REBIRTH OF WATER

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Acknowledgements

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It must be noted that this report builds directly upon previous project reports from 2012 – 2016. Given that much of the text is taken verbatim, this acknowledgement will serve as the only reference indicating the direct duplication of some content.

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Executive Summary

Water quality monitoring is a crucial tool to determine the overall health of a watercourse for both recreational human contact and for aquatic habitat for the many species that live or use these watercourses. This year water quality monitoring was conducted within eight watersheds; including the sixth year of consecutive sampling within the Marsh Creek watershed to document the impacts of Harbour Cleanup on this urbanized watershed. Additional watersheds monitored in the 2017 field season included the Newman's Brook, Caledonia Brook, Alder Brook, and Hazen Creek watersheds within the City of Saint John and Taylor Brook, Salmon Creek, and Mispec River within the Greater Saint John area.

Overall, the water quality monitoring conducted in the 2017 field season revealed that the urban and suburban watersheds have many potential impacts that have resulted in diminished water quality in some areas; however, they are still capable of, and do, support aquatic life. The most notable impact to these urban watersheds is stormwater runoff, the potential for sanitary sewer overflows being discharged into these watercourses, and riparian degradation. Stormwater runoff can cause many issues within a watercourse including sedimentation, increased erosion, and the washing in of pollutants and nutrients. Stormwater runoff coupled with degraded riparian areas can further diminish water quality through increased temperature and decreased dissolved oxygen due to lack of stream side vegetation and stream cover. That being said, all of the watersheds monitored have areas of exemplary water quality that meet the habitat and water quality needs of aquatic species. The variance between these areas indicates that these watersheds have the potential to flourish as productive habitats and that demonstrable improvements can be made to restore the degraded areas and improve stormwater runoff and filtration.

The Marsh Creek watershed is a prime example of how reducing anthropogenic impacts into a watercourse can lead to substantial improvements in water quality. Since the completion of Harbour Cleanup in 2014, the Marsh Creek watershed has shown improvements year after year in terms of water quality. The dissolved oxygen concentrations have increased at all the monitoring sites this year and surpassed the Canadian Council of Ministers of the Environment guideline recommendation concentration of 6.5 mg/L on average at all the sites. Prior to the cessation of discharging sewage into this watercourse many of the impacted sites were so low in dissolved oxygen that it would not support any aquatic life; therefore, the improvement of this watercourse to a point of surpassing this guideline is a great achievement. Additionally, the fecal coliform concentration continues to decrease however, lift station overflows still likely remain an issue within this watershed and as such only two sites were below the Health Canada guideline of an average of 200 CFU/100 mL. The concentrations found this year continue to represent a large reduction of fecal coliform contamination when compared to pre-Harbour Cleanup data, which has allowed the watercourse to slowly recover and improve its overall water quality. The improvements seen in the Marsh Creek watershed demonstrate that the efforts and costs behind Harbour Cleanup established a pioneering example of how a community can improve the management of urban waterways to enhance aquatic habitats and the health of its citizens.

1.0 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 to continue this work. Since 2016, additional watersheds have been monitored to get a better understanding of the state of the urban watersheds of 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.

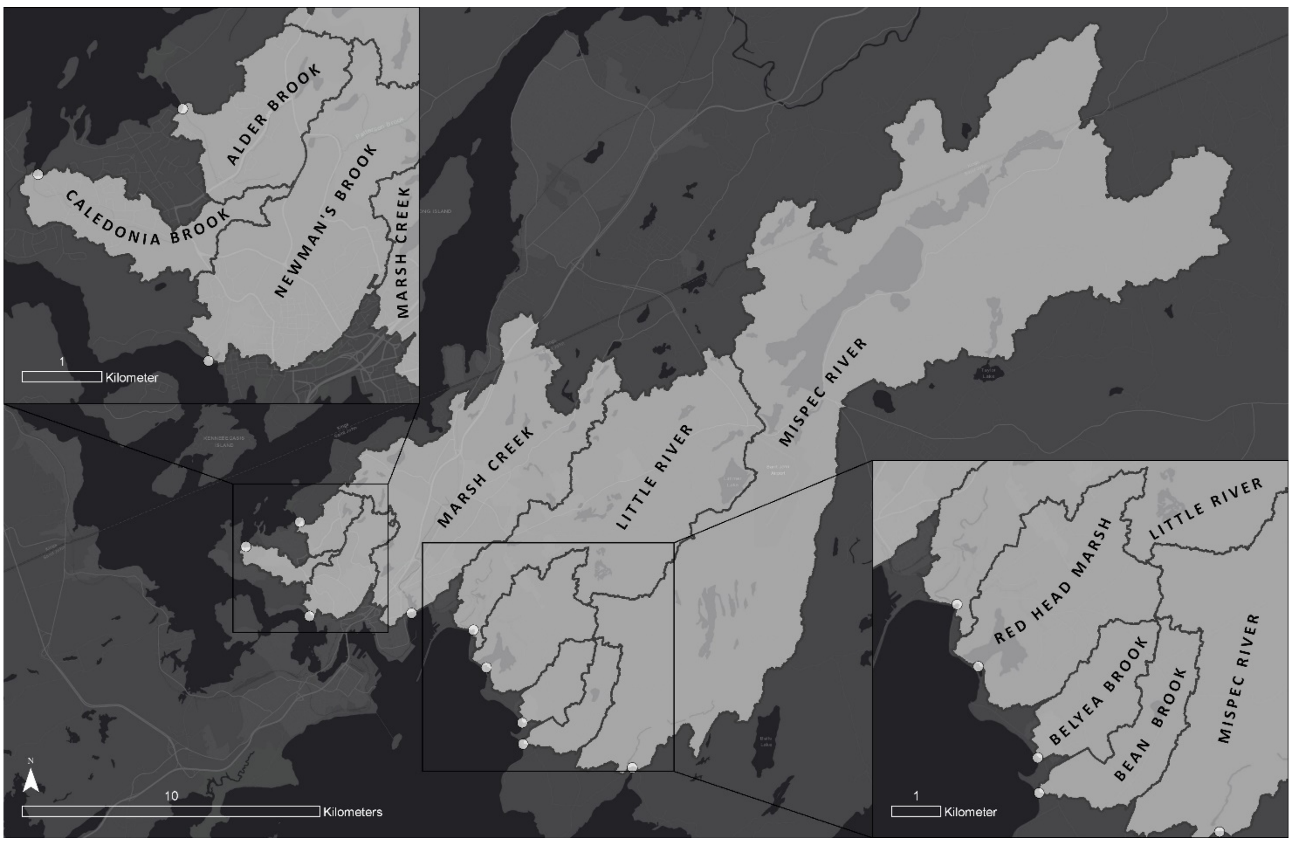

Figure 1.0: *Monitored watersheds within the City of Saint John; missing from this map are the two watersheds within Rothesay and Quispamsis – Taylor Brook and Salmon Creek. Belyea Brook and Bean Brook depicted on this map were not monitored as part of the water quality monitoring program.*

1.1 Marsh Creek Watershed

The Marsh Creek watershed is a ~4,200 hectare feature located in the eastern quadrant of Saint John, New Brunswick, Canada, that drains directly into the Bay of Fundy (Figure 1.1). 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, watercourse channel, and wetland infilling.

The Marsh Creek watershed has undergone vast improvements and changes in the past three years. The most noteworthy of these alterations is the 2014 completion of the Saint John Harbour Cleanup project, 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 has come about largely from two decades of dedicated community engagement by ACAP Saint John, represents the single greatest opportunity in recent history to restore the recipient 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.

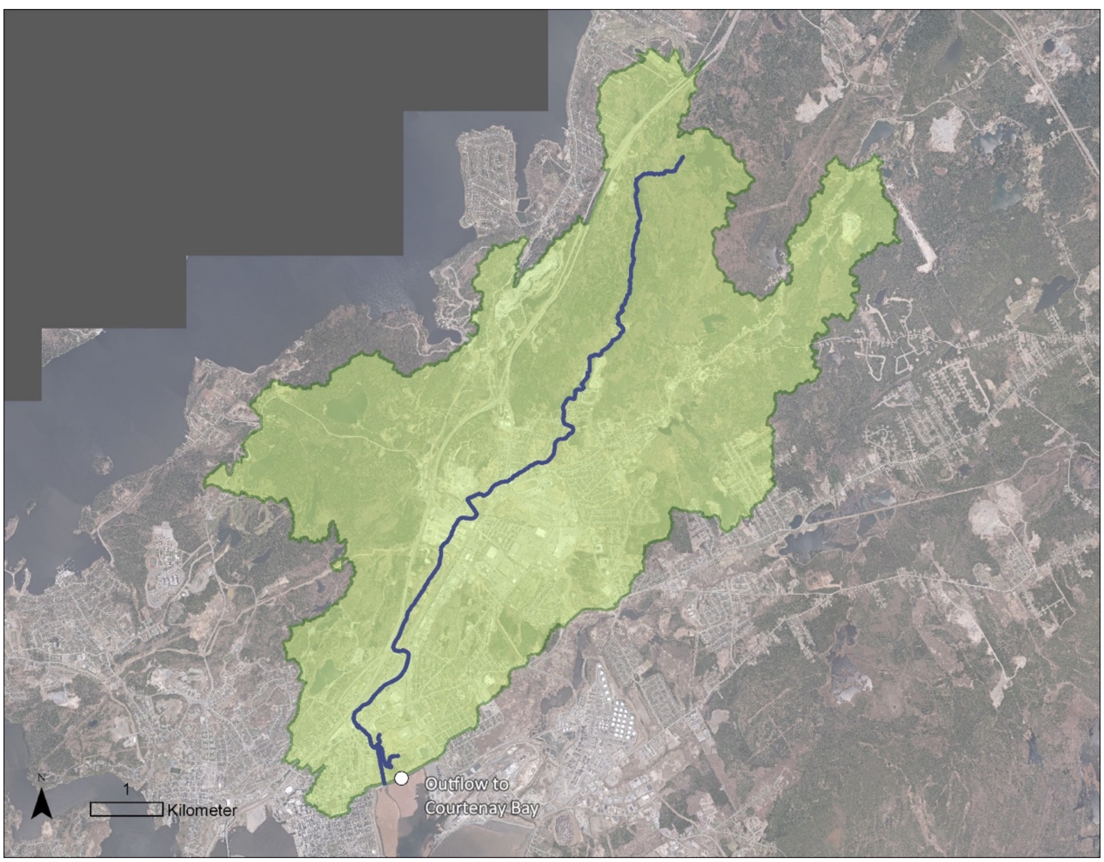

***Figure 1.1**: The Marsh Creek Watershed boundaries in Saint John, New Brunswick.*

1.2 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, which is one of the few remaining tidal marshes along New Brunswick's Fundy coast, and 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 this development.

1.3 Taylor Brook Watershed

The Taylor Brook watershed transverses the eastern most quadrant of 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 good 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.

1.4 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 located in the forested area of Rockwood Park, is in pristine condition but not long after it exists 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 habitat and riparian areas, and increased pollution into 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 dump which has not be capped completed, resulting in the potential for leachate to move throughout this brook.

1.5 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 boarders 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; including 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 Samuel-de-Champlain School.

1.6 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 old dump that may be impacting Newman's Brook; therefore the same potential for leachate movement is present within this watershed.

1.7 Salmon Creek Watershed

The Salmon Creek watershed originates in Quispamsis and flows through to Rothesay to outflow into the Kennebecasis River. Many residential homes are located within this watershed and as such 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.

1.8 Mispec River Watershed

The Mispec River watershed is the largest watershed sampled within this program at 15,742 hectares and outflows directly into the Bay of Fundy. The watershed encompasses a large portion of the semi-rural section of the East side of 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 Regional 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.

2.0 METHODOLOGY

2.1 Water Quality Site Selection

2.1.1 Marsh Creek Watershed

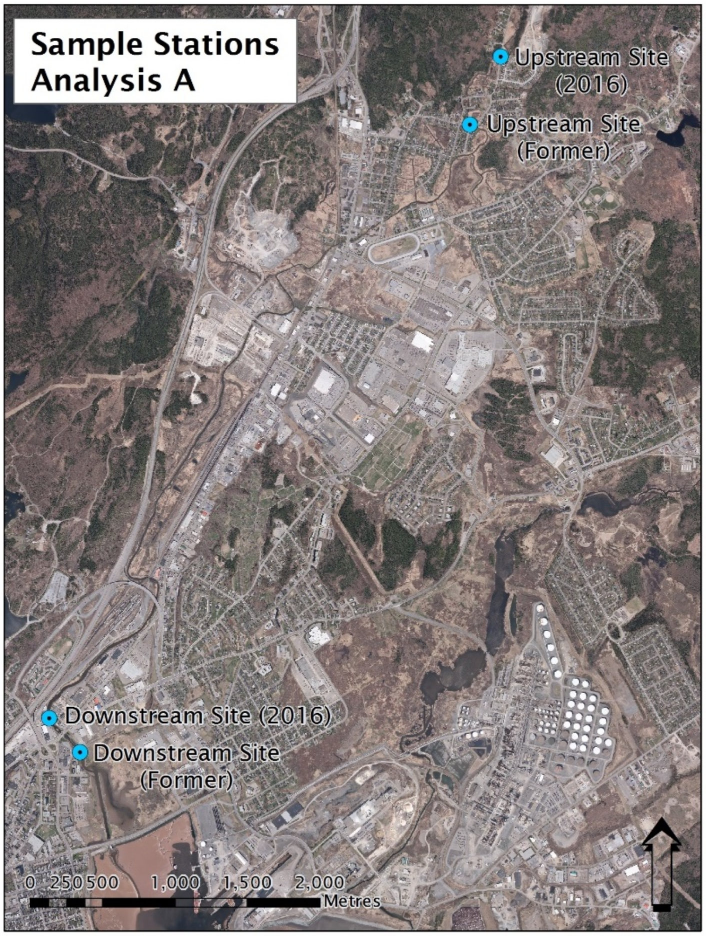

Figure 2.1.A: Water quality monitoring stations used for the Marsh Creek Watershed in 2016.

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 2.1.A). These sample stations have now acquired data in various years between 1993 and 2017.

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

2.1.1.1 Sample Stations Analysis A

Last year, due to an error locating the sampling site, sites were adjusted slightly; however, this year the samples were taken from the historical sites. 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 2.1.A (above)).

2.1.1.2 Sample Stations Analysis B

Figure 2.1.B: Map showing the location of the five sampling stations used in Marsh Creek water quality Analysis B (2012-2016).

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 2.1.B). The stations included two sites in the Courtenay Forebay and three sites above the three-culvert station used as the Downstream Sampling Station in Analysis A (Section 2.1.2). The characteristics of the five individual Sampling Stations used in Analysis B are provided in Table 2.1.A and Figure 2.1.C.

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 the Analysis B program.

Figure 2.1.C: *Sites 1(left) and 5 (right) used in Water Quality Analysis B conducted in Marsh Creek in 2012 through 2017.*

Table 2.1.A: *Characteristics of sampling stations used in Marsh Creek water quality Analysis B from 2012 through 2017.*

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 was located beneath the train bridge adjacent to Rothesay Avenue.
11	45.30963, -66.03402	Located approximately 2.21 km upstream of Site 5, on Ashburn Lake road, directly across from Strescon.

2.1.2 Hazen Creek Watershed

Figure 2.1.D: 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 – upstream located within a forested section adjacent to the industrial park and downstream located within Red Head Marsh (Figure 2.1.D).

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.

2.1.3 Taylor Brook Watershed

Sampling sites were established at three sites within the Taylor Brook watershed in 2016. Water quality monitoring was continued at these sites in the 2017 field season (Figure 2.1.E).

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.

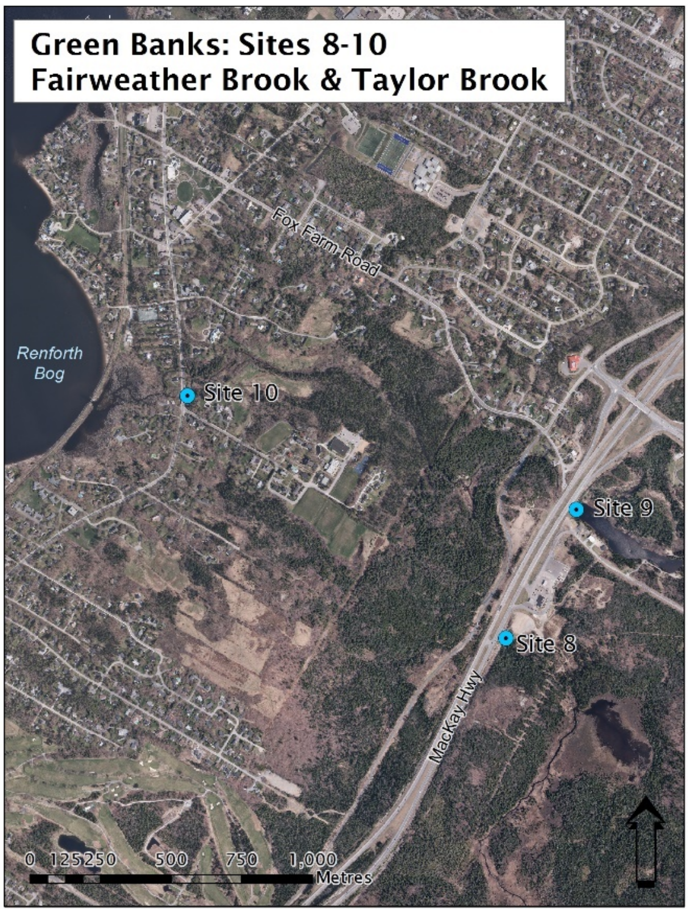

Figure 2.1.E: Map of water quality sampling sites in the Taylor Brook watershed.

2.1.4 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 2017 season (Figure 2.1.F).

Site 12, upstream Newman's Brook, (45.296902, -66.071298) was located along Sandy Point Drive, 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.

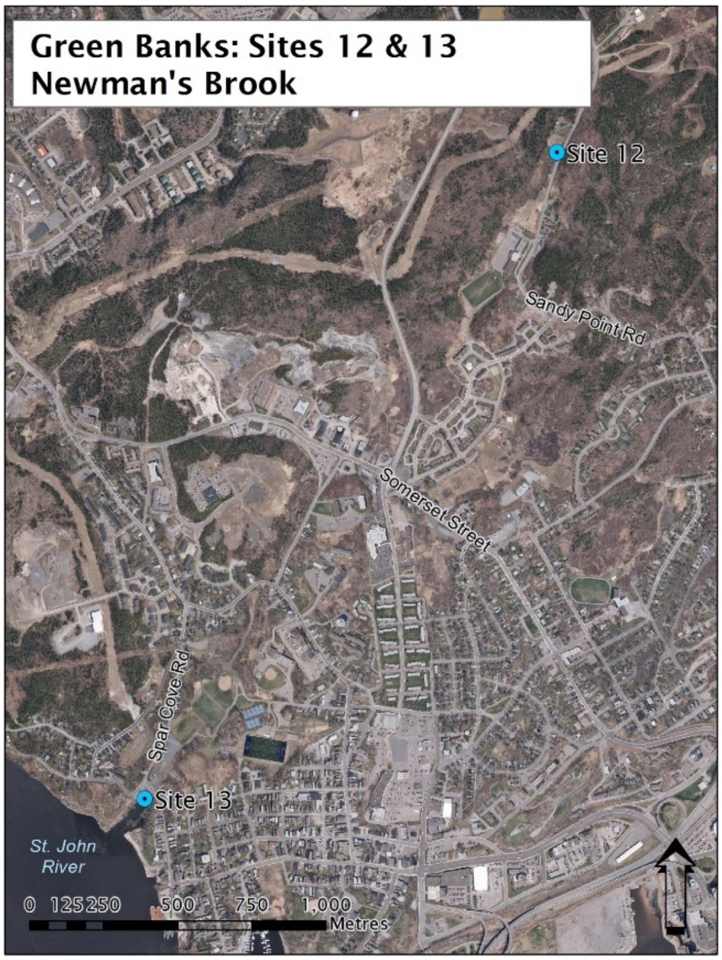

Figure 2.1.F: Map of the two water quality monitoring sites in the Newman's Brook watershed.

2.1.5 Inner 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 2.1.G).

Figure 2.1.G: Map of the two water quality monitoring sites within the Inner Saint John Harbour.

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.

2.1.6 Caledonia Brook Watershed

Within the Caledonia Brook watershed, two sampling sites were established this year to represent an upstream downstream comparison (Figure 2.1.H).

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.

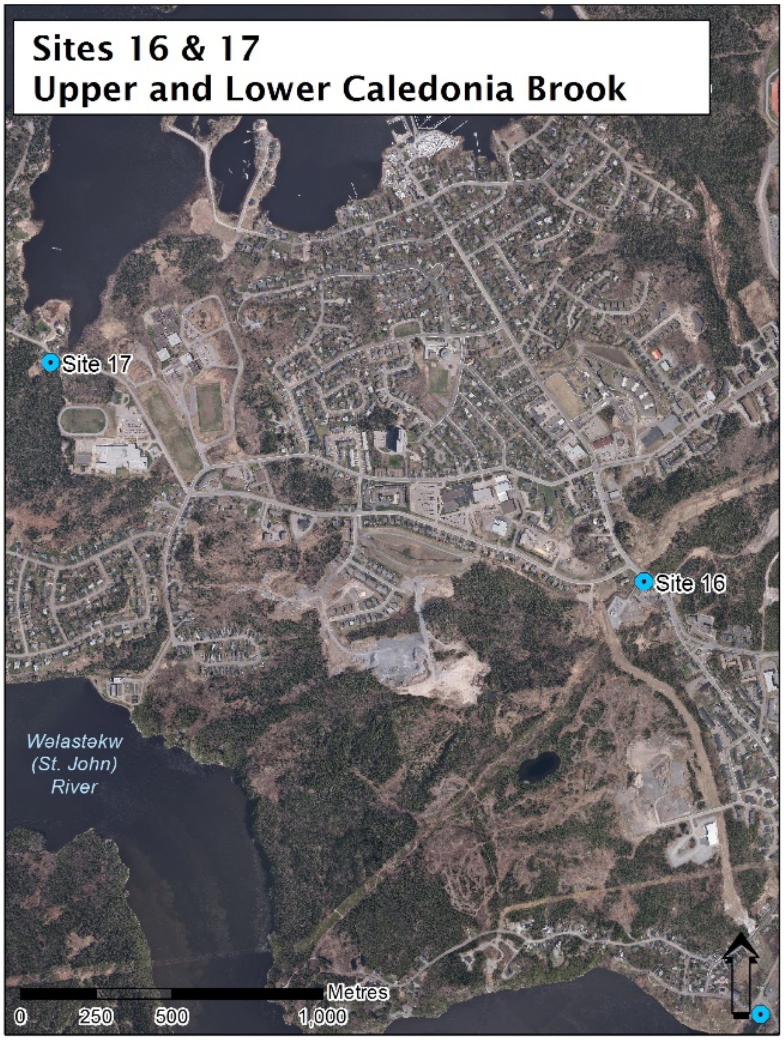

Figure 2.1.H: Map of the two water quality monitoring sites in Caledonia Brook.

2.1.7 Alder Brook Watershed

Two sampling sites were established in the Alder Brook watershed in the 2017 field season (Figure 2.1.I).

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.

Figure 2.1.I: Map of the two water quality monitoring sites within the Alder Brook watershed.

2.1.8 Salmon Creek Watershed

The two sites established in the Salmon Creek watershed were chosen to represent an upstream downstream comparison in the 2017 field season (Figure 2.1.J).

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.

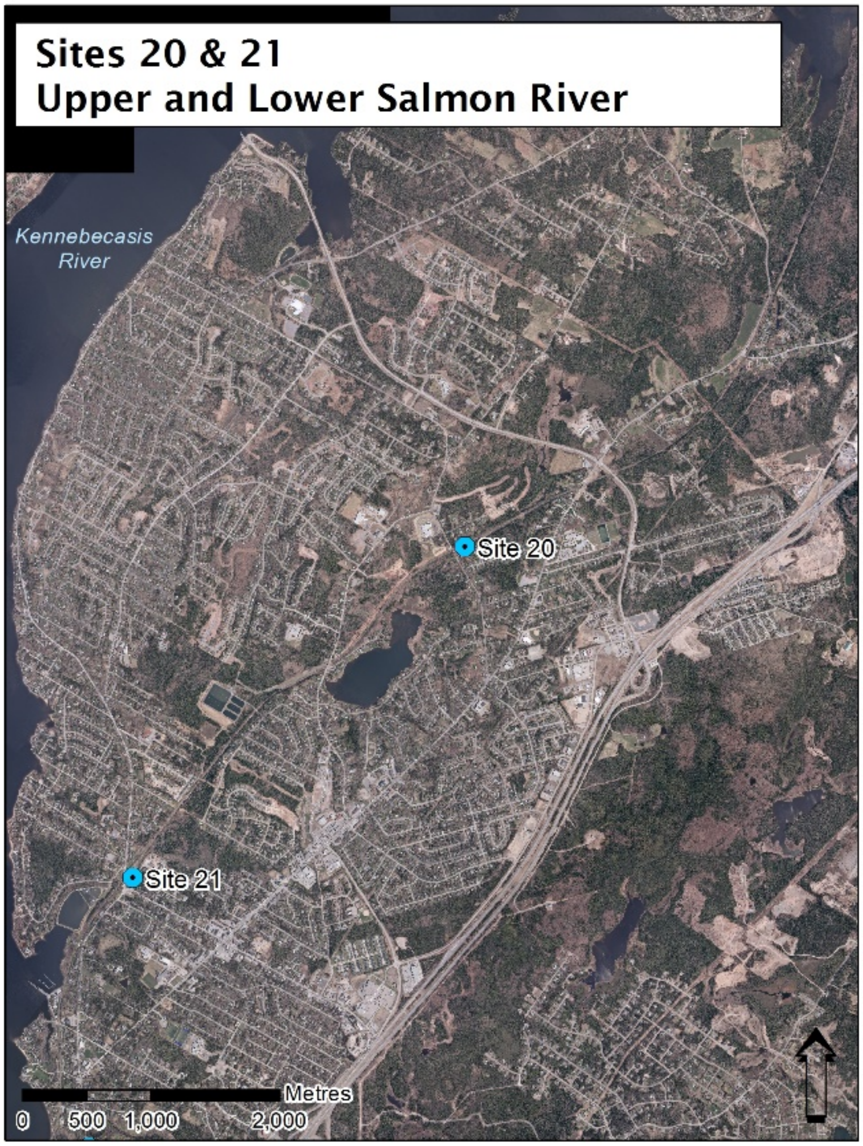

Figure 2.1.J: Map of the two water quality monitoring sites in Salmon Creek.

2.1.9 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 2.1.K).

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.

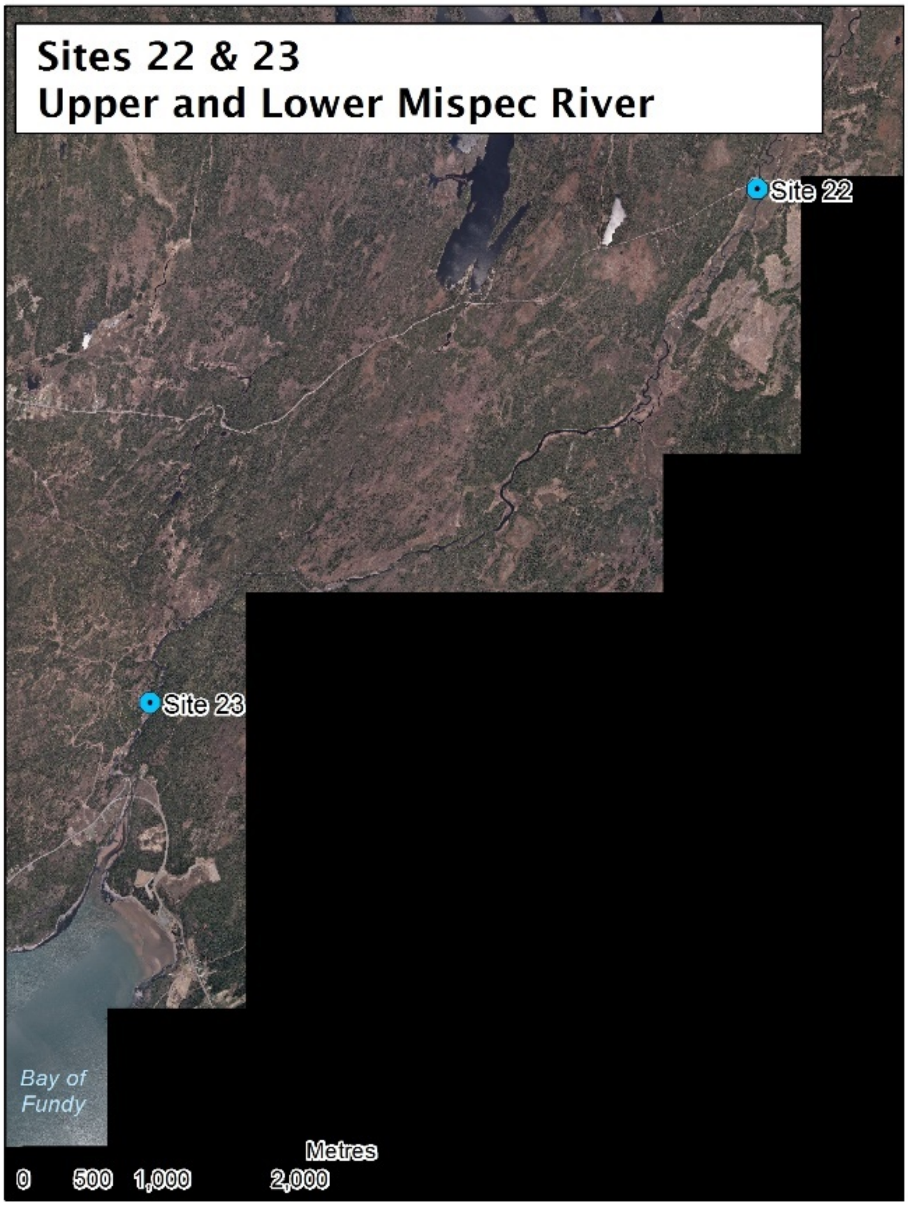

Figure 2.1.K: Map of the two water quality monitoring sites within the Mispec River watershed.

2.2 Water Quality Parameters

Water quality parameters measured again in 2017 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 liter (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 in a watercourse occurs through respiration by aquatic animals, decomposition of organic material by microorganisms, and chemical reactions. When more oxygen has been removed than added, DO levels decline causing 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. As a logarithmic scale, when pH decreases by 1 there is ten times increase in acidity (United States Environmental Protection Agency, 2012). A healthy watercourse has a pH between 6 and 8. Acidification of a stream will cause an intrusion of unwanted plankton and mosses and a decline in fish species and abundance as it reaches a pH of 5 or lower. 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 abnormal amounts are introduced into aquatic ecosystems, it can rapidly cause increases in the 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 blooms. Due to these changes, the amount of sunlight algae and other aquatic life can absorb will fluctuate throughout the seasons.

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 milliliters (mL) of water, with 10% or less of samples containing a maximum of 400 CFU/100 mL (Health Canada, 2012).

2.3 Water Quality Procedures

2.3.1 Field pH

A handheld pH meter (YSI Professional Plus) was used for all sampling to test the pH in the field. The meter was standardized prior to testing by the manufacturing company. The probe was immersed in the creek until the value on the pH meter stabilized. This procedure was repeated at each sampling site.

2.3.2 Dissolved Oxygen

Dissolved Oxygen (DO) was measured in the field using a handheld meter (YSI Professional Plus) for all sampling. The meter was calibrated every day it was used. DO was measured by immersing the probe in the creek and until the reading stabilized.

2.3.3 Salinity

Salinity was measured in the field using a handheld meter (YSI Professional Plus) for all sampling. The probe was calibrated by the manufacturing company before use. The probe was immersed in the creek until specific conductivity and salinity readings stabilized.

2.3.4 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 10 beakers in 8 mL aliquots.

The beakers were swirled for proper mixing and left for 10-30 minutes to allow color development (Figure 2.3.4). The absorbance and transmittance were recorded for all 10 beakers. The absorbance and standard concentrations were plotted with Microsoft Excel to generate a calibration curve (Appendix B). With this curve, the absorbance values recorded from the water samples were converted into concentrations in mg/L following equations provided in Appendix A.

Figure 2.3.A: *Photograph showing the colour development of standards for the orthophosphate calibration curve.*

2.3.5 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 was placed in an aluminum weigh dish and into an oven at 105 degrees Celsius for one hour. The filter and aluminum weigh dish were removed from the oven and cooled to room temperature in a desiccator. The weight was measured and recorded and 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. If the weights were within ± 0.0003 g, the filter was considered to have reached a constant weight. A 100 mL water sample was slowly poured onto the pre-weighed filter, and the apparatus was rinsed three times with deionized water to ensure the entire sample had passed through the filter and none remained on the apparatus (Figure 2.3.B). Once filtration was complete, the previous constant weight procedure was followed, and values recorded. TSS in mg/L was calculated based on the difference in weight (equation can be found in Appendix A) and results were recorded.

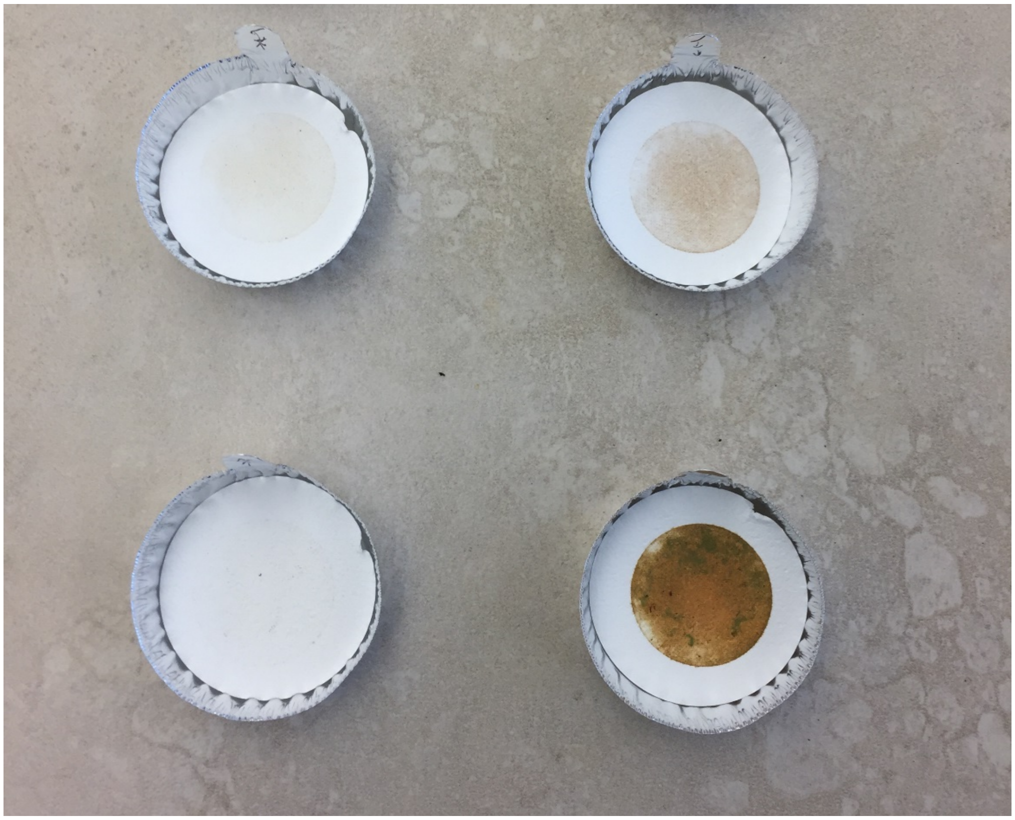

Figure 2.3.B: *Image showing the solids left on the filter paper after filtration was completed using the total suspended solids procedure.*

2.3.6 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 2.3.C). 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 particular plate, the number of CFU/100 mL of water were calculated and recorded (equations can be found in Appendix A).

All of the sample sites were diluted to 1/10, 1/100, 1/1000, and 1/10000 for the first and second weeks. For the third week all samples were diluted to 1/10, 1/100, and 1/1000, and a 10ml sample was analyzed due to the low fecal coliform count from the first 2 weeks. For the remaining weeks all sample were diluted to 1/10 and 1/100, and a 10mL sample was analyzed for all sites except Spar Cove. The Spar Cove sample was diluted to 1/10, 1/100 and 1/1000 due to increased fecal counts.

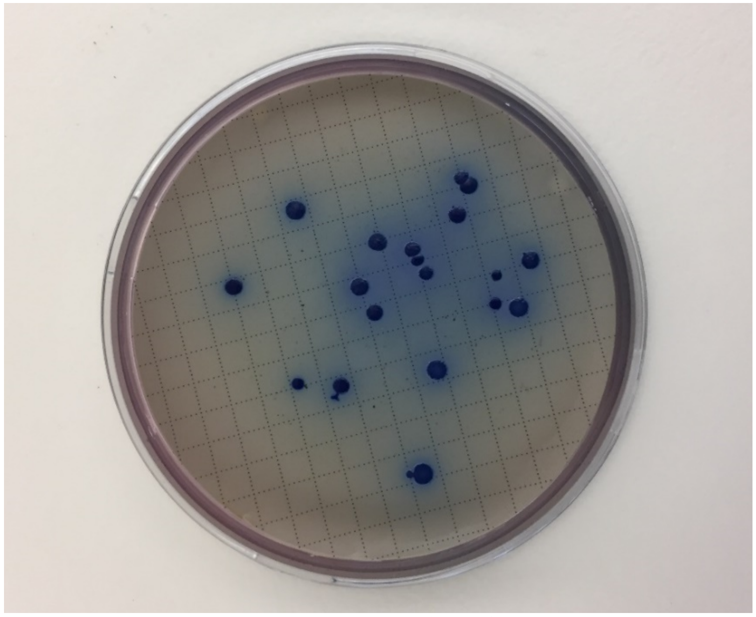

Figure 2.3.C: *Image showing the coliform forming units (CFU) per 100 mL water sample taken from Hazen Creek, site 7.*

2.3.7 Ammonia

A blank was prepared by pipetting 50.00 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, 25.00 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.

A calibration curve (Appendix B) was constructed to represent the ammonia concentration in mg/L using the equation found in Appendix A. 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 1.00 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, 25.00 mL of 10.00 mg/L NH_3N solution was then diluted in 250 mL of deionized water volumetrically to prepare 1.0 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 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 2.3.D). Absorbance versus Ammonia concentration was plotted to make a straight line passing through the origin.

Figure 2.3.D: *Photograph showing the colour development of standards for the Ammonia calibration curve.*

2.4 Sampling of Fish

2.4.1 Electrofishing

Electrofishing was conducted at numerous locations throughout the season as presence/absence surveys. Salmon Creek and Patterson's Brook were both surveyed on June 1, and Caledonia Brook and the headwaters of Newman's Brook were both surveyed on July 24. Downstream of Newman's Brook (near Hazen White-St. Francis School) was electrofished on July 26 and Taylor Brook was also surveyed on August 9. A fish rescue was conducted on October 20 prior to a culvert removal downstream of Newman's Brook near the school which required using the electrofisher and barrier nets.

Electrofishing activities were conducted using a battery-powered Smith-Root LR-24 electrofisher. The certified operators were Graeme Stewart-Robertson or 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 when necessary. The operation time and setting were noted upon completion of each site. Dip nets were used to capture fish which were then transferred into a 5-gallon bucket of water 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.

2.4.2 Fyke nets

Two fyke nets were used to collect fish in the lower reaches of Marsh Creek on June 14-16, June 28-30, July 18-20, July 31-August 2 and September 13-15. On each occasion, one net was set in the riverine section located approximately 250 m upstream of the tide gates located within the Courtenay Forebay and the second net was set in the Marsh Creek channel in the Courtenay Bay 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. Tide heights were closely monitored to prevent the nets from becoming completely emergent during any period to maintain the submergence of any trapped fish within the holding end.

Both fyke nets were also placed in Red Head Marsh on August 2-3, where one net faced the marsh side and the other faced the open Bay.

Fish were removed from nets, placed in a 5-gallon pail of water, 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.

2.4.3 Beach Seine

On October 19 three beach seine hauls were conducted at Red Head Marsh as part of a high school class demonstration using a 10 x 1.5 m seine. Fish and other species that were caught within the seine were placed in a 5-gallon pail of water, identified, measured and immediately returned to their environment. All fish mortalities and any other observations were recorded at each haul.

2.4.3 Reporting of Fish Collected

The lengths of all fish recorded herein were measured as total lengths to the nearest millimeter. The common names of fishes mentioned in this report can be referenced to their scientific names found in Appendix C.

2.5 Other Observations

ACAP Saint John instructed its staff to be vigilant in observing any other parameters that could influence the current or future integrity of the aquatic ecosystem. While these other parameters were not measured during this project, they were documented and included in this report due to their relevance to the long-term management objectives of the Marsh Creek watershed, a principle upon which this project was founded.

3.0 RESULTS AND DISCUSSION

In the following sections, the water quality and fish communities monitoring data are presented, and key highlights are explored. The raw water quality data collected in the 2017 field season can be found in Appendix D. All historic or previous monitoring data can be found in past water quality reports on the ACAP Saint John website (www.acapsj.org) or by contacting the ACAP Saint John office.

3.1 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 stopped.

3.1.1 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 seven times over the summer field season for all field parameters and five times for lab parameters. To compare the data collected this year to the previous dataset, an average of the sampling parameters over the timepoints was determined and can be found in Table 3.1.1A and the corresponding standard deviations in Table 3.1.1.B.

***Table 3.1.1.A**: Calculated averages of water quality parameters measured for Marsh Creek Analysis A (upstream/downstream) from the 2017 field season.*

Site	Temp (°C)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
Upstream	15.0	7.42	9.85	0.07	350	1.6	0.096	0.001	0.067
Downstream	18.0	7.83	10.16	2.39	551	6.6	0.058	0.004	0.048

***Table 3.1.1.B**: Standard deviations for calculated averages of water quality parameters measured for Marsh Creek Analysis A (upstream/downstream) from the 2017 field season.*

Site	Temp (°C)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
Upstream	1.62	0.18	1.75	0.015	248	1.52	0.073	0.002	0.097
Downstream	2.62	0.38	2.77	2.025	333	3.29	0.032	0.004	0.019

Historically, the upstream and downstream sites were very different with the upstream site representing an area without sewer outfalls and the downstream site being within the contaminated section. This year, the difference between these two sites, on average, was hardly noticeable and in some cases the downstream site was in better condition than upstream in terms of water quality (Table 3.1.1.A).

In particular, the dissolved oxygen concentration was higher downstream (10.16 mg/L) than upstream (9.85 mg/L) this year and both sites surpassed the Canadian Council of the Minister of the Environment (CCME) Protection of Aquatic Life guideline concentration of 9.5 mg/L for early life stages (Canadian Council of Ministers of the Environment, 2017). Since the completion of Harbour Cleanup, the dissolved oxygen concentrations at the downstream site has steadily increased due to the decrease in bacteria loading resulting in less oxygen being used by the bacteria (Figure 3.1.1.A). The increase in dissolved oxygen implies that the whole watercourse is now capable of supporting fish life if the other habitat requirements are in-place.

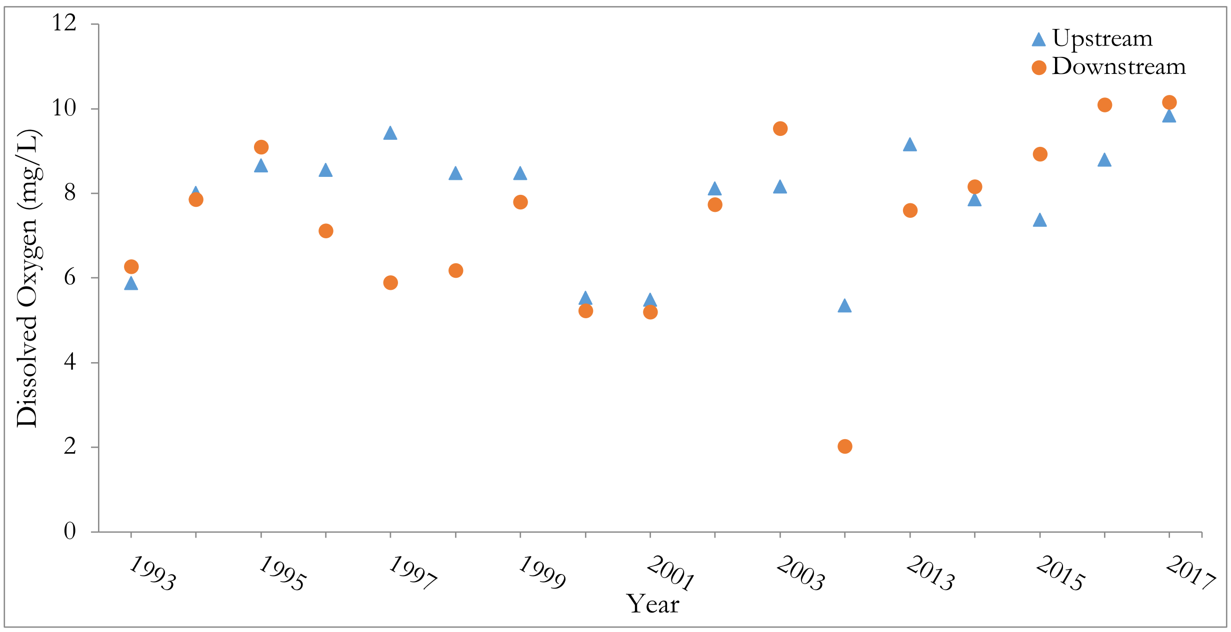

***Figure 3.1.1.A**: Dissolved oxygen (mg/L) measured in Marsh Creek upstream and downstream sample stations from 1993 to 2017. Values were not obtained in 2008, 2009, 2010, 2011 and 2012.*

The Phosphate concentrations were lower on average at the downstream site compared to the upstream site (Table 3.1.1.A) for the first time since sampling at these sites began in 2002. Overtime however, the average Phosphate concentration this year appears to have increased slightly (Figure 3.1.1.B). The increase at these sites could be due to increase stormwater and over-land runoff washing nutrients into the system especially at the upstream site which has been trending upward 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.

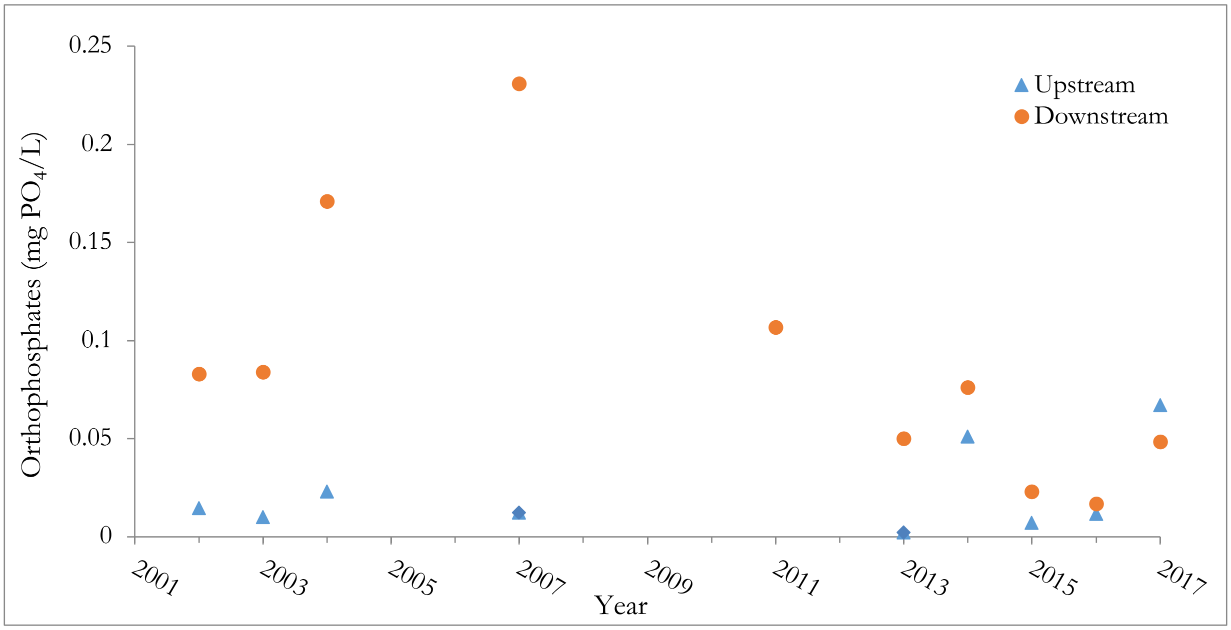

***Figure 3.1.1.B**: Orthophosphates (mg PO_4/L) measured in Marsh Creek upstream and downstream sample stations from 2002-2017. A value was not obtained for only the upstream site in the 2011 sampling year and values were not obtained in years 2005, 2006, 2008, 2009, 2010 and 2012 for both upstream and downstream sites.*

In addition, Ammonia was added to the monitoring program again this year to evaluate the changes since Harbour Cleanup. Overall, the total Ammonia concentrations at both the upstream and downstream sites have remained, on average, consistent with pre-Harbour Cleanup values (Figure 3.1.1.C). Based on the historical data available, the total Ammonia concentrations fluctuated between elevated and normal concentrations prior to the cessation of dumping raw sewage into Marsh Creek. The data from this year's monitoring, on average, is between these historic values which likely indicates that the system is reaching an equilibrium. 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 Coucil 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, 0.09 and 0.06 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 Coucil of Ministers of the Environment, 2010).

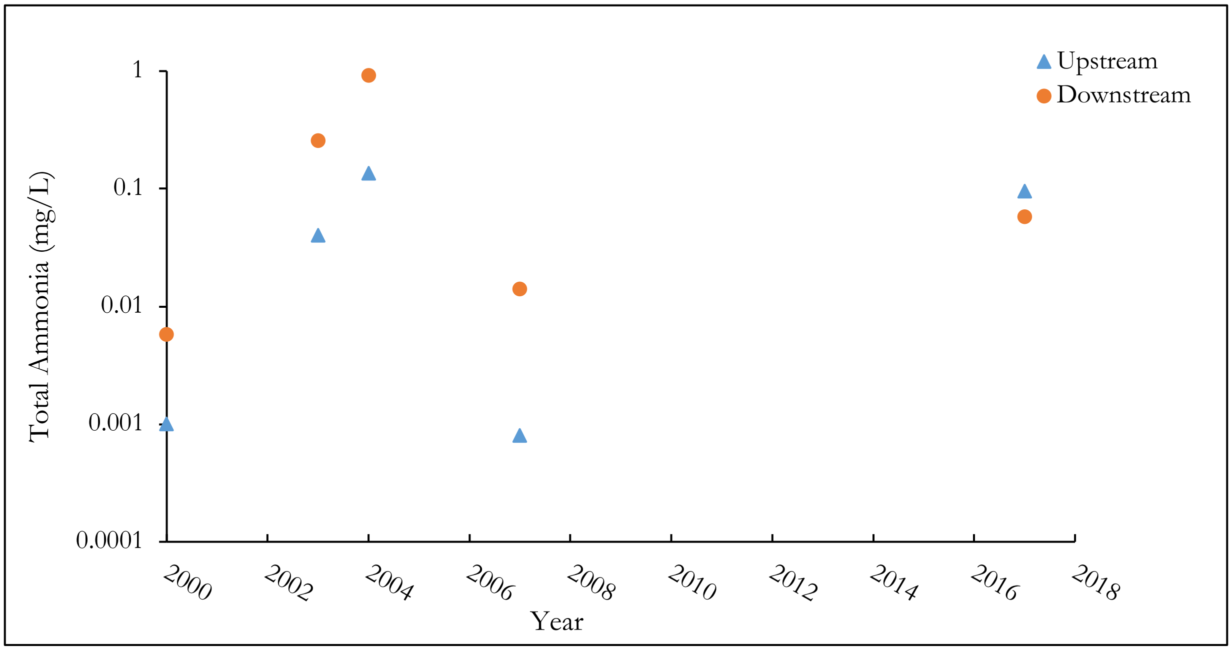

Figure 3.1.1.C: *Average total Ammonia (mg/L) concentrations measured in Marsh Creek upstream and downstream sample station in 2000, 2003, 2007, and 2017. Note that total Ammonia concentrations are plotted on log base 10 scale.*

The fecal coliform concentration at both upstream and downstream sites remain elevated when compared to the Health Canada guidelines. The average fecal coliform count was 551 CFU/100 mL at the downstream site and 350 CFU/100 mL at the upstream site. 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 from previous years due to the completion of Harbour Cleanup and the continued work to stop cross-connections and improve lift station functions (Figure 3.1.1.D).

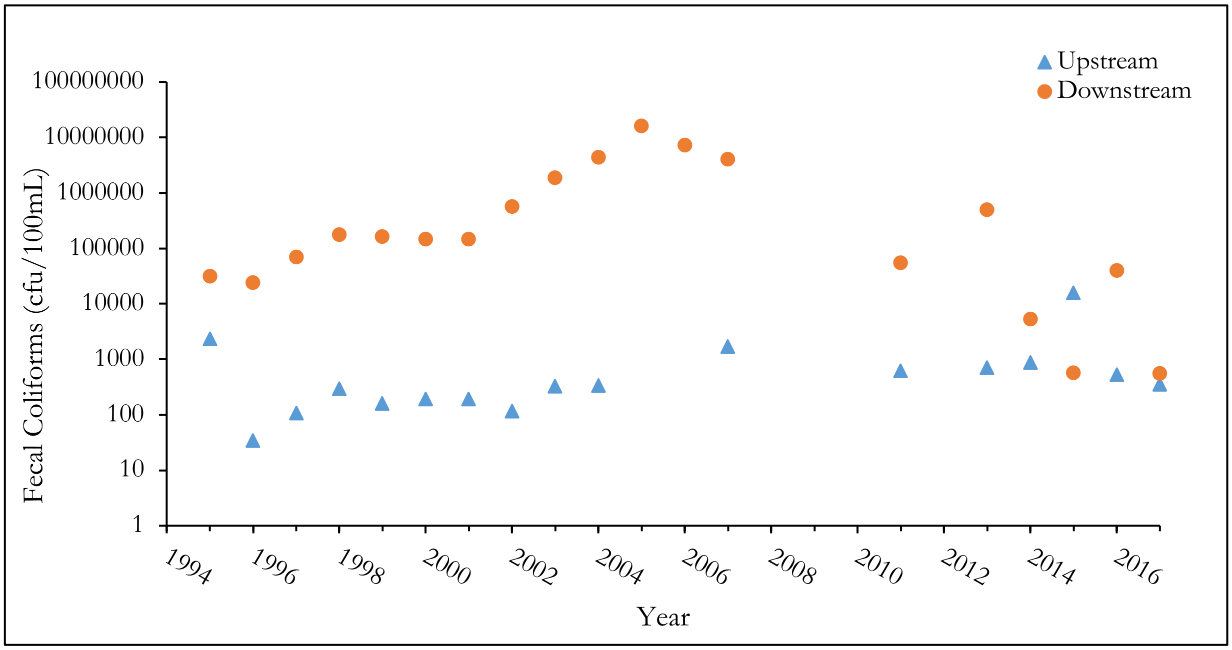

***Figure 3.1.1.D**: Fecal coliforms (CFU/100 mL sample) measured in Marsh Creek upstream and downstream sample stations from 1995 to 2017 and plotted on a log scale. Values were not obtained in 2008, 2009, 2010 and 2012.*

The total suspended solids results were 6.6 and 1.6 mg/L in the downstream and upstream site, respectively. The results for the upstream site are consistent with previous years where they were both found to follow the same trends (Figure 3.1.1.E). However, the downstream site showed that TSS concentration have increased from the two years downward trend. This increase may be due to increased erosion, stormwater inputs, or lift station overflows in the area; or alternatively, the low water levels experienced this summer may have caused sediment to be stirred up when filling the sampling bottles.

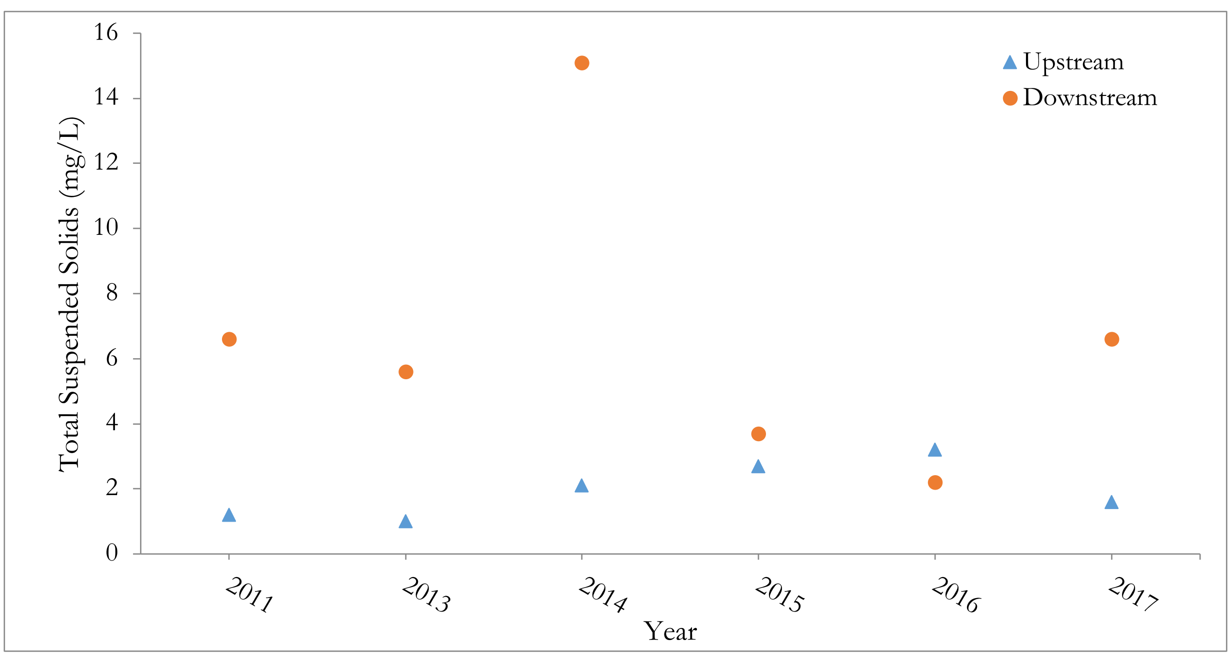

Figure 3.1.1.E: *Total suspended solids (mg/L) measured in Marsh Creek Upstream and Downstream sample stations from 2011-2017. Values were not obtained in the 2012 year.*

3.1.2 Analysis B Water Quality Parameters

Water samples were acquired in 2017 from seven sample periods all taking place around low tide, starting on May 30 and ending on August 14. 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 month of sampling. 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 3.1.2.A). 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 3.1.2.B).

Table 3.1.2.A: *Calculated averages of water quality parameters measured for Marsh Creek Analysis B from seven sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
1	16.0	7.80	9.90	15.88	383	12.4	0.097	0.004	0.042
2	18.1	7.87	10.56	4.38	1377	7.8	0.072	0.002	0.031
3	18.9	8.09	12.34	0.47	414	3.4	0.042	0.014	0.020
4	18.4	7.92	9.97	0.19	185	10.0	0.149	0.023	0.039
5	17.4	7.79	7.99	0.19	115	7.2	0.062	0.002	0.025
11	17.5	7.65	10.04	0.19	8853	1.4	2.064	0.070	0.134

Table 3.1.2.B: *Standard deviations for calculated averages of water quality parameters measured for Marsh Creek Analysis B from seven sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
1	2.87	0.14	1.42	3.96	356	2.97	0.029	0.000	0.017
2	2.52	0.36	2.71	2.67	1378	1.92	0.005	0.001	0.015
3	3.30	0.57	3.31	0.41	389	2.70	0.009	0.019	0.015
4	3.01	0.42	3.79	0.03	79	15.59	0.066	0.043	0.035
5	2.31	0.21	2.72	0.03	109	9.63	0.014	0.001	0.016
11	1.36	0.12	3.05	0.02	12851	2.07	1.462	0.062	0.121

Fecal coliform levels were plotted against the five sample stations for 2012 to 2017 (Figure 3.1.2.A). The average fecal coliform concentration for site 1 decreased from previous years with an average of 383 CFU/100 mL. Site 2 has a similar average to previous data starting after Harbour Cleanup at 1377 CFU/100 mL. The results from sites 3, 4, and 5 - 414, 815, and 115 CFU/100 mL respectively, revealed the lowest recorded average since monitoring began and site 5 fell below the CCME guideline of an average concentration of 200 CFU/100 mL. Overall, the fecal coliform concentration decreased at all five Lower Marsh Creek sites this field season; however, it must be noted that in 2015 and 2016 the average was calculated including rain days which is known to elevate the results with over-land flow and lift-station overflows increasing the bacteria load within the Marsh Creek system.

Site 11 had a significant increase from last year, going from an average of 3595 CFU/100mL to 8853 CFU/100 mL (Figure 3.1.2.A). The elevated levels of fecal coliforms 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.

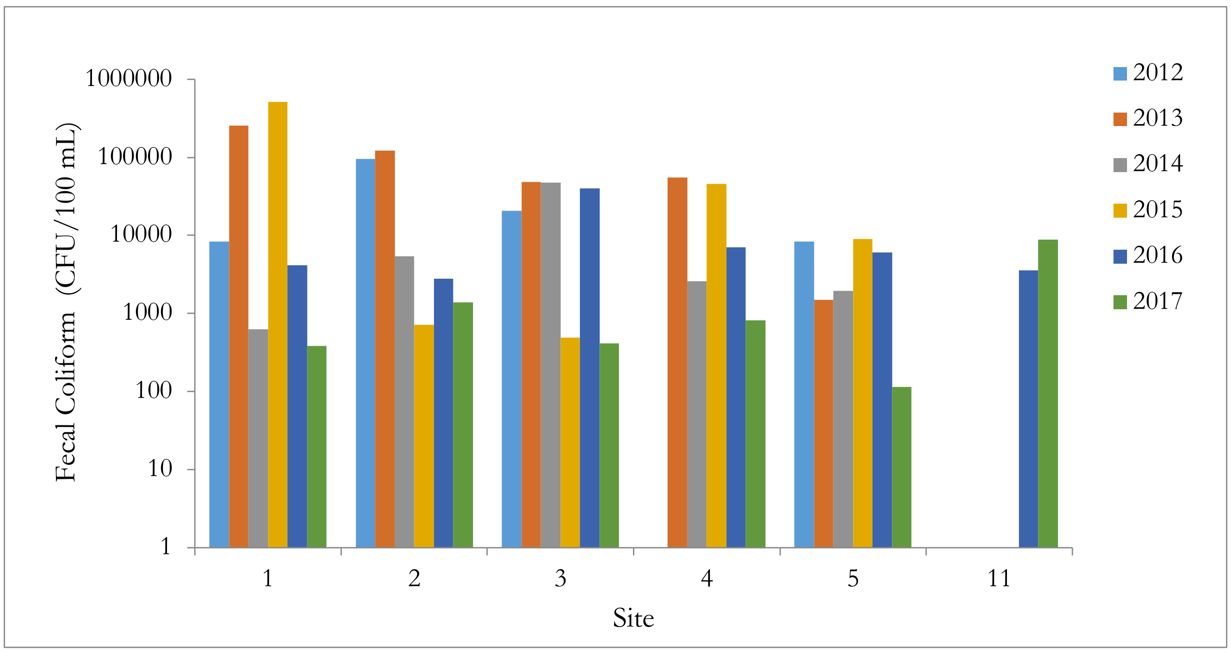

***Figure 3.1.2.A**: Fecal coliforms (CFU/100 mL) measured in five sites in Lower Marsh Creek from 2012 to 2017 and Medial Marsh Creek (site 11) from 2016 to 2017 and plotted on a logarithmic scale. The 2012 site 4 sample was discarded, and no data was acquired.*

The total suspended solids (TSS) concentration in recent years have become consistent with small variations from year to year due to rainfall amounts (Figure 3.1.2.B). The data from this year reveals a slight increase of TSS at most sites within Lower Marsh Creek and a slight decrease at site 11. The most notable increase was at site 4, which increased from 1.8 mg/L in 2016 to 10 mg/L this year. Two timepoints from site 4 this year were discarded due to a sampling error; therefore, it is possible that the remaining timepoints are not accurate as well and are misrepresenting the true value at this site. Due to the dry field season, water levels within Marsh Creek and most watercourses were very low; resulting in difficulty collecting water samples without disturbing the sediment. The water levels at site 4 were exceptionally low and resulted in two TSS samples having to be discarded when the substrate was disturbed while collecting the sample.

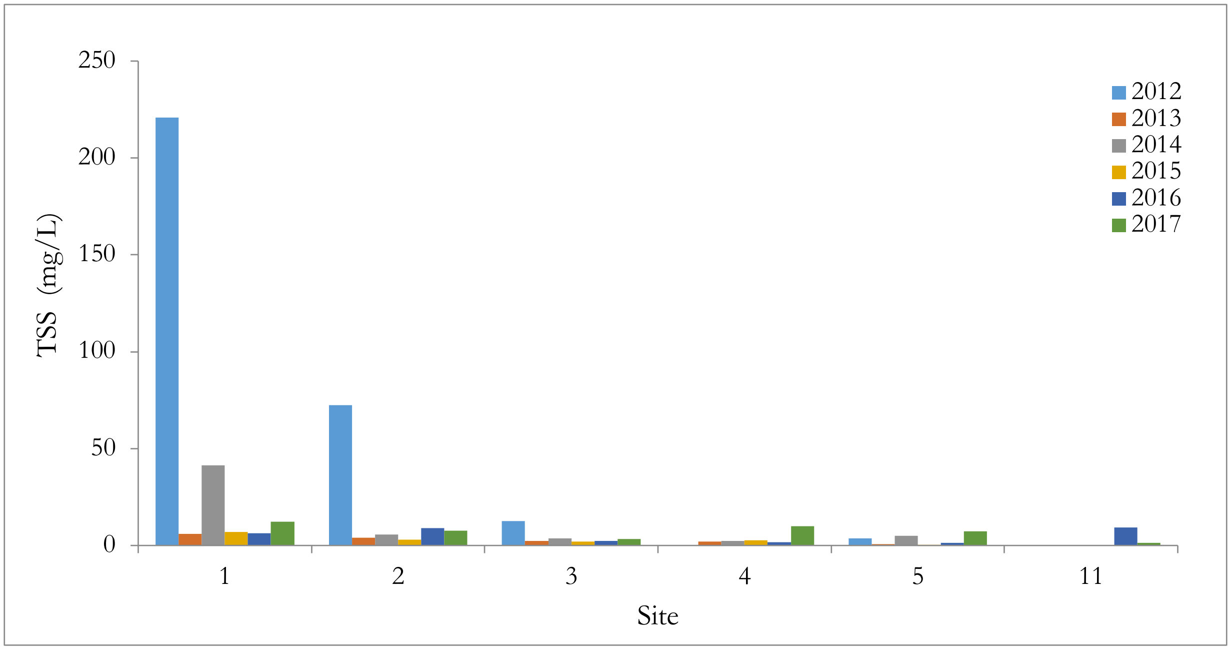

***Figure 3.1.2.B**: Total suspended solids (mg/L) measured in five sites in Lower Marsh Creek from 2012 to 2017 and one site (11) in Medial Marsh Creek from 2016 to 2017. The 2012 site 4 sample was discarded, and no data was acquired.*

The average Orthophosphate concentrations have decreased since the completion of Harbour Cleanup in 2014. This is due to the cessation of dumping raw sewage within Marsh Creek which also resulted in large nutrient loads no longer free-flowing into the watercourse (Figure 3.1.2.C). This year's results reveal that sites 1, 3, and 5 had minor increases from 2015 and 2016 results, and site 2 had a slight decrease from 2016. Sites 4 increased from 0.02 mg/L in 2016 to 0.04 mg/L this year, however, the sampling error for TSS would have also corresponded to an increase in Orthophosphate and as such the same two timepoints were removed and the remaining timepoints may have been impacted by a sampling error that were less obvious and not removed.

The Orthophosphate concentration at site 11 (0.134 mg/L) was highly elevated when compared to the 2016 data (0.03 mg/L). This increase is likely attributed to the increase in sewage present at this site as shown by the high concentration of fecal coliforms noted previously. 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 on a localized scale.

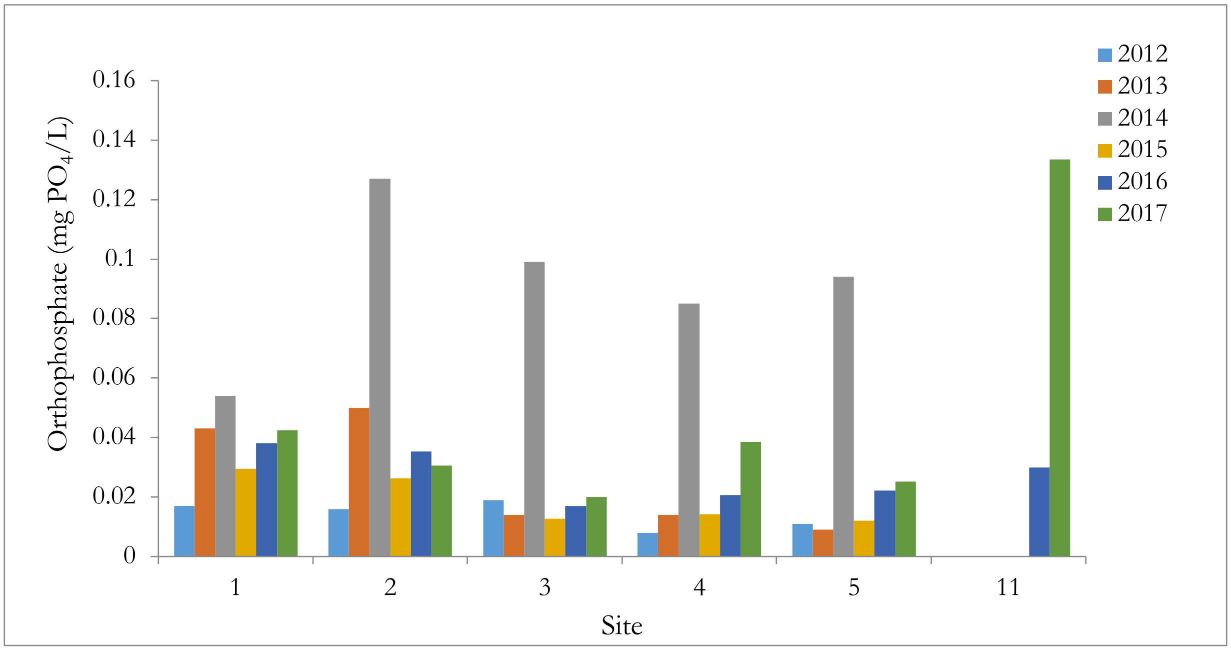

***Figure 3.1.2.C**: Orthophosphates (mg PO_4/L) measured in five sites in Lower Marsh Creek from 2012 to 2017 and one site (11) in Medial Marsh Creek from 2016 to 2017.*

The dissolved oxygen concentration at all six sites in the Marsh Creek system increased from previous years and ranged from 7.99 to 12.34 mg/L (Figure 3.1.2.F). For the first time since the water quality monitoring began at the five Lower Marsh Creek sites, all sites surpassed the 6.5 mg/L CCME guideline for the Protection of Aquatic Life for other life stages and four of the sites surpassed the 9.5 guideline for early life stages (Canadian Council of Ministers of the Environment, 2017). The rebound in dissolved oxygen allows the lower reach of the watercourse to be capable of supporting aquatic life, which prior to Harbour Cleanup, was not possible in some locations.

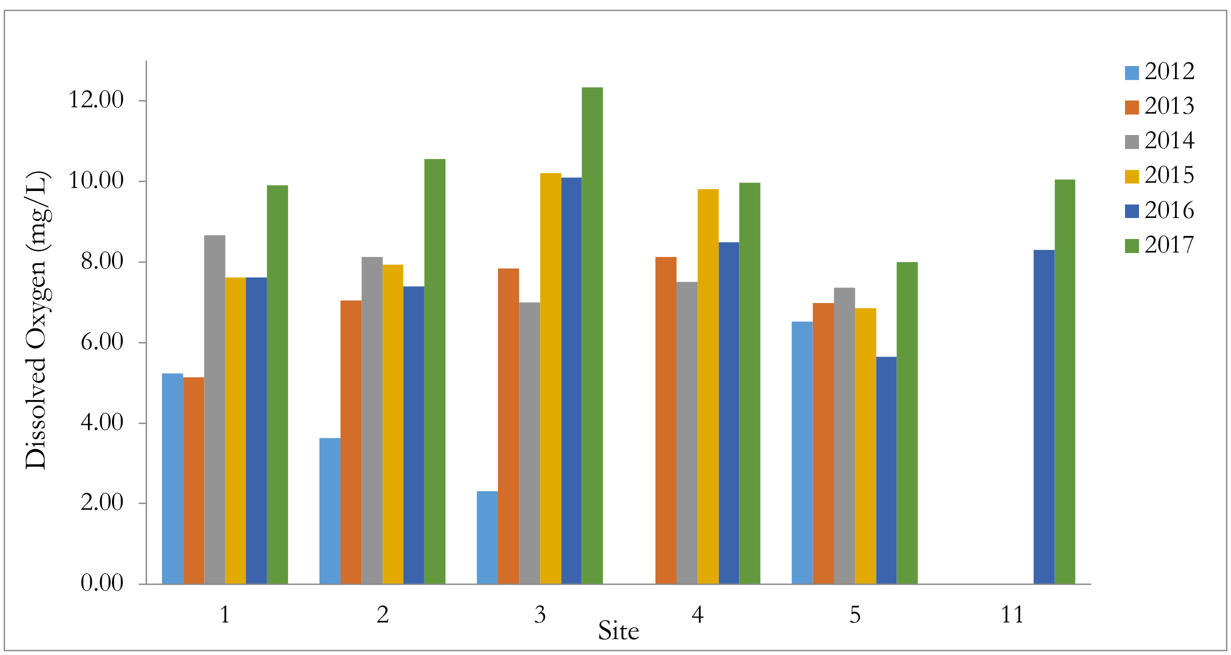

Figure 3.1.2.F: Dissolved oxygen (mg/L) measured in five sites in Lower Marsh Creek from 2012 to 2017 and one site in Medial Marsh Creek from 2016 to 2017.

Total Ammonia was tested for the first time at the six sites in Analysis B this year. As stated previously, the concentration of total Ammonia in freshwater is generally less than 0.1 mg/L (Canadian Coucil of Ministers of the Environment, 2010). For the most part, the five Lower Marsh Creek sites fell below this threshold on average apart from site 4 which fell just above with concentrations of 0.1, 0.07, 0.04, 0.15, and 0.06 mg/L respectively (Figure 3.1.2.G). Site 11 however, was way above the recommendation with an average of 2.06 mg/L. Similar to the increase in Orthophosphate concentration, the increase in total Ammonia is likely caused by increased sewage inputs in the general vicinity of this site.

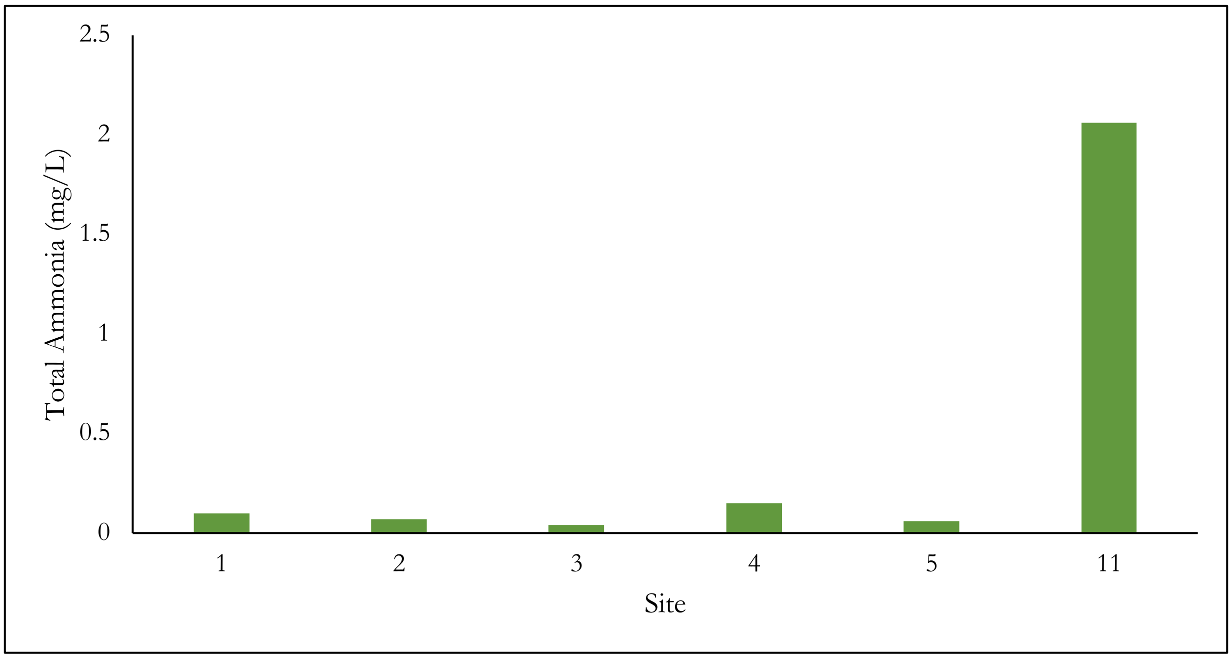

Figure 3.1.2.G: *Average total Ammonia (mg/L) measured in five sites in Lower Marsh Creek and one site in Medial Marsh Creek from the 2017 field season.*

3.1.3 Fish Communities Monitoring

Fish communities were monitored in two locations within the Marsh Creek watershed using two Fyke nets. A total of 147 fish comprised of 10 different species were collected from ten different hauls between June 15 to September 15. Fyke nets were set and checked each day at low tide. Since the nets were checked at low tide, the average temperature was higher than normal, where temperatures were expected to decrease as the tide came in.

The fyke net catch in the upstream site (Courtenay Forebay above the tide gates) contained 24 fish of six species: seven Four-spined stickleback (29.17%), seven Nine-spined stickleback (29.17%), six Pumpkinseed sunfish (25.00%), two Mummichog (8.33%), one American eel (4.17%) and one Atlantic tomcod (4.17%) (Table 3.1.3.A). During the different hauls, the Forebay had a temperature range of 16.6-28.2°C. There was one Mummichog found dead in the net over the entire sampling period. This field season represents the first documented Atlantic tomcod within the Forebay further supporting that since Harbour Cleanup Marsh Creek has rebounded to be able to support a diversity of aquatic life. It is unknown how the tomcod managed to make it past the tide gates, but it is believed that it would have been able to pass through the gates during a high tide corresponding with a large rain event when the gates may have remained slightly open or one of the gates may have been jammed open with debris during a high tide.

Table 3.1.3.A: *Fish species composition caught in Fyke nets in the Courtenay Forbay between June 15 and September 15, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
Pumpkinseed sunfish	6	25	92-100
Atlantic tomcod	1	4	170
American eel	1	4	600
Mummichog	2	8	85-109
Four-spined stickleback	7	29	35-60
Nine-spined stickleback	7	29	30

The downstream fyke net site (Courtenay Bay below the tide gates) resulted in the capture of 123 fish of six different species and was dominated by Atlantic tomcod at 62.60% (Table 3.1.3.B). Rainbow smelt was the second most-frequently captured fish (34.15%), and the remaining species were American eel (0.82%), Winter flounder (0.81%), Brown trout (0.81%) and White hake (0.81%). During the different hauls, the Bay had a temperature range of 14.3-23.6°C. In total, four fish (one Brown trout, one Atlantic tomcod and two Rainbow smelt) were found dead in the nets over the sampling period, either due to European Green crab predation or caught in the netting.

Table 3.1.3.B: *Fish species composition caught in Fyke nets in the Courtenay Bay between June 17 and September 15, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
Atlantic tomcod	77	63	115-247
Rainbow smelt	42	34	123-185
American eel	1	1	700
White flounder	1	1	110
White hake	1	1	126
Brown trout	1	1	197

Both the Courtenay Bay and Forebay fyke nets had a number of bycatch. The majority of the bycatch that was found was the European Green crab (*Carcinus maenas*), with 27 in the Forebay and 28 in the Bay. There were also two Sand shrimp (*Crangon septemspinosa*) caught in the fyke nets in the Forebay on June 30, 2017.

3.2 Hazen Creek Watershed

3.2.1 Water Quality Monitoring

The water quality of Hazen Creek was determined through monitoring a downstream site (site 6) and an upstream site (site 7) over six timepoints in the 2017 field season. The average from that sampling can be found in Table 3.2.3.A and the standard deviation in Table 3.2.3.B.

Table 3.2.1.A: *Calculated averages of water quality parameters measured for Hazen Creek from six sample periods in 2017****.***

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
6	17.9	7.71	10.83	4.46	498	5.0	0.061	0.007	0.018
7	14.1	7.81	9.99	0.15	33	0.2	0.037	0.001	0.011

Table 3.2.3.B: *Standard deviations for calculated averages of water quality parameters measured for Hazen Creek from six sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
6	4.71	0.49	2.45	3.50	560	3.74	0.031	0.006	0.010
7	3.36	0.15	0.65	0.07	9	0.45	0.014	0.001	0.010

The average temperature of the two sites were well below and temperature of concern for fish species (Table 3.2.3.A). The average upstream temperature was slightly lower than the downstream site, 14.1 and 17.9 ℃ 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, above the 9.5 mg/L recommended guideline from CCME with an average of 10.83 and 9.99 mg/L respectively (Table 3.2.3.A).

The fecal coliform concentration varied substantially over the 2017 field season at the downstream site (Figure 3.2.3.A). Two of the four timepoints were well above the guideline limits for fecal coliforms with concentrations of 1100 and 850 CFU/100 mL; the other two timepoints were much lower with 20 and 19 CFU/100 mL. This variation resulted in an average of 498 CFU/100 mL and is well above the guideline of 200 CFU/100 mL (Health Canada, 2012). The upstream site on the other hand, was quite stable over the four timepoints and was well below the Health Canada guideline with a concentration of 33 CFU/100 mL on average. 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.

For both sites, the 2017 data reveals an overall decrease in fecal coliform concentration from previous data collected in 2016 which had an average of 1566 and 765 CFU/100 mL for the downstream and upstream sites respectively. The overall decrease may be due to the extremely dry summer resulting in few rain events that may trigger overland flow and wastewater treatment issues.

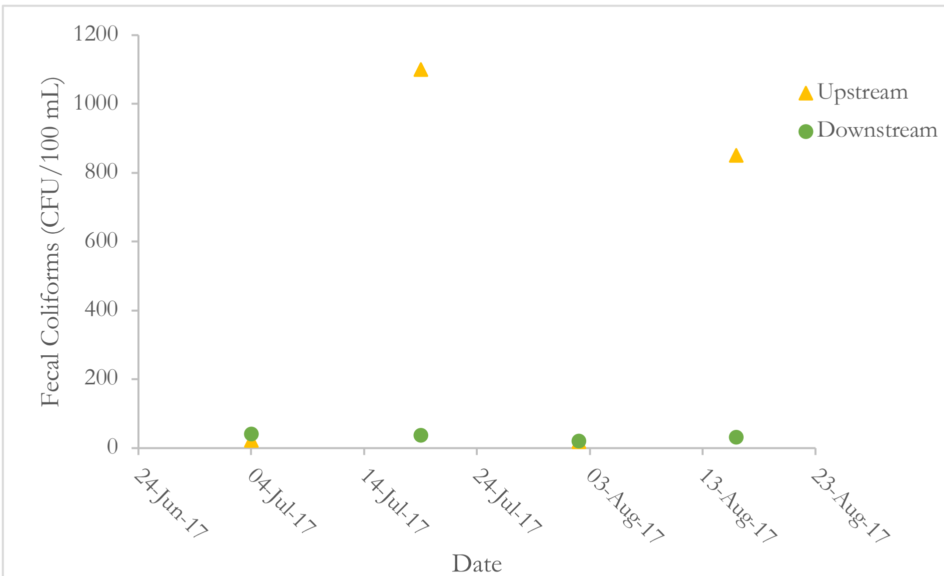

Figure 3.2.3.A: *Fecal coliform concentration from an upstream (site 7) and downstream (site 6) sites with Hazen Creek from the 2017 field season.*

3.2.2 Fish Community Monitoring

On August 2 the Fyke nets were placed in Red Head Marsh and were retrieved the following day on August 3. One net was set to face the marsh itself, and the other net was set to face the bay. The temperature of the marsh when the nets were checked was 24°C. When they were retrieved, the net facing the marsh was filled with lots of debris, such as feathers, drift wood and seaweed. It was also found to have five European Green crabs. The net that was facing the bay was empty of debris and fish, but one European Green crab was collected out of the net.

Additionally, ACAP Saint John facilitated a high school marine biology field trip within the Red Head Marsh on October 19th. As part of this trip, three beach seines were completed at the downstream site. In total, 6 Mummichogs, ranging from 32-68 mm, and 24 Rainbow smelt ranging from 55-125 mm were caught.

3.3 Taylor Brook Watershed

3.3.1 Water Quality Monitoring

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). The average from this monitoring can be found in Table 3.3.1.A and the standard deviation in Table 3.3.1.B.

***Table 3.3.1.A**: Calculated averages of water quality parameters measured for Taylor Brook from seven sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
8	18.4	7.95	9.24	0.09	23	0.0	0.024	0.001	0.005
9	20.4	7.71	8.17	0.10	106	1.0	0.038	0.002	0.007
10	18.1	7.84	9.29	0.11	54	0.3	0.020	0.001	0.005

***Table 3.3.1.B**: Standard deviations for calculated averages of water quality parameters measured for Taylor Brook from seven sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
8	1.7	0.13	0.82	0.01	15	0.00	0.003	0.0004	0.005
9	2.3	0.17	1.35	0.01	48	1.41	0.013	0.0004	0.006
10	1.8	0.14	0.84	0.02	18	0.50	0.001	0.0003	0.005

Overall, the water quality within the Taylor Brook watershed is of good enough quality to support aquatic life and recreational activities. The water temperature, on average, was mostly below 20℃ and thus, well within acceptable limits for Salmonid species. The dissolved oxygen concentration was well above the lower limit of 6.5 mg/L and 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). Additionally, the fecal coliform concentration, on average, was well below the recreational limit of 200 CFU/100 mL with averages of 23, 106, and 54 for the three sites respectively (Health Canada, 2012). 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 data from the 2017 field season is very similar to the data collected during the 2016 field season indicating that the watershed is in stable conditions. The only parameter measured that varied slightly was fecal coliform concentration with an average concentration of 870, 1322, and 860 respectively in the 2016 season. In the 2016 field season, a large rainfall event was captured in the sampling which elevated the fecal coliform concentration; however, this year no similar event transpired, resulting in a lower average fecal coliform concentration compared to last year.

3.3.2 Fish Community Monitoring

Electrofishing was conducted in a small reach of Taylor Brook on August 9th upstream of the train bridge to just upstream of the Rothesay Road bridge (downstream water quality monitoring site). The electrofisher was set to 60 Hz, 25% 100 V and ran for 668 seconds. A variety of fish species were caught, with the majority of them being White sucker. A total of 74 individual fish were caught within the small section of the brook (Table 3.3.2.A). The brook had a temperature of 19°C and there were zero fish mortalities while electrofishing. The diverse array of fish species and sizes further supports the overall water quality monitoring to indicate that the Taylor Brook watershed has great aquatic habitat.

Table 3.3.2.A: *Fish species composition caught by electrofishing a small reach of Taylor Brook on August 9, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
White sucker	34	46	22-290
Brook trout	15	20	120-195
Blacknose dace	8	11	38-71
Creek chub	8	11	41-120
American eel	8	11	60-400
Nine-spined stickleback	1	1	36

3.4 Newman's Brook Watershed

3.4.1 Water Quality Monitoring

The Newman's Brook watershed was monitored at two locations for water quality parameters – upstream (site 12) and downstream [Spar Cove] (site 13). The averages generated from the 2017 field season can be found in Table 3.4.1.A and the standard deviation in Table 3.1.4.B.

Table 3.4.1.A*: Calculated averages of water quality parameters measured for Newman's Brook from six sample periods in 2017****.***

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
12	17.3	8.08	8.93	0.18	87	0.6	0.021	0.002	0.018
13	16.0	7.20	4.56	8.83	203	41.0	0.717	0.012	0.067

Table 3.4.1.B*: Standard deviations for calculated averages of water quality parameters measured for Newman's Brook from six sample periods in 2017.*

Site		pH					Ammonia	

	Temp (℃)		DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Total Ammonia (mg/L)	Free Ammonia (mg/L)	Total Phosphates (mg/L)
12	4.56	0.13	1.35	0.05	84	0.89	0.009	0.0007	0.014
13	4.16	0.21	2.00	5.88	104	44.20	0.095	0.0016	0.039

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, which is now Newman's Brook, and thus has unnatural inputs from storm drains throughout the North End. The quality at this site would likely not support any fish communities due to very low dissolved oxygen concentrations and the network of piping would not provide appropriate aquatic habitat (Figure 3.4.1.A). The Canadian Council of Ministers of the Environment (CCME) states that cold water species require dissolved oxygen concentrations above 6.5 mg/L (Canadian Council of Ministers of the Environment, 2017). The upstream site never fell below this limit and even exceeded the 9.5 mg/L recommendation for early life stages. The downstream site, however only exceeded the lower limit once over the entire field season.

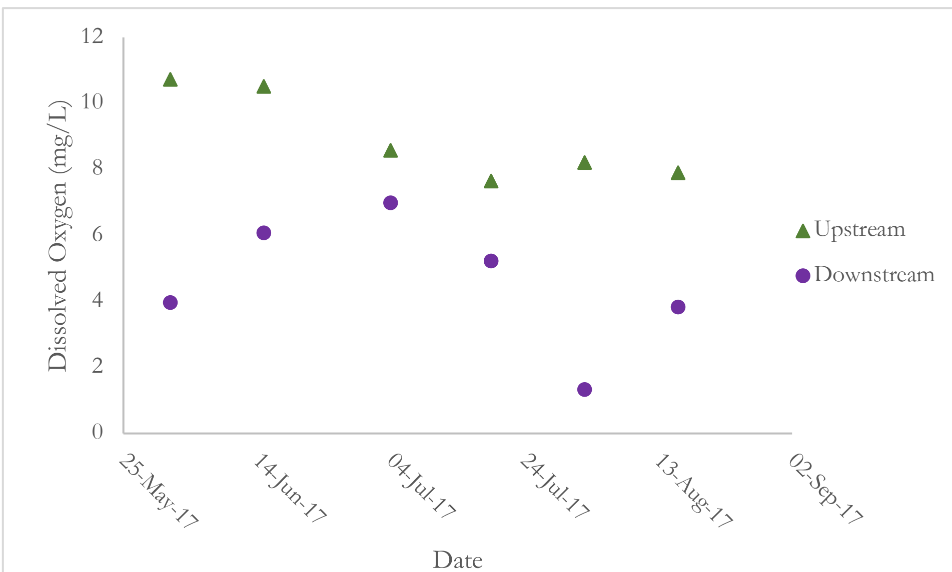

Figure 3.4.1.A: *Dissolved oxygen concentrations from both the upstream (site 12) and downstream (site 13) stations within Newman's Brook watershed.*

Additionally, the total suspended solids (TSS) concentrations at the downstream site is quite elevated when compared to the upstream site – on average 0.6 mg/L at the upstream site and 41.0 mg/L at the downstream site (Figure 3.4.1.B). 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. However, the fecal coliform concentration from this year (203 CFU/100 mL on average) was substantially lower compared to last years' average (651,400 CFU/100 mL) indicating vast improvements to the output of this watershed.

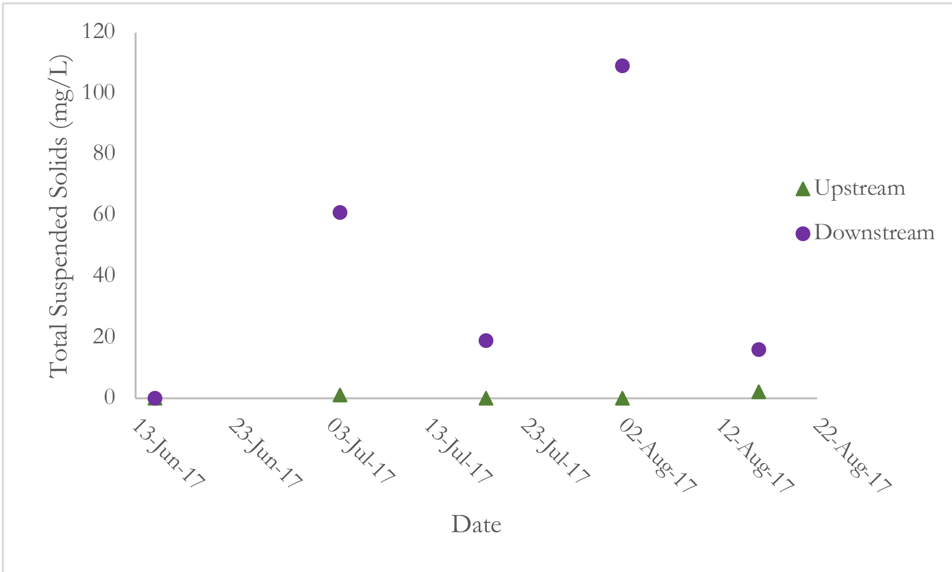

***Figure 3.4.1.B**: Total suspended solids (TSS) concentrations from both the upstream (site 12) and downstream (site 13) stations within the Newman's Brook watershed.*

3.4.2 Fish Community Monitoring

Fish communities were monitored in three different sections within the upper portion of the Newman's Brook watershed to determine if these reaches support aquatic life. Through electrofishing activities, it was determined that both Brook trout and Blacknose dace are found throughout this section. Although fish were found in the area, there are many habitat improvements that could be done to better the aquatic habitat within this watershed.

A presence survey was conducted at Patterson's Brook (tributary of Newman's Brook) next to Peacocks Lane on June 1, 2017. The electrofisher was set 30 Hz, 12 %, 230 V and ran for 1053 seconds. There was a total of 39 fish caught along this reach, representing two fish species, Brook trout and Eastern Blacknose dace (Table 3.4.2.A). In addition to the fish that were found, two salamanders were also found in the brook. The water temperature was found to be 12.2°C and there were zero fish mortalities.

***Table 3.4.2.A:** Fish species composition as a result of electrofishing in Patterson's Brook on June 1, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
Brook trout	25	64	32-150
Blacknose dace	14	36	28-63

On July 24th a presence survey was conducted beginning near the outflow of Howe's Lake to confluence of Patterson's Brook. The electrofisher was set to 30 Hz, 12 %, 150 V and ran for a total of 1818 seconds. A total of 20 Brook trout were found ranging from 45-143 mm in length. The brook had a temperature of 20.4°C and there were zero fish mortalities.

A presence survey was also conducted in the downstream portion of Newman's Brook along Sandy Point Road on July 26. The electrofisher was set to 30 Hz, 12 %, 220 V and ran for 521 seconds. A total of 14 fish were caught, with the majority of them being Brook trout (Table 3.4.2.B). The brook had a temperature of 20.8°C and there were two fish mortalities while electrofishing (one Blacknose dace and one Brook trout).

Table 3.4.2.B: *Fish species composition as a result of electrofishing in the lower reach of Newman's Brook on July 26, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
Brook trout	10	71	56-175
Blacknose dace	3	22	66-83
Northern Redbelly Dace	1	7	55

3.5 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 2017 assessments can be found in Table 3.5.A and the standard deviation in Table 3.5.B.

Table 3.5.A*: Calculated averages of water quality parameters measured for Inner Harbour from six sample periods in 2017****.***

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
14	17.5	7.85	9.25	8.40	205	6.6	0.020	0.001	0.010
15	13.1	7.98	9.76	21.21	10	21.4	0.028	0.001	0.031

Table 3.5.B*: Standard deviations for calculated averages of water quality parameters measured for Inner Harbour from six sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
14	2.83	0.26	0.57	5.55	87	2.19	0.010	0.009	0.018
15	1.93	0.11	0.33	5.42	5	6.23	0.011	0.001	0.016

Overall, both the upstream and downstream sites were categorized as having good water quality. The average water temperatures were quite low, 17.5℃ and 13.1℃ respectively, due to the tidal action bringing in cool ocean water (Table 3.5.A). These lower water temperatures over the summer season would result in great fish habitat for species that cannot tolerate high water temperatures that would be present further upstream but can also tolerate changing salinity concentrations (brackish waters). The dissolved oxygen concentrations were also higher than most of the freshwater upstream sites monitored this field season. The average dissolved oxygen concentration at the upstream site was 9.25 mg/L and the downstream site was 9.76 mg/L; providing great aquatic habitat for many aquatic species.

Additionally, both Ammonia and Phosphate concentrations were well within acceptable limits for the area and would likely pose no threat to aquatic life (Table 3.5.A). Due to advances in methodology and equipment, the Phosphate concentrations cannot be directly compared to the historic data; however, it appears the total Phosphate concentrations remains 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; however, it is likely that variation between historical data and this years' 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 3.5.A). The average concentrations this year, 0.010 and 0.011 mg/L respectively, is consistent with previous monitoring.

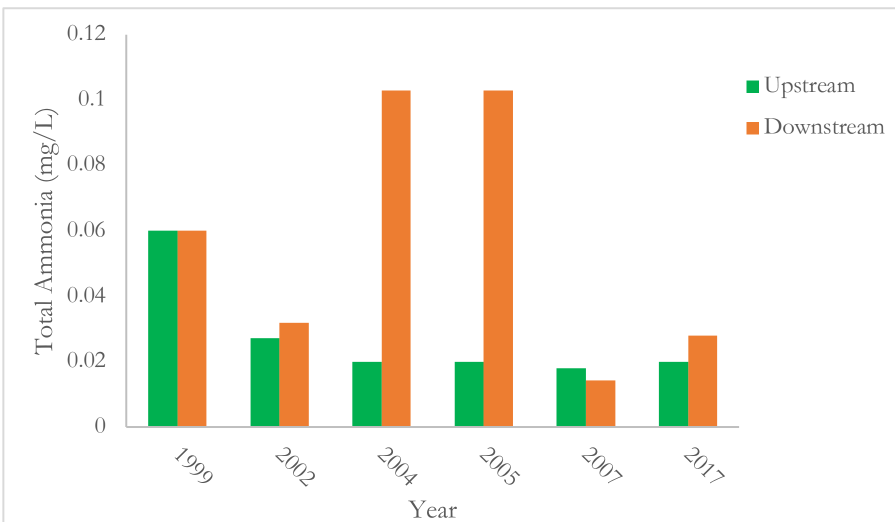

***Figure 3.5.A**: Average total Ammonia concentrations from a historical data set and 2017 monitoring at the same two Inner Harbour sites.*

The average total suspended solids concentration was substantially higher than the downstream site at 21.4 mg/L compared to 6.6 mg/L at the upstream site. 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 205 CFU/100 mL which is just over the Health Canada guideline for safe recreational contact with the water. The downstream site on the other hand, had an overall average of 10

CFU/100 mL, well below the guideline. When compared to historical fecal coliform concentrations at these two locations, the same trend – higher fecal coliforms at the upstream site, is present for most years (Figure 3.5.B). 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. This flushing results in the downstream site being affected more by marine water and the upstream site being affected more 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 decrease in fecal coliform contamination at both the upstream and downstream sites since the completion of Harbour Cleanup (Figure 3.5.B). Similar, but not to the same magnitude, the Inner Harbour sites were impacted by sewage contamination prior to the Harbour Cleanup project. This year marked the first time since the project's completion in 2014 that these sites were monitored. As such, the true extent of this change is unknown, but can be inferred from the historical data and this years' data that Harbour Cleanup has contributed the overall decrease in fecal coliform concentrations at these two Inner Harbour sites.

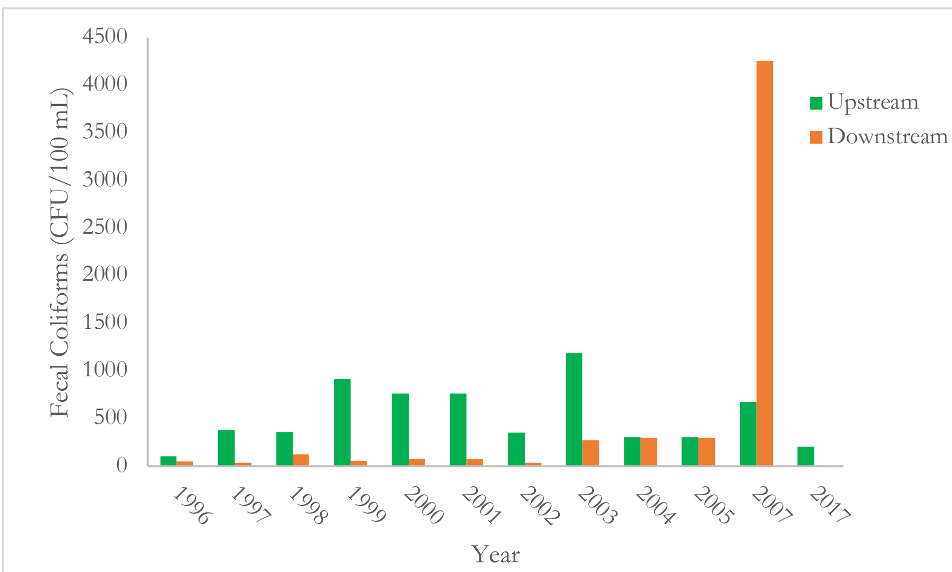

Figure 3.5.B: *Average fecal coliform concentrations from the two Inner Saint John Harbour sites from a historical data set (1996-2007) and monitoring in 2017. No monitoring was completed in 2006 and from 2008-2017 at these sites.*

3.6 Caledonia Brook Watershed

3.6.1 Water Quality Monitoring

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 a fairly 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 3.6.1.A and the standard deviation can be found in Table 3.6.1.B.

***Table 3.6.1.A**: Calculated averages of water quality parameters measured for Caledonia Watershed from six sample periods in 2017.*

Site	Temp (°C)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
16	2.0	0.17	1.60	0.02	578	13.98	0.129	0.0033	0.065
17	2.1	0.15	1.52	0.08	3807	0.82	0.002	0.0001	0.008

***Table 3.6.1.B**: Standard deviations for calculated averages of water quality parameters measured for Caledonia Watershed from six sample periods in 2017.*

Site	Temp (°C)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
16	13.5	7.83	9.21	0.21	333	11.0	0.098	0.002	0.047
17	14.7	8.29	10.59	0.34	3060	1.0	0.022	0.001	0.013

Unlike some of the other watersheds, the difference between the two Caledonia Brook sites was less obvious. Overall, both sites had suitable water temperatures and dissolved oxygen concentrations to support a diversity of aquatic life. The dissolved oxygen concentration at both sites was well above the 6.5 mg/L recommendation and exceed the 9.5 mg/L recommendation for early life stages on multiple occasions (Table 3.6.1.A).

The most notable difference between the two sites was the elevated fecal coliform concentrations at the downstream site towards the end of the field season (Figure 3.6.1.A). Since a portion of Caledonia Brook is piped underground and combined with the stormwater network, it is likely that this spike in fecal coliforms could be attributed to sewage lift station overflows during maintenance or equipment failures, as the summer was very dry, resulting in rainfall overflows being unlikely. Although no guidelines exist for fecal coliform concentration for the protection of aquatic life, an increase in bacteria load would be a deterrent to most fish species; as overtime it can lead to increased TSS and nutrient concentration and a decrease in dissolved oxygen. Luckily, for the Caledonia watershed, it appears that this increase in fecal coliform concentration has not lead to other water quality stressors so far.

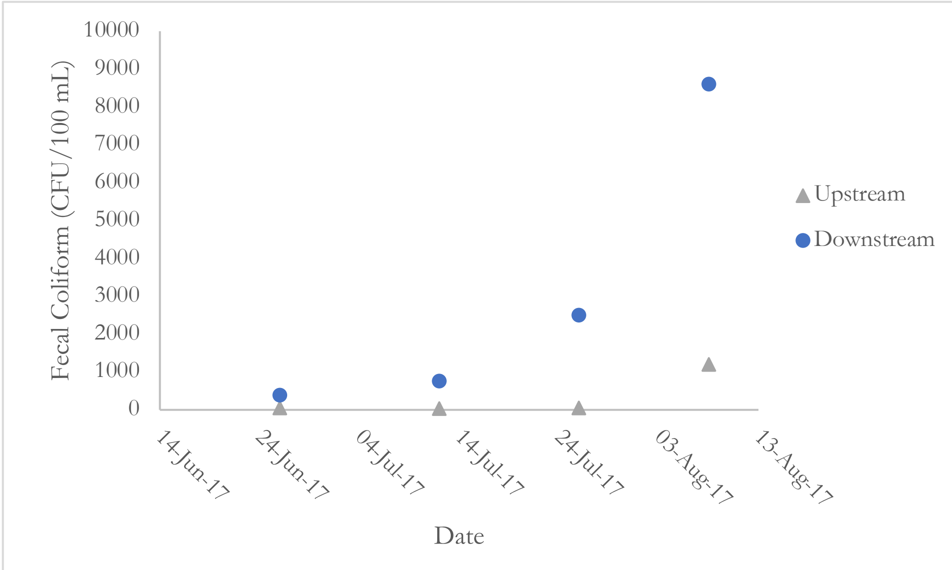

Figure 3.6.1.A: *Fecal coliform concentrations from 4 timepoints at both the upstream (site 16) and downstream (site 17) stations within Caledonia Brook.*

3.6.2 Fish Community Monitoring

Electrofishing at Caledonia Brook was conducted on July 24th from the outflow of the storm drain to the pool below the hanging culvert on Ragged Point Road in Millidgeville. The electrofisher was set to 30 Hz, 12 %, 140 V (later changed to 180 V) and ran for 1034 seconds. A variety of fish species were found within the brook, with the majority of them being American eel (Table 3.6.2.A). The brook had a temperature of 16°C and there were zero fish mortalities. It should be noted that all fish, but one American eel, were caught below the hanging culvert on Ragged Point Road indicting that the culvert is a fish barrier, at least during low flow conditions.

Table 3.6.2.A: *Fish species composition as a result of electrofishing in Caledonia Brook on July 24, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
American eel	9	50	120-430
Brook trout	3	7	160-200
Mummichog	3	11	75-97
Banded killifish	1	5	80
Three-spined stickleback	3	17	46-57

3.7 Alder Brook Watershed

The average of 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 3.7.A and the standard deviation can be found in Table 3.7.B.

***Table 3.7.A**: Calculated averages of water quality parameters measured for Alder Brook from six sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
18	15.1	7.90	8.57	0.58	56	0.5	0.024	0.0008	0.007
19	15.9	8.23	9.72	0.62	148	0.8	0.016	0.0009	0.007

***Table 3.7.B**: Standard deviations for calculated averages of water quality parameters measured for Alder Brook from six sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
18	1.6	0.07	1.38	0.04	24	1.00	0.012	0.0004	0.007
19	1.7	0.06	0.95	0.07	146	0.96	0.012	0.0007	0.007

The water quality monitoring within Alder Brook revealed that the overall quality of water for aquatic life is good. The water temperatures remained fairly low over the summer period when air temperatures were the highest with an average of 15.1 and 15.9℃ respectively and peaked at 18.0℃ (Table 3.7.A). 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 in turn allow the dissolved oxygen concentration to remain within acceptable guideline concentrations for aquatic life due to the inverse relationship between temperature and dissolved oxygen saturation - colder water allows for high dissolved oxygen concentrations. On average the dissolved oxygen concentration was 8.57 and 9.72 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). Additionally, TSS, Ammonia, and Phosphate concentrations were quite low, which further indicates good water quality with the potential to support a diversity of aquatic life.

3.8 Salmon Creek Watershed

3.8.1 Water Quality Monitoring

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 3.8.1.A and the standard deviations in Table 3.8.1.B.

Table 3.8.1.A: *Calculated averages of water quality parameters measured for Salmon Creek from seven sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
20	17.5	7.78	8.61	0.19	149	3.0	0.019	0.0007	0.012
21	17.1	8.01	10.06	0.28	583	4.8	0.028	0.0011	0.010

Table 3.8.1.B: *Standard deviations for calculated averages of water quality parameters measured for Salmon Creek from seven sample periods in 2017.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
							Total Ammonia (mg/L)	Free Ammonia (mg/L)	
20	1.7	0.18	0.76	0.04	69	2.31	0.001	0.00006	0.008
21	2.1	0.13	1.39	0.05	619	1.50	0.007	0.00035	0.005

The in-situ field parameters assessed within Salmon Creek were all adequate for supporting fish habitat. The average water temperature for both sites were below 20℃ (Table 3.8.1.A). The average dissolved oxygen concentration for the upstream site (8.61 mg/L) is well above the 6.5 mg/L CCME guideline and the downstream site exceeded the 9.5 mg/L CCME guideline recommendation for early life stages with an average of 10.06 mg/L (Canadian Council of Ministers of the Environment, 2017). Additionally, the pH and salinity values were well within the range for natural fresh waters.

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 149 CFU/100 mL. The downstream site however, exceeded this guideline with an average of 583 CFU/100 mL. As seen in Figure 3.8.1.A, the fecal coliform concentration spiked at the downstream location in July and remained high in the August sampling two weeks later. Between the upstream and downstream sites there is a waste water 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.

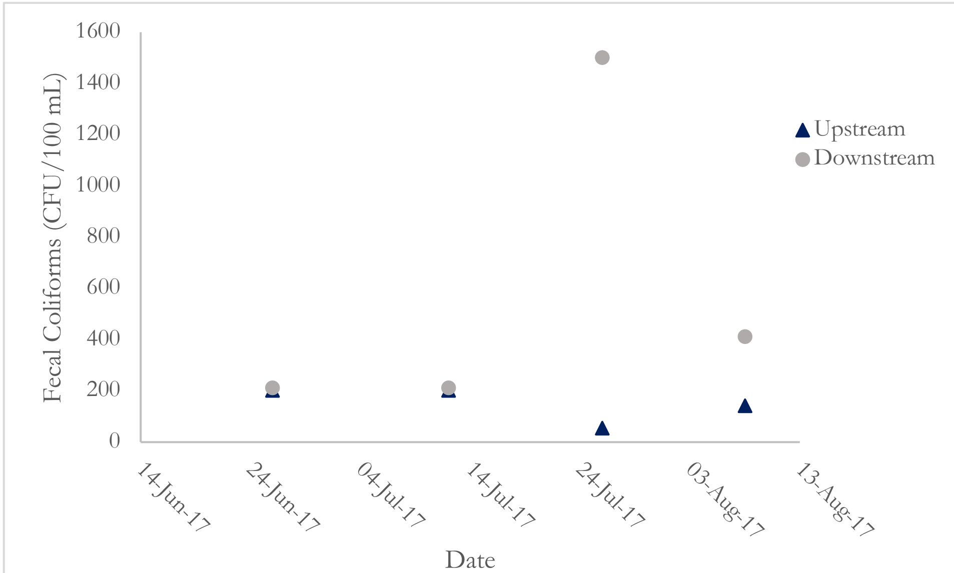

Figure 3.8.1.A: *Fecal coliform concentrations from 4 timepoints at the upstream (site 20) and downstream (site 21) stations within Salmon Creek from the 2017 field season.*

3.8.2 Fish Community Monitoring

A presence survey was conducted along a reach of Salmon Creek by the downstream water quality sampling site, on June 1st. Along this reach, the electrofisher was set at 60 Hz, 25 %, 150 V, and ran for 806 seconds. This survey was done early enough in the field season to capture the run of Alewives in Salmon Creek. A total of 23 fish were caught, identified, and measured; the majority of them being Alewife (Table 3.8.2.A). The water temperature was found to be 11.9°C and there were zero fish mortalities.

Table 3.8.2.A: *Fish species composition from electrofishing in Salmon Creek on June 1, 2017.*

Species	Total Number Caught	Percentage (%)	Range of Total Lengths (mm)
Alewife	10	44	270-300
American eel	8	35	150-400
Brook trout	2	9	130-140
Sea lamprey	1	4	180
Blacknose dace	1	4	68

3.9 Mispec River Watershed

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 due to sampling time constraints. The averages of the assessed water quality parameters can be found in Table 3.9.A and the standard deviations in Table 3.9.B.

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 many human influences and thus water quality impacts are generally quite low. The upper portion of the watershed is where the majority 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 3.9.A: *Calculated averages of water quality parameters assessed at two sites within the Mispec River watershed over the 2017 field season.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)
22	16.1	7.55	10.07	0.06
23	16.5	7.54	10.46	0.04

Table 3.9.B: *Calculated standard deviations of water quality parameters assessed at two sites within the Mispec River watershed over the 2017 field season.*

Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)
22	2.53	0.23	1.23	0.02
23	1.99	0.22	0.74	0.02

The dissolved oxygen concentrations for the two sites were on average 10.07 and 10.46 mg/L respectively (Table 3.9.A); which exceeds the CCME 9.5 mg/L guideline for early life stages indicating that this river system can support a wide range of aquatic species (Canadian Council of Ministers of the Environment, 2017). As seen in Figure 3.9.A, the dissolved oxygen concentration also exceeded the 6.5 mg/L guideline for the protection of aquatic life for the entire field season. The high dissolved oxygen concentrations and low average water temperatures seen within this watershed is likely due to the topography of the area and the limited human influences; allowing for healthy forested riparian areas that provide shade to the river. The Mispec River is also fast moving due to the slope of the area with an abundance of riffles which would allow the water to be saturated with dissolved oxygen and provides excellent fish habitat.

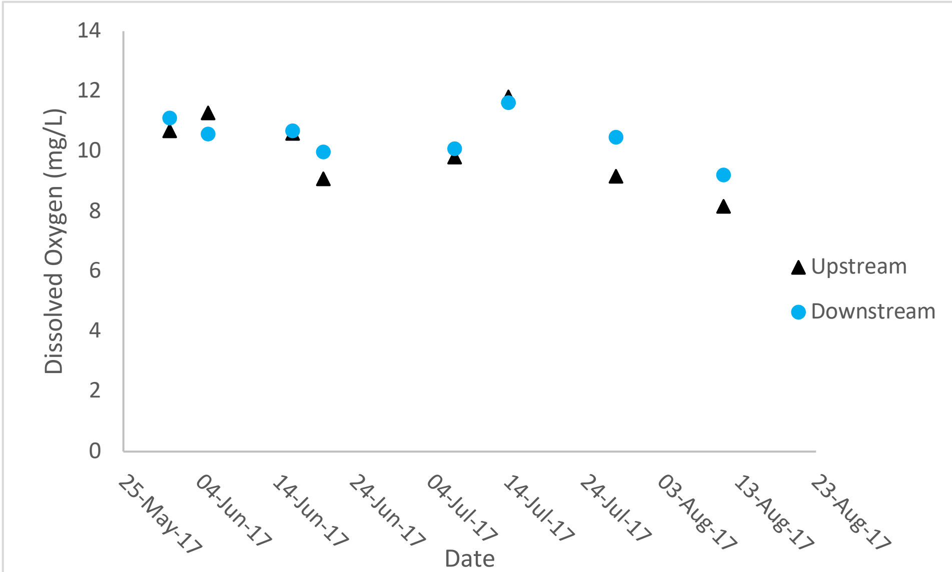

***Figure 3.9.A:** Dissolved oxygen concentrations from both the upstream (site 22) and downstream (site 23) stations within the Mispec River watershed over the entire 2017 field season.*

4.0 CONCLUSION

The water quality monitoring completed this year formed the sixth year of intensive monitoring within the Marsh Creek watershed as well as baseline and second-year follow up monitoring within an additional eight watersheds throughout the Greater Saint John area. This monitoring continues to provide good quality data to gauge changes in the quality of water, where improvements could be made, and ensure that the urban watersheds of Saint John are capable of supporting aquatic life.

Overall, the water quality monitoring conducted over the 2017 field season has revealed that the majority of the watersheds assessed provide adequate water quality to support aquatic life. Although, most of the watersheds assessed have some issues associate with their location in urban or suburban areas such as stormwater inputs, riparian encroachment, and modifications of their natural flows; these impacts either have minor impacts to the watercourse or additional areas within the watershed meet the habitat requirements needed to support an array of aquatic life. Additionally, the Marsh Creek watershed continues to show improvements year after year since the completion of Harbour Cleanup and the cessation of sewage dumping into Saint John's waterways and harbour indicating that changes in human behavior and better management of our waterways can result in profound improvement to water quality and aquatic habitat.

5.0 References

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APPENDIX A: CALCULATIONS USED TO DETERMINE WATER QUALITY PARAMETERS.

A-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:

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

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

If all plates are less than 20:

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

Sample Calculation:

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

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

If plates were less than 20:

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

A-2: Orthophosphates:

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

$$Y = 0.7737 * x$$

$$\boldsymbol{x = \frac{Y}{0.7737}}$$

Where:

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

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

<u>Sample Calculation:</u>

$$x = \frac{0.021}{0.7737} = 0.027\frac{mg}{L}$$

A-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.

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

$$\boldsymbol{x = \frac{Y + 0.0081}{1.0926}}$$

Where:

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

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

<u>Sample Calculation</u>:

$$x = \frac{0.021 + 0.0081}{1.0926} = 0.027\frac{mg}{L}$$

A-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:

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

Sample Calculation:

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

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

A-5: Average pH

In calculation an average pH value from a given number of pH values, you must first convert the pH value into a hydrogen ion concentration

$$\boldsymbol{pH = -log[H+]}$$

$$\boldsymbol{[H+] = 10^{-pH}}$$

Where:

$$pH = measured\ pH\ value$$

$$[H+] = hydrogen\ concentration\ in\ units\ of\ molarity\ (M)$$

Next you take the average of the H^+ values and then convert that average back into a pH to get your average pH value.

$$\boldsymbol{Avg[H+] = \sum[H+]\frac{1}{n}}$$

$$\boldsymbol{Avg\ pH = -\log(avg[H+])}$$

Where:

$$n = number\ of\ terms$$

$$Avg[H+] = average\ hydrogen\ concentration\ in\ units\ of\ molarity\ (M)$$

Sample Calculation:

$$[H+] = 10^{-7.25} = 5.62E-08M$$

$$Avg\ [H+] = (5.62E-08 + 5.13E-08 + 4.57E-08 + 6.46E-08 + 9.12E-08 + 1.12E-07 + 1.12E-07)\frac{1}{7} = 7.62E-08\ M$$

$$Avg\ pH = -log(7.62E-08) \ = \ 7.12$$

APPENDIX B. CALIBRATION CURVES OF ABSORBANCE VS TOTAL PHOSPHATES AND ABSORBANCE VS TOTAL AMMONIA.

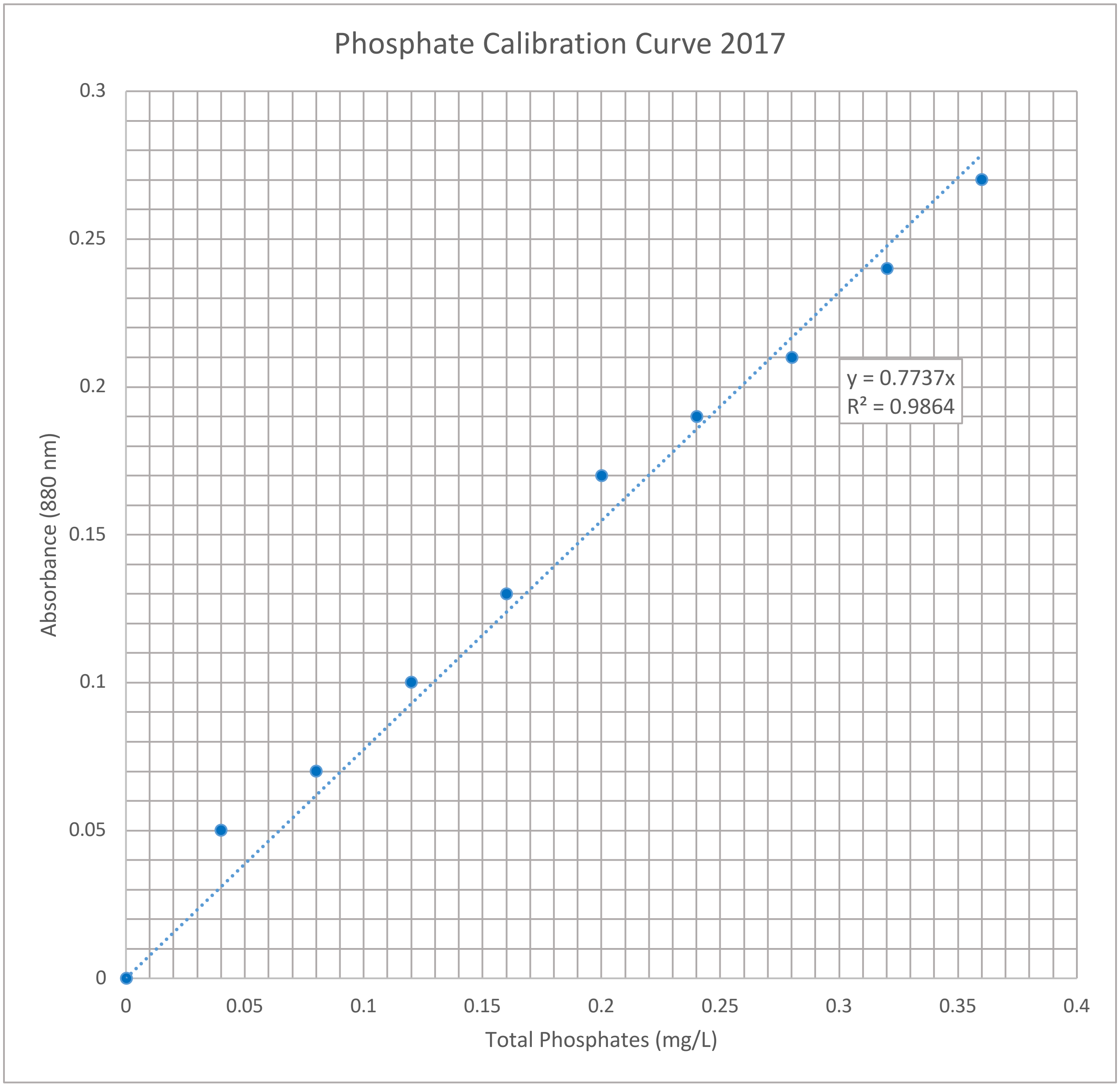

Figure B.1: *Calibration curve used to determine the total Phosphate concentration of samples collected in the 2017 field season.*

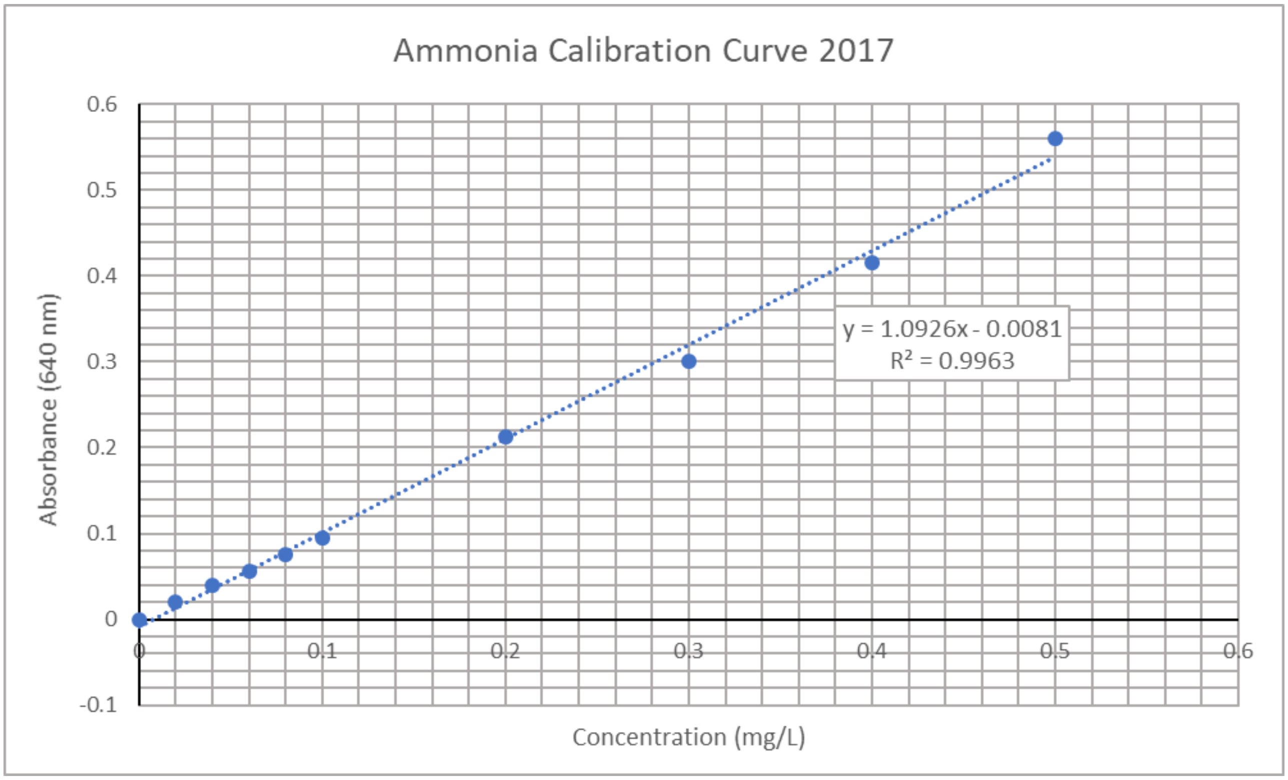

Figure B.2: *Calibration curve used to determine the Ammonia concentration of water samples collected in the 2017 field season.*

APPENDIX C. COMMON AND SCIENTIFIC NAMES OF FISH SPECIES CAUGHT BY ACAP SAINT JOHN.

Table C.1: *A list of common fish names and their corresponding scientific names.*

Common Name	Scientific Name
Alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*
Atlantic salmon	*Salmo salar*
Atlantic tomcod	*Microgadus tomcod*
Blacknose dace	*Rhinichthys atratulus*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ictalurus nebulosus*
Brown trout	*Salmo trutta*
Chain pickerel	*Esox niger*
Creek chub	*Semotilus atromaculatus*
Four-spined stickleback	*Apeltes quadracus*
Golden shiner	*Notemigonus crysoleucas*
Mummichog	*Fundulus heterclitus*
Nine-spined stickleback	*Pungitius pungitius*
Northern Redbelly dace	*Chrosomus eos*
Pearl dace	*Semotilus margarita*
Pumpkinseed sunfish	*Lepomis gibbosus*
Rainbow smelt	*Osmerus mordax*
Three-spined stickleback	*Gasterosteus aculeatus*
White flounder	*Pseudopleuronectes americanus*
White hake	*Urophycis tenuis*
White perch	*Morone americana*
White sucker	*Catostomus commersoni*
Winter flounder	*Pseudopleuronectes americanus*
Yellow perch	*Perca flavescens*

APPENDIX D. RAW WATER QUALITY DATA COLLECTED OVER THE 2017 FIELD SEASON.

***Table D.1**: Raw water quality data collected for Marsh Creek Analysis A over the 2017 field season collected at low tide.*

Date	Site	Temp (°C)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total (mg/L)	Free (mg/L)	
May 30, 2017	Upstream	13.7	7.66	11.01	0.06	-	-	-	-	-
	Downstream	13.9	7.77	8.90	0.53	-	-	-	-	-
June 14, 2017	Upstream	14.5	7.25	11.64	0.06	-	-	-	-	-
	Downstream	16.4	7.50	10.33	0.30	-	-	-	-	-
June 21, 2017	Upstream	17.5	7.51	11.63	0.06	140	3	-	-	-
	Downstream	18.0	8.55	15.32	0.65	880	9	-	-	-
June 28, 2017	Upstream	13.2	7.55	10.51	0.07	89	0	-	-	0.007
	Downstream	17.9	8.05	10.32	2.55	440	5	-	-	0.022
July 17, 2017	Upstream	16.6	7.27	8.61	0.09	460	0	0.130	0.0021	0.044
	Downstream	20.2	7.92	7.70	3.44	860	3	0.065	0.0028	0.052
July 31, 2017	Upstream	15.7	7.64	7.95	0.09	360	2	0.144	0.0033	0.007
	Downstream	22.1	8.29	11.52	3.65	77	5	0.085	0.0087	0.052
August 14, 2017	Upstream	13.9	727	7.60	0.09	700	3	0.012	0.0001	0.210
	Downstream	17.7	7.60	7.00	5.74	500	11	0.023	0.0005	0.067

***Table D.2:** Raw water quality data collected as the Marsh Creek Analysis B over the 2017 field season at low tide.*

Date	Site	Temp (°C)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total (mg/L)	Free (mg/L)	
May 30, 2017	1	10.7	7.57	9.50	12.39	-	-	-	-	-
	2	13.5	7.73	9.00	1.20	-	-	-	-	-
	3	14.2	7.80	9.62	0.17	-	-	-	-	-
	4	14.5	7.86	9.73	0.17	-	-	-	-	-
	5	13.4	7.76	9.40	0.16	-	-	-	-	-
June 6, 2017	1	14.3	7.86	10.30	13.21	-	-	-	-	-
	2	17.2	8.47	12.83	3.62	-	-	-	-	-

	3	18.7	8.83	14.31	0.23	-	-	-	-	-
	4	17.1	8.10	10.90	0.20	-	-	-	-	-
	5	16.3	7.79	9.64	0.20	-	-	-	-	-
June 21, 2017	1	17.1	7.85	12.02	10.94	940	11	-	-	-
	2	18.8	8.47	15.18	1.50	3600	9	-	-	-
	3	17.1	8.25	12.02	0.18	460	1	-	-	-
	4	18.8	8.31	15.18	0.15	220	1	-	-	-
	5	17.1	8.16	12.02	0.15	300	0	-	-	-
June 28, 2017	1	15.4	7.74	9.08	15.71	420	9	-	-	0.043
	2	17.8	7.97	10.25	3.17	1500	5	-	-	0.024
	3	17.7	7.82	10.37	0.26	200	3	-	-	0.015
	4	18.1	8.47	11.15	0.18	120	1	-	-	0.014
	5	17.8	7.67	6.52	0.19	98	2	-	-	0.009
July 17, 2017	1	17.8	7.87	9.15	17.58	410	12	0.130	0.0046	0.064
	2	19.9	7.70	8.78	7.73	1300	7	0.085	0.0026	0.052
	3	21.4	8.71	12.59	0.34	1060	8	0.048	0.0114	0.042
	4	19.5	7.65	6.05	0.22	120	28	0.035	0.0009	0.064
	5	19.3	7.88	6.91	0.20	75	5	0.028	0.0011	0.039
July 31, 2017	1	19.6	8.04	11.33	19.93	49	17	0.060	0.0032	0.027
	2	21.6	7.91	10.76	6.28	83	8	0.069	0.0032	0.020
	3	24.6	9.18	18.54	0.97	62	2	0.032	0.0297	0.012
	4	24.1	8.65	12.64	0.19	N/A	571	0.025	0.0635	0.403
	5	20.7	8.01	7.94	0.22	12	24	0.069	0.0037	0.038
August 14, 2017	1	16.8	7.80	7.90	21.39	97	13	0.101	0.0030	0.034
	2	17.8	7.60	7.10	7.14	400	10	0.061	0.0015	0.026
	3	18.9	7.80	8.90	1.14	290	3	0.045	0.0015	0.010
	4	16.5	7.52	4.12	0.24	280	293	0.158	0.0032	0.380
	5	17.0	7.54	3.48	0.22	89	5	0.090	0.0019	0.015

Table D.3: *Raw water quality data from the Hazen Creek watershed collected over the 2017 field season at low tide.*

Date	Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total (mg/L)	Free (mg/L)	
June 1, 2017	6	15.1	7.75	9.36	3.22	-	-	-	-	-
	7	10.6	7.88	10.51	0.08	-	-	-	-	-
June 15, 2017	6	13.3	7.55	9.56	1.22	-	3	-	-	-
	7	10.3	7.55	10.94	0.08	-	0	-	-	-
July 4, 2017	6	13.2	7.38	10.21	0.99	22	1	-	-	0.028
	7	19.4	7.77	10.05	0.09	41	1	-	-	0.021
July 19, 2017	6	21.1	8.25	11.46	3.88	1100	5	0.037	0.0033	0.012
	7	15.0	795	9.52	0.16	38	0	0.042	0.0015	0.006

August 2, 2017	6	24.5	8.69	15.48	8.07	19	5	0.050	0.0141	0.011
	7	15.0	7.96	9.18	0.24	20	0	0.048	0.0017	0.004
August 16	6	20.4	7.68	8.88	9.35	850	11	0.097	0.0029	0.031
	7	14.5	7.88	9.75	0.22	32	0	0.021	0.0006	0.025

Table D.4: *Raw water quality data from the Taylor Brook watershed collected over the 2017 field season.*

Date	Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total (mg/L)	Free (mg/L)	
June 2, 2017	8	16.8	7.99	10.23	0.08	-	-	-	-	-
	9	16.5	7.66	9.75	0.09	-	-	-	-	-
	10	17.0	7.94	10.33	0.10	-	-	-	-	-
June 7, 2017	8	17.4	7.91	10.05	0.08	-	-	-	-	-
	9	18.7	7.70	9.52	0.10	-	-	-	-	-
	10	18.1	7.68	9.69	0.10	-	-	-	-	-
June 26, 2017	8	18.0	7.83	9.91	0.08	23	0	-	-	0.002
	9	19.0	7.55	8.86	0.08	52	0	-	-	0.008
	10	19.7	7.80	10.35	0.10	43	0	-	-	0.005
July 5, 2017	8	21.7	7.84	8.71	0.08	-	-	-	-	-
	9	22.0	7.55	7.53	0.09	-	-	-	-	-
	10	21.7	7.66	8.46	0.10	-	-	-	-	-
July 12, 2017	8	19.8	8.04	8.65	0.09	13	0	0.026	0.0013	0.008
	9	22.4	7.81	8.23	0.11	143	0	0.036	0.0014	0.010
	10	18.9	7.91	9.08	0.11	73	0	0.022	0.0009	0.007
July 26, 2017	8	17.6	7.96	8.14	0.10	13	0	0.020	0.0008	0.010
	9	21.9	7.84	7.37	0.10	150	3	0.052	0.0022	0.014
	10	16.4	7.59	8.50	0.13	34	1	0.019	0.0004	0.011
August 8, 2017	8	17.5	8.21	8.99	0.09	44	0	0.027	0.0017	<0.001
	9	22.3	8.02	5.93	0.12	44	0	0.027	0.0015	<0.001
	10	16.5	8.05	8.60	0.16	64	0	0.020	0.0009	<0.001

Table D.5: *Raw water quality data from the Newman's Brook watershed collected over the 2017 field season at low tide.*

Date	Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total (mg/L)	Free (mg/L)	
June 1, 2017	12	11.8	7.96	10.73	0.14	-	-	-	-	-
	13	8.8	7.00	3.96	0.70	-	-	-	-	-
June 15, 2017	12	12.4	7.99	10.52	0.13	-	0	-	-	-
	13	13.0	7.11	6.07	3.87	-	0	-	-	-
	12	16.1	8.00	8.58	0.13	210	1	-	-	0.012

July 4, 2017	13	17.8	7.42	6.98	8.09	280	61	-	-	0.105
July 19, 2017	12	20.4	8.24	7.64	0.20	70	0	0.016	0.0013	<0.001
	13	18.6	7.24	5.23	11.11	70	19	0.693	0.0113	0.036
August 2, 2017	12	22.8	8.15	8.20	0.24	41	0	0.032	0.0025	0.034
	13	19.2	7.12	1.32	12.40	170	109	0.821	0.0123	0.114
August 16	12	20.2	8.25	7.90	0.24	27	2	0.014	0.0012	0.015
	13	18.3	7.56	3.82	16.81	290	16	0.635	0.0146	0.051

Table D.6: *Raw water quality data from the Inner Harbour collected over the 2017 field season at low tide.*

Date	**Site**	**Temp (℃)**	**pH**	**DO (mg/L)**	**Salinity (ppt)**	**Fecal Coliforms (CFU/100 mL)**	**TSS (mg/L)**	**Ammonia**		**Total Phosphates (mg/L)**
								Total (mg/L)	**Free (mg/L)**	
June 1, 2017	14	12.4	7.49	9.90	2.43	-	-	-	-	-
	15	10.2	7.84	10.18	12.58	-	-	-	-	-
June 15, 2017	14	16.3	7.75	9.32	3.63	-	10	-	-	-
	15	11.7	7.88	9.56	17.93	-	26	-	-	-
July 4, 2017	14	18.5	7.94	9.02	6.13	200	4	-	-	0.040
	15	13.4	8.04	9.52	20.11	17	25	-	-	0.015
July 19, 2017	14	19.4	8.06	8.51	9.45	150	6	0.021	0.0012	0.008
	15	13.2	8.04	9.60	25.51	7	26	0.037	0.0013	0.043
August 2, 2017	14	20.3	8.22	9.92	11.36	140	6	0.030	0.0023	<0.001
	15	15.4	8.14	10.19	24.16	6	12	0.033	0.0016	0.012
August 16	14	17.9	8.08	8.84	17.37	330	7	0.010	0.0005	0.024
	15	14.8	8.04	9.49	26.98	8	18	0.015	0.0006	0.039

Table D.7: *Raw water quality data from the Caledonia Brook watershed collected over the 2017 field season.*

Date	**Site**	**Temp (℃)**	**pH**	**DO (mg/L)**	**Salinity (ppt)**	**Fecal Coliforms (CFU/100 mL)**	**TSS (mg/L)**	**Ammonia**		**Total Phosphates (mg/L)**
								Total (mg/L)	**Free (mg/L)**	
June 2, 2017	16	11.0	8.00	11.17	0.19	-	-	-	-	-
	17	11.9	8.51	12.25	0.33	-	-	-	-	-
June 7, 2017	16	12.2	8.03	10.29	0.22	-	-	-	-	-
	17	13.5	8.46	11.77	0.40	-	-	-	-	-
June 26, 2017	16	12.8	8.00	10.24	0.19	49	0	-	-	0.002
	17	13.6	8.29	11.87	0.32	390	2	-	-	0.008
July 12, 2017	16	14.9	7.74	8.50	0.23	29	13	0.013	0.0003	0.030
	17	15.7	8.23	9.50	0.41	750	0	0.021	0.012	0.025

July 26, 2017	16	13.3	7.68	8.00	0.24	52	1	0.034	0.0007	0.012
	17	15.6	8.32	8.95	0.40	2500	1	0.021	0.0015	0.015
August 8, 2017	16	16.7	7.70	7.03	0.21	1200	30	0.246	0.0062	0.143
	17	17.9	8.09	9.19	0.19	8600	1	0.024	0.0012	0.006

Table D.8: *Raw water quality data from the Alder Brook watershed collected over the 2017 field season.*

Date	**Site**	**Temp (°C)**	**pH**	**DO (mg/L)**	**Salinity (ppt)**	**Fecal Coliforms (CFU/100 mL)**	**TSS (mg/L)**	**Ammonia**		**Total Phosphates (mg/L)**
								Total (mg/L)	**Free (mg/L)**	
June 2, 2017	18	12.7	8.03	10.06	0.59	-	-	-	-	-
	19	13.5	8.33	10.71	0.66	-	-	-	-	-
June 7, 2017	18	14.2	7.91	10.05	0.08	-	-	-	-	-
	19	16.2	8.22	10.25	0.71	-	-	-	-	-
June 26, 2017	18	14.2	7.93	9.91	0.53	78	0	-	-	0.003
	19	15.0	8.21	10.65	0.53	230	1	-	-	0.003
July 12, 2017	18	16.4	7.89	7.98	0.61	57	0	0.010	0.0003	0.015
	19	18.0	8.28	9.38	0.66	7	0	0.019	0.0001	0.014
July 26, 2017	18	15.9	7.86	6.82	0.62	22	2	0.029	0.0009	0.012
	19	15.0	8.17	8.66	0.61	43	2	0.028	0.0011	0.011
August 8, 2017	18	17.0	7.82	7.32	0.53	65	0	0.033	0.0010	<0.01
	19	17.4	8.19	8.66	0.54	310	0	0.022	0.0014	<0.01

Table D.9: *Raw water quality data from the Salmon Creek watershed collected over the 2017 field season.*

Date	**Site**	**Temp (°C)**	**pH**	**DO (mg/L)**	**Salinity (ppt)**	**Fecal Coliforms (CFU/100 mL)**	**TSS (mg/L)**	**Ammonia**		**Total Phosphates (mg/L)**
								Total (mg/L)	**Free (mg/L)**	
June 2, 2017	20	16.2	7.97	9.76	0.17	-	-	-	-	-
	21	15.4	8.23	11.86	0.30	-	-	-	-	-
June 7, 2017	20	18.0	7.82	9.14	0.19	-	-	-	-	-
	21	15.4	8.17	12.16	0.33	-	-	-	-	-
June 26, 2017	20	17.6	7.47	9.28	0.14	200	5	-	-	0.017
	21	17.6	7.88	9.97	0.20	210	6	-	-	0.011
July 5, 2017	20	20.7	7.72	7.90	0.16	-	-	-	-	-
	21	21.4	8.01	9.03	0.23	-	-	-	-	-
July 12, 2017	20	17.9	7.83	8.14	0.18	200	5	0.020	0.0006	0.017
	21	17.5	8.01	9.50	0.27	210	6	0.033	0.0015	0.011
	20	15.9	7.93	7.88	0.24	55	1	0.019	0.0007	0.017

July 26, 2017	21	15.7	7.99	9.22	0.31	1500	3	0.020	0.0008	0.016
August 8, 2017	20	15.9	7.95	8.20	0.26	140	1	0.021	0.0008	<0.001
	21	16.6	7.92	8.70	0.30	410	4	0.028	0.010	0.003

Table D.10: *Raw water quality data collected from the Mispec River watershed over the 2017 field season. Due to time limitations only field measurements were taken for this watershed.*

Date	Site	Temp (℃)	pH	DO (mg/L)	Salinity (ppt)	Fecal Coliforms (CFU/100 mL)	TSS (mg/L)	Ammonia		Total Phosphates (mg/L)
								Total (mg/L)	Free (mg/L)	
May 31, 2017	22	11.7	7.31	10.67	0.03	-	-	-	-	-
	23	12.7	7.47	11.11	0.03	-	-	-	-	-
June 5, 2017	22	16.6	N/A	11.28	0.04	-	-	-	-	-
	23	18.8	N/A	10.56	0.03	-	-	-	-	-
June 16, 2017	22	14.4	7.30	10.59	0.03	-	-	-	-	-
	23	15.5	7.35	10.67	0.02	-	-	-	-	-
June 20, 2017	22	15.9	7.65	9.08	0.05	-	-	-	-	-
	23	16.5	7.72	9.97	0.03	-	-	-	-	-
July 7, 2017	22	18.3	7.56	9.80	0.05	-	-	-	-	-
	23	17.9	7.38	10.08	0.03	-	-	-	-	-
July 14, 2017	22	17.0	7.73	11.81	0.07	-	-	-	-	-
	23	15.7	7.37	11.62	0.05	-	-	-	-	-
July 28, 2017	22	15.1	7.42	9.16	0.08	-	-	-	-	-
	23	16.6	7.53	10.47	0.05	-	-	-	-	-
August 11, 2017	22	19.9	7.90	8.16	0.09	-	-	-	-	-
	23	18.6	7.95	9.20	0.07	-	-	-	-	-

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