Queen's Royal Beach (M00090)

2020 Water Quality Monitoring & Data Analysis Report

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Executive Summary

Queen's Royal Beach is a popular recreational area located within Old Town Niagara-on-the- Lake (NOTL), along the shores of the Niagara River near Lake Ontario. The beach was sampled and tested for *E. coli* throughout the summer of 2020 as a component of the Niagara River Remedial Action Plan (NRRAP). The NRRAP goals indicate that at least 80% of the geometric mean results of samples (taken at least once per week) must meet provincial water quality guidelines each swimming season for at least three years. This study is the third year of monitoring toward assessing the NRRAP goal.

Similar to previous monitoring years, two Environmental Technician students employed by the Town of NOTL conducted water quality sampling at Queen's Royal Beach (QRB) and two locations at a nearby storm sewer outlet discharging stormwater from the King Street area into the Niagara River. Water sampling at the beach was conducted three times per week (Monday, Wednesday, Friday) from June 1st to September 4th, 2020. Additional in-field parameters such as air and water temperature, wind speed, wave height and turbidity were also collected and reported for each sampling day.

Over the course of the 2020 sampling season, 90.5% of samples collected at QRB met the recreational water quality guideline for safe swimming. The beach was 'Posted' (meaning samples did not meet the guideline of ≤200 *E. coli*/100 mL) a total of 4 times during the duration of the study. One of the 'Posted' dates (June 3rd) coincided with a significant rain event (i.e., more than 10 mm of precipitation within 24 hours), while the remainder (June 24th, July 17th and July 20th) occurred during periods of high wave action/high wind speeds. The spikes observed in *E. coli* levels during periods of high wave action may be related to the presence of sediment-bound environmentally persistent *E. coli* resuspended from beach sand into the beach water.

High levels of *E. coli* were usually detected in the samples taken from the mouth of the stormwater outlet and where the outlet flow met the beach water. Based on in-field observations and other monitoring studies, possible causes of high *E. coli* levels in the outlet include the presence of wildlife and fecal matter (both human and animal) within the stormwater system or human sewage linked to sewer infrastructure issues impacting the King St. drainage area. Notably, high levels of *E.coli* in the outlet did not seem to result in higher *E.coli* levels in the beach water. The Town of NOTL will be initiating additional infrastructural upgrades to the King St. drainage area during the 2021 season, including the installation of trenchless structural lining in the mainline pipes within the QRB catchment area.

Following the completion of this sampling year, QRB has met the NRRAP water quality goal for its third consecutive year of monitoring. Given that QRB has met water quality guidelines for the past 3 consecutive years, it is recommended that the RAP Team examines whether the other delisting goals have been met in order to re-designate the status of the Beach Closings challenge to 'Not Impaired'. Further, it is recommended that the Town of NOTL and Niagara Region work together to determine future monitoring requirements and responsibilities at QRB. For example, monitoring at QRB could/should continue to be performed according to local public health guidance and regularly reported to the public.

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Photo credit: N. Green, June 2020

Table of Contents

Introduction

The Queen's Royal Beach (QRB) is a small recreational beach located in the Town of Niagara-on-the-Lake (NOTL) (Figure 1). It is often used for wading, sightseeing, and as a put-in for paddleboards and kayaks. It is the only public swimming beach on the Niagara River; as such, it is subject to the Niagara River (Ontario) Remedial Action Plan (RAP). Up until the end of 2017, water quality at the beach was monitored weekly by the Niagara Region Public Health Unit (NRPHU). At that time, it was determined that a number of beaches would need to be removed from the NRPHU sampling schedule (including QRB) to allow for increased sampling and data accuracy at the other more popular beaches in the Niagara Region (i.e., Bay/Crystal, Lakeside, Nickel, Long Beach). In the interest of protecting the safety and health of people using the beach and to support the Niagara River RAP goals, the Town of NOTL began collecting water samples at QRB to monitor the levels of *Escherichia coli* (*E. coli*) bacteria at the beach during the swimming season (May to September). To maintain consistency and comparability, sample analysis continued to be conducted by the Niagara Region Public Health Unit (NRPHU) even though they did not collect the samples.

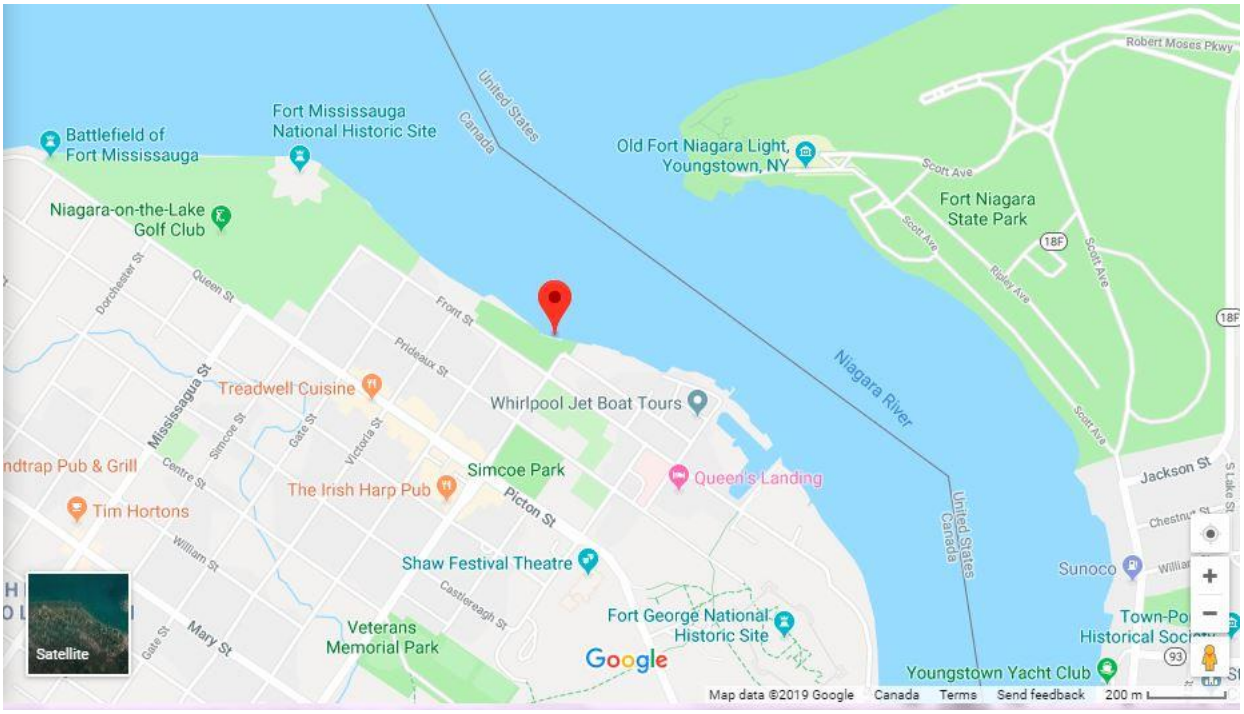

Figure 1. Map of the area showing the location of Queen's Royal Beach (red marker) in the Town of Niagara-on-the-Lake, Ontario.

Bacteria at beaches can come from natural sources (e.g., wind, wave, wildlife) and/or anthropogenic sources (e.g., untreated raw sewage). High levels of *E. coli* bacteria pose a potential health risk because they are indicators of the potential occurrence of waterborne pathogens that can cause infection and illness in people. *E. coli* bacteria can be spread via exposure to contaminated surfaces (including liquids), infected people/animals, and ingestion of contaminated food and water (Public Health Agency of Canada, 2019). Elevated levels of bacteria at beaches, in particular, can pose a risk of infection to the public due to amount of contact with contaminated water during recreational swimming. In Ontario, the water quality guidelines are set by the Ontario Ministry of Health and Long-Term Care (OMHLTC) (Health Canada, 2012; OMHLTC, 2018). People are advised to avoid using recreational waters when *E. coli* levels are higher than 200 colony forming units (CFU) per 100 mL and the beach is 'Posted' (i.e. swimming/recreational water contact should

be avoided due to unsafe conditions). The NRPHU is responsible for communicating water quality results from their monitored public swimming beaches through their website; however, since QRB is not monitored by the NRPHU, the responsibility was given to the Town of NOTL in 2020.

Queen's Royal Beach is the only public swimming beach along the Canadian side of the Niagara River and is included as part of the local RAP to improve water quality and ecosystem health in the Niagara River. There are specific goals to address water quality and ecosystem challenges in the Niagara River, including goals related to beach closings. According to the Niagara River (Ontario) RAP, this water quality challenge (called 'Beach Closings') can be re-designated to 'Not Impaired' when:

1. Prominent sources of fecal pollution that could contaminate the beach or recreational waters are known and remedial actions to address known sources are identified and completed;
2. At least 80% of the geometric mean results of recreational water samples (when sampled at least once per week) meet the Ontario Ministry of Health Recreational Water Quality Guideline (≤200CFU/100 mL) each swimming season for a minimum of three years; and
3. Risk management actions (e.g. postings, signage, education, rain rule) are in place to protect human health.

This monitoring project was conducted to determine whether QRB meets the Niagara River RAP's criterion 2 noted above for its third consecutive year. As such, the objectives of this study were to: (1) monitor and report on *E. coli* levels at QRB over the course of the 2020 summer season (beginning of June to the end of August), and (2) collect water samples at a nearby storm sewer outfall to ascertain the impacts of recent remedial actions in the catchment area.

Methodology

Study Area

The Queen's Royal Beach study area is located at 16 Front Street (UTM 656774, 4791261) in the Town of Niagara-on- the-Lake, Ontario, along the shoreline of the Niagara River (Fig. 2). Access to the beach is available from King Street into Queen's Royal Park.

Figure 2 Photo taken from Western edge of QRB on August 5, 2020 (credit: Kennedy Laufman).

Field Observations

General field observations were taken to identify consistent and notable characteristics of the study area, such as the presence of potential sources of contamination (including presence of wildlife), the general uses and amount of use of the study area by residents and tourists, shoreline erosion control methods, etc. Below are some general field observations:

- A stormwater outflow pipe at the Eastern shoreline is known as a potential source of contamination. It was actively flowing during each site visit; however, is capped with a secure plug (a WaStop inline check valve) to prevent entry by wildlife. Of note, a shallow aquifer connection supplies the majority of dry weather flow to the outlet.

- Queen's Royal Beach is frequented by residents for recreational use and access to Lake Ontario; visitors were observed swimming, kayaking, paddle boarding, walking, etc. People on/near the beach were observed on 63% of sampling days throughout the season, while kayakers and boaters were observed on 49% of sampling days. The primary launching point for recreational watercraft users was directly adjacent to, or in front of, the outfall.

- Riprap (the placement of stone along a shoreline to protect it from erosion) is present along at least half of the shoreline.

Detailed field observations and photos were noted during each sampling visit including (but not limited to) air temperature, weather, water colour, presence of algae, dead fish, or water with film or foam (**Appendix A**). Photos of notable field observations are available upon request from the Town of NOTL or the Niagara River RAP (info@ourniagarariver.ca).

Of note, public beaches across the Region of Niagara were closed from the beginning of the season to June 26th, 2020 due to restrictions related to the COVID-19 pandemic. As a result, there were no visitors to the beach prior to June 26th. Additionally, as a result of the Canada-U.S. border restrictions during the pandemic, visitors to the beach consisted solely of residents and local tourists. No tour groups were observed at the beach, and the horse-drawn carriages that operate within the downtown area were not observed during sampling for the majority of the swimming season; no animal manure observed in the roadways near QRB (as was observed in previous years). Local recreational use like wading, kayaking, and paddleboarding resumed later in the season, when public health guidelines allowed it.

Sampling

Water quality sampling was conducted at QRB (5 sampling points) as well as two locations near the King Street Storm Outlet (KSSO) from June 1st to September 4th.

A team of two Environmental Technicians from the Town of NOTL conducted water quality monitoring 3 days per week throughout the swimming season. As per the NRPHU protocol (Table 1), samples were collected from 5 sites in the water parallel to the beach (Fig. 3). In addition to the beach sampling (Fig. 4-5), one water sample was collected from the mouth of the stormwater outlet pipe draining to the beach (Fig. 6) and one sample representative of the runoff from the outfall was collected before it meets the shoreline (Fig. 7). All water samples collected were analyzed for *E. coli* concentration (*E. coli* CFU per 100 mL) by the NRPHU except for two sets of samples collected on Sept 2 and 4th which were analyzed by E3 Laboratories (a local accredited lab using the same protocols as NRPHU) because the NRPHU was not available. The geometric mean *E. coli* amount was calculated by the NRPHU and compared to the provincial guideline (200 CFU/100 mL) according to OMHLTC (2018) for the purpose of communicating results to the public and for this report.

Precipitation data was sourced from the Niagara Weather Information Systems webpage operated by Niagara Open Data (https://niagaraopendata.ca/dataset/niagara-weather-information-systems); specifically, the data from the Line 2 Weather Station located at 42R Raiana Drive in Niagara-on-the-Lake was used to track precipitation throughout the season.

Table 1: Sampling methodology for QRB, as instructed by Niagara Region Public Health.

Dates of sample collection	Every Monday, Wednesday and Friday, where possible (i.e. sampling shifted to next available day on statutory holidays)
Time of sample collection	Completed from 8:30 to approx. 9:30am; submitted to lab by 10:45am at the latest to ensure submission to lab courier on time
Location of sample collection	5 sites in the water (thigh to waist deep) labelled QR1 through QR5 1 site at the mouth of the outlet pipe draining to the beach, labelled QRS for 'source' 1 site at the point where the beach water meets the drainage from the outlet, labelled QRO
Type of sample collection	Grab samples collected by hand wearing nitrile gloves; collected using sterile plastic bottle with a 200 mL fill line and 30 mg sodium thiosulphate
Sampling method	Collect sample at hip to waist depth (approximately 0.75 m), 15-30 cm below the surface of the water, in a direction away from the body. Fill bottle to fill line, then place in cooler immediately after collection.
Sample preservation	Samples preserved in a cooler with ice packs below 10 degrees, ideally around 4 degrees.
In-situ field parameter measurements and notes	Turbidity, wind speed, precipitation, air temperature, water temperature and wave height were measured at sampling site #3; field observations and photographs were also recorded/taken throughout sampling Also note, when applicable: → if health hazards present → if sampling was not possible in any location, and reason why → if potential pollution sources present

Figure 3: Map indicating sampling locations (blue dots) as well as the two outfall locations.

Figure 4: Sampling QRB with the 12-foot-long sampling pole from the shore on August 19, 2020 (credit: Kennedy Laufman).

Figure 5: Sampling at QR4 on August 7, 2020 (credit: Kennedy Laufman).

Figure 6: Sampling from QRS, flow exiting the outlet pipe, on July 10, 2020 (credit: Ishita Patel).

Figure 7: Sampling runoff water from the outfall (QRO) where it meets the shoreline on June 29, 2020 (credit: Kennedy Laufman).

Limitations

Limitations encountered during the study were documented and, to the fullest extent possible, mitigated through QA and QC measures. Limitations encountered during the study included maximum *E. coli* concentration detection limits of 1,000 CFU/100ml as per the method used by NRPHU, and the occasional inaccessibility of sampling sites due to safety concerns during poor weather. During poor weather/unsafe conditions, a 12-foot-long sampling pole was used to collect samples from the shoreline; the bottles were affixed to the sanitized end of the pole and submerged into the water as close as possible to the original sampling point.

Health and Safety

Due to the nature of the sampling sites (i.e., working around and in water), health and safety was paramount during the study. Most importantly, the Environmental Technicians worked as a team and were never left alone working near water. As per the Town of NOTL policies, no outside work was conducted without long pants, safety vest, safety boots, safety gloves and a hard hat. Furthermore, face masks were worn during the duration of sampling in accordance with Town of NOTL COVID-19 protocols.

Quality Assurance and Quality Control

Quality assurance and quality control (QA and QC) are a key component in ensuring the accuracy of the study data. To this end, QA and QC measures were employed throughout every stage of this study. Primarily, all instructions provided by the Niagara Region Public Health department were followed closely throughout preparation, collection and transportation of the samples to ensure the accuracy and replicability of the data. Sample analysis was conducted by qualified, trained staff at the NRPHU following established protocols except on September 2nd and 4th, 2020 whereby sample analysis was performed by E3 Laboratories, an accredited lab located in Niagara-on-the-Lake.

Qualifications of Technicians

The team of Environmental Technicians completing the water quality sampling on behalf of the Town of NOTL were two graduates from Niagara College: Kennedy Laufman and Ishita Patel

Kennedy Laufman earned a Bachelor of Science (Honours) from the University of Guelph in 2017, majoring in Biomedical Sciences. She completed the Environmental Management and Assessment Post-Graduate Certificate program at Niagara College in 2019 where she received training and in-field experience in surface water/groundwater quality analysis, sediment and soil analysis, and environmental project management.

Ishita Patel recently graduated (2020) from the Environmental Technician program at Niagara College. In 2016, she earned her Bachelor of Science (majoring in chemistry) from State Gujarat University and gained experience as a Chemical Lab Technician. Her qualifications and experience have enhanced her skills in field data collection procedures and environmental project management.

Kennedy and Ishita were trained by staff from Niagara Region Public Health on the correct procedures for equipment handling, sample collection, sample transportation and sample delivery to the lab in 2020.

Results & Discussion

During this study, the beach and storm outfall were sampled 42 separate times from June to September 2020. Monitoring indicates that 90.5% of sampling events met or were below the provincial recreational water quality guideline (200 *E. coli* CFU per 100mL) (Fig. 8).

There were 4 sampling dates that resulted in the beach being 'Posted' (above 200 *E. coli* CFU per 100mL) with only one of those (June 2) occurring after or during a significant rain event (defined as precipitation greater than 10mm within 24 hours). Rainfall can exacerbate bacterial levels in waterbodies due to stormwater runoff or combined sewer overflows upstream in the Niagara River. For example, high levels of bacteria can be present in stormwater runoff from sources such as wildlife fecal matter, livestock manure, pet waste, etc. washed from the roads into the storm sewers. Further, sewer infrastructure in poor condition, wastewater treatment plant bypasses or combined sewers (where storm and sanitary water mix in high rainfall events) can convey human waste (and bacteria) to local receiving waterbodies. Past microbial source tracking studies completed in the Niagara River by Dr. Thomas Edge (ECCC, retired) indicated that the Niagara River itself delivers low concentrations of *E. coli* to the beach, usually associated with low level human sewage impacts (NRRAP 2019). Additionally, field observations recorded throughout the course of the summer noted the frequent presence of gulls and geese at QRB; birds were observed on 44% of sampling days, with up to 70 Canada geese observed at a time.

There were three instances in which *E. coli* levels exceeded the water quality limit in the absence of significant precipitation; this indicates the potential presence of other bacterial sources such as upstream sources in the Niagara River, wildlife at the beach, and/or sediment-bound *E. coli* disturbed by strong wind and waves. Studies have shown that *E. coli* binds very well to loose particles such as sand and can be re-suspended during windy/wavy weather (Vogel et al., 2016). Additionally, anecdotal observations noted that the bacterial exceedances which occurred in the absence of significant precipitation coincided with other types of turbulent weather conditions (e.g., strong winds and waves). For example, on June 24th, the *E. coli* geometric mean at the beach was 325 CFU/100 mL and no significant rainfall was recorded; however, the waters were rough/wavy and the weather report recorded wind speeds up to 30-40 km/h.

In addition to sampling the beach, one grab sample was taken from the mouth of the stormwater outlet which flows into QRB and from the point where the stormwater runoff from the outlet meets the beach water at the shoreline. Overall, grab samples taken from the mouth of the storm outfall had higher levels of bacteria compared to the geometric mean beach results; notably, high levels of bacteria measured at the outlet did not translate to higher bacteria levels at the beach (most days when the outlet was at its highest *E. coli* levels >1000 CFU/100ml, the beach *E. coli* geomean was <100 CFU/100ml and often <30 CFU/100ml). Additionally, although *E. coli* levels were on average higher at sampling points close to the outfall (e.g. QR4 and QR5 were generally higher than QR1, QR2 and QR3), the differences were generally small and there was no gradient indicating consistent downstream impacts from the outfall. At present, the Town of NOTL is concluding a separate investigation into the storm sewer catchment area that drains to the outlet at QRB and remedial actions are still underway. Accordingly, a separate report of the data collected from the storm sewer catchment area and the outlet is being prepared by GM BluePlan, an engineering consulting firm contracted by the Town.

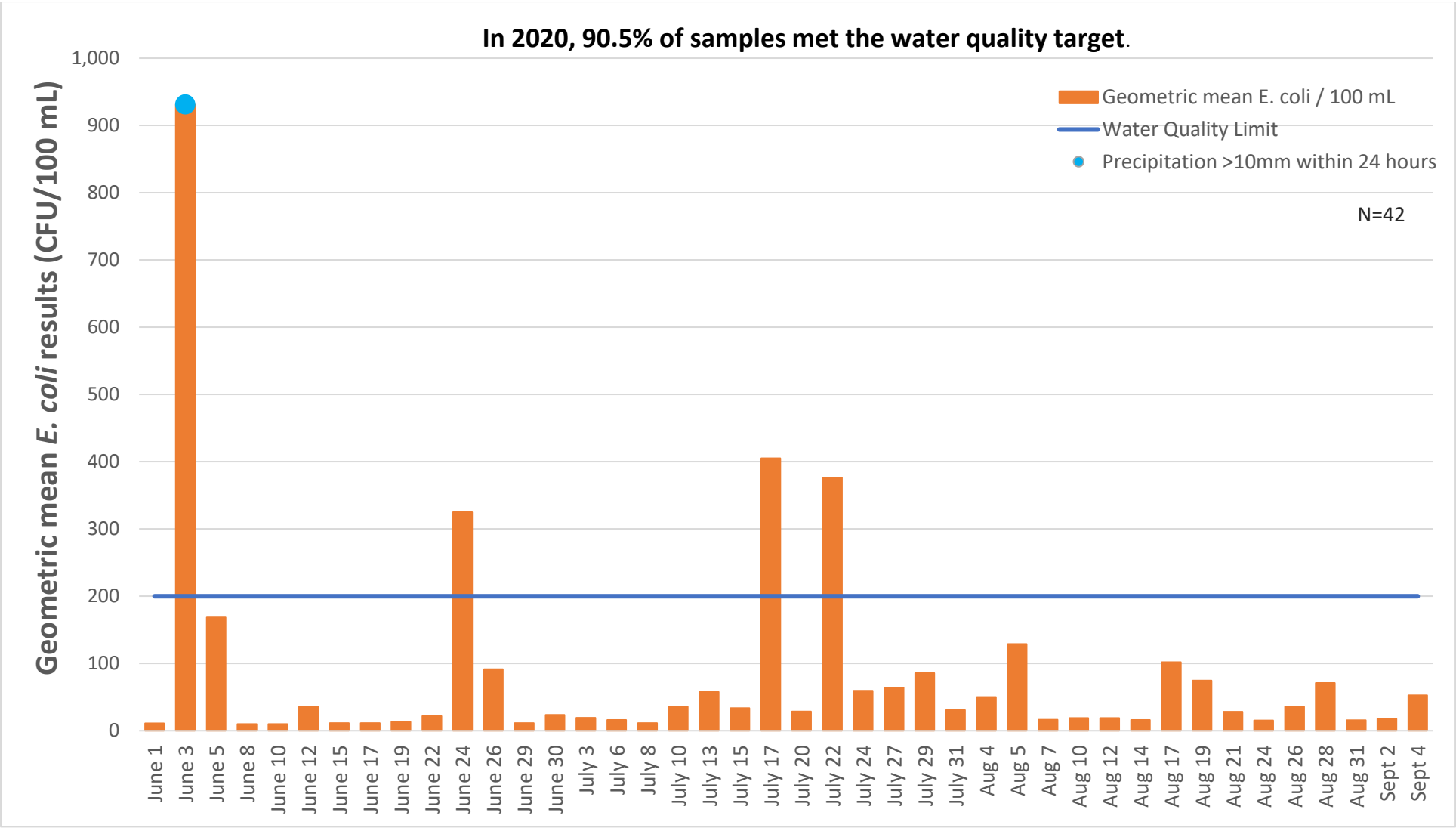

Figure 8: Geometric mean *E. coli* levels of each sampling event at Queen's Royal Beach during the 2020 swimming season. Blue dot markers indicate days with significant precipitation (i.e., greater than 10mm within 24 hours).

Conclusions

This study represents the third year of a three-year monitoring plan for Queen's Royal Beach water quality sampling. Overall, 90.5% of the sampling events from June 2020 to September 2020 met established water quality targets (i.e. geometric mean *E. coli* levels equal or less than 200 CFU/100mL). Based on the results of this study, the QRB met the Niagara River RAP's criterion #2: "at least 80% of the geometric mean results of recreational water samples (when sampled at least once per week) meet the Ontario Ministry of Health Recreational Water Quality Guideline (<200CFU/100 mL) each swimming season for a minimum of three years)".

The QRB was 'Posted' a total of 4 times during the swimming season. The peak exceedance of bacteria levels coincided with a significant rainfall event on June 4. The other exceedances were relatively low and likely due to wildlife, wave action which stirs up sediment-bound *E. coli*, or other upstream sources in the Niagara River. Samples taken from the nearby stormwater outfall consistently had higher *E. coli* levels than the beach. Results from this limited monitoring study indicate that, in 2020, the storm outfall was not significantly impacting beach water quality. Further information from a separate, concurrent monitoring study by GMBluePlan Consultants may provide additional information about the storm sewer catchment area and outfall.

Numerous remedial actions have been completed (or were in progress over the summer) by the Town of NOTL to resolve the most severe issues with the storm sewer system. For example, raccoon grates were installed in 2019, sewer infrastructure improvements completed in 2019/20, several best practices (e.g., regular maintenance of catchbasins), and a bioswale (low-impact development technique) in Simcoe Park was also constructed in 2020. The Town of NOTL will be initiating additional infrastructural upgrades to the King St. drainage area during the 2021 season, including the installation of trenchless structural lining in the mainline pipes within the QRB catchment area. All of these actions were specifically aimed at improving water quality in the storm sewer catchment area and, in turn, the beach. Further information about the efficacy of the remedial actions (including the bioswale) will be provided through a report by GMBluePlan Consultants, as it was not part of the scope of this study.

Given the QRB met water quality guidelines for the past 3 consecutive years, it is recommended that the RAP Team examines whether the other delisting goals have been met in order to re-designate the status of the Beach Closings challenge to 'Not Impaired'. The following suggestions are also recommended to complement remediation measures already underway in the Town of NOTL:

- Given the presence of wildlife at QRB, it is recommended that continued measures be put into place to deter wildlife from using the area. To deter waterfowl, measures such as reflective streamers and artificial owls/prey birds could be considered. In order to reduce the number of birds attracted to the beach, signage could also be posted at the beach advising visitors not to feed birds and other wildlife, and more garbage receptacles could be placed near/around the beach to reduce litter.
- To help protect public health, a sign should be posted at the mouth of the outlet, advising residents not to rest or allow their pets to rest or drink from the flow of water coming from the storm outlet. Additionally, general educational signage to protect human health (wash hands after swimming, avoid recreational swimming following rainfall or in high waves) could be added at the beach.
- Future long-term monitoring requirements and responsibilities for Queen's Royal Beach (beyond the scope of the RAP) need to be determined. For example, monitoring at QRB could/should be performed according to local public health guidance and regularly reported to the public.

Acknowledgements

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We would like to extend special thanks to Natalie Green (NRRAP Project Manager) for her guidance and support in preparing this report, as well as Josh Diamond from the NPCA for providing a reliable source of rain data to monitor precipitation during this study.

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Regional Municipality of Niagara. King Street, Queen's Royal Beach [map]. Layers used: 2018 Imagery, 2015 Imagery, 2010 Imagery, 2002 Imagery, 2000 Imagery, 1934 Imagery. Scale 1: 5,000. Generated by Paula Moura; using "Niagara Navigator" <http://maps.niagararegion.ca/Navigator/> (Accessed September 23, 2019).

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Appendices

Appendix A: Detailed Field Observations

Table A-1: Summary of field observations in June, organized by sampling date.

Date	Temperature (ºC)	Wind Speed (km/h)	Weather Conditions	Observations
June 1st	18	n/a	Sunny, temperate	Beach was fenced off/closed to public. Water was clear at the shoreline as well as at outflow pipe (QRS). Wave height was 5 cm and the outflow was low and steady. Algae was present on the rocks at the shoreline.
June 3rd	21.4	23	Cloudy, windy, temperate, light rain	Water was turbid (green brown coloured) due to waves. The water level at the shoreline was relatively high and outflow pipe flow was slightly higher than usual. Outflow water was also somewhat turbid.
June 5th	27	16	Sunny, warm	Water was clear at shoreline and somewhat wavy. Few people were present at the beach on arrival. Flow from outflow pipe was steady and relatively clear. Filamentous algae present in the flow from the outfall pipe and along the beach. Some (2-3) small dead fish seen near the shoreline.
June 8th	19	13	Sunny, warm	Water was somewhat turbid due to strong waves (10 cm wave height); old algae (green, brown) was present on the shoreline. Filamentous algae present in the waves. Off-white colored foam was present in the waves near the shoreline of the QR 1 location. Water from outlet was clear, flow was low and steady. There was some bird activity also present at the location, including red winged black birds on the shore and a couple of geese in the water.
June 10	23	13	Sunny, warm	Water was slightly turbid. Old algae (green, brown) present on the shoreline. Filamentous algae present in the waves. There were strong waves 10-13 cm in height. Water from outlet was turbid, slightly brown in color. Flow of the outlet was low and steady. Waterfowl like gulls and geese were seen near the beach area.
June 12	19.3	6.2	Sunny, warm	Water was slightly turbid. There were strong waves 13 cm in height. Filamentous Algae was present in the water. Water from outlet was clear but there was some filamentous algae growth near QRS, flow was low and steady. Canadian Geese and gulls were observed in the area.
June 15	16.3	13	Sunny, warm, clear	The water was very clear. The waves were about 5 cm in height; water was very calm. Water from outlet was low and steady. A group of Canadian geese was present near QR5.
June 17	19.1	0	Sunny, warm, clear	The water was very clear. The waves were about 3 cm in height. Water from outlet was low and steady. A big group of Canadian geese (approx.. 30 to 40) was present near QR2 and QR1. Squirrels and gulls were also observed near the shoreline.

Table A-1 (continued)				
June 19	24.6	13	Sunny, warm, clear	The water was very clear. The waves were about 1 cm in height; water was very calm. There were small fish present near the shoreline. A large group of approx. 70 Canadian geese was present on the shoreline near QRO. Water from outlet was low and steady.
June 22	23.8	0	Cloudy	The water was very clear. The waves were about 3cm in height. Water was very calm. There were small fish present near the shoreline. A large group of Canadian geese was present again on the shoreline. Water from outlet was low and steady.
June 24	23.8	18	Sunny, warm, windy	The water was turbid. The waves were high about 15 to 20 cm. There were Canadian geese present near shoreline. Water level from outlet was high and steady.
June 26	23.3	12.8	Partly sunny, some clouds	The water was clear and calm. The water from outlet was clear and steady. There were 8-10 Canadian geese present on the shoreline near QR3. Some visitors were present on the beach.
June 29	23.3	8.7	Sunny, clear, warm	The water was clear and calm. The waves were 5 cm high, some filamentous algae present in the water. The water from outlet was clear and steady. Visitors present on the beach, and kayakers present in the water.
June 30	21.5	21	Sunny, clear, warm	The water was clear and calm. The waves were 7 cm high, some filamentous algae present in the water. The water from outlet was clear and steady. Visitors present on the beach, and kayakers present in the water.

Table A-2: Summary of field observations in July, organized by sampling date.

Date	Temperature (ºC)	Wind Speed (km/h)	Weather Conditions	Observations
July 3	24.8	6.3	Sunny, warm, clear	The water was slightly turbid and calm. There were no waves present. The water from the outlet was clear and steady. Canadian geese were present on the shoreline during sampling. Bird droppings were found on the shoreline near QR3 and QR5. Several visitors and kayaks were present on the beach.
July 6	24.6	7.2	Sunny, warm, clear	The water was clear and calm. The waves were 6 cm high; some filamentous algae present in the water. The water from outlet was clear and steady. Canadian geese were present on arrival at the beach. Visitors present on the beach, and kayakers present in the water.
July 8	28.2	3.3	Sunny, warm, clear	The water was clear and calm; filamentous algae was floating in the waves. Water flow from outlet was moderate, clear and steady. People were present along the beachfront, and kayakers/boaters were present in the water.
July 10	26.2	0	Partly sunny, cloudy, warm	Water was slightly turbid. There were no waves present. There were group of Canadian geese (40) present on the shoreline during the sampling time. The water from outlet was clear/steady. A small number of beachgoers were present at QRB.
July 13	18	13	Cloudy, warm	The water was turbid and there were waves present (10cm). The water from outlet was clear and steady; water flow at the outlet was high. People were present along the beachfront, and kayakers/boaters were present in the water.
July 15	24.4	1.6	Sunny, warm, clear	The water was very calm and; some filamentous algae was present in the water and washed up on the shoreline. The flow from outlet was clear and steady. There was a group of geese present in the water near QR4. People were present along the beachfront, and kayakers/boaters were present in the water.
July 17	22.3	16.9	Sunny, warm, clear	Strong waves present in the water(13cm); water colour was turbid greenish-blue. Washed up filamentous algae still present on the shoreline. The water from outlet was clear and steady. People were present along the beachfront, and kayakers/boaters were present in the water.
July 20	24.5	10.3	Sunny, warm, clear, windy	10 cm waves present in the water. The water was translucent. The flow from the outlet was high, clear and steady. People were present along the beachfront, and kayakers/boaters were present in the water.
July 22	22	0	Cloudy/overcast, warm	The waves were about 2 cm, and the water was translucent. The flow from outlet was steady; the water from the outlet was turbid and dark green colored. There were geese present on the shoreline; also observed signs of guano and washed up algae near the shoreline. People were present along the beachfront, and kayakers/boaters were present in the water.
July 24	22.8	9.2	Sunny, warm, clear, windy	The waves were strong, approx. 15 cm and water was turbid. Filamentous algae was observed floating in the water and it was also seen on the shoreline. The flow from outlet was clear, moderate and steady. There were visitors present on the beach during the sampling time.

Table A-2 (continued)				
July 27	28.3	3.8	Sunny, warm, clear	The waves were about 8 cm in height; filamentous algae was floating in the water. The flow from outlet was clear and steady. A translucent, oily film was observed on the water at the end of the outlet flow, right before the beach water meets the outlet water. Old, greyish-green filamentous algae was washed up near the shoreline. People were present along the beachfront, and kayakers/boaters were present in the water.
July 29	n/a	n/a	Sunny, warm, clear	The waves were about 5 cm in height. The water was turbid and there was filamentous algae present in the water. The flow from outlet was clear and steady; the greasy film observed on July 27th was still present, as was the filamentous algae washed up on the shoreline. There were 22 Canadian geese, 4 ducks and 3 seagulls present on the beach. People were present along the beachfront, and kayakers/boaters were present in the water.
July 31	n/a	n/a	Sunny, warm, clear	Strong waves present in the water (approx. 10cm in height). The water was moderately turbid (was translucent) and filamentous algae was observed in the waves. The flow from the outlet was slow, steady and clear.

Table A-3: Summary of field observations in August and September, organized by sampling date.

Date	Temperature (ºC)	Wind Speed (km/h)	Weather Conditions	Observations
August 4	22.3	0	Cloudy, warm, raining	The water was moderately turbid. The flow from the outlet was high, clear and steady. There were only a few residents present on the beach during the sampling time.
August 5	18.9	11.8	Sunny, warm, clear	The water was slightly turbid and the waves were strong (15cm in height). The water from the outlet was slow, steady and clear. There was a flock of geese present on the west side of the beach. People were present along the beachfront, and kayakers/boaters were present in the water.
August 7	21.5	1.2	Sunny, warm, clear	The water was slightly turbid and calm. There was a group of geese present in the water. The flow from the outlet was slow and steady. There was a small area of greasy film present in the outlet water, halfway between the outlet and the shoreline. People were present along the beachfront, and kayakers/boaters were present in the water.
August 10	27.5	5.8	Sunny, clear, hot, humid	Water was calm and clear; filamentous algae was noted covering the rocks located underwater close to the shoreline. The flow from the outlet was low, steady, and translucent brown. Several residents were observed around the beach and adjacent areas.
August 12	21.6	2.3	Sunny, warm, clear	The water was calm and clear. The waves were 2cm high. The flow from outlet was high and steady. The outlet water looks moderately turbid, the film on the water was still present halfway between the outlet and the shoreline. There were a few people present on the beach during the sampling time.
August 14	21.8	0.8	Sunny, clear	The water was turbid and filamentous algae was present in waves near QR2 and QR1. The waves were 10 cm high. The flow from outlet was moderate and steady. People were present along the beachfront, and kayakers/boaters were present in the water.
August 17	22	15	Sunny, clear	The water looks slightly turbid. The waves were 10 cm high. The flow from outlet was moderate and steady. People were present along the beachfront, and kayakers/boaters were present in the water.
August 19	20.2	16.3	Sunny, warm, windy	The waves were 20 cm high and the water looks significantly turbid. We took the first sample manually at QR3 but after that we used the pole for all the other sampling points due to strong waves. The flow from outlet was moderate and steady. There was washed up algae present near the shoreline. People were present along the beachfront, and kayakers/boaters were present in the water.
August 21	24.5	0	Sunny, warm, clear	The water looks slightly turbid. The waves were 6cm high. The flow from outlet was moderate and steady. There was a greasy film present on the outlet water near the outlet. People were present along the beachfront, and kayakers/boaters were present in the water.
August 24	26.6	0	Sunny, warm, clear	The water looks clear. The waves were 2cm high. The flow from outlet was moderate and steady. There was a greasy film on the outlet water right before it meets the beach water. People were present along the beachfront, and kayakers/boaters were present in the water.

Table A-3 (continued)				
August 26	20.1	7.9	Intermittent sun, cloudy, warm	Beach water was somewhat turbulent/turbid; appeared translucent brown-green in colour. A thick layer of filamentous green/greenish-brown algae was washed up on the shoreline; approx. 2-3 feet in width, appeared contain both fresh and old algae. White foam was noted in the waves close to QR5. The flow from the outlet was steady, low and largely clear, however there was a small patch of greasy, white-hued film adjacent to the area where the outlet flow meets the beach water. Several people were present on the beach, and kayaks were located adjacent to the outlet, at the launching area.
August 31	22.4	0	Sunny, warm, clear	Beach water was calm and relatively clear; it did seem noticeably lower compared to earlier in the season, as evident by the mud level on the rocks at QR1. The thick layer of algae located along the length of the beach had been covered by sand and was considerably thicker than previously; ranging in depth from approx. 3in to 5in. Flow from the outlet was clear, steady and low.
September 2	25.2	4.7	Overcast, hot, humid, rainy	Beach water was calm and clear; translucent greenish-brown in colour. Thick layer of algae was still present along the length of the shoreline. Flow from the outlet was clear, steady and low.
September 4	21.7	10.8	Sunny, clear, warm, light wind	Beach water was turbulent/turbid; translucent greenish-brown in colour. Sampling was completed using a sterilized sampling pole due to safety concerns. Thick layer of algae was still present and prominent along the entire length of the shoreline. Flow from the outlet was clear, steady and low.

Appendix B: In-Field Measurement Data for Surface Water Parameters

Table B-1: 2020 field measurements for surface water parameters. 'BDL' represents a reading that was below the level of detection for the instrument being used.

Date Surveyed	Air Temperature (ºC)	Wind Speed (km/h)	Currently Raining	Daily Precipitation (mm)	Water Temperature (ºC)	Wave Height (in)	Turbidity (NTU)
June 1	13.0	14.0	NO	0	11.0	1.960	4.39
June 3	21.4	0	YES	12.25	14.9	1.180	5.94
June 5	23.6	2.8	NO	0	14.6	0.394	2.10
June 8	17.0	10.1	NO	0	15.8	3.940	2.20
June 10	27.7	0	NO	0	17.5	3.940	1.90
June 12	19.3	6.2	NO	0	17.6	5.120	4.61
June 15	16.3	13.0	NO	0	17.5	1.970	1.28
June 17	19.1	0	NO	0	17.5	1.180	1.19
June 19	24.6	13.0	NO	0	18.0	0.394	1.49
June 22	23.8	0	NO	0	18.9	1.180	1.28
June 24	18.8	18.0	NO	0	19.0	6.690	4.59
June 26	23.3	12.8	NO	0.25	20.8	0.394	1.88
June 29	23.3	8.7	NO	0.25	21.5	1.970	1.90
June 30	21.5	21.0	NO	0	21.8	2.760	1.60
July 3	24.8	6.3	NO	0	22.2	1.180	1.62
July 6	24.6	7.2	NO	0	23.5	2.360	1.39
July 8	28.2	3.3	NO	0	24.0	1.180	1.34
July 10	26.2	0	NO	3.25	24.5	1.570	1.90
July 13	18.0	13.0	NO	0	24.5	3.900	1.95
July 15	24.4	1.6	NO	0	24.6	5.120	1.80
July 17	22.3	16.9	NO	5.50	24.0	3.900	7.60
July 20	24.5	10.3	NO	2.50	24.6	0.788	3.91
July 22	22.0	0	YES	2.75	24.5	5.910	1.78

Table B-1 (continued)							
Date Surveyed	Air Temperature (ºC)	Wind Speed (km/h)	Currently Raining	Daily Precipitation (mm)	Water Temperature (ºC)	Wave Height (in)	Turbidity (NTU)
July 24	22.8	9.2	NO	0	24.5	5.910	2.66
July 27	28.3	3.8	NO	0	25.1	3.150	1.73
July 29	22.6	0	NO	0	25.0	1.970	3.19
July 31	23.0	1.6	NO	0	25.3	3.940	6.72
Aug 4	22.3	0	NO	0.25	24.6	0.780	3.21
Aug 5	18.9	11.8	NO	3.50	23.7	5.910	3.58
Aug 7	21.5	1.2	NO	0	24.5	0.787	5.55
Aug 10	27.5	5.8	NO	0	24.6	0.787	3.10
Aug 12	21.6	2.3	NO	0	24.5	0.787	2.75
Aug 14	21.8	0.8	NO	0	24.6	3.940	9.33
Aug 17	22.0	15.0	NO	0.25	24.3	3.940	4.12
Aug 19	20.2	16.3	NO	0	22.6	7.870	4.55
Aug 21	24.5	0	NO	0	23.5	2.360	5.82
Aug 24	26.6	0	NO	0	24.1	0.787	2.38
Aug 26	20.1	7.9	NO	0	23.6	1.960	2.82
Aug 28	23.1	5.4	NO	0	23.8	0.787	17.80
Aug 31	22.4	0	NO	0	23.2	0.390	2.91
Sept 2	25.2	4.7	YES	0	23.6	1.570	1.61
Sept 4	21.7	10.8	NO	0	22.1	7.870	11.70

Appendix C: Beach Water (QR1-QR5) *E. coli* Data

Table C-1: 2020 Beach water quality results provided by NRPHU based on samples collected during this. Results of 'ND' indicate a lack of data. Water quality results on September 2nd and 4th were provided by E3 Laboratories.

Date Sampled	QR1	QR2	QR3	QR4	QR5	Geometric Mean	Exceeds MOHLTC Guidelines?
June 1	10	20	10	10	10	11	NO
June 3	1000	1000	1000	1000	700	931	YES
June 5	260	170	90	180	190	169	NO
June 8	10	10	10	10	10	10	NO
June 10	10	10	10	10	10	10	NO
June 12	10	50	60	50	40	36	NO
June 15	10	10	10	20	10	11	NO
June 17	10	10	20	10	10	11	NO
June 19	10	10	20	10	20	13	NO
June 22	10	10	10	120	40	22	NO
June 24	500	320	350	380	170	325	YES
June 26	80	90	100	50	180	92	NO
June 29	14	10	10	14	10	11	NO
June 30	10	40	20	30	30	24	NO
July 3	30	10	10	30	30	19	NO
July 6	50	10	10	10	20	16	NO
July 8	10	20	10	10	10	11	NO
July 10	40	60	50	10	50	36	NO
July 13	40	40	110	60	60	58	NO
July 15	30	20	30	60	40	34	NO
July 17	420	310	350	420	570	405	YES
July 20	70	30	30	10	30	29	NO
July 22	150	140	360	1000	1000	376	YES
July 24	280	220	120	10	10	59	NO
July 27	50	120	40	50	90	64	NO
July 29	70	110	100	150	40	86	NO
July 31	110	50	10	50	10	31	NO
Aug 4	10	50	50	180	70	50	NO
Aug 5	50	150	180	110	200	129	NO
Aug 7	10	30	40	10	10	16	NO
Aug 10	10	30	20	20	20	19	NO
Aug 12	10	30	40	10	20	19	NO
Aug 14	10	10	20	50	10	16	NO
Aug 17	50	90	150	180	90	102	NO
Aug 19	40	60	40	100	240	75	NO
Aug 21	40	30	10	50	30	28	NO
Aug 24	20	10	20	10	20	15	NO
Aug 26	40	20	60	40	30	36	NO
Aug 28	120	100	100	50	30	71	NO
Aug 31	10	10	10	30	30	16	NO
Sept 2	10	30	10	30	20	18	NO
Sept 4	20	90	90	50	50	53	NO

Appendix D: Outlet (QRS/QRO) *E. coli* Data

Table D-1: Results of samples collected at the mouth of the storm outfall and the runoff sample where flow met the Niagara River. The detection limit for sample analysis of *E. coli* in this study was 1000 CFU/100mL (Please see page 7).

Date	QRO (runoff)	QRS (source)	Source flowing?	Sig. rainfall within 24 hrs
June 1	60	240	YES	NO
June 3	1000	1000	YES	YES
June 5	180	580	YES	NO
June 8	90	520	YES	NO
June 10	1000	1000	YES	NO
June 12	1000	360	YES	NO
June 15	30	610	YES	NO
June 17	690	50	YES	NO
June 19	410	1000	YES	NO
June 22	90	200	YES	NO
June 24	1000	1000	YES	NO
June 26	210	220	YES	NO
June 29	640	1000	YES	NO
June 30	170	300	YES	NO
July 3	210	330	YES	NO
July 6	1000	1000	YES	NO
July 8	610	930	YES	NO
July 10	1000	1000	YES	NO
July 13	1000	870	YES	NO
July 15	1000	1000	YES	NO
July 17	1000	1000	YES	NO
July 20	1000	1000	YES	NO
July 22	1000	1000	YES	NO
July 24	1000	1000	YES	NO
July 27	1000	1000	YES	NO
July 29	1000	1000	YES	NO
July 31	480	980	YES	NO
Aug 4	1000	1000	YES	NO
Aug 5	1000	1000	YES	NO
Aug 7	1000	1000	YES	NO
Aug 10	1000	1000	YES	NO
Aug 12	1000	1000	YES	NO
Aug 14	180	510	YES	NO
Aug 17	1000	600	YES	NO
Aug 19	1000	1000	YES	NO
Aug 21	580	1000	YES	NO
Aug 24	1000	1000	YES	NO
Aug 26	940	370	YES	NO
Aug 28	1000	1000	YES	NO
Aug 31	510	590	YES	NO
Sept 2	400	770	YES	NO
Sept 4	590	90	YES	NO