ACAP SAINT JOHN

REBIRTH OF WATER

SUNGMIN JEONG | LEANNE MOORE | GRAEME STEWART-ROBERTSON

Rebirth of Water 2018-2019

Jeong, Sungmin
Moore, Leanne
Stewart-Robertson, Graeme

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Atlantic Coastal Action Program [ACAP] Saint John Inc.
139 Prince Edward Street, Suite 323
Saint John, New Brunswick
Canada E2L 3S3
Tel: (506) 652-2227
Fax: (506) 801-3810
E-mail: office@acapsj.org
Web: www.acapsj.org

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Executive Summary

Continued water quality monitoring throughout the City of Saint John and the Greater Saint John area helps to gain insight into the aquatic habitats that these watercourses provide, as well as their safety for recreational use for humans. The watercourses that have had continuous monitoring this year include: Marsh Creek, Inner Harbour, Newman's Brook, Caledonia Brook, Alder Brook, Hazen Creek, Taylor Brook, Salmon Creek and Mispec River. Additional sampling sites were added this year on the west side of the City, which include Mill Creek, Spruce Lake Stream, Walker Creek, Mosquito Cove, Manawagonish Creek, and Dominion Park. These new locations were added this year to more accurately portray the water quality of the city's waterways as a whole.

Overall, the watercourses included in this year's sampling all continue to have the capability to provide sufficient aquatic habitats for various forms of aquatic life. There are several factors that potentially affect the water courses such as stormwater runoff, sanitary sewer overflows and riparian degradation. The stormwater runoff and riparian degradation as well as the hot, dry weather led to elevated temperatures and slightly decreased dissolved oxygen levels as compared to previous years. On average, most sites this year saw an increase in orthophosphate concentration when compared to previous data. At this time, there is no official guideline or recommendation for orthophosphate levels in place.

The considerable improvements of water quality parameters for aquatic life seen in Marsh Creek since the completion of Harbour Cleanup in 2014 solidifies that the funding and resources put into the project were much needed. The most notable difference in the water quality is the dissolved oxygen concentrations, although lower in 2018 than 2017, they are still above the Canadian Council of Ministers of the Environment guideline recommended concentration of 6.5 mg/L on average at all the sites sampled.

Background

The Rebirth of Water project encompasses water quality monitoring in various watersheds throughout the Greater Saint John area. Originally, this project focused on the recovery of Marsh Creek after the practice of dumping raw sewage into this watercourse was terminated in 2014; as such, the Marsh Creek watershed is still the most heavily monitored watershed within this project. Since 2016, additional watersheds have been monitored to get a better understanding of the state of the urban watersheds in the Greater Saint John Area. In 2017, five different watercourses were added to the water quality monitoring program – Caledonia Brook, Alder Brook, Saint John Inner Harbour (a historic ACAP Saint John site), Salmon Creek, and Mispec River, which together with Marsh Creek, Hazen Creek [Red Head Marsh], Taylor Brook, and Newman's Brook, encompass a large portion of the Saint John region. In 2018, it was noticed that sample sites were lacking on the West side of the city and sites were added in Mill Creek, Spruce Lake Stream, Walker Creek, Mosquito Cove, Manawagonish Creek, and Dominion Park.

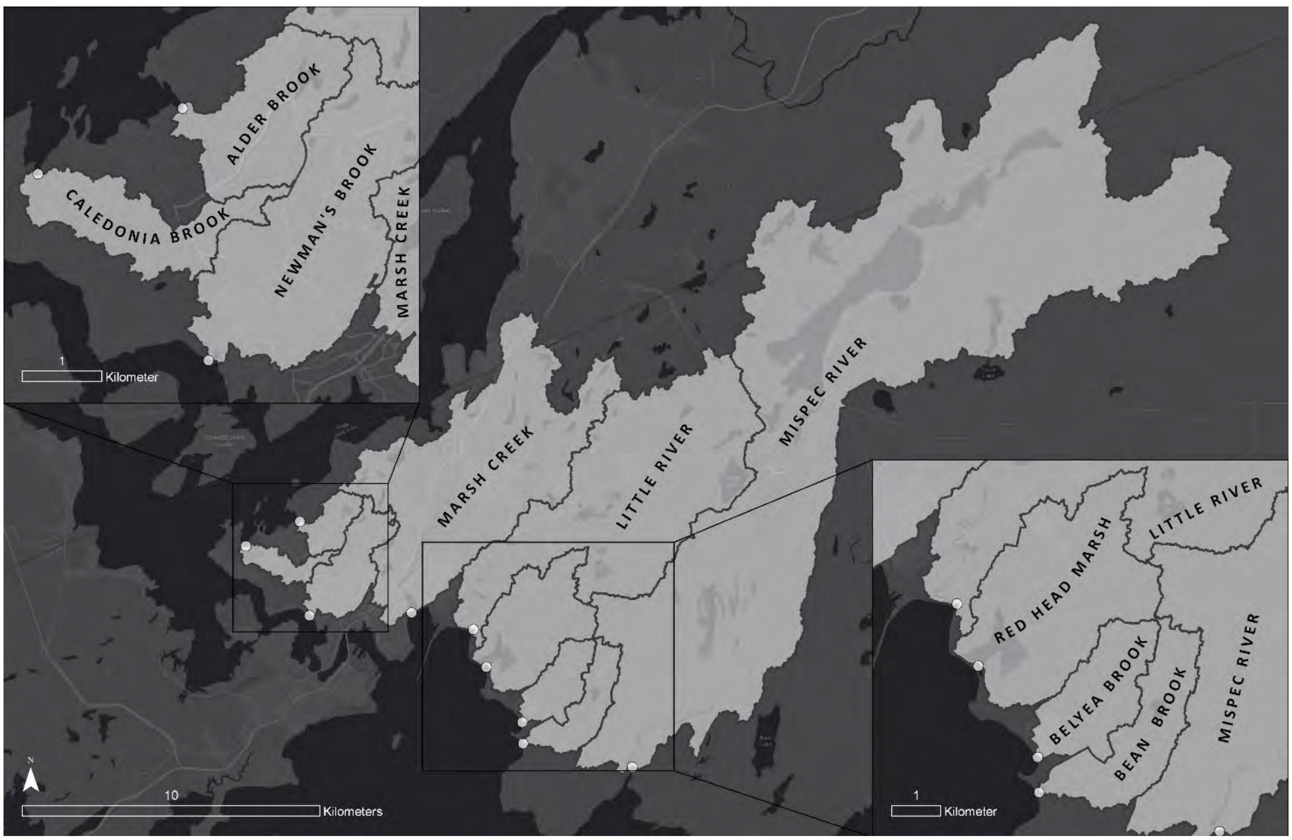

Figure 1. A few monitored watersheds within the City of Saint John; Belyea Brook and Bean Brook depicted on this map were not monitored as part of the Rebirth of Water project in 2018.

Marsh Creek Watershed

The Marsh Creek watershed is a ~4,200 hectare feature located in East Saint John, New Brunswick, Canada, that drains directly into the Bay of Fundy. The watershed consists of six primary watercourses, eighteen lakes and countless wetlands, including a brackish semi-tidal wetland at its terminus. Marsh Creek, which served as a valuable natural asset for early settlers, became an internationally recognized environmental concern due in large part to its receipt of untreated municipal wastewater and the existence of heavy creosote contamination in the sediments of its lower reaches. Locally, the creek is also subject to extreme flooding resulting from its low-lying drainage basin, commercial and residential developments in and around its floodplain, and the cumulative effects of crustal subsidence (depression of the crust under New Brunswick), watercourse channeling, and wetland infilling.

The Marsh Creek watershed has undergone vast improvements and changes over the years. The most noteworthy of these alterations is the completion of the Saint John Harbour Cleanup project (2014), which resulted in the cessation of the centuries old practice of discharging raw sewage into its urban waterways, including Marsh Creek, Courtenay Bay, Saint John Harbour, and ultimately, the Bay of Fundy.

Harbour Cleanup, which came about largely from two decades of dedicated community engagement by ACAP Saint John, represents the single greatest opportunity in recent history to restore the nearshore water quality of Saint John, thereby improving the habitat needed to increase and restore the diversity of flora and fauna. As such, the information acquired in this project represents one of the last opportunities in Canadian history to acquire the baseline metrics needed to measure and document any changes that occur in the associated biodiversity following the cessation of untreated municipal wastewater discharges into nearshore environments.

Hazen Creek Watershed

The Hazen Creek watershed is 1,030 hectares in size and is located within the East side of Saint John. The watershed is comprised of six individual tributaries that merge to form the Red Head Marsh, one of the few remaining tidal marshes along New Brunswick's Fundy coast that drains into the Saint John Harbour. Along its course, Hazen creek flows through forested, residential, commercial, and industrial areas within the East side. As such, the watershed has suffered over the years from indirect and direct influences from development.

Taylor Brook Watershed

The Taylor Brook watershed transverses East Saint John through to the Town of Rothesay and drains into the Kennebecasis River, a tributary of the Saint John River. The watershed encompasses seven lakes, numerous wetlands, and three watercourses – Taylor Brook, Fairweather Brook, and McGuire Brook. Much of the riparian area within the watershed remains forested, or at least has adequate cover to be considered as a healthy riparian area. Juvenile Atlantic salmon, *Salmo salar*, have also been found in reaches of both Taylor and Fairweather Brook in the past, indicating that the watershed also has excellent fish habitat. The main threat to this watershed is potential encroachment from development as East Saint John and the Town of Rothesay expand further into the watershed.

Newman's Brook Watershed

The Newman's Brook watershed encompasses 648 hectares, covering a large portion of Rockwood Park, down through the North end of Saint John, to Spar Cove and the Saint John River. The upper portion of the watershed, which is in a forested area of Rockwood Park, is in pristine condition. But, after it exits the park, roughly 600 m downstream, it is piped underground (just upstream of Hazen White-St. Francis School) through the City's North end until it reaches Spar Cove (roughly 3 km). Although piping the brook underground allowed for the development of the area, it has also caused issues from the watershed such as loss of aquatic and riparian habitat, and increased contamination of the brook as it combines with the stormwater network. Along with the issues posed due to the piping of the brook underground, the headwaters of Newman's Brook lie in an area that was once a landfill which has not been completed capped, resulting in the potential for leachate to move throughout this brook.

Caledonia Brook Watershed

The Caledonia Brook watershed covers 217 hectares of the Millidgeville area of Saint John through to Den Boom Cove and the Kennebecasis River. The headwaters of this watershed borders the Newman's Brook watershed on the eastern side and the Alder Brook watershed on the northern side. Similar to other urban watersheds in Saint John, it has sections that are in pristine state and other areas where encroachment and development have put pressure on the watercourse. This includes the construction of a stormwater detention pond surrounding Caledonia Brook to help control stormwater, and the piping of the brook underground from this pond to just after École Samuel-de-Champlain School.

Alder Brook Watershed

The Alder Brook watershed is also located in the Millidgeville area of Saint John but Alder Brook outflows into Brothers Cove and then the Kennebecasis River. The headwaters of Alder Brook is located on the western side of the same landfill that may be impacting Newman's Brook; therefore the same potential for leachate movement is present within this watershed.

Salmon Creek Watershed

The Salmon Creek watershed originates in Quispamsis and flows through Rothesay into the Kennebecasis River. Many residential homes are located within this watershed and the watercourse may suffer from the indirect and direct effects of this development. These effects include encroachment into the riparian area, riparian area degradation, nutrient runoff, and natural flow regime changes.

Mispec River Watershed

The Mispec River watershed is the largest watershed sampled within this program at 15,742 hectares and flows directly into the Bay of Fundy. The watershed encompasses a large portion of the semi-rural section of East Saint John, including the lake systems used as the drinking water source for the City of Saint John. Although this watershed is large, it remains fairly unimpacted due to its rural location and the upper portion of the watershed being protected as a drinking water source. The largest impact to the watershed would be the Saint John Airport in the upper portion of the watershed and illegal dumping throughout the watershed. The lower portion of the watershed has some home and cottage development as well as being used recreationally for ATVs, fishing, and kayaking. The river itself supports a healthy aquatic community and has been known to support Atlantic salmon in the past.

Mill Creek Watershed

The Mill Creek watershed is located in Ketepec on the City's West side. The watershed itself it mostly forested with some development (mostly housing) as it approaches the Saint John River and the Saint John Marina which is located at the outflow of Mill Creek into the Saint John River.

Spruce Lake Stream Watershed

As its name implies, the Spruce Lake Stream drains from Spruce Lake on the West side of the city out to South Bay off the Westfield Road. As with the Mill Creek Watershed, most of the watercourse is contained within forested areas. There is one quarry located within the watershed that may impact the stream with sediment runoff.

Walker Creek Watershed

Walker Creek begins in a large, partially regulated wetland beside Quinton Heights subdivision that also designated as a wellfield protection area for the West side drinking water system. The watercourse runs between Quinton Heights subdivision and a large quarry before entering a small forested area and emptying into South Bay and the Saint John River. The close proximity of Walker Creek to the quarry and suburban develop may cause water quality and management issues such as sedimentation and degraded riparian areas.

Manawagonish Creek Watershed

The Manawagonish Creek watershed is located in an urbanized section of the West side of Saint John which includes retail districts and a large subdivision. The aboveground portion of the creek begins on the outskirts of the subdivision at a stormwater outflow indicating that some portion of the watercourse is piped underground. The watercourse then flows through a stormwater pond and crosses Highway 1 twice before by-passing a wastewater treatment plant, into Saints Rest Marsh, and into the Bay of Fundy.

Methodology

Water Quality Site Selection

Marsh Creek Watershed

Figure 2a: Water quality monitoring stations (upstream, downstream) within the Marsh Creek watershed.

This project conducted two separate water quality analyses in the Marsh Creek watershed to enable comparisons with two distinct historical data sets. Analysis A involved a simple upstream/downstream comparison relative to the area receiving wastewater discharges (Figure 2a). These sample stations have now acquired data over various years between 1993 and 2017.

Analysis B consisted of five sample stations in the last 2 km of Marsh Creek which was used to conduct a more defined concentration gradient analyses within the wastewater discharge zone (Figure 2b). These sample stations were first established in the 2012 Marsh Creek study.

Sample Stations Analysis A

The downstream site (45.282400, -66.04946) was located immediately downstream of the access road/rail crossing containing three metal culverts just beyond the Universal Truck and Trailer parking lot; and an upstream site (45.321517, -66.015117) located on the downstream side of the small bridge on Glen Road near MacKay Street (Figure 2a).

Sample Stations Analysis B

Figure 2b: Map showing the location of the five sampling stations used in Marsh Creek water quality Analysis B.

Analysis B, which has acquired water quality measurements since 2012, incorporated five sampling stations located approximately 500 m apart within the last 2 km of Marsh Creek (Figure 2b). The stations included two sites in the Courtenay Forebay and three sites above the upstream site from Analysis A. The characteristics of the five individual sampling stations used in Analysis B are provided in Table 1 and Figure 3.

In 2016, an additional site was added within medial Marsh Creek (site 11) to better monitor the water quality between the two sample sets and is now incorporated into Analysis B.

Figure 3. Sites 1 (right) and 5 (left) used in Water Quality Analysis B conducted in Marsh Creek.

Table 1. *Characteristics of sampling stations used in Marsh Creek water quality Analysis B*

Site Number	GPS Coordinates	Site Description
1	45.277506, -66.047122	Located on the upstream side of the Courtenay tide gates at the terminus of Marsh Creek.
2	45.281560, -66.048694	Located approximately 500 m upstream from Site 1, just upstream of where Dutchman's Creek enters Marsh Creek.
3	45.284844, -66.052393	Located 500 m upstream from Site 2 immediately (2 m) upstream of the former raw sewage outfall adjacent to the Universal Truck and Trailer parking lot.
4	45.288143, -66.048764	Located 500 m upstream from Site 3, immediately upstream of the former raw sewage outfall.
5	45.290998, -66.043606	Located upstream of the raw sewage outfalls, approximately 2 km from the outlet of Marsh Creek at the tide gates (Site 1). This sampling station can be found beneath the train bridge adjacent to Rothesay Avenue.
11	45.30963, -66.03402	Located approximately 2.2 km upstream of Site 5, on Ashburn Lake road, directly across from Strescon.

Hazen Creek Watershed

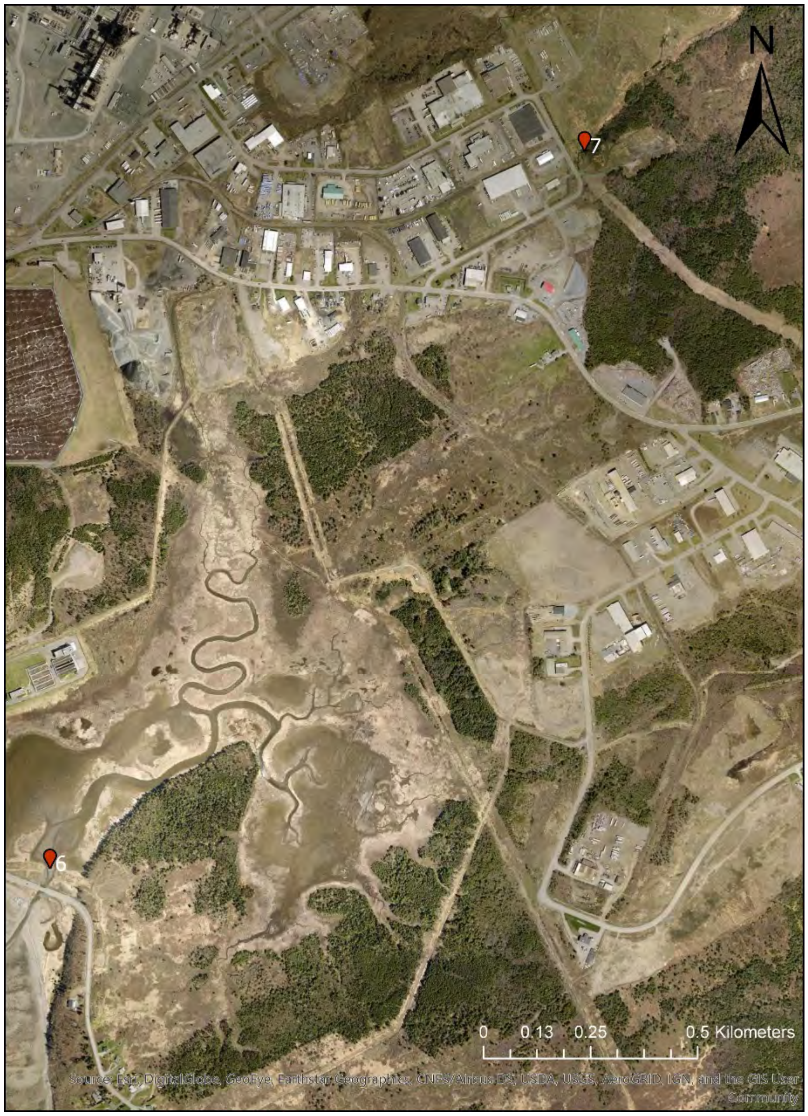

Figure 4. Map of the upstream (7) and downstream (6) sites within Hazen Creek.

Two water quality monitoring sites were established in the main branch of Hazen Creek (Figure 4).

Site 6, downstream Hazen Creek, (45.220990, -66.015505) was located upstream of the bridge crossing along Red Head Road at the outflow of Hazen Creek into the Saint John Harbour.

Site 7, upstream Hazen Creek, (45.275878, -65.998910) was located upstream of the culvert on Dedication Street within the industrial park.

Taylor Brook Watershed

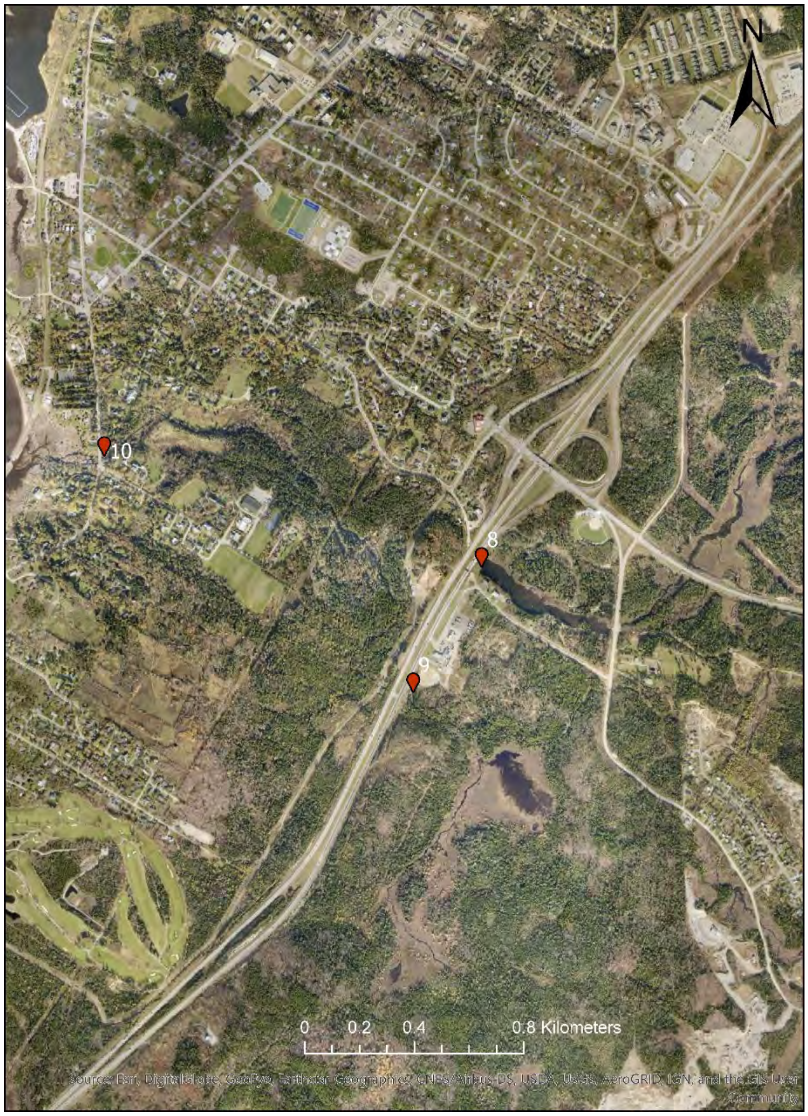

Figure 5. Map of the water quality sites located within the Taylor Brook watershed (sites 8, 9, and 10).

Sampling sites were established at three sites within the Taylor Brook watershed in 2016, where water quality monitoring continued at these sites in the 2018 field season (Figure 5).

Site 8, Fairweather Brook (45.378423, -65.978840), was located upstream of the McKay Highway (Highway 1) crossing next to the Dolan Road Irving gas station.

Site 9, Taylor Brook upstream (45.374322, -65.982063), was located at the outflow of Carpenter's Lake, upstream of the McKay Highway culvert crossing on the other side of the Dolan Road Irving gas station.

Site 10, Taylor Brook downstream (45.382143, -65.996388), was located under the bridge crossing on Rothesay Road by Rothesay Netherwood School.

Newman's Brook Watershed

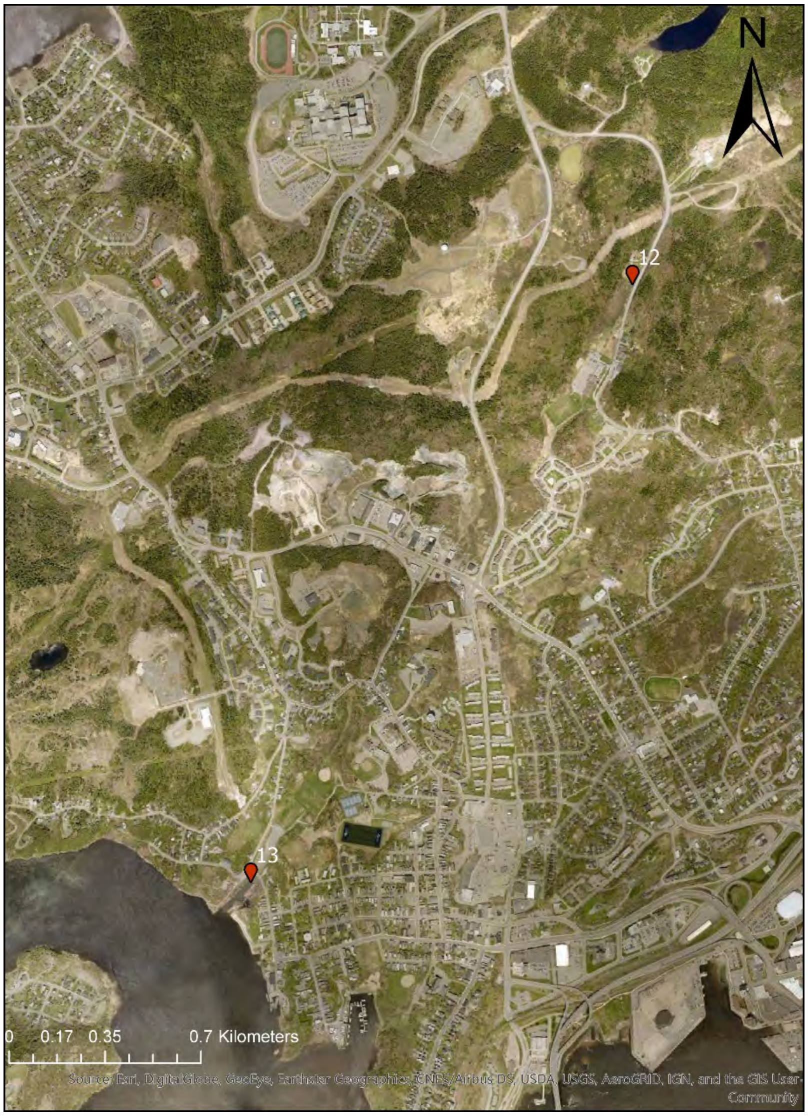

Figure 6. Map of the two water quality monitoring sites 12 (upstream) and 13 (downstream) in the Newman's Brook watershed.

Two water quality monitoring sites were established in the Newman's Brook watershed in 2016 and monitoring was continued at these two sites in the 2018 season (Figure 6).

Site 12, upstream Newman's Brook, (45.296902, -66.071298) was located along Sandy Point Road, roughly 300 m above Hazen White-St. Francis School, in the above ground section of Newman's Brook.

Site 13, downstream Newman's Brook, (45.277345, -66.089187) was located at the furthest inland point in Spar Cove, just downstream of the stormwater/Newman's Brook outflow.

Inner Harbour

Figure 7. Map of the water quality monitoring sites, site 14 (upstream) and 15 (downstream), within the Inner Saint John Harbour.

Two sites were chosen to represent the Inner Saint John Harbour [Inner Harbour] based on historic ACAP Saint John monitoring sites from the community monitoring program. These sites were last sampled prior to Harbour Cleanup and were chosen to determine the potential improvements in water quality similar to the Marsh Creek watershed (Figure 7).

Site 14, Inner Harbour upstream, (45.27469, -66.08897) was located at the very end of Main Street in the North End at the furthest tip of the rock point. Historically, an outflow was present at this site, however, due to Harbour Cleanup it is no longer being used as a sanitary sewer.

Site 15, Inner Harbour downstream, (45.27182, -66.07439) was located underneath the Harbour Bridge just off the Harbour Passage boardwalk. This site also had an outflow pipe that discharged raw sewage prior to Harbour Cleanup.

Caledonia Brook Watershed

Figure 8. Map of the water quality monitoring sites, site 16 (upstream) and 17 (downstream) in Caledonia Brook.

Within the Caledonia Brook watershed, two sampling sites were established in 2017 to represent an upstream downstream comparison (Figure 8).

Site 16, Caledonia Brook upstream, (45.29025, -66.09449) was located just downstream of the culvert crossing Millidge Avenue, next to the Saint John Energy sub-station.

Site 17, Caledonia Brook downstream, (45.29687, -66.11867) was located just upstream of the culvert crossing at 159 Ragged Point Road.

Alder Brook Watershed

Figure 9. Map of the water quality monitoring sites, site 18 (upstream) and 19 (downstream), within the Alder Brook watershed.

Two sampling sites were established in the Alder Brook watershed in the 2017 field season (Figure 9).

Site 18, Alder Brook upstream, (45.30147, -66.08162) was located downstream of Arlington Crescent, off of University Avenue but upstream of the confluence of Alder Brook and a drainage tributary.

Site 19, Alder Brook downstream, (45.30461, -66.09453) was located upstream of the culvert flowing into Brother Cove (outlet of Alder Brook) at 242 Kennebecasis Drive.

Salmon Creek Watershed

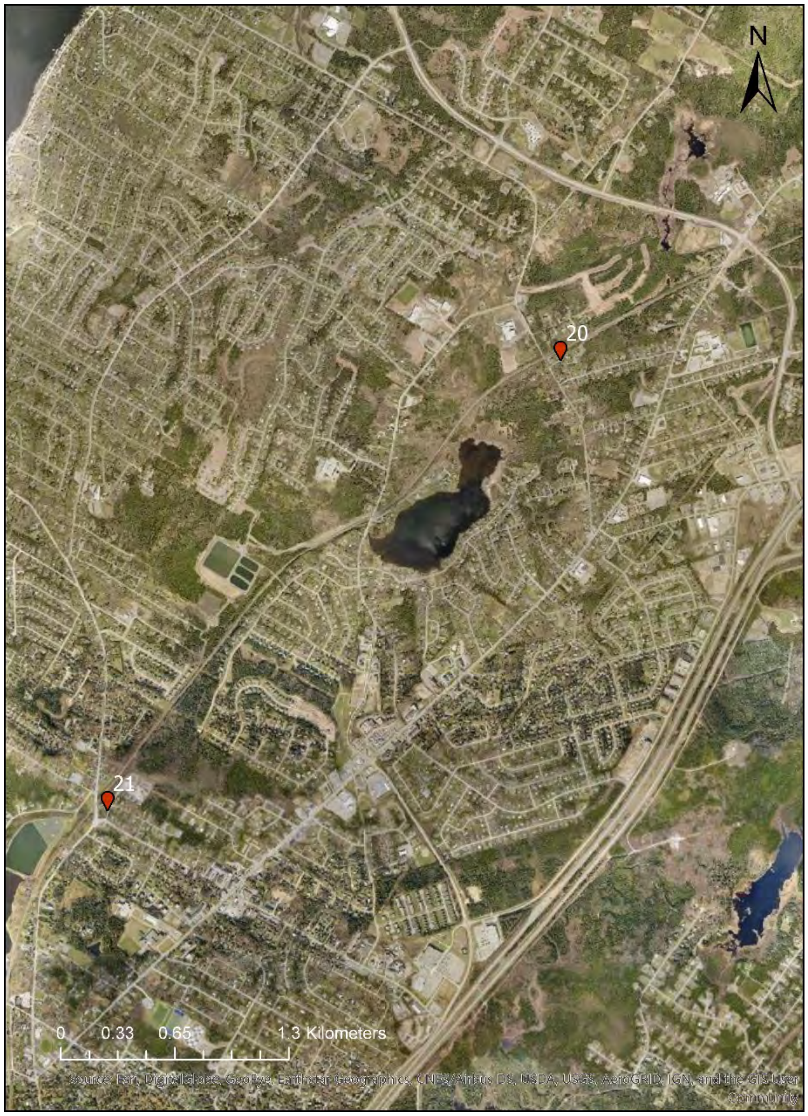

Figure 10. Map of the water quality monitoring sites, site 20 (upstream) and 21 (downstream), within the Salmon Creek watershed.

The two sites established in the Salmon Creek watershed were chosen to represent an upstream downstream comparison in the 2018 field season (Figure 10).

Site 20, Salmon Creek upstream (45.42371, -65.95859), was located upstream of the culvert crossing at 7 Rafferty Court.

Site 21, Salmon Creek downstream (45.40077, -65.9918), was located within Salmon Creek off of Salmon Crescent where it meets Clark Road.

Mispec River Watershed

Figure 11. Map of the water quality monitoring sites, site 22 (upstream) and 23 (downstream), within the Mispec River watershed.

Site 22, Mispec River upstream (45.26938, -65.89505), was located downstream of a bridge crossing along Old Black River Road; approximately 5.33 km down the dirt road (Figure 11).

Mispec River downstream, site 23 (45.23585, -65.95109), was located upstream of an ATV bridge crossing and upstream of the head of tide. The ATV path can be accessed from Old Bridge Road. From there, follow the trail and take the second trail off to the left to arrive at the site.

West Side

During the 2018 field season, seven new sampling sites were added to represent the water quality of the city's Westside. The locations of each sampling site can be found in Figure 12, and the characteristics of each sampling site can be found in Table 2.

Figure 12. Map of the new water quality monitoring sites, sites 24-30, added during 2018 located on the Westside of the City of Saint John.

Table 2. *Characteristics of sampling stations on the West side of the City of Saint John.*

Site Number	Stream Name	GPS Coordinates	Site Description
24	Mill Creek	45.27860 -66.15567	Located off the Westfield Road across the street from the Saint John Marina.
25	Spruce Lake Stream	45.25356 -66.14397	Located on the left-hand side of the street (Westfield Road) heading West; head down the embankment and sampling occurred near the culvert.
26	Walker Creek	45.25276 -66.13110	Located on the left-hand side of the street (Bay Street) heading west; head down the embankment and sampling occurred near the culvert.
27	Manawagonish Creek (Downstream)	45.24445 -66.10737	Located off of Fairville Boulevard near the Comfort Inn parking, turn into the MelMart parking lot and park towards the end. Head down the embankment until the creek is reached.
28	Manawagonish Creek (Upstream)	45.24355 -66.10259	Located off of Honeysuckle Drive, a weir is located on the outside of the street. Water was sampled 100 m upstream of the weir.
29	Mosquito Cove	45.26929 -66.11284	Located on the right-hand side of the street (Green Head Road) heading towards Milford; head down the embankment and sampling occurred near the culvert.
30	Dominion Park	45.26889 -66.1253	Located at the Dominion Beach park.

Water Quality Parameters

Water quality parameters measured included dissolved oxygen, pH, salinity, orthophosphates, total suspended solids, and fecal coliform. Historically, ammonia concentration, nitrates, and turbidity had also been recorded for the upstream and downstream (Analysis A) sampling locations and as such, this year ammonia concentrations were reintroduced to the monitoring program. Ammonia and turbidity tests were last performed during the 2007 testing period while nitrates were only measured during the 2003 testing period.

Dissolved oxygen (DO) refers to the amount of oxygen dissolved in water and is usually represented in milligrams per litre (mg/L) or percent saturation. Oxygen is introduced into a watercourse via the atmosphere and photosynthesis. DO is temperature sensitive as cold water can hold more dissolved oxygen than warm water; however, at any given temperature moving water will typically have higher concentrations of dissolved oxygen due to churning. Oxygen consumption reduces DO in a watercourse and this occurs through respiration by aquatic animals, decomposition of organic material by microorganisms, and chemical reactions. When DO levels decline too much this can cause harm or death to some of the more sensitive animals. DO fluctuates daily and seasonally due mostly to plant growth and bacterial decomposition (United States Enviornmental Protection Agency, 2012).

The **pH** scale is a logarithmic function that represents the concentration of hydrogen ions in a solution. The pH scale ranges from very acidic (pH 0) to very basic (pH 14), with neutral pH at 7. A healthy watercourse has a pH between 6 and 8. Acidification of a stream (pH of 5 or lower) will cause an intrusion of unwanted plankton and mosses and a decline in fish species and abundance. If the pH drops below 4.5, the stream will become intolerable to most fish species. As a waterway becomes more basic, external damage is caused to the eyes and gills of fish and death may occur. It also increases the toxicity of other chemicals such as ammonia, increasing harm to aquatic life (Lenntech, 2012).

Salinity represents the amount of dissolved salts present in water. Predominantly, the types of salt ions in surface waters include sodium, chloride, magnesium, calcium, and sulfate. Surface waters have varying levels of salinity. For example, fresh snowmelt is pure water and has a theoretical salinity value of zero; salinity in oceans where the water contains an abundance of salt ions, typically ranges from 32 – 36 parts per thousand (ppt) or grams of salt per litre (g/L) (Encyclopedia Britannica, 2013).

Phosphorus and **nitrogen** are essential plant and animal nutrients; in aquatic ecosystems nitrogen is generally readily available and phosphorus is a limiting growth factor. Aquatic plants use phosphorus in the form of phosphates and when excessive amounts are introduced into aquatic ecosystems it can rapidly increase biological activity of certain organisms and disrupt the ecological balance of the waterway. Some sources of phosphates are agricultural runoff (fertilizer), biological waste (sewage, manure), and industrial waste.

Total suspended solids (TSS) refers to the measurement of the dry-weight of particles trapped by a filter through a filtration process and is most commonly expressed in milligrams per litre (mg/L). The solids are a mixture of organic (algae and bacteria) and inorganic (clay and silt) components. As light passes through water, it is scattered by suspended particles. This defines the turbidity or cloudiness of a water body and is represented in Nephelometric turbidity units (NTU). Some sources of organic and inorganic components which contribute to TSS and turbidity are eroding soil, microscopic organisms, industrial and municipal effluent, and suspended bottom sediment. From early spring to early fall there is an increase in turbidity and TSS due to spring runoff, microorganisms, and algae. Due to these changes, the amount of sunlight algae and other aquatic life can absorb will fluctuate throughout the seasons. When excess sediment is being introduced it can cause many issues such as excessive nutrient loading and the infilling of riffles and pools causing a reduction in water quality and fish habitat.

Fecal coliform bacteria are largely found in the intestinal tracts of humans and other warm-blooded animals. Increased levels of fecal coliforms can be indicative of possible pathogenic contamination. Sources include failure in wastewater treatment, a break in the integrity of the distribution system, direct waste from mammals and birds, agricultural and storm runoff, and human sewage. Since fecal coliforms indicate pathogens may be present, any water body with elevated levels of fecal coliforms has the potential to transmit diseases. Fecal coliform tests are inexpensive, reliable and fast (1-day incubation). Observation of fecal coliform levels and fluctuations can provide an estimation of the relative amount of pathogenic contamination within a water body. The standard limit for recreational water (contact such as wading, swimming, and fishing) is 200 coliform forming units (CFU) per 100 millilitres (mL) of water, with 10% or less of samples containing a maximum of 400 CFU/100 mL (Health Canada, 2012).

Water Quality Procedures

YSI Professional Plus

A handheld meter (YSI Professional Plus) was used for all sampling to test the DO, specific conductivity, salinity, and pH in the field. The meter was standardized prior to testing by the manufacturing company and calibrated for DO daily. The probe was immersed in the creek until all values stabilized. This procedure was repeated at each sampling site.

Orthophosphates

Phosphate concentration was determined through the ascorbic acid method: mixed 25 mL of the sample, 2-3 drops of phenolphthalein indicator, and 4 mL the combined reagent. The combined reagent was prepared by mixing, in the order listed: 50 mL of 5N sulfuric acid, 5 mL of potassium antimonyl tartrate solution, 15 mL ammonium molybdate solution, and 30 mL of ascorbic acid solution. After the samples were sufficiently mixed, they sat for 10-30 minutes for colour development and were placed in a spectrophotometer (Thermo Scientific Genesys 20) where transmittance and absorbance were measured and recorded.

A control standard of known phosphate concentration of approximately 0.1 mg/L was also prepared. An Eppendorf pipette was used to transfer 5 mL of the stock solution into a volumetric flask and topped up to 100 mL with deionized water. A 10 mL portion of the diluted stock solution was pipetted and topped up to 250 mL. This control standard was treated as a sample and the phosphate concentration was measured using the above ascorbic acid method every time new samples were collected.

A calibration curve was constructed to represent the phosphate concentration in mg/L. A stock solution was prepared by dissolving 0.11 g of monopotassium phosphate in 250 mL of deionized water. Using an Eppendorf pipette, 1 mL of this stock solution was transferred and topped up to 250 mL with deionized water. This diluted stock solution was pipetted in amounts of 5, 10, 15, 20, 25, 30, 35, 40, and 45 mL into separately labelled 150 mL beakers and topped up to 50 mL with deionized water. This gave standards of approximately 0.04, 0.08, 0.12, 0.16, 0.20, 0.24, 0.28, 0.32, and 0.36 mg/L, respectively. A tenth beaker was also prepared with 50 mL of deionized water to serve as a blank. The combined reagent was added to all ten beakers in 8 mL aliquots.

The beakers were swirled for proper mixing and left for 10-30 minutes to allow colour development (Figure 13). The absorbance and transmittance were recorded for all 10 beakers. The absorbance and standard concentrations were plotted using Microsoft Excel to generate a calibration curve (Appendix A). With this curve, the absorbance values recorded from the water samples were converted into concentrations in mg/L following equations provided in Appendix B.

Figure 13. The colour development of standards for the orthophosphate calibration curve.

Total Suspended Solids

Total suspended solids (TSS) were determined through the vacuum filtration method. A glass fiber filter disk (Whatman Grade 934-AH Circles 55mm) was rinsed three times with 20 mL of deionized water and filtered via vacuum filtration. The filter disks were placed in an aluminum weigh dish and into an oven at 105°C for one hour. The filters and aluminum weigh dishes were removed from the oven and cooled to room temperature in a desiccator. The weights were measured and recorded, then returned to the oven for a minimum of 20 minutes. The filter and weigh dish were returned to the desiccator and weighed once at room temperature until a constant weight was achieved (± 0.0003). Water samples (100 mL) were through filtered through the vacuum filtration apparatus, prior to rinsing the filtration apparatus three times with deionized water to ensure the entire sample had passed through the pre-weighed disks (Figure 14). The filters and associated weigh dishes were then dried/desiccated, as before, and re-weighed. TSS in mg/L was calculated based on the difference in weight (equation can be found in Appendix B) and results were recorded.

Figure 14. Image showing solids left on filter paper after filtration was completed using the Total Suspended Solids procedure.

Fecal Coliform

The membrane filtration technique was used to test for fecal coliform bacteria. Serial dilutions of each sample were prepared and slowly added to the Millipore apparatus, which contained Millipore filters (EZ Pak membrane; white, gridded, 0.45 µm pore size, 47 mm), and vacuum filtration was applied. Once the filtration process was complete, the membrane filter was removed from the apparatus and placed into a previously prepared sterile Petri dish grid face up, which contained m-FC agar and 1% rosolic acid. The Petri dishes were incubated upside down at 44.5°C (±0.2°C) for 24 hours.

After 24 hours, the Petri dishes were removed from the incubator and all blue colonies were counted (Figure 15). Petri plates were counted if they contained 20 to 80 colonies. Plates that contained more than 80 colonies were represented as too numerous to count (TNTC). Plates that contained less than 20 colonies required additional steps to determine fecal concentration and were considered to only be estimations. Using the dilution ratio for each plate, the number of CFU/100 mL of water were calculated and recorded (equations can be found in Appendix B).

All of the samples collected were diluted to 1/10, 1/100, 1/1000, and 1/10000 for the first and second weeks to gauge the level of contamination. After the second week, induvial samples collected were diluted as needed based on the results from the first two weeks.

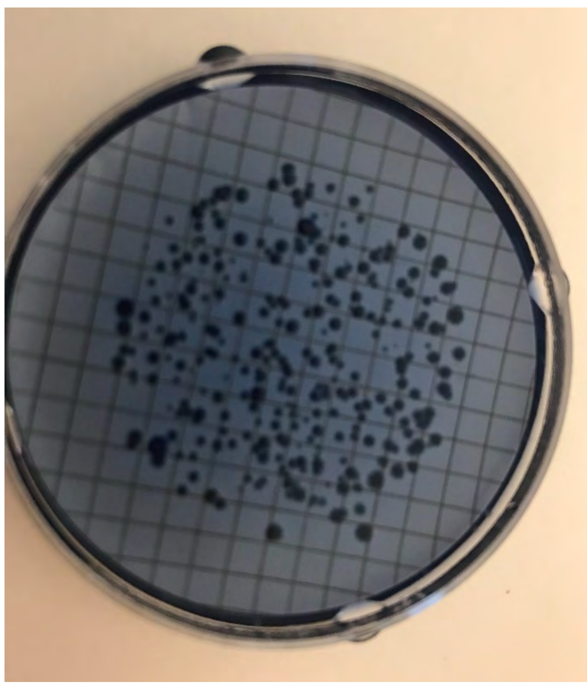

Figure 15. Image showing the coliform forming units (CFU) per 100 mL water sample taken from Marsh Creek Site 11.

Ammonia

A blank was prepared by pipetting 50 mL of ammonia free water into a 125 mL Erlenmeyer flask. In the following order, 2 mL of phenol solution, 2 mL of sodium nitroprusside solution, and 5 mL of the oxidizing reagent were added to the flask and immediately covered with parafilm (samples need to be placed in a dark space immediately after the oxidizing reagent is added to the flasks). To prepare the samples, 25 mL of the water sample was pipetted into a 50 mL Erlenmeyer flask. Additionally, 1 mL of phenol solution, 1 mL of sodium nitroprusside solution, and 2.5 ml of the oxidizing reagent were then added to the flask, covered with parafilm, and immediately placed into a dark space. After sitting for at least one hour (maximum of 24 hours), the samples were then placed in a spectrophotometer and percent transmittance, at 640 nm, was measured and recorded.

To determine the ammonia concentration, a calibration curve (Appendix A) was constructed to represent the ammonia concentration in mg/L. A stock solution was prepared by dissolving 3.819 g of dried ammonium chloride in 1000 mL of deionized water volumetrically. This produces 1000 mg/L of NH_3N solution. A standard ammonium solution was prepared by diluting 1 mL of 1000 mg/L stock NH_3N solution into 100 mL of deionized water volumetrically to produce a 10 mg/L NH_3N solution. Continuing the serial dilution, 25 mL of 10 mg/L NH_3N solution was then diluted in 250 mL of deionized water volumetrically to prepare 1 mg/L NH_3N solution. This diluted standard solution was pipetted in amounts of 25, 20, 15, 10, 5, 4, 3, 2, and 1 mL into a 125 mL Erlenmeyer flasks and topped up to a final volume of 50 mL. Standards were treated as samples in the above procedure and placed into a dark space for one hour. Percent transmittance, at 640 nm, was then measured and recorded (Figure 16). Absorbance versus Ammonia concentration was plotted to make a straight line passing through the origin to create the equation needed to calculate ammonia concentration (Appendix B) in collected samples.

Figure 16. The colour development of standards for the Ammonia calibration curve.

Data Loggers

In addition to bi-weekly water quality sampling, the variation of water temperatures throughout the sampling season were analyzed at various watercourses using temperature loggers (EasyLog USB logger, EL-USB-1 model). The loggers were attached to cinder blocks and placed in various watercourses at the beginning of April 2018 (example in Figure 17). These loggers were left to collect data for seven months and were removed at the end of October.

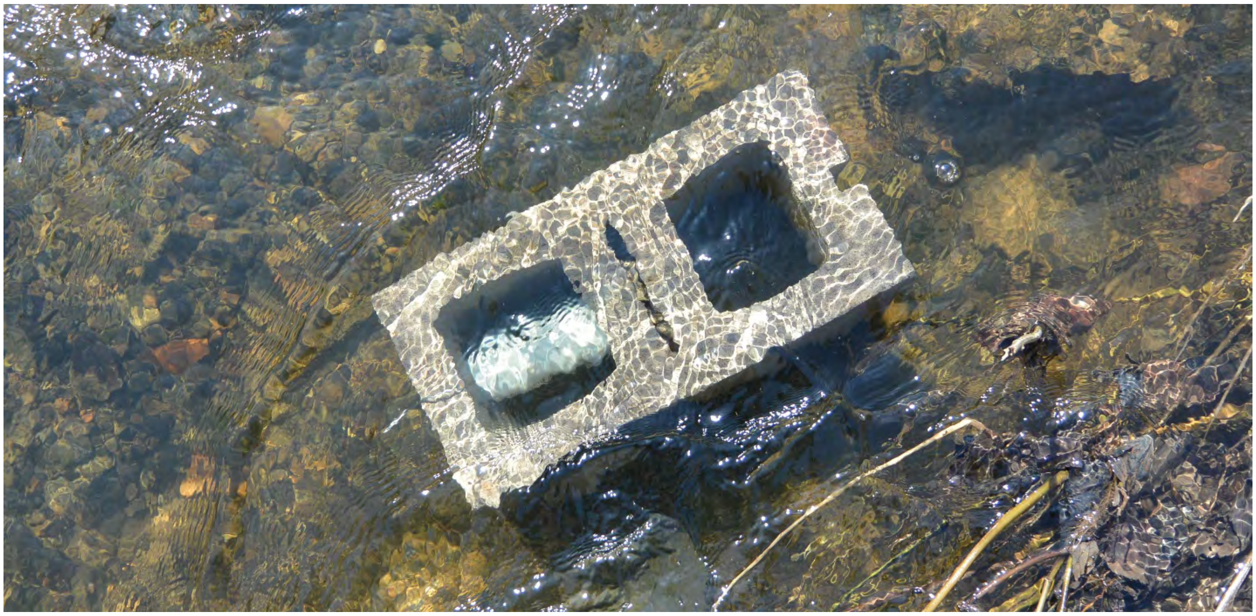

Figure 17. Example of temperature logger attached to a cinder block. All cinder blocks were covered underwater.

Fish Sampling

Electrofishing

Electrofishing was conducted in two different sections of Hazen Creek on June 1, 2018 as a presence/absence survey. One section was located downstream from the culvert under Whitebone Way, and the other section was located near the fish ladder.

Electrofishing activities were conducted using a battery-powered Smith-Root LR-24 electrofisher. The certified operators were Graeme Stewart-Robertson and Roxanne MacKinnon of ACAP Saint John. The settings used varied depending on substrate, water conductivity, and the effect they were having on fish. In most cases, the built-in quick setup option was used and minor adjustments, typically to voltage, were made as necessary. The operation time and setting were noted upon completion of each site. Dip nets were used to capture fish which were then transferred to a 5-gallon bucket of water (equipped with a Marine Metal Aerator Bubble Box 1.5 V for aeration) until they could be measured and identified before being released into their original environment as quickly as possible. The temperature of the water (°C), fish mortalities and any other observations were recorded at each site.

Fyke Nets

Two fyke nets were used to collect fish in the lower reaches of Marsh Creek on May 7-9, 2018, May 22-24, 2018 and again on June 6-8, 2018. On each occasion, one net was set approximately 250 m upstream of the tide gates located within the Courtenay Forebay and the second net was set approximately 50 m below the tide gates. The nets were set during low tide and checked during a subsequent low tide 24 hours after they were set.

Between June 18-21, 2018 both fyke nets were set in the Courtenay Forebay where one net was facing upstream and the other net was facing downstream.

All fish were removed from nets identified, measured, and immediately returned to their environment. The temperature of the water (°C), fish mortalities and any other observations were recorded at each site.

Beach Seine

Beach seining activities were conducted at the Newman's Brook downstream site (site 13), Courtenay Forebay (site 1) and the Inner Harbour downstream site (site 16). A beach seine of 9 x 1.5 m (9 mm stretch mesh) with a central collection bag was towed once for 3 minutes at a slow walking pace at each site.

Results and discussion

In the following sections, the water quality and fish community are presented, and key highlights are explored. The raw water quality data collected in the 2018 field season can be found in Appendix C. All historic or previous monitoring data can be found on Atlantic DataStream (www.atlanticdatastream.ca), on the ACAP Saint John website (www.acapsj.org) or by contacting the ACAP Saint John office.

Marsh Creek Watershed

Within this section, the Marsh Creek results are divided into two portions – analysis A and B, to correspond to two different historical datasets. In general, the Marsh Creek watershed has seen dramatic improvements since the completion of Harbour Cleanup in 2014; however, as a highly urbanized watershed it faces many development, encroachment, stormwater, and flooding issues that can now be focused on since the dumping of raw sewage has been ceased.

Analysis A Water Quality Parameters

The analysis A portion of the Marsh Creek monitoring is completed at two historical sites (upstream and downstream) that have been sampled dating back to 1993. This year, these sites were monitored five times over the summer field season for all field parameters, four times for fecal coliform and total suspended solids and three times for all lab parameters. To compare the data collected this year to previous datasets, an average of the sampling parameters over the timepoints was determined and can be found in Table 3.

Table 3. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Marsh Creek Analysis A (upstream or US, and downstream or DS) from the 2018 field season.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU/100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
US	18.9	3.7	7.6	0.2	9.4	1.1	0.07	0.02	1168	825	4.5	3.7	0.23	0.18	0.005	0.003	0.15	0.16
DS	23.6	2.1	8.2	0.2	8.4	4.4	2.70	1.13	3646	3574	5.5	3.1	0.18	0.08	0.018	0.001	0.19	0.24

While average dissolved oxygen levels are much higher than some of the historic data presented, they are at the lowest they have been since the 2014 field season (Figure 18). These results are likely due to an increase in the water's temperature and generally very low flow over the sampling period (Canadian Council of Ministers of the Environment, 2017).

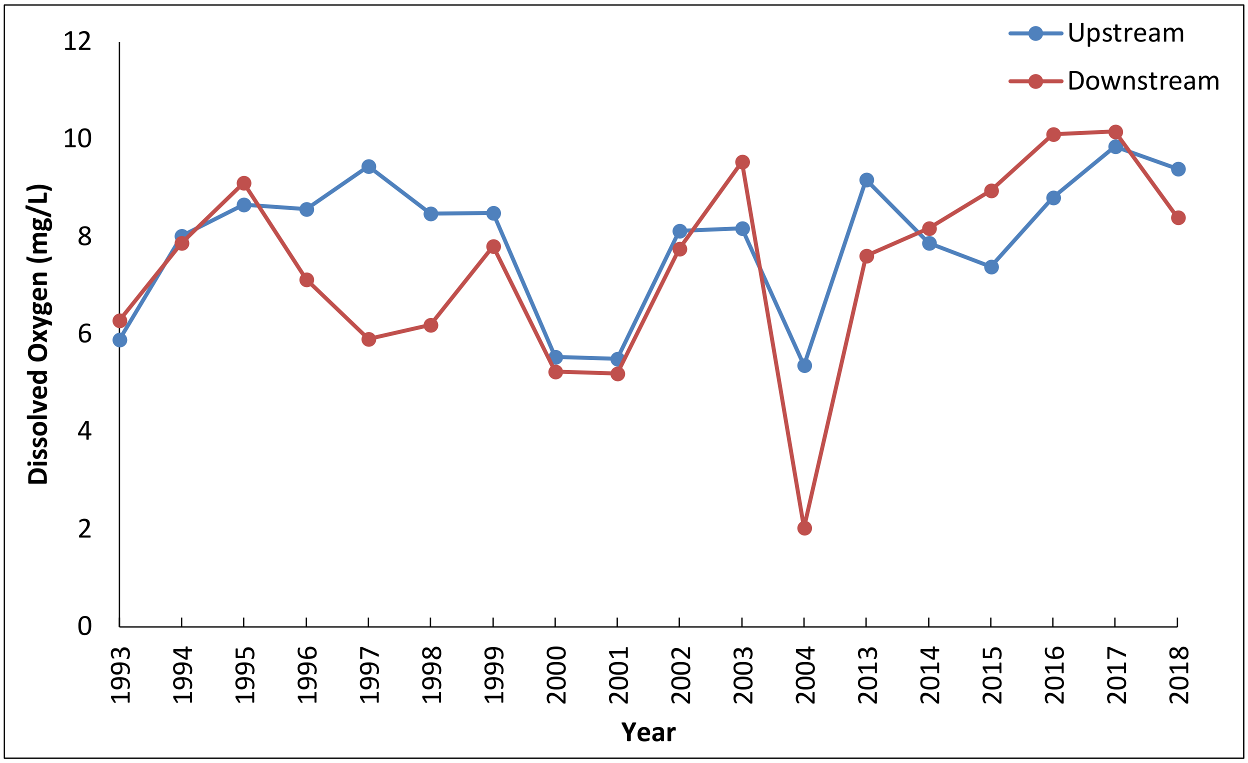

Figure 18. Dissolved oxygen (mg/L) measured at the Marsh Creek upstream and downstream sample stations from 1993 to 2018. (Values were not obtained in 2008, 2009, 2010, 2011 and 2012)

The Phosphate concentrations were higher on average at the downstream site compared to the upstream site (Table 3) and the average phosphate concentration appears to have increased over time (Figure 19). This could be due to stormwater and overland runoff washing nutrients into the system, especially at the upstream site which has been increasing in the past few years. To date, there is no set guidelines for phosphate concentration in freshwater, raising the need for long-term monitoring to track potential increases. It should also be noted that the City has begun to add orthophosphate into the drinking water to protect pipes from corrosion and, as a result, any overflows or pipe (hydrant) flushing into Marsh Creek (or any other waterbody) may be adding phosphate into the system.

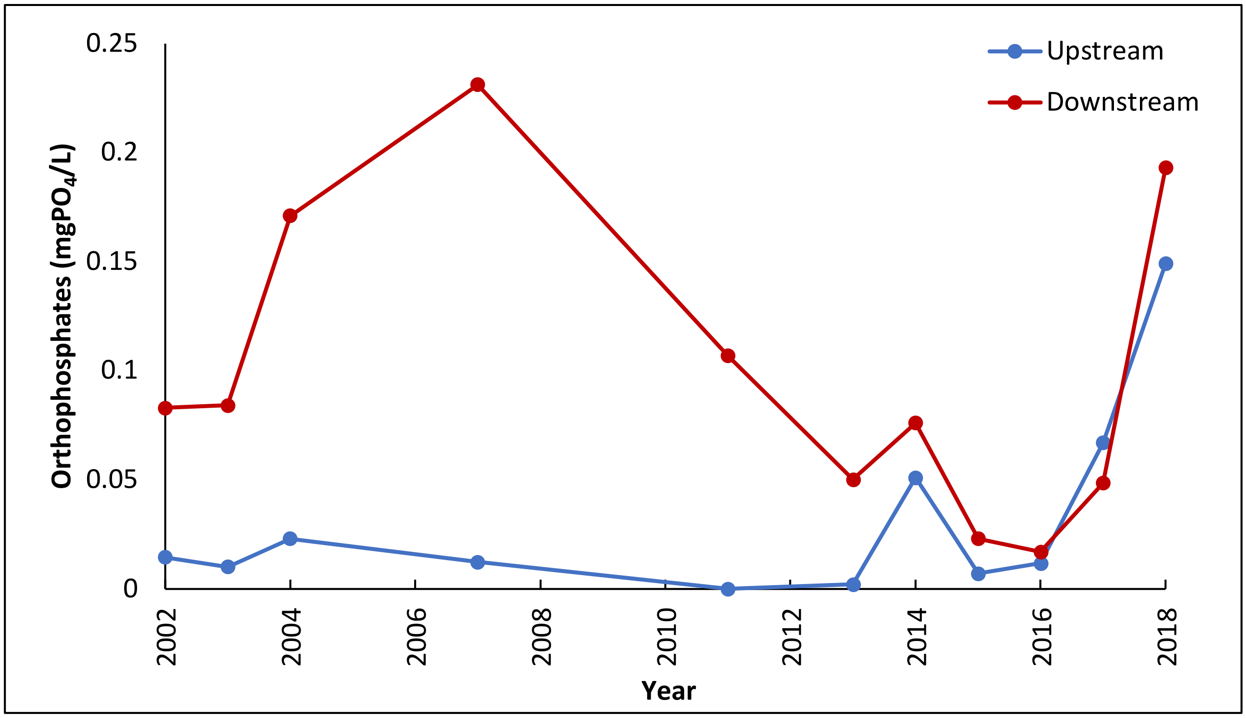

Figure 19. Orthophosphates (mg PO_4/L) measured at the Marsh Creek upstream and downstream sample stations from 2002-2018. (Values missing: 2005, 2006, 2008, 2009, 2010, 2011 & 2012 – upstream; 2005, 2006, 2008, 2009, 2010 & 2012 – downstream).

On average, the total ammonia concentrations at both the upstream and downstream sites have remained consistent with pre-Harbour Cleanup values (Figure 20). Based on the historic data available, the total ammonia concentrations fluctuated between elevated and normal concentrations prior to the cessation of dumping raw sewage into Marsh Creek. However, ammonia can be stored in sediments and re-introduced into the water and thus may take numerous years to return to normal. According to CCME, the guideline for un-ionized ammonia in freshwater is 0.0019 mg/L for the Protection of Aquatic Life (Canadian Council of Ministers of the Environment, 2010). The data represented in this report is total ammonia which includes un-ionized and ionized and is therefore not comparable to this guideline. The results from this year, 0.225 and 0.178 mg/L respectively, are more comparable to a more generalized statement than the guideline - in most freshwater systems total ammonia is less than 0.1 mg/L (Canadian Council of Ministers of the Environment, 2010). Therefore, these values are still regarded as being elevated.

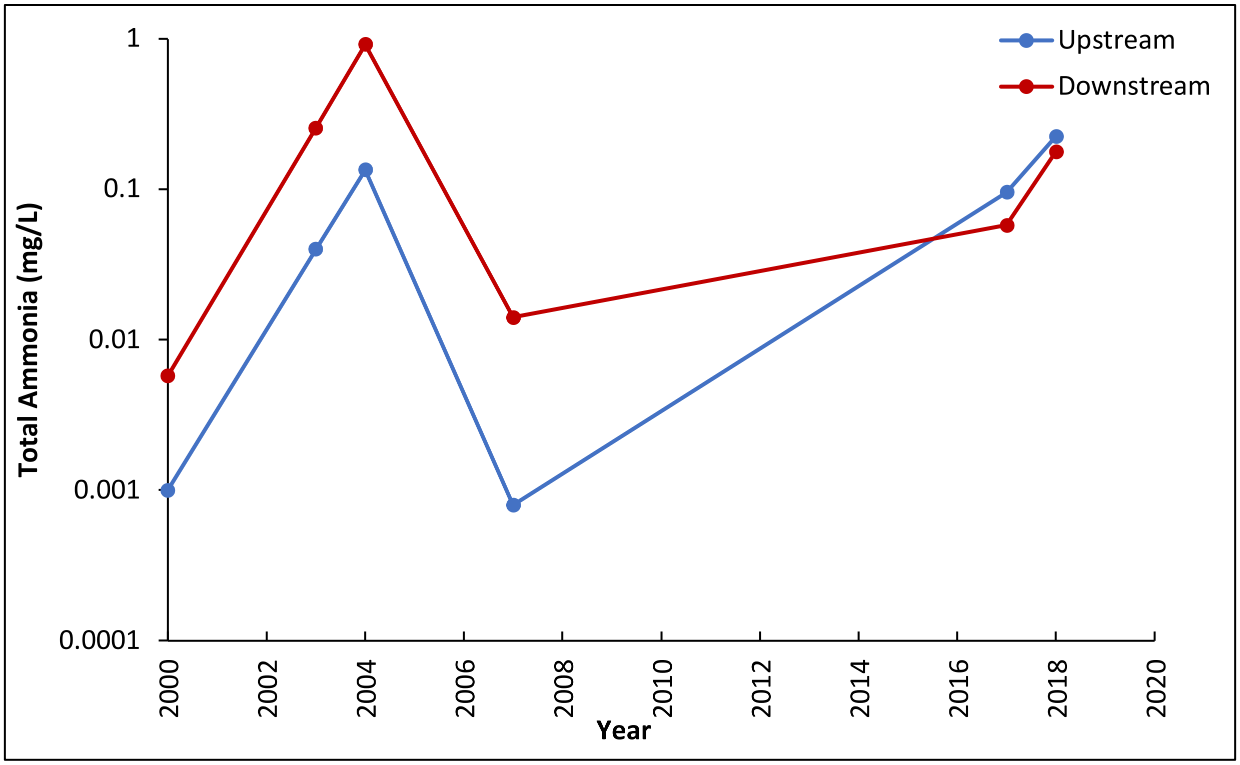

Figure 20. Average total ammonia (mg/L) concentrations measured at the Marsh Creek upstream and downstream sample stations in 2000, 2003, 2007, 2017 and 2018. (Note that total Ammonia concentrations are plotted on log base 10 scale.)

The fecal coliform concentration at the both upstream and downstream sites remain elevated when compared to the Health Canada guidelines (Health Canada, 2012). The average fecal coliform count was 3646 CFU/100 mL at the downstream site and 1168 CFU/100 mL at the upstream site (Table 3). The Health Canada guideline states that the average concentration should be below 200 CFU/100 mL for a recreational waterbody to ensure safe contact with the water (Health Canada, 2012). When compared to past historical data however, the average concentration at both sites has decreased (drastically for the downstream site) from previous years due to the completion of Harbour Cleanup and the continued work to stop cross-connections and improve lift station functions (Figure 21).

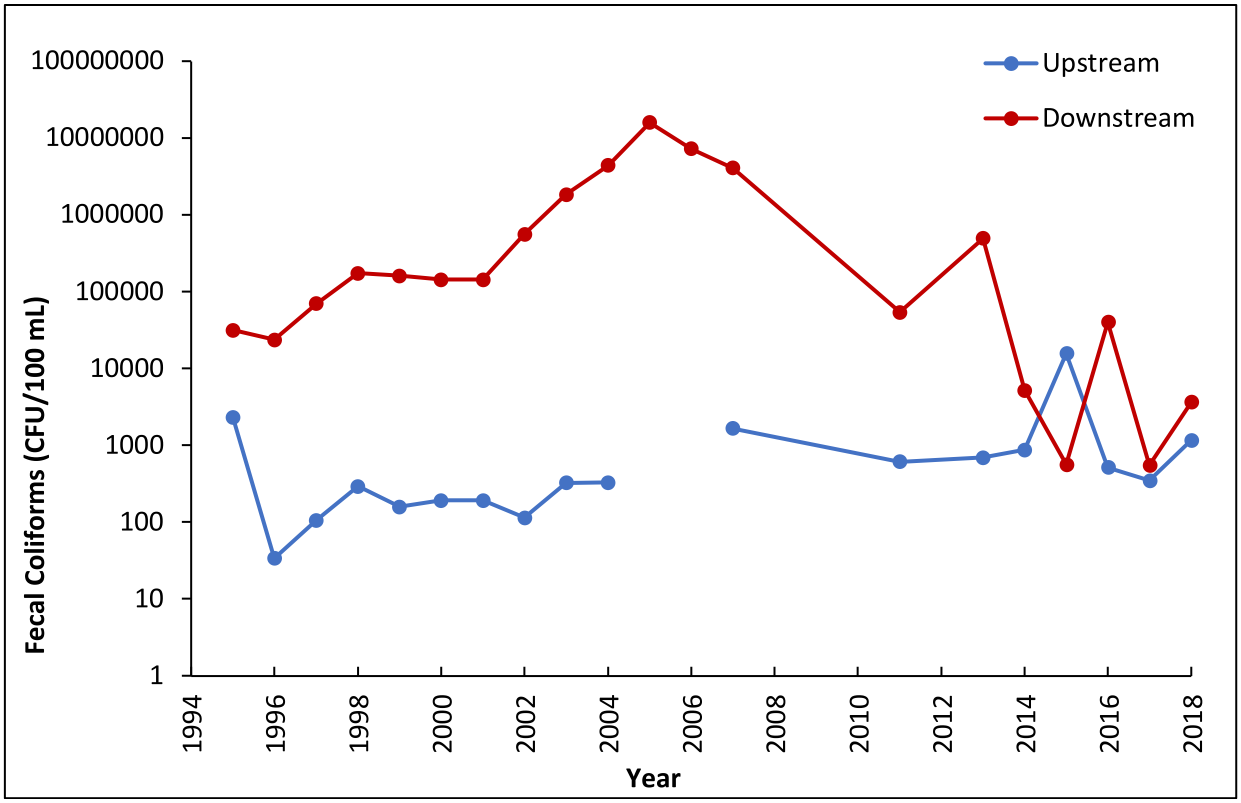

Figure 21. Fecal coliforms (CFU/100 mL sample) measured at the Marsh Creek upstream and downstream sample stations from 1995 to 2018 and plotted on a log scale. (Values were not obtained in 2008, 2009, 2010 and 2012.)

The average total suspended solids results were 5.5 and 4.5 mg/L in the downstream and upstream site, respectively (Table 3). The results for the upstream site have increased compared to previous years (Figure 22). However, the downstream site showed that TSS concentration have remained comparable to last year's data. The increase at the upstream site may be due to increased erosion or stormwater inputs; or alternatively, the low water levels experienced this summer may have caused sediment to be stirred up when filling the sampling bottles. There is no guideline value to state what is an unacceptable TSS value due to the varying nature of watercourses; however, an increase in TSS over either the short-term (25 mg/L over background) or long-term (5 mg/L over background) is outlined in the guideline by CCME (Canadian Council of Minisiters of the Enviroment , 2019). Although, the increase in TSS at the upstream site is still below the guideline, it is steadily trending upwards over the past seven years with the exception of the 2017 sampling year indicating that there may be an erosional or stormwater runoff issue upstream of this site.

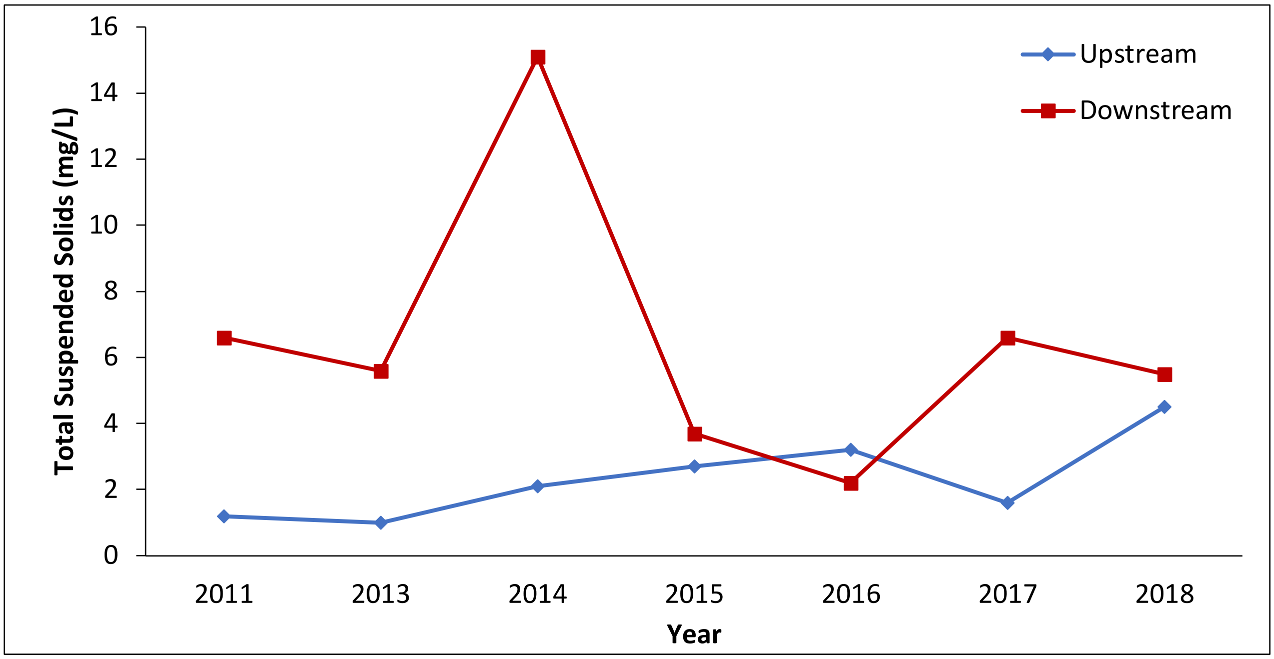

Figure 22. Total suspended solids (mg/L) measured at the Marsh Creek upstream and downstream sample stations from 2011-2018. (Values were not obtained in the 2012 year).

Analysis B Water Quality Parameters

Water samples were acquired in 2018 from five sample periods all taking place around low tide, starting on June 8 and ending on August 7, 2018. It must be noted that due to the immediate unavailability of the lab, fecal count, total suspended solids (TSS), orthophosphates and ammonia were not recorded during the first sampling date and only orthophosphates and ammonia were not recorded for the second sampling date. All other parameters were recorded. Sampling was conducted at six sites, five of which are in the last 2 km reach of Marsh Creek and have previous data dating back to 2012. The last site (site 11) is in Medial Marsh Creek and was added to the monitoring program in 2016. The average values of these parameters are representative of the values obtained during the remaining sample periods (Table 4). The wide range of values obtained within a single sample site amongst the five sample dates resulted in a considerable degree of within-site variation in some parameters, especially fecal coliforms and TSS (Table 4).

***Table 4**: Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Marsh Creek Analysis B from five sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU/100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Total Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
1	19.4	3.7	7.7	0.1	9.0	0.5	16.0	3.9	773	966	32.3	48.7	0.297	0.028	0.011	0.003	0.253	0.312
2	21.4	3.5	7.7	0.2	9.6	1.3	5.8	3.6	4700	2606	8.5	5.2	0.270	0.099	0.008	0.004	0.248	0.316
3	22.6	4.9	8.5	0.6	11. 9	2.9	0.2	0.1	1289	1255	2.0	1.8	0.067	0.009	0.031	0.013	0.192	0.265
4	22.8	4.1	8.3	0.6	9.1	1.6	0.2	0.1	170	251	45.0	26.3	0.086	0.033	0.036	0.054	0.237	0.306
5	21.3	3.0	7.7	0.2	6.7	1.2	0.2	0.1	404	230	1.5	1.3	0.072	0.061	0.003	0.002	0.191	0.266
11	20.0	3.2	8.2	0.4	10.0	1.5	0.2	0.1	91375	140433	9.5	8.7	1.530	0.992	0.120	0.065	0.334	0.251

Fecal coliform levels were plotted against the five sample stations for 2012 to 2018 (Figure 23). The average fecal coliform concentration for sites, 1, 2, 3, and 5 were slightly elevated compared to 2017 with averages of 773, 4700, 1289, and 404 CFU/100 mL respectively, but in general have decreased over time since Harbour Cleanup. Site 2 had the highest recorded levels at that site since Harbour Cleanup. Site 4 levels have been steadily decreasing with the lowest recorded average since monitoring began, falling below the CCME guideline (200 CFU/100 mL) with an average concentration of 170 CFU/100 mL. Site 11 increased from last year's value, going from an average of 8853 CFU/100mL to 91375 CFU/100 mL (Figure 23). The elevated levels of fecal coliform at this site is indicative of sewage contamination within this area as the sites upstream and downstream of this location are dramatically lower, on average. It is likely that the contamination is coming from lift stations in the area; however, this summer was exceptionally dry and overflows due to influx of stormwater is unlikely. As such, it is likely due to an improperly working lift station or a cross-connection in the stormwater network allowing the combined sewer to discharge into Marsh Creek.

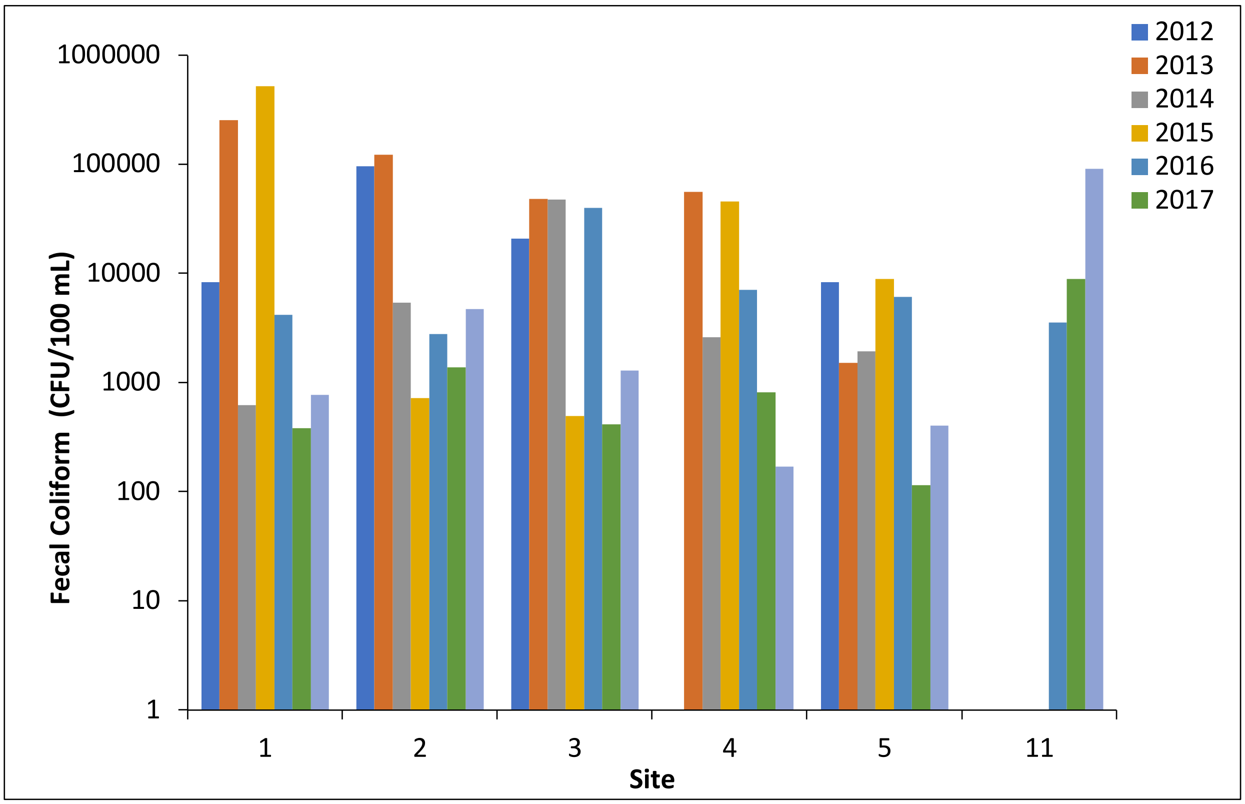

Figure 23. Fecal coliforms (CFU/100 mL) measured at five sites in Lower Marsh Creek from 2012 to 2018 (site 1 to 5) and Medial Marsh Creek (site 11) from 2016 to 2018 and plotted on a logarithmic scale. (The 2012 site 4 sample was discarded, and no data was acquired).

The total suspended solids (TSS) in recent years consistently show small variations from year to year, likely due to rainfall amounts (Figure 24). The data from this year reveals an increase of TSS at most sites within Lower Marsh Creek and a decrease at sites 3 and 5. The most notable increase was at sites 1 and 4, which increased from 12.4 mg/L in 2017 to 32.3 mg/L and from 10.0 mg/L in 2017 to 45.0 mg/L this year. The increase at both of these sites is well above the recommended guideline of a long-term increase of no more than 5 mg/L (Canadian Council of Minisiters of the Enviroment , 2019). Due to the dry field season in 2018, water levels within Marsh Creek and most watercourses were very low; resulting in difficulty collecting water samples without disturbing the sediment and thus likely falsely increasing the TSS concentration to the high concentrations seen.

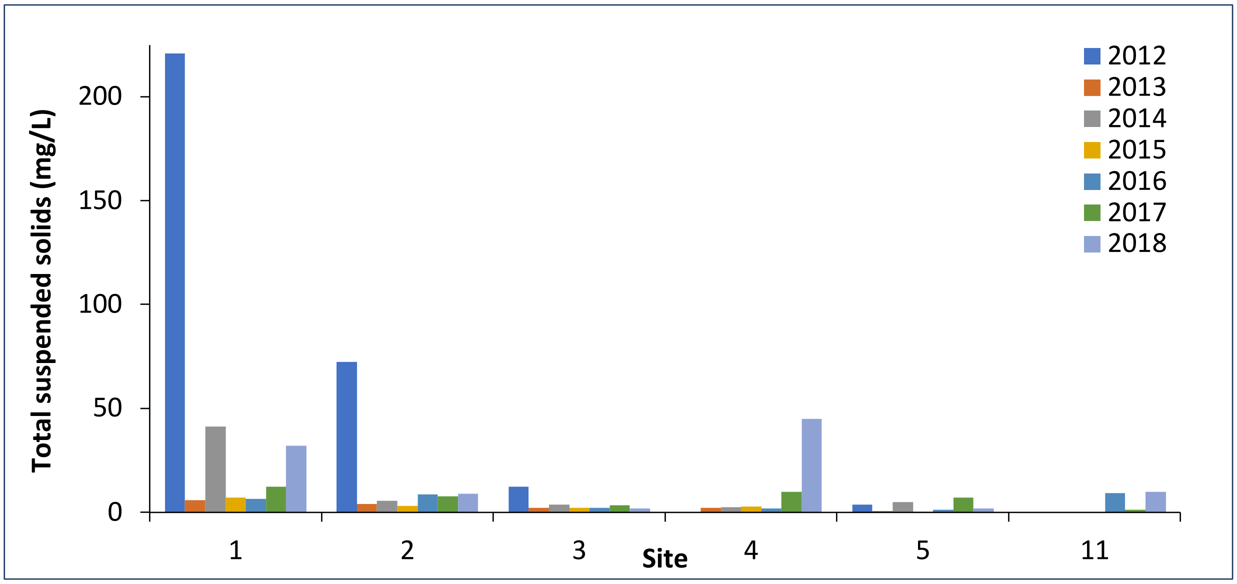

Figure 24. Total suspended solids (mg/L) measured in five sites in Lower Marsh Creek from 2012 to 2018 and one site (11) in Medial Marsh Creek from 2016 to 2018. (The 2012 site 4 sample was discarded, and no data was acquired.)

The average orthophosphate levels have dramatically increased at all the six March Creek sampling sites in the 2018 field season in comparison to previous years (Figure 25). This increase is likely linked to the increase in sewage present within the river as shown by the high concentration of fecal coliform noted previously and the addition of orthophosphate to the drinking water supply. Phosphate inputs can come from a variety of sources with the most common being fertilizer, soil, and wastewater or raw sewage inputs; with the latter being the most likely to cause large increases.

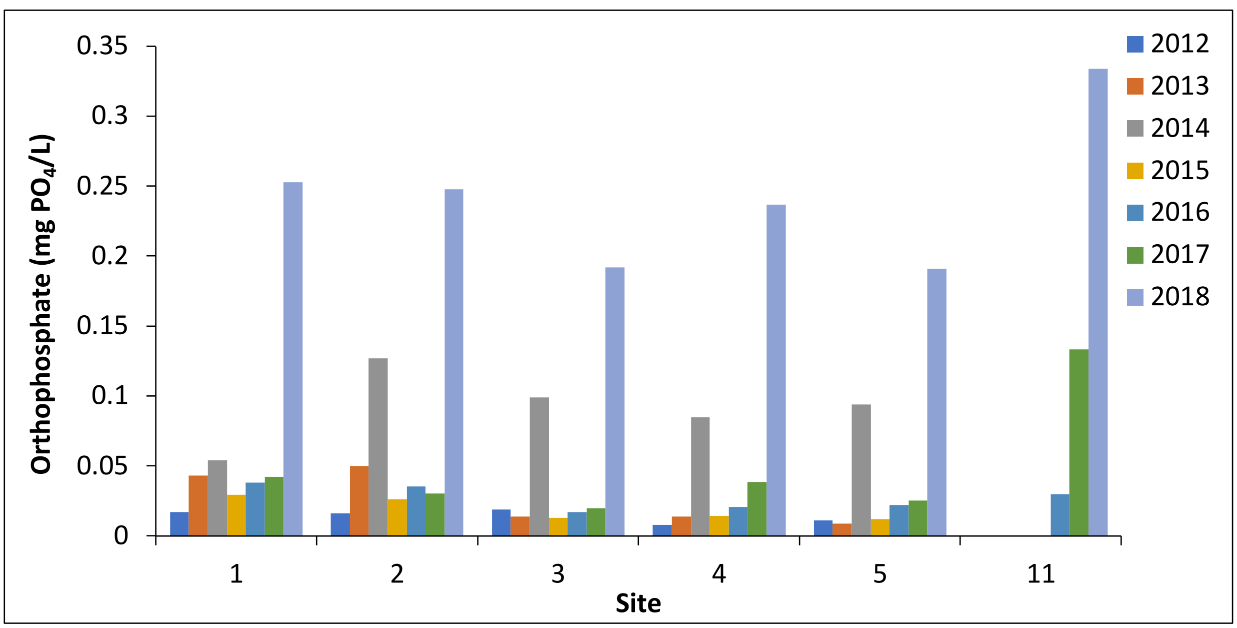

Figure 25. Orthophosphates (mg PO_4/L) measured in five sites in Lower Marsh Creek from 2012 to 2018 and one site (11) in Medial Marsh Creek from 2016 to 2018.

The dissolved oxygen concentration at all six sites in the Marsh Creek system ranged from 6.74 to 11.89 mg/L (Figure 26). All sites surpassed the 6.5 mg/L CCME guideline for the Protection of Aquatic Life for other life stages and three of the six sites surpassed the 9.5 guideline for early life stages (Canadian Council of Ministers of the Environment, 2017). The slight decrease at all locations is likely the result of higher water temperatures in 2018 and the low flow conditions.

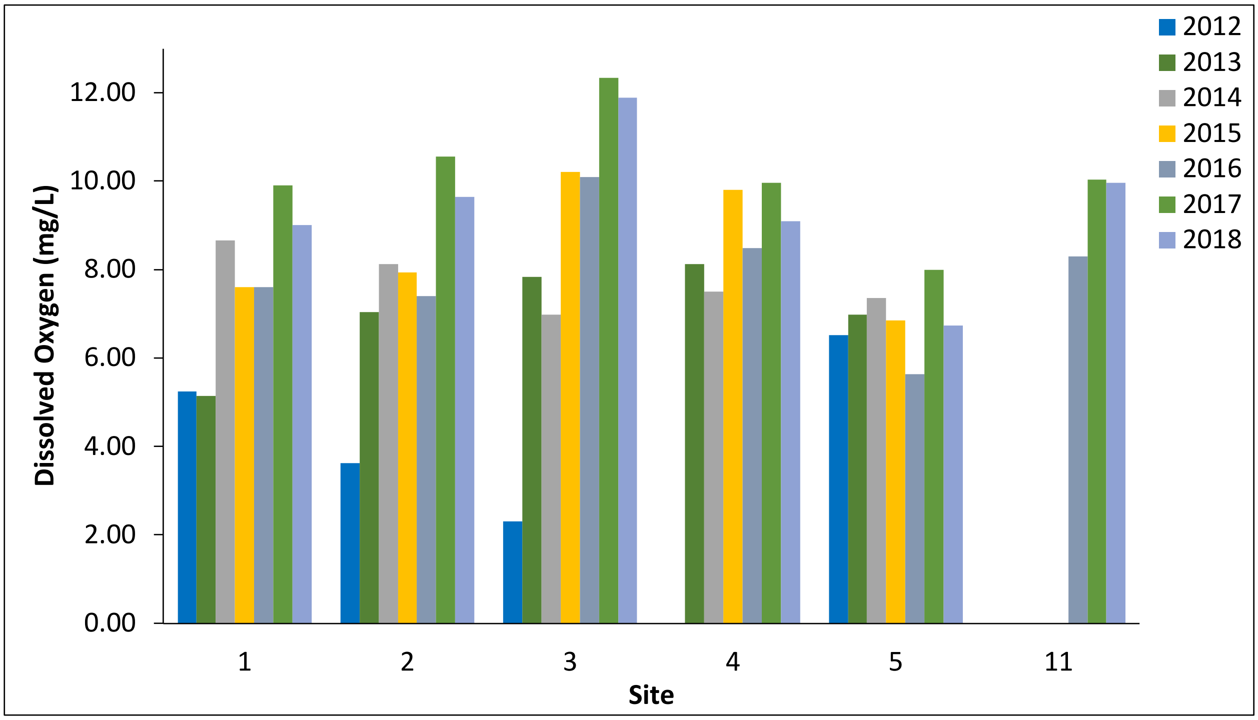

Figure 26. Dissolved oxygen (mg/L) measured in five sites in Lower Marsh Creek from 2012 to 2018 and one site in Medial Marsh Creek from 2016 to 2018.

As stated previously, the concentration of total ammonia in freshwater is generally less than 0.1 mg/L (Canadian Council of Ministers of the Environment, 2017). Sites 1, 2, and 11 were found to be above this at 0.297 mg/L,0.270 mg/L, and 1.53 mg/L, respectively. Sites 3, 4 and 5 were all below the 0.1 mg/L at 0.067 mg/L, 0.086 mg/L, and 0.072 mg/L, respectively (Table 4). Ammonia values sampled this year are compared to 2017 samples in Figure 27. Similar to the increase in orthophosphate concentrations, the increase in total ammonia is likely caused by increased sewage inputs in the general vicinity of this site.

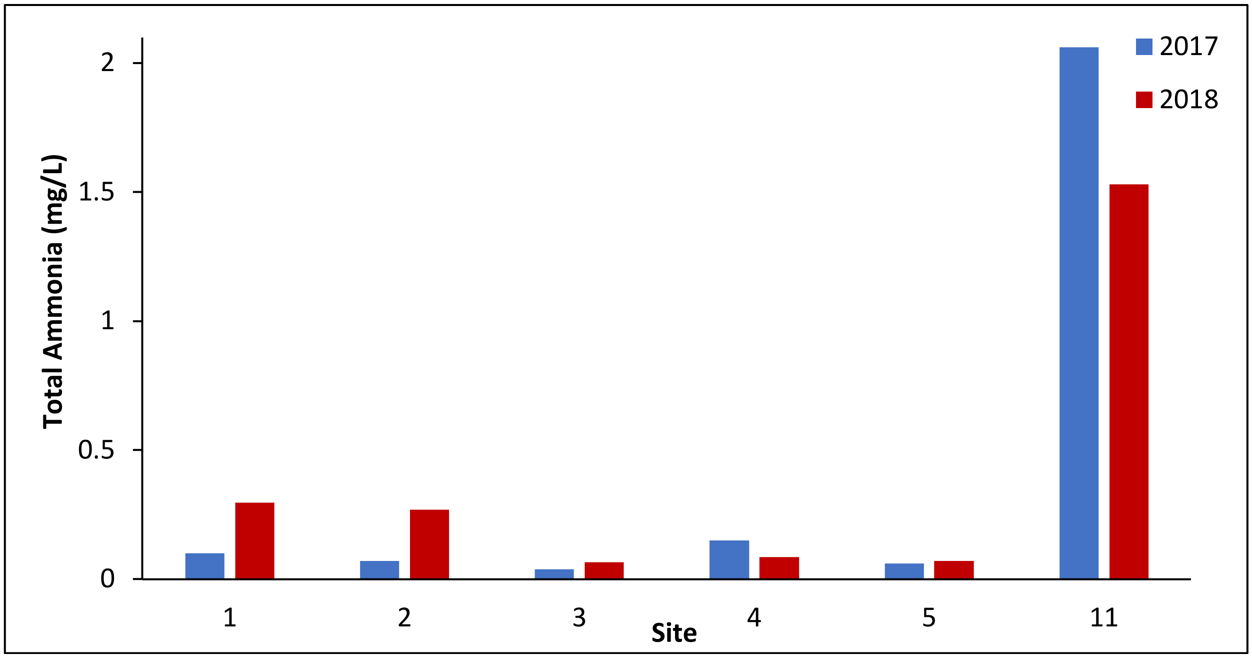

Figure 27. Average total ammonia (mg/L) measured in five sites in Lower Marsh Creek and one site in Medial Marsh Creek from the 2017-2018 field seasons.

Fish Communities

A total of 278 fish comprised of 10 different species were collected from nine different hauls between May 8, 2018 to June 21, 2018 using fyke nets. Nets were set and checked each day at low tide. Between June 19-21, 2018, two fyke nets were set up in the Courtenay Forebay above the tide gates; one net facing upstream, one net facing downstream. No nets were set in the Bay during this time period.

The fyke net catch in the upstream site (Courtenay Forebay above the tide gates) contained 18 fish of nine species: one Nine-spined stickleback (5.56%), one Three-spined stickleback (5.56%), two Mummichog (11.11%), one Four-spined stickleback (5.56%), two Common shiner (11.11%), four White sucker (22.22%), one Rainbow smelt (5.56%), three American eel (16.67%) and three Atlantic tomcod (16.67%) (Table 5). During the different hauls the Forebay had a temperature range of 13.0-21.0°C. There was one Nine-spined stickleback found dead in the net over the entire sampling period.

Table 5. *Fish species composition caught in a fyke net in the Courtenay Forebay (above the tide gates) between May 8, 2018 to June 21, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Common shiner (*Notropis cornutus*)	2	11	119-120
White sucker (*Catostomus commersonii*)	4	22	140-390
American eel (*Anguilla rostrata*)	3	17	380-500
Mummichog (*Fundulus heteroclitus*)	2	11	88-100
Atlantic tomcod (*Microgadus tomcod*)	3	17	164-242
Rainbow smelt (*Osmerus mordax*)	1	5	156
Three-spined stickleback (*Gasterosteus aculeatus*)	1	5	54
Nine-spined stickleback (*Pungitius pungitius*)	1	5	22
Four-spined stickleback (*Apeltes quadracus*)	1	5	-

The downstream fyke net site (Courtenay Bay below the tide gates) resulted in the capture of 260 fish of six different species and was dominated by Atlantic tomcod at 91.54% (Table 6). The remaining species were American eel (0.38%), Golden shiner (0.38 %), Rainbow smelt (1.92%), White sucker (2.31%) and White perch (3.08%). During the different hauls, the Bay had a temperature range of 11.0-16.0°C. In total four fish (one Goldfish, one White sucker, one White perch and one Rainbow smelt) were found dead in the nets, either due to European Green crab predation or caught in the netting, over the sampling period. Both the Courtenay Bay and Forebay fyke nets had a number of by-catch including Sand shrimp (*Crangon septemspinosa*) and European Green crab (*Carcinus maenas*).

Table 6. *Fish species composition caught in a fyke net in the Courtenay Bay (below the tide gates) between May 8, 2018 to June 8, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Golden shiner (*Notemigonus crysoleucas*)	1	0.4	173
White sucker (*Catostomus commersonii*)	8	3	96-190
American eel (*Anguilla rostrata*)	3	0.4	310
Atlantic tomcod (*Microgadus tomcod*)	238	91	125-267
Rainbow smelt (*Osmerus mordax*)	5	2	131-190
White perch (*Morone americana*)	7	3	110-376

On October 2, 2018, the Courtenay Bay (below the tide gates) was seined for the presence of fish in the area. Although no fish species were caught during the seine, more than 100 Sand shrimp were caught. The average total length of the shrimp was found to be 21.8 mm. The water temperature was found to be 11.4°C and there were no fish mortalities. In addition to the Sand shrimp, two European green crabs were found in the net. The Courtenay Forebay (above the tide gates) was also seined on the same day. A total of eight different fish species were found in the seine net (Table 7). The water temperature was found to be 11.8°C and there were three fish mortalities (all Rainbow smelt). A total of 10 European green crabs and 520 Sand shrimp were also caught during seining.

Table 7. *Fish species composition caught in the beach seine in the Courtenay Forebay (above the tide gates) on October 2, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Rainbow smelt (*Osmerus mordax*)	38	41	45-91
Atlantic silverside (*Menidia menidia*)	1	1	75
Nine-spined stickleback (*Pungitius pungitius*)	59	63	40-57
Three-spined stickleback (*Gasterosteus aculeatus*)	15	16	26-55
Four-spined stickleback (*Apeltes quadracus*)	3	3	24-35
Black-spotted stickleback	2	2	31
Winter flounder (*Pseudopleuronectes americanus*)	8	9	64-86
Mummichog (*Fundulus heteroclitus*)	4	4	34-55

Between October 2 and 3, 2018, fyke nets were set out again in the Courtenay Bay and Courtenay Forebay and were left out for one 24-hour period. The majority of fish that were found in the Courtenay Bay was the Atlantic tomcod (94%) (Table 8). The water temperature was 12.8°C and there were zero mortalities. A total of five European green crabs were also found in the fyke net.

Table 8. *Fish species composition caught in a fyke net in the Courtenay Bay (below the tide gates) on October 3, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Atlantic tomcod (*Microgadus tomcod*)	57	97	136-280
American eel (*Anguilla rostrata*)	2	3	310-330

On the same day, another fyke net was checked for fish presences in the Courtenay Forebay (above the tide gates). A total of 14 fish were found in the net with the majority of the fish being American eel (86%) (Table 9). The water temperature was found to be 13.5°C and there were zero mortalities. A total of ten European green crabs were also found in the fyke net.

Table 9. *Fish species composition caught in a fyke net in the Courtenay Forebay (above the tide gates) on October 3, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Atlantic tomcod (*Microgadus tomcod*)	2	14	212-320
American eel (*Anguilla rostrata*)	12	86	300-510

Hazen Creek Watershed

The water quality of Hazen Creek was determined through monitoring a downstream site (site 6) and an upstream site (site 7) over five timepoints in the 2018 field season. The calculated averages can be found in Table 10.

Table 10. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Hazen Creek from five sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU/100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
6	20.6	4.0	7.5	0.2	8.6	0.7	8.5	5.7	1130	2048	21.3	34.2	0.08	0.05	0.002	0.002	0.24	0.34
7	14.5	2.4	7.7	0.2	9.4	0.8	0.1	0.1	44	52	0.3	0.5	0.05	0.04	0.001	0.001	0.15	0.21

The average temperature of the two sites were well below any temperature of concern for fish species (Table 10). The average upstream temperature in site 7 was slightly lower than the downstream in site 6, which were 14.5 and 20.6℃, respectfully. The difference in temperature is most likely due to the riparian environment - a forested section above the upstream site cooling the water and the downstream site located within an open saltwater marsh providing little or no canopy cover. However, the influx of ocean water cools the water twice a day, providing great fish habitat for species tolerant of brackish conditions.

The dissolved oxygen concentrations also revealed that the Hazen Creek system is quite capable of supporting aquatic life. Both the downstream and upstream sites were, on average, below the 9.5 mg/L recommended guideline from CCME with an average of 9.37 and 8.64 mg/L respectively but were well above the 6.5 mg/L threshold (Table 10) (Canadian Council of Ministers of the Environment, 2017).

The fecal coliform concentration fluctuated substantially over the 2018 field season at the downstream site (Figure 28). One of the four concentrations showed significantly higher than the guideline limits for fecal coliforms with concentrations of 4,200 CFU/100 mL; the other three timepoints were much lower with 150, 0, and 170 CFU/100 mL. This variation resulted in an average of 1130 CFU/100 mL and was considerably above the guideline of 200 CFU/100 mL (Health Canada, 2012). The upstream site on the other hand, was found to have consistent results over the four timepoints. The average upstream concentration was 44 CFU/100 mL which is below the Health Canada guideline. The variation in fecal coliform concentration between the two sites and within different timepoints at the downstream site may be caused by the outflow of the Eastern Wastewater Treatment Facility which is located adjacent to the Red Head Marsh or an increase in wildlife abundance in the marsh.

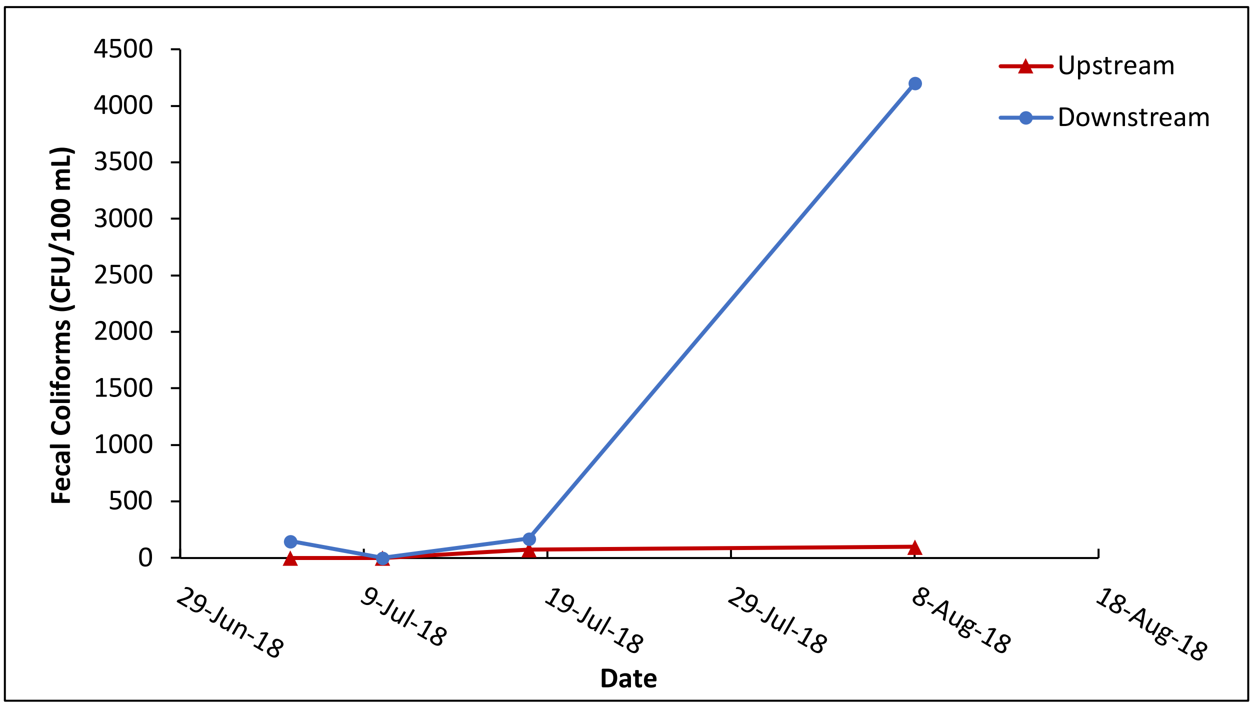

Figure 28. Fecal coliform concentration from the downstream (site 6) and upstream (site 7) sites with Hazen Creek from the 2018 field season.

For both sites, the data of fecal coliform concentration in 2018 reveals an overall increase compared to previous data collected in 2017 which had an average of 498 and 33 CFU/100 mL for the downstream and upstream sites, respectively (Figure 29). Although, the downstream site was the only one to exceed the Health Canada Guideline in 2018. It is once again not known exactly what caused the increase in fecal coliform concentration at the downstream site but its proximity to a wastewater treatment plant may be a contributing factor.

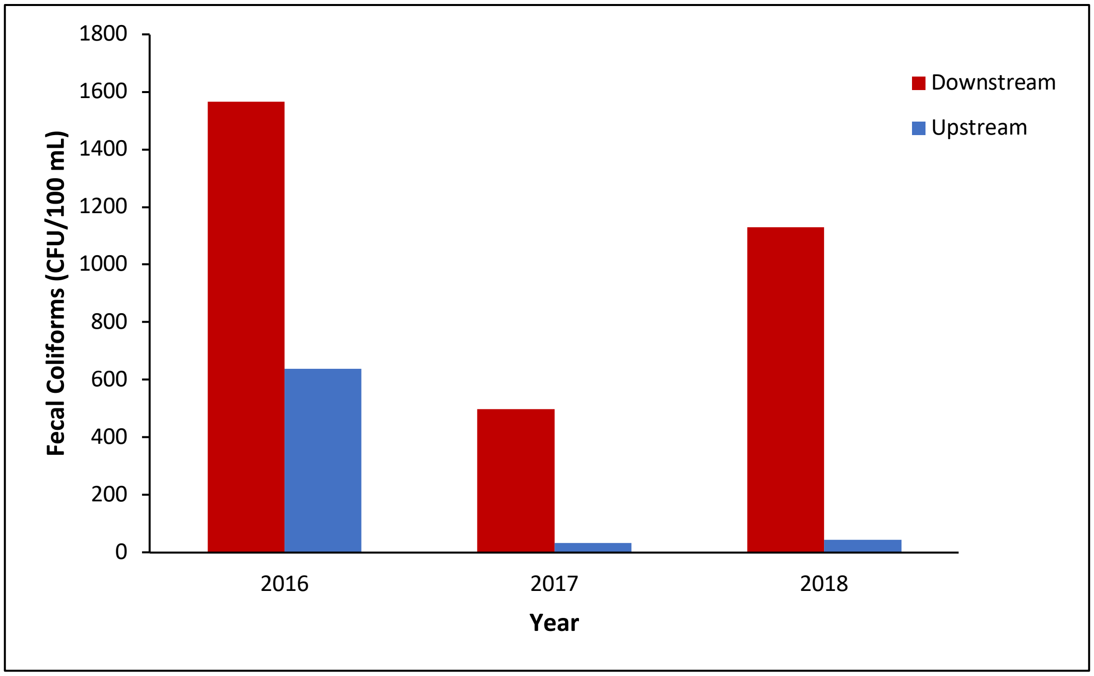

Figure 29. Fecal coliform concentration from the downstream (site 6) and upstream (site 7) sites with Hazen Creek from 2016 to 2018.

Fish Communities Monitoring

A presence survey was conducted along two different reaches of Hazen Creek on June 1, 2018 using an electrofisher. Along the first reach (downstream from the culvert under Whitebone Way) the electrofisher was set at 30 Hz, 12%, 220 V, and ran for 110 seconds. A total of 73 fish were caught, identified, and measured; the majority of them being Brook trout (Table 11). The water temperature was found to be 10°C and one Brook trout was found dead. Later that day, a different reach of Hazen creek (near the fish ladder) was electrofished as a presence survey. The electrofisher was set to 30 Hz, 12%, 195 V, and ran for 1058 seconds. A total of 36 fish were caught (Table 12). The water temperature was found to be 8°C and there were zero fish mortalities.

Table 11. *Fish species composition as a result of electrofishing in Hazen Creek (downstream from the culvert under Whitebone Way) on June 1, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Brook trout (*Salvelinus fontinalis*)	59	81	38-185
American eel (*Anguilla rostrata*)	14	19	90-300

Table 12. *Fish species composition as a result of electrofishing in Hazen Creek (near the fish ladder) on June 1, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Brook trout (*Salvelinus fontinalis*)	33	92	37-187
American eel (*Anguilla rostrata*)	3	8	125-200

Taylor Brook Watershed

Water quality monitoring was conducted at three sites within the Taylor Brook watershed – Fairweather Brook (site 8), Taylor Brook upstream (site 9), and Taylor Brook downstream (site 10). Three water sites were monitored over six timepoints in the 2018 field season. The average from this monitoring can be found in Table 13.

Table 13. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Taylor Brook over six sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
8	18.0	2.3	7.7	0.10	9.05	0.89	0.09	0.01	20	16	1.3	1.9	0.017	0.014	<0.001	<0.001	0.29	0.37
9	20.7	2.5	7.6	0.09	7.13	1.17	0.11	0.01	26	46	3.3	2.8	0.022	0.020	<0.001	<0.001	0.19	0.25
10	18.1	1.3	7.8	0.04	9.06	0.50	0.12	<0.01	73	55	2.0	2.8	0.042	0.055	0.002	0.003	0.13	0.18

Overall, the water quality within the Taylor Brook watershed is good enough quality to support aquatic life and recreational activities. The water temperature, on average, was mostly below 20°C and thus, well within acceptable limits for Salmonid species. The dissolved oxygen concentration was well above the lower limit of 6.5 mg/L. Data at Taylor Brook upstream (site 9) was observed as lower value with 7.13 mg/L (Table 13). On the other hand, the dissolved oxygen concentrations at the Taylor Brook watershed – Fairweather Brook (site 8) and Taylor Brook downstream (site 10) exceeded the 9.5 mg/L recommendation for early life stages of cold water species on multiple occasions (Canadian Council of Ministers of the Environment, 2017) (Table 13). Additionally, the fecal coliform concentration, on average, was well below the recreational limit of 200 CFU/100 mL with averages of 20, 26, and 73 for the three sites respectively (Health Canada, 2012) (Table 13). The lower fecal coliform concentration would indicate that the watershed is not overly impacted by human development and the runoff and stormwater issues associated with the more urban watersheds.

The fecal coliform concentration from the 2018 field season is very similar to the data collected during the 2017 field season, indicating that the watershed is in stable conditions (Figure 30). The only parameter measured that varied significantly when comparing to previous years, was the total phosphates with an average of 0.29, 0.189, and 0.29 mg/L, respectively in the 2018 season (Figure 31). Phosphate inputs can come from a variety of sources with the most common being fertilizer, soil, and wastewater or raw sewage inputs.

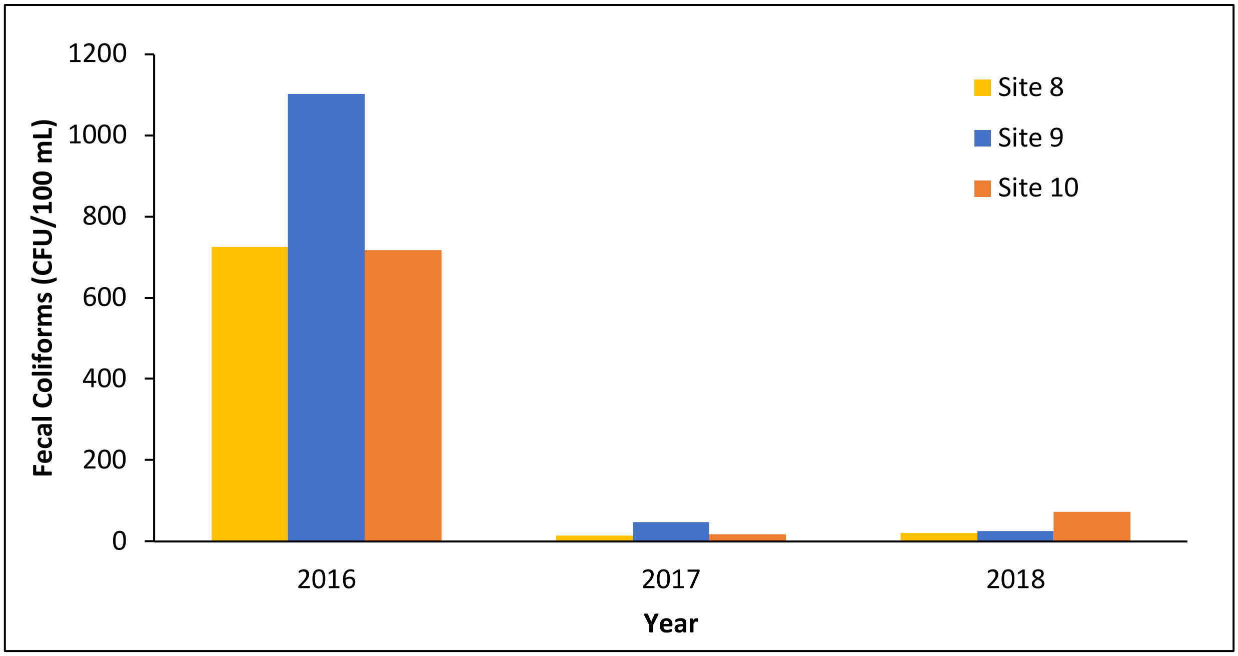

Figure 30. Average fecal coliform concentration in three Taylor Brook sites from 2016 to 2018.

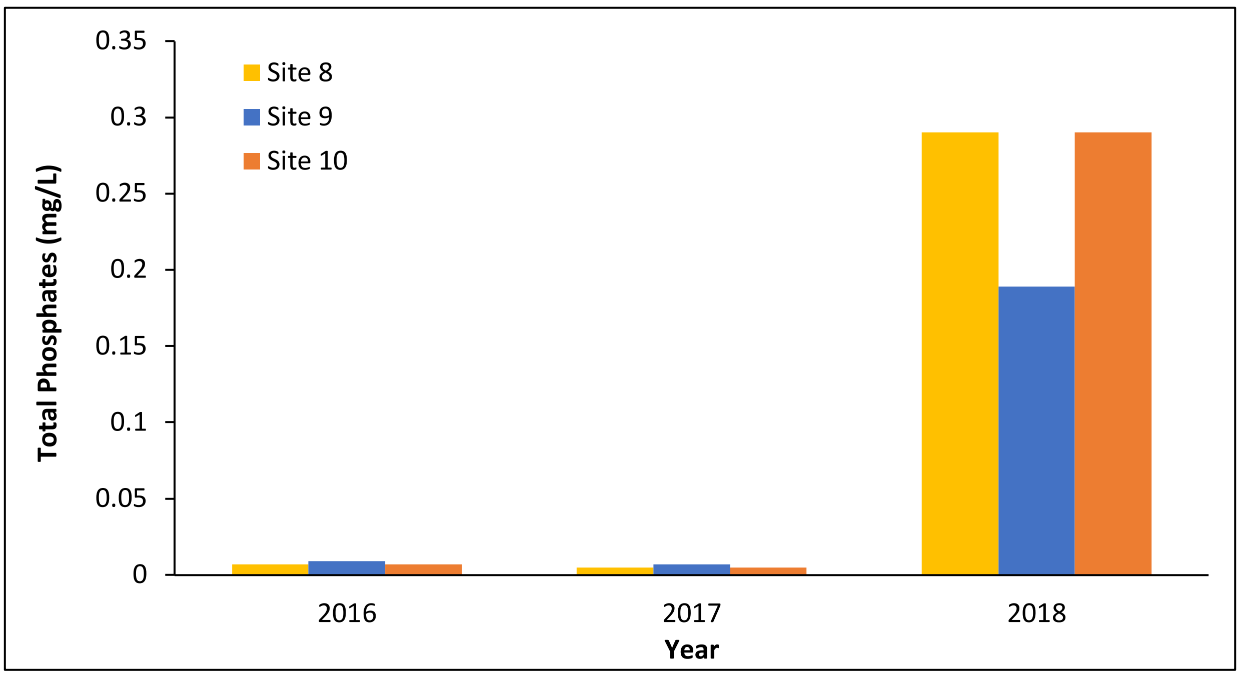

Figure 31. Average total phosphate concentration in three Taylor Brook sites from 2016 to 2018.

Newman's Brook Watershed

The Newman's Brook watershed was monitored at two locations for water quality parameters – upstream (site 12) and downstream [Spar Cove] (site 13). The upstream site was sampled over four periods, however, the downstream site was monitored only three times because of low water levels caused by dry conditions. The averages generated from the 2018 field season can be found in Table 14.

Table 14. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Newman's Brook from four sample periods in 2018.*

Site	Temp (℃)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
12	16.8	2.2	7.8	0.04	8.6	1.1	0.2	0.1	77	23	0.3	0.6	0.026	0.026	<0.001	<0.001	0.17	0.25
13	18.3	4.5	7.3	0.40	8.5	3.3	9.3	6.9	130,075	183,742	22.0	12.7	0.488	0.650	0.008	0.010	0.15	0.06

The vastly different environments between the two sampling stations is reflected in the water quality data. The upstream site is above ground and has natural inputs and although not pristine, does support fish habitat and fish communities. The downstream site is located after the stormwater outflow (Spar Cove), and thus has unnatural inputs from storm drains throughout the North End. Table 14 shows that water quality at this site was not great with elevated fecal coliform and ammonia, and generally low DO. The Canadian Council of Ministers of the Environment (CCME) states that cold water species require dissolved oxygen concentrations above 6.5 mg/L; the upstream site never fell below this limit and even exceeded the 9.5 mg/L recommendation for early life stages (Figure 32). The downstream site, however showed a tendency in near lower limit with 6.78 mg/L and 6.49 mg/L except one time as 12.29 mg/L (Figure 32).

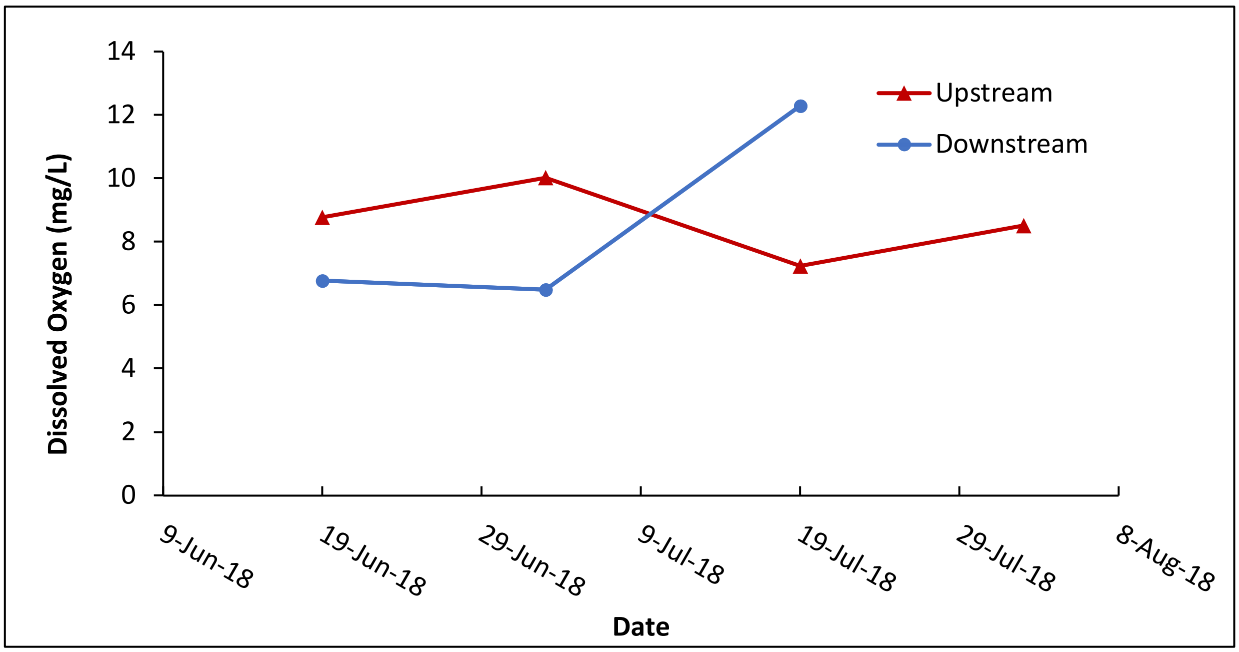

Figure 32. Dissolved oxygen concentrations from both the upstream (site 12) and downstream (site 13) stations within the Newman's Brook watershed.

Additionally, the total suspended solids (TSS) concentrations at the downstream site were quite elevated when compared to the upstream site – on average 0.3 mg/L at the upstream site and 22.0 mg/L at the downstream site (Table 14). This is likely due to the increase of particulate (sediment) being washed into the system through the storm drains which would also increase the nutrient concentrations. Brook trout especially, prefer clear water and would not likely tolerate the high TSS values at the downstream site. The most elevated timepoints in terms of TSS also correspond with the most elevated fecal coliform concentrations, which would further deter fish from this area by acting as a chemical barrier.

The fecal coliform concentration at the downstream site in 2018 field season was conducted twice and had an average concentration of 130,075 CFU/100 mL (Table 14). Compared to previous years, the fecal coliform concentration is much higher this year at the downstream site (Figure 33). On the other hand, the average fecal coliform concentration at the upstream site in 2018 (77 CFU/100 mL) was similar to the 2017 field season (87 CFU/100 mL) (Figure 33). The elevated fecal coliform concentration at the downstream site would likely only be caused by lift station overflows or the presence of an increased in combined sewers; given that the city is actively trying to stop cross-contamination of sanitary and stormwater sewers it is unlikely that they have increased in area, leading to the likely reason being lift station overflows. There is a lift station located across the street from the sampling site and would likely be the cause of fecal coliform contamination at this site.

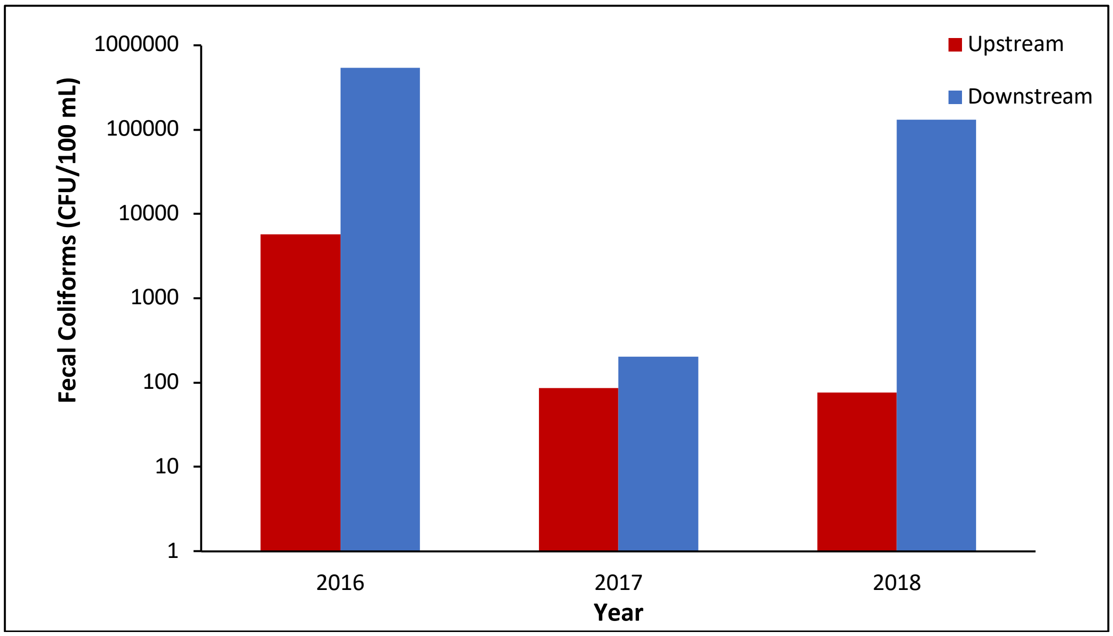

Figure 33. Fecal coliform concentrations from both the upstream (site 12) and downstream (site 13) stations within the Newman's Brook watershed from 2016 to 2018.

Fish Communities Monitoring

On October 4, 2018, the outflow of the Newman's Brook watershed (Spar Cove) was seined for the presence of fish. A total of 1043 fish were found, measured and identified to species (Table 15). The water temperature was found to be 13.6°C and there were zero fish mortalities. A total of four Sand shrimp and seven European green crabs were also caught during seining.

Table 15. *Fish species composition caught in the beach seine in Spar Cove on October 4, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Atlantic silverside (*Menidia menidia*)	1040	99	30-60
Winter flounder (*Pseudopleuronectes americanus*)	2	0.5	72-74
Banded killifish (*Fundulus disaphanus*)	1	0.5	51

On October 5, 2018 a fyke net was set at on site 13 (Spar Cove) for the presence of fish. A total of four different species were found in this area: *Alosa* sp (20%), White perch (10%), Atlantic tomcod (60%) and

Mummichog (10%) (Table 16). The water temperature was found to be 14.0°C and there was one fish mortality (one *Alosa* sp). A total of seven European green crabs were also found in the fyke net.

Table 16. *Fish species composition caught in a fyke net at Spar Cove (the outlet of the Newman's Brook watershed) on October 5, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Atlantic tomcod (*Microgadus tomcod*)	6	60	108-250
Alosa sp.	2	20	91-102
White perch (*Morone americana*)	1	10	189
Mummichog (*Fundulus heteroclitus*)	1	10	95

Inner Harbour

The Inner Saint John Harbour was monitored at two historic sites – upstream, above Reversing Falls (site 14) and downstream, below Reversing Falls (site 15). The averages from the 2018 assessments can be found in Table 17.

Table 17. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured at the Inner Harbour sites from six sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
14	18.6	2.3	7.7	0.2	7.9	0.6	10.3	3.3	315	300	10.0	10.7	0.040	0.020	0.001	<0.001	0.03	0.04
15	15.8	2.3	7.7	0.1	9.1	0.7	14.9	9.2	192	198	31.7	28.0	0.111	0.061	0.003	0.002	0.11	0.08

Overall, both the upstream and downstream sites were categorized as having good water quality. The average water temperatures were quite low, 18.6℃ and 15.8℃, due to the tidal action bringing in cool ocean water (Table 17). These lower water temperatures over the summer season would make great fish habitat for species that cannot tolerate high water temperatures but can also tolerate changing salinity concentrations (brackish waters). The average dissolved oxygen concentration at the upstream site was 7.93 mg/L and the downstream site was 9.07 mg/L, providing great aquatic habitat for many aquatic species (Table 17).

Additionally, both ammonia and phosphate concentrations were well within acceptable limits for the area and would likely pose no threat to aquatic life (Table 17). Due to advances in methodology and equipment, the phosphate concentrations cannot be directly compared to the historic data (current methods are more sensitive). However, it appears the orthophosphate concentrations remain similar to previous monitoring done from 1996-2007. The same method was used to determine the total ammonia concentration, therefore the measurements from this year can be directly compared to past data, but it is likely that variation between historical data and current data is present due to advances in equipment and detection. The average total ammonia concentration has varied over the historical sampling data, likely due to fluctuations in sewage discharge (Figure 34). The average concentrations in 2018, 0.040 (upstream) and 0.111 mg/L (downstream), are considerably higher compared to previous monitoring

(Figure 34). The cause of the increase in ammonia concentrations this year compared to last year is unknown at this point.

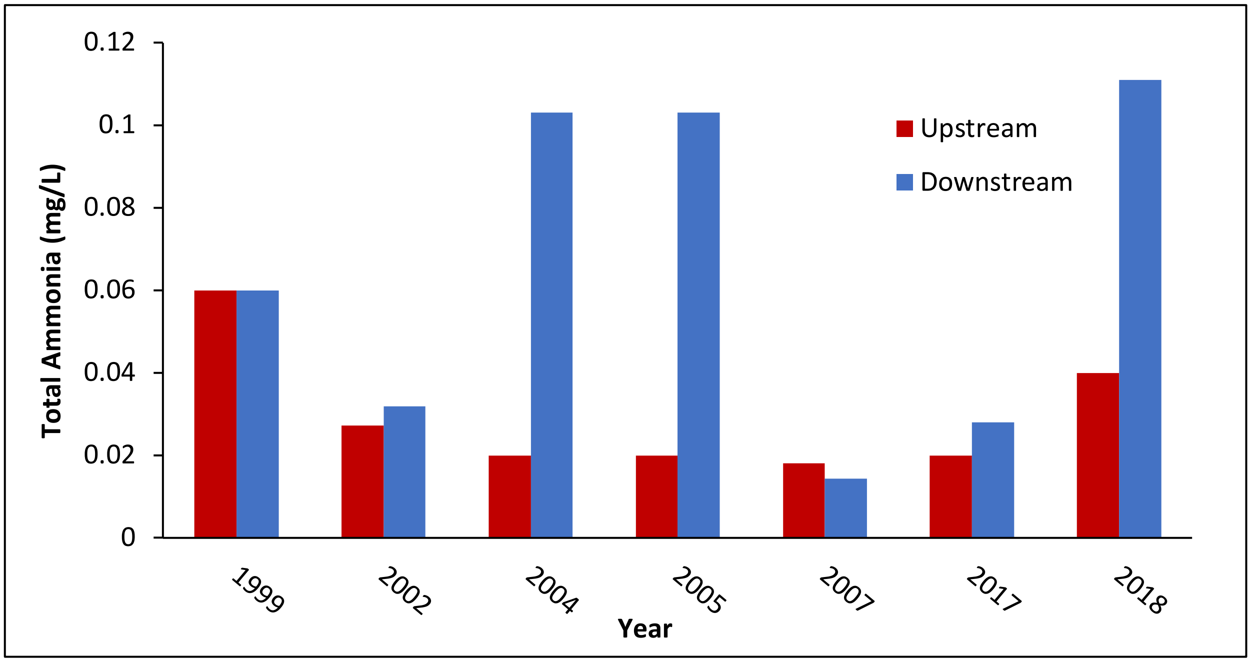

Figure 34. Average total ammonia concentrations from a historical data set and 2018 monitoring at two Inner Harbour sites.

The average total suspended solids concentration was substantially higher at the downstream site at 31.7 mg/L compared to 10.0 mg/L at the upstream site (Table 17). This increase in TSS at the downstream site is likely due to its location further into the Saint John Harbour where silt-laden Bay of Fundy waters are mixing with the clearer Saint John River waters. Although, this increase in TSS may appear as a cause for concern, the tidal mixing is completely natural and poses no water quality concerns as species living within this habitat would be adapted to these changes.

The fecal coliform concentrations varied widely between the two sites. The upstream site had an average of 315 CFU/100 mL which is over the Health Canada guideline for safe recreational contact with the water (Table 17). The downstream site on the other hand had an overall average of 192 CFU/100 mL, just below the guideline (Table 17). When compared to historical fecal coliform concentrations at these two locations, the same trend of higher fecal coliforms at the upstream site, is present for most years except 2007 (Figure 35). The difference in fecal coliform concentration at the two sites is likely due to the intense tidal flushing/mixing present at the downstream site within the Saint John Harbour, whereas the upstream site is above the Reversing Falls where the flushing/mixing is less intense. The lower marine influence at the upstream site means it is more affected by freshwater and the issues with stormwater and lift-stations as discussed previously. Overall, compared to historical values, the results from this year reveal a slight increase in fecal coliform concentration at both the upstream and downstream sites since the completion of Harbour Cleanup (Figure 35).

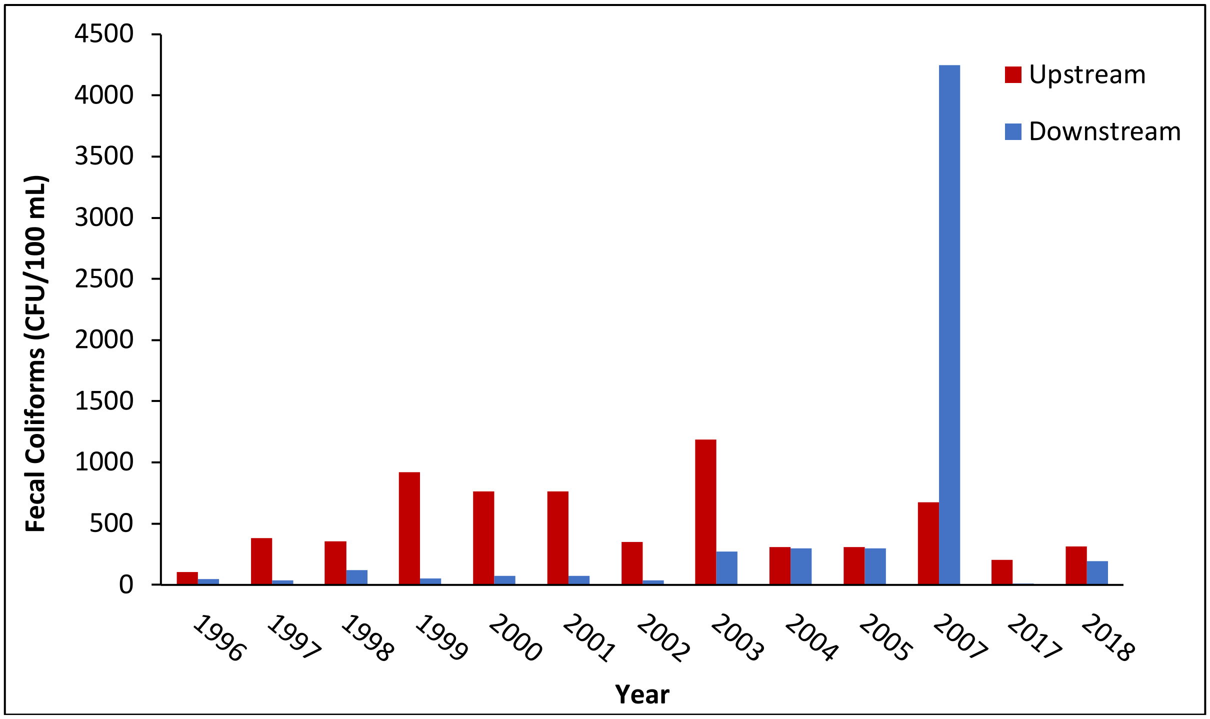

Figure 35. Average fecal coliform concentrations from the two Inner Saint John Harbour sites from a historical data set (1996-2007) and monitoring in 2017-2018. (No monitoring was completed in 2006 and from 2008-2016 at these sites).

Fish Communities Monitoring

On October 3, 2018, the Inner Harbour downstream site (site 15) was seined for presence of fish in the area. The majority of the fish caught were Atlantic silverside (97%) (Table 18). All fish caught were identified to species. The water temperature was found to be 15.0°C and there were three fish mortalities (all Atlantic silverside). A total of two Sand shrimp were also caught during seining.

Table 18. *Fish species composition caught in the beach seine near the Harbour Passage (above the tide gates) on October 3, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Atlantic silverside (*Menidia menidia*)	261	97	79-116
Three-spined stickleback (*Gasterosteus aculeatus*)	8	3	27-33

On October 4, 2018, a fyke net was set near the Inner Harbour downstream site (site 15) to check for the presence of fish in the area. The only species of fish that was found in the fyke net were Atlantic tomcod (Table 19). The water temperature was found to be 14.0°C and there were 20 Atlantic tomcod mortalities due to the water levels in lowest tide cycle being extremely low. A total of eight European green crabs were also found in the fyke net.

Table 19. *Fish species composition caught in fyke nets near the Harbour Passage on October 4, 2018.*

Species	Total Number Caught	Percentage (%)	Range of Total Length (mm)
Atlantic tomcod (*Microgadus tomcod*)	34	100	111-246

Caledonia Brook Watershed

The water quality monitoring within the Caledonia Brook watershed was also split up into an upstream (site 16) and downstream (site 17) comparison. Once again, the upstream site was within an ecologically healthy portion of the watershed and the downstream site was located downstream of outflow of the underground/stormwater section of the brook. The average of the water quality parameters assessed can be found in Table 20.

Table 20. Calculated averages (x) and standard deviations (SD) of water quality parameters measured for the Caledonia Watershed from five sample periods in 2018.

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
16	14.2	2.9	7.4	0.4	7.0	2.4	0.3	0.2	2130	2861	3.0	3.6	0.057	0.052	0.001	<0.001	0.03	0.03
17	15.2	2.4	8.0	0.1	10.1	0.5	0.3	0.1	3250	3594	0.7	1.2	0.066	0.095	0.004	0.005	0.03	0.04

Overall, both sites had suitable water temperatures and dissolved oxygen concentrations to support a diversity of aquatic life (Table 20). The dissolved oxygen concentration at both sites was well above the 6.5 mg/L recommendation. For the downstream site, the dissolved oxygen concentration exceeded the 9.5 mg/L recommendation for early life stages on multiple occasions (Table 20).

The most notable issue within this watershed was the elevated fecal coliform concentrations towards the end of the field season (Figure 36) which resulted in an elevated average fecal coliform concentration compared to 2017 (Figure 37). Overall, the fecal coliform concentrations from both the upstream and downstream site were higher than Health Canada's recreational limit; however, at the last timepoint, the elevation at both sites increased substantially. This large increase in fecal coliform concentration would likely only be possible from sewage contamination, however, the location of where a possible lift station overflow or combined sewer is unknown.

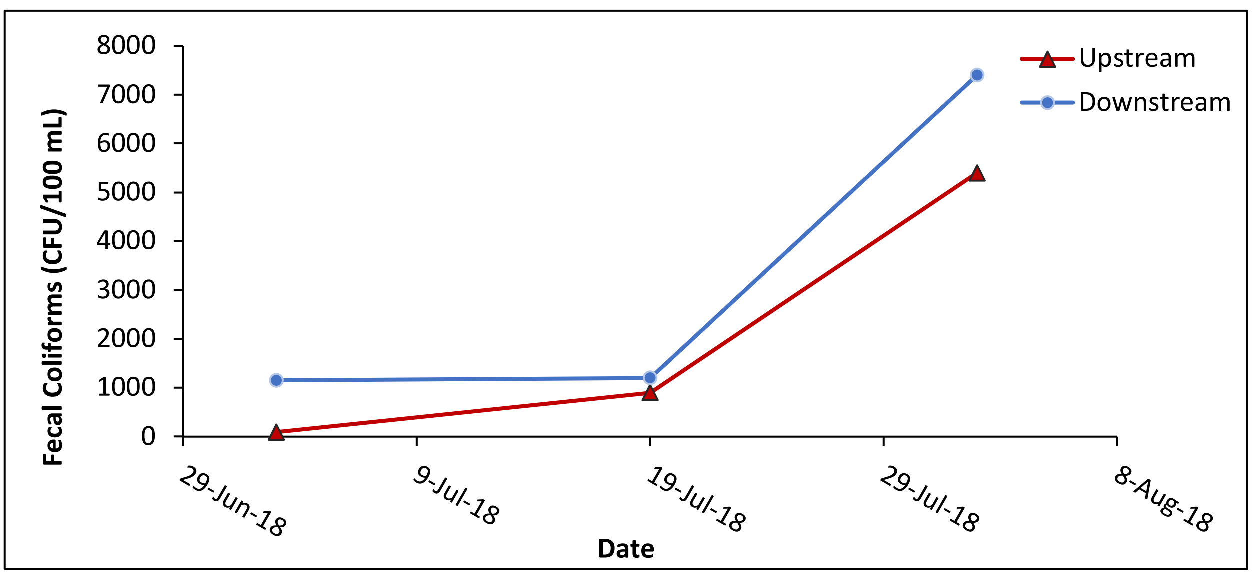

Figure 36. Fecal coliform concentrations from three timepoints at both the upstream (site 16) and downstream (site 17) stations within the Caledonia Brook watershed.

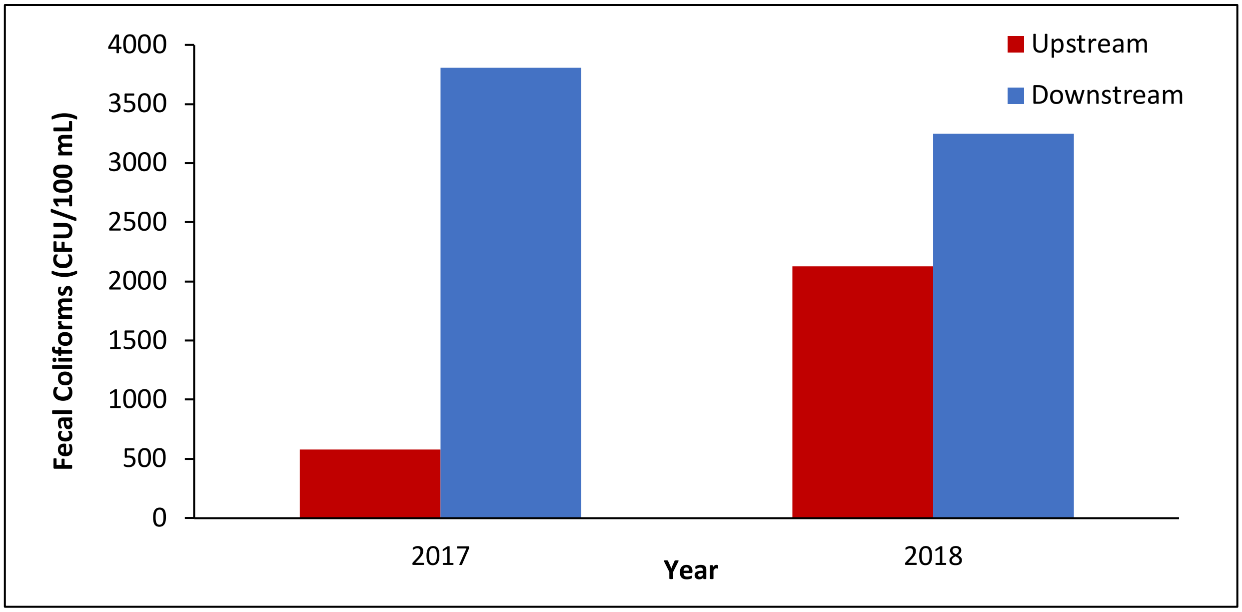

Figure 37. Fecal coliform concentrations at both the upstream (site 16) and downstream (site 17) stations within the Caledonia Brook watershed from 2017 to 2018.

Alder Brook Watershed

The results of the water quality parameters assessed within the Alder Brook watershed at an upstream site (site 18) and a downstream site (site 19) can be found in Table 21. Sampling within Alder Brook revealed that the overall quality of water for aquatic life is good. Water temperatures remained low over the summer period even when air temperatures were the high (Table 21). Although this watercourse has many urban stressors throughout, much of the riparian area has remained vegetated and as such, provides shade to the brook to help prevent high water temperatures experienced in other watercourses within the city. The low water temperatures allow for dissolved oxygen concentration to remain within the acceptable guideline concentrations for aquatic life due to the inverse relationship between temperature and dissolved oxygen saturation - colder waters allow for higher dissolved oxygen concentrations. On average, the dissolved oxygen concentration was 7.99 and 8.98 mg/L at the upstream and downstream sites respectively; exceeding the guideline recommendation of 6.5 mg/L for the protection of aquatic life (Canadian Council of Ministers of the Environment, 2017) (Table 21). Additionally, TSS and Ammonia were quite low, which further indicates good water quality with the potential to support a diversity of aquatic life.

Table 21. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Alder Brook from six sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
18	15.7	3.1	7.5	<0.1	8.0	0.9	0.7	0.2	31	17	2.8	1.9	0.035	0.055	<0.001	0.001	0.20	0.28
19	16.8	2.9	8.0	0.1	9.0	0.9	0.7	0.2	175	263	2.0	1.8	0.037	0.028	0.002	0.002	0.30	0.40

Salmon Creek Watershed

Water quality monitoring was conducted within the Salmon Creek watershed at two locations – upstream (site 20) and downstream (site 21). The averages of the water quality parameters assessed can be found in Table 22

Table 22. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Salmon Creek from seven sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
20	15.8	1.1	7.6	0.1	8.6	1.1	0.3	0.1	121	51	2.5	3.3	0.025	0.023	<0.001	0.001	0.17	0.21
21	16.0	1.3	7.9	0.3	9.8	1.7	0.3	0.1	495	301	1.8	1.3	0.069	0.062	0.002	0.002	0.21	0.25

The field parameters assessed within Salmon Creek were all adequate for supporting fish habitat. The average water temperature for both sites were below 20°C (Table 22). Both average dissolved oxygen concentration for the upstream site (8.55 mg/L) and the downstream site (9.79mg/L) are well above the 6.5 mg/L CCME guideline (Canadian Council of Ministers of the Environment, 2017) (Table 22). The pH and salinity values were well within the range for natural fresh waters (Table 22).

The most notable parameter assessed within the Salmon Creek watershed was fecal coliforms. The upstream site fell below the recreational guideline average with an average of 121 CFU/100 mL (Table 22). The downstream site however, exceeded this guideline with an average of 495 CFU/100 mL (Table 22). As seen in Figure 38, the fecal coliform concentration spiked at the downstream location in July and remained high in August. Between the upstream and downstream sites there is a wastewater treatment facility (off of Longwood Drive) that may have contributed to this spike. As stated previously, prolonged high fecal coliform concentrations can have other negative effects on water quality and act as chemical barrier to fish species.

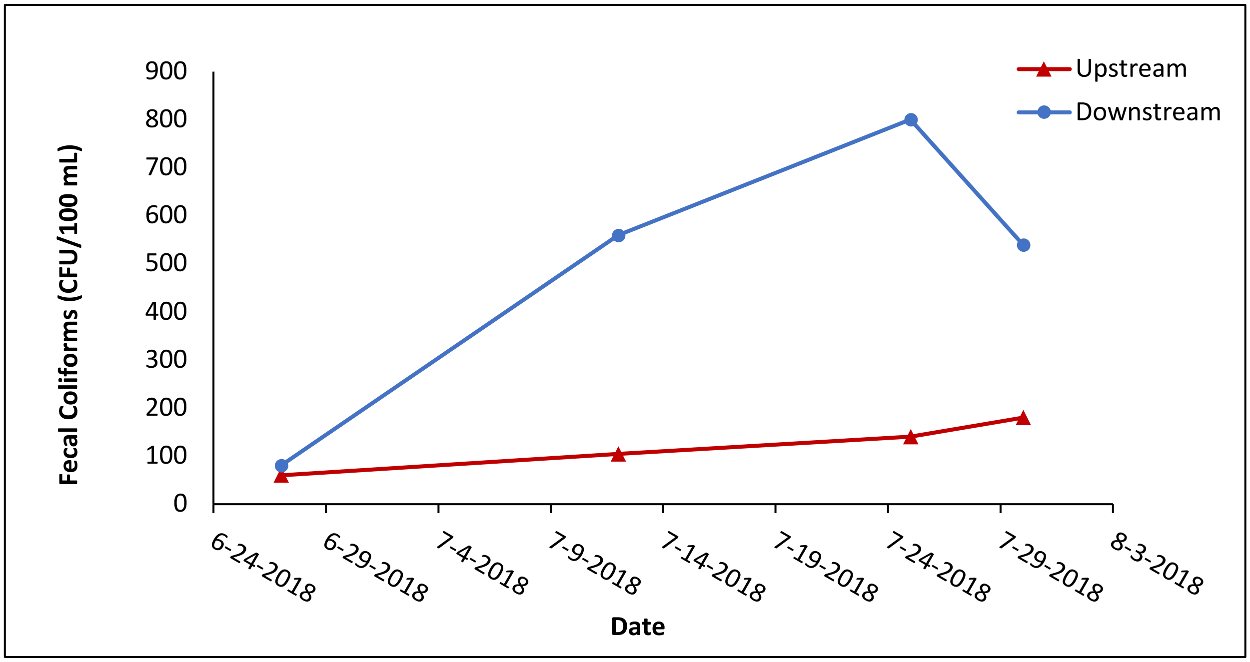

Figure 38. Fecal coliform concentrations from four timepoints at the upstream (site 20) and downstream (site 21) stations within the Salmon Creek watershed from the 2018 field season.

Mispec River

The water quality monitoring program within the Mispec River watershed consisted of only an assessment of field parameters at two locations – upstream (site 22) and downstream (site 23). Lab parameters were not assessed within this watershed. The averages of the assessed water quality parameters can be found in Table 23.

Overall, the water quality of the Mispec River was assessed to be in great standing. Due to its rural, natural location, the river is generally not impacted by as many human influences as the other urban watersheds. The upper portion of the watershed is where most of the human influences can be found, within and around the tributary lakes (Loch Lomond system); however, these lakes serve as a water source for the drinking water system for the City of Saint John and, as such, activities that would negatively impact water quality are generally not permitted. The upstream site used for monitoring was located within the medial portion of the watershed within the river itself not within the lake system to better represent the aquatic habitat of the Mispec River.

Table 23. *Calculated averages (x) and standard deviations (SD) of water quality parameters assessed at two sites within the Mispec River watershed over the 2018 field season.*

Site	Temp (°C)		pH		D.O. (mg/L)		Salinity (ppt)	
	x	SD	x	SD	x	SD	x	SD
22	22.2	4.9	7.79	0.48	8.54	0.69	0.06	0.02
23	19.9	5.1	7.91	0.14	9.16	0.94	0.05	0.02

The water temperature at both sites in the 2018 field season showed a gradual increase throughout the sampling season due to increased air temperatures and low flow conditions. The average dissolved oxygen concentrations were found to be 8.54 mg/L (upstream) and 9.16 mg/L (downstream) (Table 23) and gradually decreased throughout the summer (Figure 39). The dissolved oxygen concentration is temperature sensitive as cold water can hold more dissolved oxygen than warm water which would explain the decreasing dissolved oxygen concentration over the sampling period.

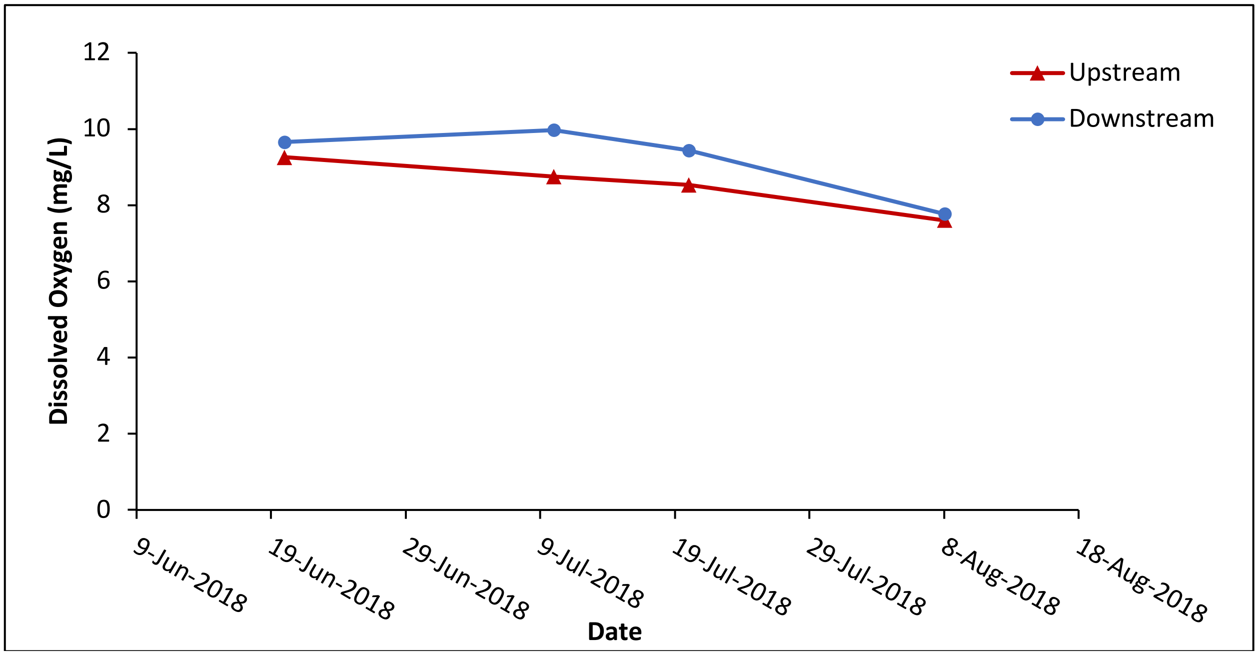

Figure 39. Dissolved oxygen concentrations from both the upstream (site 22) and downstream (site 23) stations within the Mispec River watershed over the entire 2018 field season.

Mill Creek

The 2018 field season was the first year that Mill Creek has been monitored (site 24). Due to the lack of rain this season, the creek ran dry during the end of the sampling season. The sample site was moved slightly downstream on the last day of sampling in order to accommodate for the shortage of water. Throughout the season, the average dissolved oxygen level was 7.33 mg/L which falls above the lower limit of 6.5 mg/L but below the 9.5 mg/L recommendation for early life stages of cold water species on multiple occasions and thus the water quality would indicate good aquatic habitat (Canadian Council of Ministers of the Environment, 2017) (Table 24). It is worth noting that the fecal coliform concentration was only over guideline recommendations once during the sampling period and would indicate that this watercourse is not highly impacted by stormwater or combined sewer overflows.

Table 24. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Mill Creek from five sample periods in 2018.*

Site	Temp (℃)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Mill Creek	20.7	2.1	7.7	0.2	7.3	1.3	1.9	4.3	174	275	3	4	0.018	0.019	0.001	0.001	0.13	0.19

Spruce Lake Stream

The 2018 field season was the first year that Spruce Lake Stream has been monitored (site 25). Overall, the parameters measured fell within the recommended guidelines set by Health Canada and Canadian Council of Ministers of the Environment, with the exception of the dissolved oxygen concentration. The average dissolved oxygen was 5.98 mg/L and the lower limit of the guideline is 6.5 mg/L (Table 25). The location of this sampling site, within a very slow-moving area, would contribute to the lower dissolved oxygen concentrations recorded here. The Orthophosphate concentration at this site was also elevated when compared to other sites located within the West side of the city but there is no guideline limit for Orthophosphate concentration at this time.

Table 25. *Calculated averages of water quality parameters measured for Spruce Lake Stream from three sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Spruce Lake	18.8	2.7	7.1	0.1	6.0	1.9	2.8	1.4	157	31	5.7	2.1	0.044	0.054	0.001	0.001	0.36	0.15

Walker Creek

The 2018 field season was the first year that Walker Creek has been monitored (site 26). On average all parameters, with the exception of fecal coliform concentration, were within the guidelines recommended by the Canadian Council of Ministers of the Environment. Contrarily, average fecal coliform concentration of 3157 CFU/100 mL is well above the Health Canada guideline of 200 CFU/100 mL (Table 26).

Table 26. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Walker Creek from five sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Walker Creek	17.0	2.6	7.6	0.1	8.7	1.4	0.3	0.1	3157	6066	7.8	10.8	0.047	0.041	0.001	0.001	0.16	0.20

The fecal coliform concentration varied over the field season and was exceptionally high on July 25th with a concentration of 14,000 CFU/100 mL (Figure 40). The other four readings, with the exception of one (July 16), were all above the recreational contact limit of 200 CFU/100 mL indicating that there is an issue with fecal coliform contamination within this watercourse. With these high concentrations of fecal coliforms, the only likely source of this magnitude is human sewage or a large farming operation Since no farms are in this area the most likely source is sewage. There is a lift station approximately 400 meters from this sample site on Bay Street which may have overflowed into Walker Creek over the field season.

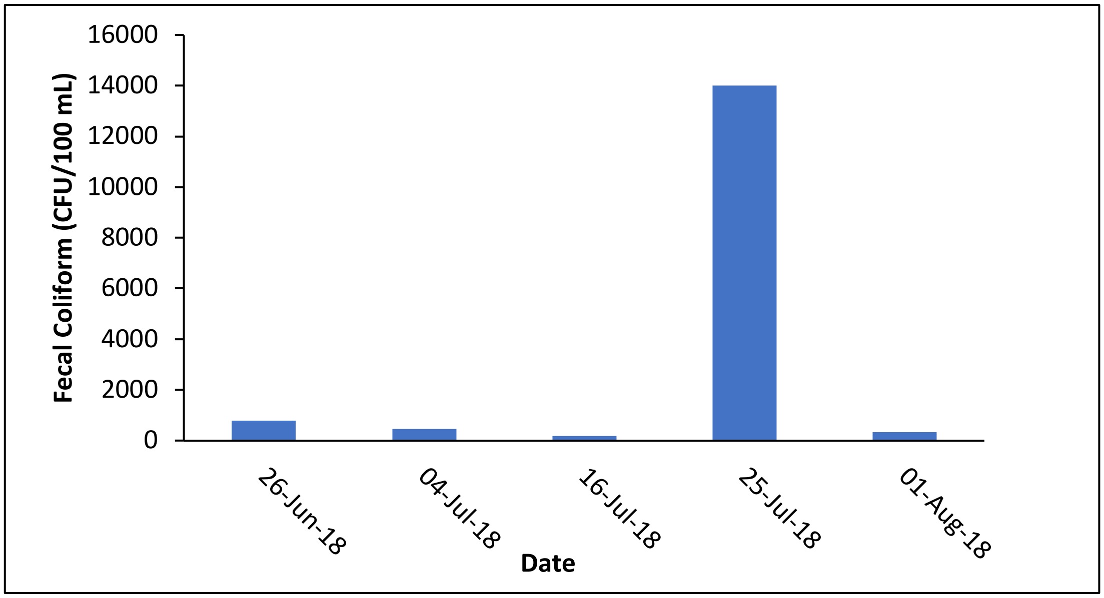

Figure 40. Fecal coliform concentrations recorded from Walker Creek in the 2018 field season.

Manawagonish Creek Watershed

The 2018 field season was the first year that Manawagonish Creek has been monitored at two sites (site 27 and 28) representing a downstream and upstream site. The dissolved oxygen concentrations and water temperature were well within guideline limits to support aquatic life (Table 27). The average fecal coliform concentration of the downstream site (site 27) was 375 CFU/100 mL and is slightly above Health Canada's guideline of 200 CFU/100 mL (Table 27). The upstream site (site 28) had an average fecal coliform concentration of 6441 CFU/100 mL which is way above the guideline and indicate sewage contamination within the watercourse (Table 27). The upstream site is located just after a stormwater pond that is surrounded by housing. It is possible that a cross-connection between the stormwater and sanitary sewer is present and is leading to sewage entering the system. There is also a wastewater treatment plant downstream of site 27 and with the tidal action within this watercourse could backflow sewage contamination; however, it is unlikely that the further upstream site would be impacted greater than the closer downstream site.

Table 27. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Manawagonish Creek from five sample periods in 2018.*

Site	Temp (℃)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
27	15.5	0.8	7.5	0.1	9.6	0.7	0.4	0.1	357	248	15.4	13.8	0.128	0.033	0.003	0.001	0.21	0.14
28	15.6	1.3	7.5	0.2	8.5	1.3	0.3	0.1	6441	12149	3.4	3.4	0.145	0.108	0.003	0.002	0.17	0.11

Mosquito Cove

Mosquito Cove was added to the monitoring program in the 2018 field season at one site (site 29). On average all parameters, with the exception of dissolved oxygen, fell within the guidelines recommended by Health Canada and the Canadian Council of Ministers of the Environment. The mean dissolved oxygen concentration was found to be 3.57mg/L which is considerably lower than the lower limit of 6.5 mg/L (Table 28). The sampling site is located within Mosquito Cove itself and thus is within an area where the water has very little flow. This lack of flow would allow the dissolved oxygen to be used but not replaced with incoming water or moving water over riffles.

Table 28. *Calculated averages (x) and standard deviations (SD) of water quality parameters measured for Mosquito Cove from three sample periods in 2018.*

Site	Temp (°C)		pH		DO (mg/L)		Salinity (ppt)		Fecal Coliforms (CFU /100mL)		TSS (mg/L)		Total Ammonia (mg/L)		Free Ammonia (mg/L)		Phosphate (mg/L)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Mosquito Cove	17.1	3.5	7.0	0.1	3.6	3.5	9.8	4.3	145	49	29.3	10.7	0.017	0.023	<0.001	<0.001	0.21	0.33

Dominion Park

The Dominion Park location was sampled on one occasion at the end of the season due to lack of water at the Mosquito Cove sampling site (site 30). The results are outlined in Table 29. The fecal coliform concentration at this site was 0 CFU/100 mL which given its location at a public beach it is expected that it would be low. The water temperature was high compared to most of the other sites monitored but once again, given its location, it was expected to be high.

Table 29. *Results of water quality monitoring parameters measured for Dominion Park from one sample event in 2018.*

Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Total Ammonia (mg/L)	Free Ammonia (mg/L)	Total Phosphates (mg/L)
Dominion Park	22.8	7.70	6.43	11.22	0	5	0.030	0.0010	0.028

Data Loggers

Extensive data was retrieved from the temperature loggers after being left out in various streams throughout the city. The average temperature from each watercourse ranged from 11.4-18.0°C (Figure 41). The averages of these water temperatures fall below 20°C and thus, would make excellent conditions for Salmonid species (Canadian Council of Ministers of the Environment, 2017). The maximum temperatures of the streams were between 20.5-30.5°C (Figure 41) which can be explained by the hot, dry summer. Although most fish species prefer cooler water temperatures, in situations where the water is too hot, fish will find refuge in cooler pools or where riparian cover is present (providing shade). The cold water temperatures, ranging from 0.5-5°C, can be explained by the loggers being left in the rivers during the later months of the year.

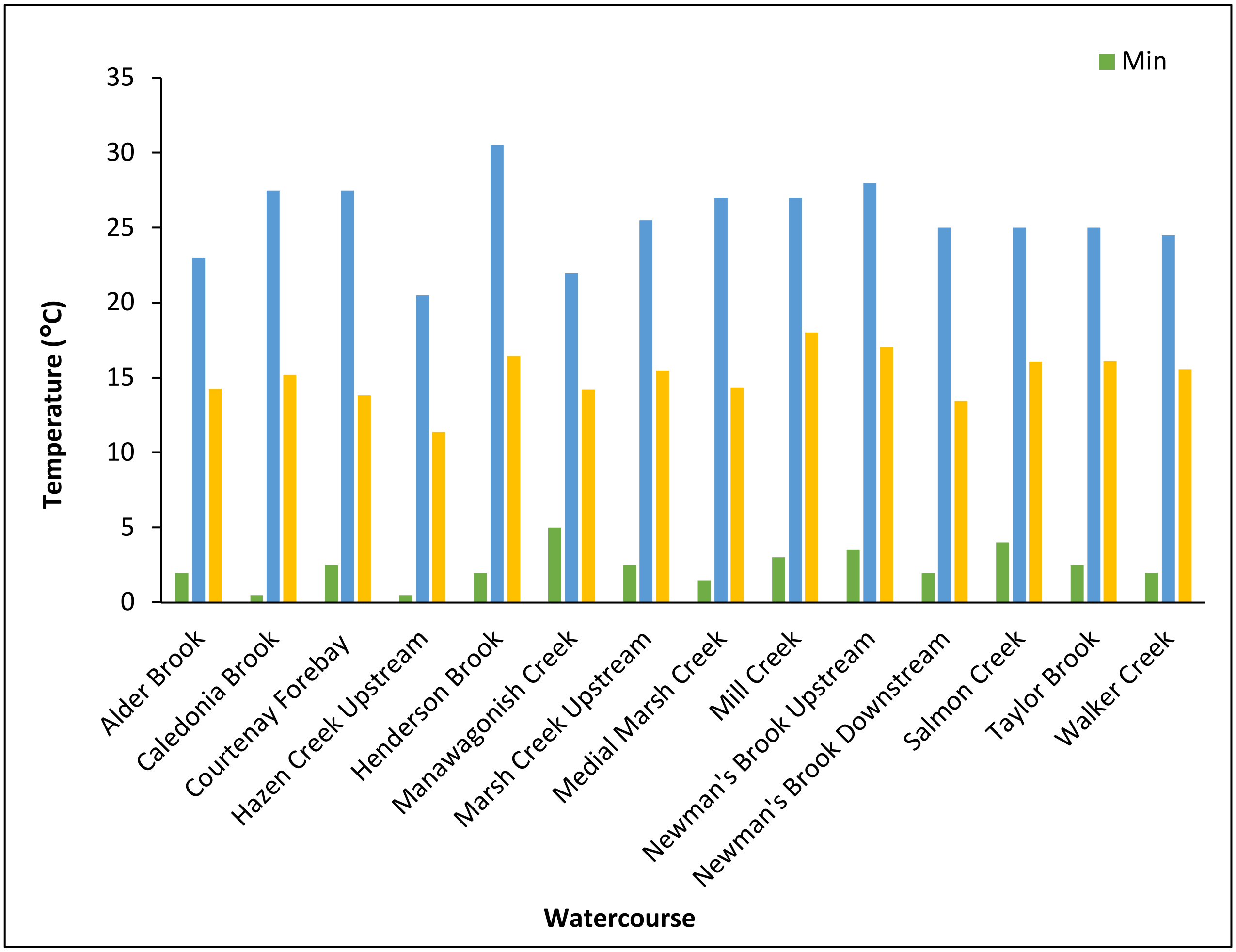

Figure 41. Minimum, maximum and average water temperatures (°C) of various streams in the Greater Saint John area (April - October 2018).

Conclusion

The water quality monitoring from 2018 has been the seventh consecutive year of water quality monitoring for the Marsh Creek, while adding more sites over the years to better represent the water quality of different watersheds throughout the Greater Saint john area. Continuous monitoring of these locations will help to gauge where the water quality needs improvement as well as recognize trends within the individual water courses in the area.

Overall, the 2018 data indicates that the watercourses in Saint John and surrounding areas are capable of supporting aquatic life. However, many of these watercourses are impacted negatively by their location in urban settings, stormwater runoff, sanitary sewer inputs and modifications to their natural flow. Marsh Creek, Hazen Creek, Newman's Brook, Caledonia Brook, Inner Harbour, Salmon Creek, Mill Creek, Walker Creek, and Manawaganish Creek showed influence from sewage with fecal coliform over the Health Canada guideline. Additionally, Marsh Creek continues to show improvement over pre-Harbour Cleanup data and the cessation of sewage dumping directly into the watercourse, thus solidifying the positive impact the efforts and funding of this project have had on the water quality and aquatic habitat.

References

Canadian Council of Minisiters of the Enviroment . (2019, 02 08). *Suspended Sediment* . Retrieved from Canadian Council of Ministers of the Environment : http://st-ts.ccme.ca/en/index.html?lang=en&factsheet=218

Canadian Council of Ministers of the Environment. (2017). *Water Quality Guidelines*. Retrieved from Canadian Council of Ministers of the Environment: http://st-ts.ccme.ca/en/index.html

Encyclopedia Britannica. (2013). *Biosphere*. Retrieved June 20, 2013, from Encyclopedia Britannica: http://www.britannica.com/EBchecked/topic/66191/biosphere/70878/Salinity.

Health Canada. (2012). *Guidelines for Canadian Recreational Water Quality.* Retrieved August 11, 2014, from Health Canada: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/guide_water-2012-guide_eau/index-eng.php.

Lenntech. (2012). *Acids & Alkalis in Freshwater*. Retrieved from Water Treatment Solutions: http://www.lenntech.com/aquatic/acids-alkalis.htm.

United States Enviornmental Protection Agency. (2012). *Dissolved Oxygen and Biological Oxygen Demand*. Retrieved July 3, 2013, from Water: Monitoring & Assessment: http://water.epa.gov/type/rsl/monitoring/vms52.cfm.

Appendix A. Calibration curves

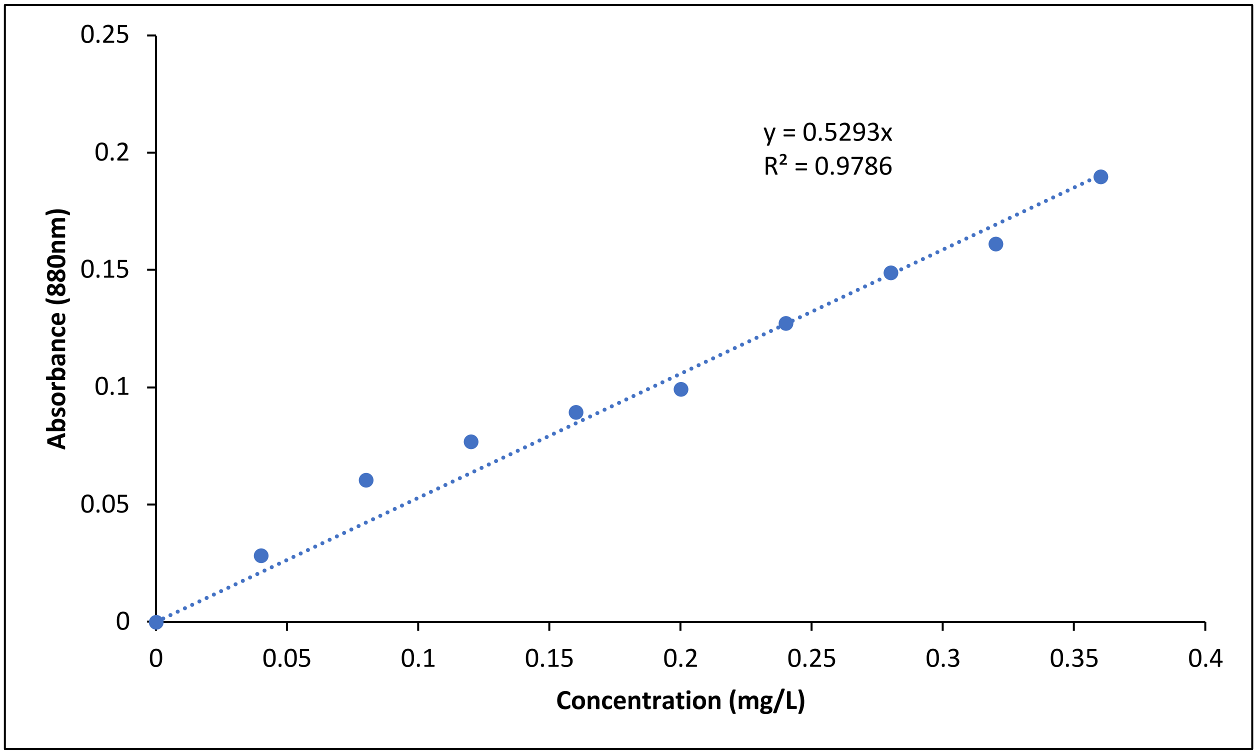

Figure 1. Calibration curve used to determine the total Phosphate concentration of samples collected in the 2018 field season.

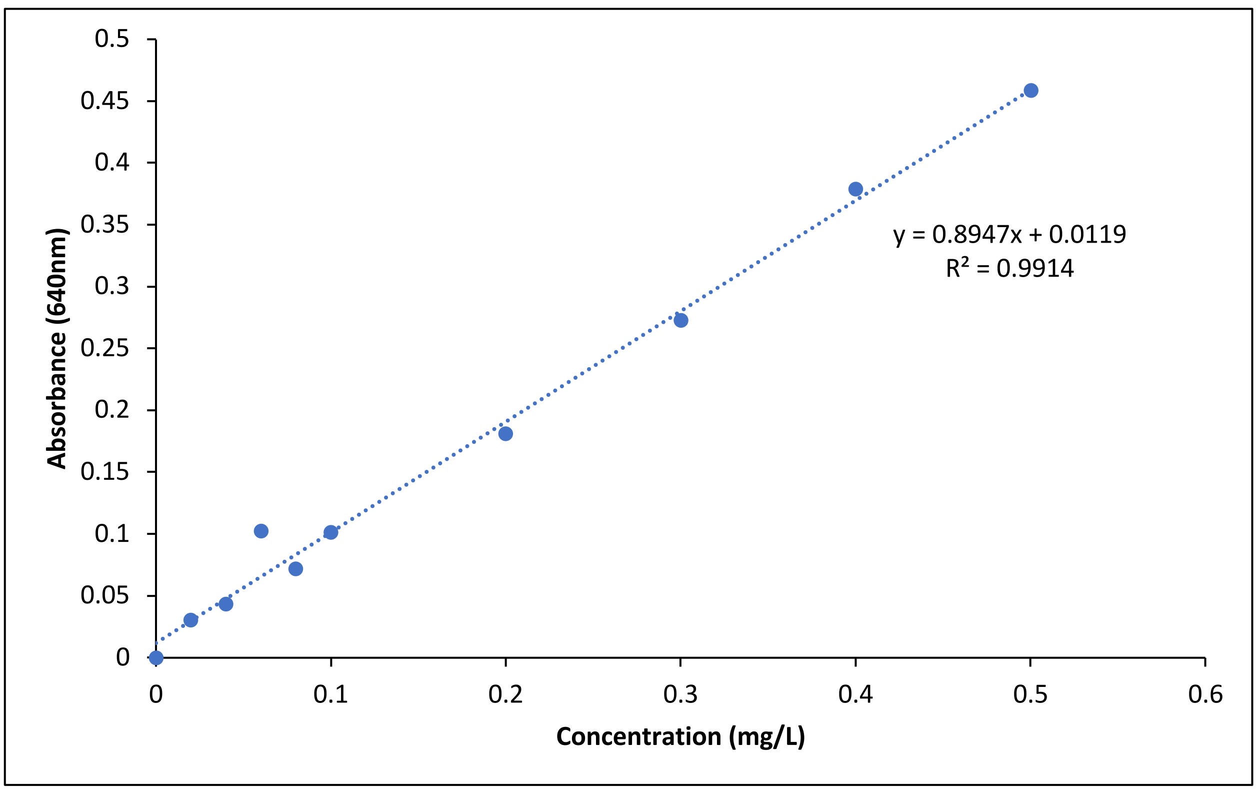

Figure 2. Calibration curve used to determine the Ammonia concentration of water samples collected in the 2017 field season.

Appendix B. Calculations used to determine water quality parameters

B-1: Fecal coliforms:

In determining the total amount of fecal coliforms in a 100 mL of sample a plate count between 20 – 80 coliform bacteria must be counted from a 10 mL sample.

$$\boldsymbol{Counted\ fecal\ coliforms = counted\ bacteria * dilution}$$

Where:

$$counted\ bacteria = the\ bacteria\ counted\ on\ a\ agar\ plate\ from\ a\ 10\ mL\ sample$$

$$dilution = dilution\ factor\ of\ the\ 10\ mL\ sample$$

$$\boldsymbol{Total\ fecal\ coliforms = counted\ fecal\ coliforms * 10}$$

Where:

$$total\ fecal\ coliforms = amount\ of\ fecal\ coliforms\ in\ a\ 100\ mL\ sample$$

$$counted\ fecal\ coliforms = number\ of\ coliform\ bacteria\ counted\ on\ the\ agar\ plate$$

<u>If all plates are less than 20:</u>

$$\boldsymbol{\frac{total\ colony\ counts}{total\ volume\ filtered} * 100}$$

<u>Sample Calculation:</u>

$$Counted\ fecal\ coliforms = 45 * 100 = 4500\,\frac{CFU}{10\ mL}$$

$$Total\ fecal\ coliforms = 4500 * 10 = 45000\,\frac{CFU}{100\ mL}$$

If plates were less than 20:

$$\frac{(19 * 10) + (2 * 100)}{20\ mL} * 100 = 1950\,\frac{CFU}{100\ mL}$$

B-2: Orthophosphates:

To determine the amount of phosphates in a litre sample of water the equation from the calibration graph (Appendix A) must be used.

$$Y = 0.5293 * x$$

$$\boldsymbol{x = \frac{Y}{0.5293}}$$

Where:

$$Y = absorbance\ vale\ from\ spectrophotometer$$

$$x = total\ phosphate\ in\ mg/L$$

<u>Sample Calculation:</u>

$$x = \frac{0.021}{0.5293} = 0.040\frac{mg}{L}$$

B-3: Ammonia:

To determine the amount of ammonia in a litre sample of water the equation from the calibration graph (Appendix B) must be used.

$$Y = (1.0926 * x) - 0.0081$$

$$\boldsymbol{x = \frac{Y - 0.0119}{0.8947}}$$

Where:

$$Y = absorbanve\ value\ from\ spectrophotometer$$

$$x = total\ Ammonia\ in\frac{mg}{L}$$

<u>Sample Calculation</u>:

$$x = \frac{0.021 - 0.0119}{0.8947} = 0.22\frac{mg}{L}$$

B-4: Total Suspended Solids:

In order to determine how much total suspended solids are in a litre of sample a calculation was made by using 100 mL of sample.

$$\boldsymbol{tss = filter\ weight\ after - filter\ weight\ prior}$$

Where:

$$tss = total\ suspended\ solids\ in\ 100\ mL\ sample\ measured\ in\frac{g}{100\ mL}$$

$$filter\ weight\ after = weight\ of\ the\ filter\ and\ aluminum\ container\ after\ the\ sample\ was\ poured$$

$$filter\ weight\ prior = weight\ of\ the\ filter\ and\ aluminum\ container\ before\ the\ sample$$

$$\boldsymbol{TSS = tss * 1000\frac{mg}{g} * 10}$$

Where:

$$TSS = total\ suspended\ soilds\ in\ a\ 1\ litre\ sample\ measured\ in \frac{mg}{L}$$

<u>Sample Calculation</u>:

$$tss = 1.4593\frac{g}{100\ mL} - 1.4591\frac{g}{100\ mL} = 0.0002\frac{g}{100\ mL}$$

$$TSS = 0.0002 * 1000\frac{g}{100\ mL} * 10\frac{mg}{g} = 2.0\frac{mg}{L}$$

Appendix C. Raw water quality data collected over the 2018 field season

Table 1. *Raw water quality data collected for Marsh Creek Analysis A & B over the 2018 field season collected at low tide.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 8, 2018	*1*	13.3	7.46	9.17	13.87	-	-	-	-	-
	2	15.8	7.74	10.03	1.64	-	-	-	-	-
	Downstream	-	-	-	-	-	-	-	-	-
	3	16.6	8.15	11.47	0.23	-	-	-	-	-
	4	17.1	7.85	10.02	0.22	-	-	-	-	-
	5	-	-	-	-	-	-	-	-	-
	11	16.0	8.51	11.50	0.19	-	-	-	-	-
	Upstream	15.0	7.74	10.63	0.06	-	-	-	-	-
June 21, 2018	*1*	19.3	7.68	9.76	10.56	175	105	-	-	-
	2	21.0	8.00	11.76	2.46	N/A	7	-	-	-
	Downstream	21.2	8.10	11.63	1.52	85	9	-	-	-
	3	18.3	7.60	7.61	0.19	220	4	-	-	-
	4	-	-	-	-	-	-	-	-	-
	5	17.5	7.46	5.73	0.18	450	3	-	-	-
	11	17.5	7.65	9.39	0.18	300000	2	-	-	-
	Upstream	14.9	7.76	10.13	0.06	320	3	-	-	-
July 9, 2018	*1*	20.8	7.71	8.40	16.46	185	14	0.270	0.0086	0.613
	2	22.7	7.68	8.81	8.36	1700	11	0.383	0.0128	0.613
	Downstream	23.5	8.29	1.94	1.94	1100	7	0.168	0.0187	0.467
	3	24.5	8.79	11.61	0.19	185	1	0.074	0.0263	0.498
	4	23.8	9.17	10.76	0.19	20	75	0.123	0.0979	0.589
	5	21.4	7.80	6.42	0.19	500	0	0.140	0.0053	0.498
	11	20.8	8.35	9.97	0.18	16000	18	1.840	0.1945	0.599
	Upstream	21.1	7.76	9.61	0.06	650	0	0.117	0.0041	0.336
July 23, 2018	*1*	20.4	7.69	8.81	18.95	2200	7	0.296	0.0090	0.068
	2	22.3	7.49	9.12	7.12	6000	2	0.197	0.0049	0.061
	Downstream	23.2	8.04	9.89	3.70	7200	4	0.262	0.0172	0.028
	3	25.1	8.70	13.28	0.22	2400	3	0.071	0.0214	0.041
	4	23.4	8.23	8.09	0.21	30	34	0.07	0.0068	0.084
	5	21.7	7.60	6.39	0.21	595	2	0.058	0.0016	0.046
	11	21.4	7.78	7.79	0.22	48000	16	2.33	0.0860	0.303
	Upstream	20.2	7.36	7.80	0.09	1600	8	0.428	0.0083	0.065
	1	23.4	7.81	8.89	20.13	530	3	0.326	0.0141	0.076

August 7, 2018	***2***	25.2	7.58	8.47	9.60	6400	14	0.230	0.0074	0.070
	Downstream	26.3	8.41	10.08	3.64	6200	2	0.104	0.0179	0.085
	3	28.4	9.04	15.50	0.18	2350	0	0.057	0.0461	0.037
	4	26.8	7.84	7.49	0.19	460	26	0.064	0.0035	0.038
	5	24.7	7.96	8.43	0.19	70	1	0.020	0.0012	0.030
	11	24.1	8.52	11.15	0.19	1500	2	0.421	0.0798	0.099
	Upstream	23.1	7.56	8.79	0.09	2100	7	0.130	0.0037	0.046

Table 2. *Raw water quality data from the Hazen Creek watershed collected over the 2018 field season at low tide.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 20, 2018	6	18.7	7.53	8.78	10.48	-	-	-	-	-
	7	12.6	7.92	9.48	0.12	-	-	-	-	-
July 5, 2018	6	20.6	7.51	8.86	1.88	150	2	0.111	0.0026	0.131
	7	13.6	7.65	9.70	0.09	0	0	0.092	0.0019	0.084
July 10, 2018	6	20.1	7.59	8.98	5.40	0	0	0.044	0.0011	0.746
	7	13.9	7.59	9.92	0.13	0	1	0.078	0.0016	0.453
July 18, 2018	6	16.5	7.14	7.47	16.93	170	72	0.023	0.0003	0.066
	7	13.6	7.52	9.83	0.15	75	0	0.009	0.0002	0.051
August 8, 2018	6	27.2	7.53	9.13	7.86	4200	11	0.121	0.0040	0.033
	7	18.7	7.77	7.92	0.20	100	0	0.031	0.0010	0.007

Table 3. *Raw water quality data from the Taylor Brook watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 7, 2018	8	16.3	7.74	10.29	0.08	-	-	-	-	-
	9	18.1	7.55	8.26	0.10	-	-	-	-	-
	10	16.7	7.84	8.54	0.11	-	-	-	-	-
June 12, 2017	8	16.4	7.67	9.39	0.09	-	-	-	-	-
	9	19.4	7.52	8.83	0.11	-	-	-	-	-
	10	17.1	7.81	8.96	0.12	-	-	-	-	-
June 27, 2018	8	15.6	7.86	9.65	0.08	20	4	0.016	0.0005	0.827
	9	18.0	7.54	6.96	0.10	95	2	0.020	0.0004	0.561
	10	-	-	-	-	20	6	0.030	-	0.400
July 12, 2018	8	18.4	7.72	8.61	0.09	20	1	0.000	0.0000	0.235
	9	21.7	7.46	6.44	0.12	0	6	0.000	0.0000	0.095
	10	18.0	7.79	9.62	0.12	150	2	0.000	0.0000	0.022

July 25, 2018	8	21.3	7.82	7.83	0.10	40	0	0.035	0.0014	0.017
	9	23.8	7.73	5.80	0.12	0	0	0.049	0.0019	0.015
	10	19.7	7.89	8.65	0.12	60	0	0.123	0.0050	0.019
July 30, 2018	8	19.9	7.59	8.53	0.10	0	0	0.017	0.0004	0.081
	9	22.9	7.60	6.48	0.12	10	5	0.018	0.0005	0.085
	10	19.0	7.87	9.55	0.12	60	0	0.015	0.0006	0.078

Table 4. *Raw water quality data from the Newman's Brook watershed collected over the 2018 field season at low tide.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 19, 2018	12	15.0	7.80	8.78	0.14	-	-	-	-	-
	13	16.9	6.93	6.78	11.16	-	-	-	-	-
July 3, 2018	12	14.9	7.77	10.02	0.12	75	0	0.057	0.0015	0.454
	13	14.7	7.30	6.49	1.60	260000	13	0.948	0.0146	0.194
July 19, 2018	12	19.1	7.87	7.24	0.21	55	1	0.010	0.0004	0.058
	13	23.4	7.73	12.29	15.01	150	31	0.028	0.0011	0.113
August 2, 2018	12	18.2	7.83	8.51	0.22	100	0	0.013	0.0004	0.006
	13	-	-	-	-	-	-	-	-	-

Table 5. *Raw water quality data from the Inner Harbour collected over the 2018 field season at low tide.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 19, 2018	14	15.4	7.48	8.71	8.56	-	-	-	-	-
	15	13.4	7.66	9.31	16.76	-	-	-	-	-
July 3, 2018	14	18.8	7.60	7.84	6.92	660	1	0.035	0.0009	0
	15	14.8	7.55	8.41	16.67	420	14	0.155	0.0031	0.082
July 19, 2018	14	20.5	7.95	7.84	11.37	50	6	0.039	0.0019	0.073
	15	18.9	7.81	9.99	2.08	85	17	0.137	0.0047	0.192
August 2, 2018	14	19.8	7.66	7.31	14.32	235	23	0.045	0.0013	0.011
	15	15.9	7.70	8.58	24.07	70	64	0.042	0.0010	0.044

Table 6. *Raw water quality data from the Caledonia Brook watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 7, 2018	16	10.3	7.71	8.94	0.21	-	-	-	-	-
	17	11.5	8.04	10.21	0.39	-	-	-	-	-

June 19, 2018	**16**	13.5	7.68	8.29	0.19	-	-	-	-	-
	17	14.8	7.86	10.71	0.20	-	-	-	-	-
July 3, 2018	**16**	13.8	7.67	8.87	0.21	90	0	0.041	0.0009	0
	17	15.1	8.00	10.19	0.32	1150	0	0.003	0.0001	0
July 19, 2018	**16**	15.2	6.77	4.73	0.62	900	2	0.015	0.0002	0.059
	17	16.5	8.16	10.13	0.42	1200	0	0.175	0.0096	0.071
August 2, 2018	**16**	18.2	7.22	4.10	0.22	5400	7	0.116	0.0018	0.023
	17	17.9	7.88	9.25	0.34	7400	2	0.018	0.0007	0.024

Table 7. *Raw water quality data from the Alder Brook watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 7, 2018	**18**	11.2	7.48	8.02	0.90	-	-	-	-	-
	19	11.5	7.71	7.74	0.82	-	-	-	-	-
June 12, 2018	**18**	13.9	7.50	8.40	0.91	-	-	-	-	-
	19	17.6	7.93	7.99	0.94	-	-	-	-	-
June 27, 2018	**18**	14.0	7.50	9.33	0.74	30	4	0.022	0.0004	0.616
	19	15.7	7.83	9.60	0.51	565	4	0.038	0.0011	0.876
July 12, 2018	**18**	17.7	7.57	8.23	0.49	20	4	0.000	0.0000	0.106
	19	17.5	8.00	9.68	0.64	95	1	0.000	0.0000	0.221
July 25, 2018	**18**	19.1	7.57	6.67	0.48	20	3	0.116	0.0028	0.012
	19	19.8	8.09	9.19	0.63	10	3	0.067	0.0039	0.017
July 30, 2018	**18**	18.4	7.55	7.30	0.60	55	0	0.001	0.0000	0.080
	19	18.6	8.02	9.70	0.65	30	0	0.043	0.0021	0.077

Table 8. *Raw water quality data from the Salmon Creek watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 7, 2018	**20**	15.2	7.64	8.81	0.24	-	-	-	-	-
	21	15.7	8.34	10.66	0.31	-	-	-	-	-
June 12, 2018	**20**	15.0	7.72	10.27	0.27	-	-	-	-	-
	21	15.3	8.29	11.87	0.34	-	-	-	-	-
June 27, 2018	**20**	15.1	7.46	9.14	0.23	60	3	0.019	0.0003	0.488
	21	14.3	7.75	11.02	0.28	80	2	0.114	0.0028	0.575
July 12, 2018	**20**	15.4	7.51	7.51	0.25	105	0	0.000	0.0000	0.111
	21	15.6	7.76	7.76	0.30	560	3	0.000	0.0000	0.149
July 25, 2018	**20**	17.6	7.65	7.58	0.31	140	0	0.054	0.0014	0.016
	21	18.0	7.78	8.13	0.34	800	2	0.129	0.0040	0.014

July 30, 2018	**20**	16.6	7.59	7.97	0.36	180	7	0.025	0.0005	0.079
	21	16.8	7.74	9.32	0.31	540	0	0.034	0.0009	0.087

Table 9. *Raw water quality data collected from the Mispec River watershed over the 2018 field season. Due to time limitations, only field measurements were taken for this watershed.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 20, 2018	**22**	17.0	7.20	9.26	0.03	-	-	-	-	-
	23	16.7	7.98	9.65	0.03	-	-	-	-	-
July 10, 2018	**22**	21.2	8.37	8.75	0.05	-	-	-	-	-
	23	-	-	-	-	-	-	-	-	-
July 13, 2018	**22**	-	-	-	-	-	-	-	-	-
	23	16.6	7.76	9.79	0.05	-	-	-	-	-
July 20, 2018	**22**	21.6	7.73	8.53	0.08	-	-	-	-	-
	23	18.9	7.81	9.44	0.06	-	-	-	-	-
August 8, 2018	**22**	28.8	7.85	7.60	0.08	-	-	-	-	-
	23	27.3	8.07	7.77	0.07	-	-	-	-	-

Table 10. *Raw water quality data from the Mill Creek watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 26, 2018	**Mill Creek**	16.9	7.64	9.11	0.12	727	7	0.034	0.0008	0.474
July 4, 2018	**Mill Creek**	19.7	7.92	8.50	0.09	80	0	0.002	0.0001	0.000
July 16, 2018	**Mill Creek**	21.4	7.66	7.65	0.10	95	0	0	0.0000	0.219
July 25, 2018	**Mill Creek**	22.7	7.45	6.24	0.11	120	0	0.000	0.0000	0.023
August 1, 2018	**Mill Creek**	22.0	7.65	6.60	0.11	20	1	0.041	0.0013	0.022

Table 11. *Raw water quality data from the Spruce Lake Stream watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 26, 2018	**Spruce Lake**	15.8	7.11	7.88	2.81	190	4	0.105	0.00145	0.524
July 4, 2018	**Spruce Lake**	19.6	7.18	5.87	1.42	130	5	0.026	0.00041	0.233
July 16, 2018	**Spruce Lake**	21.1	7.03	4.18	4.11	150	8	0.001	0.00002	0.310

Table 12. *Raw water quality data from the Walker Creek watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 26, 2018	**Walker Creek**	12.6	7.44	10.57	0.11	790	0	0.09	0.0015	0.480
July 4, 2018	**Walker Creek**	17.6	7.57	8.13	0.19	470	0	0.09	0.0020	0.000
July 16, 2018	**Walker Creek**	17.5	7.76	9.51	0.32	185	14	0	0.0000	0.249
July 25, 2018	**Walker Creek**	19.4	7.62	7.20	0.32	14000	1	0.019	0.0005	0.040
August 1, 2018	**Walker Creek**	18.1	7.77	7.95	0.29	340	24	0.038	0.0012	0.0343

Table 13. *Raw water quality data from the Mosquito Cove watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 26, 2018	**Mosquito cove**	13.0	7.16	7.00	7.02	TNTC	41.0	0.042	0.00056	0.985
July 4, 2018	**Mosquito cove**	19.2	6.99	3.60	7.63	110	20.0	0.011	0.00015	0.432
July 16, 2018	**Mosquito cove**	19.0	6.95	0.10	14.75	180	27.0	-0.002	-0.00003	0.402

Table 14. *Raw water quality data from the Manawagonish Creek watershed collected over the 2018 field season.*

Date	Site	Temp (°C)	pH	D.O. (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total Ammonia (mg/L)	Free Ammonia (mg/L)	
June 26, 2018	**27**	15.3	7.38	9.37	0.33	350	9	0.176	0.0030	0.402
	28	13.7	7.39	7.99	0.31	330	4	0.104	0.0017	0.325
July 4, 2018	**27**	16.7	7.52	9.41	0.39	360	7	0.125	0.0026	0.233
	28	15.5	7.32	7.17	0.38	28000	2	0.166	0.0027	0.212
July 16, 2018	**27**	15.7	7.65	10.09	0.36	65	40	0.089	0.0021	0.258
	28	15.9	7.60	9.72	0.30	60	1	0.027	0.0006	0.157
July 25, 2018	**27**	14.6	7.45	8.63	0.40	760	11	0.109	0.0019	0.073
	28	15.7	7.31	7.58	0.32	3700	9	0.316	0.0051	0.107
August 1, 2018	**27**	15.4	7.60	10.33	0.30	340	10	0.141	0.0030	0.060
	28	17.2	7.76	9.91	0.30	115	1	0.111	0.0032	0.028