Recreational Water Quality along Kenosha County's Fresh Coast

GLRI Beach Sanitary Survey Project

Data Report, 2010 – 2012

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Executive Summary

In 2010, all five Great Lakes Beaches in the City of Kenosha were classified as impaired waters and as such were listed on the State of Wisconsin's 303(d) list. These beaches were listed as impaired waters due to excessive risk of pathogen exposure by virtue of numerous water samples in exceedance of recreational water quality standards over a multi-year period (>15% per year). Prior to this study, little to no research had been conducted to determine sources of water quality impairments at beaches in the City of Kenosha. The detection of excess fecal indicator bacteria (FIB) in recreational waters, via routine monitoring, only reveals impairments are present, but not the source(s). Without properly indentifying sources and characterizing their interactions with surface water, any mitigation strategy is speculative. By properly indentifying sources of FIB and their relative contributions to poor water quality, mitigation strategies are more likely to be effective and economically feasible.

Sanitary surveys were conducted four days per week at all five Lake Michigan Beaches in the City of Kenosha during the summers of 2010 - 2012 to determine potential sources of water quality impairments. Surface water samples were collected from three to five open water sites per beach (size dependent) with additional weekly, biweekly or event dependent samples collected from potential sources of fecal contamination (adjacent stormwater outfalls, tributaries, etc.) on a minimum of 42 dates each year. *E. coli* concentrations were determined in each water sample collected. Ambient environmental and physical beach conditions were qualified and quantified when possible on each date water samples were collected. Biweekly, water samples were collected from multiple depths at each sampling transect to determine the geospatial distribution of water quality impairments. Beach sediment samples were also collected biweekly to determine their likelihood as a potential non-point source of fecal contamination. Bacteria concentrations observed in surface waters were compared to environmental and physical conditions at each beach and compared to adjacent potential sources of impairment.

Monitoring results were in line with the current designation of impaired water body at all beaches. However, at select locations on some beaches, notably the northern end of Simmons Island, water quality was acceptable for recreation. Factors contributing to elevated *E. coli* concentrations, beach dependent, included: the Pike River, stormwater outfalls, sediments, wildlife, excess algal blooms and zones of stagnant water. Environmental factors associated with elevated *E. coli* concentrations included precipitation, on shore winds/currents, high wave heights, turbid waters and in some cases, air and water temperatures. General recommendations to improve water quality at all beaches include reducing surface runoff, improving beach grooming strategies, reducing loafing wildlife and removing excess algal blooms and litter. Some of these recommendations will have the ancillary benefit of improving beach aesthetics. Site specific recommendations were made for all beaches.

The following report discusses the relationship between FIB concentrations and recreational water quality advisories, current beach monitoring practices, sources of FIB and applications of sanitary survey data for remediation. Data from each beach was analyzed to determine sources of fecal contamination and potential mitigation strategies to reduce fecal loading. This report summarizes the data and findings of monitoring at beaches in the City of Kenosha during the summers of 2010 – 2012.

Introduction

One of the main goals of the Clean Water Act is to make all water bodies fishable and swimmable (FWPCA, 2002). Preventing contamination of recreational water bodies and community water supplies is necessary in order to safeguard public health (Simpson et al, 2002). From 1971 to 2000, the Centers for Disease Control (CDC) reported over 7,500 cases of illness, associated with 116 disease outbreaks, attributed to exposure to ponds and lakes. However, it was suspected that a large number of cases went unreported (Craun et al, 2005). Some diseases associated with recreational water contact include gastroenteritis, dermatitis and respiratory infections (Craun et al, 2005; Seyfried et al, 1985), resulting from pathogens including *Cryptosporidium, Giardia, Shigella* and *Salmonella* amongst others (Coupe et al, 2006; Keene et al, 1994; Koopman et al, 1982; Makintubee et al, 1987). Increased contact with water, particularly submersion of the head, can enhance an individual's risk of illness (Seyfried et al, 1985). Once exposed, the risk of developing an illness is dependent upon a variety of factors including the presence and concentration of pathogens in the water, the strength of an individual's immune system and type of exposure.

Due to the expense and elusiveness of pathogens in the environment, direct measurement is not currently employed (Field, 2008). Instead, fecal indicator bacteria (FIB) are measured as surrogates for pathogens and the presence of recent fecal contamination. *E. coli* and entercocci have been shown to correlate with increased risks of gastro-intestinal illnesses and are currently the best indicators of fecal contamination in freshwater systems (Dufour, 1984; EPA 1986; US EPA, 2012). Wisconsin has a 2-tiered system for regulating recreational water quality based on an *E. coli* standard. An advisory is issued, suggesting patrons may want to avoid water contact, when *E. coli* concentrations exceed 235 colony forming units per 100 milliliters (CFU/100ml). Swimming is prohibited when *E. coli* concentrations exceed 1,000 CFU/100ml.

Sources of Fecal Indicator Bacteria

Multiple sources and portals of entry exist whereby *E. coli* and pathogens may be transported into recreational waters. *E. coli* and pathogens are present in the digestive tract of warm-blooded animals, including humans, and are excreted in feces. Once excreted, bacteria can be transported to local waterways via direct contributions, tributaries, stormwater runoff (both agricultural and urban), stormwater infrastructure and sewage overflows (Gannon and Busse, 1989). Other sources of FIB are nearshore sediments (including beach sands) (Alm et al, 2003); filamentous green algae (*Cladophora*) (Byappanahalli et al, 2009), wildlife and domesticated animals (Fogarty et al, 2003). When examining potential sources of contamination affecting water quality, both local and regional sources must be considered. Sanitary survey tools have been developed to aid local beach managers in the determination of these sources and are one of a suite of tools that can be employed as part of a rigorous investigative process (Kinzelman and McLellan, 2009).

Stormwater and Runoff. Stormwater in urban and rural environments has been found to contain FIB concentrations exceeding primary recreational standards regardless of surrounding land use (Clary et al, 2008; Novotny et al, 1985). Rainfall flows over land and conveys pollutants, including

bacteria, previously deposited on terrestrial surfaces towards receiving bodies of water. Pollutants transported into local water bodies via overland flow, stormwater infrastructure or tributaries can pose a threat to public health. Urban areas are especially susceptible to poor water quality due to impervious surfaces altering natural hydrology and decreasing infiltration. *E. coli* concentrations are often elevated in runoff due to the mobilization of non-point source pollution deposited onto impervious surfaces. For example, in Madison, WI, water samples collected during precipitation events from a variety of terrestrial surface areas (i.e. lawns, streets, driveways and parking lots in residential, commercial and industrial locations) all exceeded a geometric mean of 1,500 CFU/100 ml fecal coliforms (Bannerman et al, 1993). Samples collected from residential areas had the highest geometric means with 34,000, 42,000 and 56,000 CFU/100 ml fecal coliforms in samples collected from driveways, lawns and streets respectively. Pervious surfaces such as forested land, and green areas can absorb larger amounts of water reducing runoff volumes and associated pollutants. Land use, population density and the percentage of impervious surface within a watershed have all been positively associated with the amount of FIB observed in tributaries (Mallin et al, 2009). Runoff from agricultural areas can also pose a risk to water quality. Sources of FIB from agricultural areas include manure deposited on pastures, manure slurry applied to fields(either injected or surface application), animal feeding operations (AFOs and CAFOs), fields, barns, drainage tiles and soil erosion (Abu-Ashour and Lee, 2000; Heinonen-Tanski and Uusi-Kämppä, 2001; Jamieson et al, 2002; Gerba and Smith, 2005). Agricultural soils, even in temperate climates, have the ability to serve as a reservoir for *E. coli* with runoff mediated erosion and field tiles being a major delivery mechanism (Jamieson et al 2002, Ishii et al, 2006).

Sediments. Sediments are an important reservoir for FIB. *E. coli* concentrations in sediments have been observed ranging from three to 38 times higher in the top layer of sediments than *E. coli* concentrations in adjacent surface water samples (Alm et al, 2003). Sediments provide an ideal environment for bacteria because they are protected from inactivation due to sunlight, protozoan grazing and are provided with nutrients (Davies et al, 1995; Alm et al, 2003). Indicator bacteria can survive at high concentrations in sediments throughout the swimming season and it is suspected that bacteria reproduce to some degree inside sediments (Obiri-Danso and Jones, 1999; Beversdorf et al, 2007). Fecal indicator bacteria in sediments can be transferred to adjacent waters following precipitation events or during periods of intense wave activity (Kinzelman et al, 2004). Others have modeled sediment transfer of bacteria to surface water as a function of bed shear stress and wave run up (Ge et al, 2010). Sediments may also interact with nearshore waters via Aeolian deposition (windblown) and runoff during large rain events, although it is unclear how much bacterial transfer may occur under these scenarios. Although no current regulatory standards exist, beach sediments even in the absence of water exposure may pose a health risk (Heaney et al, 2009). Pathogens in sediments can be transferred to ones hand and may later be ingested resulting in illness (Whitman et al, 2009). In a study examining the impact of bacteria in sediments on human health, beach patrons with significant exposure to beach sand had a 20- 50% greater risk of developing gastrointestinal illness compared to individuals who were not exposed (Heaney et al, 2009). Actual risk of illness depends on a variety of factors including the type of exposure, the strength of one's immune system and the presence/concentration of pathogens in beach sand.

Cladophora and Algal Blooms. In recent years, *Cladophora,* branching, filamentous green algae found naturally inside the Great Lakes, has re-emerged as an annual problem. Massive *Cladophora* blooms impacted the Great Lakes during the 1950's through the 1970's, largely due to excess phosphate loading. Removing phosphate from laundry detergents and more stringent wastewater regulation largely alleviated this problem. However, *Cladophora* blooms have returned as a problem in recent year, believed to be caused, in part, by the introduction of quagga (*Dreissena bugensis*) and zebra (*Dreissena polymorpha)* mussels into the Great Lakes basin. Since the introduction of *Dreissenid* mussels, water clarity has improved significantly. This has lead to an increase in the euphotic zone, increasing photosynthesis and promoting greater plant growth. It is hypothesized that *Dreissenid* mussels transfer nutrient rich (particularly phosphorous) feces and pseudo-feces to the benthic zone, which further increases algal growth (Heckey et al. 2004).

Cladophora frequently occupies the nearshore areas of Lake Michigan and washes ashore onto beaches. Whether submerged in the water or stranded on the beach, large amount of algae can negatively impact water quality. Once washed ashore, algae and associated invertebrates begin to decay creating a smell that some mistake for sewage. Stranded algal mats attract wildlife that feed on invertebrates and insects that inhabit mats. *Cladophora* can harbor both pathogens and FIB deposited by wildlife as part of the feeding process, which have the potential to survive for months, as well as reproduce, inside mats (Whitman et al, 2003; Byappanahalli et al, 2009; Byappanahalli et al, 2007). *E. coli* has been observed at densities of over 100,000 CFU per gram dry weight of algae (Vanden Heuvel et al. 2010). Pathogens and FIB associated with algal mats can be released into the water column during periods of intense wave action, resulting in beach closures (Englebert et al, 2008).

Wildlife. Local wildlife and domestic animals can directly contribute fecal matter to beach water or load sediments as an intermediary (i.e. transport via surface runoff following precipitation events or through intense wave action). One of the most prevalent avian species in the nearshore environment are ring billed (*Larus delawarensis*) and herring gulls (*Larus argentatus*). From 1976 through 1990, ring billed gull populations increased from 56,000 to 283,000 breeding pairs along the Canadian portion of the lower Great Lakes (Blokpoel and Tessier, 1991). This rise in population was believed to be caused by increases in anthropogenic food sources (such as landfills or uncovered waste containers) and the increased availability/use of urban nesting sites (Dwyer et al, 1996). Gull feces contains 10^5 – 10^9 CFU *E. coli* per gram; this gives gulls the ability to produce a staggering amount of FIB when considering the number of resident gulls a beach may attract and the amount of waste each gull can produce per day (Fogarty et al, 2003). In Quebec, at a pristine location without gulls, birds were baited to a beach with food to determine their impact on water quality. Within two days after attracting gulls, water quality was impaired beyond published standards (Lévesque et al, 1993). In addition to gulls, geese have the potential to adversely impact water quality. However, while the average fecal dropping of geese weighs 15 times more than gull droppings, they contain smaller amounts of fecal coliforms (Alderisio and DeLuca, 1999). These studies demonstrate that wildlife, in particular avian species, can adversely impact water quality. However, it is difficult to attribute the amount of FIB at a beach to the presence of wildlife alone. In a Door County, Wisconsin, study, *E. coli* densities in water did not correlate to the density of gull fecal matter observed on the beach or the number of gulls present at most locations (Kleinheinz et

al, 2006). Therefore, the impact gulls may have on recreational water may be dependent on multiple factors, including: beach sediment grain size/uniformity, topography and a suitable mechanism of transport.

Bacteria Die Off. In addition to understanding sources, reservoirs, and factors influencing the release of bacteria into the aquatic environment, mechanisms that control bacteria die off or disappearance are just as important. Sunlight (Fujioka et al, 1981), sedimentation (Schillinger and Gannon, 1985), filtration, dilution and disinfection mechanisms (bacteriophage attacks, predation and toxins produced by macrophytes) are natural processes within the beach environment which reduce the presence of FIB (Schuler and Holland, 2000). Environmental factors may attenuate or exacerbate the impact FIB have on water quality. For instance, turbid waters may decrease the amount of bacteria that are deactivated due to sunlight, but may increase the amount of bacteria that are removed through sedimentation. Bacteria die off mechanisms are complex and may vary depending upon the number and types of macrophytes present, water clarity, the propensity for sedimentation to occur (low energy or high energy environment) in addition to other factors.

Beach Sanitary Surveys

With so many potential sources, pollution pathways, and complex interactions occurring in the nearshore zone, the majority of instances with poor water quality are unexplained. Within the Great Lakes approximately 90 percent of beach advisories and closures are attributed to unknown sources (Kovatch, 2006). Beach sanitary surveys are a low cost technique designed to determine sources and variables associated with excess FIB in recreational waters. Sanitary surveys are a unified, reliable and replicable data collection method. Ambient environmental and beach conditions that have the potential to impact beach water quality are recorded using a routine on site sanitary survey form at each beach visit (Appendix A). Conditions recorded at the time of sample collection include: wind speed, wind direction, rainfall amount, rainfall intensity, amount of cloud cover, air/water temperature, the amount of algae present in water or stranded ashore, alongshore current direction, wave height, water clarity, the amount/type of wildlife present, the amount of people at the beach (and their activities), and the presence of beach litter. In addition to examining environmental parameters, local infrastructure maybe evaluated such as stormwater outfalls or other potential point sources of bacteria. Variables recorded when conducting beach sanitary surveys describe sources of bacteria, conditions that may increase the amount of bacteria introduced from non-point sources, environmental conditions that can alter bacteria die off rates and factors that affect the transportation of bacteria once in the nearshore environment. Other supportive information, collected on an annual basis, includes: topographical characteristics, the location of infrastructure such as stormwater outfalls, surrounding land use and the location/condition of sanitary facilities near the beach. The use of sanitary surveys along with other source tracking methods has been effective at identifying sources of contamination and guiding remediation efforts at other beaches (Kinzelman and McLellan, 2009). The collection of this information may also used to create predictive models that can empirically estimate water quality conditions before laboratory results are available. The results of which can used to trigger beach closures or advisories before water quality results are available through traditional analytical techniques.

Public Perception Regarding Water Quality

A survey of residents inside the Root-Pike Watershed was conducted by UW-extension and Root Pike Watershed Initiative Network (WIN) to determine local perceptions towards water quality issues (Root-Pike Win, 2010). Of the 500 surveys mailed to residents within the watershed, 124 (~25%) were returned. The demographics of the population who responded to this survey differed from census estimates of the region (e.g. the demographic who responded to this survey were more likely to own a home, had a higher median family income and were more likely to have a college degree compared to census data available for the watersheds). Of respondents, 71 percent described the water quality in the region as either poor (33%) or okay (38%). The majority of people (77%) indicated closed beaches/swimming areas were a problem in their community (21, 31 and 25 percent of respondents described it as a severe, moderate or slight problem respectively). Additionally, 59 percent believed that bacteria and viruses in streams represent a problem (30, 15 and 14 percent described it as a severe, moderate and slight problem respectively) with many (34%) unsure. Most respondents either agreed or strongly agreed that economic stability (72%) and community quality of life (75%) depend on good water quality. Survey results indicated water quality is highly regarded among the populace.

Study Site

The City of Kenosha, located on the western shore of Lake Michigan, possesses five Great Lake beaches. These beaches, listed from north to south, are Alford Park, Pennoyer Park, Simmons Island Park, Eichelman Park and Southport Park Beach (Figure 1). All five Great Lake beaches in the City of

Figure 1. Location of Great Lakes beaches in the City of Kenosha.

Kenosha are currently listed on the State of Wisconsin's 303(d) list of impaired waters due to excessive risk of pathogen exposure. According to the 2010 National Resource Defense Council's report on vacation beaches, Kenosha County had the highest percentage of water samples exceeding water quality criteria at Great Lake beaches in the State of Wisconsin (NRDC, 2010). In 2009, Kenosha County's Eichelman Beach had the "dirtiest" water of all monitored beaches in the State of Wisconsin based upon the percentage of samples exceeding recreational water quality standards (46% of samples in exceedance of water quality standards).

Kenosha's impaired beaches are not unique. In 2009, Great Lake beaches exceeded water quality standards 13 percent of the time, compared to the national average of seven percent (NRDC 2010). Therefore, there is a need to improve water quality at these beaches. However, without identifying sources of water quality impairments, any proposed mitigation efforts are based upon trial and error; spending municipal resources on potentially ineffective remediation efforts. Water quality monitoring programs do not typically focus on identifying sources of impairment, thus sources frequently remain unidentified (Kovatch, 2006; NRDC, 2010). Through proper identification of pollution sources and assignation of their relative contributions to water quality, it is possible to craft successful and economically feasible mitigation measures. Prior to this study, little to no research had been conducted to determine the sources of poor water quality at beaches in the City of Kenosha and only a limited amount of information can be obtained by examining past water quality trends. This current US EPA Great Lakes Restoration Initiative grant seeks to assist local officials in indentifying sources of contamination, and environmental conditions, resulting in poor recreational water quality at all five Great Lakes beaches in the City of Kenosha.

Beaches within the City of Kenosha have the potential to be influenced by multiple sources. Potential point sources include two tributaries, the Pike River and Pike Creek, a waste water treatment facility and numerous storm water outfalls. Additional non-point sources include resident wildlife populations, pets, illegal discharges, sediments and *Cladophora*. The potential for fecal contamination from the release of untreated, or partially treated, sewage discharges in the City of Milwaukee (CSOs) exists. However, following CSOs, *E. coli* concentrations were low to undetectable two to five km from the discharge site in the Milwaukee Harbor due to die off and dilution of bacteria (McLellan et al, 2007); Kenosha is located approximately 50 km from the discharge site and thus this appears as an unlikely source. Each beach has the potential to be impacted by multiple point and non-point sources of fecal bacteria concurrently and multiple pollution sources are likely responsible for poor water quality at these beaches. A source of contamination that negatively impacts one beach may not necessarily impact water quality at an adjacent beach. Therefore, the influence of sediments, stormwater outfalls, tributaries and offshore sources need to be examined at each beach. Additionally, water quality parameters must be described and quantified when possible to determine the impact environmental conditions have on the introduction, transportation and die-off of *E. coli*. The following section describes the watersheds that discharge into the City of Kenosha, the Pike River and Pike Creek.

Pike River Watershed

The Pike River, a tributary to Lake Michigan, discharges between Pennoyer and Alford Park in

Kenosha County. The Pike River watershed drains an area of 145 km^2 in eastern Kenosha and Racine Counties (Figure 2). One hundred and thirty two square kilometers of land area drains into the Pike River, while the remaining 13 km^2 drains directly to Lake Michigan (SEWRPC, 1983). Prior to development, it was estimated that this watershed contained over 19.5 km^2 of wetlands. Today, only 1.4 km^2 of wetlands remain; a 93% loss (WDNR, 2010). The majority of wetlands have been drained for agricultural and development purposes. Forty five percent of the land inside the watershed is designated as agricultural, 30 percent is classified as either urban (17%) or suburban (13%), and less than one percent is considered wetlands (Figure 3). Wetlands, among other functions, help to filter water of impurities and mitigate peak storm water flow by providing an area for water to percolate into the ground.

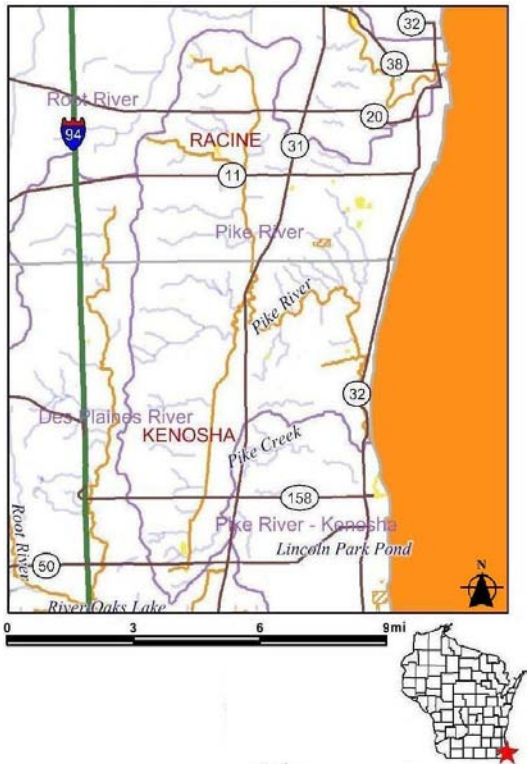

Figure 2: An overview of the Pike River Watershed.

In addition to wetland loss, the stream channels of the Pike River have been modified, particularly on the south branch, to better facilitate the removal of water from land. Development inside the watershed has increased the amount of impervious surface. The destruction of wetlands, straightening of stream channels and increasing the amount of impervious surfaces within the watershed has led to "flashy" flow conditions. Discharge volumes can change rapidly by several orders of magnitude following precipitation and spring snow melts. The increase in peak discharge has amplified erosion of river banks as there is little buffer to mitigate water entering into the river. In some areas, river banks are several meters in height due to erosion (Ehlinger and Hoverman, 2005).

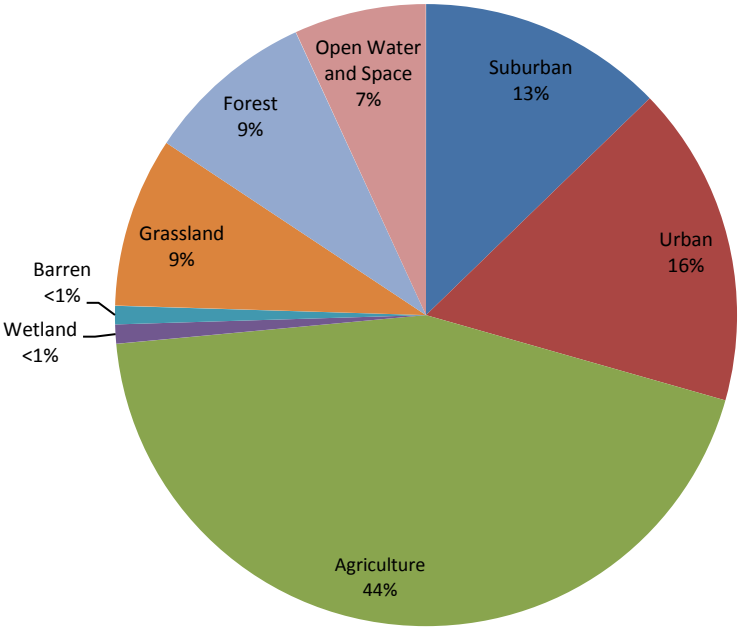

Figure 3: Land Use inside the Pike River watershed

Pike Creek Watershed

The Pike Creek drains an area entirely inside Kenosha County. This tributary drains portions of the City of Kenosha, Village of Pleasant Prairie and Town of Somers. In total, the drainage basin is 70 km^2 (WDNR, 2006). The watershed consists of three separate channels that drain separately into Lake Michigan. These channels, from north to south, are Pike Creek, Barnes Creek and Tobin Creek. Land use within the watershed is classified as 43 percent urban, 21 percent agriculture, 20 percent grassland, nine percent forest and seven percent wetlands (WDNR, 2006). The area that drains into the Pike Creek channel is likely more urban than the remainder of the watershed because this channel drains the majority of the City of Kenosha, an area that is highly developed. The Pike Creek meanders through an underground conveyance system in the City of Kenosha, discharging into the south side of the Kenosha Harbor.

The remainder of this report will detail methods used in to investigate beach advisories in the City of Kenosha, examine sources of water quality impairment, explore environmental conditions resulting in beach advisories and provide recommendations to improve water quality.

Methods

The following section provides a description of data collection methods, techniques used to process water and sediment samples and an overview of statistics used to analyze data. Prior to the start of this study, walking assessments of the beaches were conducted by the project team to identify potential point sources of bacterial contamination such as stormwater outfalls and waste water discharge locations and to determine appropriate sampling locations (transects).

Study Sites

Water samples were collected from multiple transects at each beach to determine the spatial variation in water quality. Samples were collected from June through September in 2010, 2011 and 2012, four days per week (Monday – Thursday). Water samples were collected from five, four, five, three and three transects at Alford, Pennoyer, Simmons Island, Eichelman and Southport Park Beach respectively. Additional water samples were collected from potential sources of FIB, identified through walking beach assessments, to determine their impact on water quality.

Figure 4: Alford Park Sampling Locations.

Alford Park, the northern most public beach in Kenosha County, is located adjacent to the mouth of the Pike River. The beach is oriented along the north/south axis. For the purpose of this study, Alford Park Beach was defined as being bound on the north end by the tree line adjacent to Carthage College. The mouth of the Pike River forms the southern boundary. Five sampling transects were chosen across the length of this beach and were labeled from north to south as transects AP-1 through AP-5 (Figure 4). The spacing between each transect ranged from 210 to 284 meters. A series of degraded groins are located along the beach face and a stormwater outfall is located near transect AP-3 (Figure 5). The land use immediately surrounding the beach is

Figure 5: Alford Park stormwater outfall.

parkland. Parkland and the flood plain of the Pike River are located immediately to the west of Alford Park; to the south is Pennoyer Park and to the north is Carthage College.

Beyond the five defined sampling transects at this beach, additional water samples were collected from the Pike River (once per sampling day) and from the stormwater outfall located near transect AP-3, when flowing (Figure-6). The sampling location for the Pike River was slightly upstream from the mouth (WTM84 coordinates: N42.660809, W87.82129). Additional water samples (n=11) were collected in upstream sections of the watershed on a single day; July 23rd, 2010. These water samples were collected following an intense rain event to determine water quality contributions from upstream areas within the watershed.

Figure 6: Location of monitored outfalls in the City of Kenosha.

Pennoyer Park, for the purpose of this study was defined as stretching from the mouth of the Pike River (northern boundary) to the seawall located along Kennedy Drive (southern boundary). The beach is oriented along the north/south axis. Four sampling transects were chosen across the length of this beach and were labeled from north to south as transects PP-1 through PP-4 (Figure 7). The spacing between each transect ranged from 90 to 160 meters. The area surrounding the beach is parkland to the north (Alford Park), residential properties to the west and additional parkland located to the south (Lake View Park).

Three stormwater outfalls, an intermittent seep and the Pike River were identified as potential sources of water quality impairment for this beach. One outfall, Pennoyer Park outfall, located south of transect PP-4, discharges directly onto the beach. This stormwater outfall drains 28.6 acres of residential property (Pennoyer Park Outfall, Figure 8). Two additional stormwater outfalls, 40th and 43rd Street Outfalls, discharge south of the beach along Kennedy Drive (Figure 6). These outfalls are located 200 and 600 meters from the southernmost transect at Pennoyer Park beach (PP-4). A seep was observed on the beach on a limited number of dates; this was evaluated as a potential source.

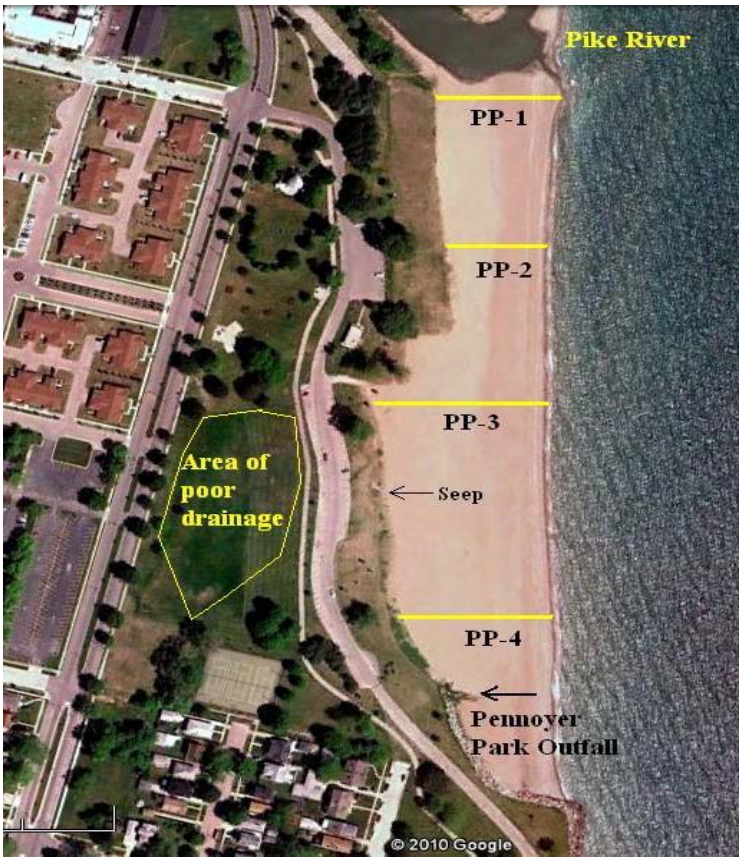

Figure 7: Location of sampling transects and potential sources of water quality impairments at Pennoyer Park.

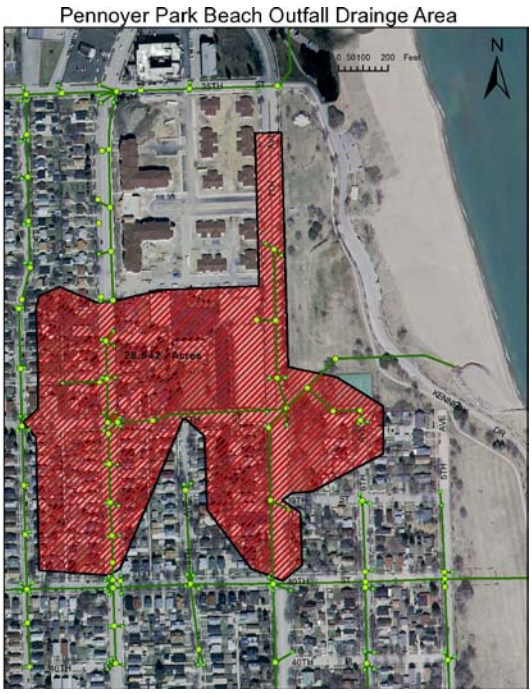

Figure 8: The drainage basin of the Pennoyer Park Outfall.

Simmons Island Park is bound on the north side by Cohorama Point and the jetty supporting the mouth of the Kenosha Harbor on the south side. The beach is oriented along the north/south axis. Five transects were selected across the length of the beach and were labeled from north to south as transects SI-1 through SI-5 (Figure 9). The spacing between transects ranged between 160 and 220 meters. To the south of Simmons Island beach is the Kenosha Harbor, immediately to the east is parkland and to the north is Lake View Park. There are several engineered structures along the beach face including a jetty supporting the mouth of the harbor, a groin and sea armor along the north end of the park.

Figure 9: Location of sampling transects and infrastructure at Simmons Island Park.

Two of the stormwater outfalls, the 40th and 43rd Street Outfalls, may impact Simmons Island Beach in addition to Pennoyer Park. The Kenosha Harbor is also a potential source (Figure 9). It receives effluent from multiple stormwater outfalls and the Pike Creek. Stormwater outfalls and the Pike Creek, which discharge into the harbor, could potentially impact water quality at Simmons Island depending on nearshore hydrodynamics.

Eichelman Park Beach is located adjacent to Wolfenbuttel Park and the Kenosha Marina. This beach is distinct in its configuration compared to other beaches in Kenosha County as it is embayed and the beach face is oriented along the east/west axis. The opening of the embayment is south of the beach. Three sampling transects were chosen across Eichelman Beach labeled from east to west as transects EM-1, EM-2 and EM-3 (Figure 10); the distance between sampling transects was 80 meters. Land use immediately adjacent to the beach was residential, commercial and park land.

Figure 10: Location of beach sampling transects and nearby infrastructure at Eichelman Beach.

Beyond the three transects at Eichelman Park, additional water samples were collected from two stormwater outfalls, 60th street outfall (150 meters north of the beach, outside the breakwall) and an outfall adjacent to the Kemper Center (300 meters south of the beach) (Figure 6, page 11). In addition to potential direct stormwater sources, there is an eroded pocket near the breakwater on the east side of the beach; water samples were collected from this pocket. Water samples were also collected east of transect EM-1 on a limited number of dates in 2012, outside the breakwater to help better define the spatial distribution of *E. coli*.

Southport Park Beach is located immediately north of Kenosha's waste water treatment facility. For the purpose of this study, Southport Beach is bound on the north end by the groin north of transect SP-1 (Figure 11) and on the south by the seawall located where 78th Street, which, if extended, would intersect with the lake. Three transects were chosen across the beach and were labeled from north to south as transects SP-1 through SP-3. Transects were spaced between 70 and 100 meters apart. In

terms of engineered structures, the beach has three degraded groins across the beach face and a stormwater outfall. Adjacent to the beach area are residential properties (west), parkland (west and north) and the City of Kenosha's wastewater treatment facility (south).

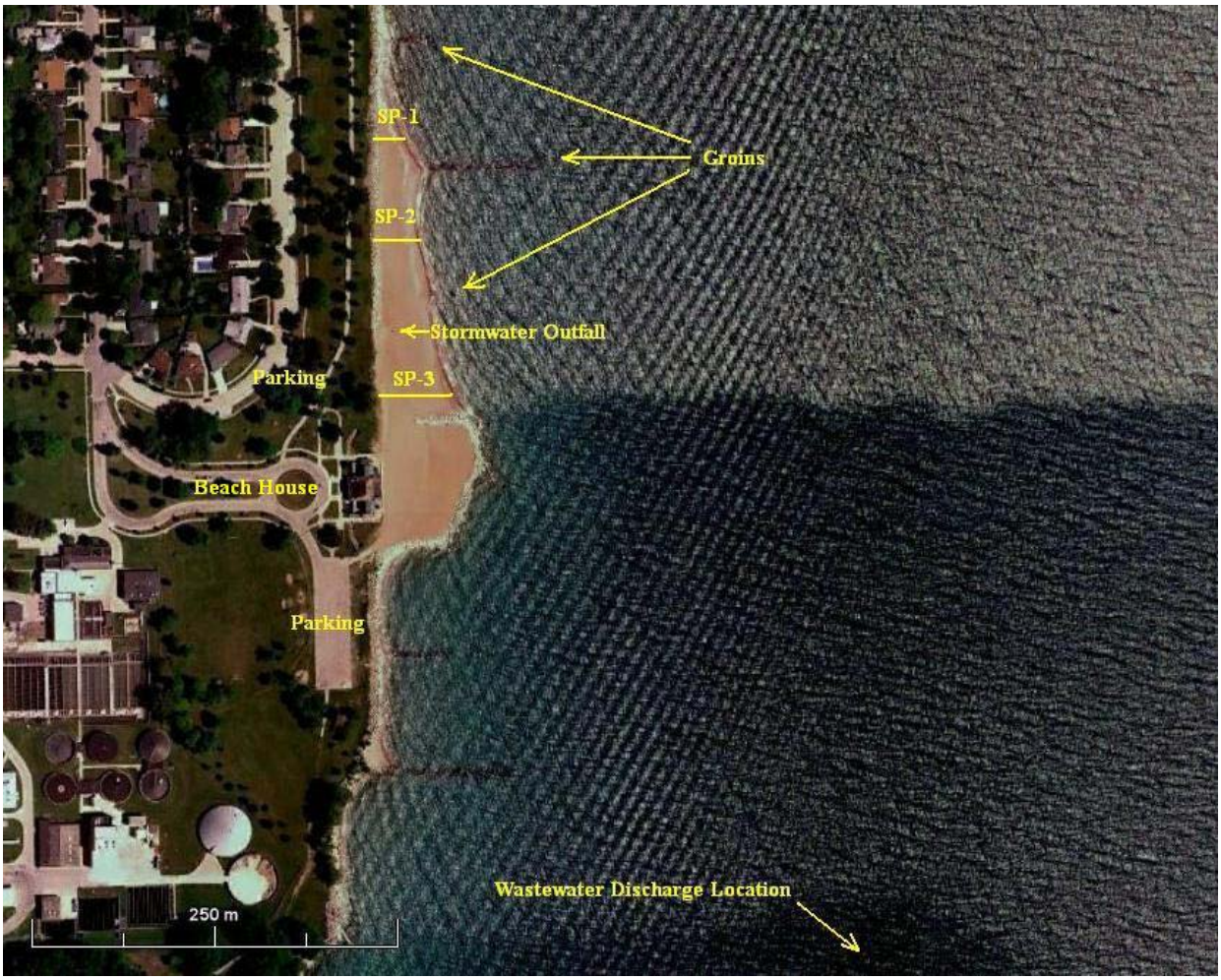

Figure 11: Location of water sampling transects and infrastructure near Southport Park Beach.

Four stormwater outfalls discharge in close proximity to the beach; these outfalls were identified as potential sources of fecal impairment. Southport Outfall discharges near transect SP-3 and directly onto the beach (Figure 12). The other three stormwater outfalls (71st, 73rd and 75th Street Outfalls) discharge to the north of the beach at distances of 200 to 600 meters (Figure 6, page 11). The City of Kenosha's wastewater treatment facility discharges effluent offshore, approximately 500 meters south of the beach. Effluent from the waste water treatment facility is discharged at a depth of approximately 5 meters below the water surface. Discharge volumes and *E. coli* concentrations of discharge from the treatment were obtained from the Kenosha Water Utility.

Figure 12: Drainage Basin for the stormwater outfall located at Southport Park. This outfall drains approximately nine acres of residential properties and pavement.

Beach Sanitary Surveys

In order to identify sources of bacterial contamination, and provide replicable and consistent data, routine sanitary surveys were employed each time a water sample was collected (Online: http://water.epa.gov/type/oceb/beaches/sanitarysurvey_index.cfm) (Appendix A). Beach conditions described and quantified when possible included: amount/type of wildlife/domestic animals, the amount of algae present (both washed ashore and submerged in the water), longshore current direction, air/water temperature, cloud cover, precipitation amounts/intensity, wind speed/direction, current speed/direction, wave height, wave intensity, water clarity, odors, the number/activities of people at the beach, the amount/type of beach litter, and stream/stormwater outfall discharge information. Methods for collecting beach sanitary survey data are described in greater detail in the Great Lakes Beach Sanitary Survey User Manual which can be found on line at the following site: http://water.epa.gov/type/oceb/beaches/upload/2008_05_29_beaches_sanitarysurvey_user-manual.pdf. The annual beach sanitary survey form was completed once during each sampling season.

***Wildlife*.** The location, species and number of animals observed were enumerated as actual numbers present.

Algae. The color of the algae was described as either light green, bright green, dark green, yellow, brown, other or any combination thereof. The amount of algae washed ashore was quantified as percent surface coverage on the berm crest and described as low (1-20% coverage), moderate (21-50% coverage) or high (>50% coverage). The amount of algae in the nearshore water was also quantified as low, moderate or high based upon surface area coverage near the sampling location.

The ***alongshore current direction***, the direction that water and associated pollutants travel parallel to the direction of the shoreline, was determined primarily through observing wave angles. For example, if one section of a wave broke to the north first, then towards the south, the alongshore current direction would be towards the south. If this method of determining alongshore current was indeterminate, an object was tossed into the water and the direction the object travelled parallel to the shore would be recorded.

Air temperature was measured upon arrival at the site using a calibrated alcohol thermometer. Air temperature measurements were taken in the shade or in lieu of shade, in the shadow generated by the technician's body. Temperature was expressed in degrees Celsius (°C).

Water temperature was measured by placing a calibrated alcohol thermometer in the water adjacent to, but down current, from where water samples were collected. Special care was taken to avoid potential contamination issues. Water temperatures were expressed in degrees Celsius (°C).

Cloud cover was estimated upon initial arrival at the site and was described as sunny (no cloud coverage), mostly sunny (1/8 to ¼ cloud coverage), partly sunny (3/8 to ½ cloud coverage), mostly cloudy (5/8 to 7/8 cloud coverage) or cloudy (total cloud coverage).

Precipitation. Rainfall amounts were obtained for the previous 24-hour period prior to sample collection from a National Oceanic and Atmospheric Administration (NOAA) weather station located at the Kenosha Regional Airport (http://www.weather.gov/data/obhistory/KENW.html). This weather station was chosen because it is the closest NOAA operated weather station to study area. Rainfall amounts were reported in centimeters (cm). Rainfall intensity was estimated as misting, light rain, steady rain or heavy rain. This parameter was not estimated unless someone was able to observe the rain intensity at the sample collection location as rain intensity can vary over short spatial and temporal distances.

Wind speed and direction data was obtained from the National Data Buoy Center (http://www.ndbc.noaa.gov/station_page.php?station=knsw3) which operates an anemometer located at the mouth of Kenosha's Harbor. This anemometer was located centrally between all beaches in Kenosha. Wind speed was vectorized into north/ south and east/west components using equations (1) and (2) respectfully where θ represents the wind direction. If equation (1) returned a negative value, there was a southern (wind moving from south to north) component to the wind speed, if a positive value was retuned, a northern component existed to the wind speed. If equation (2) returned a negative value, there was a western component (wind traveling from west to east) to the wind speed, if a positive value was returned, an eastern component existed to the wind speed. All wind speed data was expressed in units of meters per second.

$$\text{Eq(1) Wind Speed North} = (Wind\ Speed)\text{Cos}\left(\frac{\theta\ \pi}{180}\right)$$

$$\text{Eq(2) Wind Speed East} = (Wind\ Speed)\text{Sin}(\frac{\theta\ \pi}{180})$$

Lake Michigan current speed and direction estimates were obtained from the Great Lakes Coastal Forecasting System (GLCFS) nowcast model (www.glerl.noaa.gov/res/glcfs/) at the node closest to the center of each beach. Current speeds and directions were in a vector form. Current directions represent the direction water was traveling towards unlike wind directions, which represents the direction wind was coming from.

Wave height* and *intensity. Wave height was estimated by averaging the height (measured from trough to crest) of the three largest out of ten waves. Wave intensity was estimated based upon the frequency that waves hit the shoreline and was described as calm, normal or rough. Wave height estimates were also obtained from the Great Lakes Coastal Forecasting System (GLCFS) nowcast model (www.glerl.noaa.gov/res/glcfs/) from the same node current speeds and directions were obtained.

Water clarity. Qualitative water clarity descriptors were used and water was described as clear, slightly turbid, turbid or opaque. For statistical analysis purposes, this data was converted into ordinal values. (i.e. clear=1, slightly turbid=2, turbid=3, opaque=4). Analytical turbidity measurements (see page 20) were made in addition to visual estimates at Alford, Pennoyer, Eichelman and Southport Park in 2012.

Debris amounts in the water and on the beach were estimated as either low, moderate or high based upon percent surface coverage (see Methods, *Algae*). Classification of waste types included: street litter, food-related waste, medical items, sewage-related waste, building materials, fishing-related litter, household waste or other types of waste.

The ***number of people*** at the beach and in the water was recorded as actual numbers present at the time of sample collection. The type of activity people were engaged in (e.g. swimming, sunbathing, boating, walking, etc.) was also recorded.

The ***instantaneous discharge volume*** of the Pike River was determined at the time water samples were collected from a stream gauging station operated by the United States Geological Survey (USGS) (gauging station 04087257) located near the University of Wisconsin-Parkside campus (http://waterdata.usgs.gov/wi/nwis/uv/?site_no=04087257andPARAmeter_cd=00065,00060).

Surface Water Samples

Sample Collection. Surface water samples were collected in sterile Whirl-Pak™ bags (Nasco, Ft. Atkinson, WI) at a depth of 0.6 – 0.75 m (approximately knee depth). Being careful not to disturb bottom sediments or algae, the technician faced parallel to the direction of the alongshore current, removed the seal, opened the bag using tabs located on the side of bags, and collected a water sample

from approximately 0.3 m below the water surface. After collection, the Whirl-Pak™ bag was sealed, placed in a cooler on ice packs, and held at 4 ^{o} C until sample analysis occurred, generally within four hours of collection.

Multiple depth open water sampling occurred simultaneously for each corresponding beach transect bi-weekly from July 7th to September 21st, 2010 (7 sampling events per beach). Additional sampling events occurred at Simmons Island and Eichelman Beach in 2011 (n=9) and 2012 (n=12). Based on the 2010 results, multi-depth sampling at open water sites was ceased from Alford Park, Pennoyer Park and Southport Park (see Results, pages 22, 38 and 74). In order to accomplish simultaneous sample collection, four field technicians waded out to depths of 0.3, 0.6, 0.9 and 1.2 m of water, facing parallel to the direction of the longshore current in the same manner as the daily surface water samples. Upon the signal of one of the technicians, all technicians would collect a water sample from 0.3 m below the surface simultaneously (except for the 0.3 meter depth where a sample was collected at approximately 0.15 m below the surface). Once collected, water samples were sealed and placed onto ice packs where they were maintained at 4 ^{o}C until analysis for *E. coli* could be conducted, generally within four hours of collection.

Stormwater outfall samples were primarily collected following rain events that were significant enough in intensity and duration to generate flow that reached Lake Michigan. In most cases, the outfalls were no longer discharging significant amounts of water upon arrival at a site, but evidence of the disturbance and dampening of sediments adjacent to the outfall indicated recent discharge. If evidence of recent discharge were present, a water sample was also collected from the plunge pool even though the outfall was not currently discharging effluent. Due to this, water samples collected from outfalls were not always representative of the "first flush" and might have a significantly lower *E. coli* concentration than if samples would have been collected at the moment of discharge. Water samples from outfalls were collected into sterile Whirl-Pak^{TM} bags at a location as close to the discharge location of the outfall as possible. Upon collection, bags were sealed and placed onto ice packs where samples were maintained at 4 ^{o}C until analysis for *E. coli* could be conducted, generally within four hours of collection.

***Tributaries*.** Pike River samples were collected on each day that Lake Michigan field sampling occurred. Tributary samples were collected from the south bank of the Pike River near Sheridan Road; 300 m from where the Pike River discharges into Lake Michigan. Upstream sampling was conducted once, on July 23rd, 2010 following a 7.3 cm rain event. Rain event samples were collected from overarching bridges using a sampling line and sterile Whirl-Pak^{TM} bags. The sampling line was lowered into the water, where water was allowed to enter the sampling bag. Once the sample was raised, a small aliquot of water was transferred into a container where the water temperature was measured; this was done to prevent contamination of the water sample by the thermometer. The water used to measure the temperature was discarded after the reading was recorded. The Whirl-Pak^{TM} bag was then removed from the sampling line, sealed and placed onto ice packs where samples were maintained at 4 ^{o}C until analysis for *E. coli* could be conducted, generally within four hours of collection. This same routine was also used to collect water samples from the Kenosha Harbor; these samples were collected once weekly or following rain events.

E. coli Enumeration. *E. coli* was quantified using IDEXX Colilert-18® or IDEXX Colilert® (IDEXX, Inc., Westbrook, ME), a selective cultural identification method utilizing bacterial enzymatic activity and differential substrates, for the detection of *E. coli* according to previously established laboratory protocols. In brief, samples processed either undiluted (100 ml) or diluted, 1:10 (10 ml of sample + 90 ml sterile distilled water), or 1:100 (1.0 ml sample + 99 ml of sterile distilled water) based on visual inspection of the sample (using sample cloudiness as an estimation of gross turbidity). The sample was then mixed with reagent and sealed in a Quanti-Tray/2000 according to manufacturer's instructions (Colilert or Colilert-18® product insert, IDEXX Laboratories, Westbrook, ME, US). After incubation at 35.0 ^{o}C ± 0.5 ° C for 18 hours (or 24 hours for Colilert®), Quanti-Tray wells were read for yellow color indicating onitrophenyl ß-D-galactopyranoside (ONPG) hydrolysis (confirmatory for the presence of total coliforms) and fluorescence, indicating 4-methyl-umbelliferyl ß-D-glucuronide (MUG) cleavage (confirmatory for the presence of *E. coli*), with the aid of a UV light box (366 nm). Wells producing fluorescence in the absence of yellow color were determined to be false readings (*E. coli* would be classified as a total coliform and therefore should be detected by this method as such, according to the manufacturer). The number of wells producing fluorescence was compared to the MPN table provided by the manufacturer to enumerate *E. coli* as MPN/100 ml (Most Probable Number of *E. coli* per 100ml). *E. coli* concentrations below the detection limit were treated as half the detection limit for statistical calculation purposes, i.e. <10 MPN/100 ml became 5 MPN/100 ml. Quality control organisms (positive = *E. coli* ATCC #25922, negative = *P. aeruginosa* ATCC # 10145) were run once per box of reagent to validate (qualitative) test performance.

Specific conductivity, a unit of conductivity temperature corrected to 25 ^{o}C, was measured using either an Oakton 400 or Oakton 510 (Vernon Hills, IL) conductivity meter. The meter was calibrated at least monthly, according to manufactures recommendations, using NIST traceable 10, 100, 1413 and 12,880 micro-siemens (µS) standards (manufactured by/on behalf of: Fisher Scientific, Pittsburg, PA and Forestry Suppliers, Jackson, MS). In brief, prior to analysis the conductivity probe was rinsed with deionized water (0.2 µm final filtration) (~1 µS) to remove any contamination from previous samples and dried using lint free Kimwipes™. A well mixed aliquot of water was transferred into a sample cup following bacterial analysis (to prevent contamination of the sample by the non-sterile probe). The probe was lowered into the solution and allowed to equilibrate until a static value was obtained, generally within 10 seconds and the value was recorded. The probe and calibration cup was rinsed thoroughly with deionized water, dried and the next sample was processed.

Turbidity. The turbidity of surface water samples were tested on the same day that sample collection occurred in 2012, following bacterial analysis. Turbidity units were recorded in Nephelometric Turbidity Units (NTU) using a HF Scientific Inc. (Fort Myers, FL), Micro 100 Turbidimeter. The turbidimeter was calibrated at least once every 30 days according to the manufactures instructions using 0, 10 and 1000 NTU primary AMCOCLear Standards manufactured by GFS Chemicals Inc (Powel, OH).

Once daily, after allowing the turbidimeter to warm up for at least 30 minutes, the calibration of the equipment was verified using sealed secondary standards (AMCOClear) of 0, 10 and 1000 NTU. If values deviated by more than 10%, the equipment was recalibrated using primary standards. Following

calibration, samples were gently mixed and small aliquots were used to rinse a scratch free cuvette three times. After the third rinse, the cuvette was filled with sample (approximately 25 ml) and capped. The side of the cuvette was cleaned with ethyl alcohol to remove any debris or oils that may interfere with measurements and thoroughly dried using lint free wipes (Kimwipes™, Kimberly-Clark, Neenah, WI). The cuvette was placed into the turbidimeter and allowed to equilibrate (approximately 10 seconds). The cuvette was slowly rotated 360° (indexed) and the lowest displayed value was recorded. Turbidity was qualitatively visually estimated, not measured, in 2010 and 2011.

Sediment Samples

Sampling locations. Sediment samples were collected from each transect, corresponding to the water quality sampling locations in all years (2010 – 2012). Sediment samples were collected at three locations within each transect: at the berm crest, the middle beach, and the back beach. The berm is the area actively influenced by waves and comprised of deposited sand or cobble; it has two components, a crest (top) and face (slope). The middle beach and back beach, for the purpose of this study, were defined as 10 and 20 meters behind the berm crest respectively. Sediment conditions and characteristics at the sampling location were described in order to characterize potential sources of *E. coli* variation in beach sand. Sediment conditions described included the presence of: animal feces, animal tracks and algae within 0.30 meters of the sampling location. Animal tracks, while not a direct source of contamination, are useful for indicating the recent presence of animals at a given location. The inclusion of debris associated with the high water mark, i.e. stranded trash, wood, feathers was also noted. In 2012, subsurface sediments (submerged under 0.3 meters of water) were also collected from Simmons Island and Eichelman Beach at each transect. A paired water sample was collected each time that sediment sampling occurred.

Sample collection. All sediment samples were collected manually with an AMS stainless steel slotted soil recovery probe (Art's Manufacturing and Supply, American Falls, Idaho, US) with a 2.8 cm bore and sterilized butyrate liners with end caps. The sterilized butyrate liners were prelabeled at the laboratory using removable tape, one for each sample to be collected, and placed in clean Ziploc bags (S. C. Johnson, A Family Company, Racine, WI). At the site of collection, a liner was removed from the Ziploc bag and placed within the soil recovery probe whose interior had been previously coated with a light layer of silicone spray to aid in the successful removal of the liner. The sample was collected by holding the apparatus parallel to the beach sand, firmly pressing the soil recovery probe into the sediment and then removing it in the same manner. After sample collection, the liner was extracted by removing the handle and grasping the exposed exterior edge of the liner being careful not to disturb the core or contaminate the sample. Once a sufficient portion of the liner had been withdrawn from the probe an end cap was placed on the exposed end, the probe upended and the liner withdrawn completely and capped on the opposite end. The soil recovery probe was then rinsed with water and the procedure repeated once for each sample to be collected. All samples were obtained between 6:30am and 12:00 pm, maintained in a cooler on ice packs and returned to the laboratory within four hours of collection. Analysis for *E. coli* concentrations in sediments was conducted within three hours of receipt by the laboratory.

Enumeration of E. coli. Sediment cores were weighed (expressed in grams) and measured (in cm) upon arrival at the laboratory. After measuring the weight and length, the entire sediment core was aseptically transferred into a sterile container. Immediately following this step, 99 ml of sterile phosphate buffer with $MgCl_2$ (Hardy Diagnostic or Hach®, pH 7.2 +/- 0.2) was passed through the sterile butyrate liner to remove any residual sediment particles adhering to the sides. Samples were mechanically agitated for 30 seconds to suspend sediment attached *E. coli* into the phosphate buffer solution. Serial dilutions of the phosphate buffer solution with suspended *E. coli* (1 to 5ml depending on sample location and conditions) were diluted to 100 ml total volume using sterile deionized water and filtered through sterile 0.45-micron, 47 mm nitrocellulose filters (Millipore Corporation, Billerica, MA). Filters were placed onto modified m-TEC agar (US EPA Method 1603) and dry incubated at 35 °C (+/- 0.5 °C) for two hours to resuscitate stressed organisms, then transferred to a 44.5 °C (+/-0.2 °C) degree water bath for 22 (+/-2) hours. After incubation, the numbers of red or magenta colonies that formed on the filters were counted with the aid of a Quebec Colony Counter ®, multiplied by the dilution factor employed, and divided by the sediment core weight to express *E. coli* concentration as CFU (colony forming units) per gram of sediment wet weight. The CFU/gram wet weight was then divided by a factor determined by desiccating each individual sample to complete dryness in order to express the *E. coli* density as colony forming units (CFU)/gram dry weight of sand.

Quality control and quality assurance measures were maintained throughout the analytical process. Media, sterilization process controls (pre- and post-analysis), and positive (*E. coli* ATCC # 25922) and negative (*Enterococcus faecalis* ATCC #29212) quality control organisms were included with each day's membrane filtration run to insure sterility of sampling equipment, dilution agents, analytical equipment and confirm the ability of the media to exhibit the appropriate chromogenic response. The sterility of the butyrate liners was also insured through the inclusion of sterility control with each batch of prepared liners (100mL of the sterile phosphate buffer as previously described).

Moisture content. Following bacteria enumeration, sediment samples were dried to determine water content and facilitate sediment size determination. Sediments were placed into an incubator at approximately 35 ^{o}C for a period of approximately three weeks to complete sediment desiccation. After a period of two weeks, several representative samples of sediments were weighed; a week later these samples were reweighed. If there was not a change in mass in any representative sample, all sediment samples were deemed dry. The weight of dried sediments was recorded and compared to the wet weight of sediment samples to determine water content. Following drying, all sediments from the same sampling location were combined into one composite sample (i.e. all samples located at the berm crest at a specific transect were combined into a single sample).

Grain Size. Once composited, sediment grain size analysis was conducted using method ASTM C 136-05 (ASTM, 2006) at the University of Wisconsin-Parkside Geosciences Department Laboratory. In brief, samples were placed into a stack of progressively finer sieves that would allow sediments finer then 8, 4.76, 1, 0.5, 0.21, 0.125 and 0.074 millimeters to pass through. This stack of sediments sieves was then placed onto a mechanical shaker for at least three minutes to separate sediments into separate size fractions. Following mechanical agitation, the fraction of sediments remaining on each sieve was weighed. The mean grain diameter and uniformity coefficient were calculated using standard

graphical techniques based on the proportion of sediments retained on each sieve (Folk and Ward, 1957; Hazen, 1900). Mean grain size was determined using equation Eq (3), where Φ (phi) was determined by Eq (4). In Eq (4), D represents the diameter of a particle in millimeters. Φ_{16}, Φ_{50} and Φ_{84} were determined through graphical methods. Φ_{16}, Φ_{50} and Φ_{84} represent the phi size of the particles distributed at the 16th, 50th and 84th percentile respectively.

Uniformity coefficient. The uniformity coefficient (C_u) was determined using equation Eq (5). D_{60} and D_{10} represent the diameter of particles for which 60 and 10% of particles are finer. A C_u less than four is considered a well sorted sediment sample and a C_u greater than six is considered a poorly sorted sediment sample. Combined sediment samples were further described using the Unified Soil Classification System.

$$\text{Eq(3) Mean grain size } (\Phi) = \frac{\Phi_{16} + \Phi_{50} + \Phi_{84}}{3}$$

$$\text{Eq(4)}\ \Phi = -\log_2(d)$$

$$\text{Eq(5)}\ C_u = \frac{D_{60}}{D_{10}}$$

Dye Testing – Eichelman Beach

Fluorescent FLT yellow/green dye (Bright Dyes, Kingscote Chemicals Inc, Miamisburg, OH) was used to visually determine circulation patterns in the embayed region of Eichelman Park Beach on one occasion in 2011. Thirty tablets were placed into one liter of water and homogenized. A solution of dye was slowly poured into the water at each transect Eichelman Beach. The movement of the dye from the starting location was photographed and measured to determine the speed at which the water circulated and to visually inspect lateral dispersion/advection patterns.

Statistical Analysis

A number of basic statistical analyses were conducted to determine conditions impacting water quality. All *E. coli* concentration data was log-normalized to satisfy statistical conditions of normality and equal variance. All qualitative variables were converted into ordinal (i.e. given a ranking) or binary values (1 = present or 0 = absent).

Microsoft® Office Excel data analysis ToolPak™ was used to calculate descriptive statistics. Minimum significant *r* values ($\alpha < 0.05$, $p < 0.05$) were identified for every pair of variables based upon the degree of freedom present in the analysis. Trend analysis was accomplished through the generation of scatter plots and the application of linear regression analysis, in particular targeting variables with significant *r* values. If any variable appeared to be explanatory for total *E. coli* concentrations, SigmaPlot® (Systat Software, Inc., San Jose, CA) was used to determine if the means were significantly different, applying normality tests such as the Shapiro-Wilk test and equal variance tests to determine if

parametric or non-parametric tests were indicated based upon data distribution. P values of <0.05 were considered significant, unless otherwise noted. When comparing the means of multiple groups, analysis of variance (ANOVA) was employed. Test for normalcy and equal variance were used to determine post-hoc treatments should be employed, including: Tukey-Kramer Method, Bonferroni-Dunn test, Kruskal-Wallis method, for example.

Results

Pike River – Mouth

Water samples were collected near the mouth of the Pike River on 148 days over the three year study period. *E. coli* concentrations in water samples from the Pike River ranged from less than 10 to 73,300 MPN/100ml. Mean *E. coli* concentrations did not differ by year [(2010: n=43, mean=2.26, σ=0.86) (2011: n=51, mean=2.16, σ=0.57) (2012: n=54, mean=2.14, σ=0.57) (p=0.651)]. Discharge volumes ranged from 0.05 to 9.49 m^3/s. During periods of low flow, it was observed that sediments from Lake Michigan accumulated and blocked river water from discharging into the lake.

Discharge volumes were significantly higher in the 24 hours following rainfall events (>0.13 cm) (median=0.623 m^3/s) compared to dry weather events (median=0.265 m^3/s) (p<0.001). *E. coli* concentrations were positively correlated with log transformed discharge volumes (n=148, r=0.596, p<0.001) (Figure 13). *E. coli* concentrations also correlated well with discharge volumes following precipitation events greater than 0.13 cm (n=30, r=0.834, p=<0.001). The potency of a source is determined both by the concentration and volume; following precipitation both these aspects increased.

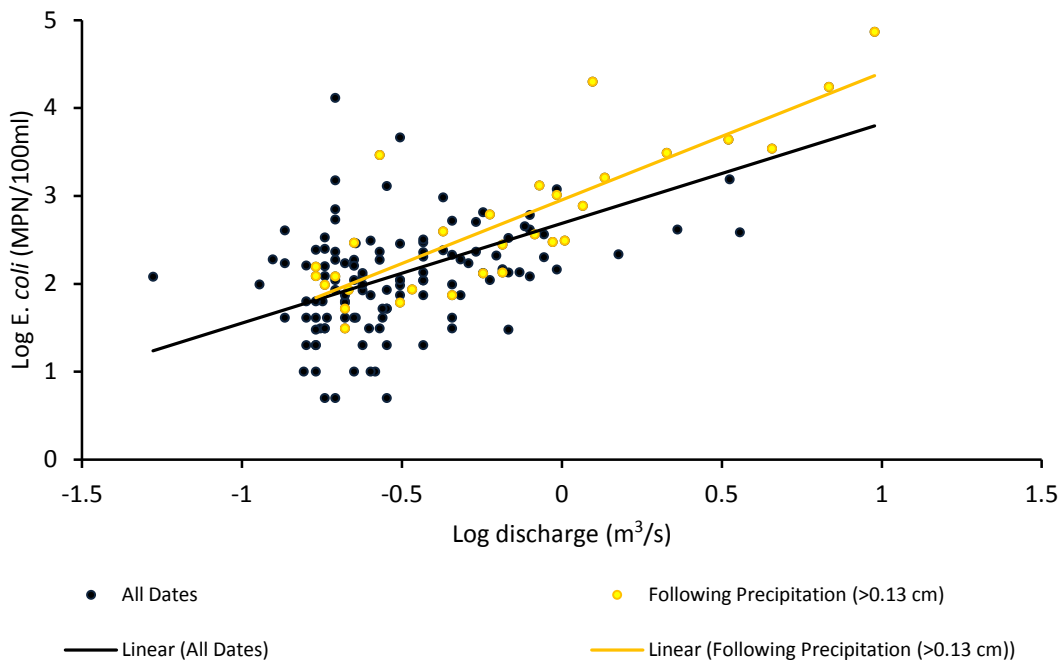

Figure 13: The relationship between river discharge volume and *E. coli* concentration in river effluent during all sampling events and following precipitation.

Specific conductivity was measured for 102 water samples in 2011 and 2012; values ranged from 419 µS to 1,037 µS (mean=701 µS, σ=144). Specific conductivity did not vary as a function of discharge volume (p=0.986), but *E. coli* concentrations were negatively correlated with specific conductivity (n=102, r=-0.201, p=0.0429).

Turbidity was measured for 53 water samples from the Pike River in 2012; turbidity ranged between 6.89 to 120 NTU (median=12.8 NTU). Log transformed turbidity values positively correlated with log transformed discharge volumes (n=53, r=0.339, p=0.0129). Pike River *E. coli* concentrations did not correlate with log transformed Pike River turbidity values (n=53, r=0.0843, p=0.548).

Pike River - Upstream

Although *E. coli* concentrations in the discharge of the Pike River were elevated during periods of higher flow, it was unclear where and how FIB enters into the river. Water samples were collected upstream of the river's discharge point once during the study period following 7.16 cm of precipitation on July 23rd, 2010. Samples were collected from 11 upstream locations (plus the mouth) including two locations on the North Branch and one location on the South Branch (Figure 14). *E. coli* concentrations were elevated (>10,000 MPN/100ml *E. coli*) on both the North and South Branch of the Pike River following this precipitation event. At the confluence of the North and South Branches, *E. coli* concentrations increased significantly (98,700 MPN/100ml). It was unclear if the water sample collected where the North and South Branch merge was representative of actual *E. coli* concentrations or if a large increase in FIB occurred from an external source. *E. coli* density quickly decreased downstream from this location (<20,000 MPN/100ml). *E. coli* concentrations ranged from 10,000 to 20,000 MPN/100ml from Petrified Springs Park to the second to last sampling location on the main stem of the river (located near Carthage College). A water sample collected at the point of discharge (river mouth) exceeded 70,000 MPN/100ml, while a water sample collected 1.7km upstream was 18,500 MPN/100ml.

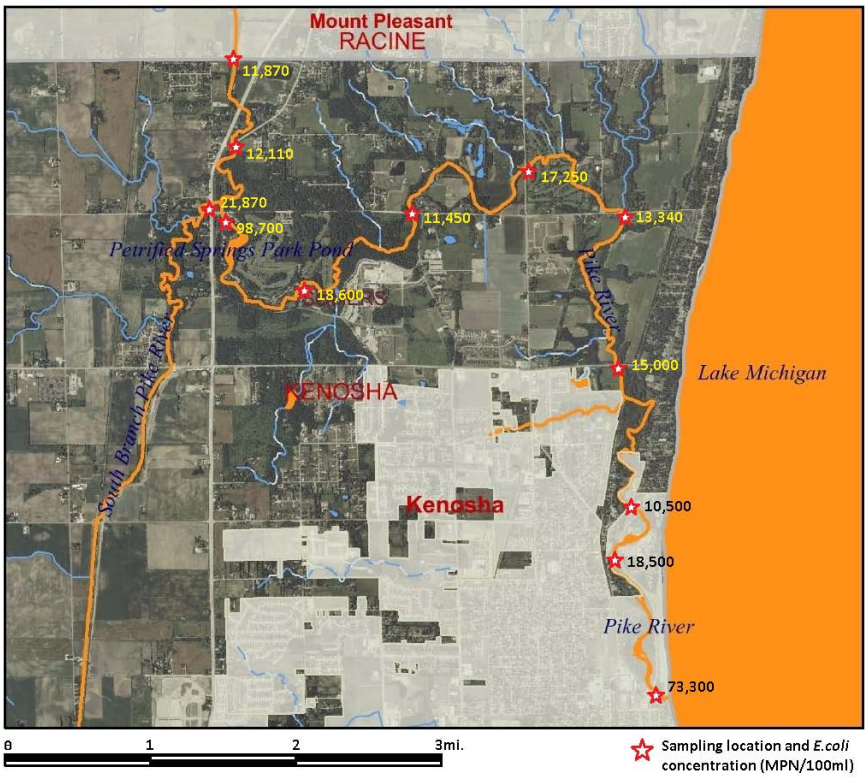

Figure 14: Monitoring of additional areas of the Pike River on July 23rd, 2010 following a precipitation event, reveal elevated *E. coli* concentrations in upstream sections of the river.

Alford Park Beach

Physical characteristics. Beach length, measured from the tree line forming the northern boundary of the beach (near transect AP-1) to the north bank of the Pike River, ranged from 1,082 to 1,103 m. Average beach width was widest at transects AP-3 (64.2 m) and AP-4 (65.0 m) and narrowest at transects AP-1 (16.6 m) and AP-2 (20.6 m) (Table 1) (Figure 15). The grass line at the back of the beach, which formed the western boundary, was not stationary at transects AP-4 and AP-5 and varied by up to an order of magnitude. The slope of the beach at all transects had a greater than five percent grade. The distance from the berm crest to a water depth of 1.2 meters was less than 10 meters at transects AP-3, AP-4 and AP-5 and less than 15 meters at AP-1 and AP-2. Water depth drops off quicker at southern transects (AP-3, AP-4, and AP-5) compared to northern transects, AP-1 and AP-2 (Figure 15).

Alford Park Beach BEACH DIMENSIONS					
Average	**AP-1**	**AP-2**	**AP-3**	**AP-4**	**AP-5**
Width (m)	16.6	20.6	64.2	65.0	45.6
Slope (%)	10.9	6.7	5.0	5.8	9.1
In-Water Measurements from Berm Crest to:					
0.3 m	3.0	5.5	4.3	4.3	4.4
0.6 m	7.8	8.5	6.3	6.4	6.3
0.9 m	9.8	11.3	8.4	8.3	8.4
1.2 m	13.1	14.9	9.6	9.8	9.8

Table 1: Average dimensions of Alford Park over the study period.

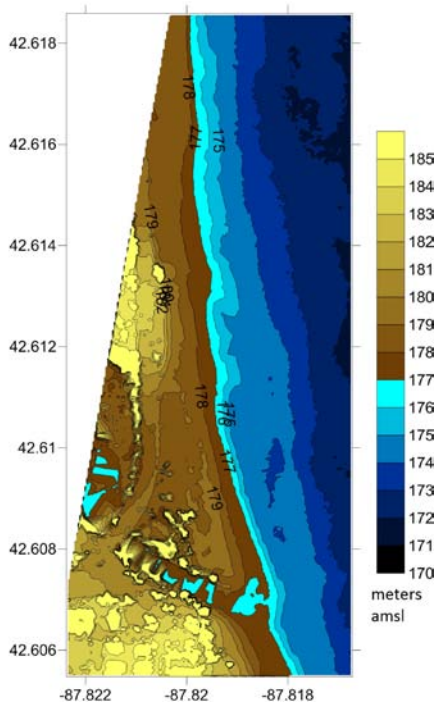

Figure 15: Digital elevation model of Alford Park Beach (Data from USACE Great Lakes Topo/Bathy LiDAR Survey).

Water quality – routine monitoring. Surface water samples were collected from five transects at Alford Park in 2010 (Table 2). The number of transects monitored at Alford Park was reduced in subsequent years because mean *E. coli* concentrations were not significantly different across beach transects in 2010 (p=0.1015) and little use of the beach occurred near the northern most transects (AP-1 and AP-2). Therefore, in 2011 and 2012, water quality was monitored only at transects AP-3, AP-4 and AP-5. Mean *E. coli* concentrations did not differ significantly by year (p=0.9056) or by transect location (p=0.5396). The percentage of samples exceeding water quality standards was 11.9 (n=5, 2010 only), 14.3 (n=6, 2010 only), 18.8 (n=28), 17.4 (n=26) and 16.1 (n=24) at transects AP-1, AP-2, AP-3, AP-4 and AP-5 respectively.

Year		AP-1	AP-2	AP-3	AP-4	AP-5	All
2010	*mean*	1.54	1.56	1.97	1.79	1.77	1.72
	σ	0.64	0.80	0.67	0.73	0.77	0.73
	n	42	42	43	43	43	213
2011	*mean*	----	----	1.71	1.63	1.72	1.69
	σ	----	----	0.75	0.76	0.80	0.77
	n	--	--	52	52	52	157
2012	*mean*	----	----	1.59	1.78	1.68	1.68
	σ	----	----	0.70	0.73	0.85	0.76
	n	--	--	54	54	54	162
All	*mean*	1.54	1.56	1.72	1.73	1.72	1.70
	σ	0.64	0.80	0.72	0.74	0.80	0.75
	n	42	42	149	149	149	532

Table 2: Mean *E. coli* concentration in water samples collected at Alford Park based upon transect and year. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Water quality – multi-depth. Samples were collected at the point where water depth first reached 0.3, 0.6, 0.9 and 1.2 meters at each transect on seven dates in 2010. *E. coli* concentrations did not vary based upon sampling depth at any individual transect or with data from all transects combined [(AP-1: n=28, r=-0.044, p=0.822), (AP-2: n=28, r=-0.064, p=0.747), (AP-3: n=28, r=-0.121, p=0.538) (AP-4, n=28, r=-0.041, p=0.835) (AP-5, n=28, r=-0.129, p=0.514), (All: n=140, r=-0.076, p=0.369)].

Water quality – Pike River (See Pike River, Page 25). *E. coli* concentrations in the Pike River (n=148, mean=2.18, σ=0.69) were significantly higher than in surface water at Alford Park (p<0.001, all transects). The median *E. coli* concentration in the Pike River was 133 MPN/100ml. When *E. coli* concentrations exceeded the median level in Pike River effluent, there was a significantly higher amount of *E. coli* present at all transects of Alford Park Beach except AP-1 (AP-1: p=0.381, AP-2: p=0.002, AP-3: p=0.003, AP-4: p<0.001, AP-5: p<0.001) (Table 3). Water quality exceeded standards 16.7 (n=4), 25.0 (n=6), 25.7 (n=19), 25.7 (n=19), and 23.0 (n=17) percent of the time when the *E. coli* level in the Pike River exceeded 133 MPN/100 ml. Comparatively, the exceedance rate was 5.6 (n=1), 0.0 (n=0), 12.0 (n=9), 9.3 (n=7) and 9.3 (n=7) percent at transects AP-1, AP-2, AP-3, AP-4 and AP-5 respectively when less than 133 MPN/100ml *E. coli* was noted. On average, water samples from Alford Park exceeded standards 3.0 times more frequently when *E. coli* in the Pike River was greater than 133 MPN/100ml.

Specific conductivity measurements were taken at transects AP-3, AP-4 and AP-5 and from the Pike River in 2011 and 2012. Mean specific conductivity measurements were consistently higher in the Pike River (n=102, mean=701 µS, σ=144) than at any beach transect [(AP-3: n=106, mean=313 µS, σ=22, p<0.001) (AP-4, n=106, mean=314 µS, σ=23, p<0.001) (AP-5: n=106, mean=320 µS, σ=36, p<0.001). Significantly higher specific conductivity values at the beach were associated with northern [(AP-3: n=52, mean=321 µS, σ=28.6) (AP-4: n=52, mean=322 µS, σ=29.1) (AP-5: n=52, mean=335 µS, σ=45.9)] rather than southern alongshore currents at each transect[(AP-3: n=54, mean=306 µS, σ=9.9, p<0.001) (AP-4: n=54, mean=305 µS, σ=10.2, p<0.001) (AP-5: n=54, mean=307 µS, σ=13.3, p<0.001)].

Pike River		**AP-1**	**AP-2**	**AP-3**	**AP-4**	**AP-5**
***E. coli* >133 MPN/100ml**	*mean*	1.58	1.86	1.89	1.93	1.99
	σ	0.73	0.86	0.73	0.78	0.79
	n	25	24	74	74	74
***E. coli* ≤133 MPN/100ml**	*mean*	1.40	1.17	1.55	1.53	1.46
	σ	0.60	0.49	0.67	0.64	0.73
	n	18	24	75	75	75

Table 3: Influence of the Pike River on *E. coli* concentration at Alford Park. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Water quality – Alford Park Outfall. It was the intent at the outset of this project to sample stormwater discharge from the single outfall at Alford Park Beach. However, little to no flow was observed. The lack of scouring (of sediments) or any other signs of recent discharge following precipitation events indicated a general lack of flow from this outfall.

Sediments. Sediment samples, collected on seven dates during 2010, were composited and analyzed to determine dominate size and sorting (See Methods Section, Page 22). Sediments collected from the berm crest were described either as poorly sorted coarse sand with some gravel (>25%) or as poorly sorted gravel with some coarse sand (Table 4). Overall, the distribution of sediments along the berm crest was similar. However, a larger amount of medium and coarse grain sands and less gravel were present at AP-5-BC, the location closest to the mouth of the Pike River. It should also be noted that samples collected from the berm crest at transects AP-1 and AP-2 were falsely skewed towards a higher percentage of fine particle due to the borehole of the soil probe (2.54 cm diameter) being smaller than some of the sediments. In actuality, less than 0.1% of sediments collected from the berm crest on a mass basis were representative of silt or clay particle sizes (with the exception of AP-2, 0.23%). Sediments collected from back and middle beach sampling locations had smaller mean grain sizes than berm crest sediments and were generally well sorted. With the exception of samples collected at AP-1-MB (1.40mm mean grain size), mean grain size of back and middle beach samples ranged from 0.43 (AP-4-BB) to 0.71 mm (AP-3-MB).

Uniformity coefficients, a measure of sediment sorting, ranged from 4.75 at transect AP-3 to 11.20 at transect AP-5 in berm crest sediments. Uniformity coefficients were smaller at back and middle beach locations less than four (well sorted), with the exception of AP-1-MB (uniformity coefficient of 4.46).

Location	Mean Grain Size (mm)	Uniformity Coefficient	Description
AP-1-BC	3.82	5.96	Poorly sorted coarse sand with some gravel(SW)
AP-1-MB	1.40	4.46	Coarse sand with little gravel (SP)
AP-2-BC	4.09	9.92	Poorly sorted gravel with some coarse sand (GW)
AP-2-BC	0.67	2.03	Well sorted coarse sand with trace gravel (SP)
AP-3-BC	4.00	4.75	Poorly sorted coarse sand with some gravel(SW)
AP-3-MB	0.72	2.15	Well sorted coarse sand with few gravel (SP)
AP-3-BB	0.48	2.12	Well sorted medium sand with trace gravel (SP)
AP-4-BC	4.54	5.20	Poorly sorted gravel with some coarse sand (GW)
AP-4-MB	0.59	2.24	Well sorted medium sand with trace gravel (SP)
AP-4-BB	0.43	1.98	Well sorted medium sand with trace gravel (SP)
AP-5-BC	2.43	11.20	Poorly sorted coarse sand with some gravel(SW)
AP-5-MB	0.55	2.46	Well sorted medium sand with trace gravel (SP)
AP-5-BB	0.64	2.78	Well sorted medium sand with trace gravel (SP)

Table 4: Mean grain size, uniformity coefficient and description of sediments at Alford Park.

E. coli was enumerated in beach sediments (Table 5). Concentrations in sediments were higher at the berm crest compared to middle beach locations at transects AP-1 (p=0.013) and AP-3 (p=0.038). *E. coli* concentrations were higher at berm crest versus back beach positions at transects AP-3 (p=0.005) and AP-5 (p=0.043). Concentrations did not differ based upon sampling location at transects AP-2 (p=0.261) and AP-4 (p=0.1319). *E. coli* concentrations in sediments did not differ by position across beach transects [berm crest (p=0.9894), middle beach (p=0.2193) or back beach (p=0.6543)].

Location		AP-1	AP-2	AP-3	AP-4	AP-5
Berm Crest	*mean*	3.07	2.94	3.08	3.04	2.95
	σ	0.78	0.85	0.84	0.74	0.64
	n	7	7	13	13	13
Middle Beach	*mean*	2.18	2.43	2.36	2.88	2.53
	σ	0.15	0.77	0.67	0.82	0.71
	n	7	7	13	13	13
Back Beach	*mean*	----	----	2.15	2.41	2.19
	σ	----	----	0.54	0.86	0.91
	n	--	--	13	13	13

Table 5: Mean *E. coli* concentration in sediment samples collected at Alford Park based upon transect and collection location. *E. coli* concentration represented as log *E. coli* CFU/100grams dry sediment.

Mean *E. coli* concentrations were unilaterally greater in berm crest sediments on a mass to mass basis (assuming 100ml of water weighs 100 grams) than in surface water samples (AP-1: p<0.001; AP-2: p=0.002; AP-3:p<0.001; AP-4:p<0.001; AP-5:p=0.002). This was also the case with middle beach sediments and adjacent surface water samples at transects AP-1 (p=0.009), AP-2 (p=0.040) and AP-4 (p=0.002). Although higher *E. coli* concentrations were present in sediment samples than in adjacent

water samples at many locations, *E. coli* concentrations in sediments and water samples did not correlate at any location (p>0.05, all locations).

Wildlife. Dogs, ducks, geese and gulls were frequently observed at Alford Park, but the type and number varied by transect (Table 6). For example, no animals were observed at transect AP-1 and only geese, on one occasion, were observed at transect AP-2. Ducks were the least represented, observed in low numbers and only twice at transects AP-3 and AP-5. Dogs were the next least frequently observed type of animal, present in low numbers and on few days. Geese (200 – 300 per transect) were present at transects AP-3 through AP-5 on 10 to 14 days per transect throughout the study period. Gulls were the most frequently seen species, in overall numbers and times observed. Gulls were most commonly observed at transect AP-3, but were also seen in high numbers at transects AP-4 and AP-5. There was no correlations between *E. coli* and the presence of wildlife (any species, p>0.05) except for gulls at transect AP-3. *E. coli* concentrations were greater when gulls were present (n=56, mean=1.87, σ=0.63) versus absent (n=93, mean=1.63, σ=0.75) (p=0.044). Recreational water quality standards were exceeded 23.2 (n=13) versus 16.1 percent of the time with gulls on the beach compared to without at transect AP-3; translating into a 44.1 percent increase in frequency at this location.

Species	AP-1	AP-2	AP-3	AP-4	AP-5
Dogs (#)	0	0	8	6	1
Ducks (Days)	0	0	7	5	1
Ducks (#)	0	0	7	0	2
Ducks (Days)	0	0	1	0	1
Geese (#)	0	7	243	272	219
Geese (Days)	0	1	14	12	10
Gulls (#)	0	0	8,177	5,207	3,821
Gulls (Days)	0	0	56	46	38

Table 6: Number and frequency of dogs, ducks, geese and gulls observed at Alford Park based upon transect location (2010 – 2012).

Algae. Submerged algae (*Cladophora*), algae in the water, was present in low, moderate and high amounts for 67.2 (n=357), 6.8 (n=36) and 0.2 (n=1) percent of sampling days respectively (Table 7). It was absent from the beach on 25.8 percent of sampling days (n=137). *E. coli* did not vary as a function of the amount of submerged algae at transects AP-1 (p=0.3708) and AP-2 (p=0.643). Higher *E. coli* concentrations were associated with moderate amounts of submerged algae at transects AP-3 (p=0.024), AP-4 (p=0.012) and AP-5 (p<0.001). At transects AP-3 (p=0.035) and AP-5 (p=0.016), *E. coli* concentrations were also higher when the amount of algae was described as moderate compared to when described as low. When moderate amounts of submerged algae were observed, the percent of recreational water quality exceedances were 37.5 (n=6), 45.5 (n=5) and 37.5 (n=3) at transects AP-3, AP-4 and AP-5, respectively. The number of exceedances was lower when lesser amounts of submerged algae were noted: 14.3 (n=5), 7.3 (n=3) and 6.0 (n=3) percent when algae were absent and 17.3 (n=17), 18.8 (n=18) and 19.8 (n=18) percent when the amount of algae submerged in the water was described as low at transects AP-3, AP-4 and AP-5 respectively.

Submerged Algae Amount		AP-1	AP-2	AP-3	AP-4	AP-5
Absent	*mean*	1.48	1.72	1.60	1.48	1.49
	σ	0.73	0.81	0.71	0.59	0.63
	n	6	5	35	41	50
Low	*mean*	1.52	1.54	1.69	1.77	1.78
	σ	0.63	0.80	0.70	0.75	0.82
	n	35	37	98	96	91
Moderate	*mean*	2.44	----	2.17	2.25	2.58
	σ	----	----	0.74	0.86	0.97
	n	1	--	16	11	8
High	*mean*	----	----	----	2.33	----
	σ	----	----	----	----	----
	n	--	--	--	1	--

Table 7: Mean *E. coli* concentration at Alford Park based on transect location and the amount of algae submerged in the water. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Algae stranded ashore was present in low and moderate, but never high amounts, for 49.0 (n=260) and 4.5 (n=24) percent of sampling days respectively (Table 8). Stranded algae was absent from the beach for 46.5 (n=247) percent of samples. *E. coli* concentrations did not vary based on the amount of stranded algae at transects AP-1 (p=0.858), AP-2 (p=0.791), AP-4 (p=0.061) and AP-5 (p=0.1406). At transect AP-3, elevated *E. coli* concentrations were significantly associated with moderate amounts of stranded algae compared to when low amounts were present (p=0.028) or no algae was present (p=0.005). There were also more water quality exceedances when stranded algae was present; 11.1 percent when absent; 21.0 percent for low (n=16) and 50.0 percent for moderate (n=5).

Stranded Algae Amount		AP-1	AP-2	AP-3	AP-4	AP-5
Absent	*mean*	1.53	1.58	1.60	1.55	1.59
	σ	0.71	0.83	0.65	0.70	0.77
	n	27	32	63	62	63
Low	*mean*	1.56	1.51	1.74	1.83	1.80
	σ	0.52	0.73	0.72	0.76	0.84
	n	15	10	76	79	80
Moderate	*mean*	----	----	2.36	2.12	2.13
	σ	----	----	0.82	0.57	0.34
	n	--	--	10	8	6
High	*mean*	----	----	----	----	----
	σ	----	----	----	----	----
	n	--	--	--	--	--

Table 8: Mean *E. coli* concentration at Alford Park based upon transect location and the amount of algae stranded on the beach. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Air temperature. Mean air temperatures averaged 23.0 (n=43, σ=3.5), 22.7 (n=52, σ=4.5) and 24.0 ^{o}C (n=54, σ=4.2) in 2010, 2011 and 2012 respectively. Mean air temperatures did not differ significantly by year (p=0.2233). *E. coli* concentrations did not correlate with air temperatures at any transect (AP-1: p=0.137; AP-2: p=0.535; AP-3: p=0.851; AP-4: p=0.692; AP-5: p=0.589) or in any year.

Water temperature. Mean water temperatures did not differ significantly across beach transects (p>0.05). Average water temperatures were 16.0 (n=43, σ=3.0), 17.1 (n=52, σ=3.3) and 19.1 ^{o}C (n=54, σ=4.5) in 2010, 2011 and 2012 respectively. Mean water temperatures were significantly higher in 2012 compared to both 2010 (p<0.001) and 2011 (p=0.017). *E. coli* concentrations were correlated with water temperature at transects AP-3 (n=149, r=0.166, p=0.043) AP-4 (n=149, r=0.237, p=0.004) and AP-5 (n=149, r=0.223, p=0.006) but not at transects AP-1 (n=42, r=-0.003, p=0.983) and AP-2 (n=42, r=0.035, p=0.824). This correlation was likely related to covariance between wind directions and water temperatures. Warmer water temperatures were associated with east (n=52, mean=18.4 C^{o}, σ=4.0) versus west winds (n=95, mean= 17.0 C^{o}, σ=3.8) (p=0.043).

Precipitation. Rainfall events of 0.13 cm or more (considered a significant amount) occurred within the 24-hour period prior to sample collection on 29 dates over the course of the study period. Significantly higher *E. coli* concentrations were associated with precipitation events at all beach transects (p = <0.001 to 0.033, Figure 16). Water quality exceeded recreational criteria 40.0 (n=2), 60.0 (n=3), 55.2 (n=16), 48.3 (n=14) and 37.9 (n=11) percent of the time when preceded by rainfall events at transects AP-1, AP-2, AP-3, AP-4 and AP-5 respectively. Comparatively, water quality standards were exceeded 8.1 (n=3), 8.1 (n=3), 10.0 (n=12), 10.0 (n=12) and 10.8 (n=13) percent of the time when less than 0.13 cm of rainfall occurred in the 24 hours prior to sample collection at the same transects. Recreational water quality criteria were exceeded 4.8 times more often following precipitation events compared to dry weather.

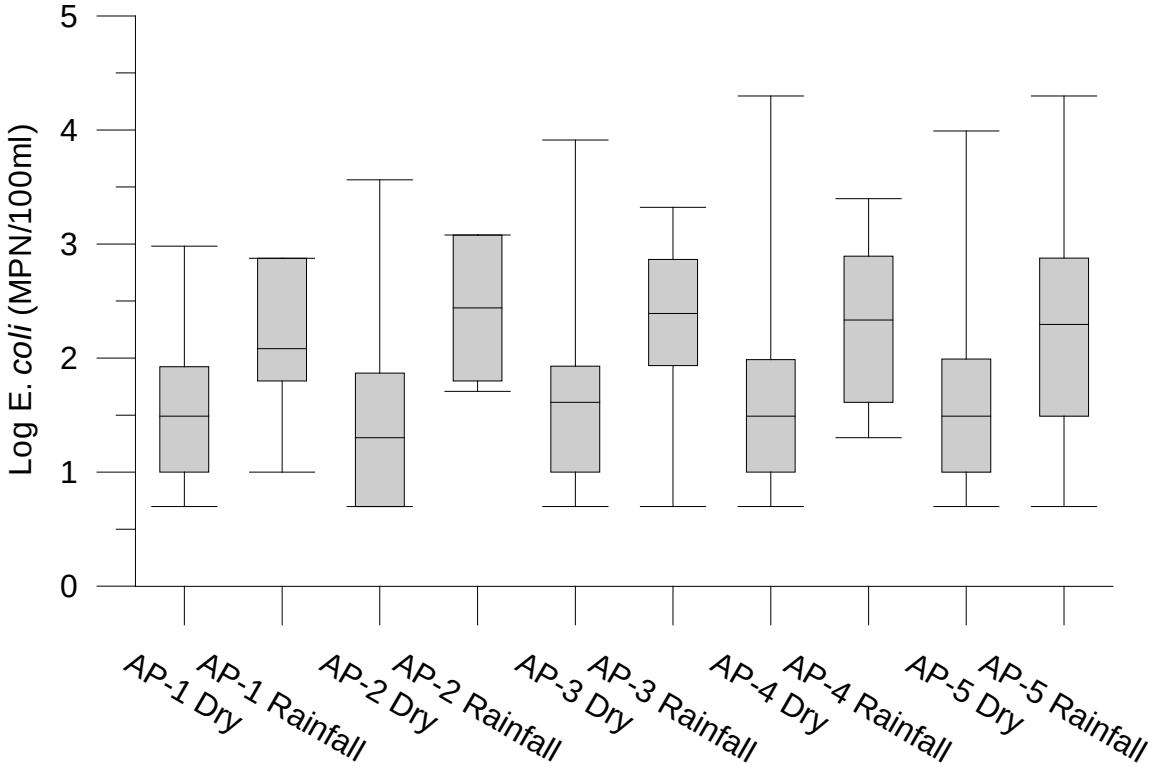

Figure 16: Mean *E. coli* concentration at each transect following precipitation (>0.13 cm prior to sample collection) and during dry weather.

Wind speed and direction. Wind speed and directions were broken down into components of velocity along the east/west and north/south axes (see Methods, page 17). Wind speeds along the north/south axis did not correspond to *E. coli* concentrations except for at transect AP-3 where higher *E. coli* concentrations were associated with winds out of the south [(AP-1: n=42, r=-0.71, p=0.653) (AP-2: n=42, r=0.099, p=0.534) (AP-3: n=149, r=-0.168, p=0.040) (AP-4: n=149, r=0.001, p=0.987) (AP-5: n=149, r=0.074, p=0.368)]. At transect AP-3, water quality exceedance rates of 23.1 (n=18) and 14.1 (n=10) percent were associated with winds out of the south and north respectively.

Higher *E. coli* concentrations were associated with winds out of the east at all transects [(AP-1: n=42, r=0.355, p=0.021) (AP-2: n=42, r=0.553, p<0.001) (AP-3: n=149, r=0.235, p=0.004) (AP-4: n=149, r=0.337, p<0.001) (AP-5: n=149, r=0.347, p<0.001). Water quality exceedance rates of 50.0 (n=3), 50.0 (n=3), 28.8 (n=15), 32.7 (n=17) and 25.0 (n=13) percent were associated with easterly winds. Comparatively, surface water samples exceeded criteria 5.6 (n=2), 8.3 (n=3), 13.4 (n=13), 9.3 (n=9) and 11.3 (n=11) percent of the time when winds did not contain an easterly vector at transects AP-1, AP-2, AP-3, AP-4 and AP-5 respectively. Water quality was exceeded 2.9 times more often with easterly (onshore) winds compared to other wind directions.

Current speed and direction. Current speed and directions were broken down into components of velocity along the east/west and north/south axes. *E. coli* concentrations were higher at transect AP-1 with northern currents (AP-1: n=42, r=0.309, p=0.046). However, *E. coli* concentrations did not correlate significantly with the velocity of the current along the north/south axis at other transects [(AP-2: n=42, r=0.292, p=0.061) (AP-3: n=149, r=0.156, p=0.058) (AP-4: n=149, r=0.016, p=0.845) (AP-5: n=149, r=-0.052, p=0.532)]. Water quality exceeded standards 23.5 (n=4) percent of the time with northern currents versus 4.0 (n=1) percent of the time with southern currents at transect AP-1. Higher *E. coli* concentrations were associated with the current velocity along the east/west axis with higher concentrations associated with western (onshore) currents at transects AP-4 and AP-5. There were no significant correlations between current speeds or direction at other transects (AP-1, AP-2 or AP-3). Water quality exceedance rates of 21.1 (n=11) and 23.1 (n=12) percent were associated with western currents and exceedance rates of 15.5 (n=15) and 12.4 (n=12) percent were associated with eastern currents at transects AP-4 and AP-5 respectively.

Wave height. Wave height measurements were available from two sources, field technician and GLCFS model estimates. Field technician wave height estimates ranged from 0 to 1.83 meters (median=0.15 meters). GLCFS model estimates ranged from 0.01 to 1.95 meters (median=0.25 meters). Field technician wave height estimates and model results were significantly correlated with each other (n=149, r=0.595, p<0.001). Field technician wave height estimates were significantly associated with *E. coli* levels at all transects (Table 9). GLCFS wave height estimates only correlated with *E. coli* concentrations at transects AP-3, AP-4 and AP-5. Overall, field technician wave height estimates explained more variation in *E. coli* concentrations than GLCFS model estimates, all transects. Water quality exceeded recreational standards 20.0 (n=3), 26.7 (n=4), 38.5 (n=20), 38.5 (n=20) and 34.6 (n=18) percent of the time when field technician's estimated wave heights of greater than 0.15 meters at transects AP-1, AP-2, AP-3, AP-4 and AP-5 respectively. Lower water quality exceedance rates were associated with wave height estimates of 0.15 meters or less at the same transects, AP-1 through AP-5

[7.4 (n=2), 7.4 (n=2), 8.2 (n=8), 6.2 (n=6) and 6.2% (n=6)]. On average, surface water samples exceeded recreational water quality standards more than 5.0 times as often when wave heights were greater than 0.15 meters.

Wave Height Source	AP-1	AP-2	AP-3	AP-4	AP-5
Field Technician Estimates	n=42 r=0.332 p=0.032	n=42 r=0.333 p=0.031	n=149 r=0.477 p<0.001	n=149 r=0.514 p<0.001	n=149 r=0.477 p<0.001
GLCFS Model	n=42 r=0.039 p=0.804	n=42 r=0.092 p=0.564	n=149 r=0.377 p<0.001	n=149 r=0.396 p<0.001	n=149 r=0.344 p<0.001

Table 9: Correlation between *E. coli* concentration at Alford Park and wave heights estimates (field technician and the Great Lakes Coastal Forecasting System nowcast model estimates).

Water clarity. Water clarity was estimated and described as clear, slightly turbid, turbid or opaque. The numbers of samples noted as each descriptor was similar at each transect (2010 - 2012) (Table 10) (i.e. there was little variation in water clarity between transects). There was a positive correlation between *E. coli* and ordinal turbidity values (e.g. clear=1, slightly turbid=2, turbid=3, opaque=4) at each transect [(AP-1, p=0.007) (AP-2, p=0.01) (AP-3, p<0.001) (AP-4, p<0.001) (AP-5, p<0.001)]. Decreased water clarity was associated with higher *E. coli* concentrations. Ordinal water clarity descriptors were positively associated with wave height (as determined by field technician estimates) at all transects (p<0.001).

Water Clarity		AP-1	AP-2	AP-3	AP-4	AP-5
Clear	*mean*	1.32	1.31	1.35	1.33	1.31
	σ	0.51	0.50	0.54	0.54	0.65
	n	18	20	54	0.52	57
Slightly Turbid	*mean*	1.46	1.42	1.59	1.54	1.55
	σ	0.66	0.63	0.57	0.51	0.57
	n	8	8	36	38	34
Turbid	*mean*	1.83	2.02	2.10	2.18	2.24
	σ	0.69	1.04	0.75	0.78	0.81
	n	16	14	54	54	53
Opaque	mean	----	----	2.51	2.45	2.14
	σ	----	----	0.32	0.42	0.44
	n	--	--	5	5	5

Table 10: Mean *E. coli* concentration at Alford Park based upon transect and water clarity. *E. coli* concentration represented as log *E. coli* MPN/100ml.

In 2012, analytical turbidity measurements were made in addition to visual estimates. Turbidity values ranged from 0.82 to 195.00 (median=7.71), 0.61 to 187.00 (median=7.95 NTU) and 0.72 to 172.00 NTU (median=6.84 NTU) at transects AP-3, AP-4 and AP-5 respectively (transects AP-1 and AP-2 were not assessed in 2012). Log transformed turbidity values were positively correlated with *E. coli* concentrations at all transects [(AP-3: n=54, r=0.558, p<0.001) (AP-4: n=54, r=0.506, p<0.001) (AP-5: n=54, r=0.460, p<0.001)]. Water quality exceedance rates of 25.9 (n=7), 33.3 (n=9) and 18.5 (n=5)

percent were associated with samples exceeding a median turbidity threshold and exceedance rates of 3.7 (n=1), 7.4 (n=2) and 7.4 (n=2) percent were associated with samples that had a median or lower turbidity value at transects AP-3, AP-4 and AP-5 respectively. Water samples with a greater than median turbidity were 4.2 times more likely to exceed water quality standards than samples with lower turbidity. Log transformed turbidity values correlated with ordinal water clarity descriptors at all transects indicating visual water clarity descriptions were accurate at describing turbidity ($p<0.001$).

Debris. The amount of debris noted on the beach was described as: absent (once), low (n=146 days) and moderate (twice). The types of debris observed included: food-related waste (n=138 days), street litter (n=108 days), household waste (n=25 days), building materials (n=13 days), sewage-related (condoms and tampons) (n=7 days), fishing-related (n=4 days), fireworks (n=4 days), clothing (n=3 days), medical waste (n=3 days) and a tire (n=1 day). Floatables (debris in the water) were observed on 10 occasions and included food-related waste (n=10 days), household waste (n=3 days), street litter (n=2 days), and building materials (n=2 days).

Beach usage. The number of people at Alford Park beach averaged <1.0 (n=31), <1.0 (n=30) and <1.0 (n=26) people per day in 2010, 2011 and 2012 respectively. Of those, <1 (n=6), <1 (n=5) and no (n=0) people per day were observed in the water. The activities of 61 people were also recorded and included: walking (n=30), playing with/walking pets (n=11), lounging (n=9), fishing (n=5), kite surfing (n=3), searching for rocks/beach glass (n=2) and taking photographs (n=1). One weekend observation was made (on 8/7/2010 @ 1500) in order to approximate peak usage. Only two people were on the beach suggesting overall low beach usage. As with all other beaches in Kenosha, the number of people recorded on the sampling days was likely not representative of total usage due to the time of day sanitary surveys were conducted (0800-0830). Due to the infrequent occurrence of people in the water at the time water samples were collected, they were not considered a significant source of pollution.

Pennoyer Park Beach

Physical characteristics. Beach length, measured from the south bank of the Pike River (forming the northern boundary of the beach; near transect; PP-1) to the seawall along Kennedy Drive (forming the southern boundary) ranged from 458 to 563 meters. The beach was widest near transects PP-3 (96.7 m) and PP-4 (96.1 m) (Figure 17) (Table 11). The slope of the beach, measured from the back of the beach to the berm crest ranged from a 2.4 to 3.2 percent grade. The distance from the berm crest to where a water depth of 1.2 meters was achieved was approximately 10 meters at all transects.

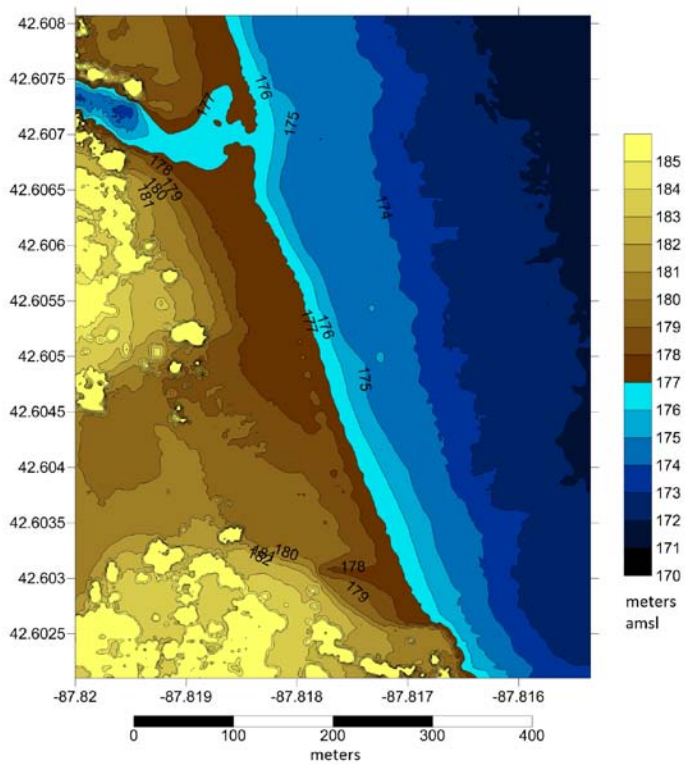

Figure 17: Digital elevation model of Pennoyer Park Beach (Data from USACE Great Lakes Topo/Bathy LiDAR Survey).

Pennoyer Park Beach BEACH DIMENSIONS				
Average	**PP-1**	**PP-2**	**PP-3**	**PP-4**
Width (m)	71.0	58.3	96.7	96.1
Slope (%)	3.2	3.8	2.4	2.9
In-Water Measurements from Berm Crest to:				
0.3 m	4.16	3.92	3.55	3.73
0.6 m	6.11	6.27	4.85	5.87
0.9 m	7.99	8.01	7.32	7.84
1.2 m	10.26	9.27	9.40	9.24

Table 11: Average dimensions of Pennoyer Park over the study period.

Water quality – routine samples. A total of 591 routine water samples (depth 0.6-0.75m) were collected from four transects at Pennoyer Park Beach (Table 12). Mean *E. coli* concentrations did not differ based upon transect location or year of sample collection (p=0.7821). The percentage of samples that exceeded water quality criteria was 23.6 (n=35), 17.6 (n=26), 21.8 (n=32) and 23.6 (n=35) at transects PP-1, PP-2, PP-3 and PP-4 respectively.

Year		PP-1	PP-2	PP-3	PP-4	All
2010	*mean*	1.82	1.78	1.77	1.87	1.81
	σ	0.69	0.65	0.69	0.68	0.67
	n	43	43	42	43	171
2011	*mean*	1.88	1.71	1.72	1.77	1.77
	σ	0.77	0.75	0.79	0.78	0.77
	n	51	51	51	51	204
2012	*mean*	1.68	1.62	1.68	1.63	1.65
	σ	0.75	0.80	0.81	0.81	0.79
	n	54	54	54	54	216
All	*mean*	1.79	1.70	1.72	1.75	1.74
	σ	0.74	0.74	0.77	0.76	0.75
	n	148	148	147	148	591

Table 12: Mean *E. coli* concentration in water samples collected at Pennoyer Park based upon transect and year. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Water quality – multi-depth. On seven dates in 2010, water samples were collected at each transect where a water depth first reached 0.3, 0.6, 0.9 and 1.2 meters. *E. coli* concentrations did not vary as a function of depth at any transect or with data from all transects combined [(PP-1: n=28, r=-0.076, p=0.701) (PP-2: n=28, r=-0.126, p=0.532) (PP-3: n=28, r=0.097, p=0.638) (PP-4: n=28, r=-0.231, p=0.238) (All: n=112, r=-0.085, r=-0.085, p=0.37)]. Due the lack of variability multi-depth sampling was discontinued at this location for the remainder of the study.

Water quality – Pike River (See Pike River, Page 25). *E. coli* concentrations in the Pike River (n=148, mean=2.18, σ=0.69) were significantly higher than at Pennoyer Park (p<0.001 all transects). The median *E. coli* concentration in the Pike River was 133 MPN/100ml. When *E. coli* concentrations exceeded the median level in Pike River effluent, there was significantly more *E. coli* at all transects of Pennoyer Park except at PP-4 (PP-1:p<0.001, PP-2:p=0.002, PP-3:p=0.025, PP-4:p=0.211) (Table 13). Water quality exceeded standards 29.7 (n=22), 23.0 (n=17), 27.0 (n=20) and 27.0 (n=20) percent of the time when the median Pike River *E. coli* level was exceeded. Comparatively, the exceedance rate was 17.6 (n=13), 12.2 (n=9), 16.4 (n=12) and 20.3 (n=15) percent at transects PP-1, PP-2, PP-3 and PP-4 respectively when the median amount of *E. coli* was not exceeded. On average, 60 percent more exceedances occurred when *E. coli* concentrations were greater than 133 MPN/100ml in the Pike River compared to dates with lesser amounts.

Pike River		PP-1	PP-2	PP-3	PP-4
***E. coli* >133 MPN/100ml**	*mean*	2.01	1.88	1.86	1.83
	σ	0.71	0.69	0.75	0.73
	n	74	74	74	74
***E. coli* ≤133 MPN/100ml**	*mean*	1.58	1.51	1.58	1.67
	σ	0.71	0.74	0.76	0.78
	n	74	74	73	74

Table 13: Influence of the Pike River on *E. coli* concentration at Pennoyer Park. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Specific conductivity measurements were taken at all beach transects and from the Pike River in 2011 and 2012. Mean specific conductivity measurements were consistently higher in the Pike River (n=102, mean=701 µS, σ=144) than at any beach transect [(PP-1: n=105, mean=367 µS, σ=88, p<0.001) (PP-2, n=105, mean=333 µS, σ=61, p<0.001) (PP-3: n=105, mean=323 µS, σ=42, p<0.001) (PP-4: n=105, mean=321 µS, σ=31, p<0.001)]. Higher specific conductivity values were also associated with transect PP-1 compared to transects PP-2 (p=0.033), PP-3 (p=0.002) and PP-4 (p<0.001). Significantly higher specific conductivity values at the beach were associated with southern [(PP-1: n=55, mean=374 µS, σ=87) (PP-2: n=555, mean=348 µS, σ=79) (PP-3: n=55, mean=333 µS, σ=54) (PP-4: n=55, mean=330 µS, σ=39)] rather than northern alongshore currents at all transects except PP-1 [(PP-1: n=50, mean=359 µS, σ=89, p=0.382) (PP-2: n=50, mean=316 µS, σ=21, p=0.005) (PP-3: n=50, mean=313 µS, σ=15, p=0.011) (PP-4: n=50, mean=312 µS, σ=15, p=0.003)].

Water quality – Pennoyer Park Outfall. Water samples were collected on 25 occasions from the outfall located on the south end of the beach over the course of the study. Following intense rainfall events, discharge volumes and flow velocities were high (Figure 18). *E. coli* concentrations ranged from below the detection limit (<10 MPN/100ml) to above the detection limit (>24,192 MPN/100ml) (n=25, mean=2.42, σ=1.19). Water samples were collected from this outfall within 24 hours of a precipitation (>0.13 cm) on 17 occasions. *E. coli* concentrations were significantly higher following precipitation (n=17, mean=2.80, σ=1.13) compared to other dates (n=8, mean=1.61, σ=0.91) (p=0.016). *E. coli* concentrations from the outfall were not significantly different than those collected from the nearshore waters off Pennoyer Park (p=0.205).

Figure 18: Discharge from the outfall located at Pennoyer Park on 7/22/2010 during an intense precipitation event.

Water quality - 40th Street Outfall. Water samples were collected from the 40th Street Outfall on 14 dates during 2012. *E. coli* concentrations ranged from 10 to 1,515 MPN/100ml. Eight samples had an *E. coli* concentration less than 235 MPN/100ml (all associated with dry weather) and 12 samples had an *E. coli* concentration below 1,000 MPN/100ml. Higher *E. coli* concentrations were associated with precipitation events (>0.13 cm) (n=6, mean=2.81, σ=0.24) compared to dry weather (n=8, mean=1.23, σ=0.44) ($p<0.001$).

Water quality – 43rd Street Outfall. Water samples were collected from the 43rd Street Outfall on 13 dates during 2012. The mouth of this outfall was partially submerged in the lake on all dates; effluent collected from this outfall was likely diluted with lake water to some degree. *E. coli* concentrations ranged from 132 to 24,192 MPN/100ml. Two, five and nine samples had *E. coli* concentrations less than 235, 1,000 and 10,000 MPN/100ml respectively. Mean *E. coli* concentrations did not differ between precipitation (n=5, mean=3.17, σ=0.98) and dry weather events (n=8, mean=3.51, σ=0.75).

Water quality – seep. A seep appeared intermittently at Pennoyer Park Beach in 2010; the source of this water was unknown. Discharge from this seep was observed on two occasions, on June 23rd following 2.36 cm of precipitation and on July 19th, no precipitation in previous 72 hours (Figure19). A grab sample of the discharge was collected on July 19th; the *E. coli* concentration was 437 MPN/100ml.

Figure 19: A seep that occasionally discharged onto the beach as observed on 7/19/2010.

Sediments. Sediment samples from Pennoyer Park, collected at transects PP-1 through PP-4 on seven dates in 2010, were composited and analyzed to determine dominant particle size and sorting (See Methods Section, Page 22). Sediments collected from the berm crest were described primarily as coarse sand with some gravel or gravel with some coarse sand (Table 14). Mean grain size of berm crest sediments ranged from 2.3 to 4.6 mm and the uniformity coefficient varied between 5.0 and 6.7. Sediment samples from the berm crest contained less than 0.1 percent silts or clays on a mass basis with the exception of PP-1 (0.15%); the location closest to the outwash plane of the Pike River. Mean grain size of sediment samples collected from the middle beach ranged from 0.99 (at PP-1 and PP-3) to 1.41

mm (at PP-2) and uniformity coefficients ranged from 2.9 at transect PP-3 to 4.8 at transect PP-1. Mean grain sizes in back beach sediments ranged from 0.44 mm at transect PP-3 to 1.02 mm at transect PP-1; uniformity coefficients for back beach samples ranged from 2.1 at PP-3 to 4.8 at PP-1. Sediments collected from back beach transects differed in mean particle size, with slightly coarser sediments at transect PP-1 compared to the rest of the beach.

Location	Mean Grain Size (mm)	Uniformity coefficient	Description
PP-1-BC	2.32	5.85	Course sand with some gravel (SP)
PP-1-MB	0.99	4.81	Medium sand with few gravel (SP)
PP-1-BB	1.02	4.82	Coarse sand with few gravel (SP)
PP-2-BC	4.59	4.96	Gravel with some course sand (GW)
PP-2-MB	1.41	4.29	Coarse sand with trace gravel (SP)
PP-2-BB	0.76	2.69	Well sorted medium sand (SP)
PP-3-BC	3.82	5.80	Course sand with some gravel (SW)
PP-3-MB	0.99	2.89	Well sorted coarse sand (SP)
PP-3-BB	0.44	2.13	Well sorted medium sand (SP)
PP-4-BC	3.65	6.67	Poorly sorted gravel with some sand (GW)
PP-4-MB	1.19	4.71	Coarse sand with trace gravel (SP)
PP-4-BB	0.55	2.32	Well sorted medium sand with trace gravel (SP)

Table 14: Mean grain size, uniformity coefficient and description of sediments at Pennoyer Park.

E. coli concentrations were higher in berm crest samples compared to samples from back beach locations at all transects [(PP-1: p=0.001) (PP-2: p=0.022) (PP-3: p=0.045) (PP-4: p=0.017)] (Table 15). At transect PP-1, higher *E. coli* concentrations were also associated with berm crest compared to middle beach sediment samples (p=0.016). *E. coli* concentrations did not vary by position across beach transects [berm crest sediments (p=0.110), middle beach sediments (p=0.1333) or back beach sediments (p=0.3707)].

Sediment Location		PP-1	PP-2	PP-3	PP-4
Berm Crest	*mean*	3.08	3.00	3.14	3.64
	σ	0.81	0.71	0.82	0.63
	n	14	14	14	14
Middle Beach	*mean*	2.37	2.64	2.90	3.13
	σ	0.51	0.89	0.88	1.10
	n	14	14	14	14
Back Beach	*mean*	2.14	2.20	2.36	2.60
	σ	0.56	0.60	0.72	1.01
	n	14	14	14	14

Table 15: Mean *E. coli* concentration in sediment samples collected at Pennoyer Park based upon transect and collection location. *E. coli* concentration represented as log *E. coli* CFU/100grams dry sediment.

Mean *E. coli* concentrations were greater in berm crest sediments, on a mass to mass basis, compared to adjacent water samples collected on the same date (assuming 100ml of water has a mass

of 100 grams) [(PP-1 water: n=14, mean=1.90, σ=0.68, p<0.001) (PP-2 Water: n=14, mean=1.70, σ=0.60, p<0.001) (PP-3 Water: n=14, mean=1.90, σ=0.65, p<0.001) (PP-4 Water: n=14, mean=2.01, σ=0.67, p<0.001)]. This same trend was apparent comparing middle beach sediment samples with adjacent water samples at all transects except PP-1 [(PP-1: p=0.367) (PP-2: p=0.027) (PP-3: p=0.008) (PP-4:p=0.008)]. *E. coli* concentrations did not differ comparing back beach sediments and adjacent water samples (all transects: p>0.05). Although higher *E. coli* concentrations were present in sediments than in adjacent water samples at many locations, *E. coli* concentrations in sediments did not correlate with *E. coli* concentrations in adjacent water samples at any location (p>0.05, any location, any transect).

Wildlife. Dogs, ducks, geese and gulls were observed on the beach, but the type and number varied by transect (Table 16). Dogs and ducks were observed infrequently and in low numbers at all locations. Approximately 200 geese were observed per transect between 2010 and 2012. Over 1,000 gulls were observed at transects PP-1 and PP-2 and more than 10,000 were noted at transects PP-3 and PP-4 over the course of the study. *E. coli* did not vary as a function of wildlife on the beach (p>0.05, any type, any transect).

Species	PP-1	PP-2	PP-3	PP-4
Dogs (#)	4	5	2	3
Dogs (days)	4	4	2	3
Ducks (#)	0	0	0	2
Ducks (days)	0	0	0	1
Geese (#)	217	253	247	198
Geese (n)	76	12	10	11
Gulls (#)	1,257	2,176	10,520	11,230
Gulls (days)	23	32	67	76

Table 16: Number and frequency of dogs, ducks, geese and gulls observed at Pennoyer Park based upon transect location (2010 -2012).

Algae. *Cladophora* submerged in the water was present in low, moderate and high amounts for 45.7 (n=270), 4.7 (n=28) and 0.2 (n=1) percent of samples collected respectively. It was absent from the beach for 49.4 (n=292) percent of samples collected. Amounts of algae submerged in the water were similar from location to location (Table 17). *E. coli* did not vary based upon the amount of submerged algae at transect PP-1 (p=0.964). At all other transects (PP-2, PP-3 and PP-4), higher *E. coli* concentrations were associated with moderate amounts of algae in the water compared to when algae was absent [(PP-2: p=0.039) (PP-3: p=0.009) (PP-4: p=0.003)]. Water quality exceedance rates of 33.3 (n=2), 55.6 (n=5) and 71.4 (n=5) percent were associated with moderate amounts of algae submerged in the water and rates of 12.0 (n=9), 13.7 (n=10) and 16.2 (n=12) percent were associated with algae absent from the water at transects PP-2, PP-3 and PP-4 respectively. On average, water samples were 3.8 times more likely to exceed water quality standards with moderate amounts of algae in the water compared to when it was absent at transects PP-2, PP-3 and PP-4.

Submerged Algae Amount		PP-1	PP-2	PP-3	PP-4
Absent	*mean*	1.71	1.55	1.57	1.56
	σ	0.69	0.71	0.72	0.79
	n	70	75	73	74
Low	*mean*	1.82	1.80	1.80	1.86
	σ	0.78	0.72	0.76	0.65
	n	72	67	65	66
Moderate	*mean*	2.37	2.32	2.36	2.59
	σ	0.60	0.84	0.84	0.71
	n	6	6	9	7
High	*mean*	----	----	----	2.48
	σ	----	----	----	----
	n	--	--	--	1

Table 17: Mean *E. coli* concentration at Pennoyer Park based upon transect location and the amount of algae submerged in the water. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Algae stranded ashore was present in low and moderate amounts for 46.4 (n=274) and 3.4 (n=20) percent of samples respectively; stranded algae was not noted in high amounts. This type of algae was absent from the shoreline for 50.3 percent (n=297) of samples. The amount of algae stranded on the beach was similar at each transect with the exception of more dates with moderate amounts of algae washed ashore at transect PP-1 (n=9) compared to the rest of the beach [(PP-2: n=3) (PP-3: n=3) (PP-4: n=5)] (Table 18). *E. coli* concentrations did not vary at transects PP-1 (p=0.213), PP-2 (n=0.1158) or PP-3 (p=0.7532) based upon the amount of algae stranded on the beach. At transect PP-4, higher *E. coli* concentrations were associated with moderate amounts of algae on the beach compared to when algae was absent (p=0.050). A water quality exceedance rate of 60 (n=3) percent was associated with moderate amounts of algae on the beach compared to 20 (n=15) percent without algae at transect PP-4.

Stranded Algae Amount		PP-1	PP-2	PP-3	PP-4
Absent	*mean*	1.70	1.57	1.70	1.65
	σ	0.73	0.63	0.71	0.75
	n	75	72	75	75
Low	*mean*	1.86	1.80	1.73	1.81
	σ	0.73	0.82	0.83	0.75
	n	64	73	69	68
Moderate	*mean*	2.08	2.07	2.03	2.49
	σ	0.87	0.55	0.65	0.75
	n	9	3	3	5
High	*mean*	----	----	----	----
	σ	----	----	----	----
	n	--	--	--	--

Table 18: Mean *E. coli* concentration at Pennoyer Park based upon transect location and the amount of algae stranded on the beach. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Air temperature. Mean air temperatures averaged 23.1 (n=43, σ=3.1), 22.0 (n=41, σ=4.6) and 24.7 ^{o}C (n=54, σ=4.6) in 2010, 2011 and 2012 respectively. There was a significant difference in air

temperatures between 2011 and 2012 (p=0.003). Difference in air temperatures may partially be explained by the time surveys were conducted; on average surveys were conducted at 0848 in 2011 and at 0922 in 2012. *E. coli* concentrations did not correlate with air temperature at transects PP-1 (n=148, r=-0.084, p=0.308), PP-2 (n=148, r=-0.156, p=0.058) or PP-3 (n=147, r=-0.124, p=0.136). At transect PP-4, there was a negative correlation between air temperature and *E. coli* concentration (n=148, r=-0.164, p=0.047). This correlation may be partially explained by differences in air temperatures based upon wind direction [(east wind: n=55, mean= 21.6 ^{o}C, σ=4.0) versus (west wind: n=95, mean=24.4 ^{o}C, σ=4.2) (p<0.001).

Water temperature. Water temperature at all transects correlated significantly (i.e. there was little to no variation in water temperature across the beach). Mean water temperatures averaged 16.1 ^{o}C in 2010 (n=43, σ=3.4), 17.9 ^{o}C in 2011(n=51, σ=3.3) and 19.1 ^{o}C in 2012 (n=54, σ=4.4). Mean water temperatures were significantly higher in 2012 compared to 2010 (p<0.001). *E. coli* concentrations positively correlated with water temperatures at all transects [(PP-1: n=148, r=0.244, p=0.003) (PP-2: n=148, r=0.213, p=0.009) (PP-3: n=147, p=0.284, p<0.001) (PP-4: n=148, r=0.315, p<0.001)]. Correlations between water temperatures and *E. coli* concentrations may be partially representative of differences in water temperatures based upon wind directions. Higher water temperatures were associated with eastern compared (n=55, mean=18.9 C^{o}, σ=3.9) to western winds (n=90, mean=17.3 C^{o}, σ=3.8) (p=0.016).

Precipitation. Precipitation events of 0.13 cm or more (considered a significant amount) occurred within the 24-hour period prior to sample collection 33 times during this study. Higher *E. coli* concentrations were associated with precipitation events at all transects (p<0.001 to p=0.001, Figure 20). Recreational water quality standards were exceeded 45.5 (n=15), 39.4 (n13), 42.4 (n=14) and 45.5

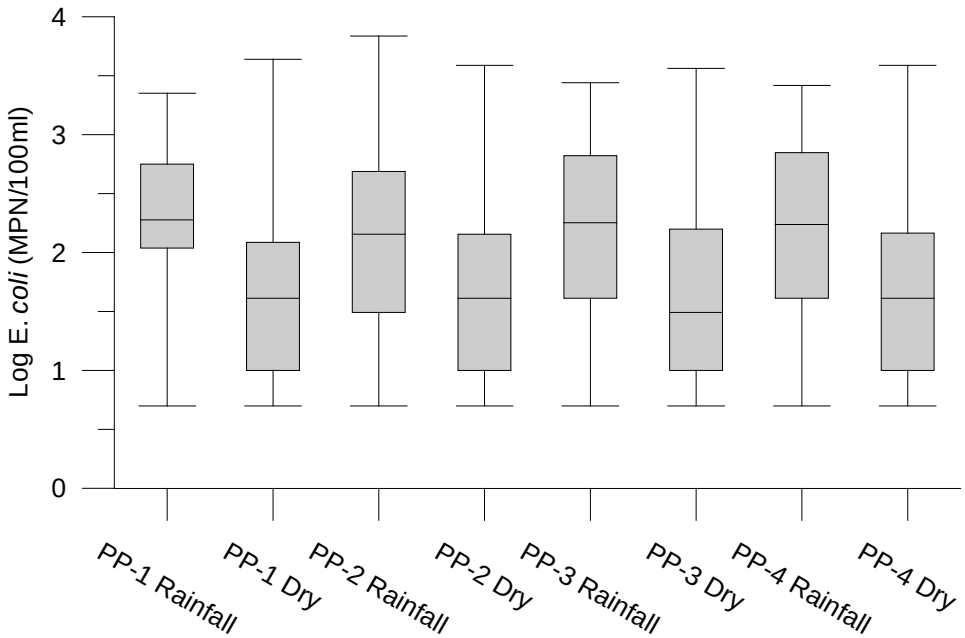

Figure 20: Mean *E. coli* concentration at each transect following precipitation (>0.13 cm prior to sample collection) and during dry weather.

(n=15) percent of the time following precipitation events at transects PP-1, PP-2, PP-3 and PP-4 respectively. Comparatively, 17.4 (n=20), 11.3 (n=13), 15.8 (n=18) and 17.4 (n=20) percent of samples exceeded water quality criteria when there was less than 0.13 cm of precipitation in the 24 hours preceding sample collection at the same transects. On average, water samples were 2.8 times more likely to exceed water quality criteria following precipitation compared to dry weather.

Wind speed and direction. Wind speeds and directions were broken down into components of velocity along the east/west and north/south axes. *E. coli* did not correspond to wind speed along the north/south axis at any transects [(PP-1: p=0.817) (PP-2: p=0.513) (PP-3: p=0.793) (PP-4: p=0.397)]. *E. coli* concentrations did correlate with wind speed along the east/west axis at all transects with higher *E. coli* concentrations associated with winds out of the east [(PP-1: n=145, r=0.273, p=0.001) (PP-2: n=144, r=0.332, p<0.001) (PP-3: n=144, r=0.366, p<0.001) (PP-4: n=145, r=0.383, p<0.001)]. Water quality exceedance rates of 29.1 (n=16), 27.3 (n=15), 36.4 (n=20) and 38.2 (n=21) percent were associated with winds out of the east and rates of 20.4 (n=19), 11.8 (n=11), 13.0 (n=12) and 15.1 (n=14) percent were associated with winds out of the west at transects PP-1, PP-2, PP-3 and PP-4 respectively. On average, samples were 2.2 times more likely to exceeded water quality criteria with east compared to west winds.

Current speed and direction. Current speeds and directions were broken down into components of velocity along the east/west and north/south axes. *E. coli* concentrations did not correlate with current velocity along the north/south axis [(PP-1: n=148, r=-0.071, p=0.39) (PP-2: n=148, r=-0.099, p=0.231) (PP-3: n=147, r=-0.075, p=0.365) (PP-4: n=148, r=-0.151, p=0.067)] or the east/west axis at any transect except for PP-4 [(PP-1: n=148, r=-0.07, p=0.401) (PP-2: n=148, r=-0.113, p=0.171) (PP-3: n=147, r=-0.117, p=0.16) (PP-4: n=148, r= -0.195, p=0.018)]. Higher *E. coli* concentrations at transect PP-4 were associated with western currents.

Wave height. Wave heights were available from two sources, field technician and GLCFS model estimates. GLCFS wave height estimates ranged from 0.027 meters to 2.446 meters with a median height of 0.275 meters. Field technician wave height estimates ranged from 0.03 to 1.52 meters with a median wave height of 0.15 meters. Field technician and GLCFS wave height estimates were significantly correlated with each other (n=148, r=0.723, p<0.001) and with *E. coli* concentrations at all transects (Table 19). Field technician wave height estimates were a better explanatory variable for *E. coli* at all transects compared to GLCFS model estimates. Water quality exceedance rates of 47.5 (n=28), 39.0 (n=23), 44.1 (n=26) and 45.8 (n=27) percent were associated with field technician wave heights greater than 0.15 meters; exceedance rates of 7.9 (n=7), 3.4 (n=3), 6.8 (n=6) and 9.0 (n=8) percent were associated with waves 0.15 meters or less at transects PP-1, PP-2, PP-3 and PP-4 respectively. On average, water samples were 6.5 times more likely to exceed water quality standards with wave heights greater than 0.15 meters compared to wave heights of 0.15 meters or less.

Wave Height Source:	PP-1	PP-2	PP-3	PP-4
GLCFS Model	n=148, r=0.369, p<0.001	n=148, r=0.393, p<0.001	n=147, r=0.363, p<0.001	n=148, r=0.339, p<0.001
Field Technician Estimates	n=148, r=0.529, p<0.001	n=148, r=0.553, p<0.001	n=147, r=0.488, p<0.001	n=148, r=0.495, p<0.001

Table 19: Correlation between *E. coli* concentration at Alford Park and wave heights estimates (field technician and the Great Lakes Coastal Forecasting System nowcast model estimates).

Water clarity. Water clarity was described as clear, slightly turbid, turbid, or opaque for each sample collected (Table 20). A similar number of samples at each transect were described as clear (54-59), slightly turbid (37-40), turbid (46-54) and opaque (n=3) per transect. There was a positive correlation between *E. coli* and ordinal turbidity values (e.g. clear=1, slightly turbid=2, turbid=3, opaque=4) at all transects (p>0.001 all transects). Higher *E. coli* concentrations were associated with more turbid waters. Ordinal water clarity descriptors were also positively associated with wave height (field technician estimates) at all transects (p<0.001).

Water Clarity		PP-1	PP-2	PP-3	PP-4
Clear	*mean*	1.30	1.17	1.32	1.39
	σ	0.53	0.49	0.64	0.70
	n	54	57	58	59
Slightly Turbid	*mean*	1.69	1.71	1.67	1.56
	σ	0.63	0.58	0.61	0.64
	n	37	37	37	40
Turbid	*mean*	2.33	2.25	2.22	2.34
	σ	0.63	0.66	0.73	0.56
	n	54	51	49	46
Opaque	*mean*	2.29	2.17	2.01	2.29
	σ	0.57	0.63	0.79	0.66
	n	3	3	3	3

Table 20: Mean *E. coli* concentration at Pennoyer Park based upon transect and water clarity. *E. coli* concentration represented as log *E. coli* MPN/100ml.

In 2012, analytical turbidity measurements were made in addition to visual estimates. Turbidity values ranged from 0.86 to 153 (median=7.02), 0.78 to 146 (median=5.96 NTU), 0.65 to 188 (median=4.89 NTU) and 0.51 to 187 NTU (median=4.90) at transects PP-1, PP-2, PP-3 and PP-4 respectively. Log transformed turbidity values were positively correlated with *E. coli* concentrations at all transects [(PP-1: n=54, r=0.605, p<0.001) (PP-2: n=54, r=0.646, p<0.001) (PP-3: n=54, r=0.543, p<0.001) (PP-4: n=54, r=0.569, p<0.001)]. Water quality exceedance rates of 25.9 (n=7), 25.9 (n=7), 29.6 (n=8) and 29.6 (n=8) percent were associated with greater than the median turbidity values and rates of 14.8 (n=4), 3.7 (n=1), 14.8 (n=4) and 14.8 (n=4) percent were associated with a median or lower turbidity value at transects PP-1, PP-2, PP-3 and PP-4 respectively. Water samples with a greater than median turbidity were 2.3 times more likely to exceed water quality standards than samples with lower turbidity. Log transformed turbidity values correlated with ordinal water clarity descriptors at all

transects indicating visual water clarity descriptions were accurate at describing turbidity ($p<0.001$, all transects).

Debris. Debris was often present on the beach; 146 out of 148 monitoring days. The amount of refuse was described as low for all days present. The types of debris observed included: food-related debris (n=142 days), street litter (n=91 days), household waste (n=28 days), clothing (n=6 days), sewage-related waste (n=5 days), fishing-related debris (n=4 days) and expended fireworks (n=1 day). Floatables, debris in the water, was observed on nine occasions and included household waste (n=5 days), food-related waste (n=3 days) and street litter (n=1 day).

Beach usage. The number of people at the beach averaged 1.7(n=43), 1.2 (n=51) and 2.0 (n=54) people per day in 2010, 2011 and 2012 respectively (of those, 0.3 (n=15), 0.2 (n=10) and 0.1 (n=3) people per day were observed in the water). The activities of 201 out of the 245 people observed at this beach were recorded and included people: walking (n=73), fishing (n=41), collecting beach glass (n=20), playing in the sand (n=15) playing with/walking pets (n=14), lounging (n=14), swimming (n=8), feeding wildlife (n=5), bird watching (n=4), taking photographs (n=4), camping (n=2), biking (n=1), kayaking (n=1) and kite surfing (n=1). Beach usage was observed on one weekend day (August 7th, 2010 at 1500), when the weather was sunny and 34 ^{o}C. On this day, 43 people were observed at Pennoyer Park, eight in the water (Figure 21). Beach usage at Pennoyer Park was low on monitored dates; this was most likely reflective of the time the surveys were conducted (0800 – 0900). Because of low usage, bathers were hypothesized to not be a significant source of bacterial contamination.

Figure 21: Individuals present at Pennoyer Park on August 7th 2010.

Simmons Island

Physical characteristics. Beach length, measured as the distance from the jetty supporting the mouth of the harbor to the shore armor on the north side of the beach was between 930.3 and 932.1 m in each of the years. The width of the beach increased from north (SI-1: 26.2 m) to south (SI-5: 94.8 m) (Figure 22) (Table 21). Slopes decreased from transect SI-1 (7.0%) to SI-5 (1.3%). The distance from the berm crest to a water depth of 1.2 meters was approximately 20 meters at transects SI-1, SI-2 and SI-3 and increased at transects SI-4 (27.7m) and SI-5 (44.5 m).

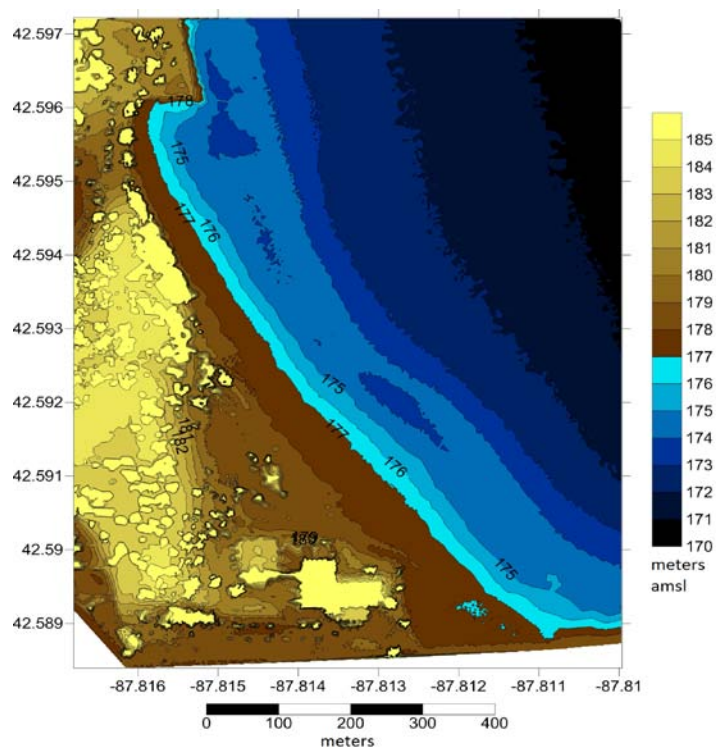

Figure 22: Digital elevation model of Simmons Island Beach (Data from USACE Great Lakes Topo/Bathy LiDAR Survey).

Simmons Island Park Beach BEACH DIMENSIONS					
Average	**SI-1**	**SI-2**	**SI-3**	**SI-4**	**SI-5**
Width (m)	26.2	39.2	53.9	85.6	94.8
Slope (%)	7.0	4.8	2.3	2.2	1.3
In-Water Measurements from Berm Crest to:					
0.3 m	5.3	3.6	4.1	5.8	5.3
0.6 m	7.7	13.5	11.1	14.5	14.4
0.9 m	10.2	19.1	16.7	23.6	31.8
1.2 m	18.9	22.8	21.7	27.7	44.5

Table 21: Average dimensions of Simmons Island over the study period.

Water quality – routine monitoring. A total of 674 routine water samples were collected from Simmons Island Beach over the course of this study (Table 22). Water samples were not collected at transect SI-2 in 2011 because mean *E. coli* concentrations at this transect were not significantly different compared to transect SI-1 in 2010; samples were collected at this location again in 2012 to provide a more robust data set. Mean *E. coli* concentrations did not differ significantly based upon the year samples were collected (p=0.1181), but differed based upon transect location. *E. coli* concentrations were higher at transects SI-4 and SI-5 compared to transects SI-1 and SI-2 [(SI-1 vs. SI-4; p<0.001) (SI-1 vs. SI-5; p<0.001) (SI-2 vs. SI-4; p=0.023) (SI-2 vs. SI-4; p=0.022) (Figure 22). The percentage of samples that exceeded recreational water quality criteria was 9.0 (n=13), 11.7 (n=11, 2010 and 2012 only), 15.2 (n=22), 22.1 (n=32) and 23.4 (n=34) at transects SI-1, SI-2, SI-3, SI-4 and SI-5 respectively. Water samples exceeded standards 2.3 times more often at transects SI-4 and SI-5 compared to transects SI-1 and SI-2.

Year		SI-1	SI-2	SI-3	SI-4	SI-5	All
2010	*mean*	1.45	1.51	1.73	1.97	1.87	1.71
	σ	0.54	0.60	0.60	0.61	0.73	0.64
	n	42	42	42	42	42	210
2011	*mean*	1.34	----	1.51	1.70	1.80	1.59
	σ	0.61	----	0.70	0.70	0.83	0.73
	n	51	--	51	51	51	204
2012	*mean*	1.56	1.57	1.78	1.83	1.81	1.71
	σ	0.73	0.74	0.73	0.65	0.69	0.71
	n	52	52	52	52	52	260
All	*mean*	1.45	1.55	1.67	1.82	1.82	1.67
	σ	0.64	0.68	0.69	0.66	0.66	0.70
	n	145	94	145	145	145	674

Table 22: Mean *E. coli* concentration per transect at Simmons Island. *E. coli* concentrations expressed as log mean *E. coli* (MPN/100ml).

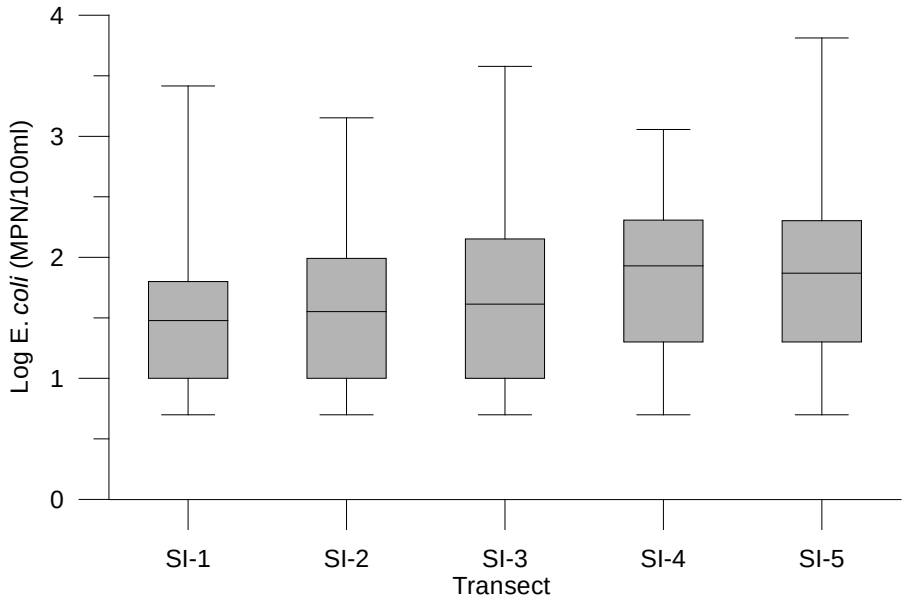

Figure 22: Mean *E. coli* concentration per transect (2010-2012) at Simmons Island.

Water quality – multi-depth samples. Water samples were collected where water depths first reached 0.3, 0.6, 0.9 and 1.2 meters on 27 dates between 2010 (n=7 events), 2011 (n=8 events) and 2012 (n=12 events). *E. coli* concentrations did not differ based upon the depth samples were collected at transects SI-1 (n=108, r=-0.079, p=0.419) and SI-3 (n=108, r=-0.168, p=0.083). However, there was a trend of decreasing bacteria associated with increased sample depth at transects SI-2 (n=76, r=-0.250, p=0.029), SI-4 (n=108, r=-0.236, p=0.014) and SI-5 (n=108, r=-0.263, p=0.006) (Figure 23).

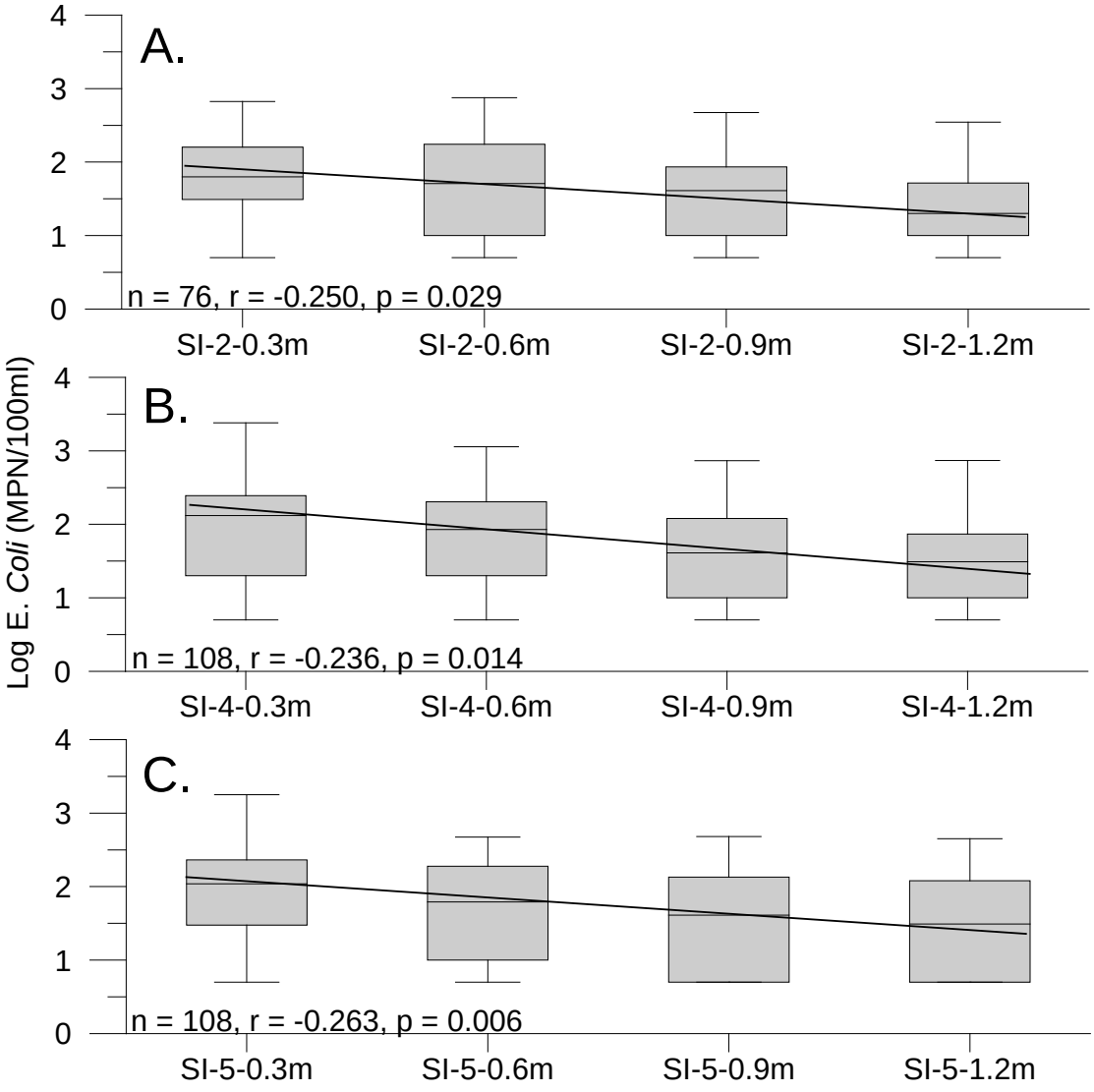

Figure 23: Effect of sample depth on *E. coli* concentration at transects SI-2 (A), SI-4 (B) and SI-5 (C).

Water quality – Pike River (See Pike River, Page 25). *E. coli* concentrations in water samples from the Pike River were significantly higher than in samples collected at any transect of Simmons Island (p<0.001 all transects). The median *E. coli* concentration in the Pike River was 133 MPN/100ml. When *E. coli* concentrations exceeded the median level in Pike River effluent, there was a significantly higher amount of *E. coli* present at transect SI-1 [(>133 MPN/100ml: n=71, mean=1.56, σ=0.66) (≤133

MPN/100ml: n=73, mean=1.35, σ=0.61) (p=0.047); this trend was not present at other transects [(SI-2: p=0.113) (SI-3: p=0.820) (SI-4: p=0.345) (SI-5: p=0.280)]. Water quality exceeded standards 11.2 (n=8) percent of the time when *E. coli* level in the Pike River were above the median level. Comparatively, the exceedance rate was 6.8 (n=5) percent at transect SI-1 when there was equal or less than the median amount of *E. coli*.

In addition to the Pike River having a higher *E. coli* concentration than water samples collected at Simmons Island, it also had significantly higher specific conductivity values [(Pike River: n=99, mean=703 µS, σ=140) versus (Simmons Island: n=102, mean=304µS, σ=11) (p<0.001)]. Specific conductivity values at Simmons Island did not differ at any transect based upon alongshore current direction [(SI-1: p=0.775) (SI-2: p=0.286) (SI-3: p=0.439) (SI-4: p=0.698) (SI-5: p=0.603)].

Water quality - 40th and 43rd Street Outfalls. Please refer to page 40 for the results of water quality data from these stormwater outfalls as they pertain to coastal water quality.

Water quality – Kenosha Harbor. Eleven stormwater outfalls discharge directly into the Kenosha Harbor. Additional stormwater outfalls (n=18) discharge into the Pike Creek which flows underground and into the harbor. Water samples were collected from the harbor on 41 occasions throughout this study. Twenty (51.2%) of the samples collected from the harbor had *E. coli* concentrations below the detection limit (<10 MPN/100ml) and only four samples (9.8%) had concentrations in excess of 235 MPN/100ml. Higher *E. coli* concentrations in the harbor were correlated with precipitation events of greater than 0.13 cm (p=0.013) [(rain events: n=10, mean=1.95, σ=0.94) vs. non-precipitation events (n=31, mean=1.02, σ=0.49)].

Mixing between water from the harbor and Simmons Island beach would most likely occur at transect SI-5 due to its close proximity. During dry weather, *E. coli* concentrations in the harbor were significantly lower than concentrations at transect SI-5 (n=31, mean=1.77, σ=0.84). Following precipitation events, when *E. coli* concentrations were higher in the harbor, concentrations in the harbor and at transect SI-5 did not differ (n=10, mean=2.20, σ=0.81) (p=0.536). *E. coli* concentrations were lower in the harbor than at transect SI-5 for all dates with recreational water quality exceedances when samples were collected from the harbor and transect SI-5 jointly.

Sediments. Sediment samples from the berm crest, middle beach and back beach were collected for grain size and uniformity distribution at Simmons Island on seven dates in 2010. These samples were composited and analyzed to determine dominant particle size and sorting (See Methods Section, Page 22). Sediments were described as well sorted sands at all locations. Sands from the berm crest had a slightly larger mean grain size at northern transects (SI-1 and SI-2) compared to southern transects (SI-3, SI-4 and SI-5) (Table 23). Samples from the berm crest contained less than 0.1 percent particles representative of silts and clays on a mass basis at all locations except transect SI-1 (0.175%). The mean grain size of sediments from middle and back beach locations did not differ based upon transect (mean grain size = 0.29 – 0.34 mm). Uniformity coefficients were less than four for all samples (i.e. well sorted).

Location	Mean Grain Size (mm)	Uniformity Coefficient	Description
SI-1-BC	0.40	1.83	Well sorted fine grain sand (SP)
SI-1-MB	0.32	1.97	Well sorted fine grain sand (SP)
SI-1-BB	0.34	1.64	Well sorted fine grain sand (SP)
SI-2-BC	0.48	1.87	Well sorted fine grain sand (SP)
SI-2-MB	0.32	1.59	Well sorted fine grain sand (SP)
SI-2-BB	0.32	1.64	Well sorted fine grain sand (SP)
SI-3-BC	0.34	1.73	Well sorted fine grain sand (SP)
SI-3-MB	0.32	1.59	Well sorted fine grain sand (SP)
SI-3-BB	0.32	1.59	Well sorted fine grain sand (SP)
SI-4-BC	0.33	1.76	Well sorted fine grain sand (SP)
SI-4-MB	0.32	1.59	Well sorted fine grain sand (SP)
SI-4-BB	0.31	1.67	Well sorted fine grain sand (SP)
SI-5-BC	0.30	1.89	Well sorted fine grain sand (SP)
SI-5-MB	0.31	1.70	Well sorted fine grain sand (SP)
SI-5-BB	0.29	1.94	Well sorted fine grain sand (SP)

Table 23: Mean grain size and uniformity coefficient of sediments at Simmons Island.

E. coli concentrations were enumerated in sediments collected from the berm crest, middle beach and back beach at each transect in all years (Table 24). Submerged sediment samples, at a depth of 0.3 m, were collected in 2012 only. *E. coli* concentrations were significantly higher in sediments from the berm crest compared to those from the back beach at transects SI-1 ($p=0.035$) and SI-2 ($p=0.045$). Mean *E. coli* concentrations in sediments did not differ at transect SI-3 based upon sampling location ($p=0.0789$). Higher *E. coli* concentrations were associated with sediments from the berm crest ($p=0.015$), middle beach ($p=0.050$) and back beach ($p=0.035$) compared to submerged sediments at transect SI-4. At transect SI-5, higher *E. coli* concentrations were noted in sediments collected at the berm crest compared to submerged ($p=0.040$) and back beach sediments ($p=0.050$).

Location		SI-1	SI-2	SI-3	SI-4	SI-5
0.3m Submerged	*mean*	2.42	2.40	2.15	2.21	2.48
	σ	0.50	0.42	0.50	0.32	0.43
	n	7	7	7	7	7
Berm Crest	*mean*	2.58	2.68	3.15	3.19	3.66
	σ	0.60	0.67	0.63	0.48	0.95
	n	29	18	29	29	29
Middle Beach	*mean*	2.20	2.53	3.13	3.12	3.62
	σ	0.71	0.73	1.26	1.01	1.23
	n	17	14	17	17	17
Back Beach	*mean*	2.06	2.05	2.98	3.16	2.83
	σ	0.47	0.57	1.04	0.92	0.97
	n	17	14	17	17	17

Table 24: Sediment *E. coli* concentration based upon transect and sediment collection location. *E. coli* concentrations expressed in log CFU/100g dry weight sediment.

E. coli concentrations in submerged sediments did not differ based upon transect location (p=0.5722). Berm crest *E. coli* concentrations were significantly higher at transects SI-3 (p=0.018), SI-4 (p=0.008) and SI-5 (p<0.001), compared to sediments collected from the same location at transect SI-1. In addition, higher *E. coli* concentrations were also associated with sediments from the berm crest at transect SI-5 compared those at transect SI-2 (p<0.002). At middle beach sampling locations, higher *E. coli* concentrations were associated with sediments from transect SI-5 compared to sediments from transects SI-1 (p=0.001) and SI-2 (p=0.044). At back beach locations, *E. coli* concentrations in sediments were higher at transects SI-3 and SI-4 compared to sediments from transects SI-1 [(SI-1 vs SI-3: p=0.019) (SI-1 vs SI-4: p=0.002)] and SI-2 [(SI-2 vs SI-3: p=0.026) (SI-2 vs. SI-4: p=0.004)].

Mean *E. coli* concentrations were greater in berm crest sediments on a mass to mass basis (assuming 100ml of water weighs 100 grams) compared to adjacent water samples at all transects (p<0.001 all transects). This same trend was also apparent when comparing middle beach sediment samples to water samples at all transects [(SI-1, p=0.032) (SI-2, p=0.005), (SI-3, p<0.001), (SI-4, p<0.001), (SI-5, p<0.001)]. At transects SI-3, SI-4 and SI-5, higher *E. coli* concentrations were associated with back beach sediments compared to adjacent surface water samples [(SI-1, p=0.244), (SI-2, p=0.127), (SI-3, p<0.001), (SI-4, p<0.001), (SI-5, p<0.001)].

E. coli concentrations in berm crest sediments and in adjacent surface water samples correlated positively and significantly at transects SI-1 (n=29, r=0.56, p=0.002), SI-3 (n=29, r=0.518, p=0.004) and SI-4 (n=29, r=0.476, p=0.009). *E. coli* concentrations in back beach sediments and water samples correlated at transect SI-2 (n=14, r=0.594, p=0.025). *E. coli* concentrations in surface water samples and submerged sediments correlated at transect SI-3 (n=7, r=0.892, p=0.007).

Wildlife. Dogs, ducks, geese and gulls were noted at Simmons Island; the type and number observed varied by transect (Table 25). Compared to other types of wildlife, gulls were observed most frequently and in the greatest number. The majority of gulls were observed at southern transects (SI-3, SI-4 and SI-5); relatively few were observed at northern transects (SI-1, SI-2). The median number of gulls observed per day was zero for transects SI-1 through SI-4 and 80 for transect SI-5.

Type of Wildlife	SI-1	SI-2	SI-3	SI-4	SI-5
Dogs (#)	34	15	34	16	24
Dogs (days)	19	12	18	11	11
Ducks (#)	0	14	5	2	20
Ducks (days)	0	2	1	1	1
Geese (#)	34	13	22	31	135
Geese (days)	2	1	2	3	10
Gulls (#)	122	155	4,923	8,457	24,742
Gulls (days)	13	7	57	70	119

Table 25: The number of animals and the number times animals were observed per transect, Simmons Island beach (2010 - 2012).

E. coli concentrations did not vary at any transect (p>0.05) based upon the presence of dogs, ducks or geese. Additionally, *E. coli* did not vary at transects SI-1 (p=0.613), SI-2 (p=0.603) and SI-3 (p=0.174) based upon the presence of gulls (Figure 24). At transects SI-4 and SI-5, higher *E. coli* concentrations were associated with a greater than median number of gulls on the beach [(SI-4 with gulls: n=70, mean=1.97, σ=0.63) vs. (SI-4 without gulls: n=75, mean=1.69, σ=0.67) (p=0.001)] [(SI-5 >80 gulls: n=71, mean=2.04, σ=0.76) vs. (SI-5 ≤ 80 gulls: n=74, mean=1.62, σ=0.76) (p<0.001)] (Figure 24). With greater than the median number of gulls at transects SI-4 and SI-5, 31.1 (n=20) and 28.6 (n=23) percent of surface water samples exceeded recreational water quality standards respectively. Comparatively, 16.0 (n=12) and 15.5 (n=11) percent of samples exceeded recreational water quality standards when lesser amounts of gulls were observed at the same locations. On average, surface water samples exceeded recreational water quality criteria 1.9 times more frequently when more than 80 gulls were noted on the beach at transects SI-4 and SI-5.

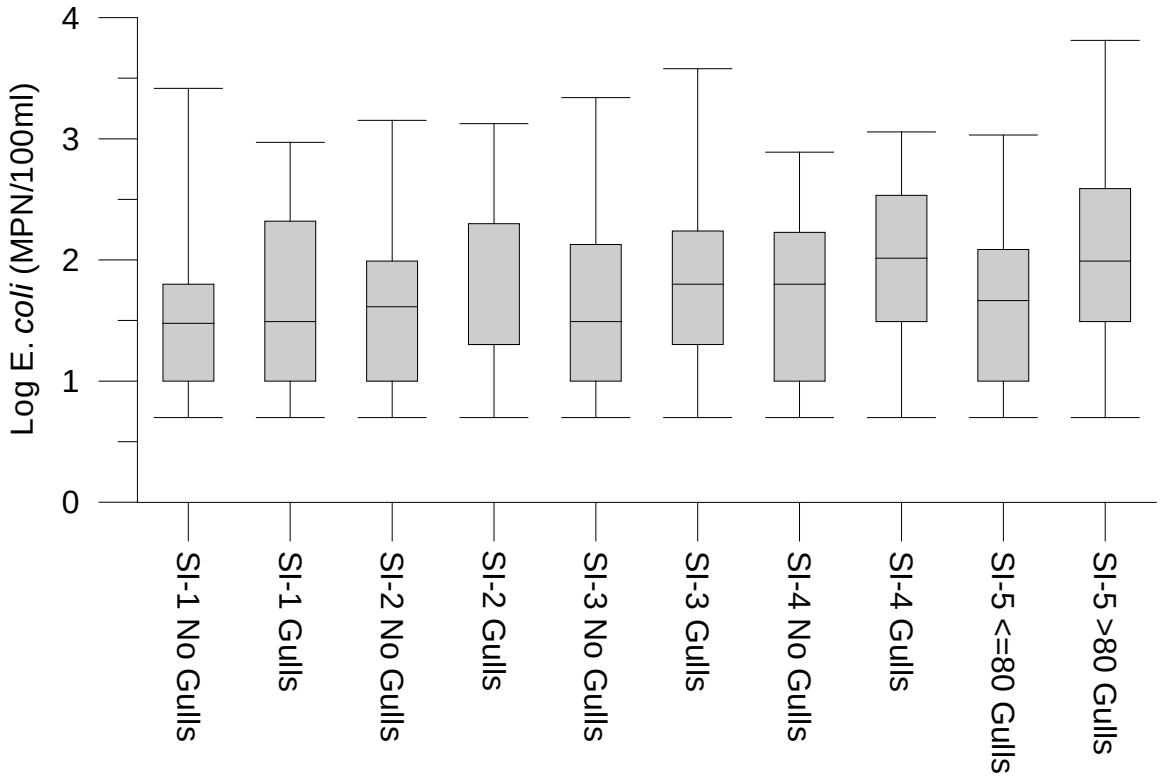

Figure 24: Influence of gulls on *E. coli* concentrations at Simmons Island.

Algae. Algal biomass (*Cladophora*), submerged in the water, was present in low, moderate and high amounts for 55.9 (n=377), 3.4 (n=23) and 1.3 (n=9) percent of sampling days respectively (Table 26). It was absent from the beach for 39.3 percent of samples (n=265). *E. coli* concentrations did not differ at any transect based upon the amount of submerged algae in the water [(SI-1: p=0.4562) (SI-2: p=0.099) (SI-3: p=0.4501) (SI-4: p=0.3460) (SI-5: p=4269)].

Submerged Algae Amount		SI-1	SI-2	SI-3	SI-4	SI-5
Absent	*mean*	1.42	1.52	1.77	1.91	1.70
	σ	0.62	0.60	0.65	0.69	0.64
	n	61	32	58	58	56
Low	*mean*	1.44	1.51	1.61	1.74	1.91
	σ	0.64	0.70	0.71	0.64	0.80
	n	77	56	82	81	81
Moderate	*mean*	1.90	2.25	1.72	2.16	1.90
	σ	0.90	0.54	1.00	0.21	0.78
	n	5	5	3	4	6
High	*mean*	1.55	1.00	1.25	2.03	1.60
	σ	0.08	---	0.35	1.03	1.27
	n	2	1	2	2	2

Table 26: Affect of submerged *Cladophora* on *E. coli* concentration. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Algae stranded ashore was present in low, moderate and high amounts for 50.0 (n=337), 4.2 (n=28) and 1.3 (n=9) percent of sampling days respectively. Stranded algae was absent from the beach for 44.5 (n=300) percent of samples. The amount of stranded *Cladophora* on the beach was similar at all transects (Table 27). *E. coli* concentrations did not differ based upon the amount of *Cladophora* on the beach at any transect [(SI-1: p=0.1228) (SI-2: p=0.8152) (SI-3: p=0.6255) (SI-4: p=0.9773) (SI-5: p=0.1786)].

Stranded Algal Amount		SI-1	SI-2	SI-3	SI-4	SI-5
Absent	*mean*	1.32	1.51	1.59	1.83	1.78
	σ	0.59	0.65	0.73	0.70	0.73
	n	69	34	62	67	68
Low	*mean*	1.56	1.55	1.73	1.83	1.86
	σ	0.67	0.69	0.66	0.65	0.76
	n	71	55	75	70	66
Moderate	*mean*	1.79	1.72	1.84	1.82	1.61
	σ	0.82	0.80	0.79	0.33	0.78
	n	4	5	5	6	8
High	*mean*	1.49	----	1.53	1.62	2.68
	σ	----	----	0.07	0.45	0.54
	n	1	--	3	2	3

Table 27: Affect of stranded *Cladophora* on *E. coli* concentration. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Air temperature. Air temperatures averaged 23.9 ^{o}C in 2010 (n=42, σ=3.1), 23.6 ^{o}C in 2011 (n=51, σ=5.4) and 25.2 ^{o}C in 2012 (n=52, σ=4.7). Air temperatures did not differ significantly between years (p=0.1705). *E. coli* concentrations did not correlate with air temperatures at any transect [(SI-1, p=0.213) (SI-2, p=0.727) (SI-3, p=0.334) (SI-4, p=0.458) (SI-5, p=0.214)].

Water temperature. Water temperatures were correlated positively and significantly across all transects (e.g. little variation in water temperature across the beach) (p<0.001). Water temperatures

averaged 16.7 (n=41, σ=3.1), 17.8 (n=51, σ=3.4) and 19.5 ^{o}C (n=52, σ=4.3) in 2010, 2011 and 2012 respectively. Water temperatures were significantly higher in 2012 compared to 2010 (p=0.001). *E. coli* concentrations were positively correlated with water temperatures at transects SI-1 (n=144, r=0.235, p=0.005), SI-3 (n=144, r=0.254, p=0.002) and SI-4 (n=144, r=0.241, p=0.004), but did not correlate at transects SI-2 (n=93, r=0.171, p=0.100) and SI-5 (n=144, r=0.086, p=0.305). Higher water temperatures were associated with east (n=55, mean=19.1 C^{o}, σ=3.8) compared to west winds (n=88, mean= 17.5 C^{o}, σ=3.7) (p=0.014), which may partially explain the correlation between water temperature and *E. coli*.

Precipitation. Precipitation events greater than 0.13 cm (considered a significant amount) occurred within the 24-hour period prior to sample collection on 26 days over the course of this study. Higher *E. coli* concentrations were associated with precipitation events at transects SI-1, SI-2 and SI-3, but not at transects SI-4 and SI-5 (Figure 25) [(SI-1; p<0.001) (SI-2; p=0.002) (SI-3; p=0.003) (SI-4; p=0.059) (SI-5; p=0.066)]. The percentage of samples exceeding water quality standards was 19.2 (n=5), 21.4 (n=3) and 23.1 (n=6) following precipitation events and 6.8 (n=8), 10.3 (n=8) and 12.8 (n=15) percent during dry weather at transects SI-1, SI-2 and SI-3 respectively. A 2.8, 2.1 and 1.8 times higher exceedance rate was associated with precipitation events compared to dry weather at transects SI-1, SI-2 and SI-3 respectively.

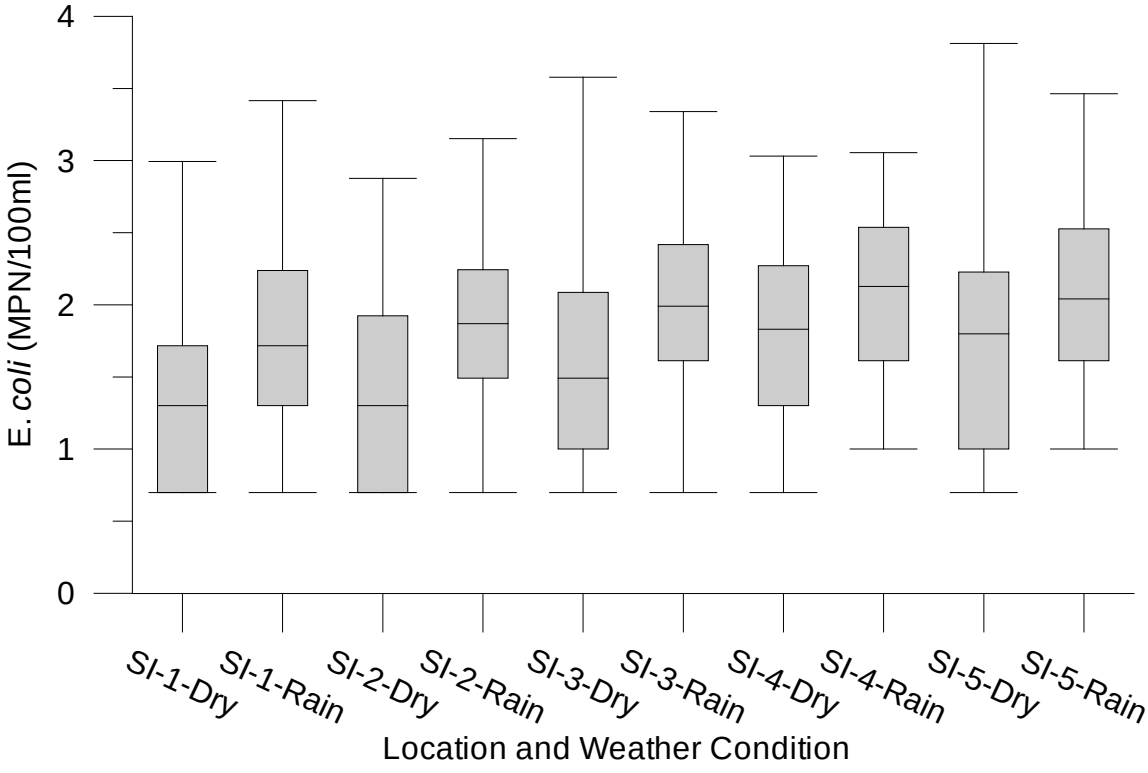

Figure 25: Affect of precipitation (<24 hours) on water quality.

Wind speed and direction. Wind speeds and directions were broken down into components of velocity along the east/west and north/south axes. A significant correlation was present between wind velocity along the east/west axis and surface water *E. coli* concentrations, with higher *E. coli* densities associated with eastern winds at all transects [(SI-1: n=144, r=0.336, p<0.001) (SI-2: n=93, r=0.298,

p=0.004) (SI-3: n=144, r=0.203, p=0.015) (SI-4: n=144, r=0.178, p=0.033) (SI-5: n=144, r=0.186, p=0.026)]. Exceedance rates of 16.4 (n=9), 17.2 (n=5), 18.2 (n=10), 25.5 (n=14) and 30.9 (n=17) percent were associated with east winds; exceedance rates of 4.5 (n=4), 9.4 (n=6), 13.5 (n=12), 19.1 (n=17) and 19.1 (n=17) percent were associated with west winds at transects SI-1, SI-2, SI-3, SI-4 and SI-5 respectively.

A significant correlation was present at all transects, except SI-4 (n=144, r=0.040, p=0.317), between the wind velocity along the north/south axis and *E. coli* concentrations. Higher *E. coli* concentrations were associated with winds out of the south at transects SI-1 through SI-3 [(SI-1: n=144, r=-0.256, p=0.002)(SI-2: n=93, r=-0.205, p=0.049)(SI-3: n=144, r=-0.165, p=0.048)]. Greater *E. coli* concentrations were associated with winds out of the north at transect SI- 5 [(SI-5: n=144, r=0.248, p=0.003)]. The percentage of samples exceeding recreational water quality standards was 11.8 (n=9), 13.5 (n=7) and 19.7 (n=15) with winds out of the south versus 5.9 (n=4), 9.8 (n=4) and 10.3 (n=7) percent with winds out of the north at transects SI-1, SI-2 and SI-3 respectively. At transect SI-5, 32.4 (n=22) and 15.8 (n=12) percent of samples exceeded water quality with winds out of the north and south respectively.

Current speed and direction. Current speeds and directions were broken down into components of velocity parallel and perpendicular to the beach face. A significant correlation was present at transect SI-1 (n=145, r=0.199, p=0.016) and SI-2 (n=94, r=0.232, p=0.024) between current velocity perpendicular to the beach with higher *E. coli* concentrations associated with currents directed away from the beach. There were no significant correlations between *E. coli* and current velocity perpendicular to the beach face at transects SI-3 (n=145, r=0.093, p=0.265) and SI-4 (n=145, r=-0.003, p=0.973). Higher *E. coli* concentrations at transect SI-5 were associated with currents directed into the beach (n=145, r=-0.218, p=0.008).

Higher *E. coli* concentrations at transects SI-1 (n=145, r=0.263, p=0.001), SI-2 (r=94, n=0.294, p=0.004) and SI-3 (n=145, r=0.178, p=0.032) were also associated with currents parallel to the beach, with higher FIB concentrations seen with currents travelling in a northern direction. *E. coli* concentrations were not associated with currents parallel to the beach at transect SI-4 (n=145, r=0.024, p=0.733). At transect SI-5, *E. coli* concentrations were associated with the velocity of the current parallel to beach, but when currents were travelling in a southern direction (n=145, r=-0.177, p=0.033).

Wave height. Wave height measurements were available from two sources, field technician and GLCFS model estimates. Field technician wave height estimates ranged from 0 to 1.83 meters (median=0.15 meters); GLCFS model estimates ranged from 0.02 to 1.79 meters (median =0.27 meters). Field technician wave height estimates and model results were significantly correlated (n=145, r=0.615, p<0.001). *E. coli* concentrations correlated with both field technician and GLCFS model wave height estimates at all transects except SI-5 (Table 28). However, GLCFS wave height estimates were a better explanatory variable for *E. coli* at transects SI-1, SI-2 and SI-3 and field technician estimates were a better explanatory variable at transect SI-4. More recreational water quality exceedances and a larger exceedance percentage was associated with waves larger than 0.27 m, based on GLCFS model estimates for transects SI-1, SI-2 , SI-3 and SI-4 [(SI-1: n=12; 16.7% vs. n=1; 1.4%) (SI-2: n=8; 16.3% vs. n=3; 6.7%) (SI-3: n=16; 22.2% vs. n=6; 8.2%) (SI-4: n=21; 29.2% vs. n=11; 15.1%)]. Recreational water quality

samples exceeded standards 12.2, 2.4, 2.7 and 1.9 times more frequently when greater than 0.27 m waves were noted at the beach at transects SI-1, SI-2, SI-3 and SI-4 respectively.

Wave height source	SI-1	SI-2	SI-3	SI-4	SI-5
GLCFS model	n=145 r=0.517 p<0.001	n=94 r=0.448 p<0.001	n=145 r=0.333 p<0.001	n=145 r=0.262 p=0.001	n=145 r=0.065 p=0.436
Field Estimates	n=145 r=0.418 p<0.001	n=94 r=0.332 p=0.001	n=145 r=0.332 p<0.001	n=145 r=0.279 p=0.001	n=145 r=0.027 p=0.743

Table 28: Correlation between wave height and *E. coli* concentration at Simmons Island beach.

Water clarity. Water clarity descriptors were assigned ordinal values (e.g. clear=1, slightly turbid=2, turbid=3, opaque=4). There was a positive correlation between ordinal water clarity descriptors and *E. coli* concentrations at all transects [(SI-1: p<0.001), (SI-2: p<0.001), (SI-3, p=0.011), (SI-4, p=0.004), (SI-5, p=0.009)]. Higher *E. coli* concentrations were associated with turbid waters (Table 29). GLCFS wave height estimates correlated with ordinal turbidity descriptors as each transect (p<0.001).

Water Clarity		SI-1	SI-2	SI-3	SI-4	SI-5
Clear	*mean*	1.17	1.32	1.54	1.69	1.66
	σ	0.49	0.60	0.71	0.69	0.70
	n	74	49	73	76	84
Slightly Turbid	*mean*	1.50	1.68	1.67	1.86	1.96
	σ	0.62	0.71	0.63	0.65	0.72
	n	35	28	35	34	32
Turbid	*mean*	1.99	1.97	1.94	2.10	2.31
	σ	0.60	0.58	0.62	0.54	0.71
	n	30	17	32	30	24
Opaque	*mean*	1.93	----	1.79	2.00	1.34
	σ	0.61	----	0.89	0.40	0.83
	n	6	--	5	5	5

Table 29: Affect of water clarity on *E. coli* concentration. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Debris. Litter was observed on the beach for 90.3 (n=131) percent of sampling days. Debris was present in low amounts for 87.6 percent (n=127) of days, present in moderate amounts for 2.8 percent of days (n=4) and absent from the beach face on 6.9 (n=10) percent of days. The type of debris on the beach was described as: food-related (n=131 days), street litter (n=99 days), house hold waste (n=38 days), sewage-related (n=8 days), fishing-related (n=2 days), building material (n=2 days) and medical-related (n=1 day). Floatables (debris in the water) were observed on 35.9 (n=52) percent of days. The types of floatables observed included food-related waste (n=36 days), household waste (n=21 days), street litter (n=8 days), sewage-related (n=3 days), clothing (n=2 days) and building materials (n=1 days). The most likely source of litter in the water and on the beach was beach patrons. Although there was easy access to waste bins across the beach, they were not utilized to their full potential. In other instances, for example the 4th of July weekend, there was no room in waste bins on the beach; they

were full. In some cases, it appeared that strong winds may have blown over the waste cans, depositing trash across the beach and into the water.

Beach usage. The number of people at the beach averaged 10.1 (n=425), 11.4 (n=580) and 16.9 (n=879) people per day in 2010, 2011 and 2012 respectively. Of the people at the beach, 2.1 (n=90), 1.5 (n=74), and 3.4 (n=177) people per day were in the water. One warm weather (34 °C) weekend observation was made (August 7th, 2010 @ 1530). On that day there were 110 people at the beach (25 observed in the water) (Figure 26). The activities of the 1,416 people observed at Simmons Island beach in 2011 and 2012 were recorded and included: walking (n=408), playing in the sand (n=335), lounging (n=218), swimming (n=194), exercising (n=109), walking their dog (n=61), wading (n=56), collecting beach glass (n=29), bird watching (n=2), taking photographs (n=1), metal detecting (n=1), flying a kite (n=1) and kayaking (n=1).

Figure 26: Individuals at Simmons Island Park Beach on August 7th 2010.

Eichelman Park Beach

Physical characteristics. Beach length, measured from the breakwater on the east side of the beach to the shore armor on the west side of the beach, ranged from 207.6 to 222.6 meters. The width of the beach decreased from east to west, from transect EM-1 (68.1 m) to EM-3 (50.3 m) (Figure 27) (Table 30). The slope of the beach also decreased from transect EM-1 (2.7%) to EM-3 (2.1%). The distance from the berm crest to a water depth of 1.2 meters ranged between 37.1 (EM-2) and 47.8 meters (EM-1).

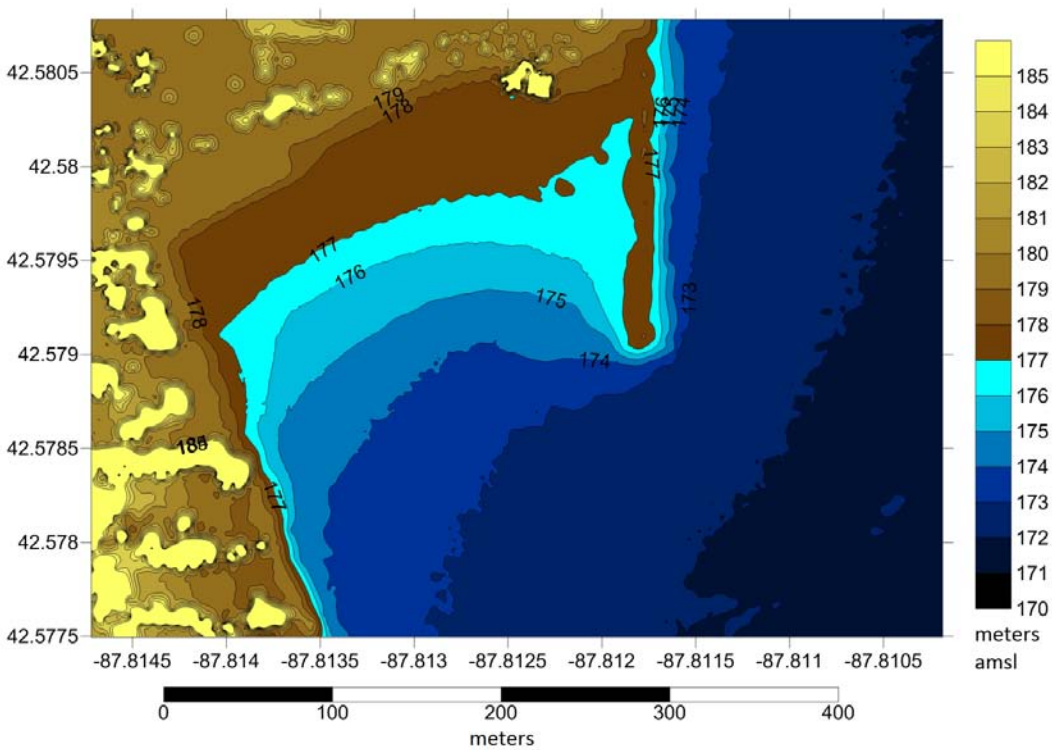

Figure 27: Digital elevation model of Eichelman Park Data from USACE (Great Lakes Topo/Bathy LiDAR Survey).

Eichelman Park Beach BEACH DIMENSIONS			
Average	**EM-1**	**EM-2**	**EM-3**
Width (m)	68.1	62.3	50.3
Slope (%)	2.7	2.5	2.1
In-Water Measurements from Berm Crest to:			
0.3 m	2.7	2.5	2.1
0.6 m	17.9	13.2	13.2
0.9 m	36.7	26.7	24.4
1.2 m	47.8	37.1	41.7

Table 30: Average dimensions of Eichelman Park over the 3-year study period, 2010 - 2012.

Water quality – routine monitoring. A total of 432 routine surface water samples were collected from three transects at Eichelman Park Beach over the course of this study (Table 31). Mean *E. coli* concentrations did not differ based upon year of sample collection (p=0.1539), but did so based upon transect location. Higher *E. coli* concentrations were associated with transects EM-1 (p<0.001) and EM-2 (p<0.001) compared to transect EM-3 (Figure 28). At transects EM-1, EM-2 and EM-3, 44.8 (n=65), 36.4 (n=52) and 21.5 (n=31) percent of surface water samples exceeded recreational water standards respectively. Transects EM-1 and EM-2 were closest to the breakwater.

Year		EM-1	EM-2	EM-3	All
2010	*mean*	2.39	2.14	1.82	2.12
	σ	0.71	0.77	0.75	0.77
	n	42	40	41	123
2011	*mean*	2.26	2.12	1.77	2.05
	σ	0.85	0.75	0.83	0.83
	n	51	51	51	153
2012	*mean*	2.16	2.00	1.65	1.94
	σ	0.75	0.73	0.80	0.79
	n	52	52	52	156
All	*mean*	2.26	2.08	1.74	2.03
	σ	0.77	0.75	0.79	0.80
	n	145	143	144	432

Table 31: Mean *E. coli* concentration at Eichelman Park based upon transect and water clarity. *E. coli* concentration represented as log *E. coli* MPN/100ml.

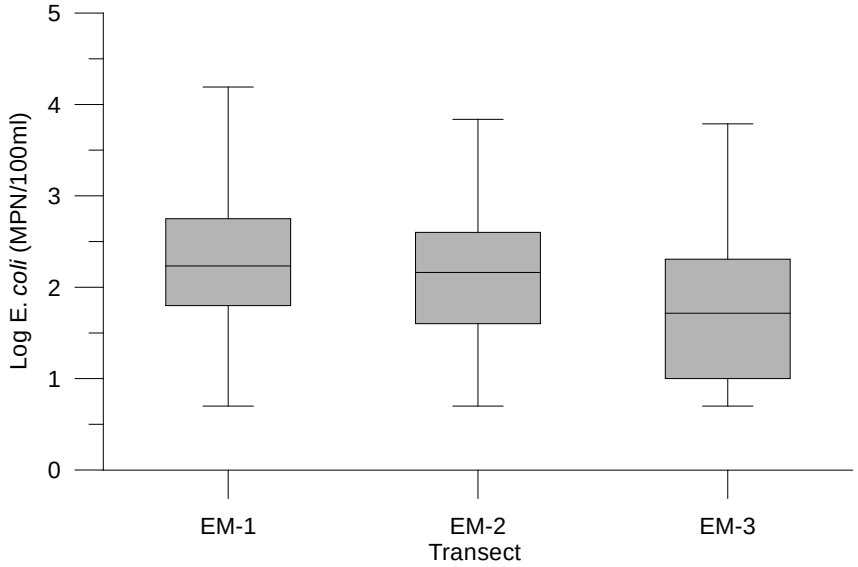

Figure 28: Mean *E. coli* concentration per transect (2010-2012).

Water quality – multi-depth samples. Additional surface water samples were collected at depths where water first reached 0.3, 0.6, 0.9 and 1.2 meters, on 27 dates in 2010 (n=7 events), 2011 (n=8 events) and 2012 (n=12 events). *E. coli* concentrations decreased with increased sampling depths, across all transects (Figure 29). Turbidity was also measured for 45 multi-depth samples at each transect in 2012. There was a negative correlation between log transformed turbidity and the depth samples were collected at all transects [(EM-1: n=45, r=-0.379, p=0.010) (EM-2: n=45, r=-0.355, p=0.017) (EM-3: n=45, r=-0.462, p=0.001)], i.e. water clarity improved with increased sample depth. Log transformed turbidity and *E. coli* concentrations were positively associated at all transects individually and with samples from all depths combined [(EM-1: n=44, r=0.538, p<0.001) (EM-2: n=45, r=0.355, p=0.017) (EM-3: n=44, r=0.39, p=0.009)].

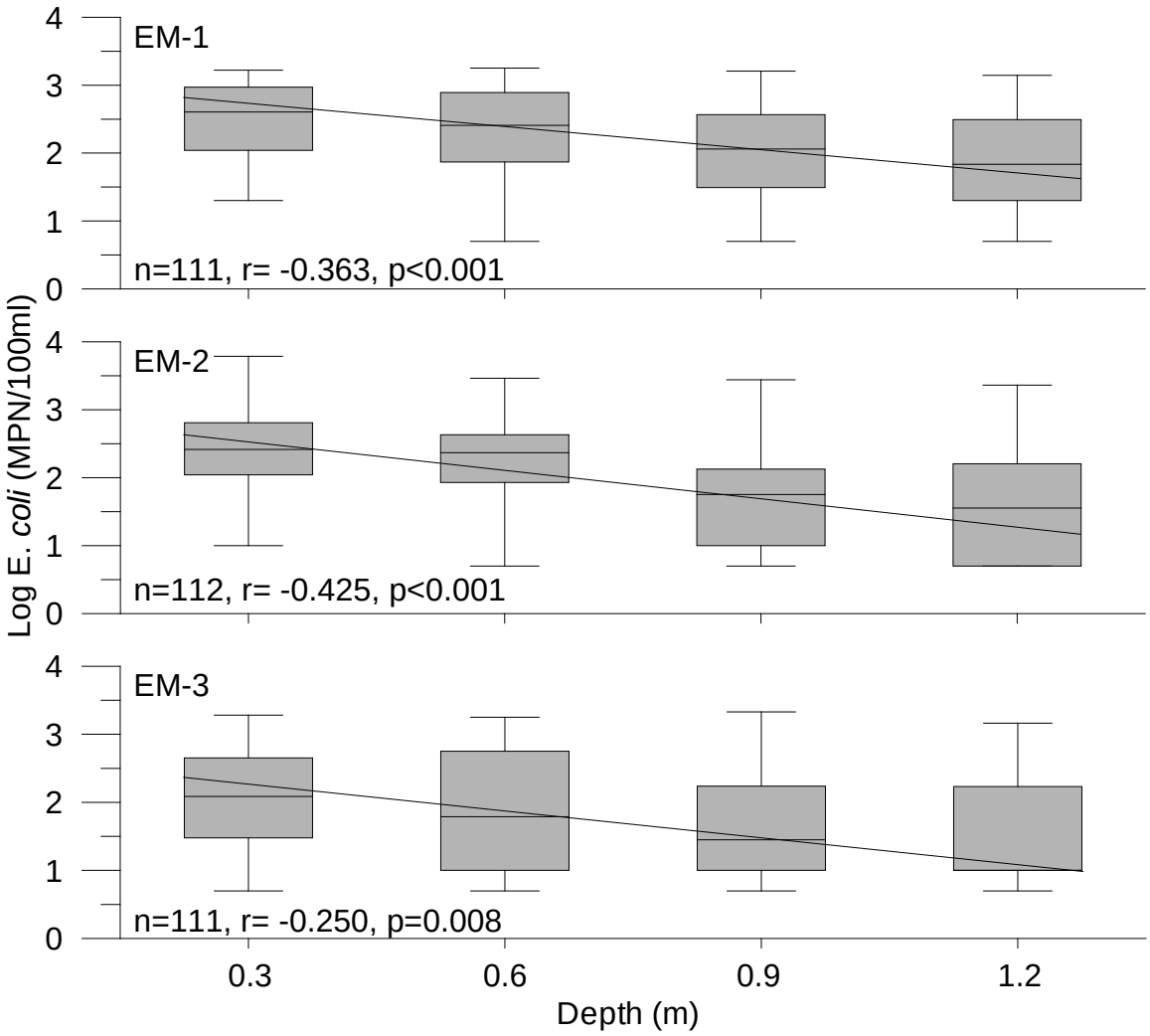

Figure 29: Affect of sample depth on *E. coli* concentration.

Water quality – 60th Street Outfall. Water samples were collected from the 60th Street outfall on 14 dates during 2012. *E. coli* concentrations ranged from 200 to 24,191 MPN/100ml. Discharge was noted from this outfall on all occasions (wet and dry weather). One, six and 12 water sample(s) from this outfall had an *E. coli* concentrations less than 235, 1,000 and 10,000 MPN/100ml respectively. *E.*

coli concentrations were significantly higher following precipitation events (>0.13 cm) (n=5, mean= 3.66, σ=0.59) compared to dry weather (n=9, mean=2.98, σ=0.44) (p=0.030).

Kemper Center Outfall. Water Samples were collected from the outfall adjacent to the Kemper Center on 14 dates during 2012. *E. coli* concentrations ranged from 173 to 15,531 MPN/100ml. One sample from this outfall had an *E. coli* concentration less than 235 MPN/100ml, six samples had a concentration less than 1,000 MPN/100ml and 13 samples had a concentration less than 10,000 MPN/100ml. *E. coli* concentrations were significantly higher following precipitation events (>0.13 cm) (n=5, mean= 3.67, σ=0.51) compared to dry weather (n=9, mean=2.95, σ=0.45) (p=0.017).

Water quality – open waters of Lake Michigan east of the breakwater. Thirteen water samples were collected from outside the breakwall, east of transect EM-1 (2012 only). *E. coli* concentrations ranged from below the detection limit (<10 MPN/100ml) (n=10) to 20 MPN/100ml. *E. coli* concentrations were lower outside the breakwall (n=13, mean=0.80, σ=0.20) compared to samples collected at any transect of Eichelman Beach (p<0.001).

Water quality – eroded area west of the breakwater. Significant shoreline erosion exists on the east side of the beach near the breakwater. The breakwater is partially porous and low enough for waves to overtop. This has allowed water to erode the beach face and scour out a pocket which holds a shallow pool of standing water. Vegetation adapted for moist soil conditions surrounds this depression, primarily purple loosestrife and canary reed grass (Figure 30).

Figure 30: Image of the eroded shoreline on the east side of Eichelman Park Beach surrounded by purple loosestrife and canary reed grass.

E. coli concentrations in water samples collected from this pool of standing water ranged from 85 to 24,192 MPN/100ml (n=42) with a log mean concentration of 3.25 and a geometric mean of 1,778 MPN/100ml (σ=0.67). The majority of samples collected from this location, 85.7 percent (36/42), had an *E. coli* concentration greater than 235 MPN/100ml and 69.0 percent (29/42) of samples had an *E. coli*

concentration greater than 1,000MPN/100ml. Wildlife was frequently observed (ducks, geese, gulls) in and adjacent to this pocket of water and may have contributed to excess *E. coli* concentrations. The same intense wave activity that created this pool, as well as seiches, may introduce stagnant water from this depression into the beach proper. *E. coli* concentrations inside the standing pocket of water were significantly higher than surface water samples collected from adjacent transect EM-1 on the same dates (n=42, mean=2.26, σ=0.77, p<0.001).

Sediments. Sediment samples from the berm crest, middle beach and back beach were collected for the determination of grain size distribution and uniformity on seven dates in 2010. These samples were composited and analyzed to determine dominant particle size and sorting (See Methods Section, Page 22). All sediment samples were described as well sorted medium to fine grain sands (SP) or well sorted medium to fine grain sands with trace amounts of gravel (SP). The mean grain size of samples collected from the berm crest ranged from 0.34 (EM-3) to 0.39 mm (EM-1) (Table 32). Finer particles (<0.074 mm in diameter), silts and clays, were present in berm crest samples representing 0.31, 0.25 and 0.15 percent of samples by mass at transects EM-1, EM-2 and EM-3 respectively. Samples collected from back and middle beach sampling locations appeared to have little variation in mean grain size, all samples ranged in size from 0.32 mm (EM-2-BB) to 0.42 mm (EM-1-BB). Uniformity coefficients were less than four for all samples indicating well sorted sediments.

Location	Mean grain size (mm)	Uniformity Coefficient	Sediment Description
EM-1-BC	0.39	2.11	Well sorted medium to fine grain sand with trace gravel (SP)
EM-1-MB	0.36	2.06	Well sorted medium to fine grain sand with trace gravel (SP)
EM-1-BB	0.42	2.24	Well sorted medium to fine grain sand with trace gravel (SP)
EM-2-BC	0.36	1.94	Well sorted medium to fine grain sand with trace gravel (SP)
EM-2-MB	0.32	1.80	Well sorted medium to fine grain sand (SP)
EM-2-BB	0.32	1.80	Well sorted medium to fine grain sand with trace gravel (SP)
EM-3-BC	0.34	1.85	Well sorted medium to fine grain sand with trace gravel (SP)
EM-3-MB	0.33	1.95	Well sorted medium to fine grain sand with trace gravel (SP)
EM-3-BB	0.35	1.95	Well sorted medium to fine grain sand with trace gravel (SP)

Table 32: Mean grain size, uniformity coefficient and description of sediments at Eichelman Park.

Bacteria concentrations were enumerated in sediments samples collected from berm crest, middle beach and back beach (2010 – 2012) (Table 33). Bacteria concentrations were also enumerated in submerged sediment samples, collected at a depth of 0.3 meters (2012 only). *E. coli* concentrations were higher in berm crest sediment samples than at all other sampling positions, all transects [EM-1: BC vs. submerged (p=0.007); BC vs. middle beach (p=0.019); BC vs. back beach (p<0.001)] [EM-2: BC vs. submerged (p=0.004); BC vs. middle beach (p=0.005); BC vs. back beach (p<0.001)] [EM-3: BC vs. submerged (p=0.014); BC vs. middle beach (p<0.001); BC vs. back beach (p<0.001)]. *E. coli* concentrations in beach sand did not differ between other sampling locations at any transect (p>0.05).

E. coli concentrations were higher in sediment samples collected from the berm crest at transects EM-1 (p<0.001) and EM-2 (p<0.001) than at transect EM-3. Higher *E. coli* concentrations were

also associated with transects EM-1 (p=0.002) and EM-2 (p=0.039) compared to transect EM-3 at the mid-beach sampling location. *E. coli* concentrations in back beach (p>0.05) and submerged sediment samples (p>0.05) did not differ by transect.

Higher *E. coli* concentrations were present in berm crest sediment samples on a mass to mass basis compared to adjacent water samples (assuming 100ml of water has a mass of 100 grams) at all transects [(EM-1 Water: n=29, mean=2.43, σ=0.71; p<0.001) (EM-2 Water: n=29, mean=2.28, σ=0.51; p<0.001)(EM-3 Water: n=29, mean=1.72, σ=0.86; p<0.001)]. Although higher *E. coli* concentrations were present in sediment samples at some locations compared to adjacent surface water samples, *E. coli* concentrations in surface water samples and sediment samples did not correlate (all locations, all transects, p>0.05).

Location		EM-1	EM-2	EM-3
0.3 m-submerged	*mean*	2.95	2.76	2.47
	σ	0.61	0.51	0.54
	n	7	7	7
Berm Crest	*mean*	4.07	3.85	3.20
	σ	0.66	0.53	0.59
	n	29	29	29
Middle Beach	*mean*	3.34	3.08	2.41
	σ	0.67	0.94	0.61
	n	17	17	17
Back Beach	*mean*	2.83	2.62	2.22
	σ	1.07	0.84	0.38
	n	17	17	17

Table 33: Mean *E. coli* concentration in sediment samples collected at Eichelman Park based upon transect and collection location. *E. coli* concentration represented as log *E. coli* CFU/100grams dry sediment.

Wildlife. Ducks, geese and gulls were observed most frequently and in the greatest number at transect EM-1 (Table 34) compared to other beach transects. Gulls were the most prevalent species and were observed on 65.5, 23.1 and 13.9 percent of dates at transects EM-1, EM-2 and EM-3 respectively. *E. coli* concentrations did not vary based upon the presence of dogs (EM-1: p=0.412, EM-2: p=0.160, EM-3: p=0.172) or ducks at any transect (EM-1: p=0.359, EM-2: p=0.674, EM-3: p=0.321). At transect EM-1, higher *E. coli* concentrations were associated with the presence of geese [(with geese: n=17, mean=2.97, σ=0.78) (without geese: n=128, mean=2.17, σ=0.72) (p<0.001)] but not at transects EM-2 (p=0.967) or EM-3 (p=0.321). Higher *E. coli* concentrations at transect EM-3 were associated with the presence of gulls [(with gulls, n=20, mean=2.09, σ=0.76) (without gulls: n=124, mean=1.69, σ=0.79) (p=0.036)] but not at transects EM-1 (p=0.754) or EM-2 (p=0.064).

Species	EM-1	EM-2	EM-3
Dogs (#)	23	25	12
Dogs (Days)	17	16	9
Ducks (#)	335	22	20
Ducks (Days)	28	3	4
Geese (#)	289	86	70
Geese (Days)	17	6	4
Gulls (#)	5,998	1,644	490
Gulls (Days)	95	33	20

Table 34: Number and frequency of dogs, ducks, geese and gulls observed at Eichelman Park based upon transect location.

Algae. The amount of algae (*Cladophora*) submerged in the water at each transect was estimated (Table 35). *E. coli* concentrations in surface water did not vary significantly based upon the amount of algae submerged in the water at transects EM-1 (p=0.107) or EM-2 (p=0.1681). Higher *E. coli* concentrations at transect EM-3 were associated with moderate amounts of algae in the water compared to when low amounts were present (p=0.001) or when algae was absent (p=0.002). Exceedance rates of 12.5, 18.9 and 57.1 percent were associated with no, low and moderate amounts of submerged algae respectively at transect EM-3.

Submerged Algae Amount		EM-1	EM-2	EM-3
Absent	*mean*	2.55	2.32	1.59
	σ	0.68	0.75	0.74
	n	16	26	32
Low	*mean*	2.19	1.99	1.65
	σ	0.77	0.73	0.75
	n	110	83	90
Moderate	*mean*	2.37	2.02	2.48
	σ	0.77	0.63	0.71
	n	16	22	14
High	*mean*	2.97	2.29	2.13
	σ	1.06	0.92	0.98
	n	3	12	8

Table 35: Mean *E. coli* concentration at Eichelman Park based upon transect location and the amount of algae submerged in the water. *E. coli* concentration represented as log *E. coli* MPN/100ml.

The amount of algae stranded on the beach was similar at all transects (Table 36). *E. coli* concentrations did not differ based upon the amount of stranded algae present at transects EM-1 (p=0.3005) or EM-2 (p=0.2227). Higher surface water *E. coli* concentrations were noted at transect EM-3 when moderate amounts of algae were stranded on the beach versus low (p=0.001) or no (p=0.011) amounts of algae present. Surface water samples exceeded recreational criteria 23.5 percent of the time when algae was absent, 17.4 percent with low amounts of algae stranded on the beach and 45.5 percent with moderate amounts of algae on the beach at transect EM-3.

Stranded Algal Amount		EM-1	EM-2	EM-3
Absent	*mean* *σ* *n*	2.38 0.83 48	2.08 0.79 48	1.75 0.79 51
Low	*mean* *σ* *n*	2.14 0.74 72	2.05 0.69 68	1.61 0.76 69
Moderate	*mean* *σ* *n*	2.41 0.74 16	2.37 0.80 17	2.55 0.66 11
High	*mean* *σ* *n*	2.38 0.80 9	1.77 0.75 10	1.74 0.78 13

Table 36: Mean *E. coli* concentration at Eichelman Park based upon transect location and the amount of algae stranded on the beach. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Air temperature. Air temperatures averaged 23.8 (n=41, σ=3.6), 24.2 (n=51, σ=5.8) and 25.8 ^{o}C (n=52, σ=4.4) in 2010, 2011 and 2012 respectively. Air temperatures did not differ significantly by year (p>0.05). *E. coli* concentrations were not correlated with air temperatures at transect EM-1 (n=144, r=-0.057, p=0.501). A negative correlation existed between air temperature and *E. coli* at transects EM-2 (n=142, r=-0.200, p=0.017) and EM-3 (n=143, r=-0.246, p=0.003). This correlation maybe partially reflective of differences in current directions associated with warmer air temperatures. West (offshore) winds were associated with higher air temperatures (n=79, mean=25.9 C^{o}, σ=4.8) compared to east winds (n=65, mean=23.2, σ=4.4) (p=0.001).

Water temperature. Mean water temperatures did not differ based upon transect (p=0.8719) (e.g. little to no variation in water temperature across the beach). Mean water temperatures averaged 17.7 (n=41, σ=3.2), 17.9 (n=51, σ=4.5) and 20.3 ^{o}C (n=52, σ=4.1) in 2010, 2011 and 2012 respectively. Water temperatures were significantly warmer in 2012 compared to 2010 (p=0.007) or 2011 (p=0.011). *E. coli* concentrations did not correlate with water temperatures at any transect [(EM-1: n=143, r=0.109, p=0.195) (EM-2: n=141, r=0.096, p=0.256) (EM-3: n=142, r=0.044, p=0.603)].

Precipitation. Precipitation events greater than 0.13 cm, considered a significant amount, occurred within the 24-hour period preceding sample collection on 26 dates from 2010 to 2012. Higher

E. coli concentrations were associated with precipitation events at all transects (p<0.001, all transects) (Figure 31). Following rainfall, 65.4, 65.4 and 57.7 percent of samples exceeded water quality standards; comparatively, 40.3, 29.4 and 13.4 percent of samples exceeded water quality standards at transects EM-1, EM-2 and EM-3 respectively during dry weather. Differences in wave height following precipitation may partially explain differences in *E. coli* concentrations. Larger wave heights were also associated with precipitation events (min=0.03m, 25%=0.08m, median=0.15m, 75%=0.35m, max=1.22m) versus dry weather (min=0.00m, 25%=0.08m, median=0.08m, 75%=0.15m, max=0.76m) (p=0.025).

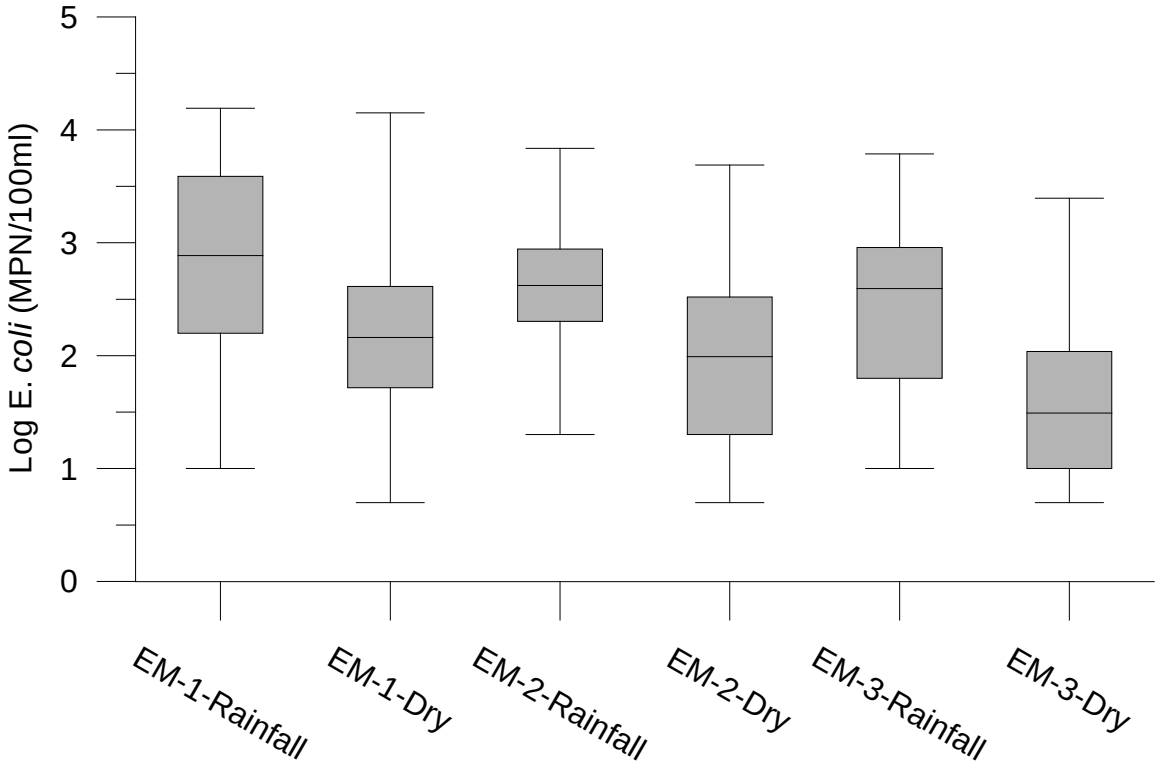

Figure 31: Mean E. *coli* concentration at each transect following precipitation (>0.13 cm prior to sample collection) and during dry weather.

Wind speed and direction. Wind speeds and directions were broken down into components of velocity along the east/west and north/south axes. *E. coli* concentrations did not vary based upon wind speed along the north/south axis at any transect (EM-1: n=145, r=-0.145, p=0.081) (EM-2: n=143, r=-0.145, p=0.083) (EM-3, r=-0.054, p=0.519). Neither was there a trend between wind speed along the east/west axis at transect EM-1 (n=145, r=0.017, p=0.839). However, at transects EM-2 (n=143, r=0.276, p=0.001) and EM-3 (n=144, r=0.326, p<0.001), higher *E. coli* concentrations were associated with winds out of the east.

Current speed and direction. Current speeds and directions were converted into components of velocity along the east/west and north/south axes. *E. coli* concentrations did not correlate with velocity along the north/south [(EM-1: n=145, r=0.047, p=0.572) (EM-2: n=143, r=0.095, p=0.258) (EM-3: n=144, r=-0.036, p=0.671)] or east/west axis at any transect [(EM-1: n=145, r=-0.017, p=0.847) (EM-2: n=143, r=-0.066, p=0.434) (EM-3: n=144, r=-0.133, p=0.120)].

Wave height. Wave height estimates were available from two sources, field technician estimates and GLCFS model estimates. *E. coli* concentrations correlated with both wave height sources; however, field technician estimates were a better explanatory variable for *E. coli* at all transects (Table 37). Median field technician wave height estimates were 0.076 meters; waves exceeded this height on 69 days. Exceedance rates of 63.8, 50.0 and 30.9 percent were associated with wave heights greater than 0.076 meters. Comparatively, exceedance rates of 27.6, 24.0 and 13.2 percent were associated wave heights of 0.076 m or less at transects EM-1, EM-2 and EM-3 respectively.

Wave Height Source	EM-1	EM-2	EM-3
Field Technician	n=145, r=0.399, p<0.001	n=143, r=0.444, p<0.001	n=144, r=0.450, p<0.001
GLCFS	n=145, r=0.195, p=0.019	n=143, r=0.194, p=0.020	n=144, r=0.255, p=0.002

Table 37: Correlation between *E. coli* concentration at Eichelman Park and wave heights estimates (field technician and the Great Lakes Coastal Forecasting System nowcast model estimates).

Water clarity. Water clarity descriptors were assigned ordinal values (e.g. clear=1, slightly turbid=2, turbid=3, opaque=4) (Table 38). A positive correlation was present between ordinal water clarity descriptors and *E. coli* at all transects (p<0.001). More turbid waters were associated with higher *E. coli* concentrations. Ordinal water clarity water descriptors were also positively associated with wave height, using field technician estimates, at all transects [(EM-1: n=145, r=0.448, p<0.001) (EM-2: n=145, r=0.470, p<0.001) (EM-3: n=145, r=0.513, p<0.001)].

Water Clarity		EM-1	EM-2	EM-3
Clear	*mean*	1.83	1.59	1.32
	σ	0.71	0.75	0.63
	n	47	39	43
Slightly Turbid	*mean*	2.30	2.10	1.63
	σ	0.73	0.58	0.61
	n	56	61	55
Turbid	*mean*	2.69	2.56	2.26
	σ	0.62	0.61	0.79
	n	37	36	42
Opaque	*mean*	2.77	2.22	2.34
	σ	0.87	1.09	1.43
	n	5	7	4

Table 38: Mean *E. coli* concentration at Eichelman Park based upon transect and water clarity. *E. coli* concentration represented as log *E. coli* MPN/100ml.

In 2012, analytical turbidity measurements were made in addition to visual estimates. Turbidity values ranged from 0.8 to 62.4 (median=4.5 NTU), 0.9 to 172.0 (median=6.5 NTU) and 0.9 to 26.8 NTU (median=4.2 NTU) at transects EM-1, EM-2 and EM-3 respectively. Log transformed turbidity values positively correlated with *E. coli* concentrations at all transects [(EM-1: n=52, r=0.534, p<0.001) (EM-2: n=52, r=0.385, p=0.005) (EM-3: n=52, r=0.415, p=0.002)]. Water quality exceeded recreational standards 57.7, 46.2 and 34.6 percent of the time when the median turbidity value was exceeded at transects EM-1, EM-2 and EM-3 respectively. Standards were exceeded 26.9, 19.2 and 7.7 percent of the

time when turbidity values were in lesser amounts at transects EM-1, EM-2 and EM-3 respectively. Log transformed turbidity values correlated with ordinal water clarity descriptors at all transects indicating visual water clarity descriptions were accurate at describing turbidity [(EM-1: n=52, r=0.694, p<0.001) (EM-2: n=52, r=0.752, p<0.001) (EM-3: n=52, r=0.601, p<0.001)].

Debris. Debris amounts on the beach were described as low for 125 dates and moderate for five dates; debris was absent for 15 dates. Types of debris included: food-related waste (n=115 days), street litter (n=104 days), household waste (n=27 days), building materials (n=3 days), sewage-related (condoms) (n=2 days), medical waste (syringes with needles) (n=2 days) and clothing (n=1 day). Floatables were observed on 50 dates and included: food-related waste (n=31 days), street litter (n=31 days), household waste (n=12 days), sewage-related waste (n=3 days), lawn clippings (n=2 days), and fishing related waste (n=1). Although the source of the litter could not be confirmed, it was clear some had washed ashore (based upon the presence of debris deposited onto the shoreline) with the remainder deposited by beach goers (based upon the presence of debris above the ordinary high water mark). When the amount of waste was described as moderate, the majority appeared to have washed ashore (Figure 32).

Figure 32: Moderate amounts of waste washed ashore near transect EM-3 on September, 21st 2010. Additional dates occurred during the beach season when moderate amounts where present washed ashore.

Beach usage. The number of people at the beach averaged 4.8 (n=201), 5.5 (278) and 8.6 (n=8.6) people per day in 2010, 2011 and 2012 respectively. Of those, 1.0 (n=43), 1.2 (n=61) and 1.6 (n=84) people were observed in the water per day. The activities of 684 people at this beach were recorded and included: playing in the sand (n=277), walking (n=132), lounging (n=95), swimming (n=82), walking/playing with their dog(s) (n=48), wading (n=42), kayaking/boating (n=4), taking photographs (n=3) and fishing (n=1). A local daycare occasionally brought young children to this beach for outings. Parents with young children frequented this beach, likely because it is the shallowest beach with the lowest average wave height. One weekend observation was made (8/7/2010 @ 1530) in order to

approximate peak usage. On this date, 48 people were present at the beach and ten individuals were in the water (Figure 33). As with the other Kenosha beaches, the number of people recorded was likely not representative of total usage due to the time of day sanitary surveys were conducted (1000 – 1100). Due to the infrequent occurrence of people in the water at this beach at the time water samples were collected, direct FIB contribution by beach patrons was not considered a significant source of pollution.

Figure 33: Individuals present at Eichelman Park Beach on August 7th, 2010.

Dye testing – circulation patterns. A non-toxic florescence dye was placed into the water at each transect of Eichelman Beach on June 24th, 2011 in order to determine circulation patterns. At the time of application, the water was clear, there was little wave action (<0.076 m) and the winds were from the north-west ranging from 2.3 to 3.1 m/s. Dye circulated from west to east at transects EM-2 and EM-3 at approximately 2.5 cm/s. The dye primarily moved laterally along the shoreline rather than away from it except for at the top five cm of water column. Currents, induced by NW winds, appeared to draw the topmost layer of surface water away from the shoreline. At transect EM-1, water initially circulated along the shoreline (east to west) but then changed directions, moving from north to south before exiting the beach area along the break wall. General circulation patterns on this date were in a clockwise direction, with water circulating along the shoreline, across the beach face, and finally exiting the embayment near the breakwater on the east end of the beach (Figure 34).

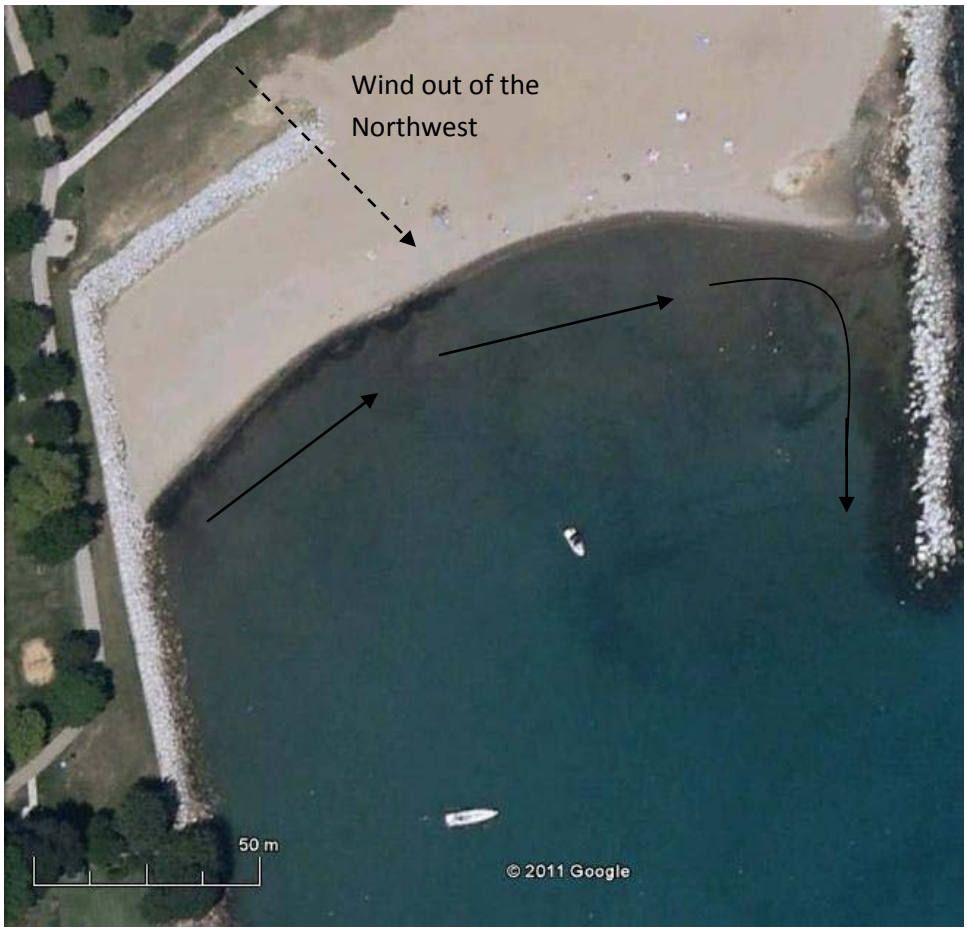

Figure 34: Circulation patterns at Eichelman Beach on June 24th, 2011.

Southport Park

Physical characteristics. Beach length, measured from the groin north of transect SP-1 to the shore armor adjacent to transect SP-3, varied between 229.9 (in 2012) to 265.6 (in 2011) meters. The width of the beach was approximately 20 meters at transects SP-1 and SP-2 and 43.6 meters at transect SP-3 (Figure 35) (Table 39). The slope of the beach had a greater than five percent gradient at each transect. The distance from the berm crest to a water depth of 1.2 meters was approximately 15 meters or less at all transects.

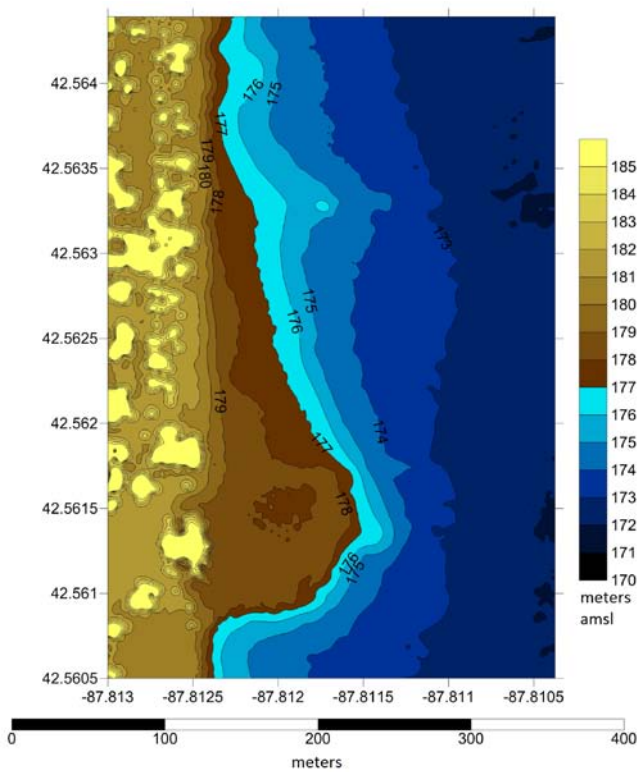

Figure 35: Digital elevation model of Southport Park Beach (Data from USACE Great Lakes Topo/Bathy LiDAR Survey).

Southport Park Beach BEACH DIMENSIONS			
Average	**SP-1**	**SP-2**	**SP-3**
Width (m)	21.2	23.3	43.6
Slope (%)	7.4	6.5	5.2
In-Water Measurements from Berm Crest to:			
0.3 m	2.5	3.4	2.8
0.6 m	5.5	5.2	5.0
0.9 m	11.8	11.2	8.2
1.2 m	15.6	14.8	12.8

Table 39: Average dimensions of Southport Park over the study period.

Water quality – routine monitoring. Water samples (n = 435) were collected from three transects at Southport Beach: SP-1, SP-2 and SP-3 (Table 40). *E. coli* concentrations did not differ across transects (p=0.400) or by year in which samples were collected (p=0.095). The percentage of samples exceeding recreational water quality standards at transects SP-1, SP-2 and SP-3 was 21.4 (n=31), 20.7 (n=30) and 17.9 (n=26) percent respectively.

Year		SP-1	SP-2	SP-3	All
2010	*mean*	1.67	1.52	1.44	1.54
	σ	0.72	0.58	0.58	0.63
	n	42	42	42	126
2011	*mean*	1.64	1.87	1.69	1.73
	σ	0.72	0.78	0.79	0.76
	n	51	51	51	153
2012	*mean*	1.77	1.66	1.62	1.69
	σ	0.81	0.76	0.78	0.78
	n	52	52	52	156
2010-2012	*mean*	1.70	1.69	1.59	1.66
	σ	0.75	0.73	0.74	0.74
	n	145	145	145	435

Table 40: Mean *E. coli* concentration in water samples collected at Southport Park based upon transect and year. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Water quality – mulit-depth samples. Water samples were collected at multiple depths, where water depth first reached 0.3, 0.6, 0.9 and 1.2 meters on seven dates in 2010. *E. coli* concentrations did not vary based upon sample depth at any individual transect or with data from all transects combined [(SP-1: n=28, r=-0.119, p=0.547), (SP-2: n=28, r=-0.106, p=0.591), (SP-3: n=28, r=0.176, p=0.370), (All years combined data: n=84, r=-0.033, p=0.766)].

Water quality – 71st Street Outfall. Water samples were collected from the 71st Street outfall on five dates (2012 only). The field technician attempted to collect samples on a further eight sampling days; however, there was no discharge. Discharge volumes, when flow was present, were visually estimated at one liter per minute (low flow). *E. coli* concentrations ranged from 5,040 to 24,192 MPN/100ml, with three samples (60%) exceeding 10,000 MPN/100ml. Four of the sampling events were obtained following precipitation events of 0.13 cm or greater, within 24 hours prior to collection and one sample was representative of dry weather flow. The same collected from the dry weather flow had an *E. coli* concentration of 24,192 MPN/100ml. The mean concentration of *E. coli* in samples from this outfall was greater than in surface water at Southport Beach (p<0.001 all transects).

Water quality – 73rd Street Outfall. Water samples were collected from the 73rd Street outfall on 14 dates (2012 only). *E. coli* concentrations ranged from 31 to 24,192 MPN/100ml. Seven, five and one water sample(s) from this outfall had an *E. coli* concentration greater than 235, 1,000 and 10,000 MPN/100ml respectively. Six samples from this outfall were obtained following precipitation events of 0.13 cm or greater within 24 hours prior to sample collection and eight samples were representative of dry weather flow. Effluent *E. coli* concentrations did not differ as a function of precipitation: after

rainfall (mean=2.81, σ=1.00) and dry weather (mean=2.70, σ=0.89). The mean concentration of *E. coli* in effluent from this outfall was significantly higher than in surface water at Southport Beach when samples were collected on the same day [(SP-1: p=0.036) (SP-2: p=0.018) (SP-3: p=0.047)].

Water quality – 75th Street Outfall. Water samples were collected from the 75th Street outfall on 13 dates (2012 only). *E. coli* concentrations ranged from 10 to 2,909 MPN/100ml. Four samples from this outfall had an *E. coli* concentration greater than 235 MPN/100ml and two samples had a concentration greater than 1,000 MPN/100ml. Five samples from this outfall were obtained following precipitation events 0.13 cm or greater within 24 hours prior to sample collection and eight samples were representative of dry weather flow. Effluent *E. coli* concentrations were higher after rainfall (mean=2.43, σ=0.95) compared to dry weather (mean=1.45, σ=0.59) (p=0.042). There was no significant difference in mean effluent *E. coli* concentration and ambient water quality at Southport Beach (p=0.913).

Water quality – Southport Outfall. Samples were collected from the outfall discharging directly onto Southport Beach on 25 dates over the course of this study. *E. coli* concentrations ranged from 399 to over 24,192 (n=4) MPN/100ml with a median concentration of 5,475 MPN/100ml. The majority of samples (23/25) had an *E. coli* concentration greater than 1,000 MPN/100ml and six samples had a concentration greater than 10,000 MPN/100ml. Most of the samples from this outfall (n=17) were obtained following precipitation events of 0.13 cm or greater (within 24 hours); only eight samples were representative of dry weather flow. There was no significant difference between effluent *E. coli* concentrations following precipitation events (mean=3.79, σ=0.52) compared to samples collected during dry weather (mean=3.47, σ=0.43) (p=0.153). Mean effluent *E. coli* concentration was significantly higher than observed *E. coli* levels in adjacent surface water (p<0.001, all transects).

Kenosha Wastewater Treatment Plant. Discharge volumes, ranging from 0.63 to 1.84 m^3s^{-1}, were obtained from the Kenosha Water Utility for 144/145 sampling dates throughout the study period. The *E. coli* concentration in discharged effluent was available for 107/145 of sampling dates. Concentrations, as determined by the Kenosha Water Utility ranged from 12 to 9,678 MPN/100ml with a median concentration of 240 MPN/100ml. Mean *E. coli* concentrations in the discharge from the wastewater treatment facility were significantly higher than *E. coli* concentrations observed at Southport Beach [(wastewater treatment facility: n=107, mean=2.45, σ=0.61) vs. (SP-1: n=107, mean=1.64, σ=0.74, p<0.001) (SP-2: n=107, mean=1.66, σ=0.71, p<0.001) (SP-3: n=107, mean=1.58, σ=1.58, p<0.001)]. *E. coli* concentrations at Southport beach were grouped into categories based upon if *E. coli* values and discharge volumes were below or higher than the median concentration/discharge volume. Surface water *E. coli* concentrations across all transects of Southport Beach did not vary based upon the *E. coli* concentration [(SP-1: p=0.386) (SP-2: p=0.349) (SP-3: p=0.461)] or the discharge volume of [(SP-1: p=0.550) (SP-2: p=0.104) (SP-3: p=0.522)] effluent from the wastewater treatment plant.

Sediments. Sediment samples were collected at Southport Park Beach from nine separate locations (three transects, three positions per transect), for the purpose of determining grain size and uniformity, on seven dates in 2010 (See Methods Section, Page 22). These samples were composited prior to being analyzed. Sediment descriptions ranged from well sorted fine grained sands with trace

amounts of gravel (SP) to medium sands with little gravel (SW) (Table 41). The mean size of berm crest samples ranged from 0.78 (SP-2) to 1.22 mm (SP-3) and uniformity coefficients ranged from 3.19 (SP-1) to 5.36 (SP-3). Particles representative of silts and clays comprised 0.14, 0.00 and 0.17 percent of sample mass from berm crest locations at transects SP-1, SP-2 and SP-3 respectively. The mean grain size of sediments from back and middle beach locations ranged from 0.41 (SP-1-BB) to 0.57 mm (SP-2-MB). Uniformity coefficients indicated well sorted sediments (coefficients less than four).

Sample	Mean grain size (mm)	Uniformity coefficient	Description
SP-1-BC	0.83	3.19	well sorted medium sand with few gravels
SP-1-MB	0.55	2.36	Well sorted fine sand with trace gravel
SP-1-BB	0.41	1.96	Well sorted fine sand with trace gravel
SP-2-BC	0.78	3.54	Well sorted medium sand with few gravels
SP-2-MB	0.57	2.63	Well sorted fine sand with few gravels
SP-2-BB	0.45	2.09	Well sorted fine sand with trace gravel
SP-3-BC	1.22	5.36	Medium sand with little gravel
SP-3-MB	0.56	2.70	Well sorted fine sand with trace gravel
SP-3-BB	0.55	3.00	Well sorted fine sand with trace gravel

Table 41: Mean grain size, uniformity coefficient and description of sediments at Southport Park.

On 14 occasions over the course of this study, *E. coli* was enumerated in sediments collected from the berm crest, middle beach and back beach (Table 42). Higher *E. coli* concentrations were associated with samples collected from the berm crest compared to samples collected from the back beach at transects SP-1 (p=0.002) and SP-2 (p=0.009). Higher *E. coli* concentrations were also associated with berm crest compared to middle beach samples at transect SP-1 (p=0.009). *E. coli* concentrations did not vary across transect SP-3 based upon sample location (p=0.820).

Location		SP-1	SP-2	SP-3
Berm Crest	*mean*	2.90	3.40	2.61
	σ	0.81	0.87	0.59
	n	14	13	14
Middle Beach	*mean*	2.18	2.85	2.66
	σ	0.48	0.85	1.00
	n	14	14	14
Back Beach	*mean*	2.04	2.33	2.82
	σ	0.48	0.70	1.07
	n	13	14	14

Table 42: Mean *E. coli* concentration in sediment samples collected at Southport Park based upon transect and collection location. *E. coli* concentration represented as log *E. coli* CFU/100grams dry sediment.

Higher *E. coli* concentrations were associated with berm crest samples at transect SP-2 compared to samples collected at transect SP-3 (p=0.027). *E. coli* did not differ across middle beach sampling locations across transects. Higher *E. coli* concentrations were associated with back beach samples at transect SP-3 than at transect SP-1 (p=0.039).

E. coli concentrations were higher in berm crest samples than in adjacent surface water samples on a mass to mass basis, assuming 100ml of water weighs 100 grams, all transects [(SP-1: p<0.001) (SP-2: p<0.001) (SP-3: p=0.020)]. *E. coli* concentrations were higher in middle beach sediment samples than in adjacent surface water samples at transects SP-2 (p=0.002) and SP-3 (p=0.014) but not SP-1. *E. coli* concentrations were also higher in back beach sediment samples than in surface water samples at transect SP-3 (p=0.003). Although *E. coli* concentrations were generally higher in sediments than in water samples, *E. coli* concentrations in surface water and in sediments did not correlate (p>0.05).

Widlife. The type, number and location of wildlife were recorded. Gulls were observed most frequently and in the greatest number (Table 43). Gulls were often observed roosting on the groin adjacent to transect SP-1 (Figure 36). Dogs, ducks and geese were also observed, but less frequently. On several instances, field technicians noted dog feces on the beach and on multiple occasions pet owners were observed improperly disposing of feces, i.e. dumping the feces into the lake, rather than using appropriate receptacles. *E. coli* concentrations did not vary based upon the presence of wildlife, any species, any transect (p>0.05), with the exception of geese at transect SP-3. At transect SP-3, the *E. coli* concentration (log) averaged 2.46 MPN/100ml (n=5, σ=0.56) when geese were on the beach compared to 1.56 (n=140, σ=0.72) (p=0.007) when geese were absent.

Species	SP-1	SP-2	SP-3
Dogs (#)	4	10	22
Dogs (Days)	3	9	17
Ducks (#)	1	0	2
Ducks (Days)	1	0	1
Geese (#)	55	11	64
Geese (Days)	4	1	5
Gulls (#)	2,328	1,391	1,330
Gulls (Days)	70	28	23

Table 43: Number and frequency of dogs, ducks, geese and gulls observed at Southport Park based upon transect location.

Figure 36: Gulls roosting on the groin near transect SP-1.

Algae. The amount of algae submerged in the water varied based upon transect (Table 44). Algae was noted as absent more often at transect SP-3 (n=60) compared to transects SP-2 (n=48) and SP-1 (n=27) (Table 44). However, for the majority of dates, the amount of algae submerged in the water was noted as low. *E. coli* density in surface water did not vary significantly based upon the amount of algae submerged in the water at any transect [(SP-1: p=0.977) (SP-2: p=0.378) (SP-3: p=0.347)].

Submerged Algae Amount		SP-1	SP-2	SP-3
Absent	*mean*	1.71	1.78	1.61
	σ	0.78	0.72	0.74
	n	27	48	60
Low	*mean*	1.69	1.65	1.58
	σ	0.76	0.74	0.74
	n	110	93	83
Moderate	*mean*	1.79	2.39	2.26
	σ	0.79	----	----
	n	5	1	1
High	*mean*	1.55	1.65	1.71
	σ	0.49	0.32	----
	n	3	3	1

Table 44: Mean *E. coli* concentration at Southport Park based upon transect location and the amount of algae submerged in the water. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Stranded algal mats were infrequently noted on the beach (Table 45). When present, the amount was described as low for all water samples collected except for one, at transect SP-1. *E. coli* concentrations did not vary based upon the amount of stranded algae on the beach at any transect [(SP-1: p=0.105) (SP-2: p=0.783) (SP-3: p=0.427)].

Stranded Algae Amount		SP-1	SP-2	SP-3
Absent	*mean*	1.62	1.68	1.63
	σ	0.75	0.74	0.75
	n	92	90	100
Low	*mean*	1.83	1.72	1.52
	σ	0.75	0.71	0.72
	n	52	55	45
Moderate	*mean*	1.61	----	----
	σ	----	----	----
	n	1	--	--
High	*mean*	----	----	----
	σ	----	----	----
	n	--	--	--

Table 45: Mean *E. coli* concentration at Southport Park based upon transect location and the amount of algae stranded on the beach. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Air temperature. Mean air temperatures averaged 24.4 (n=41, σ=3.4), 25.0 (n=51, σ=5.8) and 26.1 ^{o}C (n=52, σ=4.9) in 2010, 2011 and 2012 respectively. Mean air temperature did not differ between study years (p=0.231). *E. coli* concentrations did not correlate with air temperatures at transect SP-1 (n=144, r=-0.0029, p=0.973) but did negatively correlate with air temperatures at transects SP-2 (n=144, r=-0.192, p=0.0214) and SP-3 (n=144, r=-0.182, p=0.0288). This correlation maybe partially explained by the variation in air temperature as result of wind direction. Mean air temperatures differed based upon wind direction with lower air temperatures associated with east (n=69, mean=23.8 ^{o}C, σ=4.9) versus west winds (n=75, mean=26.5 ^{o}C, σ=4.5) (p<0.001).

Water temperature. Mean water temperatures did not differ between transects (p=0.992). Average water temperatures were 16.5 (n=41, σ=3.2), 17.4 (n=50, σ=3.8) and 19.7 ^{o}C (n=52, σ=4.4) in 2010, 2011 and 2012 respectively. Mean water temperatures were warmer in 2012 compared to 2010 (p<0.001) and 2011 (p=0.007). *E. coli* concentrations correlated positively with surface water temperature at all transects [(SP-1: n=143, r=0.227, p=0.006) (SP-2: n=143, r=0.282, p=0.001) (SP-3: n=143, r=0.310, p<0.001)]. The correlation between air temperature and *E. coli* may partially be explained by the difference in wind direction. Mean water temperatures were significantly higher with east (n=69, mean=18.9 ^{o}C, σ=3.8) versus west winds (n=75, mean=17.1 ^{o}C, σ=4.1) (p=0.008).

Precipitation. Precipitation events of 0.13 cm or greater (considered a significant amount) occurred within the 24-hour period prior to water sample collection on 26 dates over the course of this study. *E. coli* concentrations were higher at all transects following precipitation events compared dry weather (p<0.001, all transects) (Figure 37). Water quality exceedance rates of 46.2 (n=12), 42.3 (n=11) and 50.0 (n=13) percent were associated with significant precipitation prior to sample collection at transects SP-1, SP-2 and SP-3 respectively. Exceedance rates of 16.0 (n=19), 16.0 (n=19) and 10.9 (n=13) percent were associated with dry weather events at transects SP-1, SP-2 and SP-3 respectively.

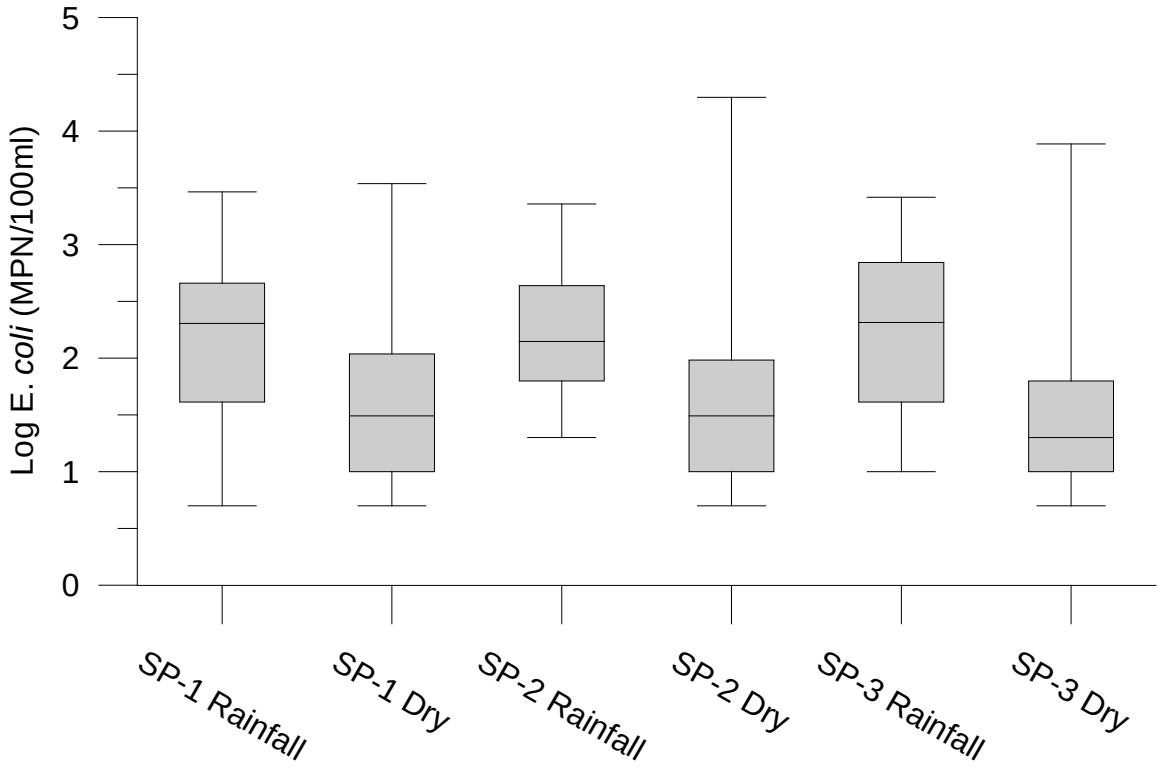

Figure 37: Mean E. *coli* concentration at each transect following precipitation (>0.13 cm prior to sample collection) and during dry weather.

Wind speed and direction. Wind speeds and directions were broken down into components of velocity along the east/west and north/south axes. *E. coli* concentrations did not correlate with wind speeds along the north/south axis at transects SP-1 (n=145, r=0.006, p=0.943) or SP-2 (n=145, r=0.108, p=0.194), but did at transect SP-3 (n=145, r=0.326, p<0.001). Higher *E. coli* concentrations were associated with winds out of the north at transect SP-3. At transect SP-3 a water quality exceedance rate of 26.2 percent (n=16) was associated with winds out of north versus an exceedance rate of 11.9 percent (n=10) with winds out of the south. *E. coli* concentrations did not correlate with wind strength along the east/west axis at transect SP-1 (n=145, r=0.156, p=0.0605), however, a correlation with wind speeds along the east/west axis was present at transects SP-2 (n=145, r=0.283, p=0.001) and SP-3 (n=145, r=0.326, p<0.001). At transects SP-2 and SP-3, higher *E. coli* concentrations were associated with winds out of the east. Water quality exceedance rates of 34.3 (n=24) and 30.0 (n=21) percent were associated with east winds versus exceedance rates of 8.0 (n=6) and 6.7 (n=5) percent with west winds at transects SP-2 and SP-3 respectively.

Current speed and direction. Current speeds and directions were broken down into components of velocity along the east/west and north/south axes. *E. coli* concentrations did not correlate with current velocity along the north/south axis at transects SP-1 (n=145, r=0.0556, p=0.507) or SP-2 (n=145, r=-0.111, p=0.183) but did at transect SP-3, where higher *E. coli* concentrations were associated with southern currents (n=145, r=-0.190, p=0.0224). Water quality exceedance rates of 18.7 (n=14) and 17.1 (n=12) percent were associated with southern and northern currents respectively at transect SP-3. *E. coli* concentrations did not correlate with current velocity along the east/west axis at transect SP-1

(n=145, r=-0.0970, p=0.246). However, positive correlations were present at transects SP-2 (n=145, r=-0.175, p=0.0354) and SP-3 (n=145, r=-0.292, p<0.001), where higher *E. coli* concentrations were associated with western currents (onshore). Water quality exceedance rates of 30.3 (n=66) and 27.3 (n=66) percent were associated with western currents and rates of 12.7 (n=10) and 10.1 (n=8) percent were associated with eastern currents at transect SP-2 and SP-3 respectively.

Wave height. Wave height estimates were available from two sources, field technician and GLCFS model estimates. Field technician wave height estimates ranged from 0.03 to 2.44 meters (median=0.18 meters) and GLCFS model estimates ranged from 0.02 to 1.51 meters (median=0.28 meters). *E. coli* concentrations correlated with both sources of wave height estimates, however, field technician estimates were a better explanatory variable for *E. coli* concentrations at all transects (Table 46). Water quality exceedance rates of 29.2 (n=21), 36.1 (n=26) and 30.6 (n=22) percent were associated with field technician wave height estimates of greater than 0.18 meters and exceedance rates of 13.7 (n=10), 5.5 (n=4) and 5.5 (n=4) percent were associated with field wave height estimates of 0.18 meters or less at transects SP-1, SP-2 and SP-3 respectively.

Wave Height Source	SP-1	SP-2	SP-3
Field Technician	n=145, r=0.397, p<0.001	n=145, r=0.476, p<0.001	n=145, r=0.502, p<0.001
GLCFS	n=145, r=0.230, p=0.001	n=145, r=0.301, p<0.001	n=144, r=0.405, p<0.001

Table 46: Correlation between *E. coli* concentration at Southport Park and wave heights estimates (field technician and the Great Lakes Coastal Forecasting System nowcast model estimates).

Water clarity. Each water clarity descriptor was assigned an ordinal value (e.g. clear=1, slightly turbid=2, turbid=3, opaque=4). The number of samples described with each water clarity description was similar at each transect (Table 47). There was a positive correlation between *E. coli* and ordinal water clarity values at all transects [(SP-1: n=145, r=0.394, p<0.001) (SP-2: n=145, r=0.493, p<0.001) (SP-3: n=145, r=0.447, p<0.001)]. Higher *E. coli* concentrations were associated with more turbid waters. When water clarity descriptors were assigned ordinal values, water clarity was positively associated with wave height, as determined by field technician estimates, at all transects [(SP-1: n=145, r=0.627, p<0.001) (SP-2: n=145, r=0.650, p<0.001) (SP-3: n=145, r=0.617, p<0.001)].

In 2012, analytical turbidity measurements were made in addition to visual estimates for 44, 45 and 45 samples at transect SP-1, SP-2 and SP-3 respectively. Turbidity values ranged from 0.87 to 347.00 (median=6.57), 0.96 to 342.00 (median=8.37 NTU) and 0.84 to 350.00NTU (median=6.50 NTU) at transects SP-1, SP-2 and SP-3 respectively. Log transformed turbidity values positively correlated with *E. coli* concentrations at transect SP-1 but not at transects SP-2 or SP-3 [(SP-1: n=44, r=0.309, p=0.041) (SP-2: n=45, r=0.241, p=0.111) (SP-3: n=45, r=0.192, p=0.206)]. A water quality exceedance rate of 40.9 (n=9) percent was associated turbidity values greater than 6.57 NTU compared to a rate of 22.7 (n=5) percent when water was less turbid water at transect SP-1. Log transformed turbidity values correlated with ordinal water clarity descriptors at all transects indicating visual water clarity descriptions were accurate at describing turbidity [(SP-1: p=0.005) (SP-2: p<0.001) (SP-3: p=0.006)].

Water Clarity		SP-1	SP-2	SP-3
Clear	*mean*	1.42	1.36	1.31
	σ	0.67	0.55	0.60
	n	68	69	67
Slightly Turbid	*mean*	1.73	1.78	1.52
	σ	0.70	0.67	0.67
	n	41	41	41
Turbid	*mean*	2.20	2.25	2.21
	σ	0.69	0.75	0.69
	n	32	31	32
Opaque	*mean*	2.02	2.27	1.96
	σ	0.98	0.82	0.93
	n	4	4	5

Table 47: Mean *E. coli* concentration at Southport Park based upon transect and water clarity. *E. coli* concentration represented as log *E. coli* MPN/100ml.

Debris. The amount of debris on the beach was described as low for 123 dates, moderate for 10 dates and as absent for 12 dates. Types of debris included: food-related waste (n=129 days), street litter (n=98 days), household waste (n=33 days), sewage-related (n=8 days), building materials (n=4 days), medical waste and clothing (n=2 days). Floatables were observed on 11 dates and included: food-related waste (n=8 days), household waste (n=2 days), street litter (n=1 day) and clothing (n=1 day).

Beach usage. The number of people at the beach averaged 4.4 (n=184), 2.4 (n=123) and 2.8 (n=147) people per day in 2010, 2011 and 2012 respectively. Of those, 1.0 (n=42), < 1.0 (n=51) and <1.0 (n=52) people were observed in the water. The activities of 259 people at this beach were recorded and included: walking (n=75), playing in the sand (n=60), lounging (n=35), playing with/walking pets (n=30), swimming (n=29), searching for beach glass (n=13), fishing (n=7), taking photographs (n=6) and kayaking/boating (n=4). The number of beach goers was observed on one weekend date (8/07/2010 at 1500) (Figure 38); the amount of people was higher than observed on weekdays. Thirty-one people were observed at the beach with 23 people in the water. Sanitary surveys were not conducted on days/times reflective of peak beach usage (0900 – 1200, Monday – Thursday), therefore beach usage may be higher on other days of the week/times of the day than what was observed. Due to the low beach usage when water samples were collected, bather shedding of *E. coli* was not considered a significant source of FIB.

Figure 38: Individuals present at Southport Park Beach on August 7th, 2010.

Discussion

The following section discusses the results of routine monitoring and beach sanitary survey data for the determination of site specific characteristics and potential sources of impairment impacting Kenosha beaches.

Recreational Water Quality

Alford Park. Mean *E. coli* concentrations at Alford Park did not vary based upon transect or year samples were collected indicating relatively similar sources of impairment at all transects throughout the study period. The percentage of samples exceeding water quality standards were greater than 15 percent at transects AP-3, AP-4 and AP-5 indicating poor water quality. Although there was not a significant difference in mean *E. coli* concentrations across transects at this beach, a lower exceedance rate was present at transects AP-1 (11.9%) and AP-2 (14.3%).

Pennoyer Park. *Mean E. coli* concentrations at Pennoyer Park also did not vary based upon transect or study year indicating similar sources of impairment at all transects throughout the study period. Over 15 percent of samples exceeded water quality standards at each transect indicating poor recreational water quality.

Simmons Island Park. Mean *E. coli* concentrations at Simmons Island Park did not vary based upon the year samples were collected, but were significantly lower at the northern transects, SI-1 and SI-2, compared to the southern transects, SI-4 and SI-5, suggesting differences in sources of fecal contamination on each end of the beach. Greater than 15 percent of samples exceeded water quality standards at transects SI-3, SI-4 and SI-5 indicating poor recreational water quality. Water quality exceedances did not occur as frequently at transects SI-1 (9.0%) or SI-2 (11.7%).

Eichelman Park. Mean *E. coli* concentrations at Eichelman Park did not differ based upon study year but did vary based upon transect. Higher mean *E. coli* concentrations were associated with transects EM-1 and EM-2 compared to transect EM-3 suggesting differences in sources of fecal contamination between the east and west side of the beach. Even though there was a difference in mean *E. coli* concentrations between transects, over 15 percent of samples exceeded water quality standards at all locations indicating poor recreational water quality throughout the beach.

Southport Park Beach. Mean *E. coli* concentrations at Southport Park did not differ significantly based upon year or transect location indicating similar sources of impairment at all locations throughout the study period. Over 15 percent of samples exceeded recreational water quality standards at each transect indicating generally poor water quality.

Surface Water Quality, Multi-Depth Samples

Multi-depth samples indicated a significant trend of decreasing bacteria concentrations with increased depth and, by proxy, distance from the shoreline at one or more transects of Simmons Island and Eichelman Beach. This trend was not present at any transect of Alford, Pennoyer or Southport

Beach. At Simmons Island, this trend was present at transects SI-2, SI-4 and SI-5 and at Eichelman Beach, this trend was present at all transects. Generally, the places where this trend was significant had the highest amount of samples exceeding *E. coli* standards. The decrease in *E. coli* concentration with increased distance from the shoreline suggests that localized sources at the shoreline behave as a source of impairment. Where significant correlation between these parameters and surface water quality did not exist it does not indicate that the shoreline was not a source, but rather, the interaction between multiple variables may explain the lack of a correlation. At beaches where this trend was not present, the distance from the shoreline to depths of 0.3, 0.6, 0.9 and 1.2 meters was less indicating a rapid drop off, limiting the ability to determine the presence of a significant offshore *E. coli* gradient.

Surface Water Quality - Tributaries

Pike River. Monitoring results revealed elevated levels of *E. coli* in discharge from the Pike River, particularly with high discharge volumes. Discharge volumes increased rapidly following rainfall events. *E. coli* concentrations correlated with discharge volume and turbidity indicating that the majority of bacteria in river water were due to the mobilization of non-point sources by rainfall mediated processes. Upstream monitoring, following one rainfall event, indicated high concentrations of *E. coli* in multiple sections of the watershed as well as at the mouth of the river. Data collected during this study was not sufficient enough to indicate the origin of *E. coli* entering into the river. The results of upstream monitoring programs that have been implemented on the Pike River since the start of this project (June 2012) will help to elucidate where and under what conditions *E. coli* enters the river.

The Pike River also had significantly higher *E. coli* concentrations than samples collected from all transects of Alford, Pennoyer and Simons Island Park indicating it could behave as a potential source of bacterial contamination at all these beaches. When higher than median *E. coli* concentration were present in the effluent from the Pike River (>133 MPN/100ml), significantly higher *E. coli* concentrations were present at all transects of Alford Park (except AP-1), all transects of Pennoyer Park (except PP-4), and at the northern most transect of Simmons Island (transect SI-1) compared to when lower FIB concentrations were discharged. This indicates the Pike River significantly, adversely, influences surface water quality at these locations. With higher *E. coli* concentrations in the effluent from the Pike River (>133 MPN/100ml), the percentage of surface water samples exceeding water quality standards were approximately 300 percent higher at Alford Park and 60 percent higher at Pennoyer and Simmons Island Park (transect SI-1) compared to when lower concentrations were present. Furthermore, specific conductivity measurements, proportional to the ionic strength of water, were higher in the river than in at the open water locations on Lake Michigan. When a northern longshore current was present, higher specific conductivity values were present at Alford Park indicating mixing between the Lake Michigan and the river; therefore, a northern longshore current supports the hydrodynamics required for the river to behave as a source of water quality impairment at this beach. This same trend was present at Pennoyer Park, but with a southern longshore current supporting mixing between the river and the beach. Conductivity values at Simmons Island did not differ based upon longshore current direction.

Pike Creek. The Pike Creek flows underground, through municipal infrastructure, discharging to the Kenosha Harbor. Tributary flow is comingled with stormwater and its direct influence, a sole contributing source, on surface water quality cannot be assessed.

Localized Sources of Pollution

Pennoyer Park - Seep. Water flowing from an unknown origin was observed on the back of Pennoyer Park Beach near transect PP-3 on two dates, 2010 only. A single water sample was collected from what was described in the study as a seep. It had an elevated *E. coli* concentration (437 MPN/100ml). It was unlikely that this intermittent source has a significant and consistent impact on recreational water quality at Pennoyer Park due to the infrequent appearance.

Eichelman Park - Eroded Area West of the Breakwater. An eroded area exists on the inside of the breakwater on the east side of Eichelman Beach. This eroded area was created through waves overtopping and/or penetrating the porous breakwater. Receding waters removed sediments from this area creating a shallow depression. The majority of samples collected from the eroded pocket exceeded recreational water quality standards (85.7%). Excess *E. coli* concentrations in standing water from this pocket may have been related to wildlife observed adjacent to this pocket and poor circulation patterns limiting the dilution of this water. *E. coli* concentrations in samples from this pocket were significantly higher than adjacent water samples. The same processes that created this pool and seiches may introduce stagnant water from this depression into the beach proper increasing the probability of water quality exceedances. Furthermore, consistently high levels of *E. coli* in this pocket indicate it poses a threat to public health regardless of the impact it has on adjacent surface water quality.

Eichelman Park – Open Waters of Lake Michigan Outside the Breakwater. Additional water samples were collected in 2012 from outside the breakwater on the east side of Eichelman Beach to determine if any sources of impairment were located originating from the open waters of Lake Michigan. The majority of samples (77%) collected at this location had *E. coli* concentrations below the detection limit (<10 MPN/100ml). The maximum concentration was 20 MPN/100ml. *E. coli* concentrations in these samples were lower than samples collected at all transects of Eichelman Beach. Pollution sources influencing the beach from outside the breakwater do not appear to be present.

Stormwater Outfalls and Municipal Infrastructure

Ten stormwater outfalls discharge into the coastal waters of Lake Michigan within 600 meters of beaches in the City of Kenosha. In addition, 18 stormwater outfalls and the Pike Creek discharge into the Kenosha Harbor, immediately adjacent to Simmons Island. The City of Kenosha wastewater treatment facility discharges 500 meters southeast of Southport Beach.

Alford Park Outfall. Alford Park outfall, near transect AP-3, likely had little to no affect on surface water quality. Discharge was not observed from this outfall and there were not any signs to indicate effluent from this outfall ever directly reached Lake Michigan. Most of the discharge from this outfall, when flow occurred, likely infiltrated into the sediments very quickly. In the process of infiltrating into the ground water, effluent was filtered through the sediments.

Pennoyer Park Outfall. Pennoyer Park Outfall had high flow volumes following precipitation events. During dry weather, there was usually a small amount of flow, but not great enough to reach the lake before infiltrating into the sediments. *E. coli* concentrations were significantly higher following precipitation compared to samples collected during dry weather. Although *E. coli* concentrations in effluent were not significantly higher than concentrations in lake samples collected at Pennoyer Park on the same date, this outfall was likely a source of impairment due to the high flow volumes and *E. coli* concentrations following precipitation. Pennoyer Park Outfall and its drainage basin are currently undergoing remediation via another GLRI grant funded project; this should reduce its impact.

40th Street Outfall. *E. coli* concentrations in water samples collected from this outfall were typically low; 57 percent of samples had an *E. coli* concentration below 235 MPN/100ml while only two samples (14%) had concentrations greater than 1,000 MPN/100ml. *E. coli* concentrations were higher following rainfall compared to dry weather. The influence of this outfall on water quality was likely limited, particularly during dry weather due to generally low *E. coli* concentrations and considering the distance between the outfall and each adjacent beach (300 meters from Pennoyer Park, 600 meters from Simmons Island).

43rd Street Outfall. *E. coli* concentrations were typically high in samples collected from this outfall, 61.5 percent of samples had concentrations greater than 1,000 MPN/100ml. However, this outfall was partially submerged on all dates which likely diluted effluent with lake water; actual versus observed concentrations are likely higher. *E. coli* concentrations did not differ significantly between wet and dry weather events. The influence this outfall had on surface water quality at adjacent beaches was uncertain due to the distance between it and the nearest beaches (600 meters from Pennoyer Park, 300 meters from Simmons Island). However, the closest transect to this outfall, SI-1, had relatively few samples that exceeded water quality standards.

Kenosha Harbor. *E. coli* concentrations were generally low in samples collected from the Kenosha Harbor. Concentrations were below the detection limit for the majority of samples (51.2%) and few samples had concentrations greater than 235 MPN/100ml (9.8%). *E. coli* concentrations in the harbor were significantly higher following rainfall events compared to during dry weather. During dry weather, *E. coli* concentrations were lower in the harbor than at the closest transect, SI-5, indicating the harbor was not a source of impairment during dry weather. Following precipitation, concentrations from these two locations did not differ significantly. Additionally, there were no water quality exceedances at transect SI-5 with higher FIB concentrations in the harbor than in open which would indicate a gradient extending from the harbor to the beach. This suggests minimal adverse influence from the Kenosha Harbor on surface water quality at the nearest beach, Simmons Island.

60th Street Outfall. The majority of samples collected from this outfall had *E. coli* concentrations greater than 1,000 MPN/100ml (57%). Continuous flow was present from this outfall during both wet and dry weather. *E. coli* concentrations in effluent were significantly higher following precipitation compared to samples collected during dry weather. Although the majority of samples from this outfall had *E. coli* concentrations above 1,000 MPN/100ml, the impact on water quality at the nearest beach, Eichelman, was likely limited. The breakwater on the east side of Eichelman Beach reduces mixing

between sources outside the breakwater and the beach. Furthermore, if this outfall impacted water quality at Eichelman, water quality outside the breakwater on the east end of the beach would also be degraded; this was not the case. Water quality was significantly better outside the breakwater compared to the beach side indicating a minimal influence of sources from outside the breakwater.

Kemper Center Outfall. Water samples collected from this outfall typically had *E. coli* concentrations greater than 1,000 MPN/100ml (57%). *E. coli* concentrations in effluent from this outfall were significantly higher following precipitation events compared to samples collected during dry weather. Multi-depth samples at Eichelman indicated a general gradient of decreasing *E. coli* concentrations with increased distance from shoreline. If this outfall were a significant source of impairment at Eichelman, a gradient of decreasing bacteria with respect to distance from this outfall would have likely been observed; this was not the case. Although the exact *E. coli* contributions from this outfall to surface water quality at Eichelman Beach cannot be quantified with data from this study, the impact was likely limited, particularly during dry weather. Although *E. coli* contributions were likely low, this outfall may have been a source of debris and floatables observed at Eichelman Beach.

71 Street Outfall. All samples collected from this outfall had *E. coli* concentrations greater than 1,000 MPN/100ml. However, flow from this outfall generally was not present (no flow on 62% of dates). Discharge from this outfall was associated with precipitation events (4/5 samples associated with precipitation). When flow was present, it was estimated at approximately one liter per second. Even though *E. coli* concentrations were typically high in effluent from this outfall, the impact it had on water quality was likely limited, particularly during dry weather. The distance from this outfall to the nearest sampling transect (600m, transect SP-1), the lack of flow on most dates, and low flow volume when discharge was present limits the impact this outfall had on recreational water quality.

73rd Street Outfall. Half (50%) of the samples collected from this outfall had *E. coli* concentrations below 235 MPN/100ml. Higher *E. coli* concentrations were associated with samples collected following precipitation events. *E. coli* concentrations in effluent from this outfall were greater than concentrations observed in open surface water samples at Southport, indicating it could behave as a potential source of impairment. The impact of this outfall on water quality at Southport Park was likely limited to large scale rain events.

75th Street Outfall. The majority of samples collected from this outfall (69%) had *E. coli* concentrations below 235 MPN/100ml. *E. coli* concentrations were significantly higher in effluent from this outfall following precipitation events compared to samples collected during dry weather. *E. coli* concentrations in samples from this outfall did not differ significantly from surface water samples collected at the nearest beach, Southport. Due to the distance from the beach (250 m) and generally low *E. coli* concentrations, the influence of this outfall on water quality at Southport Beach was limited.

Southport Outfall. *E. coli* concentrations in samples from this outfall were usually above 1,000 MPN/100ml (92%). Flow from this outfall was low during dry weather and would infiltrate into the adjacent sediments before reaching the lake. Although there was no difference in effluent *E. coli* concentrations between wet and dry weather, effluent would only reach the lake following precipitation

events. *E. coli* concentrations in effluent from this outfall were greater than concentrations observed at adjacent open water locations. Due to the close proximity to recreational water sampling locations (in between transects SI-1 and SI-2) and high *E. coli* concentrations, this outfall was likely a source of fecal contamination following precipitation events.

City of Kenosha Wastewater Treatment Facility. The median *E. coli* concentration of effluent from the wastewater treatment facility (240 MPN/100ml) was greater than recreational water quality standards, and concentrations were greater than at open water locations of Southport Beach. However, *E. coli* concentrations at Southport Beach did not respond to changes in the *E. coli* concentration or discharge volume of the wastewater treatment facility. The wastewater treatment facility discharges at a depth of five meters below the surface of the water, 500 meters south east of the beach. There were uncertainties gauging the hydrodynamics that indicated interactions between the beach and effluent on each day. Due to these uncertainties, it was unclear what impact the wastewater treatment facility has on water quality at Southport Beach; further investigation is merited to rule it in or out as a source of FIB.

Sediments

Sediments were described primarily as poorly sorted coarse sand with some gravel or gravel with some sand at Alford and Pennoyer Park. At Simmons Island and Eichelman, sediments were mostly described as well sorted medium to fine grain sands. Sediments were described as medium sands with the inclusion of gravel at Southport Beach. Fine particles (particles that passed through a #200 sieve) represented less than 0.1% mass at the majority of berm crest locations at all beaches except Eichelman. The consistent presence of finer particles at all berm crest locations of Eichelman Beach was likely related to the beach shape. The embayed nature reduces wave height at this beach allowing for smaller particles to settle. The rest of the beaches in this study, open water beaches, experience greater and more consistent wave action limiting the presence of finer particles. The greater presence of fine sediments, silts and clays, at Eichelman Park may provide conditions more favorable for the reproduction and survival of FIB (Skalbeck et al, 2010). This may be due to small particles having a larger surface area to mass ratio and greater water content which decreases the desiccation of bio-films.

When there were differences in sediment *E. coli* concentrations positionally within each transect (e.g. comparing berm crest sediments to middle beach sediment), higher *E. coli* concentrations were exclusively associated with berm crest compared to middle beach, back beach or submerged sediments. Higher *E. coli* concentrations were associated with berm crest compared to middle beach samples at one or more transect at all beaches: Alford Park (transects AP-1, AP-3) Pennoyer Park (transect PP-1), Simmons Island Park (transects SI-4), Eichelman Park (all transects) and Southport Park (transect SP-1). This same trend was present comparing berm crest to back beach sediment samples as well: Alford Park (transects AP-3, AP-5), Pennoyer Park (all transects), Simmons Island Park (transects SI-1, SI-2, SI-4 and SI-5), Eichelman Park (all transects) and Southport Park (transects SP-1, SP-2). At beaches where submerged sediments were collected (2012 only), there were also typically higher *E. coli* concentrations in berm crest verus submerged sediments: Simmons Island Park (transect SI-5) and Eichelman Park (all transects). These results indicate sediments along the shoreline had the greatest potential to influence

water quality due to higher overall *E. coli* concentrations and the greater presence of direct wave action; washing bacteria attached to sediments into nearshore water at these locations. These results were consistent with Skalbeck et al (2010) where *E. coli* concentrations were generally four times higher in shoreline (berm crest) sediments compared to back or middle beach sediments.

E. coli concentrations in sediment did not differ by position (berm, middle or back beach) across beach transects at Alford Park or Pennoyer Park. However, at Simmons Island, Eichelman and Southport Beach, there were significant differences in berm crest sediment *E. coli* concentrations depending upon sampling transect. *E. coli* concentrations were significantly higher at the berm crest locations of transects SI-3, SI-4 and SI-5 compared to samples collected from SI-1; samples from SI-5 were also higher than samples from SI-2. At Eichelman Park, berm crest sediments had significantly higher concentrations at transects EM-1 and EM-2 compared to samples at EM-3. Similarities were seen at Southport Park where berm crest samples from transect SP-2 had greater concentration than those from SP-3. At all beaches, except Southport, a significant difference in mean berm crest *E. coli* concentration between transects was also associated with significant differences in the mean *E. coli* concentration in surface water samples between the same transects.

At Simmons Island and Eichelman Beach, differences in *E. coli* concentrations were also present at middle and back beach sampling locations. Higher *E. coli* concentrations in middle and back beach samples at Simmons Island followed the same general pattern present in berm crest samples; higher *E. coli* concentrations were associated with southern sampling transects (SI-3, SI-4 and SI-5) and lower concentrations were associated with northern sampling transects (SI-1 and SI-2). At Eichelman, middle beach *E. coli* concentrations were significantly higher at transects EM-1 and EM-2 compared to transect EM-3. Variations in *E. coli* concentrations across transects suggest differences in sources or environmental variables. At areas where there were differences in *E. coli* concentrations in sediments across transects, the higher *E. coli* concentrations were generally located at areas wildlife frequented. Wildlife can transfer bacteria in their feces into sediments as an intermediate which can subsequently be transferred into the water (Koski and Kinzelman, 2009).

E. coli concentrations were greater in berm crest sediment samples at all transects and beaches compared to adjacent surface water samples collected on the same day. The results were the same in middle beach samples at Simmons Island (all transects) and Southport Beach (Transect SP-2) as well as back beach samples at Simmons Island (Transect SI-3, SI-4 and SI-5) and Southport Beach (Transect SP-3). Greater *E. coli* concentrations in sediments versus surface water samples indicate sediments can behave as a source of FIB. Although *E. coli* concentrations were greater in berm crest sediments than in adjacent water samples, *E. coli* concentrations in these media only correlated at select transects of Simmons Island: the berm crest at transects SI-1, SI-3 and SI-4, the back beach at transect SI-2 and submerged sediments at transect SI-3. The lack of correlation suggests that the release of bacteria from sediments into surface waters was transient. Previously published articles indicate wave action or wave run up can transfer bacteria between these two media (Kinzelman et al, 2004; Ge et al, 2010). If there was little wave action occurring at the time of sample collection, correlations between *E. coli* concentrations in these two media could be biased. Further sampling is necessary to determine the exact relationship and loading potential.

Wildlife

Gulls and geese were the most frequently observed species in number and dates at all beaches. Dogs and ducks were observed infrequently. However the distribution of wildlife numbers and species were not similar. Gulls were most frequently observed at the widest portions of the beach at Alford, Pennoyer, Simmons Island and Eichelman Park: transects AP-3, PP-3, PP-4, SI-4, SI-5 and EM-1. At Southport, gulls were most frequently observed roosting on the groin south of transect SP-1. Geese did not predominantly roost at a single transect of Alford, Pennoyer or Southport Park, but similar to gulls, geese were most prominent at the widest sections of Simmons Island and Eichelman Park. Gulls and geese were likely attracted to the widest sections of these beaches because these locations provided ample room to spot potential predators due to the general absence of vegetation on Kenosha beaches.

The presence of gulls at select transects of Alford (transect AP-3), Simmons Island (transect SI-4 and SI-5) and Eichelman (transect EM-3) were associated with higher *E. coli* concentrations than when absent. Additionally, the presence of geese were associated with higher *E. coli* concentrations at Eichelman (transect EM-1) and Southport Beach (transect SP-3). The presence of dogs or ducks was not associated with elevated *E. coli* concentrations. The only beach without a significant correlation between *E. coli* and some form of wildlife at any transect was Pennoyer Park. A study of Door County beaches rarely observed correlations between wildlife and *E. coli* concentrations (Kleinheinz et al, 2006) suggesting physical wildlife counts maybe a poor predictor of the fecal impact wildlife has on water quality. Other studies have observed the consistent presence of avian DNA markers in surface waters adjacent to where gulls tend to congregate. The presence of these DNA markers corresponded to higher *E. coli* concentrations in water samples (Lu et al, 2011). Even though there were no direct correlations between wildlife at Pennoyer Park, they likely impacted water quality directly or used sediments as an intermediary due to the large numbers observed, most notably at transects PP-3 and PP-4. In addition, gulls likely impacted water quality at transect SP-1 of Southport Beach due to their preferred roosting location. The location gulls tended to roost on at Southport beach, the groin south of transect SP-1, had no sediments or other media to limit the transfer of feces into the water. Most feces at this location were directly transferred into the lake, deteriorating recreational water quality.

Although dogs were observed infrequently and there were no correlations between their presence and *E. coli*, field notes indicated that poor pet management practices may have an impact on water quality. On several occasions, pet owners were observed refusing to pick up animal waste or worse, disposing pet waste into the lake.

Algae

Algal blooms, in water and stranded ashore, were frequently noted at all beaches. In terms of frequency of observations, in water algal blooms were observed most often at Eichelman (82.9% of samples), followed by Southport (69.0% of samples), Alford (67.7% of samples), Simmons Island (60.7% of samples) and Pennoyer Park (45.7% of samples). Stranded algal blooms were observed most frequently at Eichelman (66.0% of samples), followed by Simmons Island (55.5 % of samples), Alford (53.5% of samples), Pennoyer (49.7% of samples) and Southport Park (35.2% of samples). The

prevalence of algae at each beach was related to two factors: if algae growth occurred near the beach and beach shape. At Alford and Southshore Park, algal blooms were likely related to the growth of algae on rocky media at the beach. Large accumulations of stranded and submerged algae at Eichelman Beach are likely related to its embayed configuration. Once algal mats enter the beach area, there are no counter currents to remove it. Algae would remain on the beach until it decayed if not removed.

Moderate amounts of submerged algae were associated with elevated *E. coli* concentrations at select transects of Alford (transects AP-3, AP-4 and AP-5), Pennoyer (transects PP-2, PP-3, PP-4) and Eichelman Beach (EM-3 only). Moderate amounts of stranded algae were also associated with elevated *E. coli* concentrations at select transects of the same beaches (AP-3, PP-4 and EM-3). Algal blooms can contain high *E. coli* concentrations, numerous times higher than what are typically observed in water samples, indicating they can behave as a source of fecal contamination if dispersed into the water (Vanden Heuvel et al. 2010). It was unclear why algal blooms would be associated with higher *E. coli* concentrations at some beaches but not others. Perhaps the density of algae blooms was not as important of an explanatory variable as the shear stress applied to algal blooms which can serve to release the attached bacteria into the water column.

Air and Water Temperature

Air temperatures did not differ between study years except at Pennoyer Park where temperatures were higher in 2012 than in the previous year. This could have been caused by air temperatures being taken on average 30 minutes later in 2012 than in the previous year. Water temperatures were significantly warmer at all beaches in 2012 than in the previous years. Negative correlations were observed between *E. coli* concentrations and air temperatures at Pennoyer (PP-4), Eichelman (EM-2 and EM-3) and Southport Park (SP-2, SP-3); there were no correlations at other beaches. Water temperatures were also positively correlated with *E. coli* concentrations at select transects of Alford (AP-3, AP-4 and AP-5), Pennoyer (all transects), Simmons Island (SI1-, SI-3 and SI-4) and Southport Park (all transects). Warmer water temperatures and cooler air temperatures were associated with changes in wind directions. Eastern winds supported warmer water temperatures and cooler air temperatures. This suggest that correlations between air temperatures, water temperatures and *E. coli* were not caused by changes in temperatures, but were rather covariate with other factors that affect *E. coli* concentrations, wind directions.

Precipitation

Precipitation events were associated with higher *E. coli* concentrations compared to dry weather at all transects of Alford, Pennoyer, Eichelman and Southport Park and at the majority of transects at Simmons Island Park (transects SI-1, SI-2 and SI-3). The percentage of samples exceeding water quality standards was 4.8, 2.8, 2.2, 2.7 and 3.4 times greater at Alford, Pennoyer, Simmons Island (when precipitation was significant), Eichelman and Southport Park respectively. This suggests rainfall mediated processes such as increased discharge from tributaries, stormwater outfalls or localized runoff influences water quality at these beaches. However, at Eichelman Park, wave heights were also higher following precipitation events which may have influenced water quality in addition to precipitation.

Wind and Current Speeds and Directions

E. coli concentrations increased with the velocity of eastern (onshore) winds at all beaches except transects EM-1 at Eichelman Park and SP-1 at Southport Park. *E. coli* concentrations also correlated with the strength of western (onshore) currents at most locations. Higher *E. coli* concentrations were associated with western currents at select transects of Alford (AP-4 and AP-5), Pennoyer (all transects), Simmons Island (SI-5) and Southport Park (SP-2 and SP-3). Conversely, at transects SI-1 and SI-2 of Simmons Island, higher *E. coli* concentrations were associated with eastern (offshore) currents. Wind speeds and directions drive circulation patterns. Therefore an eastern wind, a wind traveling from east to west, will generate a western current, a current traveling from east to west. Wind speed and direction analysis was congruent with current speed and direction analysis except at transect SI-1 and SI-2 of Simmons Island. Higher sustained onshore winds and currents increase interactions between the water and shoreline, releasing bacteria from shoreline sources. Furthermore, onshore currents prevent point sources from diluting into offshore waters; promoting nearshore hydrodynamics which favor water quality exceedances.

At select transects, there were also correlations between wind velocities along the north/south axis with higher *E. coli* concentrations associated with southern winds at select transects of Alford (AP-3), and Simmons Island Park (SI-1, SI-2 and SI-3) and northern winds at select transects of Simmons Island (transect SI-5) and Southport Park (SP-3). Results from hydrodynamic models also indicate correlations between north/south current vectors and *E. coli* concentrations. Higher *E. coli* concentrations were associated with northern currents at select transects of Alford (AP-1) and Simmons Island Park (SI-1, SI-2, SI-3) and with southern currents at select transects of Simmons Island (transect SI-5) and Southport Park (transect SP-3). Similar to comparisons between east/west wind and current velocities, results between these two variables were congruent.

Wave Height

Wave height estimates were available from two sources, model (Great Lakes Coastal Forecasting estimates) and field technician estimates. Both sources of wave height estimates correlated significantly with each other. *E. coli* concentrations correlated significantly with wave heights from field technician estimates at all beaches except for transect SI-5 at Simmons Island. GLCFS estimates correlated with wave height estimates at all beach transects except for AP-1 and AP-2 at Alford Park and SI-5 at Simmons Island. Although both forms of wave height estimates correlated with *E. coli* concentrations at the majority of transects, field technician wave height estimates were a better explanatory variable for *E. coli* at all beaches except for transects SI-1, SI-2 and SI-3 of Simmons Island Park. The correlation between wave height and *E. coli* was likely due to the suspension and washing of bacteria from shoreline source such as coastal sediments, algal blooms and nearby fecal deposits.

Water Clarity and Turbidity

Water clarity descriptors, when assigned ordinal values, correlated with wave height estimates (either GLCFS or Field Technician estimates) at all locations. Higher *E. coli* concentrations were associated with more turbid water at all beaches (all transects). Furthermore, ordinal water clarity

descriptors correlated with analytical turbidity measurements when and where available (Alford, Pennoyer, Eichelman and Southshore Park in 2012 only) indicating water clarity descriptors were an accurate surrogate for turbidity measurements. At Eichelman Park, there was also a depth dependent relationship between turbidity; decreased turbidity was associated with increased sampling depth. The decrease in turbidity with respect to depth explained much of the reduction in *E. coli* observed further from the shoreline. Elevated turbidity in water samples can be caused by the suspension of coastal sediments, high levels of algae or other organic material in water samples, erosional processes and the introduction of suspended solids from allogenic sources (e.g. sediment plumes from rivers or outfalls). Correlations between wave height and water clarity indicate the suspension of coastal material via wave action was a major source of elevated turbidity. Coastal sediments contained high concentration of bacteria, particularly in sediments along the shoreline. Previous studies have also shown high *E. coli* concentrations in *Cladophora* (Vanden Heuvel et al. 2010). Interaction and suspension of these materials into the water contributed to elevations of *E. coli* in coastal recreational waters at all locations.

Debris

Debris was present on all the beaches for the majority of sampling events. Generally, the amount of debris was described as low, but was infrequently described as moderate. Moderate amounts of debris were usually associated with holidays or debris washing ashore. Following holidays, the majority of trash bins were full preventing the proper disposal of waste, notably at the most popular beaches. At other times, mostly at Simmons Island, trash cans were blown over by the wind. At times, large amounts of street litter were present at the shoreline of Eichelman beach suggesting it had washed ashore. Typical types of debris observed included: street litter, food-related waste, sewage-related debris, fishing-related items, building materials and clothing. Floatables were most frequently observed at Simmons Island (n=36) followed by Eichelman (n=31), Southport (n=11), Alford (n=10), and Pennoyer Park (n=9). The presence of more floatables at Simmons Island and Eichelman Park compared to the rest of the beaches suggest more of the debris on these beaches had washed ashore. The frequent presence of food-related debris may provide a steady food source for resident wildlife populations, indirectly, and adversely, influencing recreational water quality.

Beach Usage

Beach usage was greatest at Simmons Island, followed by Eichelman, Southport, Pennoyer and Alford Park. The majority of people at these beaches were not in the water. Due to the low number of people in the water, bather shedding of *E. coli* was not considered a significant source of fecal pollution. Typical activities people were engaged in included: walking, lounging, playing with pets (dogs), fishing, wading, swimming, collecting beach glass, kite surfing, exercising, playing in the sand, photography, metal detecting, kayaking/boating, flying kites and camping. The number of people observed at all beaches was likely low due to the time of day surveys were conducted which was not representative of peak bathing times. Visual observations at all beaches on weekends, taken once during the study period suggested moderate to high uses at all beaches other than Alford Park.

Circulation Patterns

Circulation patterns were investigated at Eichelman Beach on a single date in 2011 only. Results indicated little lateral dispersion of dye, except in the top most layers of water, and a clock wise circulation pattern, likely induced by a northwest wind, and the deflection of dye circulation near the breakwater to the south. Little lateral dispersion of dye along the shoreline suggests minimal dilution with offshore waters with respect to water close to the shoreline. The direction dye circulated on this date, clockwise, likely was reflective of the wind direction and probably varies based upon wind directions. The change in the direction dye circulated near transect EM-1 was reflective of the influence of the adjacent breakwater. The breakwater reduces circulation between beach water and water containing lower *E. coli* concentrations outside of the breakwater.

Conclusions and Recommendations

At all beaches, 15 percent of samples or greater exceeded water quality standards at one or more transect; these results are consistent with classification as impaired water bathing beaches. At some beaches, water quality was significantly different depending upon monitoring location(s). Sources of pollution varied depending upon the beach and at some beaches, varied between transects. Although sources of contamination varied, there were overarching sources of impairment at all beaches, i.e. non-point sources such as stormwater runoff. Other factors contributing to elevated *E. coli* concentrations, beach dependent, included: the Pike River, stormwater outfalls, sediments, wildlife, and excess algal blooms. Environmental factors associated with elevated *E. coli* concentrations included precipitation, on shore winds/currents, high wave heights, turbidity and in some cases, air and water temperatures as co-variants with other environmental parameters.

Several management practices can be instituted resulting in public health and ancillary aesthetic improvements. Some recommendations are specific to each beach while other can be applied to all beaches. Beach grooming practices should be evaluated to determine if current techniques can be optimized to decrease *E. coli* concentrations in sediments. Improper grooming techniques have been shown to increase sediment *E. coli* concentration, whereas deep grooming can reduce concentrations, likely through the desiccation of bacteria (Kinzelman et al, 2003; Kinzelman et al, 200b). This should decrease the probability of water quality exceedances by reducing the potency of a non-point source. Further, where possible, vegetated swales or buffers at the interface of impervious surfaces and turf grass and turf grass and sandy areas are recommended to reduce direct runoff onto beaches.

Efforts should be made to reduce the population of wildlife that loafs on or near all beaches. Although there was not significant correlation between the presences of wildlife and *E. coli* at all beaches, wildlife likely influences water quality due to the large amounts of *E. coli* in their feces and close proximity to the water. However, at select locations, there was a direct correlation between *E. coli* concentrations and the presence of wildlife. Wildlife loafing behavior on the beach should be reduced, specifically at areas where wildlife was most frequently observed: the widest sections of Alford, Pennoyer, Simmons Island and Eichelman beaches and the groin on the north end of the beach at Southshore Beach. This can be accomplished through either harassment techniques or habitat modifications. The use of Border Collies has been successful in reducing *E. coli* concentrations at other beaches (Converse et al, 2012). Habitat modifications have also been shown to be effective; this

employs dunes and other vegetation to create areas that could potentially harbor predators. The threat of predation deters wildlife from loafing on the beach. These techniques have been used at airports to reduce avian plane collisions and at other Great Lake beaches to improve water quality (Washburn and Seamans, 2004; GLSLCI, 2009). Habitat modification techniques may result in a reduction of usable space. Depending upon the level of integration necessary with existing park master plans, and the amount of open areas required, naturalized engineering control measures are viable options at all sites.

In addition, while there was not a clear link between elevated *E. coli* concentrations and *Cladophora* at all beaches, there was a direct relationship at some, i.e. Eichelman. Therefore, efforts should be made to remove algal biomass when present in moderate and high amounts to improve aesthetics and reduce FIB loading potential. Beyond direct water quality influences, *Cladophora* and associated invertebrates serve as a food source for wildlife which can indirectly influence water quality.

Sanitary survey data generated over the course of this study should be used to help create models that can predict water quality in real time. Water quality can change rapidly at bathing beaches and the water quality results of the previous day are not always representative of current conditions. This leads to some days when public health is not adequately protected (beach is open with poor water quality) and other days which can have negative economic consequences (beach is closed with acceptable water quality); this is problematic. Data collected as part of routine beach sanitary surveys may be used to create models that predict bacteria concentrations before analytical results are available. Several years of data have been generated, sufficient to create operation models, but models must be evaluated before implementation.

Specific recommendations for each beach are listed below:

Alford Park

- Continue to monitor the stormwater outfall located at this beach for changes in characteristics
- Develop models and identify characteristics to determine when the Pike River is influencing water quality
- Evaluate methods for cleaning up debris on the northern sections of this beach where rocky sediments prevent access using the beach groomer
- Institute best management practices to reduce wildlife loafing (habitat medications/shoreline naturalization), particularly at the center of the beach (transect AP-3)
- Consider large scale naturalization and habitat restoration at this site; it is not highly used for active recreational purposes and this type of site modification could enhance passive uses and deter nuisance wildlife

Pennoyer Park

- Continue to monitor the stormwater outfall located at this beach following stormwater basin planning efforts and infrastructure redesign and retrofit activities
- Continue to monitor outfalls to the south of the beach for changes in characteristics
- Develop models and identify characteristics to determine when the Pike River is influencing water quality and consider allowing it to return to a natural flow and discharge pattern

- Institute best management practices (habitat medications/shoreline naturalization) particularly at southern areas of the beach (transects PP-3, PP-4) to reduce nuisance wildlife

Simmons Island

- Continue to monitor stormwater outfalls located to the north of the beach for changes in characteristics
- Continue to monitor the Kenosha Harbor for changes in characteristics
- Evaluate best management practices to deter the presence of gulls/geese from the north end of the beach (including habitat modifications)
- Evaluate current waste receptacles used at the beach and consider replacing/modifying with ones that are covered/anchored to prevent wildlife feeding and blowing over.
- Increase the frequency of beach grooming and modify current grooming practices to decrease sediment bacteria concentrations
- Implement naturalized engineering control measures such as bioretention cells, swales, dunes, and vegetation to reduce loafing habits of gulls at the widest transects and intercept and redirect stormwater runoff (see attached conceptual redesign plan)
- Incorporate engineered and naturalized modifications and best management practices into Simmons Island Park master plan

Eichelman Park

- Continue to monitor stormwater outfalls near the beach for changes in characteristics
- Develop plans to fill in the pocket of standing water on the east side of the beach due to consistent high bacteria concentration at this location
- Increase the height of the breakwater on the east end of the beach to prevent waves from overtopping and investigate methods to decrease wave penetration near the beach area to prevent the pocket of standing water from reappearing
- Evaluate techniques to deter the presence of nuisance wildlife from the beach (habitat modification), notably on the east end
- Increase the frequency of beach grooming and modify current grooming practices to decrease sediment bacteria concentrations
- Implement naturalized engineering control measures to intercept localized stormwater runoff (see attached conceptual design plan)
- Improve beach accessibility, utility and aesthetics as it appears to be well used

Southport Beach

- Continue to monitor the stormwater outfall located at this beach and determine mitigation options to decrease *E. coli* concentrations/discharge volumes following precipitation
- Continue to monitor stormwater outfalls north of the beach
- Collect additional data to determine if/when the WWTP serves as a significant source of fecal contamination
- Evaluate techniques to deter the presence of gulls from the groin on the north end of the beach

The continued accumulation of sanitary survey data can provide guidance on future projects that may improve water quality. Continued monitoring will heighten awareness of beach health and provide knowledge to managers, state and local leaders, and the beach-going public to make well informed decisions.

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Appendix

GREAT LAKES BEACHES ROUTINE ON-SITE SANITARY SURVEY

Name of Beach:	Date and Time of Survey:
Beach ID:	Surveyor Name(s):
Sampling Station(s)/ID:	Surveyor Affiliation:
STORET Organizational ID:	

PART I – GENERAL BEACH CONDITIONS

Air Temperature: _____ °C or °F | Wind: Speed (mph) _____
Direction (e.g., E or 90°) _____ (From which direction the wind is coming)

Rainfall: ☐ <24 hours ☐ <48 hours ☐ <72 ☐ >72 hours since last rain event and _____ inches or _____cm rainfall measured

Rain Intensity: ☐ Misting ☐ Light Rain ☐ Steady Rain ☐ Heavy Rain ☐ Other

Weather Conditions:

Sky Condition	☐ Sunny	☐ Mostly Sunny	☐ Partly Sunny	☐ Mostly Cloudy	☐ Cloudy
Amount of cloud coverage	No Clouds	1/8 to 2/8	3/8 to 1/2	5/8 to 7/8	Total Coverage

Wave Intensity: ☐ Calm ☐ Normal ☐ Rough Wave Height: _____ft ☐ Estimated or ☐ Actual

Longshore current speed and direction (cm/sec, S or 180°):

Comments/Observations

PART II – WATER QUALITY

Bacteria Samples Collected (list samples collected from beach water and potential pollution sources, if applicable—see Part IV)

Sample Point	Sample #	Parameter (*E. coli*, enterococci, etc.)	Comments:

Water Temperature: _____°C or °F Change in Color? ☐ yes ☐ no If yes, describe _____

Odor: ☐ None ☐ Septic ☐ Algae ☐ Sulfur ☐ Other _____

Turbidity: ☐ Clear ☐ Slightly Turbid ☐ Turbid ☐ Opaque or NTU:

Comments/Observations

PART III – BATHER LOAD

Total number of people in the water: _____ Total number of people out of the water: _____

Total number of people at the beach: _____

List of Activities Seen (optional):

Type of Activity				
Number of People				

Comments/Observations

1 5/20/08

PART IV – POTENTIAL POLLUTION SOURCES

Sources of Discharge:

Type	River(s)	Pond(s)	Wetland(s)	Outfall(s)	Other (specify):
Name(s) of Source(s)					
Amount (H, M, L)					
Flow Rate (M/sec)					
Volume					
Characteristics					

Did you collect any bacteria samples from the sources listed in the table above? ☐ yes ☐ no

If "Yes", did you list the samples in the table in Part II, Water Quality? ☐ yes ☐ no

Floatables present: ☐ yes ☐ no Please circle the following floatables if found:

Type	Street litter	Food-related litter	Medical items	Sewage-related	Building materials	Fishing related	Household waste	Other:
Example	Cigarette filters	Food packing, beverage containers	Syringes	Condoms, tampons	Pieces of wood, siding	Fishing line, nets, lures	Household trash, plastic bags	

Amount of Beach Debris/Litter on Beach: ☐ None ☐ Low (1-20%) ☐ Moderate (21-50%) ☐ High (>50%)

Type of Debris/Litter Found (please circle)

Type	Street litter	Food-related litter	Medical items	Sewage-related	Building materials	Fishing related	Household waste	Tar	Oil/ Grease	Other:
Example	Cigarette filters	Food packing, beverage containers	Syringes	Condoms, tampons	Pieces of wood, siding	Fishing line, nets, lures	Household trash, plastic bags	Tar balls	Oil slick	

Amount of Algae in Nearshore Water: ☐ None ☐ Low (1-20%) ☐ Moderate (21-50%) ☐ High (>50%)

Amount of Algae on Beach: ☐ None ☐ Low (1-20%) ☐ Moderate (21-50%) ☐ High (>50%)

Circle the types of algae found

Type	Periphyton	Globular	Free floating	Other
Description	Attached to rocks, stringy	Blobs of floating materials	No obvious mass of materials	Please describe

Circle the color of algae found

Light green	Bright green	Dark green	Yellow	Brown	Other

Presence of Wildlife and Domestic Animals

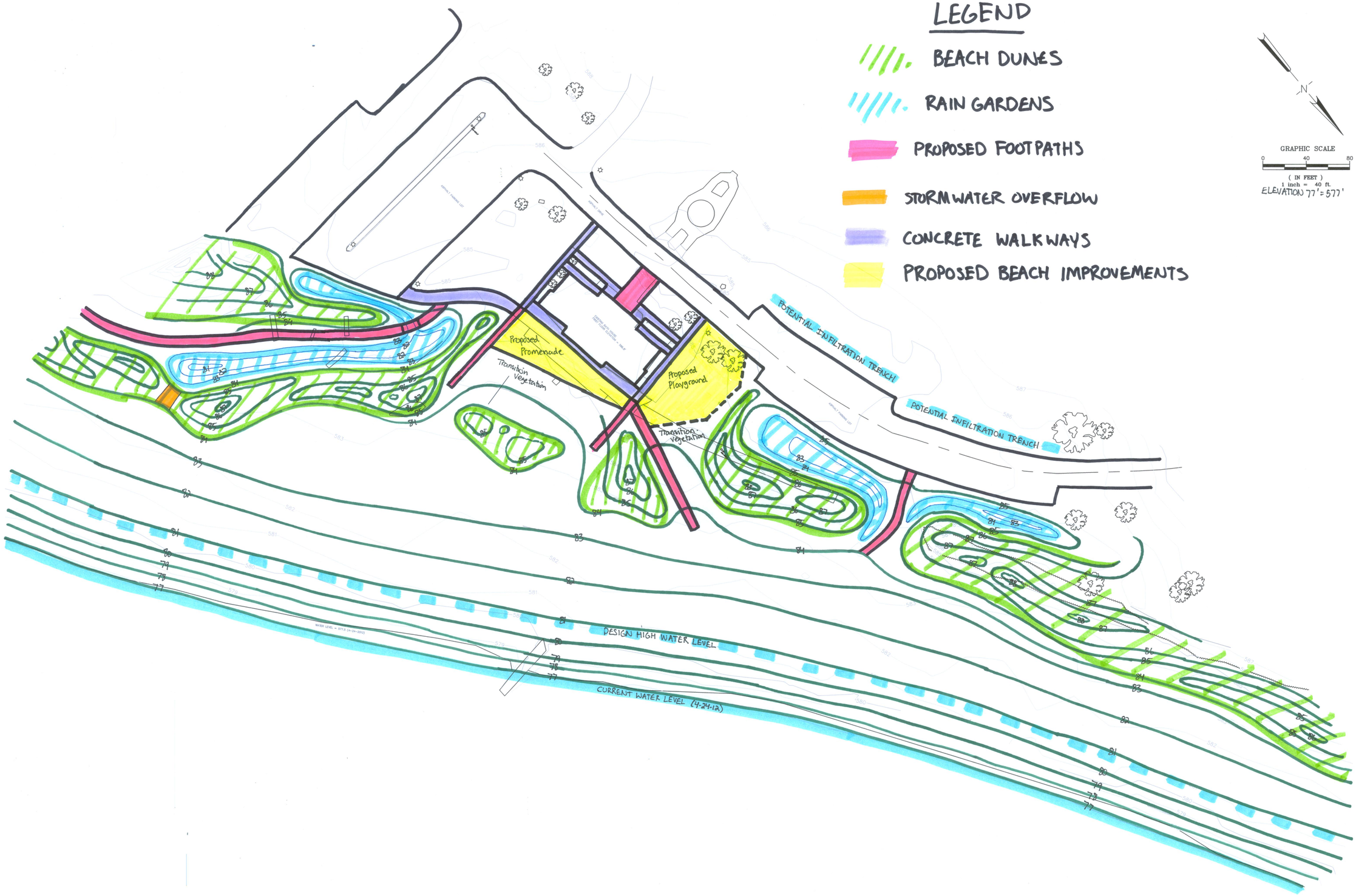
Type	Geese	Gulls	Dogs	Other (specify)
Number				

List the number of each species of bird found dead on the beach

Type	Common loons	Herring gulls	Ring-billed gulls	Double crested cormorants	Long-tailed ducks	White-winged scoter	Horned grebes	Red-necked grebes	Other
Number found dead									

Number of dead fish found on the beach: _____

Comments/Observations (continue on back if necessary):



PRELIMINARY

SITE DESIGN

MILLER ENGINEERS SCIENTISTS
5308 S. 12th Street
Sheboygan, WI 53081-8099
Phone 920-458-6164
Fax 920-458-0369
www.startwithmiller.com

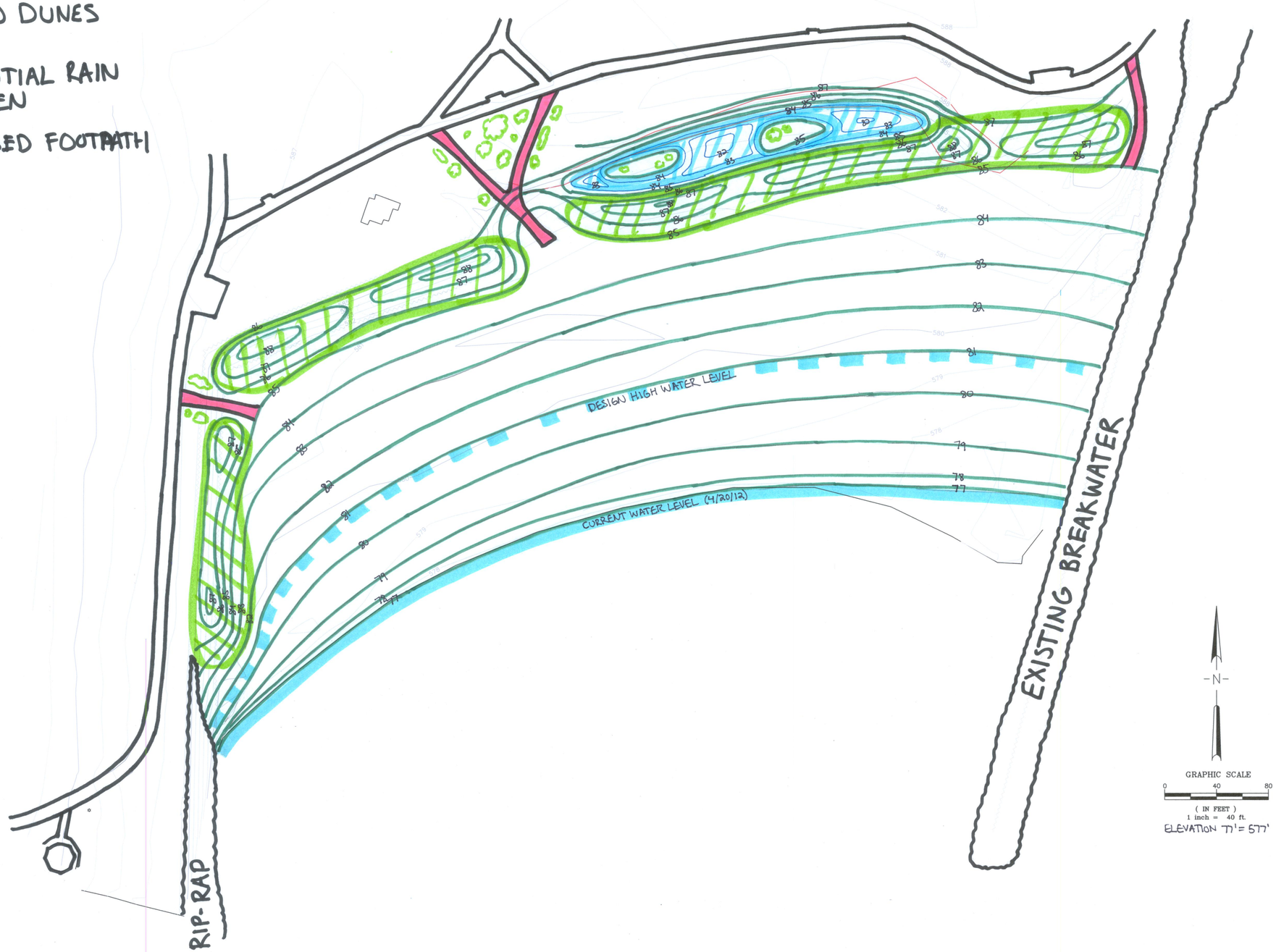
NO.	DATE	DESCRIPTION	BY

UW OSHKOSH
SIMMONS ISLAND
5001 SIMMONS ISLAND DRIVE
KENOSHA, WISCONSIN

SCALE HOR.	1"=40'
VER.	
DATE	4-27-12
JOB	10-18585
BY	TRO
CK	PGP
SHEET	1 OF 1

LEGEND

- SAND DUNES
- POTENTIAL RAIN GARDEN
- PROPOSED FOOTPATH



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NO.	DATE	DESCRIPTION	BY

UW OSHKOSH
EICHELMAN PARK
6125 3RD AVENUE
KENOSHA, WI

SCALE
HOR. X"=XXX'
VER.

DATE 4/4/12

JOB 10-18585

BY TRO

CK PGP

SHEET 1 OF 1