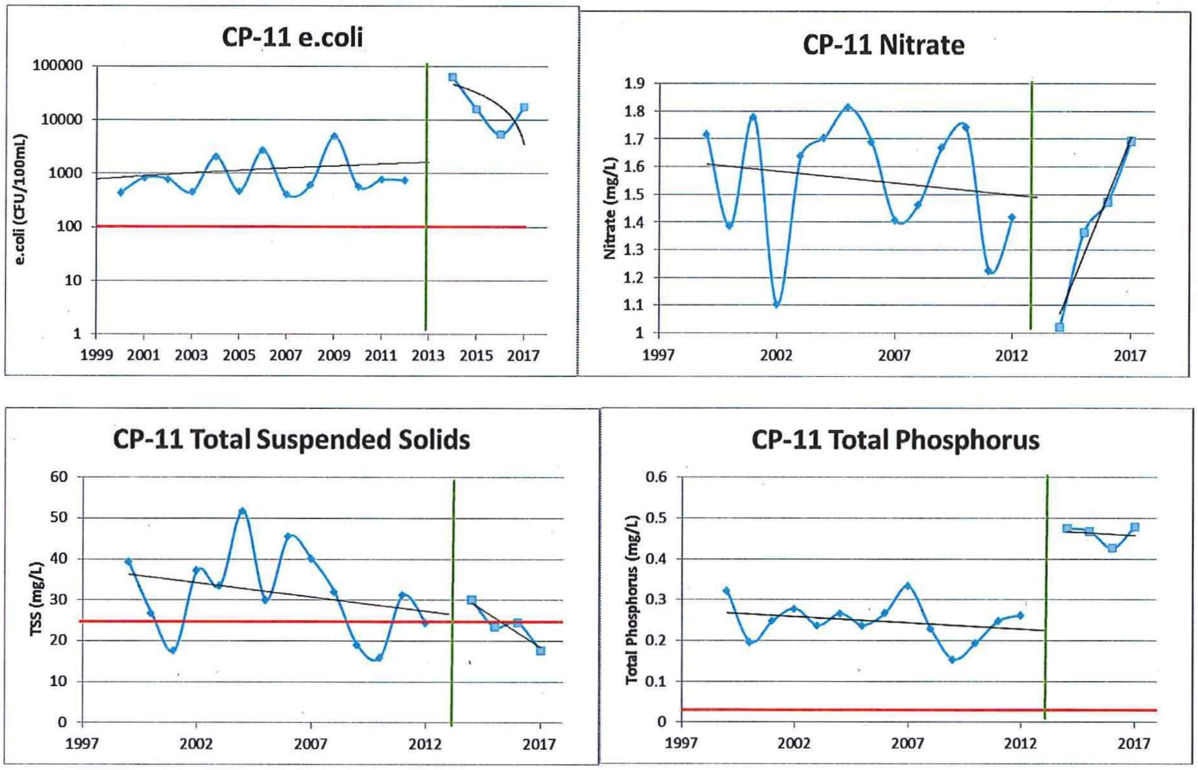

Figure 6.2-1: CP-11 Annual Total Average Concentrations

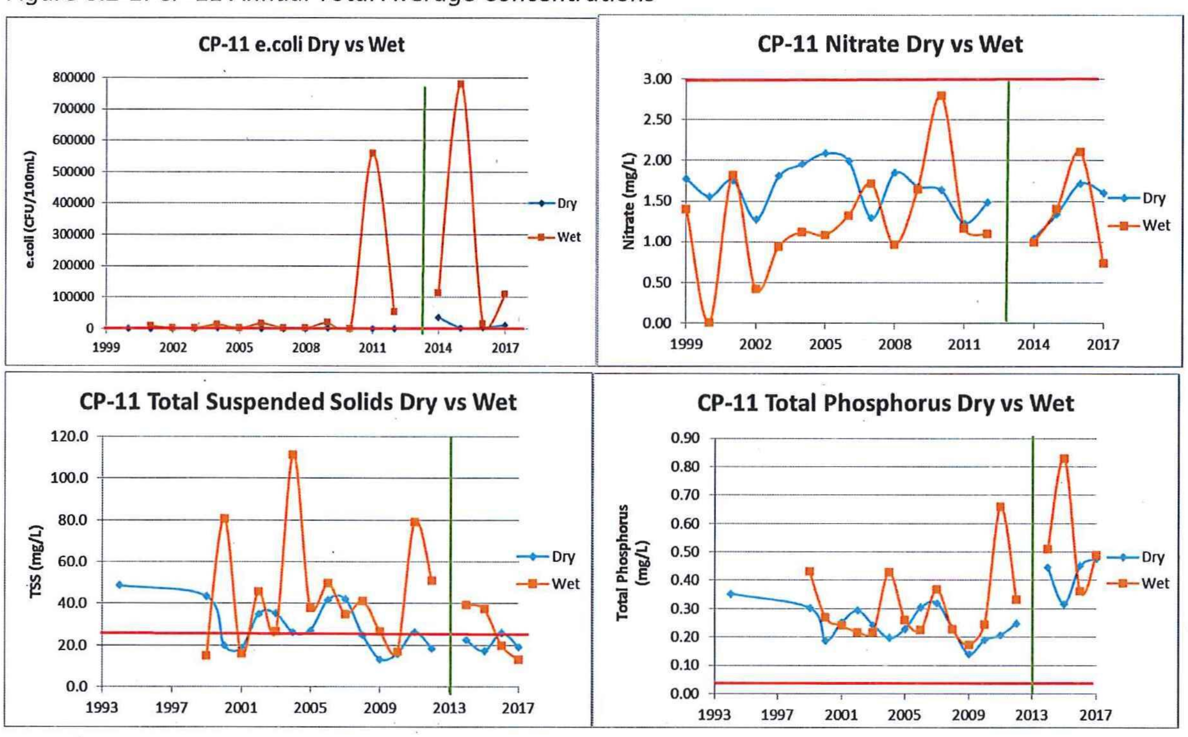

Figure 6.2-2: CP-11 Annual Wet Event and Dry Event Average Concentrations

6.3 CP-18.1 (Borers Creek)

Annual average concentrations (total samples and dry events) suggest a downward trend over time for all four key parameters.

For E. *coli* and TP the majority of the annual average concentrations have been well above the objectives (for dry event, wet event, and total samples).

For TSS, some of the annual average concentrations are above the objective, while some are below. An equal proportion of the annual average concentrations for wet events are above the objective compared to below the target, while most annual dry event averages are below the objective.

For nitrate, the annual average concentrations are almost entirely well below the objective.

For all parameters, wet event annual average concentrations vary more year to year than dry event averages. In addition, wet event annual average concentrations are typically higher than dry event averages, for all water quality parameters except nitrate. For nitrate, dry event averages are more often higher than wet event averages.

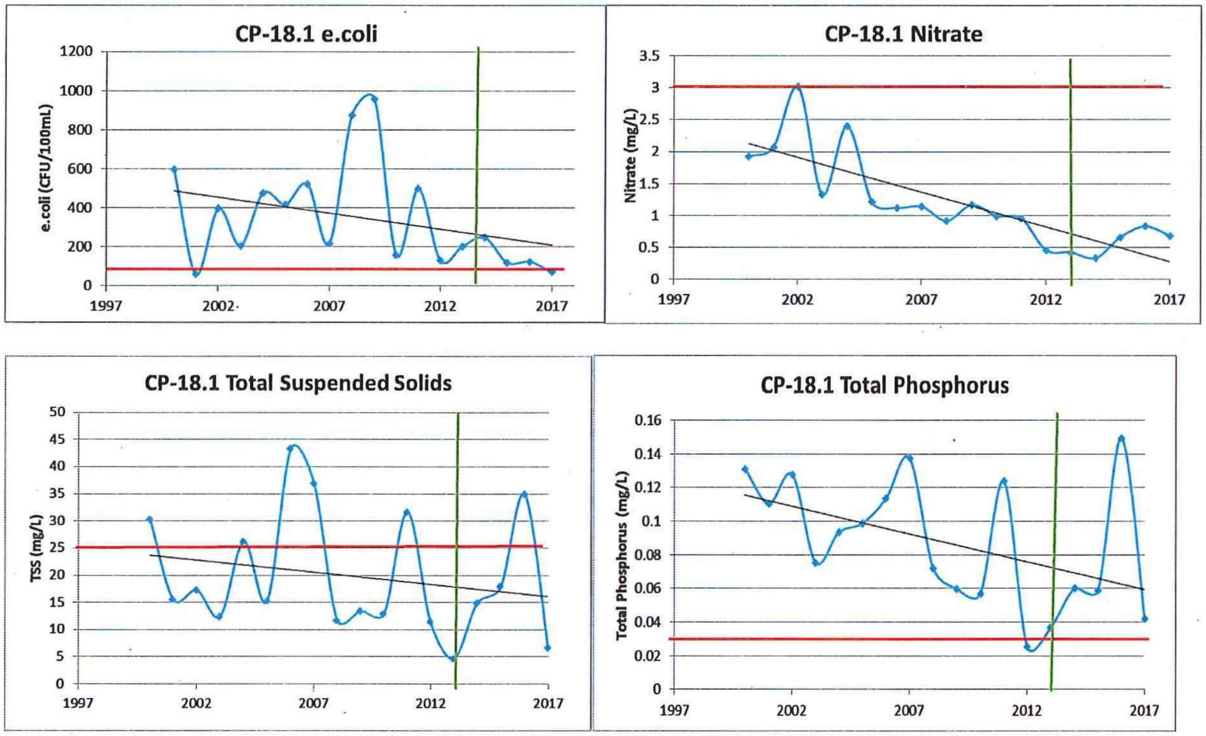

Figure 6.3-1: CP-18.1 Annual Total Average Concentrations.

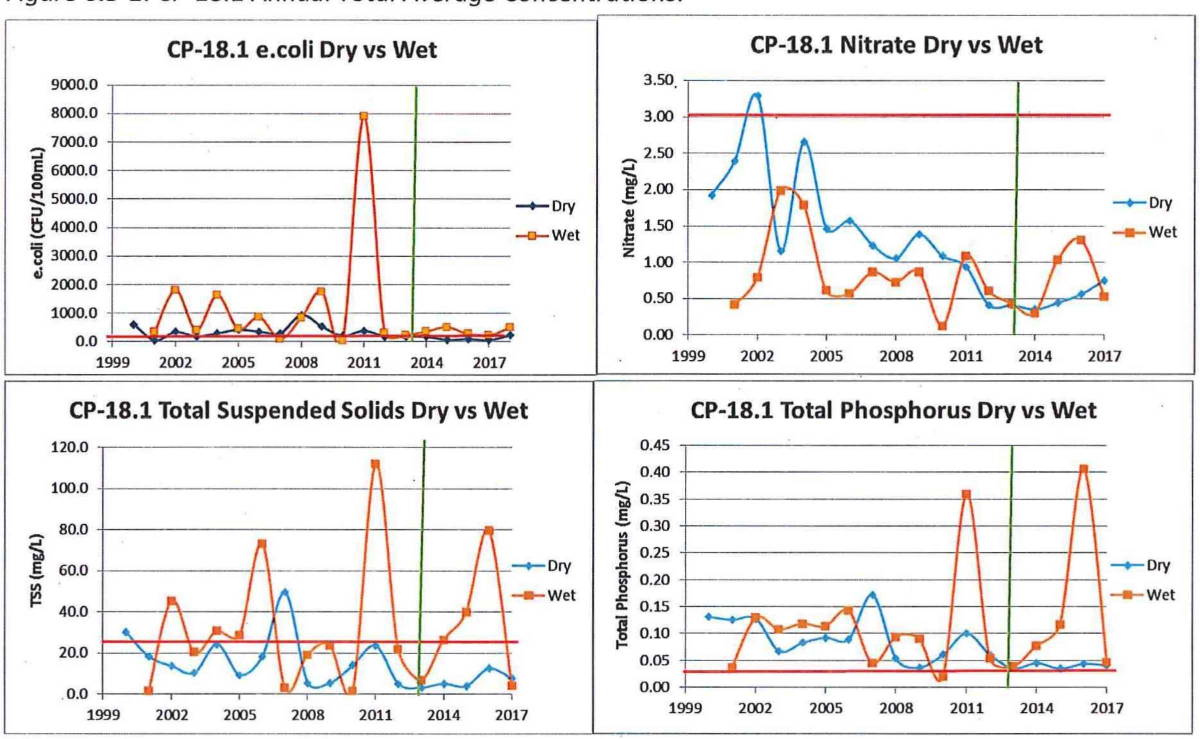

Figure 6.3-2: CP-18.1 Annual Wet Event and Dry Event Average Concentrations.

7. Conclusions

The 2017-2018 monitoring year resulted in expanded understanding of the overall water quality contributions from creeks entering Cootes Paradise Marsh. This second season of year-round monitoring has also provided more insight into the effects winter, early spring, and larger wet events have on water quality.

Site CP-11 (at the downstream end of Chedoke Creek) continues to be the most impacted location.

Regarding grab sample water quality, *E. coli* and TP were determined to be the key water quality concerns. Average TP and *E. coli* concentrations (dry event, wet event, and total samples) typically exceeded the objectives, at all to most of the sites. However, AC-1, AC-2, and AC-3 averages were just above the TP objective, and AC-2 and CP-18.1 had *E. coli* average concentrations for total samples and dry event samples that were below the objective.

In general, TSS was not a water quality parameter of concern. Only a small number of grab samples at a few sites exceeded the objective (at AC-1, AC-2, CP-11, and AC-4). In addition, nitrate, unionized ammonia (UA), and nitrite were also not generally found to be of concern. The exception was nitrite at CP-11.

With respect to wet event verses dry event grab sample concentrations, *E. coli* wet event concentrations were considerably higher than dry event averages at all sites. For TP, wet event concentrations were generally slightly higher than for dry events, with the exceptions being AC-2 and CP-11. Conversely, average nitrate, TSS, and UA concentrations for baseflow events were typically higher than wet event averages at the majority of sites, however there were some exceptions.

That said, storm events resulted in substantially greater average concentrations than grab samples, for key water quality parameters (TP*, E. coli*, TSS). These findings may indicate that significant storm events can greatly increase the amount of sediments, nutrients, and bacteria being transported downstream. However, additional years of sampling of intense rain events, as well as possible large snowmelt events is needed to gain further understanding of how intensity and other pre-post precipitation events and their frequency affects water quality in the creeks.

From a seasonal perspective, some water quality parameters showed clear seasonality across the sites, while for other parameters seasonal concentration trends varied amongst the sites.

Historical data suggests that for most locations water quality is improving. At CP-7, an improving trend over time, or no trend, is suggested. At CP-11 for monitoring years prior to 2014, it is suggested that there has been a slight improving trend over time however; *E. coli* appears to have a slight increasing trend in concentrations over time. For monitoring years after 2014, decreasing, increasing, and no trends were all suggested, dependent on water quality parameter and whether all samples were considered or only dry event samples. At CP-18.1, there appears to be an improving trend over time for all four key parameters.

There is a higher level of confidence on the suggested historical trends regarding dry event (baseflow) average concentrations. Caution is recommended regarding the suggested trends in total sample annual average concentrations. Furthermore, although data is presented, trends for wet events were not assessed. This is due to the significant fluctuations in wet event annual averages and relatively low number of wet event grab samples often collected in a given monitoring year.

The continued monitoring of these sites year-round is important not only to the continuing knowledge of the water quality entering the marsh but also provides revised background levels in the creeks to help direct improvement targets for parameters, as well as to measure the relative effects of future mitigation actions.

8. Future Planned Monitoring

For the 2018-2019 sampling season year-round routine grab sample monitoring will continue along with storm event sampling. There is a target of capturing 8 storm events at all four automated sampling stations.

Five new routine grab sampling locations have been added for the 2018/19 season. One is located in Ancaster Creek (AC-5) at Wilson Street where automated storm event sampling already occurs. This will allow for comparison of baseline, wet event grab sample, and storm event samples.

The other four new sites are located in various branches of Chedoke Creek as seen in Figure 8-1 (CC-3, CC-5, CC-7, and CC-9). Lower reaches of Chedoke Creek (site CP-11) have exhibited very poor water quality making it beneficial to explore upstream reaches of Chedoke Creek to identify areas of concern and non-point sources of nutrients and bacteria. The addition of these 4 new grab sample locations are to further investigate areas that have shown to be contributing to the net negative water quality entering Cootes Paradise Marsh and to identify certain reaches that may be contributing more nutrients and bacteria than others.

Additionally, flow measuring devices are planned to be installed in Chedoke Creek and in Lower Spencer Creek, to continually monitor flows at these locations. This flow data will allow discharge and improved loadings calculations to be completed for the mouths of Spencer Creek and Chedoke Creek as they flow into Cootes Paradise Marsh. This information will provide a more accurate understanding of water quality in the watershed and possible remediation efforts from the various sources.

Greater data analysis will also be conducted for the next monitoring season. Further classification of wet days based on the amount of precipitation received will be conducted. In addition, available flow data will be reviewed on each creek to better classify baseflow and wet events. With the incorporation of flow data and year-round sampling it will be possible to identify snow-melt events and the impact they have on water quality. The HCA monitors flow in Spencer Creek at Market Street in Dundas, and Ancaster Creek at Rousseaux Street in Ancaster, with the addition of flow monitoring devices to be installed further down Spencer Creek and on Chedoke Creek it will be possible to better quantify loadings into the marsh, and classify various runoff events and their intensity. For example a 5 mm rainfall event vs. a 50 mm rainfall event may have very different influences on water quality, and understanding how rainfall intensity and duration may affect different watercourses will give further insight as to when and how sediments and nutrients are being transported through the creeks and tributaries into Cootes Paradise Marsh.

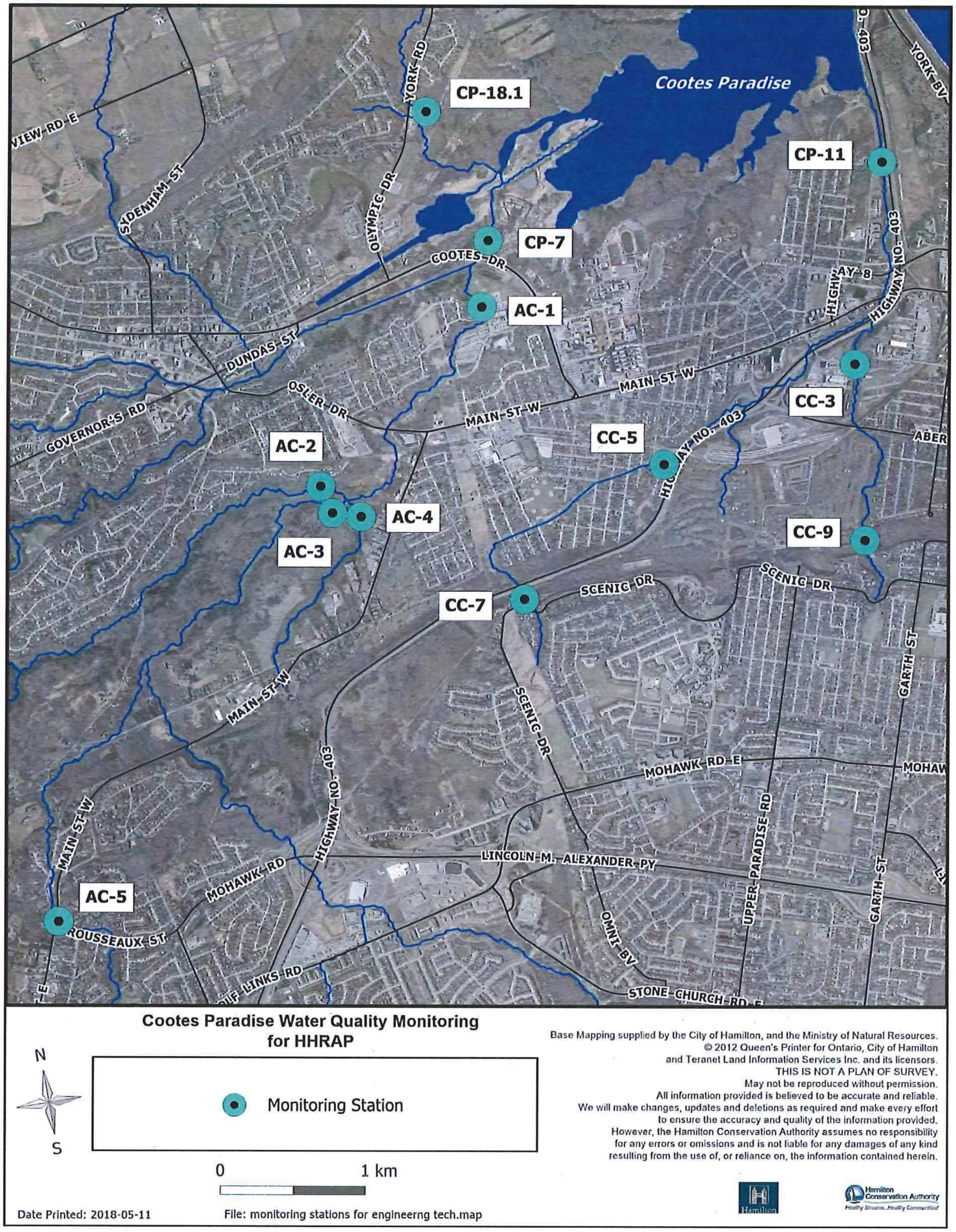

Figure 8-1: Cootes Paradise HCA Monitoring Locations