Bond Street Beach Water Quality Report

April 18th, 2021

KAWARTHA CONSERVATION

Discover · Protect · Restore

About Kawartha Conservation

Who we are

We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?

Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support

We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance

In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*. The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan Monaghan.

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Abbreviations

%CV:	Coefficient of variation
µS/cm:	Microsiemens per centimeter
ºC:	Degree Celsius
BCLMP:	Balsam Lake and Cameron Lake Management Plan
CAL:	Calculated
CCME:	Canadian Council of Ministers of the Environment
CKL:	City of Kawartha Lakes
Cond:	Conductivity
DO:	Dissolved Oxygen
E. coli:	*Escherichia coli*
ECCC:	Environment and Climate Change Canada
km^2	Square kilometers
masl:	Meters above sea level
MECP:	Ontario Ministry of the Environment, Conservation & Parks
NH_3:	Ammonia
NTU:	Nephelometric Turbidity Unit
OMNRF:	Ontario Ministry of Natural Resources and Forestry
PWQMN:	Provincial Water Quality Monitoring Network
PWQO:	Provincial Water Quality Objectives
Temp:	Temperature
TN:	Total Nitrogen
TKN:	Total Kjeldahl Nitrogen
TP:	Total Phosphorus
TSS:	Total Suspended Solids
TSW:	Trent Severn Waterway
Turb:	Turbidity

Executive Summary

Kawartha Conservation is a local watershed management organization that is tasked to deliver balanced programs that protect and manage natural resources. Through the Balsam Lake and Cameron Lake Management Plan, the Bond St. Beach in Fenelon Falls was identified as an area of concern as it had an average recreational water quality exceedance rate of 53% from 2010-2017. Since then, much work was done by the City of Kawartha Lakes, specifically, the removal of the concrete piers which promoted high *E. coli* densities. This resulted in a reduction of the average exceedance rate to 12% (2018-2020) and a better recreational water quality for Bond St. Beach.

The aim of this study was to determine where the greatest densities of *E.coli* occurred at the beach and at two other adjacent sites. This study also evaluated any relationships between *E.coli* densities, water chemistry parameters, and shoreline conditions at Bond St. Beach.

Results suggested that high densities of *E.coli* were of animal origins, primarily from avian (birds) inputs. Within the bathing area, exceedances of the Ontario recreational water quality standard (A total of 8 dates) mostly occurred during the month of July. Weak relationships with rain events (24 and 48 hour periods) may suggest dry event sources such as the input of animal feces. Higher density events that occurred in the bathing area also occurred in the beach sand samples, where the highest density was found on July 25th.

Surprisingly, there was an unnamed stormwater outflow site found at Bond St. Beach (located north of the public beach). The unnamed site was found to contribute a significant amount of dissolved salt to Bond St. Beach during precipitation events.

To enhance one of Kawartha's most popular beaches, this report outlines the following key recommendations:

- **Continue to monitor Bond St. Beach during the recreational period of June – August. The Beach Management Plan for Bond St. Beach should aim to be Blue Flag recognized.**
- **With further funding and collaboration, investigate the source (human, bird, or dog) of *E.coli* . This can be done through microbial source tracking and analysis.**
- **Enhance community involvement through volunteer events such as community clean-up days, or a citizen science monitoring program.**
- **Redirect (and naturalized) the unnamed stormwater outflow to a downstream (of the beach) location.**
- **Implement a natural landscaping approach along parts of the shoreline.**
- Continue the removal of fecal matter (and other pieces of litter) prior to peak beach usage (in the mornings). This could be done by seasonal municipal staff alongside community volunteers.

1.0 Introduction

Kawartha Conservation plays a pivotal role in natural resource management within its 2600 km^2 jurisdiction. Bond Street Beach (BSB) is one of many popular recreational areas found in the Kawartha Conservation jurisdiction, specifically within the Cameron Lake watershed. Its central location in Fenelon Falls and its proximity to the Trent-Seven Waterway attracts many users to the area, where many often bath in the waters during the summer period. Through the Balsam Lake and Cameron Lake Management Plan (BCLMP; Kawartha Conservation 2015), several concerning water quality issues have been identified throughout the region. These issues can have lasting impacts on tourism, recreational opportunities, and ecological health.

To assess the recreational water quality (and the risk to human health) of BSB, the Haliburton, Kawartha Pine Ridge District Health Unit monitors the densities of fecal indicator bacteria (FIB), specifically, *Escherichia coli* (*E. coli)*, in surface waters surrounding the bathing area. These assessments follow strict methods set out by the Ministry of Health and Long-Term Care's *Operational Approaches for Recreational Water Guideline (2018).*

The BCLMP has identified Bond St. Beach as an area of concern. This is due to its popularity, and its historical exceedances for both the provincial water quality objectives (PWQO) and the Ontario recreational water standards.

Under the previous 100 cfu/100 mL standard, BSB had exceeded the recreational water quality standards 53% of the time (2010-2017). However, it should be noted that the Bond St. Beach area has undergone significant changes to enhance the water quality of Cameron Lake. This includes the removal of the concrete piers on March 2017 (Figure 1). The removal of the concrete piers has discouraged waterfowl usages (a source of *E. coli*) and has encouraged water circulation in the area (reducing favourable condition for fecal bacterial to thrive) (Figure 1). Under the current 200 cfu/100 mL standard (Ministry of Health and Long-Term, 2018), BSB exceeded the standard only 12% of the time (2018-2020).

High *Escherichia coli (E. coli)* densities are likely the result of a combination of factors: excessive feces from birds (particularly Canada Geese and Mallard Ducks), urban runoff, pet feces, and/or shallow, warm waters with limited water circulation (Kawartha Conservation, 2015). Additionally, studies have concluded that sand located near the shoreline at freshwater beaches demonstrated higher densities of *E. coli* than the adjacent shallow surface water (Kinzelman *et al*., 2004: Staley *et al*., 2015; Vogel *et al.,* 2017). This may suggest that beach sand may act as a reservoir or source of *E. coli* in recreational beaches and may contribute to poor water quality.

Figure 1. Site photos of Bond St. Beach prior (top) and after (bottom) the removal of the concrete piers.

The aim of this study was to determine where the greatest densities of *E.coli* occur at the beach and at two other adjacent sites and to establish any relationships between *E.coli* densities, water chemistry parameters and shoreline conditions. This study also attempts to assess foreshore (the area of the shore between the high- and low-water marks) *E*. coli densities at Bond St. Beach. To look at all of these aspects, a small scale study was carried out from June to the end of August in collaboration with the Haliburton, Kawartha Pine Ridge District Health Unit.

2.0 Methodology

2.1 Site Description

Bond Street Beach, also known as Garnett Graham Park, is located on the Trent Severn Waterway on Cameron Lake in Fenelon Falls, Ontario. The beach is located within a residential area at the end of both Bond and Francis Streets adjacent to the Victoria Rail Trail which sees a high density of users throughout the seasons (Figure 2, 3).

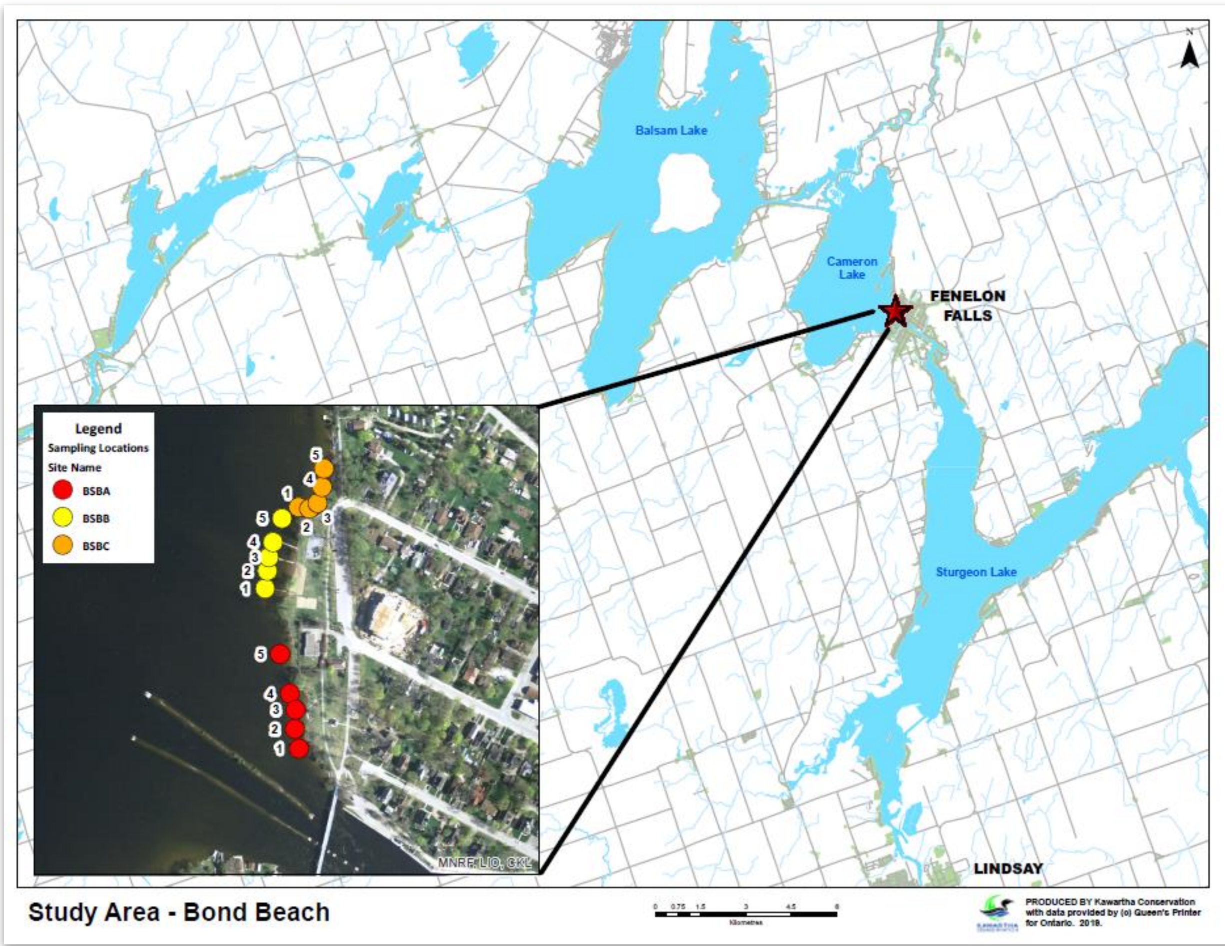

Figure 2. Map depicting the locations of the sampling sites (inserted map) and the location of Bond St. Beach in Fenelon Falls.

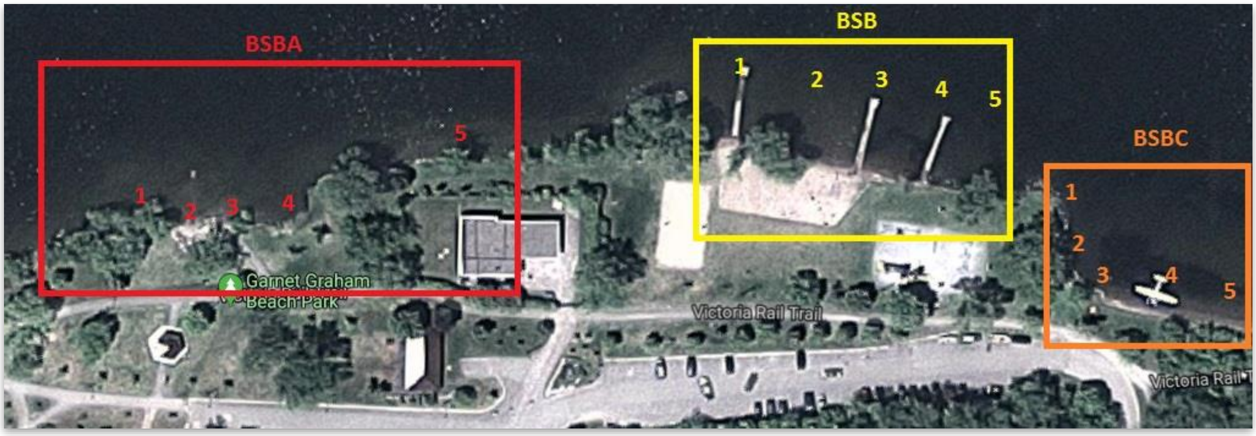

Figure 3. Map depicting the sampling locations for each site (BSBA, BSB, and BSBC).

2.2 Sampling Methods

The Ministry of Health and Long-Term Care *Operational Approaches for Recreational Water Guideline* (2018) provides the monitoring protocol that was followed. The protocol states that five (5) water samples are to be taken, determined by the length of the beach, and sample collection 0.15 to 030 m below the water surface where the depth is 1 to 1.5 m, or if less than 1 m in depth, sampling will occur as far from the shore as possible within the bathing area. Water samples for *E. coli* were collected daily (Monday to Friday) from the beach site from the beginning of June to the end of August, approximately around 9:00 am by Kawartha Conservation Staff. Additional data was collected during daily sampling, which included air and water temperature, turbidity, beach user and bather density, presence of feces, wave type and wind direction, and potential pollution sources (i.e., stormwater runoff, waterfowl or wildlife presence, dogs on beach). For more details see Appendix A. Beach survey data was also collected by volunteers each time they visited and removed geese feces.

Water chemistry sampling was completed weekly on Wednesdays at approximately 9:00 am at the beach site (BSB), as well as two upstream sampling locations (BSBA and BSBC) (Figure 3) for the following: total phosphorus, nitrogen (ammonia, nitrate, nitrite), total suspended solids, and chloride. Water samples for *E. coli* were also taken weekly (Wednesdays) for upstream sampling sites. General water quality data was collected for all sites using a YSI ProDSS handled multi probe unit, which included: water temperature, turbidity, pH, conductivity, and dissolved oxygen.

Table 1. General site characteristics and associated sampling frequency and parameter.

Site code	Media	Water chemistry	Vegetated buffer condition
BSB	Surface Water (daily)	Weekly	Beach
BSBA	Surface Water	Weekly	Limestone/renaturalized
BSBC	Surface Water	Weekly	Degraded
BSB1	Beach Sand	NA	Beach
BSB2	Beach Sand	NA	Beach

Beach sand samples were collected weekly (Wednesdays) at two different locations along a transect 5 metres up from the swash zone (the area where the water is able to each onto the shore). Sand was collected as composite samples comprised of 5 subsamples 30 cm apart and 10 cm deep with a sterilized spoon and placed in a sterile amber glass bottles provided by SGS Environmental Laboratories. Both surface water and beach sand samples were analysed by SGS Environmental Laboratories.

Methods for data analysis can be found in appendix B.

3.0 Results & Discussion

Field water quality parameters of Temperature (Temp), Dissolve Oxygen (DO), pH, conductivity (Cond), and Turbidity (Turb) were measured during every sampling event (daily for BSB and weekly for BSBA and BSBC). This aligned with the microbiological (*E. coli*) assessment of surface water samples by the Haliburton, Kawartha Pine Ridge District Health Unit. In addition, surface water samples for chemical analysis were sampled at a weekly interval by Kawartha Conservation. Chemical parameters that were assessed were: Ammonia (NH3), Nitrite (NO2), Nitrate (NO3), Total Phosphorus (TP), Chloride (Cl), and Total Suspended Solids (TSS).

Total Phosphorus (TP) is the measurement of all dissolve and bounded phosphorus in the water sample. Phosphorus is an important parameter to measure as it is one of the key nutrients for the growth of aquatic plants. Excess phosphorus in the water can contribute to nuisance growth of aquatic plants, starting the process eutrophication.

Total Nitrogen (TN) is the measurement of all organic (ammonia) and inorganic (nitrite and nitrate) nitrogen compounds in the water. Ammonia is a form of nitrogen that can be found in water. It is taken in as food by many aquatic plants, but can be toxic in high concentrations. Nitrogen is another essential nutrient needed for plant growth. Total Suspended Solids (TSS) is the measurement of all solid particles (not dissolve) in the water sample. In total, there were 87 field measurements, 87 *E. coli* results, and 39 chemical results (Table 2).

Table 2. Summary statistics of selective parameters for all sites and for all samples collected. Other parameters can be found in appendix C Table 1.

		ºC	mg/L	µS/cm	NTU	mg/L	CAL	mg/L	mg/L
SID	**Statistics**	**Temp**	**DO**	**Cond**	**Turb**	**NH3**	**TN**	**TP**	**TSS**
BSB	Count	61	61	61	36	13	12	13	13
	Mean	22.72	7.80	145.41	3.76	0.02	0.32	0.01	12.31
	%CV	10.4	7.8	4.7	164.8	42.7	17.5	107.5	151.2
	Median	23.40	7.95	145.10	1.20	0.02	0.33	0.01	2.00
	Min	16.90	5.82	119.80	0.44	0.01	0.22	0.003	1.00
	Max	26.10	9.15	165.60	30.37	0.05	0.43	0.06	47.00
BSBA	Count	13	13	13	7	13	13	13	13
	Mean	22.78	7.79	145.58	1.73	0.02	0.30	0.01	4.08
	%CV	10.6	8.5	3.6	75.3	68.2	26.7	71.7	133.0
	Median	23.10	8.01	146.70	1.31	0.02	0.33	0.01	2.00
	Min	16.30	6.41	131.40	0.73	0.01	0.10	0.003	1.00
	Max	25.40	8.77	152.50	4.59	0.06	0.43	0.03	16.00
BSBC	Count	13	13	13	7	13	13	13	13
	Mean	22.90	7.50	153.28	1.78	0.26	0.27	0.01	2.31

	%CV	10.0	12.7	5.0	102.9	329.2	24.3	67.7	79.9
	Median	23.30	7.78	154.40	1.08	0.03	0.28	0.01	2.00
	Min	16.80	5.65	143.10	0.51	0.002	0.10	0.004	1.00
	Max	25.80	8.85	168.40	5.83	3.06	0.33	0.03	7.00
Total	Count	87	87	87	50	39	39	39	39
	Mean	22.76	7.75	146.61	3.20	0.10	0.29	0.01	6.23
	%CV	10.3	8.7	4.9	167.9	480.0	28.8	84.8	189.4
	Median	23.40	7.92	146.60	1.20	0.02	0.33	0.01	2.00
	Min	16.30	5.65	119.80	0.44	0.002	0.05	0.003	1.00
	Max	26.10	9.15	168.40	30.37	3.06	0.43	0.06	47.00

Throughout the study period (June 4^{th} to August 30^{th}, 2018) surface water temperatures ranged from 16.30-26.10ºC, with a mean and median value of 22.76ºC and 23.40ºC (Table 2). The highest surface water temperature (26.10ºC) recorded was measured on July 4^{th}, 2018 at BSB.

Many aquatic organisms require different levels of dissolved oxygen (DO) to survive. Species such as Green Sunfish, Bluegill, and the Common Carp can tolerate lower levels of DO than other species such as Largemouth Bass, Northern Pike, and Rainbow Trout (Tang *et al*., 2020). Surface water temperatures greatly affect the concentration of oxygen in the water, where warmer waters tend to hold less oxygen than that of colder waters. Across all sites, levels of DO range from 5.65 to 9.15 mg/L, and a value of 7.75 and 7.92 mg/L was found for the mean and median of 7.75 and 7.92 mg/L (Table 2). Generally, BSBC had the lowest median (7.92 mg/L) and mean (7.75 mg/L), however, DO was consistent across all sites and within sites (%CV <30%) (Table 2). When compared to the PWQO (temperature dependant), all measurement did not exceed guidelines for warm water biota. In addition, measurements did not exceed CCME's (Canadian Council of Ministers of the Environment) lowest acceptable DO concentrations for the early (6.0 mg/L) and other life (5.5 mg/L) stages of fish for warm-water ecosystems (CCME, 1999). Thus, DO values measured at Bond St. Beach are found within acceptable levels outlined by PWQO and by CCME.

Water conductivity measures the ability of the water to conduct electricity and is influenced by the amount of dissolved salts in the water. Conductivity ranged from 119.8 to 168.4 µS/cm (Table 2). Mean and median values were calculated at 146.61 µS/cm and 146.60 µS/cm (Table 2) and are within the range found by Kawartha Conservation (2015). When compared between sites (only using weekly data), there was a significant different (Dunn's z test = -2.27, p=0.01) between sites BABA and BSBC (Figure 4). This suggest that there are an influence of dissolved salts at BSBC, which could originate from the parking lot (site BSBC is closer to the roadway and parking lot; Figure 2), and/or stormwater discharge (Figure 9).

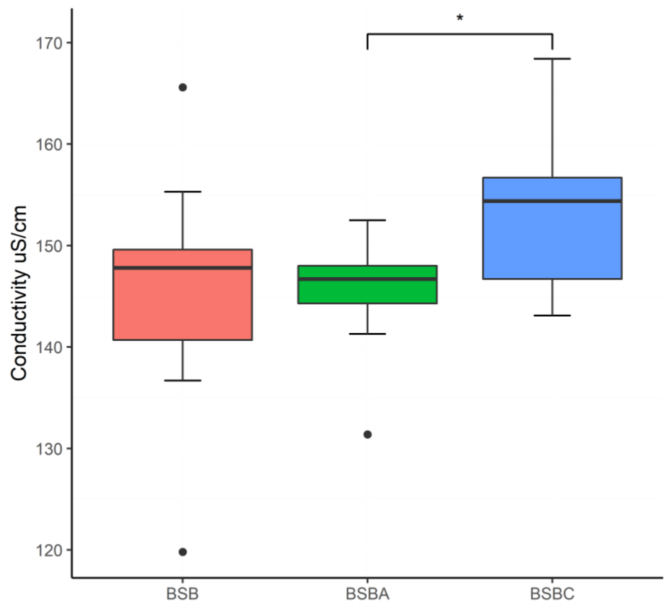

Figure 4. Boxplots of conductivity levels across the three sites. Statistical difference is depicted between BSBA and BSBC.

3.1 Nutrients

Phosphorus is one of the two primary nutrients required for the growth of aquatic plants and algae. Excess nutrients can cause aquatic plants and algae to grow uncontrollably. When this large biomass starts to decay, it consumes large amounts of oxygen, causing the system to become anoxic (lack of oxygen) through a process call eutrophication. The Provincial Water Quality Objective (PWQO) for total phosphorus (TP) in lentic systems, i.e., lakes and ponds, is set at 0.02 mg/L or 0.01 mg/L for naturally low TP systems (MECP, 1994). This objective is set to prevent nuisance algae and aquatic plant growth (MECP, 1994).

A total of 39 samples were collect for TP analysis. Results range from 0.003-0.056 mg/L with a mean and median value of 0.01 mg/L (Table 2, Figure 3). There were only three instances (7.7%) were TP concentrations exceeded the PWQO. This occurred on July 25th, 2018 for BSB (0.06 mg/L) August 15th, 2018 for BSBA (0.03 mg/L), and on August 8th, 2018 for BSBC (0.03 mg/L) (Table 2, Figure 3). There were no significant differences found between sites.

Generally, Cameron Lake is classified as oligotrophic (lacking nutrients; Kawartha Conservation, 2015). During the BCLMP, TP concentrations varied from 0.005 to 0.014 mg/L (note that these are mid-lake samples and not nearshore). When compared to historical values of TP at the Cameron Lake outlet, mean and median values were found to be consistent with values found by the PWQMN (1986-2014). However, higher values found (0.06 and 0.03 mg/L) were well above all other values found during that same period (1986-2014) and were more align with values measured between 1971-1985 (Max range = 0.03 to 0.05 mg/L) (Kawartha Conservation, 2015). There are concerns regarding the higher values found in this study as continue input of elevated phosphorus will lead to the deterioration of water quality and possible increase the frequency of harmful algae blooms.

Nitrogen is the other key nutrient required for the growth of aquatic plants and algae. In surface water, nitrogen can be present in different forms such as free ammonia and ammonium, nitrite, nitrate, and organic nitrogen. Anthropogenic (human sources) of nitrogen can originate from fertilizers (common ingredient is ammonia nitrate), discharge of wastewater, and human waste.

In this study, we sampled for ammonia, nitrite, nitrate, and total kjeldahl nitrogen. With that we can calculate Total Nitrogen (TN) by the sum of total kjeldahl nitrogen (ammonia, organic nitrogen) and nitrate-nitrite. Although there has not been a provincial and federal guideline for total nitrogen, others have proposed or adopted guidelines for TN, these are 1.0 mg/L by Alberta Environment (1999), and 1.07 for streams among agricultural fields (Chambers *et al*., 2008).

Total nitrogen results range from 0.05-0.43 mg/L, with a mean of 0.29 mg/L and a median of 0.33 mg/L (Table 2, Figure 5). Mean and median values were similar to that found further in the lake by Kawartha Conservation (2015) (Mean = 0.23-0.27 mg/L, median = 0.23-0.27 mg/L). However, maximum values from this study (0.43 mg/L) were higher than found in the BCLMP (0.30-0.37 mg/L; Kawartha Conservation, 2015). Generally, TN concentrations were consistent at BSB and were higher than those found in BSBA and BSBC (Figure 5), however no significant differences were found between sites. Total Nitrogen results from this study did not exceed guideline values outlined by Alberta Environment (1999) and Chambers *et al*., 2008), however, higher values found in this study are of concern as it could lead to poor water quality if left unchecked.

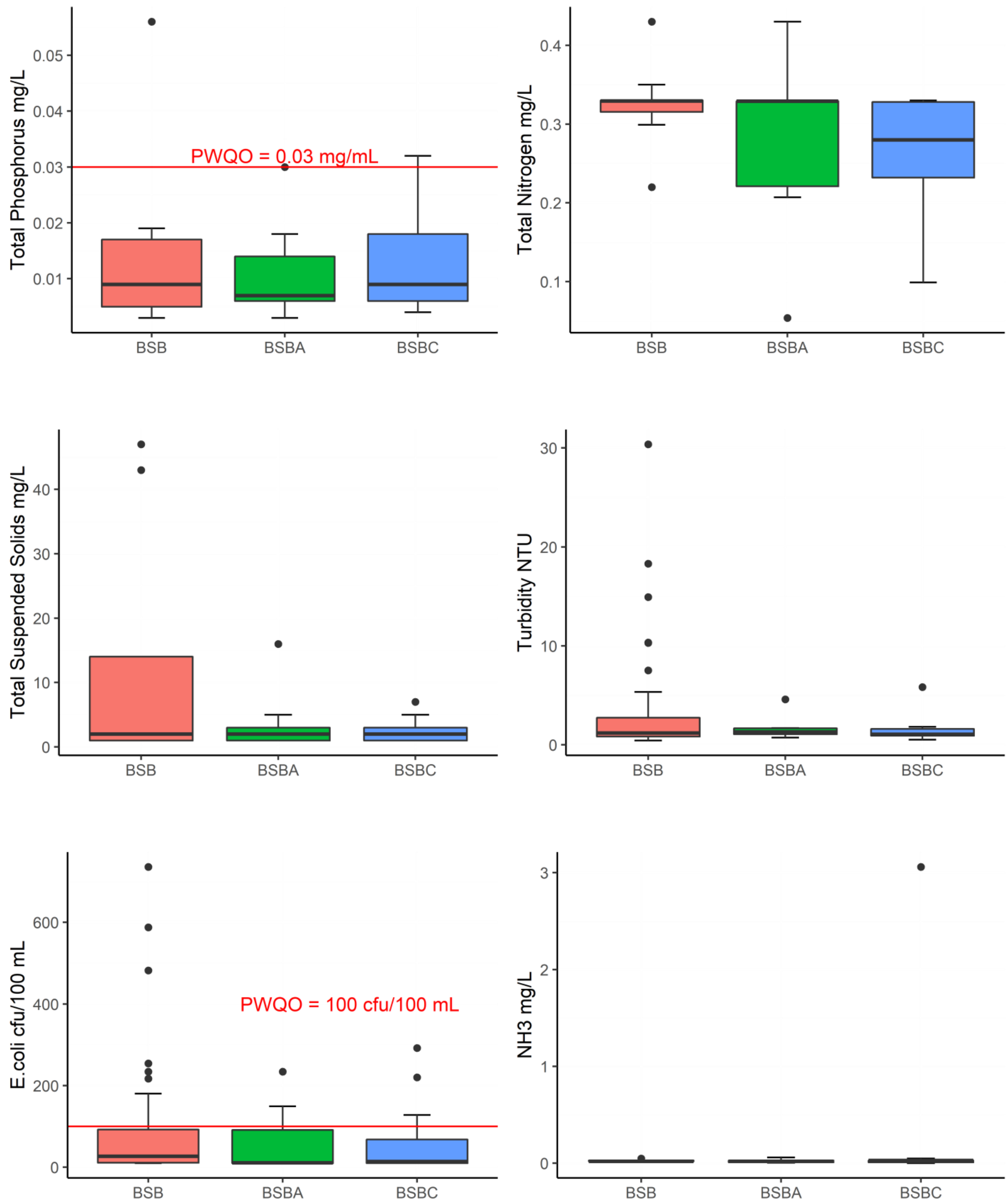

Figure 5. Boxplots of selective parameters for each site. The PQWO value is depicted by the red horizontal line.

3.2 Escherichia coli – Water

The bacterial *Escherichia coli* (*E. coli*) is a specific kind of fecal coliform bacteria that is naturally found in the large intestines of mammals. Because of this, it is used as an indicator of fecal contamination when found in recreational waters such as beaches (Health Canada, 20103). Current guidelines for recreational water (such as those at Bond St. Beach) are set at ≤ 200 *E. coli* per 100 mL (geomean of 5 samples) and a single sample maximum ≤ 400 *E. coli* per 100 mL (Ontario, 2018).

The Haliburton, Kawartha, Pine Ridge District Health Unit monitors the bacteriological contamination at Bond St. Beach during the recreational period from mid-June to the end of August. Between 2012 and 2017, Bond St. Beach has exceeded the recreational water guidelines approximately 53.1% of the time.

During the study period (June-August 2018), a total of 440 surface water samples were collected for *E. coli* analysis. The geometric mean (geomean) is a special way to calculate the average when there are a time lagged between the variable and its previous self. It is also log-transformed and thus less prone to biases or fluctuation than other forms of means. This is often true for microbiological samples as the population of the bacteria may change with time, either growing or decaying. For recreational water, specifically *E. coli*, the geomean of five samples is used. Geomeans range from 10 to 736 cfu/100mL, with median of 18 cfu/100mL for across all sites and observations. The highest geomean (736 cfu/100mL) was found on July 30th, 2018 in site BSB (Figure 6). During this period, there was approximately 0.36 mm of precipitation within the previous 48 hours. A weak correlation coefficient of 0.4 was found between surface water *E. coli* densities and precipitation (day of and 48 hrs prior), which may suggest non-event factors are of greater influence, such as inputs from waterfowl.

In total, 8 dates (most of them occurred in the month of July) were found to exceed the recreational water quality standard of ≤ 200 *E. coli* per 100 mL (Figure 6). No significant differences were found between sites, suggesting that *E. coli* sources are consistent across all sites.

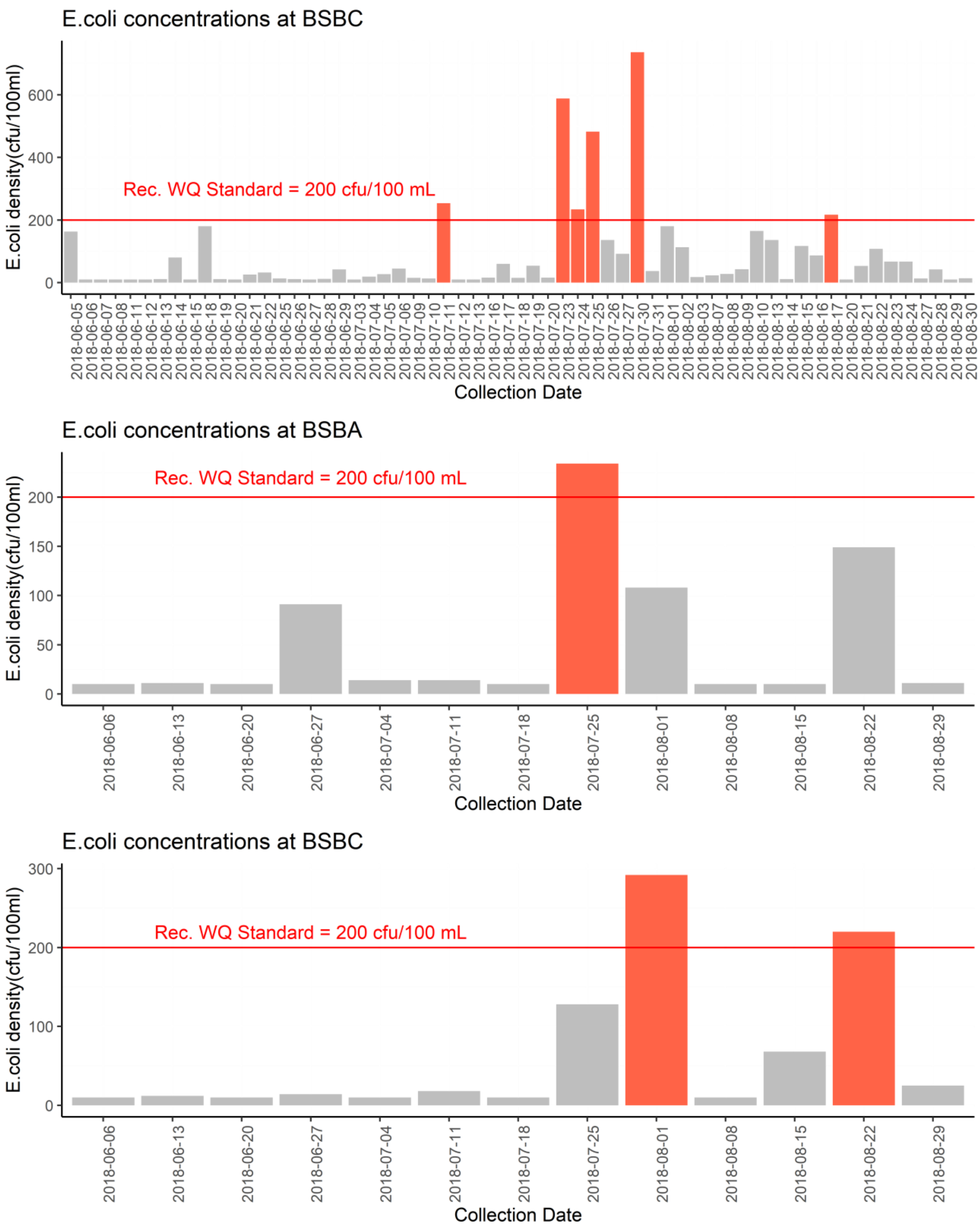

Figure 6. *E. coli* densities found in surface water at all three sites over the entire study period. The recreational water quality standard (Rec.WQ Standard) of 200 cfu/100ml is depicted as the red horizontal line

3.4 *Escherichia coli* – Beach Sand

In addition to surface water samples, beach sand samples were collected for *E. coli* analysis. A total of 26 sand samples (13 for each site) were collected from June 6th to August 29th, 2018 (Table 3; Figure 7). Highest values found were measured at 1100000 cfu/g for BSB2 and 28000 cfu/g for BSB1, both occurred on July 25th, 2018 (Figure 7) where approximately 0.36 mm of precipitation had been received within the previous 48 hours. This coincides with higher *E. coli* densities found in surface water (Figure 4) but was weakly indicated by the correlation coefficient (ρ=0.3; Figure 6 Bottom) between the beach sand and surface water.

The mean, geomean and median values were calculated at 43674 cfu/g, 76 cfu/g, and 60 cfu/g for all samples (Table 3). Generally, BSB2 had higher variability (%CV = 360, min = 5, max = 1100000) but had consistent lower concentrations (median = 10 cfu/g, 25th percentile = 5 cfu/g, 75th percentile = 80 cfu/g) than that of BSB1 (Table 3). However, there was no significant difference between BSB1 and BSB2 for *E. coli* densities (V = 55, p-value = 0.05). This suggests that higher values found were of outlier conditions.

Table 3. Summary statistics of *E. coli* densities found in beach sand at BSB1 and BSB2.

Statistic	BSB1	BSB2	Total
Count	13	13	26
Mean	2701	84648	43674
Geomean	178	32	76
%CV	285	360	493
Median	230	10	60
Min*	5	5	5
Max	28000	1100000	1100000
25th Percentile	40	5	5
75th Percentile	400	80	275

*minimum values are DL (10)/2

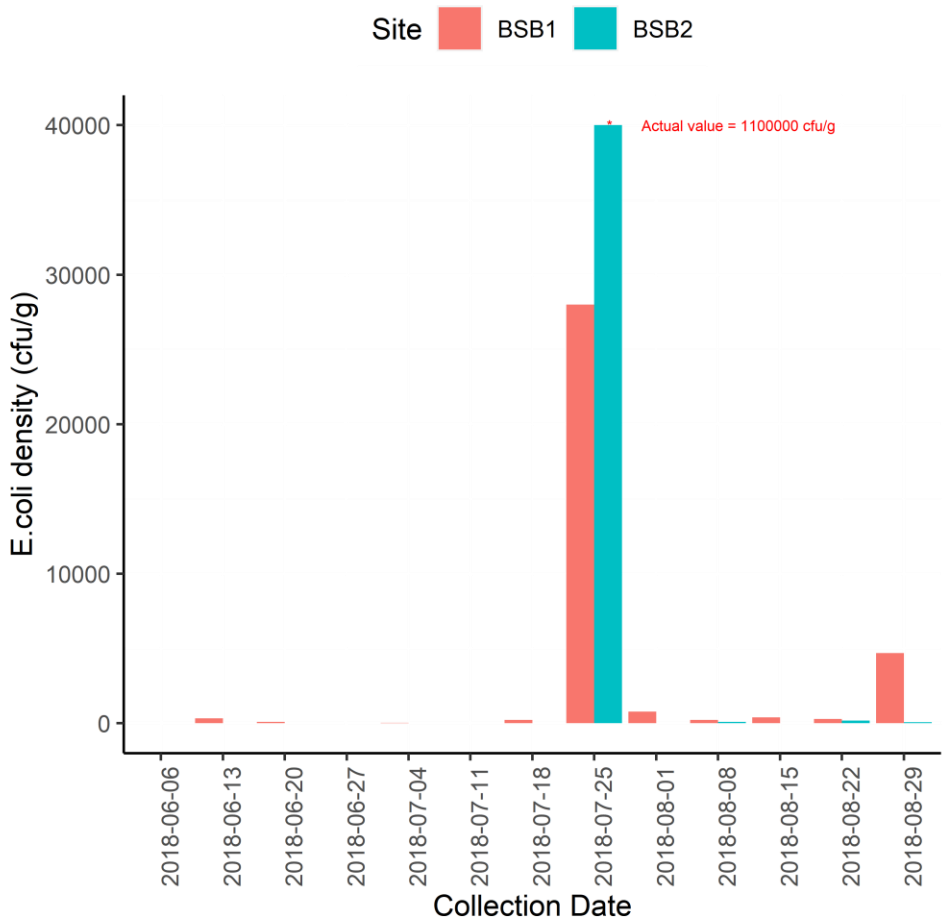

Figure 7. *E. coli* densities found in beach sand at BSB1 and BSB2 over the entire study period. Note that values for BSB2 on July 25th are not fully depicted.

3.5 Relationships among Parameters

A correlated matrix was used to assess the relationship between the different physical, chemical and microbiological parameters of Bond St. Beach (Figure 6). A stronger relationship ($\rho \geq 0.7$) was found between TN-TSS, TKN-TSS, TN-TP and Cond-*E.coli* (Figure 6 Top). The relationship between TKN-TN and Precip-P48 was ignored as TKN is used to calculated TN, and Precip. was used to calculated P48

While it is known that phosphorus tends to bind to soil particles, the weak relationship between TP-TSS (ρ=0.5; Figure 8 Top) is expected as Cameron Lake is classified as oligotrophic (Kawartha Conservation, 2015).

Although mean and median TN concentrations found in this study were similar to lake samples taken by Kawartha Conservation (2015), higher TN concentrations were driven by high TKN concentrations. This suggests an organic nitrogen and/or ammonia source, which may be derived from human and animal waste (Udert *et al*., 2003, 2006), and or fertilizer. The relationship between TSS and nitrogen (TKN and TN) may suggest some association between nitrogen bounded particles to sand/sediment, i.e., input of nitrogen from the beach and leaching into the water, or the resuspension of particles (from wave action) that are bounded to nitrogen compounds.

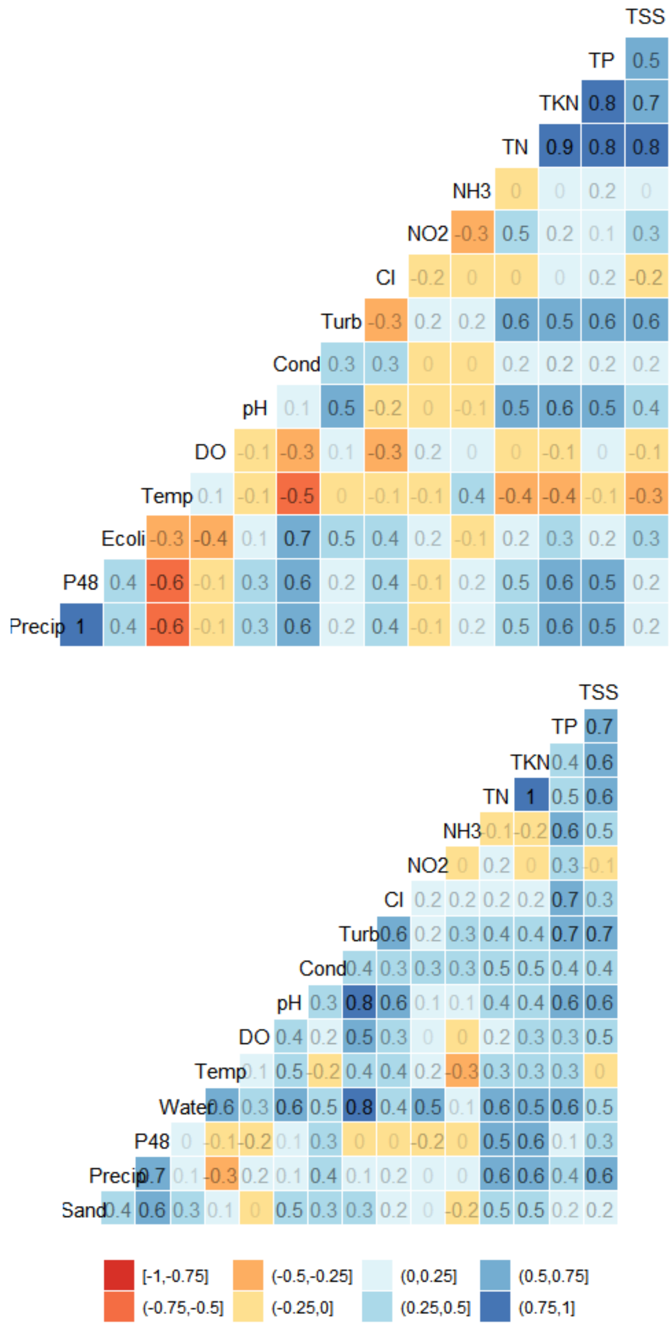

Figure 8. Correlation (relationships) between selected physical, chemical and microbiological parameters of surface water samples (Top) and with sediment samples (Bottom). Precipitation of the day of ("Precip"; a 24hrs period) and 48 hrs prior (P48) was also included. Correlation values are depicted as values between -1 (redder; negative correlated) and 1 (bluer; positively correlated). Lower coefficients (weaker relationships; <0.5) are less opaque than those of higher coefficient values (stronger relationship; >0.8).

Throughout the study period, field sheets indicate the present of feces in the grasses area between the beach and the parking lot. This along with observations of Canada Goose, ducks, and dogs, may suggest that a greater portion of *E. coli* may originate from animal fecal matter. This was common among other studies, where FIB were tracked back to birds (Standrige *et al*., 1979; Fremaux *et al*., 2010; Wright *et al*., 2010; Kobayashi *et al*., 2013), dogs (Kildare *et al*., 2007; Ahmed *et al*., 2019), and to some extent, humans (Newton *et al*., 2003; Staley *et al*., 2018). For freshwater beaches, it is commonly been found that FIB were predominately associated with avian inputs (Whitman and Nevers, 2003; Cloutier *et al*., 2017; Ahmed *et al*., 2019). For Bond St. Beach, it is suggested that *E.coli* found may originate from avian sources; however, a more accurate survey is needed for confirmation (see recommendations 4.3 Research and Monitoring).

When compared to each other, *E. coli* densities were higher within the beach sand ($V = 219$, $p = 0.05$) than the surface water. This coincides with results found by other studies (Whitman and Nevers, 2003; Skalbeck *et al*., 2010; Vogel et al., 2016; Cloutier *et al*., 2017), where sand was found to have significantly higher amounts of *E. coli* than that of surface water. It could be suggested that when a beach is posted for poor recreational water quality that both the beach water and sand to be closed off from the public. Additional work and monitoring is required for this.

While there has been a strong relationship between *E. coli* densities in beach sand and surface water (Whitman and Nevers, 2003; Ishii *et al*., 2007), we did not see this in our study (ρ=0.3; Figure 8). It is inconclusive if the beach sand at Bond St. Beach is a source of *E. coli* or a sink.

It is also inconclusive that precipitation (day of or 48 hrs prior) is an influence on *E. coli* densities found in both surface water and beach sand (Precip: Water = 0.4, Sand = 0.4, P48: Water = 0.4, Sand = 0.6). However, this does not mask the concern regarding high *E. coli* values at Bond St. Beach.

4.0 Recommendations

Bond St. Beach is a small sand and stone beach in Garnet Graham Beach, Fenelon Falls. Due to its accessibility from downtown and from the Trent Severn Waterway, it is a popular destination. It is also connected to the Victoria Rail Trail, which adds to its popularity. However, due to its higher exceedance (~53.1% between 2012 and 2017) of recreational water quality guidelines, there is an opportunity to improve the water quality, and ultimately reduce beach postings. This provides a great opportunity for the community to become involved in the maintenance and stewardship of their beach. Moving forward, it is vital that communications between the community, Kawartha Conservation and the City of Kawartha Lakes are continued.

Below are recommendations for enhancing the water quality of Bond St. Beach. Recommendations are categorized into four strategies:

- **Stewardship:** actions tailored to beach users for implementing best management practice for the benefit of all and the future of the beach and lake.
- **Urban and Rural Infrastructure:** actions that focus on existing and new infrastructure, or associated work such as stormwater networks, roads, drains, etc.
- **Research and Monitoring:** actions that focus on addressing knowledge gaps.
- **Communication and Outreach:** actions that stimulate dialogue and information sharing among stakeholders and members of the public.

4.1 Stewardship

- Implement lot-level measures such as increasing infiltration, capturing stormwater runoff, and other practices that reduce pollution from entering the lake.
- Implement a natural landscaping approach along the stormwater outflow. This would reduce the loading of contaminates (microbiological and chemical) from the beach.
- Naturalization of the area on surrounding BSB to enhance filtering of contaminate, i.e., reduce the input of dissolve salts (Figure 2, 4).
- Continue to groom Bond St. Beach:
    - It is suggested (Kinzelman *et al*., 2003) that higher frequency of beach grooming may favour higher densities of *E. coli* in beach sand. The mechanism is that, grooming causes feces to be turned under and placed in a dark and moist environment, away from the lethal effects of sunlight.
    - A deeper (7-10cm) grooming method may allow for better UV-light penetration and for better drying rates (more aeration) (Kinzelman *et al*., 2004).
    - Continue the removal of fecal matter (and other pieces of litter) prior to peak beach usage (in the mornings). This could be done by seasonal municipal staff along site with the community volunteer group.
    - Extend the beach grooming area to cover the lower section of the beach (Figure 9).

Figure 9. Stormwater runoff and channelization at Bond St. Beach.

4.2 Urban and Rural Infrastructure

- Through stormwater management planning, improve the quality and control of stormwater in areas surrounding and within the Bond St. Beach.
- Determine if there is a need for a goose management plan. If so, follow the best management practices for Canada goose and Cackling goose (Canadian Wildlife Service, 2011).
- Better position existing waste disposal containers near areas where beach users may frequent.
- Redirect (and naturalized) the stormwater outflow to a downstream (of the beach) discharge site. This will help mitigate contaminant and microbiological loading from above the beach to the beach bathing area.
- Septic inspection and care should be implemented to assess the input of contaminates (*E. coli*) from these systems.

Figure 10. Depiction of the extent of beach grooming (Top) and the present of waterfowl species found (Bottom).

4.3 Research and Monitoring

- Continue to monitor Bond St. Beach for FIB during the recreational periods of June – August. The Beach Management Plan for Bond St. Beach should aim to be Blue Flag recognized.
- With further funding and collaboration, investigate the source (human, bird, or dog) of FIB. It is still unknown to the source of *E. coli* at Bond St. Beach. This can be done through microbial source tracking and analysis.
- Determine if different grooming technics (Kinzelman *et al*., 2003, 2004) can significantly reduce *E. coli* densities at Bond. St. Beach.
- Develop a more intensive approach, similar to that of Whitman and Nevers (2003) to determine if the beach sand of Bond St. Beach is a source or sink for *E. coli*. The intensive approach should look at *E. coli* densities in surface and subsurface beach sand (in the pore water), submerged sand adjacent to the foreshore, and further out into the bating area.
- Investigate the effects of the removed concrete piers on *E. coli* densities, i.e., compare pre and post-removal *E. coli* densities.

4.4 Communication and Outreach

- Facilitate educational campaign that aims to educate the public on:
  - Feeding wildlife, including geese and seagulls at the park and beach.
  - Proper disposal of litter and waste
  - Keeping dogs on leashes and discouraging having pets in the bathing area.
  - Fertilizer usage for lawns
- Inclusion of quick patrols of the beach by municipal by-law officers to ensure that beach users are obeying regulations associated with using public beaches, i.e., pets, feeding wildlife, proper waste disposal, etc.
- Community involvement through volunteer events such as community clean-up days, or a citizen science monitoring program. Emphasise should be placed on recognizing the actions of these volunteers through social media, traditional media, or a physical installation of signage.

Figure 11. Portraying the common (left) and uncommon (right) types of litter found at Bond St. Beach.

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Appendix A – Beach Survey Sheet

HKPR District Health Unit 2019

Beach Survey – Weekly Field Data Report

Name of Beach:	Beach Code:
Surveyor Name:	Posted at Time of Sampling: ○ Yes ○ No
Date of Survey (mm/dd/yyyy):	Time of Sampling (hh:mm): ________ AM/PM

General Beach Conditions

Air Temperature: ________°C	Dew Point Temperature: ________°C
Water Temperature†: ________°C	Relative Humidity: ________ %
Sky Conditions (cloud cover %): ○ Sunny (0%) ○ Mostly sunny (1-33%) ○ Partly cloudy (34-66%) ○ Mostly cloudy (67-99%) ○ Cloudy (100%)	
Wind Direction: ○ None ○ Away from shore ○ Toward shore ○ Parallel to shore	Wind Speed: ________ km/h
Wave Type: ○ Calm (no waves) ○ Wavy (soft waves, rolling, no white caps) ○ Choppy (white caps)	Wave Height: ________ cm
Rain Intensity: ○ None ○ Light (spitting; <2.5mm/h) ○ Medium (showers; 2.6-7.5mm/h) ○ Heavy (downpour; >7mm/h)	
Water Clarity: ○ <100 cm (cannot see feet) ○ >100 cm (can see feet)	Water Turbidity: ________ NTU
Approximate number of people observed in the water: ○ 0 (none) ○ 1 – 10 ○ 11 – 20 ○ >20	Approximate number of people using the beach but not in the water at time of observation: ○ 0 (none) ○ 1 – 10 ○ 11 – 20 ○ >20

Potential Pollutants

Type of Source	Source Present?	General Observations (e.g. approximate #)
Wildlife/waterfowl (e.g. turtles, geese, ducks)	○ Yes ○ No	
Domestic animals (e.g. dogs)	○ Yes ○ No	
Fecal matter (e.g. bird droppings)	○ Yes ○ No	
Dead animals (e.g. fish*, frogs)	○ Yes ○ No	
Wastewater discharges (e.g. boats, water treatment plant bypass*)	○ Yes ○ No	
Stormwater/natural/urban/agricultural runoff* (e.g. water flowing from roads, nearby farms, debris*)	○ Yes ○ No	
Watercraft access/boat dockage	○ Yes ○ No	
Seasonal watercourse (new temporary stream)	○ Yes ○ No	
Biochemical hazards* (e.g. chemical spill, needles)	○ Yes ○ No	
Algal blooms*/pollen	○ Yes ○ No	
Other	○ Yes ○ No	

Part IV: Water Quality			
Sample Number	Sample Point	Parameter: ○ E. coli ○ Other (specify)	Comments
1			
2			
3			
4			
5			
Geometric Mean Concentration (GMC):			
Additional Comments/Notes:			
Surveyor Signature:			

† Water should not be entered if water temp is below 16°C due to personal safety reasons, therefore water clarity and wave height should not be assessed (instead enter "N/A" and record a note explaining in the additional notes section)

* If any potential hazards are present (heavy algae growth/blue green algae, debris, fish die off, waste water treatment plant bypass, chemical/oil/manure/sewage spill), call Bernie for instruction

Appendix C – Data Analysis

All data analysis was performed with the statistical program, R (R Core Team, 2021). Methods used to manage censored data (values below the detection limit) were followed from Kawartha Conservation (2018, 2020) where half of the detection limit was substituted. Precipitation data from Indian Point Provincial Park (24 hrs and 48 hours) was also included in the dataset to determine if precipitation was a factor for *E. coli* densities.

All chemical and microbiological data were assessed for normality (Shapiro-Wilk normality test) and linearity (quantile-quantile plots) (*stats*, R Core Team, 2021). In addition, data was transformed (Log+1) and was re-assessed for normality and linearity. Under both assessments, almost all parameters were significantly ($p<0.05$) different than a normal distribution, thus non-parametric tests were used. A subset of data from BSB was used in conjunction of weekly data of BSBA and BSBC to determine differences between sites. This was done through a Kruskal-Wallis rank sum test (*stats*, R Core Team, 2021) and was followed up with a post-hoc Dunn's Test (Dinno, 2017). This subset was also used with a Spearman's rank correlation (ρ) from the package *GGally* (Barret *et al*., 2021) to quantify relationships between two variables. For comparison between two independent groups of non-normal distribution (Beach Sand), a Wilcoxon rank-sum test (also called Mann-Whitney test) was used (*stats*, R Core Team, 2021).

Appendix C – Summary Statistics for Supplementary Water Quality Results

Appendix C. Table 1. Summary statistics of all other water quality results

Site	Statistic	pH	mg/L Cl	mg/L NO2	mg/L NO3	mg/L TNK
BSB	Count	61	13	13	13	13
	Mean	8.44	7.78	0.00	0.03	0.27
	%CV	3.9	8.7	13.0	0.0	29.7
	Median	8.53	7.80	0.01	0.03	0.30
	Min	9.34	7.10	0.004	0.03	0.07
	Max	7.89	9.60	0.01	0.03	0.40
BSBA	Count	13	13	13	13	13
	Mean	8.29	7.71	0.00	0.03	0.26
	%CV	5.0	5.9	17.4	0.0	39.4
	Median	8.36	7.70	0.004	0.03	0.30
	Min	9.20	7.00	0.004	0.03	0.03
	Max	7.92	8.50	0.01	0.03	0.40
BSBC	Count	13	13	13	13	13
	Mean	8.28	20.44	0.00	0.17	0.24
	%CV	4.2	214.1	24.3	308.2	27.3
	Median	8.56	8.30	0.01	0.03	0.25
	Min	8.99	7.10	0.003	0.03	0.07
	Max	7.69	166.00	0.01	1.94	0.30
All Sites	Count	87	39	39	39	39
	Mean	8.39	11.97	0.00	0.07	0.26
	%CV	4.1	211.5	18.6	413.8	32.1
	Median	8.50	7.90	0.01	0.03	0.30
	Min	9.34	7.00	0.003	0.03	0.03
	Max	7.69	166.00	0.01	1.94	0.40

Appendix D – Water Quality Results

Appendix D. Table 1. Water and sediment quality results for this study. Precipitation amounts (mm) for 24 hrs and 48 hrs periods are also included.

Site_ID	Sample_Type	Collection_Date	Precip24hrs_mm	Precip_48hrs_mm	E.coli_Geomean_cfu_100mL	E.coli_cfu_g
BSB	Water	2018-07-25	48.86	50.39	482	NA
BSBA	Water	2018-08-15	0.00	0.00	10	NA
BSBA	Water	2018-08-22	24.54	24.54	149	NA
BSB	Water	2018-06-13	2.90	2.90	11	NA
BSB	Water	2018-08-08	0.30	21.47	28	NA
BSBA	Water	2018-08-29	2.65	19.27	11	NA
BSB	Water	2018-07-11	0.00	0.00	254	NA
BSB	Water	2018-08-15	0.00	0.00	117	NA
BSB	Water	2018-08-22	24.54	24.54	108	NA
BSBC	Water	2018-08-15	0.00	0.00	68	NA
BSBC	Water	2018-08-22	24.54	24.54	220	NA
BSB	Water	2018-07-18	0.00	20.46	15	NA
BSB	Water	2018-08-29	2.65	19.27	10	NA
BSBA	Water	2018-06-20	0.00	4.07	10	NA
BSBA	Water	2018-07-18	0.00	20.46	10	NA
BSBA	Water	2018-07-25	48.86	50.39	234	NA
BSBA	Water	2018-08-01	0.00	0.00	108	NA
BSBA	Water	2018-08-08	0.30	21.47	10	NA
BSBC	Water	2018-07-25	48.86	50.39	128	NA
BSBC	Water	2018-07-18	0.00	20.46	10	NA
BSB	Water	2018-08-01	0.00	0.00	180	NA
BSBC	Water	2018-07-04	0.00	0.00	10	NA
BSBC	Water	2018-08-01	0.00	0.00	292	NA
BSB	Water	2018-06-20	0.00	4.07	10	NA
BSBC	Water	2018-06-06	0.33	0.56	10	NA
BSBC	Water	2018-06-20	0.00	4.07	10	NA

Appendix D. Table 1. Continuation.

BSBC	Water	2018-06-13	2.90	2.90	12	NA
BSBC	Water	2018-08-08	0.30	21.47	10	NA
BSBC	Water	2018-08-29	2.65	19.27	25	NA
BSBA	Water	2018-07-11	0.00	0.00	14	NA
BSBC	Water	2018-07-11	0.00	0.00	18	NA
BSBA	Water	2018-06-06	0.33	0.56	10	NA
BSB	Water	2018-06-06	0.33	0.56	10	NA
BSB	Water	2018-07-04	0.00	0.00	19	NA
BSBA	Water	2018-06-13	2.90	2.90	11	NA
BSBA	Water	2018-07-04	0.00	0.00	14	NA
BSB	Water	2018-06-27	0.00	0.00	10	NA
BSBC	Water	2018-06-27	0.00	0.00	14	NA
BSBA	Water	2018-06-27	0.00	0.00	91	NA
BSB	Water	2018-06-04	9.20	9.20	NA	NA
BSB	Water	2018-06-05	0.24	9.43	163	NA
BSB	Water	2018-06-07	1.17	1.50	10	NA
BSB	Water	2018-06-08	0.00	1.17	10	NA
BSB	Water	2018-06-11	0.00	0.00	10	NA
BSB	Water	2018-06-12	0.00	0.00	10	NA
BSB	Water	2018-06-14	12.01	14.90	80	NA
BSB	Water	2018-06-15	0.00	12.01	10	NA
BSB	Water	2018-06-18	0.00	0.00	180	NA
BSB	Water	2018-06-19	4.07	4.07	11	NA
BSB	Water	2018-06-21	0.00	0.00	26	NA
BSB	Water	2018-06-22	0.00	0.00	32	NA
BSB	Water	2018-06-25	0.39	0.53	13	NA
BSB	Water	2018-06-26	0.00	0.39	11	NA
BSB	Water	2018-06-28	3.25	3.25	12	NA
BSB	Water	2018-06-29	0.00	3.25	42	NA
BSB	Water	2018-07-03	0.00	0.00	10	NA
BSB	Water	2018-07-05	0.00	0.00	27	NA

Appendix D. Table 1. Continuation.

BSB	Water	2018-07-06	24.86	24.86	45	NA
BSB	Water	2018-07-09	0.00	0.00	15	NA
BSB	Water	2018-07-10	0.00	0.00	13	NA
BSB	Water	2018-07-12	0.00	0.00	10	NA
BSB	Water	2018-07-13	0.00	0.00	10	NA
BSB	Water	2018-07-16	0.00	0.40	16	NA
BSB	Water	2018-07-17	20.46	20.46	60	NA
BSB	Water	2018-07-19	0.00	0.00	54	NA
BSB	Water	2018-07-20	0.00	0.00	16	NA
BSB	Water	2018-07-23	9.56	10.17	588	NA
BSB	Water	2018-07-24	1.53	11.09	234	NA
BSB	Water	2018-07-26	0.19	49.05	136	NA
BSB	Water	2018-07-27	4.96	5.14	92	NA
BSB	Water	2018-07-30	0.00	0.36	736	NA
BSB	Water	2018-07-31	0.00	0.00	37	NA
BSB	Water	2018-08-02	0.00	0.00	113	NA
BSB	Water	2018-08-03	0.00	0.00	18	NA
BSB	Water	2018-08-07	21.17	21.17	23	NA
BSB	Water	2018-08-09	12.58	12.88	43	NA
BSB	Water	2018-08-10	0.00	12.58	165	NA
BSB	Water	2018-08-13	0.00	0.00	136	NA
BSB	Water	2018-08-14	0.00	0.00	11	NA
BSB	Water	2018-08-16	0.00	0.00	87	NA
BSB	Water	2018-08-17	1.87	1.87	217	NA
BSB	Water	2018-08-20	0.00	0.00	10	NA
BSB	Water	2018-08-21	0.00	0.00	53	NA
BSB	Water	2018-08-23	0.00	24.54	67	NA
BSB	Water	2018-08-24	0.00	0.00	67	NA
BSB	Water	2018-08-27	0.00	3.97	13	NA
BSB	Water	2018-08-28	16.61	16.61	42	NA
BSB	Water	2018-08-30	0.75	3.40	14	NA

Appendix D. Table 1. Continuation.

BSB1	Sand	2018-06-06	NA	NA	NA	<10
BSB1	Sand	2018-06-13	NA	NA	NA	340
BSB1	Sand	2018-06-20	NA	NA	NA	90
BSB1	Sand	2018-06-27	NA	NA	NA	10
BSB1	Sand	2018-07-04	NA	NA	NA	40
BSB1	Sand	2018-07-11	NA	NA	NA	<10
BSB1	Sand	2018-07-18	NA	NA	NA	230
BSB1	Sand	2018-07-25	NA	NA	NA	28000
BSB1	Sand	2018-08-01	NA	NA	NA	780
BSB1	Sand	2018-08-08	NA	NA	NA	220
BSB1	Sand	2018-08-15	NA	NA	NA	400
BSB1	Sand	2018-08-22	NA	NA	NA	290
BSB1	Sand	2018-08-29	NA	NA	NA	4700
BSB2	Sand	2018-06-06	NA	NA	NA	<10
BSB2	Sand	2018-06-13	NA	NA	NA	<10
BSB2	Sand	2018-06-20	NA	NA	NA	10
BSB2	Sand	2018-06-27	NA	NA	NA	<10
BSB2	Sand	2018-07-04	NA	NA	NA	<10
BSB2	Sand	2018-07-11	NA	NA	NA	<10
BSB2	Sand	2018-07-18	NA	NA	NA	10
BSB2	Sand	2018-07-25	NA	NA	NA	1100000
BSB2	Sand	2018-08-01	NA	NA	NA	20
BSB2	Sand	2018-08-08	NA	NA	NA	90
BSB2	Sand	2018-08-15	NA	NA	NA	<10
BSB2	Sand	2018-08-22	NA	NA	NA	180
BSB2	Sand	2018-08-29	NA	NA	NA	80

Appendix D. Table 1. Continuation

Site_ID	Sample_Type	Collection_Date	Water_Temperature_C	Dissolved_Oxygen_mg_L	Dissolved_Oxygen_%	pH	Conductivity_µS_cm
BSB	Water	2018-07-25	23.7	7.61	90	7.95	165.6
BSBA	Water	2018-08-15	25.4	8.14	99.3	7.95	141.3
BSBA	Water	2018-08-22	21.6	8.4	95.4	7.92	152.5
BSB	Water	2018-06-13	22.2	8.48	98	8.65	149.6
BSB	Water	2018-08-08	25.9	5.82	70.8	8.49	142.4
BSBA	Water	2018-08-29	22.8	8.01	93.1	8.43	143.3
BSB	Water	2018-07-11	24.5	7.97	95.6	8.32	147.8
BSB	Water	2018-08-15	25.4	7.97	97.1	7.89	144.6
BSB	Water	2018-08-22	21.8	8.17	93.1	8.3	155.3
BSBC	Water	2018-08-15	25.2	8.09	98.2	8.17	143.1
BSBC	Water	2018-08-22	21.7	8.31	94.6	8.03	159.1
BSB	Water	2018-07-18	24.2	6.94	82.6	8.34	147.8
BSB	Water	2018-08-29	23	7.91	92.1	8.01	140.7
BSBA	Water	2018-06-20	21.9	7.72	87.1	9.2	145.7
BSBA	Water	2018-07-18	23.8	6.68	80.6	8.3	146.7
BSBA	Water	2018-07-25	23.7	7.89	93.3	8.16	150.9
BSBA	Water	2018-08-01	23.1	7.35	85.8	8.04	148.5
BSBA	Water	2018-08-08	25.3	6.41	78.1	8.38	144.3
BSBC	Water	2018-07-25	23.5	7.66	90.4	8.19	168.4
BSBC	Water	2018-07-18	23.6	6.23	73.8	8.74	148.1
BSB	Water	2018-08-01	23.3	7.58	88.3	8.16	148.9
BSBC	Water	2018-07-04	25.8	8.29	101.9	8.3	146.6
BSBC	Water	2018-08-01	23.3	7.8	91.5	8.56	155.1
BSB	Water	2018-06-20	22.1	7.2	82.6	8.77	119.8
BSBC	Water	2018-06-06	16.8	7.78	80.1	8.62	146.7
BSBC	Water	2018-06-20	21.9	6.08	69.7	8.7	149.6
BSBC	Water	2018-06-13	22.4	8.85	101.6	8.61	156.7
BSBC	Water	2018-08-08	25.2	5.65	68.6	8.99	155.6
BSBC	Water	2018-08-29	22.9	7.5	81.75	7.69	164.2

Appendix D. Table 1. Continuation

BSBA	Water	2018-07-11	23.7	8.1	95.8	8.36	145.1
BSBC	Water	2018-07-11	24	7.99	85	8.3	145
BSBA	Water	2018-06-06	16.3	8.11	82.5	9.18	147.1
BSB	Water	2018-06-06	16.9	7.17	74	8.77	140.5
BSB	Water	2018-07-04	26.1	8.36	103.6	8.31	136.7
BSBA	Water	2018-06-13	22.1	8.77	99.7	8.67	148
BSBA	Water	2018-07-04	25.4	8.21	100.1	8.29	147.7
BSB	Water	2018-06-27	21.4	7.31	82.7	8.62	150.6
BSBC	Water	2018-06-27	21.4	7.32	83	8.59	154.4
BSBA	Water	2018-06-27	21.1	7.49	84.4	8.72	131.4
BSB	Water	2018-06-04	19.8	8.34	91.5	8.57	143.9
BSB	Water	2018-06-05	17.1	8.85	92	8.79	155.4
BSB	Water	2018-06-07	17	7.53	77.4	8.89	144.9
BSB	Water	2018-06-08	17.8	7.82	82.3	9.07	146.7
BSB	Water	2018-06-11	17.5	7.69	79.9	9.13	142.1
BSB	Water	2018-06-12	18.7	7.58	81.4	9.06	147.2
BSB	Water	2018-06-14	18.5	9.15	97.8	8.64	157.6
BSB	Water	2018-06-15	NA	NA	NA	NA	NA
BSB	Water	2018-06-18	23.4	8.98	105.7	8.85	144.4
BSB	Water	2018-06-19	22	8.06	92.2	8.92	145.7
BSB	Water	2018-06-21	22.3	7.17	82.9	8.96	150.7
BSB	Water	2018-06-22	21.3	7.11	80	8.96	143.8
BSB	Water	2018-06-25	20.1	7.6	83.7	9.11	149.5
BSB	Water	2018-06-26	20.4	6.69	7.49	8.97	145.5
BSB	Water	2018-06-28	20.2	7.97	88.1	7.97	148.1
BSB	Water	2018-06-29	21.1	8.41	94.5	8.14	150.9
BSB	Water	2018-07-03	24.6	8.43	99.2	8.39	144.8
BSB	Water	2018-07-05	25.9	8.31	102.3	8.36	148.2
BSB	Water	2018-07-06	24.4	7.82	93.7	8.23	147.9
BSB	Water	2018-07-09	23.8	8.08	95.6	8.39	147.5

Appendix D. Table 1. Continuation

BSB	Water	2018-07-10	24.6	7.66	92	8.42	151.1
BSB	Water	2018-07-12	24.5	8.17	98.2	8.5	145.1
BSB	Water	2018-07-13	25.2	8.06	97.4	8.73	161
BSB	Water	2018-07-16	25.9	6.98	89.4	8.34	150.4
BSB	Water	2018-07-17	24.2	7.1	84.7	8.63	152.3
BSB	Water	2018-07-19	23.7	8.03	94.9	148.8	8.5
BSB	Water	2018-07-20	24.5	7.96	95.6	8.46	151
BSB	Water	2018-07-23	23.2	7.89	92	8.73	148.2
BSB	Water	2018-07-24	23.4	7.63	89.6	8.53	136.1
BSB	Water	2018-07-26	23.5	8.03	94.7	8.51	142.1
BSB	Water	2018-07-27	23.5	8.15	96.2	8.47	143.7
BSB	Water	2018-07-30	22.9	8.28	96.3	8.78	147.3
BSB	Water	2018-07-31	23.5	8.07	95	8.58	142.3
BSB	Water	2018-08-02	22.9	8.22	95.7	8.61	141.2
BSB	Water	2018-08-03	23.6	7.95	93.9	8.21	145.6
BSB	Water	2018-08-07	25.1	7.78	95.9	8.23	144.8
BSB	Water	2018-08-09	24.3	7.92	94.6	8.3	133
BSB	Water	2018-08-10	24.1	8.25	98.2	8.68	141.8
BSB	Water	2018-08-13	25	6.69	81	9.34	135.8
BSB	Water	2018-08-14	24.9	7.2	86.9	8.4	141.1
BSB	Water	2018-08-16	23.5	8.15	99.1	8.39	137.1
BSB	Water	2018-08-17	25.2	7.77	94.3	8.69	145.1
BSB	Water	2018-08-20	24.1	6.45	77.2	9.15	142.2
BSB	Water	2018-08-21	23.8	6.97	81.3	8.93	143.9
BSB	Water	2018-08-23	21.5	8.41	95.7	8.54	140.6
BSB	Water	2018-08-24	22.2	7.99	91.8	8.82	136.1
BSB	Water	2018-08-27	22.3	7.99	92	8.19	142.5
BSB	Water	2018-08-28	22.7	7.88	91.5	8.08	143.5
BSB	Water	2018-08-30	21.9	8.01	91.6	8.25	141

Appendix D. Table 1. Continuation

Site_ID	Sample_Type	Collection_Date	Chloride_mg_L	Nitrite_mg_L	Nitrate_mg_L	Ammonia_mg_L	Total_Nitrogen_Cal
BSB	Water	2018-07-25	9.6	0.005	<0.05	0.03	0.405
BSBA	Water	2018-08-15	7.7	0.005	<0.05	0.02	0.405
BSBA	Water	2018-08-22	7.7	0.005	<0.05	0.02	0.405
BSB	Water	2018-06-13	7.2	0.005	<0.05	0.01	0.325
BSB	Water	2018-08-08	7.8	0.006	<0.05	0.02	0.306
BSBA	Water	2018-08-29	8.2	0.006	<0.05	0.01	0.306
BSB	Water	2018-07-11	8.1	0.005	<0.05	0.03	0.305
BSB	Water	2018-08-15	7.6	0.005	<0.05	0.03	0.305
BSB	Water	2018-08-22	7.6	0.005	<0.05	0.03	0.305
BSBC	Water	2018-08-15	8.3	0.005	<0.05	0.02	0.305
BSBC	Water	2018-08-22	8.3	0.005	<0.05	0.002	0.305
BSB	Water	2018-07-18	7.1	0.004	<0.05	0.02	0.304
BSB	Water	2018-08-29	8.2	0.004	<0.05	0.02	0.304
BSBA	Water	2018-06-20	7.1	0.004	<0.05	0.02	0.304
BSBA	Water	2018-07-18	7.1	0.004	<0.05	0.02	0.304
BSBA	Water	2018-07-25	8.5	0.004	<0.05	0.06	0.304
BSBA	Water	2018-08-01	7.7	0.004	<0.05	<0.01	0.304
BSBA	Water	2018-08-08	7.9	0.004	<0.05	0.02	0.304
BSBC	Water	2018-07-25	11.8	0.004	<0.05	0.03	0.304
BSBC	Water	2018-07-18	7.1	0.003	<0.05	0.03	0.303
BSB	Water	2018-08-01	7.8	0.006	<0.05	0.01	0.296
BSBC	Water	2018-07-04	7.9	0.005	<0.05	3.06	0.295
BSBC	Water	2018-08-01	8.5	0.005	<0.05	<0.01	0.295
BSB	Water	2018-06-20	7.1	0.004	<0.05	0.02	0.274
BSBC	Water	2018-06-06	7.5	0.005	<0.05	0.03	0.255
BSBC	Water	2018-06-20	7.3	0.003	<0.05	0.05	0.243
BSBC	Water	2018-06-13	8.4	0.004	<0.05	0.01	0.234
BSBC	Water	2018-08-08	166	0.007	<0.05	0.02	0.207
BSBC	Water	2018-08-29	8.6	0.006	<0.05	0.01	0.206

BSBA	Water	2018-07-11	7.9	0.004	<0.05	0.05	0.204
BSBC	Water	2018-07-11	8	0.004	<0.05	0.03	0.204
BSBA	Water	2018-06-06	7	0.006	<0.05	0.03	0.196
BSB	Water	2018-06-06	7.1	0.005	<0.05	0.03	0.195
BSB	Water	2018-07-04	8	0.005	<0.05	0.02	0.195
BSBA	Water	2018-06-13	7.4	0.004	<0.05	0.01	0.184
BSBA	Water	2018-07-04	8	0.004	<0.05	0.01	0.182
BSB	Water	2018-06-27	7.9	0.005	<0.05	0.05	0.075
BSBC	Water	2018-06-27	8	0.004	<0.05	0.03	0.074
BSBA	Water	2018-06-27	8	0.004	<0.05	0.03	0.004

Appendix D. Table 1. Continuation

Site_ID	Sample_Type	Collection_Date	Total_Kjeldahl_Nitrogen_mg_L	Total_Phosphorus_mg_L	Total_Suspended_Solids_mg_L
BSB	Water	2018-07-25	0.4	0.056	47
BSBA	Water	2018-08-15	0.4	0.03	16
BSBA	Water	2018-08-22	0.4	0.018	16
BSB	Water	2018-06-13	0.32	0.005	2
BSB	Water	2018-08-08	0.3	0.012	<2
BSBA	Water	2018-08-29	0.3	0.008	3
BSB	Water	2018-07-11	0.3	0.019	14
BSB	Water	2018-08-15	0.3	0.017	43
BSB	Water	2018-08-22	0.3	0.017	43
BSBC	Water	2018-08-15	0.3	0.018	2
BSBC	Water	2018-08-22	0.3	0.018	2
BSB	Water	2018-07-18	0.3	0.004	<2
BSB	Water	2018-08-29	0.3	0.009	3
BSBA	Water	2018-06-20	0.3	0.004	<2
BSBA	Water	2018-07-18	0.3	0.007	<2
BSBA	Water	2018-07-25	0.3	0.016	2
BSBA	Water	2018-08-01	0.3	0.007	5
BSBA	Water	2018-08-08	0.3	0.014	<2
BSBC	Water	2018-07-25	0.3	0.021	<2
BSBC	Water	2018-07-18	0.3	0.011	<2
BSB	Water	2018-08-01	0.29	0.005	<2
BSBC	Water	2018-07-04	0.29	0.006	<2
BSBC	Water	2018-08-01	0.29	0.004	5
BSB	Water	2018-06-20	0.27	0.003	<2
BSBC	Water	2018-06-06	0.25	0.009	<2
BSBC	Water	2018-06-20	0.24	0.005	7
BSBC	Water	2018-06-13	0.23	0.006	3
BSBC	Water	2018-08-08	0.2	0.032	<2
BSBC	Water	2018-08-29	0.2	0.006	2

Appendix D. Table 1. Continuation

BSBA	Water	2018-07-11	0.2	0.006	2
BSBC	Water	2018-07-11	0.2	0.007	<2
BSBA	Water	2018-06-06	0.19	0.005	<2
BSB	Water	2018-06-06	0.19	0.006	2
BSB	Water	2018-07-04	0.19	0.007	<2
BSBA	Water	2018-06-13	0.18	0.003	3
BSBA	Water	2018-07-04	0.178	0.006	<2
BSB	Water	2018-06-27	0.07	0.009	<2
BSBC	Water	2018-06-27	0.07	0.018	3
BSBA	Water	2018-06-27	<0.05	0.013	<2