Parlee Beach Water Quality :

Monitoring Plan for 2017

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Executive Summary

Recent instances of elevated bacterial concentrations at Parlee Beach have renewed attention to water quality at the beach. Previous studies examining water quality in the Shediac Bay/Parlee Beach area, plus relevant literature describing other studies investigating fecal bacteria contamination, are reviewed and summarised. There are significant challenges in investigating bacterial contamination in a beach environment, including multiple potential sources and poorly understood transport and fate of bacteria-laden inputs. Nevertheless, a targetted monitoring program offers the potential of assembling a body of information that should allow improved understanding of bacterial dynamics in the area and support improved decision-making. Studies elsewhere indicate the importance of stormwater monitoring, event sampling following heavy rains, the significance of bacteria in soil, sand and sediments, the application of complimentary investigative techniques including microbial and chemical source tracking, and ground surveys.

This report presents recommendations for a range of water and related monitoring at over 30 locations, including sampling of effluents at selected wastewater treatment and other facilities, stormwater, surface water (streams), locations potentially affected by agriculture, marine water and sediments.

The proposed monitoring program needs to remain adaptable and take into account the findings of related investigations planned by the Steering Committee on Water Quality at Parlee Beach.

BACKGROUND AND CONTEXT

During the summer of 2016, several episodes of elevated bacterial concentrations were observed at Parlee Beach, which resulted in beach closures on a number of occasions. This resulted in renewed attention to water quality at the beach, and a desire to pursue a variety of interventions aimed at improving beach water quality. The present report forms part of a scientific work plan prepared by the Steering Committee on Water Quality at Parlee Beach in support of this overall goal. This committee consists of staff from the departments of Environment and Local Government, Tourism, Heritage and Culture, Health and Agriculture, Aquaculture and Fisheries. More information can be found at : http://www2.gnb.ca/content/gnb/en/corporate/promo/ParleeBeach.html

Goals and objectives

The primary goal of this work is:

To provide practical recommendations on the gathering of water quality and related data that will support a more complete understanding of the sources that are contributing to bacterial contamination in the bathing waters and immediate environment of Parlee Beach, New Brunswick.

Related objectives :

- To identify and outline the catchment areas that potentially influence water quality at Parlee Beach.
- To identify all existing water monitoring within these watersheds.
- To develop a water monitoring plan designed to identify sources of bacterial contamination in the bathing waters of Parlee Beach, and the associated environment (e.g. adjacent wetlands, minor water courses).
- To describe the proposed monitoring plan in a written report.
- To consult key stakeholders in the development of the monitoring plan.
- To design the monitoring plan to enable the identification of both point and non-point sources of bacteria within the study region.

The above primary goal and objectives provide the framework for this report.

Terminology - bacteria

This report deals with issues relating to bacterial contamination. Some relevant background information on bacteria is summarised for reference in Appendix A (p.33). The differences between some of the commonly used laboratory tests for bacteria such as coliforms, E. coli, and Enterococci, for example, can be confusing. In this report the term *fecal indicator bacteria*, abbreviated to FIB, is used as a collective term.

SHEDIAC BAY AND PARLEE BEACH - PHYSICAL SETTING

Parlee Beach is located in southeastern New Brunswick about 50 kilometres northeast of the City of Moncton, at the southern edge of Shediac Bay, an adjunct to the Northumberland Strait.

The largest rivers entering the bay are the Shediac and Scoudouc Rivers. The Shediac River watershed covers 201.8 km^2. The river is divided into two main branches which join together near Shediac River and empty into the northern part of the bay near Shediac Bridge. The smaller Scoudouc River has a drainage area of 143.3 km^2 (Henderson, 1999). The mouth of the Scoudouc River system is located in the Town of Shediac. In addition there are a number of smaller tributary streams directly entering the bay, located in several composite coastal watersheds.

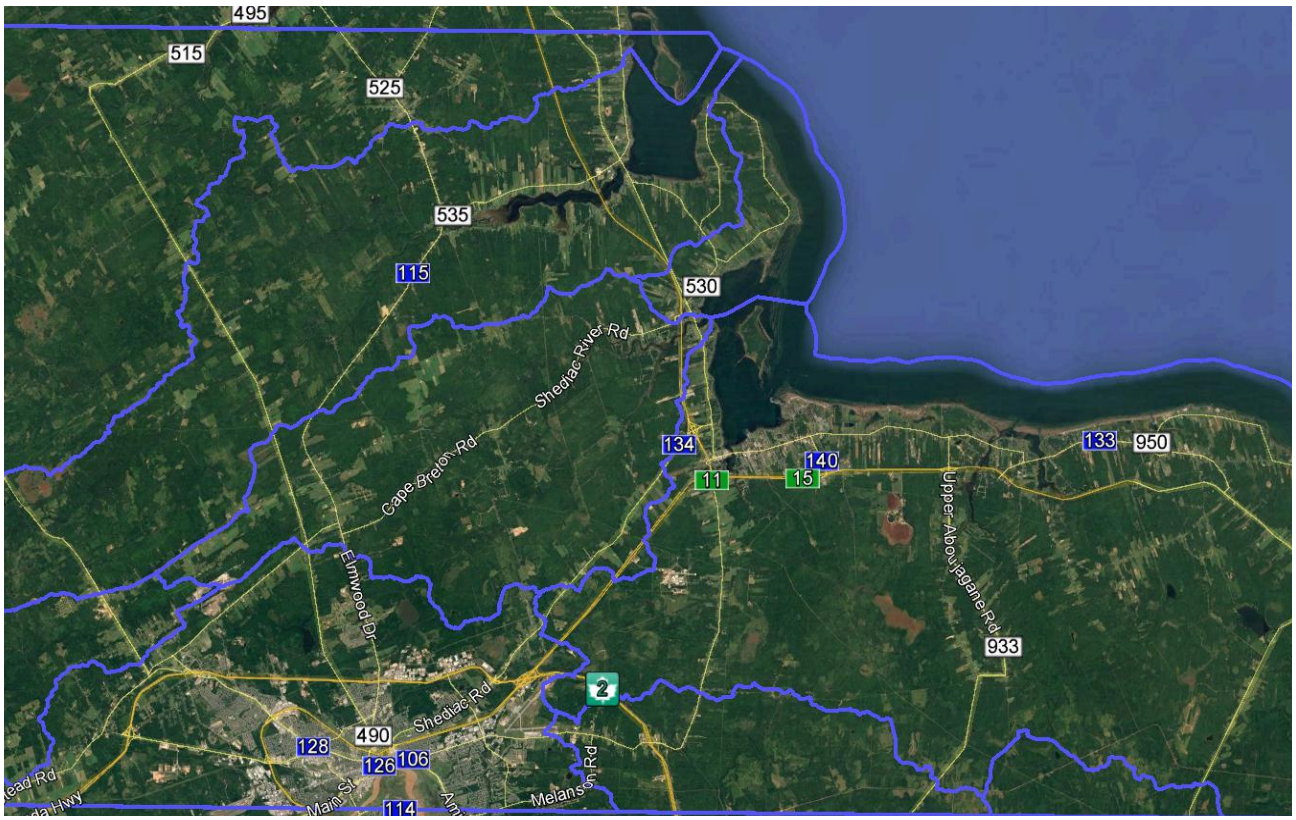

Figure 1. Major watershed boundaries in the study area.

In addition to the land-based watersheds that drain to Shediac Bay and undoubtedly contribute FIB to its waters, an additional 'catchment' should be recognised – the waters of the Bay itself. Boats using the bay have the potential to release untreated human waste directly to its waters. This catchment has no definite boundaries.

The physical and ecological characteristics of Shediac Bay and its watersheds have been well-summarised in LeBlanc et al., (2009). This is a comprehensive overview worth consulting in full. A few of the more pertinent aspects are summarized here.

The topography of the watersheds in the coastal hinterland consists of gentle undulating slopes with elevations ranging from sea level at the coast to just over 560 m near Lutes Mountain, 29 km inland, at the head of the Shediac River watershed.

Figure 2. Location map showing Shediac and environs in southeastern New Brunswick.

Figure 3. Location map showing the immediate environs of Shediac, Pointe du Chêne and Parlee Beach.

The flushing-time of Shediac Bay is approximately 40 hours. Freshwater input tends to be lowest in late summer (September). Tidal influence on the Shediac River reaches approximately 6.5 km upstream. The same distance is observed for the Scoudouc River, however, the river bed is shallower.

A notable feature of Shediac Bay is its shallowness. Extensive areas hundreds of meters from shore are less than 2-3 m deep. This combined with low fresh water inputs, and relatively weak tidal mixing enables the waters of the bay to reach high temperatures in summer (typically in excess of 20ºC (monthly mean)) contributing to the appeal of the local swimming beaches.

An important factor relating to water quality in the context of bacterial contamination is runoff, the overland flow of water, which may carry contaminants directly into receiving waters, lakes, rivers, streams or directly into the ocean. The study location is fairly typical of much of New Brunswick in that heavy runoff is common in spring during snowmelt, when the ground is often either frozen or saturated. Rapid melting of snow or significant rain at this time of year often creates major runoff events. Heavy rains at any time of year can also lead to significant runoff, usually for shorter periods.

The LeBlanc et al. Report (2009) also includes a short section dealing with pathogens and bacterial contamination, principally from the point of view of shellfish habitat and quality and closures. Along with the usual sources, fish plant effluents are noted as a source category of concern for shellfish contamination. A list of issues of concern in the region includes episodic poor water quality, shellfish closures, nutrient pollution, sediment loading in watercourses, and the loss of important coastal habitats.

BACKGROUND INFORMATION TO INFORM A MONITORING APPROACH

Previous water quality studies

Concerns over bacterial contamination at Parlee Beach are not new. In the 2006 report, Status of Shediac Bay and its Watershed (SBWA, 2006), it is noted that water quality issues were identified as long ago as the 1940s in the area, and in 1947 there were shellfish harvesting closures. Other episodes of impaired water quality were noted during the 1980s and 1990s, including numerous exceedances of health guidelines. The 1990s episode prompted a study of the factors affecting water quality in the region. This study (Henderson, 1999) was overseen by a technical committee including the provincial departments of health and environment, plus local authorities, the Greater Shediac Sewerage Commission, and Mount Allison University.

1999 Henderson Consulting studies and report

A range of water quality monitoring in the Shediac Bay region was summarised in the 1999 Henderson Consulting summary report (Henderson Consulting, 1999), as carried out by a number of government agencies including the NB Departments of Health and Environment, Economic Development ,Tourism and Culture (responsible for parks) and Environment Canada. Sampling was carried out in the vicinity of many of the known or suspected sources or hot spots for bacterial contamination or release. Elevated turbidity and coliform counts were observed at numerous sampling locations during the summer months. For example in 1998 all sites except one had at least one sample exceeding the applicable guidelines for bacteria (Guidelines for Canadian Recreational Water Quality).

Based on the available data, the Henderson report speculated that locations showing 'chronic' bacterial contamination were influenced by 'outfalls from domestic and industrial sewage systems, runoff from agriculture or pastures or both'. The Shediac and Pointe du Chêne marinas were noted as locations with generally good water quality. Across all the sites sampled, other possible sources of bacteria listed included motel waste, 'cross-connections' at shellfish plants, cottage septic systems, and local boats. It is important to note that all these source attributions were speculative and based on anecdotal evidence, as there were no tracer studies or other in-depth investigations carried out that might have more definitively linked specific sources or source regions with the measured elevated bacteria counts. Nevertheless, the work carried out to investigate water quality issues in the late 1990s is useful in providing context and data.

The Henderson report concluded by noting that a variety of source categories (as noted above) were contributing to water quality issues in Shediac Bay. The authors also noted that additional sources such as wildlife, swimmers and dogs could also be important contributing factors. A range of recommendations was also made in the report regarding future monitoring, planning, management and investigative work in the region, as well as at Parlee Beach specifically.

Marine modelling

In terms of the potential area of influence on Parlee Beach water quality, a companion study to the Henderson Report was also produced in 1999, modelling the tidal currents and marine flows in the bay (Coastal Ocean Associates, 1999). This study, although short and exploratory in nature, concluded that the net shoreline drift was westward, and that tidal advection is likely to bring marine releases to the beach from locations at least 1.5 km to the east and west.

SBWA Water Classification Report 2003

Poirier (2003) summarised water sampling results gathered in both the Shediac and Scoudouc river watersheds during 2000-2002. Sample locations are shown in Figure 4. Overall the results indicated generally good water quality in both watersheds, although there were some exceedances of the Canadian Water Quality Guidelines for the Protection of Aquatic Life for aluminum, calcium and iron. Occasional high levels of NO_3 and NO_2 were measured in the Shediac River as well as elevated phosphorus concentrations in the Scoudouc River. Additionally, high concentrations of E. coli were observed at many stations. Although it was noted that the source of the FIB may have been manure

Figure 4. Locations of monitoring sites used in 2000-2002 for water classification purposes.

piles, overflowing septic systems or wildlife, there was no systematic investigation or identification of specific sources of E. coli as part of this water classification work.

2016 Investigations and Report by the SBWA

In 2015-2016 the Shediac Bay Watershed Association carried out a campaign of water quality monitoring in Shediac Bay, summarised in Weldon and Donelle (2016). Marine water samples were collected at 11 sites around the bay on a total of 10 occasions during the summers of 2015 and 2016.

These samples were analysed for fecal coliforms. Some other physical data such as temperature and salinity were also recorded. Elevated coliform counts, in excess of the recreational water quality guidelines, were observed on multiple dates in both seasons, and most of the sample sites had at least one occasion when high values were seen. The highest coliform counts were measured on October 11th 2016, following a large rain event (over 45 mm over the previous two days). On this date, values exceeded 35 CFU/100 mL at all 5 sites monitored and were in excess of 1500 CFU/100 mL at two locations. This is consistent with other work both in this region and elsewhere around the world that shows that the greatest coliform levels are typically seen after heavy rains.

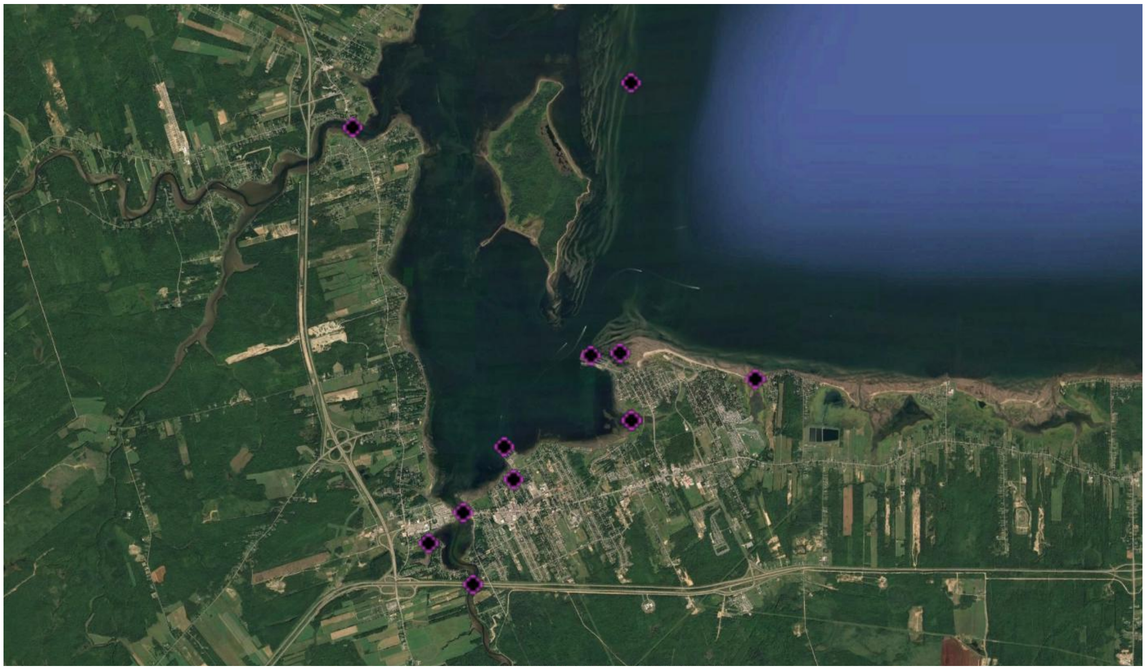

Figure 5. Monitoring sites sampled by the SBWA in 2015-2016.

The 2015-2016 sampling showed similar results and patterns to earlier work: elevated coliform counts can occur almost anywhere around the bay, and tend to be most frequent and with higher concentrations later in the season. The total number of samples and sample dates was not large. The authors did not feel able to make firm conclusions regarding the significance of different potential sources other than to note that fall manure spreading on farm fields might have been significant at one location and at another, high coliform levels may have been due in part to the adjacent tern nesting raft.

DNA testing

DNA testing was carried out on samples collected in 2016 at 5 locations. This enables the origin of any coliforms detected to be ascribed to various mammalian or avian groups. The findings were that coliforms from human, cattle and dog sources were the most common, with gull found at one location and pig at another. It is not possible to form any detailed conclusions from samples on a single date at a small number of locations. Nevertheless this information provides some indication that the observed coliform load is composed of bacteria from multiple sources. Earlier work (Henderson 1999) had speculated that wildlife and dogs might contribute, and this testing supported this view. Some caveats should be acknowledged. Library-based genomic testing that is not based on an extensive, locally developed library may produce misleading results. False positives are possible in this situation (Edge, 2017, pers. comm.).

Other Monitoring

In addition to the 1999 and 2006 studies which aimed to assess conditions in the bay from the point of view of the effects of bacterial contamination on general amenity and use of the waters, beach and local environment, there have been other monitoring activities and occasional surveys associated with university research projects, shellfish habitat assessment, watershed surveys for the purpose of classifying the local watersheds, and stream and river monitoring by provincial government staff. The most extensive marine sampling has been carried out in support of the Canadian Shellfish Sanitation Program (CSSP). Coastal waters are monitored annually in support of the CSSP with reports produced every three years (Richard, 2017). Figure 6 shows locations sampled in the period 1940-2016 in Shediac Bay and environs under various programs for which data are available (based primarily on Campbell and Corkum, 2017). Sample sites are identified by program code, with details provided in the Figure caption.

CABIN surveys

The Canadian Aquatic Biomonitoring Network, overseen by Environment and Climate Change Canada, organises periodic assessments of the rivers and watershed through by the sampling of invertebrate communities. These assessments provide additional insight into aquatic life and water quality. There have been sampling events in the Shediac/Scoudouc watersheds in 2012, 2014, 2015 and 2016. Sample locations are shown in Figure 7. Although the results of invertebrate surveys provide no specific measure of bacterial concentrations in waterways, certain assemblages of invertebrates are indicative of degraded environmental quality. This may be useful in pinpointing locations where more investigation is warranted to determine the cause of such adverse impact.

Beach sampling

In addition to the watershed-wide monitoring mentioned above, measurements of bacterial concentrations (both Enterococci and E. coli) have been made during most summer seasons at Parlee Beach since the 1990s. Elevated counts (in excess of 100 CFU/100mL) have been observed in most years, usually most frequently later in the season. While there is some evidence of inter-annual variation in the results that may relate to differences in weather, the majority of results fall into a similar envelope of values in most years. Complete uniformity in terms of timing of sampling, location, tide and analytical methods has apparently not been maintained throughout the period of record which introduces additional difficulty when interpreting the results.

Ongoing monitoring

While there are no sites within the Shediac and Scoudouc watersheds as part of routine monitoring by the DELG under its SWMN network (NBDELG, 2017*a*), the SBWA continues to be active in the region and may be expected to continue sampling at its established sites (Figure 4) as well as to undertake other project-specific sampling at other locations in the watersheds. The CSSP shellfish and CABIN surveys are also ongoing, as is regular sampling at Parlee Beach itself in support of public use of the beach at the provincial park.

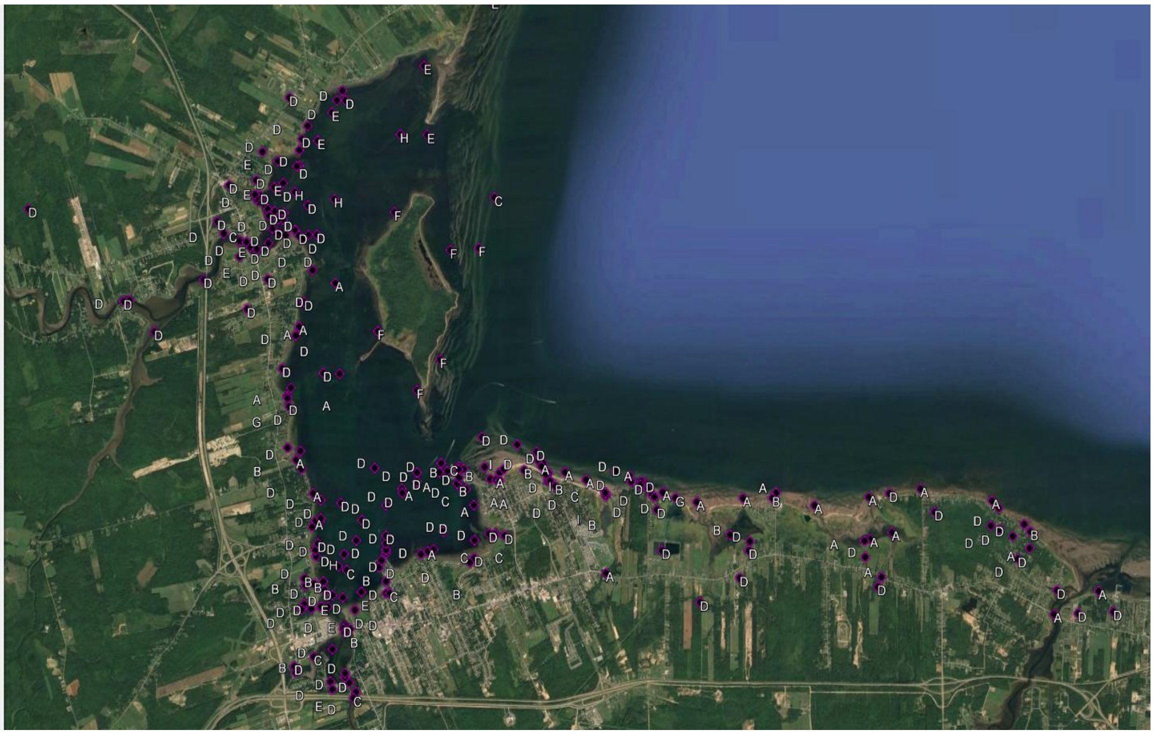

Figure 6. Locations of sites sampled under various programs and studies, 1940-2016 (Based on data summarised by Campbell and Corkum, 2017).

Legend for plotted points (per Campbell and Corkum, 2017):

A	Environment Canada Survey Plans for Shediac Watershed, 2001
B	SBWA Investigation Part 4 1998
C	Water Sampling in Shediac Bay 2015-2016,SBWA
D	EC Shellfish surveys (various)
E	B.J. Richards C.G. Roberts Environment Canada. NB-07-010-001(EP-AR-93-1) Shediac River and Harbour 1993
F	Patrice Godin and Bernard Richard NB-07-010-003 (ST-AR-2013-22-A) Shediac Island 2004-2013.pdf
G	Shediac Bay 2002
H	Lakshminarayana J.S.S. L. Jean-Pierre. 1975. Changes in the Coliform Populations of the Shoreline Waters Shediac New Brunswick. The Science of the Total Environment (3) 293-300.
I	Parlee Beach June 30-Aug21 2016 RTI Response, Laura Booth

Figure 7. Locations of sites sampled under the CABIN invertebrate monitoring program.

The site plots indicates the year of sampling: 12 = 2012, 14 = 2014, etc.

Learnings from previous local studies

For the purposes of the present work, information relating to bacterial concentrations or sources of FIB is of primary interest, as opposed to other measures of water quality. With this proviso in mind, the following can be concluded:

- Elevated FIB concentrations have been observed in many parts of the combined land/marine system over many years;
- Bacterial concentrations tend to be highly variable in space and time;
- Water quality in the major watersheds is good overall, with occasional instances of impairment;
- High bacterial counts at Parlee Beach are often correlated with major precipitation events;
- Bacterial sources identified or suggested by surveys and specific studies have included sewage releases from domestic/commercial systems, wastewater treatment effluent, industrial waste (including fish processing plant wastes), cattle/agriculture, stormwater runoff, wildlife, pets, swimmers and discharges from boats.

These findings are in line with experiences in many locations worldwide where bacterial contamination issues have been investigated.

Since the earlier studies in the 1990s a number of changes have been made in the area that should have eliminated or at least reduced the potential impact of some of the sources. For example premises on the Pointe du Chêne wharf are now all connected to the piped sewerage system with waste treated at the Greater Shediac Sewerage Commission facility. Disinfection systems at this treatment plant have been modernised.

Individual household septic systems are now rare or absent in the developed areas immediately inland from Parlee Beach . Nevertheless, experience elsewhere has shown that underground cross-connections between sanitary pipework and stormwater or other drainage pipes are often encountered (e.g. Hyer, 2007, Edge and Hill, 2007). Such cross connections can be a legacy of old abandoned piping, pipe connections repaired or improvised following excavations for drainage or other underground work, as well as piping damaged by the passage of heavy machinery, frost heave, or materials failure due to aging of pipes. These types of connections may only be active irregularly during periods of high groundwater or heavy precipitation. Such cross connections can result in significant FIB loadings in discharged stormwater/wastewater mixes, and can exist in unexpected locations that make them hard to identify.

Most if not all of the suggested causes or sources contributing to bacterial contamination at Parlee Beach noted in previous work were fundamentally speculative, in that a clear chain of causation or impact between source(s) and receptor was not established. Further work should narrow the remaining gaps in knowledge and understanding, and increase overall confidence in conclusions. Given the complexities involved, this is likely to take significant time and effort.

Learnings from other relevant studies

Numerous intensive studies of bacterial contamination in watersheds and beaches have demonstrated that there is no 'magic bullet' monitoring or assessment solution. This is due to the great complexities of real-world environments involving living organisms, some of which are described above. However, a weight of evidence approach can potentially provide sufficient confidence to guide any necessary abatement or control activities (e.g. Gilpin, Gregor and Savill, 2002, Hyer, 2007). Systematic monitoring is a key component of this approach.

Survival of bacteria in sediment, sand and soil

Traditionally, the presence of FIB has been considered indicative of recent, fresh contamination with fecal wastes. This is based on the assumption that E. coli can survive for only limited time in an oxygen-rich environment, and outside the warm environment of the mammalian body. More recently there has been an accumulation of evidence that E. coli is not only able to survive for extended periods in the environment in temperate regions, but also to persist and reproduce in the soil. A few illustrative examples are given here. This complicates investigations of FIB contamination as there may be a variety of source zones that could contribute to the coliform load in receiving environments, even if the originating (presumably more concentrated) sources of bacteria are well-managed and controlled.

In a study of bacterial dynamics in southern Lake Michigan, Whitman et al. (2006) found that E. coli persisted in the fluvial-lacustrine system including in forest soils, sediments surrounding springs, bank seeps, stream margins and pools, foreshore sand, and surface groundwater, and that year-round background loading from these components can influence beach water quality. They also demonstrated that after sterilising plots of local soil, coliform bacteria from adjacent soil re-colonised the plots within a few weeks, indicating the existence of viable, naturalised populations of bacteria.

Burton et al. (1987) reported FIB levels in sediment many times (100-1000 fold) higher than the overlying water. Their work showed that these reported higher concentrations were due, in part, to greater survival in sediments (for many months). They note that re-suspension of bacteria may account, in part, for the erratic FIB levels often encountered in water monitoring programs.

Boutilier et al. (2008) examined the fate and survival of coliform bacteria in engineered wetlands used to treat agricultural waste in Truro, Nova Scotia. They reported that cold winter temperatures may increase the survival of bacteria within these wetland systems, decreasing the wetland's ability to reduce bacterial concentrations during the winter months.

Whitman et al (2014) presented an extensive review of research into FIB in beach sand. They note that in various beach studies, geese, gulls, dogs and human sources have been found to be the greatest contributors to FIB. Significantly, they report that that FIB can persist and replicate in secondary environments such as sand, soil, sediment and seaweed. When this takes place the bacteria are considered 'naturalised' in such environments - they constitute established, permanent or semi-permanent populations. The microbial community in beach sand can contain bacteria, fungi, viruses and protozoa that are collectively referred to as *micropsammon*. One significant conclusion reached by Whitman et al. was that abating nearby offshore fecal pollution sources (e.g., wastewater effluents) may deliver only limited or short-term improvement unless onshore fecal pollution sources (e.g., bird fecal droppings) and the sand micropsammon are also addressed. This paper includes a detailed overview of the topic and is recommended for further reading.

Edge, and Hill (2007) in a study of bacterial contamination at a beach in Hamilton Harbour, Lake Ontario, found gulls and geese to be major contributors. E. coli concentrations were highest in wet foreshore sand (114,000 CFU/g dry sand) and ankle-depth water (177,000 CFU/100 mL). At this location, wastewater impact was greater further offshore.

Disturbance and re-suspension of bacteria from sediments could potentially affect other areas, seeding them with bacteria, which in suitable conditions can then multiply further. The warm, shallow marine environment of Shediac Bay offshore from Parlee Beach with extensive areas of sand and mudflats, appears to offer the potential for this mechanism. However at this time there are no data to confirm that this is occurring.

McCulloch (2015) in a study in South Carolina, found that by monitoring bacteria in sediment, as well as the overlying water column, a more accurate depiction of water quality could be obtained. Numerous researchers have shown the levels of fecal coliforms in bed sediment can be 1 to 4 orders of magnitude greater than in overlying water, (e.g. Matson et al., 1978; Irvine and Pettibone, 1993; Center for Watershed Protection, 1999, Irvine et al. 2002).

Shibata et al. (2004) used a dense spatial sampling network to study bacterial concentrations in shoreline waters in a study in Dade county, Florida. They found the highest concentrations at shoreline points, decreasing offshore. The highest microbe concentrations were observed at high tide, when the wash zone area of the beach was submerged. Beach sands within the wash zone tested positive for all indicator microbes, suggesting that this zone may serve as a source of indicator microbes. Sources of microbes were thought to include humans, animals, and possibly the survival and regrowth of indicator microbes within the beach /inter tidal zone. Moisture and temperature conditions within this zone favour bacterial survival and reproduction and they are screened from the sterilising effect of uv light (sunlight).

Tidal mudflats extend up to 300 meters offshore near Pointe-du-Chêne and 50 to 75 meters at Parlee Beach (Henderson 1999). These areas are probably important in terms of bacterial dynamics in the area of the beach given that these flats are frequented by large numbers of shorebirds including plovers, sandpipers and dowitchers congregate on mudflats to feed on marine worms and molluscs (Campagne 1997). These mudflats might serve as a reservoir for bacteria that are re-mobilised by tidal currents while birds are regularly providing a fresh input of coliforms to the system.

Converse et al. (2012) in a study of water quality at a beach in Lake Michigan, showed that E. coli and Enterococci in the bathing waters decreased dramatically when gulls were chased from the beach. Pramod et al. (2014) also found that birds were a significant source of FIB found on beaches.

Specialised Source Identification Techniques

Microbial Source Tracking (MST)

Microbial Source Tracking applies a variety of methods for investigating fecal contamination that include, but go beyond the use of FIB. MST is an evolving approach that can employ a range of sophisticated genomic techniques: it is an evolving field and new methods are continually being identified and tested.

In 2006 a major workshop on the topic of Microbial Source Tracking was held in Burlington Ontario. A significant conclusion was that there is no universally accepted best method of application of this kind of technique. MST methods are still in the category of applied research and have not yet reached the stage where an off the shelf, standardised method can be selected for a given issue or application (confirmed by pers. comm. to Dr T., Edge, May 2017). While MST methods can provide useful insights into bacterial contamination problems, multiple lines of evidence should typically be pursued to resolve fecal pollution source tracking problems. While there are several laboratory studies supporting the use of library-dependent approaches for MST, their accuracy in field study situations has been questioned due to a number of problems associated with the target organisms, the stability of the markers used, and poor sampling protocols. Library-based methods, such as those based upon E. coli, were also seen to suffer from high misclassification rates and the need to have increasingly larger libraries to represent the diversity of potential E. coli isolates from fecal sources.

Staley and Edge (2016) used microbial tracking methods to investigate FIB issues on beaches in the Toronto area of Lake Ontario. Examining sites across the Humber river watershed, they found FIB along the river and at the beach. Indicators of contributions from human and bird sources were common everywhere but the bird(gull) was signal strongest at beach, some markers indicating ruminants were found in the river but not at the beach. They concluded that multiple MST methodologies can add significant value when interpreting FIB data to more comprehensively assess fecal contamination source(s) and risks to public health, as well as guiding cost-effective remediation strategies.

Staley et al. (2016) used a range of chemical and microbial source tracking techniques to investigate FIB in the Humber river, Ontario. They found pervasive human sewage contamination in storm water outfalls and throughout the urban watershed. They found that while CST markers were helpful in identifying raw sewage contamination, the additional use of MST methodologies provided more reliable identification of the source(s) of fecal contamination and helped alleviate potential confounding factors related to use of CST methods alone.

In addition to the references cited above, there is a useful basic overview of MST at this Environment Canada web site:
https://www.ec.gc.ca/inre-nwri/default.asp?lang=En&n=D575CDF5-1&offset=5&toc=show

Chemical source tracking

Chemical source tracking (CST) makes use of the fact that there are numerous substances released into waste streams by human activity that can be used as tracers. They are often persistent and have no natural sources to complicate interpretation. For example, there are no natural sources of the fluorescent brightening agents added to detergents. If they are found in the environment, they got there due to human activity. Substances used in CST include industrial chemicals, pharmaceuticals, and other substances that may be traced directly to fecal contamination. They are typically found in surface water or stormwater impacted by wastewaters in concentrations ranging from micrograms to nanograms per litre.

The table below lists a number of substances often used in CST studies. The data in this table are based on the references cited in this section.

Substance	**Notes**
Caffeine	Ubiquitous and relatively long-lived in human-derived wastewater.
Fluorescence whitening agents (FWA), aka optical brighteners	Used in laundry detergents, relatively persistent in wastewater. Water soluble.
Carbamazepine	Anti-seizure medication, found in most human-derived wastewater.
Surfactants (various)	Common in wastewater.
Cotinine	Metabolic product of nicotine. Common in wastewater.
Coprostanol	Coporostanol/cholestanol ratio: if >0.5, indicates contamination with wastewater.
Menthol	Fragrance
Skatole	Fragrance
Triclosan	Antimicrobial used in many consumer products
Diethyl phthalate (DEP)	Plasticiser
Diethylhexyl phthalate (DEHP)	Plasticiser
Galaxolide	Fragrance
Tonalide	Fragrance
Acetaminophen	Pain relief medication
Acesulfame	Artificial sweetener

Standley et al. (2002) used various molecular tracers to identify wastewater and agricultural effluent signals in receiving waters. Some of the indicators they used included caffeine, fecal steroids (to track fecal matter sources such as human, agricultural manures, and wildlife), caffeine and fragrances (used to assist in separating human from agricultural and wildlife sources of fecal matter), and polycyclic aromatic hydrocarbons (PAHs) (used to track road runoff).

Fecal sterols and stanols, caffeine, detergents, laundry brighteners, fragrance materials and pharmaceuticals are among chemicals proposed as markers of fecal pollution (Elhmmali et al. 2002; Roser et al. 2003; Glassmeyer et al. 2005).

Derriena et al (2012) also used six stanol compounds (i.e. coprostanol, epicoprostanol, campestanol, sitostanol, 24-ethylcoprostanol and 24-ethylepicoprostanol) as discriminators in determining the origin of fecal contamination in surface water.

Sankararamakrishnan and Guo (2005) examined concentrations of caffeine, anionic surfactant, fluoride, and fluorescence whitening agent (FWA) as chemical indicators of water contamination by

FIB. They found a strong correlation between fecal coliform counts and chemical parameter values. In addition, a strong correlation among the chemical parameters suggested that only one of them may be needed as a chemical tracer to detect the presence of human input.

Sauvé et al. (2012) tested the efficacy of caffeine and carbamazepine (a common anti-seizure drug) as chemical tracers of wastewater. They found that caffeine was strongly correlated with fecal coliform counts. All the water samples with more than 400 ng/L caffeine—an arbitrary threshold selected by the authors—were contaminated with fecal coliforms at concentrations exceeding 200 cfu/100 mL. Hyer (2007) used a multiple-tracer approach in the intensive investigation of sewage impacts on urban waterways in a watershed in Virginia. This study was able to identify human sewage impacts via use of a suite of chemical source indicator compounds. They found that relatively high specific conductance, chloride, boron, chloride/bromide ratio, surfactants, and fecal coliform bacteria, along with relatively low dissolved-oxygen concentrations provided strong evidence of sewage contamination. This study is a good example of the application of multiple techniques in investigating watershed-wide bacterial contamination and is recommended for further reference.

Bacterial sources

In the table below some potential sources are listed that may contribute to FIB contamination. They are listed in no particular order, and the list is not necessarily comprehensive. Whether a given source is an area or point source is also not always black and white.

Potential sources of bacterial contamination	**Source type**
Boats dumping waste	Area
Wildlife (mammals, birds)	Area
Pet waste (on streets, trails, beaches)	Area
Farms -pastured livestock, manure spreading	Area
Livestock watering in streams	Area
Dumping of domestic waste	Area
Runoff from roads, trails and parking lots (stormwater)	Area/ Point
Septic pump truck operations	Point
Dumpster staging areas	Point
Fish/shellfish processing plants	Point
Slaughterhouses, meat packaging, processing	Point
Dumps/landfills/transfer stations	Point
Campgrounds, trailer parks	Point
Wastewater system infrastructure	Point
Sewage treatment plants, lagoons	Point
Farms-feedlots: cattle, pigs, poultry, other	Point
Domestic/commercial septic systems	Point/Area
Composting operations	Point/Area

Bacteria transport

Bacteria can enter water via point or non-point sources of contamination. Point sources are those that are readily identifiable and typically discharge through a pipe. Non-point or area sources are those that originate over a widespread area and can be difficult to trace back to a specific starting point. Non point sources are also usually regulated by hydrological conditions. Examples of non-point sources include farm fields and built up areas. Contamination in such cases can originate from manure piles, feedlots, or cattle defecating directly in streams. In built-up areas, bacteria-laden waste such as pet and wildlife excrement accumulates on impermeable surfaces and can then be flushed into watercourses through stormwater systems. Whitman et al. (2014) noted that the degree of urbanization of a watershed is one of the strongest predictors of fecal indicator abundance.
Water containing high concentrations of FIB can be released underground or near the surface from broken sewage pipes (often termed 'lateral lines') for example pipes connecting residences to the street sewer line. These are sometimes damaged by excavation work, subsidence or corrosion, or by heavy equipment driving over the immediate surface. Domestic septic systems or holding tanks are subject to a range of similar failures whereby polluted water may be released. Depending on the porosity of the soil and bedrock geology, channels of high hydraulic conductivity may allow such polluted water streams to travel significant distances. It may then enter water channels open to the atmosphere and pollute streams, lakes or other water bodies.

At or near the surface, bacteria can be transported in surface runoff during spring snowmelt or at other times when precipitation rate exceeds the infiltration rate into the ground. Bacteria can also travel through the soil via subsurface flow, and thence into surface waters. Bacteria can be transported either freely in suspension in water or water films, as well as attached to or within particles of soil or sediment. During periods of saturated ground and high runoff, sanitary sewers or pumping stations can be flooded with surface water, leading to uncontrolled releases of water contaminated with FIB to the environment.

Transfer functions for predicting FIB concentrations

There is usually a strong positive correlation between precipitation rate (and hence runoff), sediment load in surface waters, and bacterial counts or concentrations. Faster surface flow is able to mobilise and suspend more soil and sediment particles, or wash accumulated material from roads, roofs and parking lots. Bacteria are more abundant in soil and sediments, hence greater runoff leads to higher concentrations in receiving waters. Turbidity, a measure of the optical opacity of water, increases directly with sediment load. Accordingly, there is also usually a strong positive correlation between turbidity and bacterial concentrations.

Kistemann et al. (2002) examined the relationship between turbidity and microbial load in surface water. Lawrence (2012) in a Georgia study, was able to develop a relationship via multiple regression relating E. coli density to turbidity, streamflow characteristics, and season at two sites. The regression equation explained 78 percent of the variability in E. coli density by the variability in turbidity values , streamflow, season (cool or warm), and an interaction term that is the cross product of streamflow and turbidity. The model was tested against independent data and was able to predict E. coli density in real time at both sites to within the 90 percent prediction intervals of the equations.

Aldom et al. (1997) used a predictive system based on wind and weather conditions for beaches on Lake Huron. They found that elevated E. coli levels occurred with few exceptions, when winds were onshore at between 0 and 40 km per hour. Alternatively, the lowest E. coli levels occurred when waves were diminished in height and when winds were off-shore. In their paper they drew attention to the fact that the decision-making process in terms of beach closures is usually flawed due to the fact that the results of bacteriological sampling and testing are usually available only after 32 to 36 hours at the earliest. Hence the significant value of a predictive system based on real- or near real-time data.

King (2016) carried out a study of FIB levels and other environmental variable at Edgewater beach, Ohio, on Lake Erie. Results of correlation tests demonstrated that water turbidity had the most significant correlation with E. coli and Enterococci concentrations, both in excess of .52.

These examples highlight the potential for developing useful predictive relationships between FIB concentrations and other supplementary data that can more readily be measured in real time. This approach is recommended for investigation as part of future monitoring and assessment work at Parlee Beach.

Summing up

Although "What is causing high levels of bacteria in the swimming waters at Parlee Beach?" may seem like a simple question, experience gained from related studies worldwide show that it is not.

While it may be clear that an obvious point source of bacterial pollution is affecting the immediate receiving environment (metres to terms of metres), it becomes much more difficult to determine which individual or collective sources are responsible for bacterial contamination at locations some distance (hundreds of metres to kilometres) from multiple pollution sources. This is especially difficult when the receptor location is an ocean beach; apart from the possible impacts of discharges from local boats, and possible bacterial sources within the beach environment itself, all other potential sources are not in immediate proximity.   In the marine environment, the releases from multiple sources mix together, greatly complicating the identification of each source.

Even intensive studies such as that carried out in the Accotink watershed in Virginia (Hyer, 2007), which involved over 140 sites in an area of less than 50 square kilometres, still had significant difficulty identifying some sources of bacterial contamination. Cross connections between storm and wastewater streams, even when located, often defied explanation and complete understanding. This study employed multiple instances of hourly sampling, and illustrates how hard it can be to obtain a full understanding of bacterial fate and dynamics even given this level of detail in sampling data.

Challenges

Some other significant challenges include the following:

- Bacterial pollution is especially hard to assess because bacteria do not behave like chemical substances in the environment.   It is possible to use a mass balance approach within a defined region such as a watershed to track and account for many types of pollutants. This approach does not work well with bacteria, as following release they may either die off or reproduce;

- Detail on the transport, fate and particularly the persistence of FIB in Shediac Bay and its many niche environments is lacking. Although it used to be believed that bacteria such as E. coli had a relatively short lifespan in the environment, many studies in recent years have shown that this is not the case. FIB have been found to persist in a viable state for extended periods in sand, soil and sediments in a wide range of environments;

- At a given receptor location, there is no established method of monitoring and analysis that will determine what proportion of a measurement say, of E. coli, is due to various source categories such as domestic sewage, agricultural manure, or wildlife. This includes “DNA testing” or other genomic techniques. Such techniques can provide useful insights in terms of of the presence of an indicator of a particular source type (e.g. a contribution from birds), but do not quantify its impact;

- Detailed information on the hydrological and oceanographic dynamics in the study area is rudimentary. The Shediac and Scoudouc rivers have no hydrometric gauge (flow) records (Burrell & Anderson, 1991). Uncertainty exists regarding marine currents, flushing rates and residence times;

- Groundwater flow at shallow depths in areas near the coast could deliver bacteria to marine waters.

Studies are already planned that should address the last two points above. This will help provide a better understanding of the bacterial dynamics and hydrology in the area.

Despite these challenges, a systematic program of data gathering and investigation should enable continuous progress in understanding the issues, and support improved decision making in areas where action is indicated.

DEVELOPING A MONITORING APPROACH

The monitoring program presented in this report has been designed bearing in mind the findings of previous local studies and a review of literature and methods of investigation currently being used in similar studies of bacterial contamination around the world.

Some basic assumptions have been made following consideration of the various studies, reports and technical papers cited previously:

- While a monitoring program should include a watershed-wide component, potential sources and locations closer to the receptor location (Parlee Beach) are likely to be more significant, and should receive priority attention;
- The influence of discharge from the Shediac River, while significant, is likely to have less impact than discharges from the Scoudouc River due to location, distance and water circulation patterns;
- The largest inputs of bacteria-laden waters take place during and following significant rain events, therefore sampling should focus on these events;
- The existence and persistence of FIB in sand and sediments has not been previously investigated, and merits attention;
- Similarly stormwater, a known source of bacterial contamination, has not been previously studied in the area and needs to be investigated.

It is stressed that these are judgments, based on available data and information and the indications of other research. They should be reviewed as additional data are gathered, as adjustments may be indicated.

Supplementary Data

The interpretation of test results can be greatly enhanced if supplementary information is obtained when samples are collected. It is strongly recommended that the following are recorded at the time of collecting all samples:

> **Water quality data**: using a hand held probe, water temperature, conductivity, pH, dissolved oxygen and turbidity. Turbidity in particular can be very useful in relating FIB levels to environmental conditions and should be prioritised.
>
> **Visual and other observations** on the sample and water being sampled, especially colour, odours, presence particles or foam, or any other notable characteristics of the water being sampled.
>
> **Prevailing conditions**: significant weather (including any precipitation at the time of observation and over the previous 24 hrs, wind direction and speed, cloud cover, air temperature, and state of tide).
>
> **Nearby activities**: - that may influence the sample, e.g. construction, boating, forestry, agricultural /landscaping activities, wildlife numbers or anything else thought relevant.

Sampling protocols

The implementation of monitoring recommended in this report is likely to be overseen and managed by the Steering Committee on Water Quality at Parlee Beach and the Water Quality and Quantity Section of the Department of Environment and Local Government. These authorities will ultimately need to approve any specific details of sample collection, handling and management, as well as the acceptability of any analytical test methods used. For the most part these procedures are well-established, and existing references such as the NB Volunteer's Guide to Water Quality Monitoring (NBDELG, 2000), the Guidelines for River Sample Collection and Lab Submission for Watershed Groups in New Brunswick (NBDELG 2017b) and the CCME Protocols Manual (CCME, 2011) provide good guidance.

Obtaining quality data requires the careful implementation of a complete sampling and analysis system that involves adequately trained personnel following acceptable sampling techniques, plus accurate record keeping and quality control. This is especially important when sampling for trace indicator substances that are present at very low concentrations. If these tests are undertaken, the lab handling the analysis should provide final guidance on sampling methodology (e.g. filter samples obtained for later PCR analysis).

The Steering Committee has indicated that a specialist in microbiology will be engaged to assist with field planning and the interpretation of results. Input from such an expert to review these monitoring plans, as well as to help interpret the results, is highly recommended.

Analyses

The majority of recommended testing is for E. coli and Enterococci. Additionally some sites are recommended for a general surface water package analysis, including trace metals. A full listing of this package is included in the spreadsheet file that accompanies this report. The additional information provided by the surface water package will allow for more detailed analysis and interpretation of results, for example ratios of some elements/ions can be used as indicators of human wastewater, such as the boron/chloride ratio. Multivariate analysis would also be possible, which could identify and clarify relationships and patterns in the results for samples in different locations.

For some locations, analysis for wastewater indicator compounds has been flagged. These substances, listed in the table on page 13, require specialist laboratory services. The ability to obtain such testing will depend on available resources, but if available these tests can be helpful in clarifying the presence of human waste impact in a given sample, if bacterial contamination is found to be significant.

Similarly, some sample locations are flagged for PCR testing. This is a molecular genomic technique used to identify the origin of FIB in samples by testing for specific genetic markers. As with trace wastewater indicator substances, PCR analysis requires specialist laboratory services, oversight and interpretation. If available, this method is a useful additional tool to help interpret the overall results.

Timing of Sampling

This report was commissioned in April 2017 for delivery by May 31. As such June is likely to be the first full month of operations in 2017. However, so as to be usable if needed in future years, the plan is presented in a generic format, identifying the target sampling season as May-October.

Management Considerations and publication of results

Managing field sampling activities that are likely to involve multiple individuals, groups and other agencies poses a significant challenge. It is recommended that a single point of authority be established to oversee the organization of fieldwork. It would also be useful to ensure that all data are ultimately managed in a single database system to promote efficient and comprehensive interpretation. There would be great value in summarizing the findings of this work in a scientific publication where it would benefit from expert review, as well as being available for future use by provincial, municipal or other authorities and the general public. By contrast, information contained in locally issued 'grey literature' reports tends to be hard to access and often goes missing over time.

Flexibility, review and adjustment

The plans put forward in this report are recommendations that should not be viewed as inflexible. The information gathering process should be regularly reviewed as data come in, and if necessary, adjusted. It is likely that some surprises will be encountered and if so, monitoring should be refocused or adjusted accordingly. It is impossible to predict which sites in particular group (stormwater, agriculture etc) may experience high levels of bacterial contamination. Sites showing high values may benefit from additional sampling and if possible, efforts should be made to keep the overall monitoring effort agile enough to respond to the indications of results as they come in. Similarly, it is not worthwhile allocating resources to expensive trace substance analysis and genomic testing for samples that show low bacteria concentrations.

Relationship with other projects

The monitoring effort should remain closely linked to a number of other projects planned under the Scientific Work Plan published by the Steering Committee.

Weather Station at Parlee Beach

Meteorological data are very important in environmental studies of this kind and offer the potential of developing functional relationships with observed FIB concentrations. This could allow more sophisticated management options in future in terms of beach advisories or closures. The data obtained from weather observations made as part of this project will be valuable in supporting data interpretation.

Hydrodynamic Modelling

More detail on marine flows, currents and transport will enable more confident planning of both future monitoring and beach management.

Beach Sand Bacteria and Shallow Groundwater Flow Paths

The importance of bacteria in sand and sediment has been noted in the literature review. Some basic recommendations are put forward for sediment testing. It is assumed that there will be significantly more work of this kind undertaken as part of the shallow groundwater study.

Watershed Reconnaissance Survey

The findings of any additional ground-based surveys should be considered as input to the monitoring plan as information becomes available. This might include direct observations such as potential sources of contamination, flow paths and volumes in the surface stormwater network, odours, or large congregations of shorebirds or other wildlife.

PROPOSED MONITORING PLAN

Proposed monitoring is grouped according to the sample medium (freshwater, marine, effluent etc).

Complete details of site types and locations, the types of sampling recommended, supplementary data required, sampling conditions and other notes are contained in an accompanying spreadsheet file.

Monitoring site locations are shown in Figures 8-10.

Figure 8. Locations of sites recommended for monitoring in 2017.

Site types:
E = Effluent, SW = Stormwater, FW = Freshwater, AG = Agricultural, M = Marine, SED = Sediment.

Effluent monitoring

Four sites are recommended for effluent testing.

There are 13 facilities in the Scoudouc/Shediac river watersheds that operate under Certificates of Approval for wastewater discharge issued by the Department of Environment and Local Government. The following table summaries these operations (information provided by the DELG Industrial Processes Section).

ID	Facility/location/distance from Parlee Beach	Type	Discharge (m^3/d)	Notes
1	The Greater Shediac Sewerage Commission - Cap-Brule 3 km E	Domestic wastewater treatment plant	5,000 – 9,000	Final effluent is disinfected via UV sterilisation.
2	The Greater Shediac Sewerage Commission - Scoudouc , 3180 Route 132 11 km S	Domestic wastewater treatment plant	300-400	No disinfection before effluent release
3	Scoudouc Industrial Park 55 Brenan Avenue, Scoudouc 9 km S	Commercial/industrial wastewater treatment plant	300-500	No disinfection before effluent release
4	Shediac Lobster Shop Ltd , 261 Main Street, Shediac 2 km SW	Shellfish processing, process water	Approx 500	Summer only. No treatment beyond screening particles to 0.71 mm
5	Murray Beach Provincial Park Campground, 1679 Route 955, Murray Corner 40 km E	Domestic wastewater treatment plant	Approx 2-10	No disinfection before effluent release
6	Camping Plage Gagnon Beach Inc., 30 chemin Plage Gagnon, Grand-Barachois 14.5 km E	Domestic wastewater treatment plant	N/A	Subsurface drainage field.
7	Westmorland County Condominium Corporation No 45 - Villa sur Plage, 90 chemin de la Breche, Grand-Barachois 12 km ESE	Domestic wastewater treatment plant	4 to 6	Filter bed system.
8	H&J Mullin Holdings Inc - KOK Campground, 1884 Route 530, Grande-Digue 10 km N	Domestic wastewater treatment plant	N/A, up to 55 potentially	Final effluent chlorinated.
9	Le Village Gedaique Inc, 3954 Route 134, Grande-Digue 7 km NW	Domestic wastewater treatment plant	Approx 16	UV disinfection system for final effluent.
10	Le P'tit Chez-Nous, 38 Route 530, Grande Digue 7 km NW	Domestic wastewater treatment plant	Approx 10	Peat filtration system.
11	La Résidence Monseigneur Arsène Richard Inc, 3148 highway 132, Scoudouc 12 km SW	Domestic wastewater treatment plant	< 2	Peat filtration system.
12	KC Properties (GP) Limited - Lakeside Estates 16 km SW	Domestic wastewater treatment plant	300-350	No disinfection before effluent release.
13	Cap-Pelé , rue de l'aréna, Cap-Pelé 17 km E	Domestic wastewater treatment plant	1100-1700	No disinfection before effluent release.

There is a great range in the volume of effluent discharged, type of treatment and potential impact on Parlee Beach between these facilities, due to varying distance and location of effluent discharges. The Cap Brûlé plant has by far the greatest discharge and is relatively close to Parlee Beach. Its final effluent is disinfected. Nevertheless it warrants attention due to the high volume discharged, and proximity. As part of the 2017 monitoring schedule, continuous turbidity monitoring could be considered for the Cap Brûlé plant effluent. This may enable a useful relationship between FIB concentrations and turbidity to be developed.

The potential impact of some of the other facilities will be addressed via marine/freshwater monitoring.

The objectives of monitoring the effluent locations is to check for residual FIB in the effluents and provide additional information on the composition of these effluent sources. This characterisation should help identify the existence of any cross-connections between the surface/stormwater network and effluent from domestic sources, if evidence of this is found.

Figure 9. Locations of sites recommended for monitoring in 2017 (south section). Codes as per Fig. 8.

Stormwater monitoring

Eight sites are recommended for stormwater monitoring. There is some piped stormwater infrastructure in the study region, principally in the Town of Shediac. Outside this relatively small built-up area, stormwater is managed via roadside ditches. These could be a significant source of FIB discharging to waterways. Unlike large piped storm systems in major developed urban areas, there is little or no baseflow in the Shediac stormwater network (Margot Allain Bélanger, Town of Shediac, pers. comm, 2017). This means that sampling will need to be targetted to follow rain events.

Figure 10. Locations of sites recommended for monitoring in 2017 (central section). Codes as per Fig. 8.

The small streams within the Town of Shediac, although natural drainage channels, can be expected to be significantly influenced by contaminants entering from a number of local stormwater drains that connect to the stream channels. Accordingly they are classified as 'stormwater' sites.

There is potential for stormwater to have relatively high bacteria levels that could be from a range of sources. If consistently high levels are seen then testing for human wastewater indicator substances and molecular testing may be useful to help determine the sources. Some sites are flagged for these tests but depending on results obtained, plans should be reviewed and if necessary adjusted.

In the sampling plan, these sites are listed for sampling following rain events of > 10 mm/24h. There is no existing guidance as to whether this will produce adequate flow at all sites to allow for the collections of samples. If not, fewer samples may be collected than planned, although it would be acceptable to sample quite low flows by collecting water from shallow parts of channels via syringe or similar methods.

Freshwater monitoring

Eleven sites are recommended for freshwater monitoring.

Many of the freshwater sites are small local tributaries that may be influenced by a range of local FIB sources such as small septic treatment systems, stormwater inputs, or runoff from fields. Other sites are selected to assess the input from some possibly significant effluent sources (e.g. Scoudouc Industrial Park), or to serve as sites higher in the main river or stream systems to allow contrast and comparison with those at points further downstream. A mixture of analyses is recommended depending on the site type.

Agricultural Monitoring

Three sites are recommended for agricultural monitoring. These sites are intended to check for the potential influence of some livestock operations, with one site added as a comparison/control site that is not expected to be influenced by livestock to the same degree, but which includes some horticultural activity. Depending on the FIB levels seen, samples could be additionally tested using PCR to help verify the origin of the FIB.

Marine monitoring

Five sites are recommended for marine monitoring.

The marine sites selected are chosen:

- to provide a general picture of offshore FIB levels;
- to check concentrations in the NW part of the Bay in case marine modelling suggests significant input towards Parlee Beach from that sector (and the Shediac River estuary in particular);
- to monitor the South Cove sector, influenced by discharge from the Scoudouc Watershed;
- to assess the possible impact of 'rafting' boats, and
- to provide a comparison or control location (Cap Bimet) to observations gathered directly off Parlee Beach .

Offshore data can also be compared to the readings gathered daily directly at Parlee Beach.

Beach Sampling

Water sampling at Parlee Beach itself has been organised by the Steering Committee and is already underway as of May 2017. Samples are collected daily at 5 sites along the beach (as conditions allow) for analysis of E. coli and Enterococci. As an adjunct to that sampling, it is recommended that two samples per month be obtained using membrane filtration and the filters preserved in a low temperature freezer for potential PCR analysis (May-October). A decision on whether to analyse these filters can be made based on the FIB concentrations observed. The additional samples can be obtained at any of the beach sampling locations. To have the highest probability of being usable for this testing, they should be obtained on days of stronger winds, more turbid water or following major rainfall events.

Sediment Sampling

Five sites are recommended for sediment sampling.

Although the main focus of this work is on water monitoring, one of the objectives provided by the Steering Committee is:

- To design the monitoring plan to enable the identification of both point and non-point sources of bacteria within the study region.

Given what is known from many other studies, it is unlikely that an adequate understanding of bacterial sources and fate will be obtained without efforts to sample soil, sand and sediments. Some suggested sites are therefore included that should provide useful information on whether the sediments in some locations adjacent to Parlee Beach contain FIB. These are put forward in the expectation that the bulk of this aspect of investigation will be covered in the planned project on Beach Sand Bacteria and Shallow Groundwater.

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Appendix A

Bacteria: Terminology

This report focusses on bacteria in the environment, specifically indicator bacteria that are commonly used in the field of environmental health to identify the potential presence of pathogens, for example in water (drinking water, surface water or seawater) or food.

As it is not feasible to test water or other types of samples for all possible disease-causing pathogens, measurements are commonly made of **fecal indicator bacteria** typically found in the intestines of humans and other mammals. The presence of these indicator bacteria suggests that the water may be contaminated with sewage or fecal material from other sources, and that other, more dangerous, organisms may be present.

Depending on the medium being examined or the objective of testing, different measures may be used. Common tests include:

Total coliforms: This measure of contamination is obtained by a laboratory test that incubates the sample at 35±0.5 C. Most coliforms represented by this test are not themselves pathogenic.
Fecal coliforms: This measure of contamination is obtained by a laboratory test that is distinguished from total coliforms by incubation at 44.5±0.2 C.
Fecal coliforms are coliform bacteria that originate specifically from the intestinal tract of warm-blooded animals (e.g., humans, beavers, raccoons, etc.). Fecal coliform has been a standard test for some aspects of fecal contamination for many years but for some applications has been supplanted by specific tests for either E. coli or enterococcus (see below).
E. coli: Escherichia coli is a bacterium found in the gut of mammals and is generally benign. Some strains of Escherichia coli, can cause illness. One such strain is E. coli O157: H7, which is found in the digestive tract of cattle. As with fecal coliforms, the presence of E. coli is used as an indicator of contamination from sewage or other animal wastes. Commonly used to test for contamination in surface waters, groundwater or drinking water.
Fecal enterococci: This is another group of bacteria that is present in feces. Fecal enterococci indicate the presence of fecal contamination by warm-blooded animals, birds, insects or reptiles. Commonly used to test for contamination in marine waters and beaches.

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