ABSTRACT

COMPREHENSIVE SANITARY SURVEY EVALUATION OF HIGH RISK BEACHES IN NORTHERN WISCONSIN

By Kimberly M. Busse

In 2008 13% of Great Lakes beaches exceeded health standards; approximately 90% of those exceedances were attributed to unknown pollution sources. In this project, sanitary surveys were conducted at all impaired beaches [CWA, 303(d)] in Northern WI to identify pollution sources and drive mitigation. This project covered the entire Lake Superior and northern Lake Michigan shoreline. One inland beach in northern Wisconsin as also selected to assess the transferability of the Great Lakes Beach sanitary survey tool to inland beaches (located on still or flowing waters). This project clearly addressed the goal of identifying unknown pollution sources by not only investigating sources of contamination at numerous locations around Wisconsin, but also began the process of planning for the mitigation of these microbial contamination sources. In years one and two of this project sanitary surveys (SS) were conducted at all northern Wisconsin beaches listed (and proposed) on the 303d list. Study beaches were located on the northern shore of Lake Michigan and Lake Superior, encompassing both rural and urban settings and various stages within the investigative process (none to fairly extensive monitoring with/without mitigation measures). The US EPA Sanitary Survey tools (routine and annual) were used to conduct site assessments for the purpose of determining probable pollutant sources and suggesting mitigation measures. Data collected as part of the sanitary survey process was entered into and archived within the WI "Beach Health" website such that they were accessible for the construction of predictive models. In year three of the study, a sample plan was developed based on previous years data to target potential pollution source identification. Based on three years of data, statistical analysis was conducted to identify sources at each of the ten beaches selected. Source identification was the first step in the effort to improve water quality at recreational beaches in Wisconsin.

COMPREHENSIVE SANITARY SURVEY EVALUATION OF HIGH RISK BEACHES IN NORTHERN WISCONSIN

by

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A Thesis Submitted
In Partial Fulfillment of the Requirement
For the Degree of

Masters of Science – Biology

Microbiology

at

The University of Wisconsin Oshkosh
Oshkosh, WI 54901-8621

June 2014

COMMITTEE APPROVAL

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6-23-14 Date Approved

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6-23-14 Date Approved

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6/23/14 Date Approved

DEAN OF
GRADUATE STUDIES

6-30-14
Date Approved

FORMAT APPROVAL

6/26/14
Date Approved

To my parents for their continued support throughout my educational career. In particular a great deal of gratitude is owed to my father for his guidance and advice to continue my education and obtain an advanced degree. It is because of him, I am where I am today. I also want to mention the rest of my family and close friends for their unconditional support through my educational journey. Finally, to my thesis advisor and mentor Greg Kleinheinz for his extraordinary encouragement and support throughout undergraduate and graduate school. He has always pushed me to my greatest potential and given me every professional opportunity he could. I will forever be grateful to him for sharing his passion for environmental quality and his desire to succeed.

ACKNOWLEDGEMENTS

I would like to first acknowledge the United States Environmental Protection Agency as the funding agency for this project. Through the Great Lakes Restoration Initiative, a total of $250,000 was awarded to identify pollution sources at select beaches in Wisconsin. I would also like to acknowledge Dr. Greg Kleinheinz and Dr. Julie Kinzelman as principle investigators on this project and who made this proposal a reality. I would like to acknowledge my thesis advisor Dr. Greg Kleinheinz and my committee members Dr. Colleen McDermott and Dr. Sabrina Mueller-Spitz for their support of my research. A special acknowledgement should be given to all of the staff and students at the Environmental Research and Innovation Center including but not limited to Brian Langolf, Nilay Sheth, Samantha Jo Kirst, Michelle Bogden-Muetzel, Ryan Bartell, and the many undergraduate students who all assisted as part of this project.

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INTRODUCTION

In 1998, the U.S. Environmental Protection Agency (US EPA) released a water quality standards status report outlining bacterial water quality standards for marine and freshwater recreational areas (64). In October 2000, Congress passed the Beaches Environmental Assessment and Coastal Health Act (BEACH Act) designed to reduce the risk of disease to users of the nation's coastal recreational waters (63). The aim of the BEACH Act is to better inform the public of health concerns at beaches by requiring states with coastal beaches (including Great Lakes beaches) to follow an approved plan for monitoring microbial contamination and for informing the public when established standards are exceeded (16, 48). While the BEACH Act allowed for determination of the amount of microbial contamination at various locations, its goal was not to identify the sources of the found contamination (23).

Potential Sources of Fecal Indicator Bacteria

Fecal indicator bacteria (FIB), like *Escherichia coli,* are organisms used to indicate potential public health risks associated with water impacted by humans and other animal feces (46, 47, 55, 65). Major sources of FIB include stormwater, wild and domesticated animals, sediments, and algae (*Cladophora*) (1, 2, 3, 66). Each FIB source requires a unique set of best management practices to prevent or control these potentially harmal organisms (34, 43).

Stormwater. Elevated FIB in stormwater runoff in urban areas, especially during wet weather, has been well documented (32, 53, 57). Recent studies have shown significantly elevated concentrations of FIB, well above regulatory limits, regardless of the type of land use in the watershed (11, 24). The sources of FIB in stormwater runoff can be from human-induced problems that may exist due to illicit connections of sanitary storm sewers, overflows, improper disposal of pet waste, and leaking of sanitary sewers (27, 30, 44). Even in smaller communities in Northern, WI, stormwater is still a large contributing factor to elevated *E. coli* concentrations in nearshore beach water (45).

Wildlife and Animals. There are several major types of wildlife and domestic animals that contribute FIB to lakes, streams, and rivers. The fecal material from various animals can carry harmful pathogens that can cause illness in humans (13). Avian species, especially the ringed billed gulls (*Larus delawarensis*) and herring gulls (*Larus argentatus*), are one of the main contributors of FIB at recreational beaches (20, 38, 42). Gull feces can contain up to $10^5 – 10^9$ CFU *E. coli* per gram, and ring billed gull populations increasing from 56,000-283,000 from 1976-1990, FIB concentrations become significant (8, 17). Several studies have been conducted to evaluate methods of geese and gull removal from beaches (12). Other animals, including humans, bovine, dogs, deer, and other wildlife, also are potential contributors to poor water quality (6, 26).

Sediments. Beach sediments are an important reservoir for FIB, such as *E. coli*. *E. coli* concentrations in the topmost layers of sand have been observed to be 3-38 times higher than adjacent surface water (3). Sediments provide an ideal environment for bacteria, where they are protected from inactivation due to sunlight, protozoan grazing, and are provided with nutrients (3, 15). FIB can persist at high concentrations in sediments throughout the swimming season, and it is suspected some degree of bacterial replication also occurs (7, 21, 52). FIB can be transferred from sediments to the adjacent surface waters by wind, precipitation events, and during periods of intense wave activity (bed shear stress and wave run-up) (25, 33, 36). Although no current regulatory standards exist for exposure to beach sands, they may pose a risk to public health when contaminated (28). Pathogens in sediments can be transferred to beach goer's hands, and ingested, resulting in illness (61, 67). In a study examining the impact of bacteria in beach sands on human health, patrons with significant exposure had a 20- 50% greater risk of developing gastrointestinal illness than individuals who were not exposed (28). 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 (37, 39, 40).

***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 (5). Phosphate removal from laundry detergents and more stringent wastewater regulation largely alleviated this problem. In addition to increased phosphate levels, lake levels have decreased in the last 20 years, allowing for more direct sunlight to penetrate deeper into shallow waters. This allows for increased growth of filamentous algae on rocky surfaces. *Cladophora* blooms have returned as a problem in recent years; believed to be caused, in part, by the introduction of quagga (*Dreissena bugensis*) and zebra (*Dreissena polymorpha)* mussels in the Great Lakes basin. Since the introduction of *Dreissenid* mussels, water clarity has improved significantly. This has led to an increase in the euphotic zone, increasing photosynthesis and promoting greater green plant growth. It is also hypothesized that *Dreissenid* mussels transfer nutrient rich (particularly phosphorous) feces and pseudo-feces to the benthic zone, which further increases algal growth (29).

Cladophora frequently occupies the nearshore areas of aquatic environments and washes ashore onto beaches. Whether submerged in the water or stranded on the beach, large amount of algae can negatively affect 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 (*Salmonella, Campylobacter,* and *Clostridium*) and FIB deposited by wildlife during the feeding process, which have the potential to survive for months, as well as reproduce, inside mats (9, 10, 66, 68). *E. coli* has been observed at densities of over 100,000 CFU per gram dry weight of algae (66) Pathogens and FIB associated with algal mats can be released into the water column during periods of intense wave action, resulting in beach closures (18, 22).

Microbial Source Tracking (MST)

When considering the risk associated with concentrations of pathogen indicator organisms, it is important to also consider the sources of these microbes (60). In recent years there have been many methods utilized and/or proposed for tracking the source of these contaminants in water – commonly known as *microbial source-tracking* (MST) (19). While high-tech methods receive attention from the media, funding agencies, and the public, methods such as sanitary surveys and spatial/temporal sampling of outfalls and water surrounding beach area are underutilized and need to be re-evaluated as successful and cost-effective options to MST.

Beach Sanitary Surveys

In light of the fact that approximately 95% of water quality advisories within the Great Lakes are not attributed to an identifiable contamination source (41, 48, 49), it is surprising that more locales have not adopted at least some of these strategies when confronted with the "mystery" associated with source identification of fecal contamination (14). After all, before sources can be mitigated they must be identified and all factors associated with the contamination source must be evaluated so that the best available strategy for mitigation can be adopted. This investigative approach has proven successful at several Great Lakes beaches.

The USEPA developed the Beach Sanitary Survey Tool (BSS) as part of the 2004 Great Lakes Regional Collaboration (GLRC) to provide local beach managers with a standardized and simplistic approach in potential pollution source identification (62, 63).

Prior to a 2007 pilot study targeted at implementation of the US EPA sanitary survey tool for beaches, 84% of study participants had unidentified pollution sources. After participation the number of unidentified sources was reduced to 24% (41). In Racine, WI a toolbox approach, combining site assessments, sanitary surveys, and source attribution techniques led to the development of targeted mitigation measures. These improvements resulted in a drastic improvement to surface water quality, with beach advisories/closures being reduced from 62 per bathing season to five or less for each of the last five years (2005 – 2009) (35, 36).

There are two types of sanitary surveys created, a routine sanitary survey (RSS) and an annual sanitary survey. The RSS should be conducted each time water quality samples are taken. The form included observational and physical measurements taken on or near the beach proper (Appendix C). The annual sanitary survey form records information regarding factors about the surrounding watershed that may affect water quality. The annual sanitary survey form also summarizes the RSS data collected throughout the beach season in an effort to identify potential pollution sources at the beach (63, 69).

Stepwise Approach to Beach Mitigation

The state of Wisconsin is the leader of the Great Lakes in water quality monitoring, identification of pollution sources at recreational beaches, development of beach redesign plans, and implementation of beach mitigation. This stepwise approach to beach restoration is unique and innovative to the researchers in the state of Wisconsin.

This approach is a "cradle to grave" approach to beach mitigation. The following steps outline this stepwise approach and the benefits of using this type of methodology (USEPA GLRI Proposals, 2010, 2011, 2012). This process was developed and proven through successional grant proposals submitted and awarded from the USEPA Great Lakes Restoration Initiative.

Initial Site Assessment. The initial site assessment includes visiting the beach and conducting an annual sanitary survey to identify potential pollution sources, including outfalls and tributaries, stormwater inputs, wildlife, topography and other physical characteristics of the beach, and other potential inputs of FIB (bathhouse, concession stand, garbage cans, etc). This assessment helps in developing a future sample plan at the beach to identify potential pollution sources (31). Studying Geographical Information Systems (GIS) information already available may show potential sources not easily identified directly at the beach.

Historical Water Quality. If the beach has been previously monitored, an evaluation of previously collected data is essential in understanding the water quality trends. These types of data include bather load, wildlife type and amount, water temperature, wave height, and *E. coli* concentrations. This understanding will allow for a proper development of a targeted and direct sample plan to identify pollution sources.

Developing a Sample Plan. Based on the initial site assessment and the historical water quality data, a sample plan is developed to conduct the proper sampling techniques from the appropriate locations. The sample plan generally consists of:

1. Conducting an annual sanitary survey each year of the study to identify any possible changes at the beach from the initial site assessment.
2. Conducting RSS three to five times per week to record physical and chemical components of the beach on a daily basis.
3. Collecting spatial water samples at various depths and transects to understand *E. coli* concentrations at different points in the water column in relation to the beach.
4. Collecting spatial sand samples at various transects to enumerate *E. coli* in different sand conditions.
5. Sampling sources of stormwater input including pipes, tiles, tributaries, and sheet flow from impervious sources to evaluate *E. coli* concentrations and the correlation with water quality in nearshore water.
6. Collecting samples for specific human or other animal markers from stormwater inputs at the beach to accurately identify pollution sources (if necessary).

Statistical Analysis. It is important to perform statistical analysis to determine relationships between physical, chemical, and biological parameters and *E. coli* concentrations. Types of analyses would include averages, linear regression, ANOVA, Tukey Post-Hoc test, paired t-tests, multivariate statistical regression, box plots, and several other statistical tests based on specific data collected. These types of analyses should help to develop an accurate characterization of potential pollution sources.

Beach Redesign. Once the sources are identified, a plan to mitigate the microbial input from each source should be developed in conjunction with community partners at select beaches. Based on the sources identified a conceptual engineering plan can be developed. These plans should have preliminary cost estimates and all general information needed for remediation of the beach location. Once these conceptual engineering plans are received by the communities the local unit of government can gather additional public input and then easily obtain construction-ready engineering plans that are tailored to the specific needs of the community as the next step. In some cases mitigation may require little, if any, cost and can be implemented at the local level. At a minimum, affected communities should have a plan to act upon at the local level when resources and interest allow.

Beach Implementation and Best Management Practices. This is a multiple step process including:

1. Working with local partners to conduct final public meetings to inform the public of the mitigation plans for their local beach restoration
2. Identifying the resources available and required to accomplish each beach restoration.
3. Conducting the actual beach restorations and mitigation work.
4. Developing Best Management Practices (BMP) for each beach.

5. Conducting BMP trainings for community members, if needed.

Water Quality Assessment Post Mitigation. It is imperative to conduct post-restoration monitoring to demonstrate effectiveness of the mitigation. A post-mitigation assessment should include at minimum one year of data collection once the mitigation is complete. This assessment should mimic the sample collection plan using BSS, investigative sampling, and source identification (NOAA Sea Grant, 2013-2014).

This project not only investigated sources of contamination at numerous locations in northern Wisconsin, but also began the process of planning for the mitigation of these microbial contamination sources. In years one and two of this project sanitary surveys (SS) were conducted at all northern Wisconsin beaches listed (and proposed) on the 303d list. Study beaches were located on the northern shore of Lake Michigan and on Lake Superior, encompassing both rural and urban settings and various stages within the investigative process (none to fairly extensive monitoring with/without mitigation measures). The USEPA Sanitary Survey tool (routine and annual) was used to conduct site assessments for the purpose of determining probable pollutant sources and suggesting mitigation measures. Data collected as part of the sanitary survey process was entered into and archived within the WI "Beach Health" website such that they are accessible for the construction of predictive models. Data was further analyzed to determine potential sources of contamination.

Additionally, in year three of the study, the sanitary survey data was used to assist in the beach redesign plans to reduce or prevent microbial contamination (plans not presented in this thesis). These redesigns were targeted at pollution mitigation in the form of stormwater treatment, and identified non-point sources. These redesigns would include all engineering and would be presented as construction ready projects to the local municipality.

OBJECTIVES

The overarching goal of this project was to evaluate high-risk beaches in northern Wisconsin in order to identify potential pollution sources so that beach redesign plans could be developed.

Specific Objectives:

1. To conduct a site assessment of each study beach using the USEPA annual sanitary survey tool to identify potential pollution sources and document physical characteristics of the beach.
2. To identify potential pollution sources at high-risk beaches in northern Wisconsin using the USEPA routine sanitary survey tool.
3. To evaluate relationships between physical, chemical, and/or biological parameters and fecal indicator bacteria at selected beaches.

METHODS

Study Sites

A total of ten beaches were selected in northern Wisconsin and were located on both the Lake Michigan and Lake Superior shorelines (Table 1).

Table 1: List of beaches selected for beach sanitary survey project.

Beach Name	**County**	**Water Body**
City of Kewaunee (Selner Beach)	Kewaunee	Lake Michigan
Crescent Beach	Kewaunee	Lake Michigan
Fisher Park Beach	Manitowoc	Lake Michigan
Kreher Park Beach	Ashland	Lake Superior
Maslowski Beach	Ashland	Lake Superior
Menominee Park Beach (Inland)	Winnebago	Lake Winnebago
Neshotah Beach	Manitowoc	Lake Michigan
Red Arrow Beach	Manitowoc	Lake Michigan
Thompson's West End Park Beach	Bayfield	Lake Superior
YMCA Beach	Manitowoc	Lake Michigan

City of Kewaunee Beach (Selner Park)

Figure 1. Aerial photo of City of Kewaunee Beach (Selner Park) in Kewaunee, WI.

Selner Park Beach is the official City of Kewaunee public bathing beach. There is park land and single-family beachfront residential property to the west, Pioneer Park and a breakwater to the north, and residential property to the south. Pioneer Park is located approximately 30 meters north of City of Kewaunee Beach (Selner Park) and is the two are treated essentially as one beach (Figure 1).

Crescent Beach

Figure 2. Aerial photo of Crescent Beach, marina, and Ahnapee River in Algoma, WI.

Crescent Beach is a municipal beach and located at the base of a small bluff. It is bounded on the north by a jetty and on the west side by park land. A major roadway and multi-purpose trail are above and run parallel to the beach (Figure 2).

Fisher Park Beach

Figure 3. Aerial photo of Fisher Park Beach in Manitowoc, WI.

Fisher Park is a rural beach located in southern Manitowoc County. The surrounding area is comprised mostly of agricultural land with some residential properties (Figure 3). The beach is located at the bottom of a bluff with a park located on the top, with public access to the beach on both the north and south ends of the park.

Kreher Park Beach

Figure 4. Aerial photo of Kreher Park Beach in Ashland, WI.

Kreher Park Beach is a municipal beach located in central Ashland, WI, on Lake Superior. This beach is located adjacent to a historical oar dock that was recently named a "Super Fund" site. This oar dock is currently being removed. The beach is below a large bluff that has a large municipal stormwater drain. This drain only flows during and after rain events. There is a marina west of the beach with heavy boat traffic. There is also a park and campground directly west of the beach (Figure 4).

Maslowski Beach

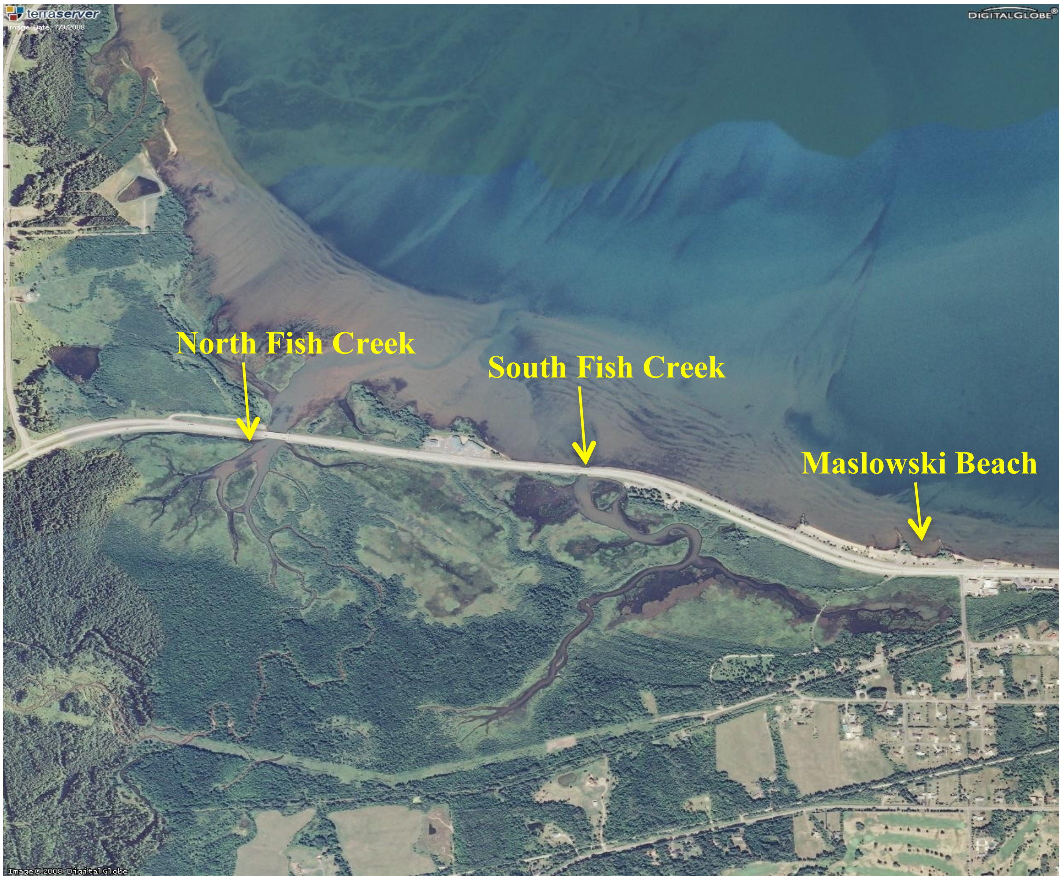


Figure 5. Aerial photo of Maslowski Beach in Ashland, WI, located on Lake Superior. North Fish Creek and South Fish Creek are west of the beach and potential pollution sources.

Maslowski Beach is a municipal beach located in Ashland, WI, along the shore of Lake Superior. Maslowski Beach is located on a major highway (Hwy 2) on the western edge of the City of Ashland. There is a large area of impervious surfaces surrounding the beach (Figure 5). Municipal stormwater drains from a seven-foot stormwater pipe east of the beach. There are two tributaries (North and South Fish Creek) west of Maslowski Beach that flow into Lake Superior and potentially contribute to poor water quality at the beach.

Menominee Park Beach

Figure 6. Aerial photo of Menominee Park Beach in Oshkosh, WI located on an inland lake, Lake Winnebago.

Menominee Park is an inland municipal beach located on Lake Winnebago in Oshkosh, WI. Menominee Park Beach is located within Menominee Park; a large park with a small zoo, baseball diamonds, and a marina. There is a large play area near the beach and a concession stand/bath house located upshore of the beach (Figure 6). The Oshkosh Water Treatment plant is directly south of the beach. Water intake for the plant is several hundred yards offshore from the beach.

Neshotah Beach

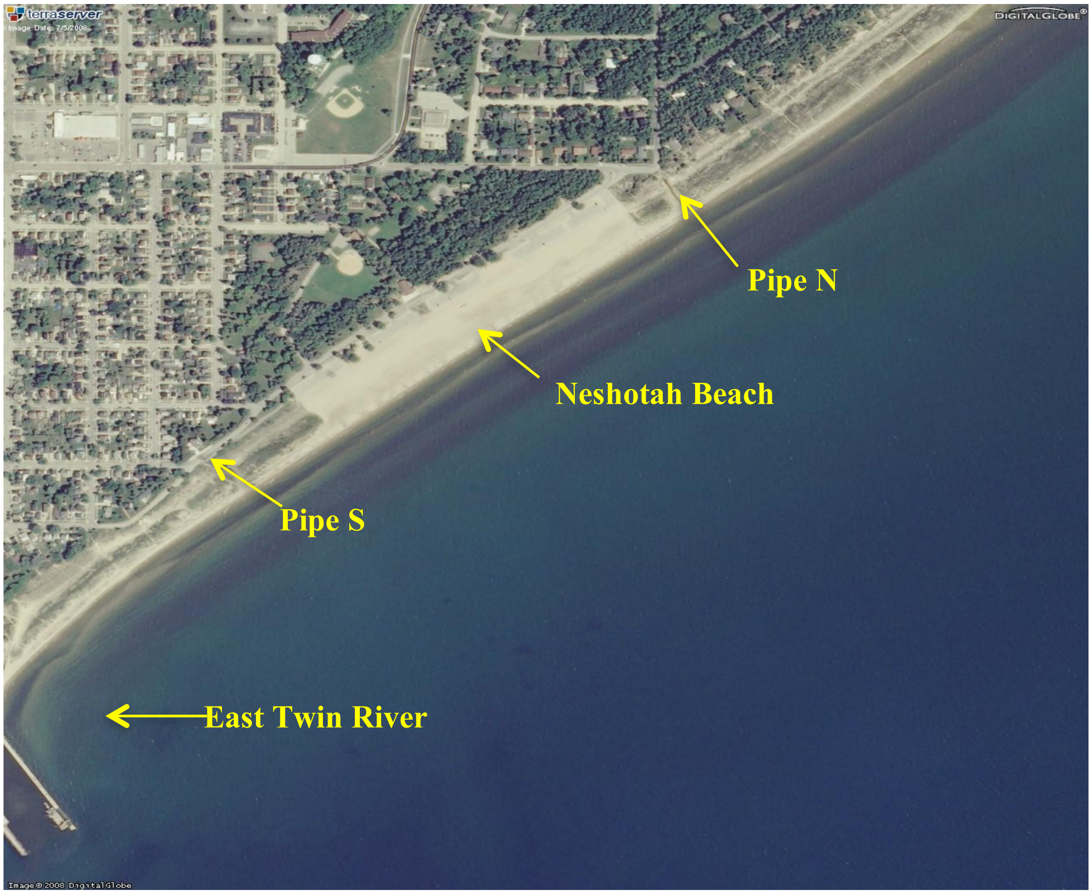


Figure 7. Aerial photo of Neshotah Beach in Two Rivers, WI, and nearby outfalls.

Neshotah Beach is a municipal/county beach used for swimming, walking, kite flying, and basketball. The beach is bounded by a road and parkland to the west (Figure 7).

Red Arrow Beach

Figure 8. Aerial photo of Red Arrow Beach, Manitowoc, WI and two outfalls located on the north and south end of the beach.

Red Arrow Beach is located in a very large municipal park. The lakefront is handicapped accessible and there is a beach walkway, boardwalk, and boat launch (north end). Surrounding area is comprised of park land and industrial sites, including a railroad. The beach is bounded to the south by a large stormwater outfall pond and to the north by groins (small pier-like structures) (Figure 8). About seven acres of the lakefront to the south of the beach has been set aside as a conservancy area. There are some concrete structures several hundred feet offshore, about mid-beach.

Thompson's West End Park Beach

Figure 9. Aerial photo of Thompson's West End Park Beach in Washburn, WI.

Thompson's West End Park Beach is primarily used for swimming, boating, and other recreational activities in the adjacent park and campground. There is a campground directly west of the beach and a jetty extending into the water to the south. There is also a boat launch bordering the east side of the beach with several docks (Figure 9).

YMCA Beach

Figure 10. Aerial photo of YMCA Beach in Manitowoc, WI.

YMCA Beach is located in an urban region of Manitowoc, WI. This beach is not only used for swimming, but a number of other recreational activities throughout the summer, including triathlons and dragon boat races. Surrounding area is primarily made up of impervious surfaces and hard infrastructure such as parking lots, a pier, a marina, and boulders placed for bluff stabilization (Figure 10). There is very little vegetation between the adjacent parking lot and beach proper.

Sampling Plan

A sampling plan was developed based on the initial site assessment to evaluate all potential pollution sources. Routine sanitary surveys (RSS) were conducted at all beaches one to four times a week in 2010 and 2011, and 2012. Each plan included frequency of sampling, water and sand sampling locations, and investigative sampling locations (outfalls, tributaries, impervious surfaces, and other). This plan was adjusted based on each year of data collected to target specific sources of pollution discovered at each beach.

Annual Sanitary Surveys

Annual sanitary surveys were conducted in all three years of the study (2010-2012). An annual sanitary survey is more comprehensive than a RSS in that it not only evaluates the beach proper, but includes the entire surrounding watershed. With an annual sanitary survey, the length and width of the beach are measured, potential pollution sources are identified, topography of the beach is documented, the surrounding area is categorized (e.g. rural, agricultural, residential), and RSS data is compiled and analyzed for the entire beach season. An annual survey was conducted on each beach once a year to determine the condition of the beach, locate potential pollutant sources, and determine whether there was other issues that could affect water quality. This survey was conducted by the end of a beach season, before the next season began. Based on information discerned from that survey, changes were made to the current monitoring program before the next season began.

Collection of Samples

To assure consistency in collecting samples for analysis, specific sites were designated for collecting samples during the bathing season. Samples were collected exclusively at these sites for the duration of the sampling period. Sample bottles were prepared and provided by the laboratories charged with conducting bacteria analyses (UW Oshkosh).

General Rules of Sampling. Extreme care was taken to avoid contaminating the sample and sample container when samplers were at the beach. The bottle covering and closure was not removed until just prior to obtaining each sample. The inside of the sample container was not touched or contaminated in any way. The sample container was not rinsed prior to sampling. Caps were not placed on the ground or in the water while sampling. Samples were not transported with other environmental samples and were always placed on an ice slurry. Samples were analyzed within USEPA hold times for surface water, which is six hours from collection. Samples were labeled, iced or refrigerated at 1 - 4 degrees Celsius immediately after collection and during transit to the lab. Care was taken to ensure that sample bottles were not totally immersed in water during transit or storage. The sampler completed the laboratory data form noting time, date, and location of sample collection, current weather conditions (including wind direction and velocity), water temperature, clarity, wave height and any abnormal water conditions.

Sampling Method. The following procedure was carried out for all samples that were collected. The sampler carefully moved to the sampling location. The water depth was previously determined by the specific sample plan (30, 60, 120 centimeters). While wading slowly in the water, the sampler avoided kicking up bottom sediment at the sampling site. The sampling bottle was opened while grasping it at the base with one hand and the bottle mouth was plunged downward into the water to avoid introducing surface scum. The sampling depth was approximately 15 to 30 centimeters below the surface of the water. The bottle mouth was positioned into the current away from the sampler's hand. If the water body was static, an artificial current was created by moving the bottle horizontally with the direction of the bottle pointed away from the sampler. The bottle was tipped slightly upward to allow air to exit and the bottle to fill. The bottle was completely filled before removing it from the water. The bottle was removed from the water body and a small portion of water was poured out to allow an air space of 2 centimeters for proper mixing of the sample before analyses. The cap was closed tightly and the bottle was labeled. The sample was stored in a cooler filled with ice immediately following collection.

Collection of Surface Water Samples. Spatial and depth water samples were collected one to four times per week during the summer months (May-August) at sanitary survey beaches and analyzed for *E. coli* concentrations. A total of ten water samples were collected on these days. Samples were taken at the left, center, and right of the beach and at 30, 60, and 120-centimeter depths (Figure 11). In addition, a tenth sample was collected at the center 60-centimeter location for turbidity analysis (sample was collected in the field and analyzed in the lab). Data was recorded in Microsoft Excel and an online database created by the United States Geological Survey (USGS) called GLRI.

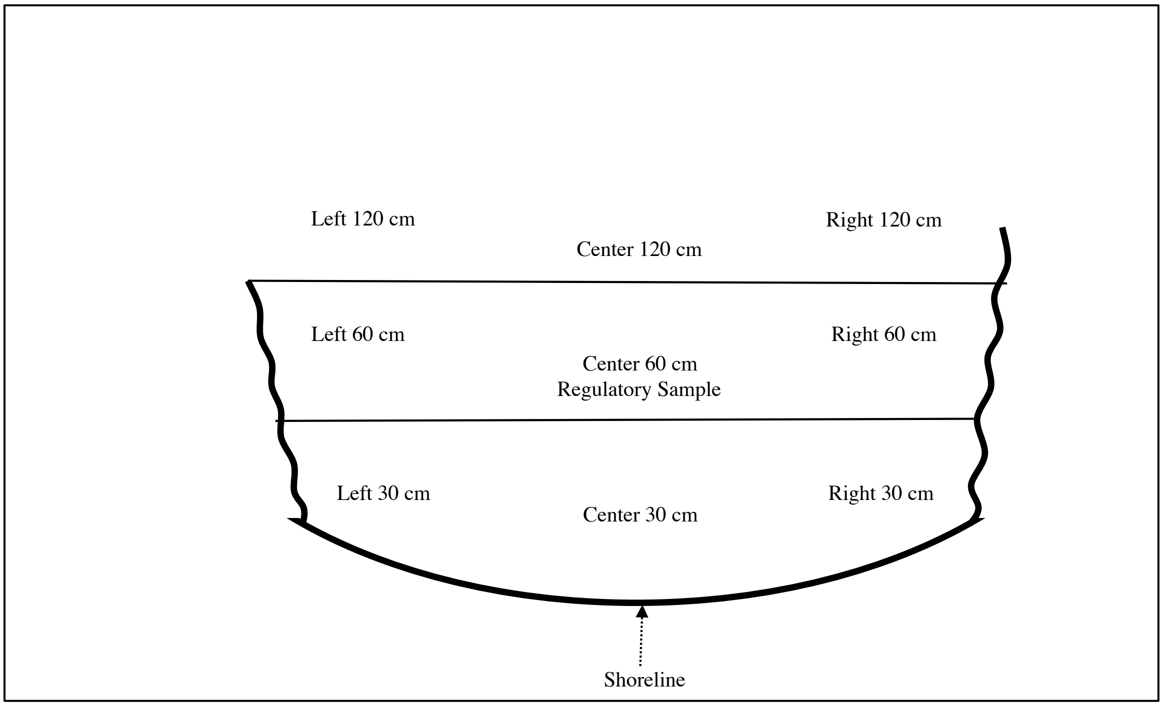


Figure 11. Location for water samples for sanitary survey water testing. An additional sample was taken at middle, 60 centimeter for turbidity.

Collection of Sand Samples. Sand or sediment was collected at sanitary survey beaches and analyzed for *E. coli* concentration using Colilert (IDEXX, ME) on a biweekly or monthly basis depending on the beach. A total of nine sand samples were collected at each beach using a sediment core sampler and were collected three days per week. Sand (7.2 cm^3 per sand core) was collected at the left, center, and right of the beach at upshore, swashzone, and 60 centimeter depths (Figure 12). Note, that the routine monitoring water samples were still collected during the sand sampling week for reporting purposes (collected at center of the beach, 60 centimeters depth of water). Data was recorded in Microsoft Excel and an online database created by the United States Geological Survey (USGS) called GLRI.

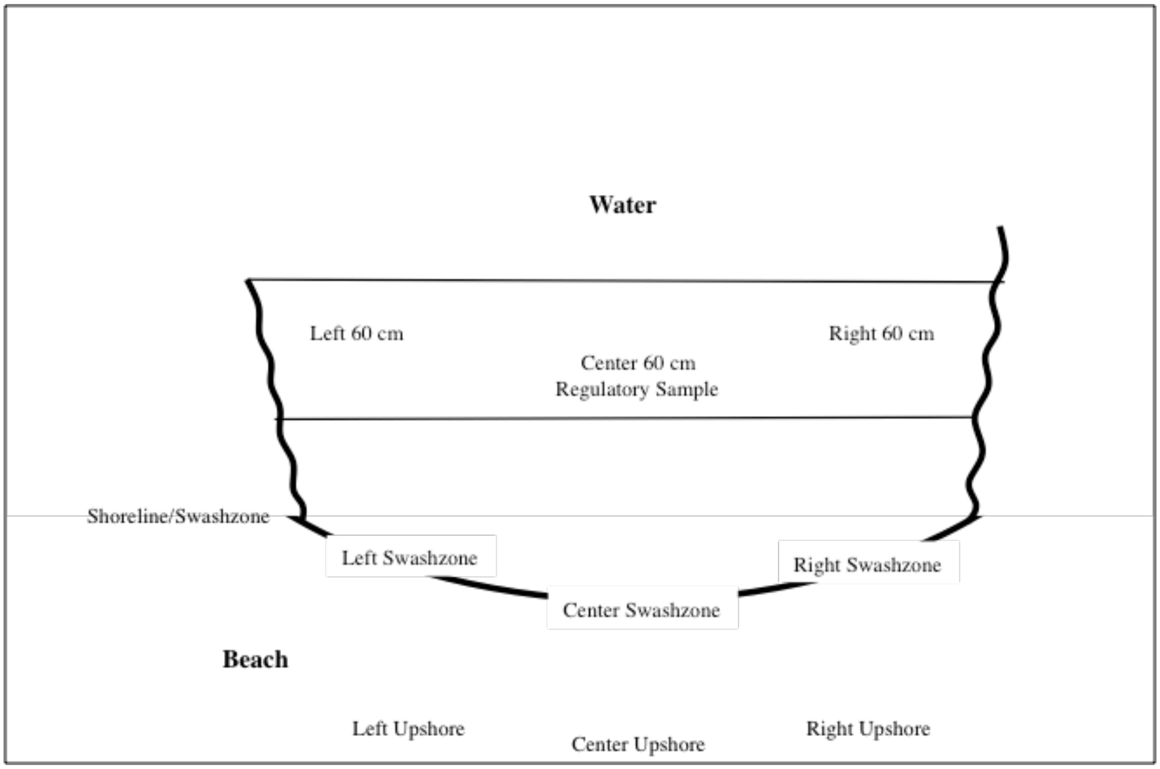


Figure 12. Location for samples for sanitary survey sand sampling.

Collection of Investigative Samples. Potential pollution sources were identified in the initial site assessment. If samples were able to be collected from these sources they were incorporated into the sample plan. These samples were collected in the same frequency as surface water samples and also collected during sand collection events. Some examples of investigative samples included stormwater pipes and tiles, tributaries (rivers, streams, and creeks), runoff from impervious surfaces, and additional surface water samples. Tracking stormwater contamination in the municipal stormwater system also occurred. These samples were analyzed and statistically compared to *E. coli* concentrations at the beach.

Routine Sanitary Surveys

A routine sanitary survey (RSS) was conducted each time the beach was visited. Below is the list of data fields required, along with a description of sampling protocol for each parameter. The procedure followed for conducted RSS was from the USEPA Great Lakes Beach Sanitary Survey User Manual (EPA-823-B-06-001) developed in 2008.

General "weather" conditions were observed, including air temperature, rainfall, wind speed and direction, sky conditions, wave height, and longshore current direction and speed. Air and water temperatures were measured using a digital thermometer and recorded in Celsius.

The amount of rainfall was recorded in centimeters, as was the time (24, 48, 72, or more hours) since the rainfall event occurred. If rainfall was measured using a rain gauge near the sampling stations (weather station or airport), the distance from the rain gauge was recorded in miles. The intensity of the rainfall was also documented. An anemometer was used to measure the speed of the wind (Skymaster SM-28, Great Falls, VA). Wind direction was always reported as the direction from which the wind is coming. When reporting wind speeds, the data was always reported in miles per hour (mph).

Sky conditions were estimated based on a scale used by the National Oceanic and Atmospheric Administration (NOAA) and further by the USEPA Sanitary Survey Manual. Wave height was measured by estimating using the units with which the sampler was most comfortable. In this case all units were converted to centimeters. The wave intensity was documented on the survey form. Longshore current speed and direction were measured using a method adapted from Education Program at the New Jersey Marine Sciences Consortium. The procedure used a tape measure for distance, an orange, a stopwatch to time the orange from point A to B, and the formula speed = distance/time. The final units were calculated as cm/sec for current speed. To measure current direction, the direction the orange flowed was observed. Current direction, recorded in degrees, was the direction toward which the current was going (as in 0 to 360 degrees, 0 being north, 90 east, 180 south, and 270 west). If a current was going from north to south, the current direction is recorded as south or south-going; similarly, a current going from east to west is recorded as west or west-going.

Water Quality

FIB , including *E. coli*, were enumerated froms amples using the most probable number, ONPG-MUG test (Standard Methods 9223B, AOAC 991.15, Colilert, Colilert-18, and Autoanalysis Colilert). Further description of analysis is found under the section *E. coli* Enumeration in Surface Water. Water temperature was measured using electronic thermometers (Fisher Scientific, Ann Arbor, MI) capable of measuring to the tenth of the degree Celsius. The sampler noted odor during sampling and recorded it on the survey form. Turbidity was measured using a nephelometer (LaMotte 2020we, Chestertown, MD) and recorded as NTU’s. Samples were measured per manufactures instructions at the lab. The bather load was recorded by counting the number of people residing at the beach, in the water (e.g., swimming, diving, clamming) and not recreating in or on the water.

Visible sources of pollution affecting the beach up to 152.4 meters from the sampling station were identified. If visible sources were suspected of affecting water quality, bacterial samples were collected from these sources. If floatable debris was observed it was documented on the RSS form.

The amount of algae found in the nearshore water and covering the beach was estimated and recorded. There are separate fields on the RSS form for algae in the nearshore water and for algae on the beach itself. The types of algae present, if known, were recorded, as well as the color of the algae. Additional information was given, if needed, in the Comments and Observations section of the form.

The presence of animals at the bathing beach was determined through visual observation. In the Comments and Observations section the number of each type of animal present in the water, on the beach, and in the air was recorded. Dead birds on the shore or in the water or on the beach were recorded during the RSS. If the species of bird could not be identified, a description of the bird was written or a photo was taken, if possible. The number of dead fish on the beach or in the nearshore water was counted and recorded. If the species of fish could not be identified, a description of the fish was written or a photo was taken, if possible.

***E. coli* Enumeration in Surface Water**

Samples arrived at the laboratory on an ice slurry within 6 hours of sample collection. Samples were analyzed within 8 hours of collection according to EPA standards. Bench tops were properly sanitized prior to analysis. The sample bottle was shaken approximately 25 times or for 2 minutes to homogenize the water sample. The excess water was poured out to the marked 100 milliliter (mL) line to produce a 100 mL sample of water. Once the sample was at proper volume, contents of one snap pack (Colilert or Colilert-18, IDEXX, ME) were added to the 100 mL water sample in the sterile vessel. The vessel was capped and shaken until dissolved (approximately 2 minutes). If the Colilert did not readily dissolve, the sample was warmed to room temperature and mixing began again. The sample/reagent mixture was poured into a sterile Quanti-Tray®/2000. The tray was placed into the IDEXX Quanti-Tray® Sealer (IDEXX, Main). It was then heated and completely sealed by the time the tray was removed from the sealer. The sealed tray was placed in a 35° ± 0.5°C incubator for a minimum of 24 hours (18 hours if using Colilert-18). The Quanti-Tray was observed for color changes (yellow) and fluorescence. The numbers of positive wells (small and large) were counted separately and the MPN table was used to obtain a Most Probable Number (MPN). Fluorescence was observed with a 6-watt, 365 nm, UV light held within five inches of the sample in a dark environment. The results were reported as *E. coli* MPN/100 mL of water.

***E. coli* Enumeration in Sand**

Sand samples were collected using a pre-sanitized sand sleeve at approximately 15 cm sand depth at locations previously determined in the sample plan created by UW Oshkosh researchers (4). Caps were placed on the sleeves, labeled, and returned to the lab on ice. At the designated laboratories, empty wash cups were placed on a balance and tarred. Approximately 25 g of sand was poured into the sterile empty wash cup and the exact weight of the sand was recorded. Approximately 100 mL of 0.85% saline was added to the cup containing the pre-measured sand. The lid was replaced and the contents shaken for approximately two minutes. The container was placed on the bench to allow sand to settle down. Once the sand was settled, 10 mL of supernatant was aseptically transferred using a serological pipette to a 100 mL sterile sample bottle. Sterile saline was added to the 100 mL line of the bottle resulting in a 1/10 dilution and mixed. Colilert was added to the 100 mL of sand wash solution and mixed well. The contents of the bottle were poured into a labeled Quanti-Tray® 2000 and sealed. The samples were incubated for 24 hours at 35° ± 0.5°C. The Quanti-Tray was observed for color changes (yellow) and fluorescence. The numbers of positive wells (small and large) were counted separately and the MPN table was used to obtain a Most Probable Number (MPN). Fluorescence was observed with a 6-watt, 365 nm, UV-light held within five inches of the sample in a dark environment. The *E. coli* concentration calculated from the MPN table was multiplied by ten to obtain the number of *E. coli* in the undiluted wash solution. The final result was expressed as concentration of *E. coli* MPN/g of wet weight of sand (which was previously weighed). The wet sand was saved at room temperature for particle size determination. Sand sleeves were disinfected in a 10% bleach solution for 24 hours, rinsed with DI water and allowed to dry.

Statistical Analysis

Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters, and *E. coli* concentrations determined from samples collected at the center of the beach at 60 centimeters water depth. Parameters with the highest R^2 value were further evaluated using other statistical tool including linear regression, ANOVA, Tukey Post-Hoc test, paired t-tests, multivariate statistical regression, box plots, and several other statistical measures based on specific data obtained. While these factors alone do not explain all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations. The overall goal of the statistical analyses was to accurately characterize potential pollution sources identified by the beach sanitary survey process.

RESULTS

In this project, approximately 7,500 water and sand samples were collected over the three-year study, which averaged approximately 750 samples per beach. These samples were collected from multiple transects and depths and designated outfalls. Each beach had its own individual sample plan to target possible contamination sources identified in the annual sanitary surveys. Samples were analyzed for *E. coli* concentrations. In addition to sample collection, other parameters were recorded including ancillary data such as weather conditions, water conditions, animals, and debris and litter on the beach. All of these parameters were analyzed and later correlated with *E. coli* concentrations to identify potential pollution sources.

Historical Water Quality

An evaluation was conducted of historical water quality data, previously collected and funded by BEACH Act since 2003. Regulatory samples were collected from the center of the beach at 60 cm water depth. Based on this historical data the Wisconsin Department of Natural Resources (WDNR) determined that beaches with a predetermined number of exceedances and poor water quality over a set number of years were placed on the USEPA Impaired Waters List (303d). All beaches selected as part of this study were previously or currently on the USEPA Impaired Waters List (303d).

Table 2: Average *E. coli* (MPN/100mL) from 2003 - 2012. Data collected prior to 2010 was for BEACH Act routine monitoring purposes.

Beach	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total Average
Crescent Beach	354.2	656.6	483.2	258.5	383.6	226.6	97.2	144.0	361.0	191.6	**315.7**
Fisher Park	303.3	361.6	84.4	682.9	298.1	569.8	80.1	502.1	231.4	375.9	**349.0**
Kreher Park	40.7	147.2	85.4	134.2	57.8	42.8	150.4	104.7	144.4	143.8	**105.1**
Maslowski Beach	187.0	220.2	164.0	98.1	107.8	137.8	89.1	201.6	178.8	280.5	**166.5**
Menominee Park	x	x	x	x	x	x	x	109.2	87.6	128.1	**108.3**
Neshotah Beach	308.9	473.8	197.0	669.1	199.5	246.3	67.9	59.1	122.8	55.1	**240.0**
Red Arrow Park Beach	323.4	281.7	173.2	721.6	473.9	462.1	133.2	577.4	416.3	322.1	**388.5**
Selnar Park, City of Kewaunee	178.4	180.3	431.0	398.9	480.4	335.4	51.5	304.7	329.1	150.1	**284.0**
Thompson's West End	31.5	97.7	193.2	375.4	227.6	151.0	20.5	198.0	154.7	88.3	**153.8**
YMCA Beach	567.9	377.5	315.8	1285.8	832.5	x	x	562.5	461.2	465.2	**608.6**

*x indicates that there was no data collected

In Table 2, six of the ten selected beaches have averaged above the regulatory threshold of 235 MPN/100mL over the last 10 years of routine monitoring data. The number of exceedances (>235 MPN/100mL) averaged 4 – 14 days per year for a majority of the beaches selected in this study. The total exceedances over ten years ranged from as low as 6 to as high as 129 (Table 3). By only evaluating historical *E. coli* data, a determination can be made that these beaches have poor water quality and require additional investigation.

Table 3: Number of exceedances (*E. coli* >235 MPN/100mL) resulting in a beach advisory or closure over a ten year period.

Beach	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total Exceedances
Crescent Beach	13	16	12	11	13	2	4	8	9	5	**93**
Fisher Park	12	11	2	6	10	16	1	20	7	11	**96**
Kreher Park	1	6	2	3	1	1	5	5	8	4	**36**
Maslowski Beach	5	8	5	2	5	7	1	6	4	20	**63**
Menominee Park	x	x	x	x	x	x	x	2	2	2	**6**
Neshotah Beach	16	10	5	13	12	16	0	2	7	1	**82**
Red Arrow Park Beach	18	10	4	14	12	13	4	23	17	14	**129**
Selnar Park, City of Kewaunee	7	4	3	7	6	3	0	13	15	1	**59**
Thompson's West End	0	1	2	7	8	3	0	9	8	4	**42**
YMCA Beach	20	11	7	22	22	x	x	7	16	14	**119**

*x indicates there was no data collected

Annual Sanitary Survey Results

Several physical parameters were evaluated by the annual sanitary survey. An annual survey was conducted each year of the project (2010-2012) at all select beaches. The main physical parameters are described in Table 4. Beach length, width, slope, and sand particle size were evaluated each year and averaged. The other physical parameters, including location, primary land use, bounding structures, and outfalls/tributaries, remained the same over all three years. Potential pollution sources identified included stormwater, algae and waterfowl.

Table 4: Annual Sanitary Survey results indicating physical parameters and potential sources identified each year of the survey.

Beach	*Beach Length (m)	*Beach Width (m)	% Slope	*Sand Particle Size (in.)	Beach Location	Primary Land Use in Watershed	Bounding Structures	Outalls Identified (Y/N)	Tributaries Identified (Y/N)	Other Potential Pollution Sources
Crescent Beach	802	31	10	0.021	Urban	Agrigultural	Seawall	Y	Y	Gulls/Algae
Fisher Park	194	9.4	15	0.026	Rural	Agricultural	None	Y	Y	Algae
Kreher Park	71	14	10	0.061	Urban	Forest	Jetty/Oar Bridge	Y	Y	Sheetflow
Maslowski Beach	361	53	<10	0.057	Urban	Forest	Jetty	Y	Y	Geese
**Menominee Park	43	11	15	X	Urban	Agricultural	Parking Lots	N	Y	Geese
Neshotah Beach	658	75	10	0.030	Urban	Residential	Seawall	Y	Y	Gulls
Red Arrow Park Beach	372	21	<10	0.023	Urban	Residential	Parking Lots	Y	Y	Gulls
Selnar Park, City of Kewaunee	77	49	10	0.061	Urban	Agricultural	Parking Lots	Y	Y	Algae/Gulls
Thompson's West End	236	10	10	0.048	Urban	Forest	Jetty	Y	Y	Geese
YMCA Beach	115	11	10	0.060	Urban	Forest	Pier	Y	Y	Gulls

*Indicates average values over 3 years of data
**Demonstration site on inland lake.
NOTE: Urban indicates beach located within the city limits. Rural is located outside the city limits.

Routine Sanitary Survey Results

Routine sanitary surveys were conducted three to four times per week for the duration of each summer beach season (May – August). Water samples were collected at a minimum of three transects (north, center, and south) and three depths (30 cm, 60 cm, and 120 cm). After the first two years of sampling, collection was more concise to target potential pollution sources. Figure 13 illustrates an overall summary of water quality over the three years of the project based on average *E. coli* concentrations. In most cases *E. coli* concentrations did not statistically vary over each year ($p>0.05$). However, multiple years of data are required to evaluate changes in weather and other impacts.

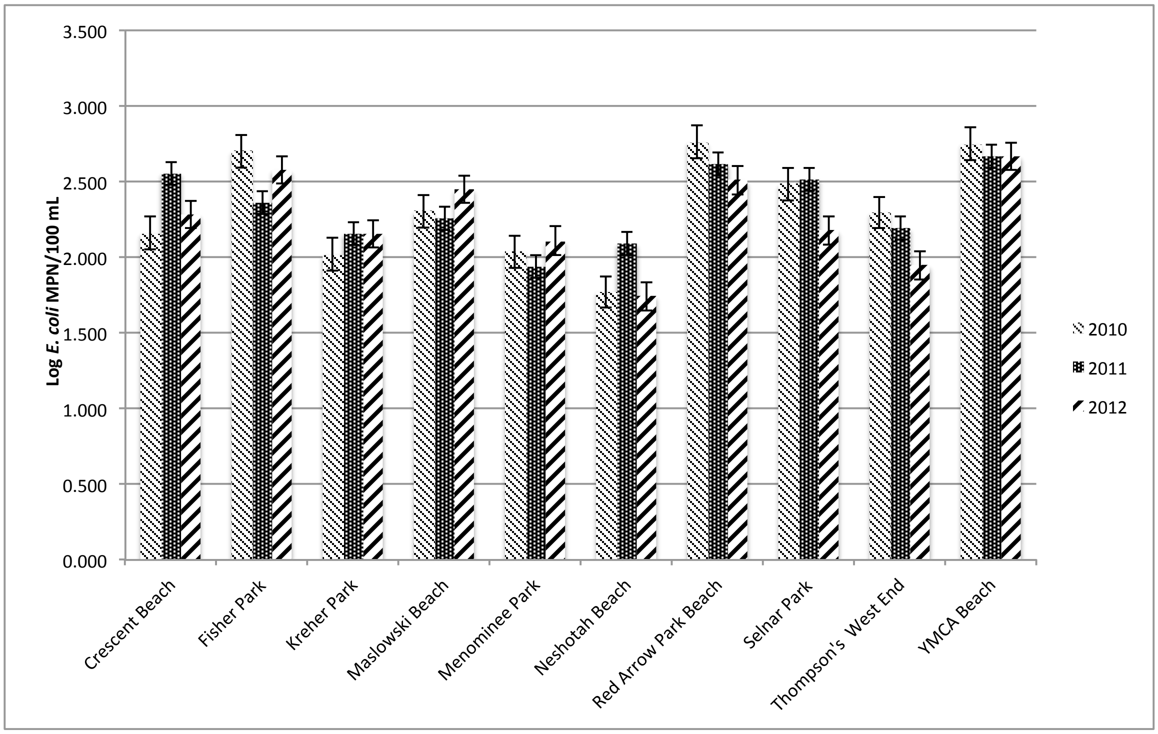


Figure 13: Average *E. coli* concentrations for ten beaches over three years of sampling. Error bars indicate standard error (Crescent Beach n=855, Fisher Park n=262, Kreher Park n=751, Maslowski Beach n=464, Menominee Park n=595, Neshotah Beach n=658, Red Arrow Park Beach n=597, Selnar Park n=353, Thompson's West End n=452, YMCA Beach n=234).

In addition to collecting water samples, as part of the routine sanitary survey, other physical and chemical data also were evaluated. These data are collected to determine if parameters like wave height, turbidity, and waterfowl had an impact on *E. coli* concentrations and therefore contributed to poor water quality. Linear regression analysis was performed to determine correlations between ancillary parameters and *E. coli* concentrations (Table 5). The parameters that produced the highest R^2 value across all beaches were wave height, turbidity, and rain. Sources of contamination at each beach were assessed based on the highest R^2 values, keeping in mind there was not only one source responsible for poor water quality.

Table 5: Linear regression between *E. coli* concentrations and ancillary parameters collected from the routine sanitary survey and averaged over the three-year study. R^2 values are reported to four decimal points.

Ancillary Parameter	Crescent Beach	Selnar Park	Fisher Park	Kreher Park	Neshotah Beach	Red Arrow Park Beach	Menominee Park	Maslowski Beach	Thompson's West End	YMCA Beach
Wind Direction (°)	0.1660	0.1269	0.0259	0.0101	0.0241	0.0118	0.0731	0.0279	0.0388	0.0536
Wind Speed (mph)	0.0187	0.0610	0.1233	0.0836	0.0560	0.0468	0.0421	0.0382	0.0520	0.1124
Water Temperature (°C)	0.0351	0.1143	0.0668	0.0718	0.0251	0.0165	0.0243	0.0218	0.0409	0.0627
Air Temperature (°C)	0.0717	0.0961	0.0508	0.0496	0.0336	0.0344	0.0280	0.0366	0.0031	0.0944
Turbidity (NTU)	0.1490	0.1982	0.3400	0.1019	0.0850	0.1444	0.0946	0.2594	0.2260	0.0265
Wave Height (ft)	0.2165	0.1181	0.2105	0.0193	0.2123	0.0838	0.1059	0.0360	0.1228	0.0381
Within 24hr Rain (cm)	0.0156	0.0920	0.0183	0.0575	0.0593	0.0905	0.1478	0.0166	0.1479	0.0536
Algae (1-3)	0.0370	0.1667	0.0557	0.0013	0.0284	0.0476	0.0691	0.0113	0.0059	0.1173
Gulls (#)	0.1080	0.0614	x	0.0640	0.0485	0.0347	0.0192	0.0687	x	0.1579
Geese (#)	x	x	x	x	x	x	0.0032	x	x	0.0086
Bathers at Beach (#)	0.0024	x	x	0.0118	0.0441	x	0.0057	0.0004	x	x
Bathers In Water (#)	x	x	x	x	0.0528	x	0.0296	x	x	x
Longshore Current Speed (cm/sec)	0.0864	0.1365	0.0615	0.0118	0.1042	0.0954	0.1725	0.0166	0.0134	x
Longshore Current Direction (°)	0.0264	0.0463	0.0777	0.0621	0.0350	x	0.0628	0.0072	0.0594	0.0334

*x indicates insufficient data to perform linear regression analysis

Beach Specific Source Identification

The following source identifications of contamination are beach specific. While some beaches show similarities, beaches are often miles apart and exhibits unique geographical and topographical characteristics. Each beach specific source identification assessment includes historical water quality results, potential sources, correlation analysis, source identification, and additional statistical analysis if needed.

City of Kewaunee (Selner Park) Beach. City of Kewaunee (Selner Park) Beach has been monitored routinely under BEACH Act legislation and funding since 2003 and has been on the impaired waters (EPA 303d) list since 2006. The historical water quality data (Table 2) showed multiple years where the average *E. coli* concentration exceeded water quality standards (235 MPN/100mL). The average *E. coli* concentration from 2003 to 2012 exceeds the advisory standard of 235 MPN/100mL (302.6 MPN/100mL, Appendix A). A total of 579 samples were collected at City of Kewaunee (Selnar Park) from 2010-2012 through the GLRI project (2010 n=288, 2011 n=276, 2012 n=15). *E. coli* concentrations exceeded water quality standards in 2010 (304.7 MPN/100mL, Appendix A) and 2011 (321.9 MPN/100mL, Appendix A) (Figure 14) during the GLRI study from 2010-2012.

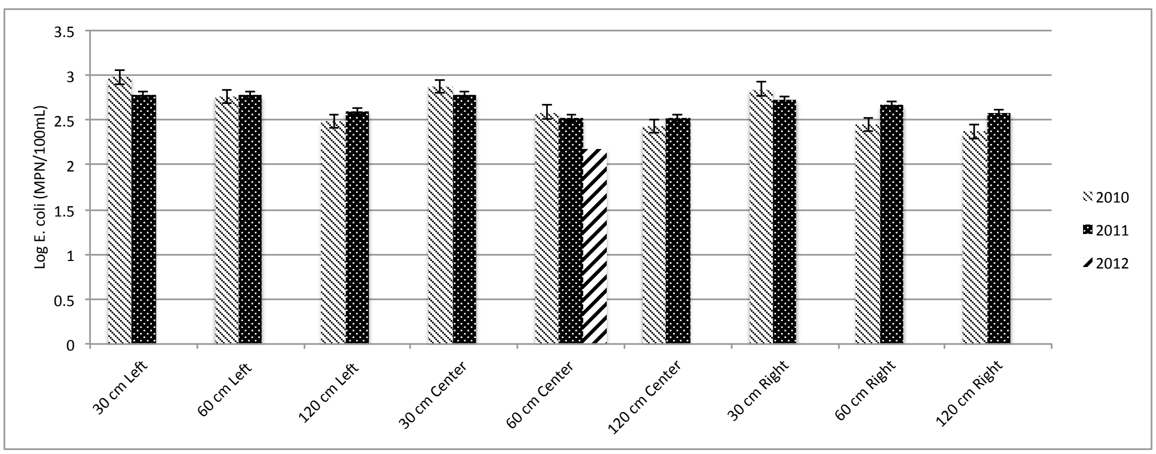


Figure 14: City of Kewaunee (Selner Park) Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=353).

There were a few potential pollution sources identified in the initial site assessment, including gulls, stormwater pipes in the back beach, and sheet flow run off from the adjacent parking lot. Over all three years of data collection, the stormwater outfall averaged 1123.5 *E. coli* MPN/100mL (n=2) (Appendix A). Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters, and *E. coli* concentrations at the center of beach at 60 centimeters. Parameters with the greatest R^2 value at City of Kewaunee (Selner Park) Beach included wind direction, turbidity, wave height, algae, and longshore current speed (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

Additional statistical analyses (Minitab16) were also conducted to evaluate average *E. coli* concentrations at three water depths at City of Kewaunee Beach in order to assess the impact of algae (*Cladophora*) in nearshore water on *E. coli* concentrations. The difference between *E. coli* concentrations found in water with a depth of 30 centimeters, 60 centimeters, or 120 centimeters was not significant (ANOVA $p=0.144$ where $p<0.05$). These results may be due to homogenous mixing of the algae due to wave action extending outward greater than 120 centimeters water depth.

Crescent Beach. Crescent Beach has been on the impaired waters (EPA 303d) list since 2006. Crescent Beach was recently removed from the 303d Impaired Waters List in 2012. The historical water quality data (Table 2) shows multiple years where the average *E. coli* concentration exceeded water quality standards (235 MPN/100mL). A total of 1275 samples were collected at Crescent Beach from 2010 to 2012 through the GLRI project (2010 n=288, 2011 n=396, 2012 n=591) (Table A-6). Average *E. coli* concentrations from 2010-2012 (236.3 MPN/100mL, Appendix A) collected from the north transect exceeded water quality standards (Figure 15).

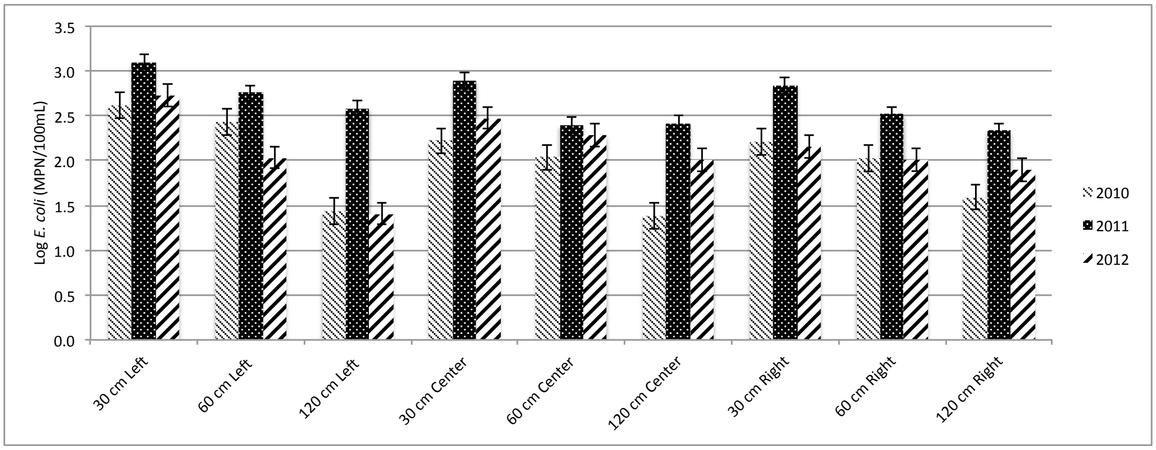


Figure 15. Crescent Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=855).

There were several potential pollution sources identified in the initial site assessment, including stagnant algae mats (northern region), extensive gull and geese populations, stormwater (six outfalls), and surface runoff from impervious surfaces in conjunction with a low, flat, sand-starved beach. The average *E. coli* from Pipe 1 located on the north end of the beach was 1106.8 (n=8). The average *E. coli* from Pipe 6 on the south end of the beach was 606.6 (n=56) (data not shown). Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters, and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Crescent Beach include wind direction, turbidity, wave height, gull populations, and tributary contribution (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

Additional statistical analyses (Minitab16) were conducted at Crescent Beach to evaluate average *E. coli* concentrations at three transects in order to assess the possibility of moving the designated swimming area from the north end of the beach to the south end. An ANOVA (Estimate Model) was used in conjunction with a Post Hoc Tukey Test between the three transects and a $p=0.002$ was calculated ($p<0.05$). The Tukey Test was used to determine which means were different between transects. The Tukey test revealed that the *E. coli* concentration at the north transect was significantly higher than the center and south transects, which was expected. The stagnant algal mats, which are trapped by the adjacent breakwall and nearby stormwater drain, have a significant impact on *E. coli* concentrations within this transect.

Fisher Park Beach. Fisher Park Beach was on the Impaired Waters (EPA 303d) list since 1998 but was recently delisted. Fisher Park Beach has been monitored since 2003 and exceeded water quality standards (235 MPN/100mL) 7 out of 10 years (Table 2). A total of 572 samples were collected at Fisher Park Beach from 2010 to 2012 through the GLRI project (2010 n=53, 2011 n=314, 2012 n=205). The average results of *E. coli* from the sanitary surveys conducted from 2010 to 2012 also exceeded water quality standards (370.9 MPN/100mL, Appendix A) (Figure 16). Fisher Creek has exhibited high levels of *E. coli* from 2010 to 2012, resulting in average concentrations exceeding 500 MPN/100 mL (Appendix A) (Figure 16).

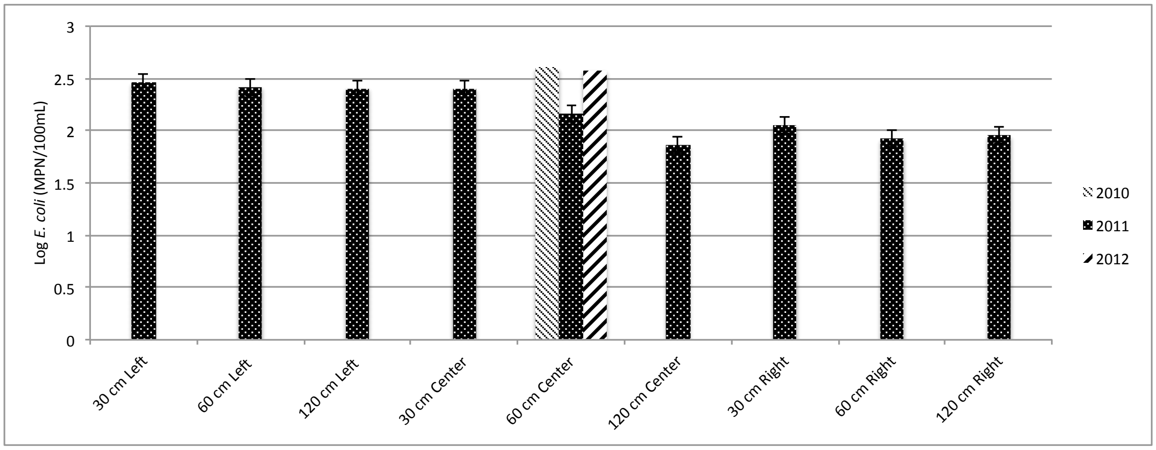


Figure 16. Fisher Park Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=262).

There were several potential pollution sources identified in the initial site assessment including stagnant algae mats, extensive gull populations, and potential pollution contribution from Fisher Creek. Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Fisher Park Beach included turbidity, wave height, and Fisher Creek sample points (Table 5). The most significant correlation was calculated between *E. coli* from Fisher Creek and *E. coli* from Fisher Park Beach at the center transect at 24 inches (R^2=0.6705).

Additional statistical analyses (Minitab16) were also conducted to evaluate the impact of Fisher Creek *E. coli* concentrations on Fisher Park Beach water quality. An ANOVA (Estimate Model) was used to determine if there was a statistical difference between mean *E. coli* concentrations at three transects (p=0.488). This evaluation shows that there is no statistical difference between mean *E. coli* concentrations at Fisher Park Beach. Fisher Park Beach is a small beach, and *E. coli* concentrations may not differ between transects in such a small geographic area. A 2-sample t-test was performed to evaluate differences in means of *E. coli* in Fisher Creek and Fisher Park beach. The results of the 2-sample t-test showed a P-value of 0.025 ($p<0.05$) indicating a significant difference between mean *E. coli* concentrations in Fisher Creek and Fisher Park Beach. Finally, a paired t-test was performed between Fisher Creek sampling sites (one upstream and one near the mouth) to determine if mean *E. coli* concentrations were different. The result of the t-test showed no statistical difference between sample sites ($p=0.878$). At this time it would be difficult to assume significant pollution input upstream since *E. coli* concentrations are not statistically different upstream or near the mouth of the river.

After statistical analysis, it is evident that Fisher Creek is a significant source of pollution contributing to high *E. coli* concentrations at Fisher Park Beach. In addition to the creek's pollution input, high levels of algae were present at the beach, which potentially contributed to the high turbidity levels measured. The algae particles and particulates from Fisher Creek allow for *E. coli* attachment, serving as a suitable environment for *E. coli* survival in the nearshore water at Fisher Park Beach.

Kreher Park Beach. Kreher Park Beach has been monitored routinely through BEACH Act legislation and funding since 2003. The historical water quality is fairly good; however, since 2003, the beach has been under advisory 9% of beach days where the average *E. coli* concentration exceeded water quality standards (235 MPN/100mL)

(Table 2). A total of 1,148 samples were collected at Kreher Park Beach from 2010 to 2012 through a GLRI project (2010 n=280, 2011 n=392, 2012 n=476). The yearly average *E. coli* from 2010 to 2012 (142.7 MPN/100mL, Appendix A) did not exceed water quality standards (Figure 17). The nearby creek appeared as an obvious contributor of fecal indicator bacteria since the average *E. coli* was 1118.2 (n=45) over three years (Appendix A).

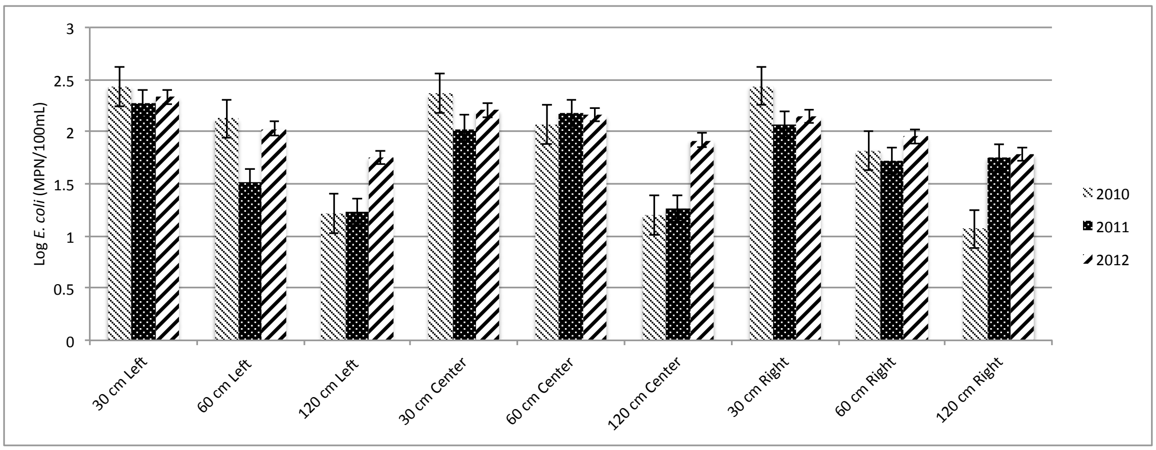


Figure 17. Kreher Park Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=751).

Pollution sources identified during the initial site assessment were primarily related to stormwater influences including sheet flow and direct stormwater flow. Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Kreher Park Beach included turbidity and rain (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

The major source of contamination at Kreher Park Beach is stormwater, including municipal and sheet flow from adjacent impervious surfaces. Visual observation showed little-to-no stormwater infiltration due to extensive impervious surfaces surrounding the beach. Since the beach is embayed, normal hydrological circulation is unable to occur. These characteristics along with the low, flat, sand starved beach serve as an optimal reservoir for *E. coli* survival.

Maslowski Beach. Maslowski Beach has been monitored routinely through BEACH Act legislation and funding since 2003, and was previously on the impaired waters (EPA 303d) list from 2006 to 2011. The historical water quality data (Table 2) shows multiple years where the average *E. coli* concentration approaches water quality standards (235 MPN/100mL). A total of 965 samples were collected at Maslowski Beach from 2010 to 2012 through a GLRI project (2010 n=332, 2011 n=517, 2012 n=116). The yearly mean *E. coli* concentrations from 2010 to 2012 was not significantly different (p=0.342) (Figure 18). The nearby creeks appeared as an obvious contributor of fecal indicator bacteria since the average *E. coli* from all tributaries exceeded water quality standards (South Fish Creek, 432.7 MPN/100mL; North Fish Creek 383.0 MPN/100mL; Whittlesey Creek, 545.1 MPN/100mL; Maslowski Pipe, 1226.4).

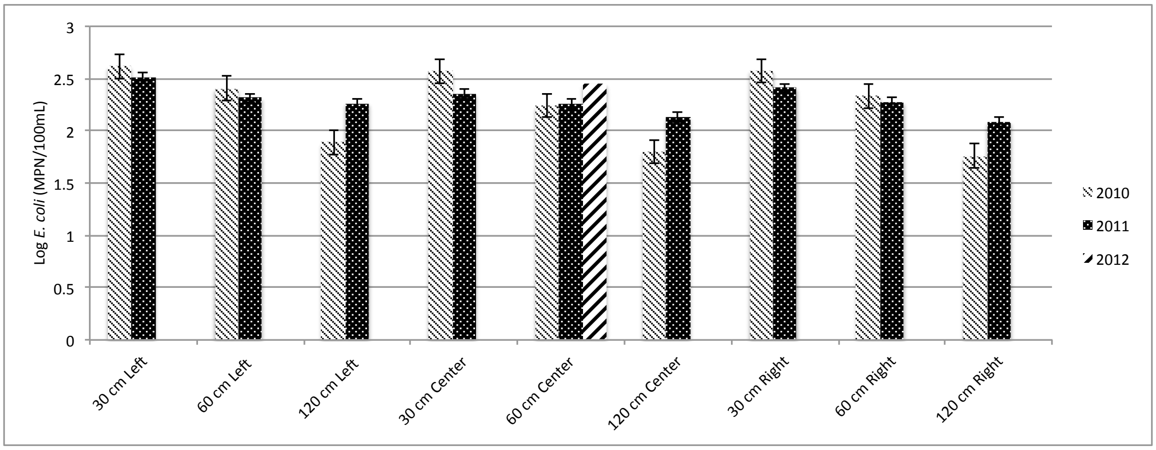


Figure 18. Maslowski Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard (n=464).

The potential pollution sources identified in the initial site assessment included gull and geese populations, stormwater influence to the east of the beach, sheet flow runoff from the adjacent parking lot, and nearby tributaries. Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. The parameter with the greatest R^2 value at Maslowski Beach was turbidity (Table 5). This result was not anticipated since there were several creeks and a nearby stormwater outfall with high concentrations of *E. coli*. Assumptions can be made, however, about the significant amount of sheet flow from the impervious surfaces surrounding the beach.

Additional statistical analyses (Minitab16) were also conducted to evaluate average *E. coli* concentrations from water with three different depths at Maslowski Beach in order to assess the impact of surface runoff in nearshore water on *E. coli* concentrations. The differences between *E. coli* concentrations in water with a depth of

30 centimeters, 60 centimeters inches, and 120 centimeters was significant (ANOVA p=0.026 where p<0.05). Further analysis was done using a Tukey's Post Hoc test to determine which mean depths were different from each other. The Tukey test revealed that mean *E. coli* concentrations were different in water with depth of 30-centimeter and water with a 120-centimeter depth. This indicates that *E. coli* contamination may be coming from onshore rather than offshore, and could be linked to stormwater.

Menominee Park Beach. Menominee Park Beach has only been monitored since 2010 by the City of Oshkosh. Since Menominee Park Beach is an inland beach, BEACH Act legislation and funding does not apply. This beach was chosen as a pilot beach for conducting sanitary surveys on an inland beach in order to serve as a comparative model using methods approved for Great Lake beaches. Menominee Park had moderate water quality with only six water quality exceedances since 2010 (Table 2). A total of 847 samples were collected at Menominee Park Beach from 2010 to 2012 through a GLRI project (2010 n=398, 2011 n=178, 2012 n=271). The mean *E. coli* concentrations from 2010 to 2012 was not significantly different between the three years of collection (p=0.813) (Figure 19). The overall average of *E. coli* from 2010 to 2012 (114.9 MPN/100mL, Appendix A) was well below the 235 MPN/100mL exceedance level.

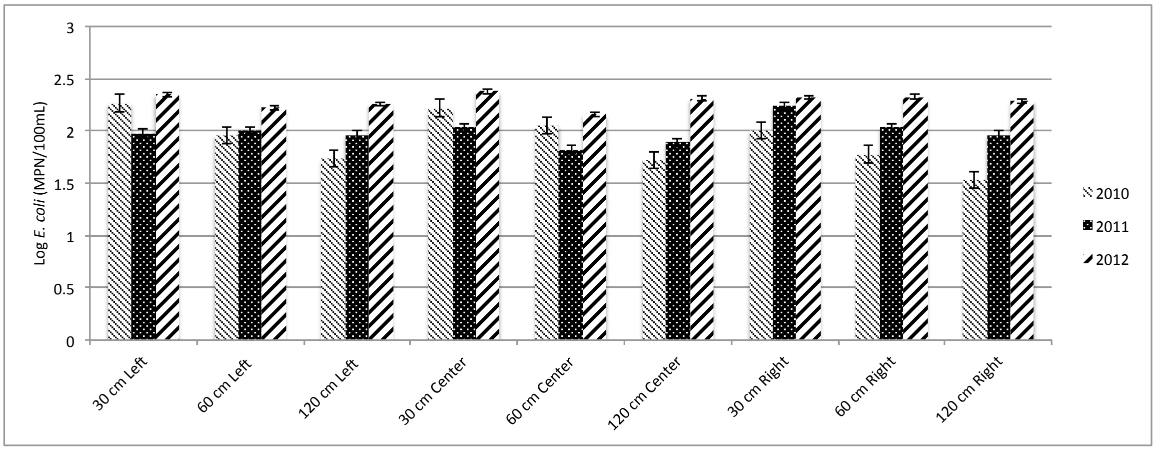


Figure 19. Menominee Park Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=595).

The potential pollution sources identified in the initial site assessment include geese populations and runoff from impervious surfaces. Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Menominee Park Beach include wave height and rain (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

Neshotah Beach. Neshotah Beach has been intermittently listed on the impaired waters (EPA 303d) list since 2003. The historical water quality data (Table 2) shows multiple years where the average *E. coli* concentration exceeded water quality standards (235 MPN/100mL). The overall water quality from 2003 to 2012 was poor, with 240 *E. coli* MPN/100mL, which exceeds water quality standards. A total of 977 samples were collected at Neshotah Beach from 2010 to 2012 through a GLRI project (2010 n=50, 2011 n=391, 2012 n=536). The mean *E. coli* from each year was well below the 235 MPN/100mL exceedance level (79.0 MPN/100mL) (Figure 20). The overall mean *E. coli* concentration from Pipe S from 2010-2012 was 234.6 MPN/100mL (Appendix A).

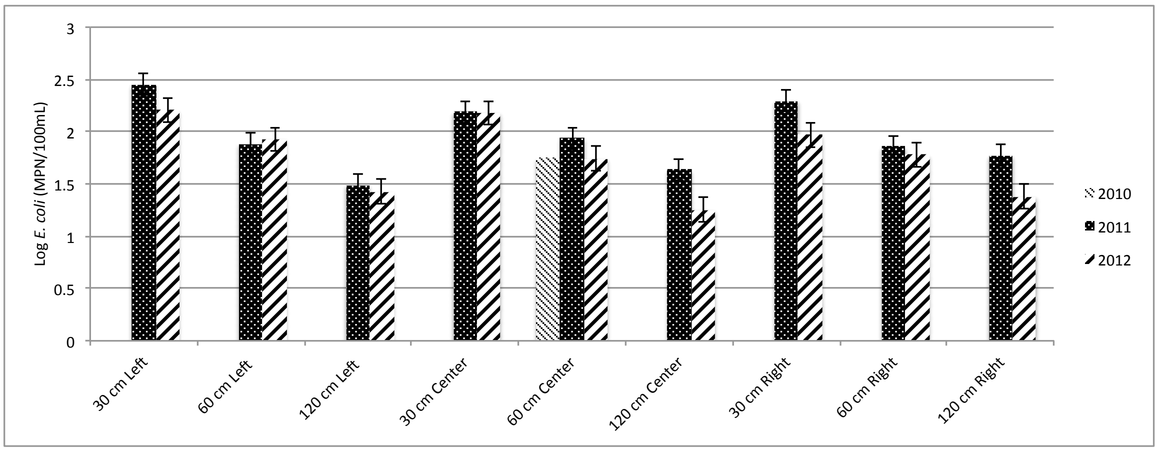


Figure 20. Neshotah Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=658).

There were several potential pollution sources identified in the initial site assessment, including extensive gull and geese populations, stormwater, and surface runoff from impervious surfaces in conjunction with a low, flat beach which is sand starved. Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters, and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Neshotah Beach include wind, turbidity, and outfall contribution (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

Additional statistical analyses (Minitab16) were also conducted to evaluate average *E. coli* concentrations at three transects at Neshotah Beach in order to assess the impact of stormwater on *E. coli* concentrations. An ANOVA (Estimate Model) was used in conjunction with a Tukey Post-Hoc Test to determine difference in means (and which means were statistically different) between the three transects, and a $p=0.542$ was calculated where $p<0.05$. There is no statistical evidence that mean *E. coli* concentrations are different between transects; however, there was a positive correlation between the north and south outfalls ($R^2=0.5968$ and 0.2431) in 2011 and therefore still potentially impacts Neshotah Beach.

Red Arrow Beach. Red Arrow Beach has been monitored routinely through BEACH Act legislation and funding since 2003 and has been the on the impaired waters (EPA 303d) list since 1998. The historical water quality data (Table 2) shows multiple years where the average *E. coli* concentration exceeded water quality standards (235 MPN/100mL). The average *E. coli* concentration since 2003 was 388.5 MPN/100mL which exceeds the advisory standard of 235 MPN/100mL. A total of 922 samples were collected at Red Arrow Beach from 2010-2012 through a GLRI project (2010 n=53, 2011 n=368, 2012 n=501). The mean *E. coli* from each year from 2010 to 2012 exceeded the 235 MPN/100mL exceedance level (Figure 21). The overall mean *E. coli* for the south outfall from 2010 to 2012 was 463.6 MPN/100mL, which may indicate the south outfall as a possible source of pollution for Red Arrow Beach (data not shown).

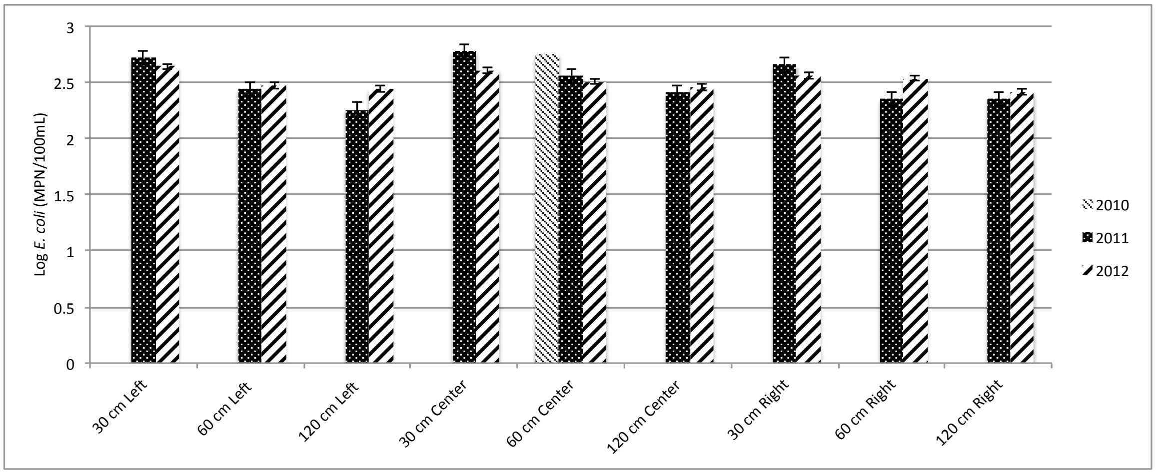


Figure 21. Red Arrow Park Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=597).

The potential pollution sources identified in the initial site assessment were gulls and other avian populations, stormwater infrastructure on the south end of the beach, and sheet flow runoff from the adjacent parking lot above the bluff. Following three years of data collection, statistical linear regression was conducted between physical/chemical/biological parameters and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Red Arrow Beach included turbidity, wave height, longshore current speed, and the south outfall (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

Statistical linear regression was done between each beach transect and the south stormwater outfall. The south transect, which is closest to the outfall, had the highest correlation with *E. coli* from the outfall (R^2=0.267). The correlations at the center (R^2=0.1695) and north (R^2=0.1691) transects decreased as samples were taken further away from the outfall. These data suggest that the stormwater outfall at Red Arrow Park is a significant contributor to high *E. coli* concentrations at the beach, especially at the southern region of the beach.

Additional statistical analyses (Minitab16) were also conducted to evaluate average *E. coli* concentrations at three transects at Red Arrow Beach in order to assess the impact of stormwater pipe on the south end on *E. coli* concentrations. The difference between *E. coli* concentrations at the north, center, and south transects were not significant (ANOVA $p=0.982$ where $p<0.05$). These results may be due to homogenous mixing of the stormwater due to wave action or that *E. coli* is significantly high extending the entire beach.

Thompson's West End Beach. Thompson's West End Beach was listed on the impaired waters (EPA 303d) list from 2008 to 2012. The historical water quality data (Table 2) shows a peak in *E. coli* in 2006, where the average *E. coli* concentration was 375.4 MPN/100mL which exceeded water quality standards. A total of 1,042 samples were collected at Thompson's West End Park Beach from 2010 to 2012 through a GLRI project (2010 n=331, 2011 n=548, 2012 n=163). The mean *E. coli* concentration for each year from 2010 to 2012 was well below the 235 MPN/100mL exceedance level (Figure 22). The overall mean *E. coli* for Thompson's Creek from 2010 to 2012 was 310.4 MPN/100mL, which may indicate Thompson's Creek is a possible source of pollution for Thompson's West End Park Beach (data not shown).

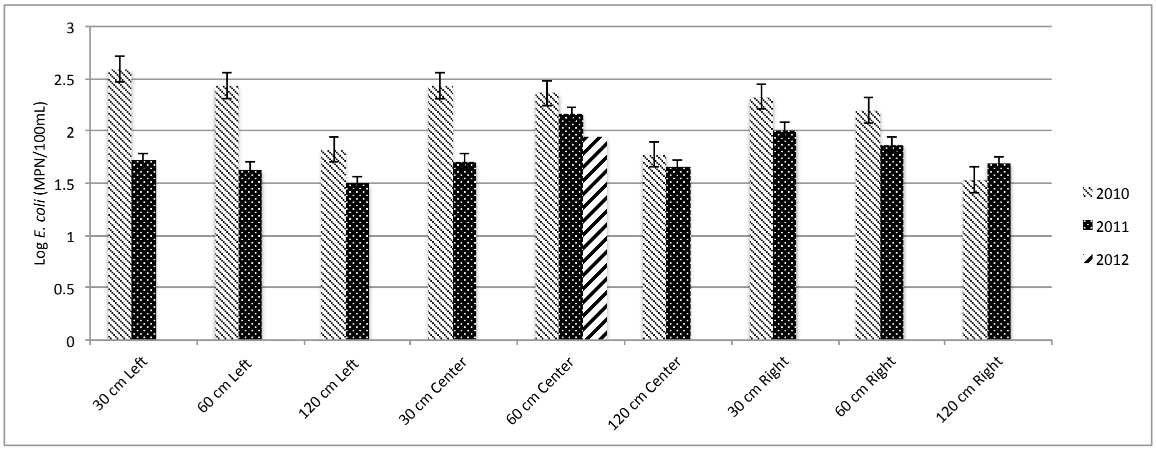


Figure 22: Thompson's West End mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=452).

There were several potential pollution sources identified, including stormwater from an artesian well, possible campground dump station waste, stormwater from impervious surfaces including the adjacent parking lot, and stormwater from a large area of the City of Washburn. Additional sources include woody debris on the beach and various recreational activities from the park and campground.

Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at Thompson's West End Beach include turbidity, wave height, rain, and tributary/stormwater input (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations. Investigative sampling in 2011 revealed that the most significant pollution source was stormwater input. The City of Washburn is located on a hill and approximately half of the city's stormwater is channeled directly to Thompson's West End Beach.

YMCA Beach. YMCA Beach has been on the impaired waters (EPA 303d) list since 2004. The historical water quality data (Table 2) shows several years where the average *E. coli* concentration exceeded water quality standards (235 MPN/100mL). YMCA Beach has been closed 52% of the beach days after the beach started being monitored in 2003. A total of 689 samples were collected at YMCA Beach from 2010 to 2012 through a GLRI project (2010 n=266, 2011 n=310, 2012 n=113). The mean yearly *E. coli* from 2010 to 2012 was 485.8 MPN/100mL which was above the 235 MPN/100mL exceedance level (Figure 23). The overall mean *E. coli* concentration for water from Outfall 1 from 2010 to 2012 was 297.5 MPN/100mL, which also exceeded water quality standards (data not shown).

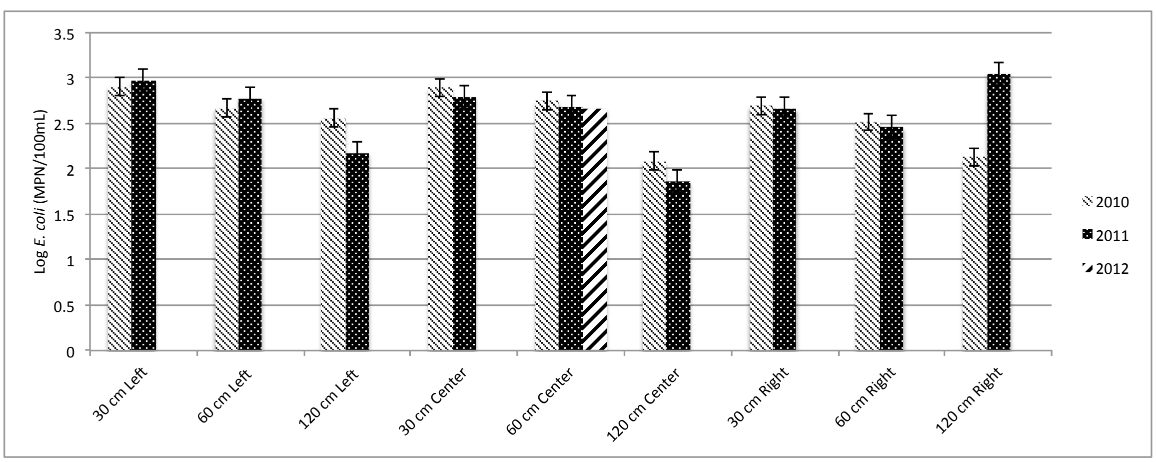


Figure 23. YMCA Beach mean *E. coli* results from spatial sampling from 2010-2012. Error bars indicate standard error (n=234).

The potential pollution sources identified during the initial site assessment include stormwater from a pipe in the adjacent pier, and storm water from impervious surfaces such as the adjacent parking lot. Additional sources include woody debris on the beach and various recreational activities such as kayaking, boating, and other marina related activities.

Following three years of data collection, statistical linear regression was conducted between physical, chemical, and biological parameters, and *E. coli* concentrations at the center of beach from water with a depth of 60 centimeters. Parameters with the greatest R^2 value at YMCA Beach include wind speed, wave height, gull populations, and tributary/stormwater input (Table 5). While these factors alone cannot be attributed to all *E. coli* variation, when they are combined, they contribute to a significant amount of the variability in *E. coli* concentrations.

YMCA Beach is utilized for several recreational activities in the summer months, including dragon boat races, kayaking, boating, swimming, and triathlons. With this beach exceeding water quality standards over 50% of beach days, it was imperative that these sources were identified and a redesign plan developed to protect public health.

Results Associated With Each Objective

Based on the aforementioned results based on each select beach, a comprehensive analysis was done based on each objective of this study.

1.To conduct a site assessment of each study beach using the USEPA annual sanitary survey tool to identify potential pollution sources and document physical characteristics of the beach.

Table 6. Major potential pollution sources identified during the Annual Sanitary Surveys at each of the ten beaches selected.

Beach	Potential Sources Identified - Annual Sanitary Survey				
City of Kewaunee Beach	Waterfowl	Stormwater Pipes	Sheet Flow		
Crescent Beach	Waterfowl	Stormwater Pipes	Sheet Flow	Algae	Ahnapee River
Fisher Park	Waterfowl	Algae	Fisher Creek		
Kreher Park	Stormwater Pipes	Sheet Flow			
Maslowski Beach	Waterfowl	Stormwater Pipes	Sheet Flow	North Fish Creek	South Fish Creek
Menominee Park	Waterfowl	Sheet Flow			
Neshotah Beach	Waterfowl	Stormwater Pipes	Sheet Flow	Sand	
Red Arrow Park Beach	Waterfowl	Stormwater Pipes	Sheetflow	Sand	
Thompson's West End	Waterfowl	Stormwater Pipes	Sheet Flow	Camground Dump Station	
YMCA Beach	Stormwater Pipes	Sheet Flow			

During each assessment of the beach, the surveyor identified potential sources by physically inspecting for point and non-point sources of pollution evident during the survey. The significant potential sources of pollution identified during the Annual Sanitary Survey were waterfowl, stormwater (point and non-point), and tributaries located near the beach (Table 6). Most sources identified were visible and able to be observed physically.

2.To identify potential pollution sources at high-risk beaches in Wisconsin using the USEPA routine sanitary survey tool.

Table 7. Fecal pollution sources identified at each beach based on the highest correlations between *E. coli* and environmental parameters at each beach.

Beach	Sources Identified - Routine Sanitary Survey				
City of Kewaunee Beach	Wind Direction	Turbidity	Wave Height	Algae	Longshore Current Speed
Crescent Beach	Wind Direction	Turbidity	Wave Height	Gulls	Ahnapee River
Fisher Park	Turbidity	Wave Height	Fisher Creek		
Kreher Park	Turbidity	Rain			
Maslowski Beach	Turbidity				
Menominee Park	Wave Height	Rain			
Neshotah Beach	Wind Direction	Turbidity	North Outfall	South Outfall	
Red Arrow Park Beach	Turbidity	Wave Height	Longshore Current Speed	South Outfall	
Thompson's West End	Turbidity	Wave Height	Rain	Thompson's Creek	Stormwater Input
YMCA Beach	Wind Speed	Wave Height	Waterfowl	Stormwater Input	

The sources identified in Table 7 were identified based on three years of data collection and performing statistical correlations between environmental parameters and *E. coli* concentrations in water. When compared to Table 6, which identified potential sources based on observation, and Table 7, which was based on statistical comparisons; not all sources match up. While the Annual Sanitary Surveys are important in identifying potential sources of pollution, it is imperative to perform the routine sanitary survey to base source identification on sound science. Sources identified in the Routine Sanitary Survey could not solely be determined by the annual sanitary survey of the beach.

3. To evaluate relationships between physical, chemical, and/or biological parameters and fecal indicator bacteria at selected beaches.

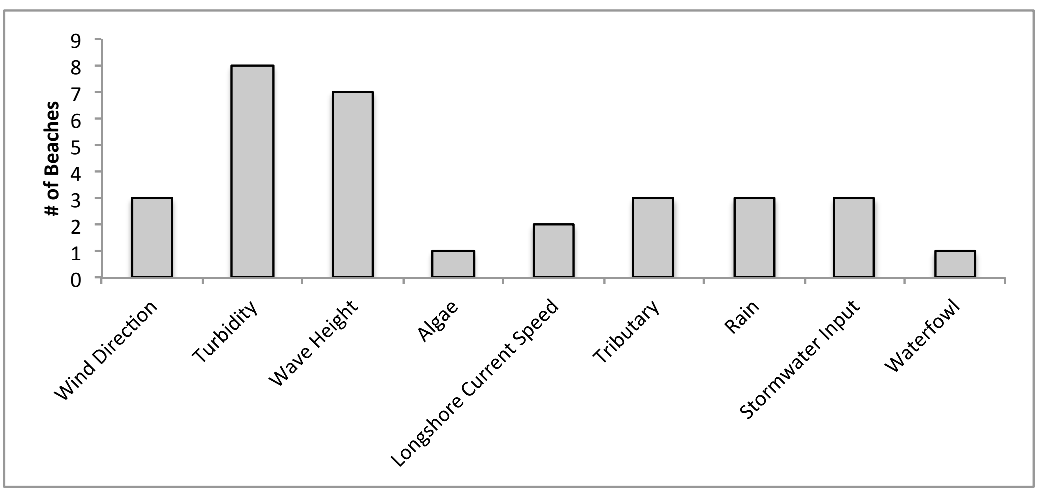


Figure 24. The number of beaches with environmental parameters identified as sources of pollution.

While each beach in this study had unique sources identified, a trend began to develop between sources identified and beaches in the study. Turbidity and wave height were significant sources at seven of the ten beaches in the study. Wind, tributaries, rain, and stormwater input were also identified at three of the ten beaches (Figure 24).

DISCUSSION

The overall goal of this project was to identify pollution sources at ten beaches in Wisconsin located on Lake Michigan and Lake Superior. In order to accurately identify sources of fecal pollution, three years of data were collected and analyzed to determine parameters that influenced *E. coli* concentrations. This stepwise approach was successful in identifying several pollution sources that were specific to each particular beach. Each beach is unique in layout, location, and fecal impacts, and thus showed unique trends that were discovered throughout this project.

In general, beaches are impacted by either point or non-point sources of pollution, or combinations of both (45). Point sources are direct sources of discharge such as stormwater pipes, farm tiles, or other discharge sites. Non-point sources do not have a clearly defined discharge point and include sources such as stormwater sheetflow, tributaries, and fecal deposition by various warm-blooded animals (51, 54). Beaches that were located in an urban setting (impacted by municipal infrastructure) were more heavily impacted by stormwater. This was due in part to large regions of impervious surfaces and stormwater discharge points on or near the beach (56). There was also a tendency for gulls to loaf on the large, flat sand starved beaches with little vegetation. Gulls and geese in particular are drawn to these types of beaches because they have a direct line of sight to spot predators and therefore feel “safe” (58, 69). Especially at urban beaches, birds are also searching for litter and debris left behind by beachgoers. These beach problems are generally easier to mitigate than those found at rural beaches since there are more easily identifiable point sources at urban beaches. Beaches located in a rural setting tended to be impacted by nearby tributaries, waterfowl, and algae. The tributaries may have been contaminated by bovine feces or other agricultural inputs. These beach problems are much more difficult to mitigate since they are often limited to no point sources of contamination. Watershed studies could be conducted in cases where tributaries are a known source of contamination in an attempt to determine the source of contamination upstream.

Below are beach-specific analyses of contamination sources for each beach, based on the sanitary survey results presented earlier.

City of Kewaunee (Selner Park) Beach. The physical impacts on beach water quality at City of Kewaunee Beach, include high algal concentrations, which increase turbidity; wave action drives the algae onto the beach front and into nearshore water, and therefore allows for *E. coli* attachment to particulate matter. Historically, algal accumulation has been a problem in the nearshore water and stranded on the beach. It is unknown where the algae originated. Further evaluation of GIS data and lake current patterns should be conducted to pinpoint the location of the growing *Cladophora*. Phosphorus may also be evaluated from the mouth of the Kewaunee River to determine if elevated phosphorus may be promoting the grown of nearby *Cladophora* blooms. At this particular beach the initial site assessment and data analysis seemed to coincide. However, gulls and/or geese numbers did not correlate with *E. coli* concentrations, even though there were large numbers of avian species at the beach on a regular basis. Further source tracking should be conducted to evaluate the potential impact of avian fecal material at City of Kewaunee Beach.

Crescent Beach. Crescent Beach is considered an urban beach since it is located within the city limits and impacted by municipal infrastructure. It exhibited a number of stormwater and waterfowl related sources of contamination. Crescent Beach is the longest beach in this study (>800 meters). The sheer size required additional sampling transects (five instead of three) to evaluate the beach spatially. Data showed correlation between stormwater, turbidity, waterfowl, and wave height, and *E. coli* concentration. These parameters were previously identified during the initial site assessment and were expected sources of contamination. Since there is a large breakwall that restricts waterflow and serves as an algae trap, the ideal solution would be to remove this breakwall. Unfortunately, this is not financially possible and therefore, the next best option was to provide evidence of improved water quality further south of the breakwall. Statistical analysis showed significantly lower *E. coli* concentrations at the center and south end of the beach. Even though moving the beach may be a valid option for protecting public health it is still important to discover the source of fecal contamination within the stormwater pipes running during dry weather. These pipes are contributing significant amounts of fecal pollution and may be traced back to elicit connections or leaking sewer systems in the City of Algoma. Use of DNA markers for identification of *Bacteroides* (from human sources) or other markers that target pet waste or yard waste may be needed to trace the fecal source to humans or other sources within these storm sewers.

Fisher Park Beach. Fisher Park Beach is located in rural Manitowoc County outside the city limits. There is no municipal infrastructure impacting this beach. Fisher Park Beach should be evaluated for the presence of molecular markers for bovine and human fecal material upstream in Fisher Creek. The creek is the largest contamination source at Fisher Park Beach and therefore requires additional watershed studies, that include microbial source tracking to determine the sources of *E. coli* being deposited into Fisher Creek. Since this beach is primarily impacted by non-point sources it is much more difficult to identify and mitigate sources of contamination. In the meantime, it is recommended that Fisher Park Beach be monitored for *E. coli,* and its water quality status be posted at the beach to protect public health.

Kreher Park Beach. Kreher Park Beach is extremely impacted by municipal stormwater during rain events. The beach is nested between a campground and small marina with a large impervious surface area. There are also significant areas of turf grass with low flat terrain and little to no vegetative buffering between impervious surfaces and the beach face. The obvious sources contributing to poor water quality at Kreher Beach were turbidity and rain. Additional research should be conducted to identify additional sources of contamination, including waterfowl (geese specifically) that commonly nested near the beach. DNA fingerprinting could be conducted in an attempt to identify avian fecal material in nearshore water. If a redesign plan would be developed it should address methods for better infiltration of stormwater or deferment from the beach proper. This beach is currently closed to the public while the nearby oar dock is under construction and being removed. Once the oar dock is removed, it is recommended that Kreher Park Beach be reassessed for water quality and beach usage.

Maslowski Beach. Maslowski Beach is located within the City of Ashland along Lake Superior. It is highly impacted by waterfowl and sheet flow over the low flat beach face. The only significant correlation was between turbidity and *E. coli* concentrations. Stormwater from impervious surfaces could account for high turbidity at Maslowski Beach in addition to tributary drainage to the west. Although the beach averaged more than 35 waterfowl per day over the three year study (Table A-19), a significant correlation was not found based on the data collected. Further studies should be conducted to detect avian FIB DNA markers to accurately identify waterfowl as a contamination source at Maslowski Beach. If a design plan was developed it should integrate transition infiltration beds at the north edge of the parking lot to absorb sheet flow runoff. Dune grass should also be planted on the upshore of the beach to hold nourished sand on the beach and further infiltration of stormwater. The jetties located on the east edge of the beach should be removed to restore proper hydrodynamic flow.

Menominee Park Beach. Menominee Park Beach is an inland beach located on Lake Winnebago in Oshkosh, WI. This beach served as an inland demonstration beach to evaluate whether routine sanitary surveys and annual sanitary surveys could be utilized on inland beaches.

These data show that conducting sanitary surveys to identify potential pollution sources is effective at inland beaches. Menominee Park Beach exhibited similar characteristics to Great Lake beaches, including ineffective stormwater management, lacking deterrence of waterfowl, and sand starved beach front with few or no sand dunes. With this in mind, Menominee Park Beach is located on a large inland lake (Lake Winnebago). These results may not be the same for beaches located on smaller inland lakes where longshore current, wave action, and macrophytic algae are not present. It is recommended that Menominee Park Beach continue to be monitored to keep the public informed of the water quality. If mitigation is feasible in the future, an assessment should be conducted afterwards to evaluate the effectiveness of the newly mitigated beach.

Neshotah Beach. Neshotah Beach is an urban beach located in the City of Two Rivers. It is the most heavily visited beach in this study. It is a large flat beach with large areas of impervious surfaces and grassy terrain. There are few vegetative barriers between the parking lots and beach face. Stormwater was determined to be a source of fecal contamination specifically from the two outfalls at the north and south ends of the beach. Sheetflow was suspected from the parking lots, but further testing is required during rain events to more accurately determine this as a definitive source. It was surprising that waterfowl was not verified as a source of contamination based on the routine sanitary surveys conducted at Neshotah Beach. The number of gulls at Neshotah Beach averaged >200 per day during the duration of the study. Although there was no statistical correlation between waterfowl and *E. coli* concentration, it is still considered a potential source of contamination. Further DNA fingerprinting should be conducted to determine avian fecal contamination in nearshore water. If a design plan was developed it should address stormwater infiltration at the two stormwater drains, beach nourishment, a curb and gutter system lining the parking lot and walkway along with infiltration basins, and dune plantings to mitigate runoff of stormwater and hold sand on the beach.

Red Arrow Beach. Red Arrow Beach is an urban beach located in the City of Manitowoc with a large flat beach below a bluff skirted with impervious surfaces. In addition to the sheetflow from impervious surfaces, there is a large outfall with extensive dry and wet weather flow. This outfall is the primary source of contamination at Red Arrow Park Beach. This outfall is so large however, that it will be a financial strain on municipal budgets to remove. It is important to utilize best management practices to prevent bathers from wading and swimming near this outfall. In addition to stormwater impacts, gulls loaf on the large flat beach face. On average, 90 gulls were observed on the beach per day (Table A-32), but gull numbers did not correlate well with *E. coli* concentrations at the beach. This was not expected and still needs to be addressed. DNA fingerprinting could be conducted to detect avian markers or more numerous counts/day should be taken of gulls and other waterfowl. A design plan should be developed to address sheet flow runoff from the parking lot above the bluff, beach nourishment, dune grass planting, and stormwater mitigation.

Thompson's West End Beach. Thompson's West End Beach is an urban beach located on Lake Superior in a small rural town. The major source of contamination at this beach was clearly stormwater. The other sources identified, like turbidity and rain, were suspected to have an impact on water quality due to the low flat beach profile, with little vegetative buffers and large area of turf grass. Geese also historically have been a nuisance at Thompson's West End Beach and were not identified as a contamination source, however best management practices should still be implemented to avoid future problems. Vegetation would help deter geese from migrating to the beach face by limiting line of sight. If a redesign plan was developed it should address stormwater mitigation at both stormwater drains, abandoning the artesian well, beach nourishment, placement of sand dunes, moving the play area, and rain gardens that border the roadways and parking lot.

YMCA Beach. YMCA Beach is located in downtown Manitowoc, WI surrounded by a marina and harbor that restrict water flow. In addition, stormwater flows over the beach face from the YMCA parking lot and contributes to poor water quality. This beach has had historically poor water quality with exceedances 52% of beach days, intermittently since 2003 (Table A-37). This exceedance rate cannot be attributed only to stormwater during rain events. This beach is surrounded by a large marina with significant municipal infrastructure. The fecal pollution sources are still largely unknown and may not be easily identifiable. If a design plan were developed it should address stormwater mitigation, beach nourishment, placement of sand dunes, vegetation to deter gull and geese, and rain gardens that border the roadways and parking lot. Since there is such extensive municipal infrastructure and the nearby Manitowoc River input, this beach may be better designated as a recreational beach for non-full human body contact. Rather, designating it as a beach for other recreational activities like kayaking, boating, (which already existed at this beach) would better protect public health.

CONCLUSIONS

This project determined pollution sources at ten beaches in Wisconsin by utilizing sanitary surveys and investigative water sampling. Utilizing three years of sanitary survey data were used to determine the characteristics of the ten beaches that impacted water quality. Each beach exhibited unique characteristics that attributed to high *E. coli* concentrations leading to advisories or closures. Since each beach is geographically and characteristically different from one another, no two beaches had the same set of sources or impacts. Even with these differences, as the study progressed, trends began to develop especially between rural and urban beaches. These beaches are impacted by a combination of point sources and non-point sources. Based on the data collected the following major conclusions can be made:

- Sanitary surveys were effective at accurately identifying fecal pollution sources at recreational beaches in northern Wisconsin.
- Urban beaches and nearshore water quality (located within the city limits) were primarily impacted by stormwater from stormwater discharge points and sheet flow from impervious surfaces.
- Rural beaches and nearshore water quality (located outside the city limits) were impacted by tributaries (rivers, streams, creeks), waterfowl, and algae.
- The beach sanitary survey tool can be applied to inland beaches to identify pollution sources.

- In cases where non-point sources like tributaries were identified as impacting the beach, additional techniques are needed to identify the source of fecal contamination (i.e. DNA fingerprinting, qPCR).

FUTURE PROJECTS

As a result of this project a continued step-wise approach should be used in the process of beach restoration. This project addressed historical water quality review and source identification through the use of sanitary surveys. Future projects should address the following:

- Additional source tracking using detection of specific DNA markers for fingerprinting where sources were not easily identified using the sanitary survey tool.
- Watershed assessments where tributaries are a potential source of contamination at select beaches (i.e. Fisher Park Beach).
- Investigate phosphorus concentrations where *Cladophora* impacts the beach (i.e. City of Kewaunee Beach).
- Development of bid-ready redesign plans based on data collected through the sanitary surveys.
- If mitigation occurs, conduct post-remediation sampling to evaluate if the mitigation was effective.

If mitigation is not a cost effective option it is still important to establish best management practices (BMPs) at beaches. These BMPs are an inexpensive way to maintain a beach and reduce water quality exceedances. BMPs could include things like beach grooming, easily accessible trash cans, signage about not feeding the birds or no dogs on the beach, restrooms, and avoiding stormwater outfalls for swimming. All of these BMPs can improve water quality without actual mitigation and construction.

The environmental and financial advantages of beach mitigation and BMPs are noticeable. Not only will water quality improve and provide a healthier and safer recreational experience, but it is anticipated that beach usage will increase, therefore stimulating the local economy. For every beachgoer it is estimated that approximately $35 is generated per person per trip to the beach (59). This includes spending on gasoline, food, hotel stays, and other expenses associated with visiting the beach. If capital is invested in mitigating problems at a beach with a history of poor water quality this will improve the health of the beach, which allows for fewer beach closures, increased usage, and stimulation of local tourism. This investment will benefit the local community for years to come.

APPENDIX A

Additional Results

City of Kewaunee (Selner Park) Beach

Table A-1. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

City of Kewaunee (Selner Park) Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	7	26	27%	178.4
2004	4	19	21%	180.3
2005	3	17	18%	431.0
2006	7	21	33%	398.9
2007	6	21	29%	480.4
2008	3	17	18%	335.4
2009	0	13	0%	51.5
2010	13	53	25%	304.7
2011	15	47	32%	329.1
2012	1	15	7%	150.1
Totals	**59**	**249**	**24%**	**284.0**

Table A-2. Summary of total *E. coli* samples collected over the duration of the study at City of Kewaunee Beach (Selner Park).

Summary of *E. coli* Samples Collected (2010-2012) City of Kewaunee Beach (Selner Park)					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	17	136	135	0	288
2011	31	144	99	2	276
2012	15	0	0	0	15
Total	63	280	234	2	579

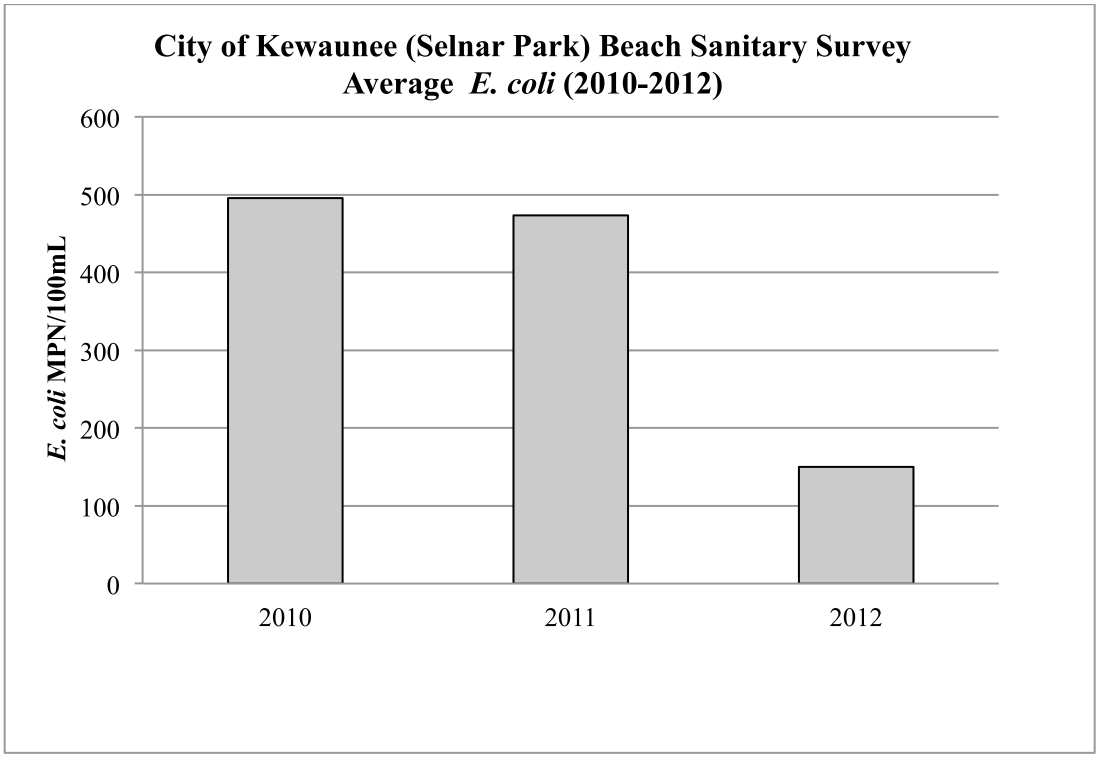


Figure A-1. Average *E. coli* (MPN/100mL) at City of Kewaunee (Selner Park) Beach in Kewaunee, WI, from 2010-2012.

Table A-3. Mean Seasonal *E. coli* Concentrations and Associated Beach Parameters 2010-2012

City of Kewaunee (Selner Park) Beach Mean Results–2010-2012						
E. coli Center 24" (MPN/100mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)	Outfall 1 *E. coli* (MPN/100mL)
302.6	171.8	17.8	38.4	6	2	1123.5
n=64	n=26	n=89	n=87	n=89	n=88	n=2

Table A-4. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

City of Kewanuee (Selner Park) Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0838	0.2781	0.0187
Wind Speed (mph)	0.0194	0.0242	0.1395
Water Temperature (°C)	0.2764	0.0041	0.0623
Air Temperature (°C)	0.0600	0.1365	0.0919
Turbidity (NTU)	0.0894	0.4709	0.0343
Wave Height (ft)	0.0035	0.2848	0.0661
Within 24hr Rain (cm)	0.0208	0.1061	0.1491
Algae (1-3 scale)	0.2094	0.2361	0.0546
Gulls (#)	0.0158	x	0.1070
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	x	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.0635	0.3083	0.0376
Longshore Current Direction (°)	0.1230	0.0130	0.0030
Tributaries/Outfalls *E. coli* – Outfall 1	x	x	x

*x indicates insufficient data collected for statistical analysis.

Crescent Beach

Table A-5. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Crescent Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	13	47	28%	354.2
2004	16	37	43%	656.6
2005	12	35	34%	483.2
2006	11	35	31%	258.5
2007	13	39	33%	383.6
2008	2	28	7%	226.6
2009	4	31	13%	97.2
2010	8	52	15%	144.0
2011	9	33	27%	361.0
2012	5	47	11%	191.6
Totals	**93**	**384**	**24%**	**315.7**

Table A-6. Summary of total *E. coli* samples collected over the duration of the study at Crescent Beach.

Summary of *E. coli* Samples Collected (2010-2012) Crescent Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	18	144	126	0	288
2011	29	180	91	96	396
2012	47	437	63	44	591
Total	94	761	280	140	1275

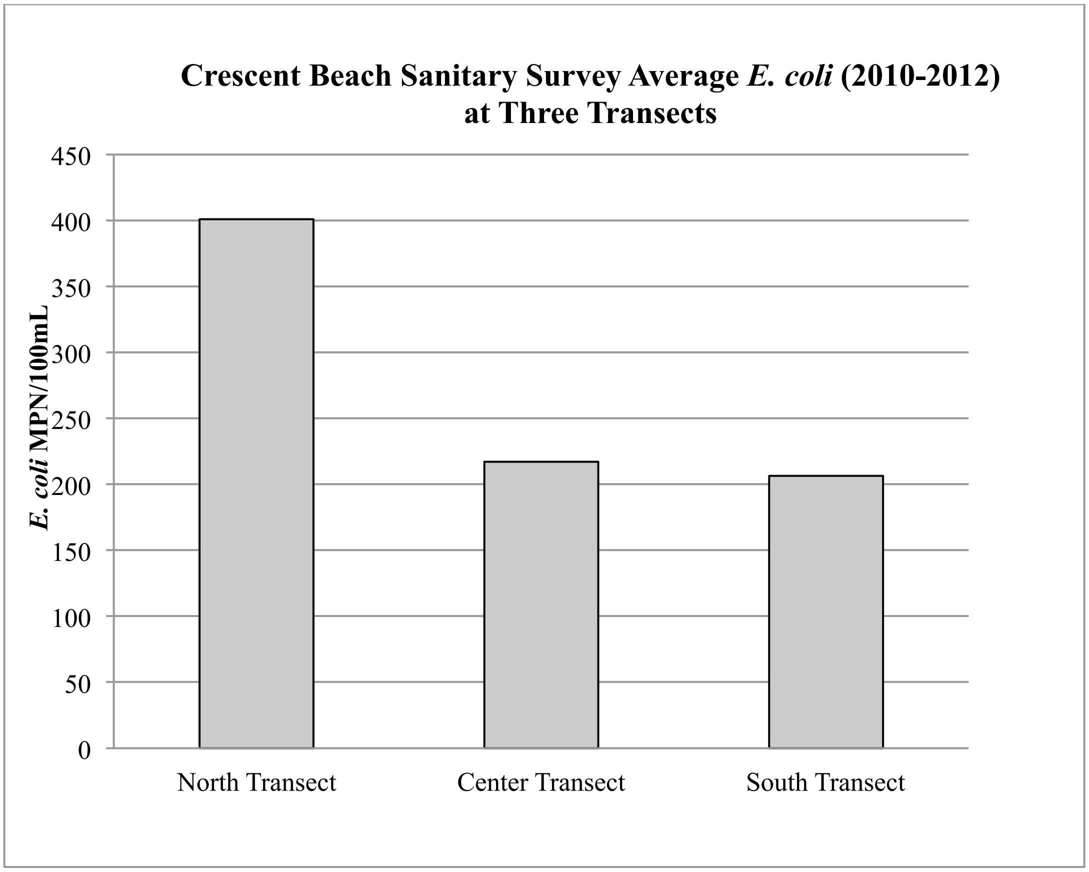


Figure A-2. Average *E. coli* (MPN/100mL) at Crescent Beach in Algoma, Wisconsin, from 2010-2012 (ANOVA p=0.002).

Table A-7. Mean Seasonal Results 2010-2012

Crescent Beach Mean Results– 2010-2012							
E. coli Center 24" (MPN/100 mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)	Pipe 1 Outfall *E. coli* (MPN/100mL)	Pipe 6 Outfall *E. coli* (MPN/100mL)
236.3	25.1	17.7	12.8	100.3	3.7	1106.8	606.6
n=95	n=31	n=120	n=118	n=120	n=120	n=8	n=56

Table A-8. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Crescent Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.3477	0.0473	0.1029
Wind Speed (mph)	0.0020	0.0481	0.0059
Water Temperature (°C)	0.0162	0.0056	0.0835
Air Temperature (°C)	0.0149	0.1969	0.0032
Turbidity (NTU)	0.2348	0.1556	0.0567
Wave Height (ft)	0.1984	0.1991	0.2520
Within 24hr Rain (cm)	0.0116	0.0059	0.0294
Algae (1-3 scale)	0.0006	0.0975	0.0128
Gulls (#)	0.0171	0.2724	0.0344
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	0.0007	0.0041
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.0358	0.1358	0.0876
Longshore Current Direction (°)	0.0744	0.0045	0.0003
Tributaries/Outfalls *E. coli* Pipe 1	x	0.0098	x
Tributaries/Outfalls *E. coli* Pipe 2	x	0.0010	x
Tributaries/Outfalls *E. coli* Pipe 3	x	0	x
Tributaries/Outfalls *E. coli* Pipe 4	x	0.0008	x
Tributaries/Outfalls *E. coli* Pipe 5	x	x	x
Tributaries/Outfalls *E. coli* Pipe 6	x	x	0.2105

*x indicates insufficient data collected for statistical analysis.

Fisher Park Beach

Table A-9. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Fisher Park Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	12	24	50%	303.3
2004	11	25	44%	361.6
2005	2	18	11%	84.4
2006	6	16	38%	682.9
2007	10	23	43%	298.1
2008	16	36	44%	569.8
2009	1	25	4%	80.1
2010	20	64	31%	502.1
2011	7	54	13%	231.4
2012	11	52	21%	375.9
Totals	**96**	**337**	**28%**	**349.0**

Table A-10. Summary of total *E. coli* samples collected over the duration of the study at Fisher Park Beach.

Summary of *E. coli* Samples Collected (2010-2012) Fisher Park Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	53	0	0	0	53
2011	37	120	81	76	314
2012	52	0	63	90	205
Total	142	120	144	166	572

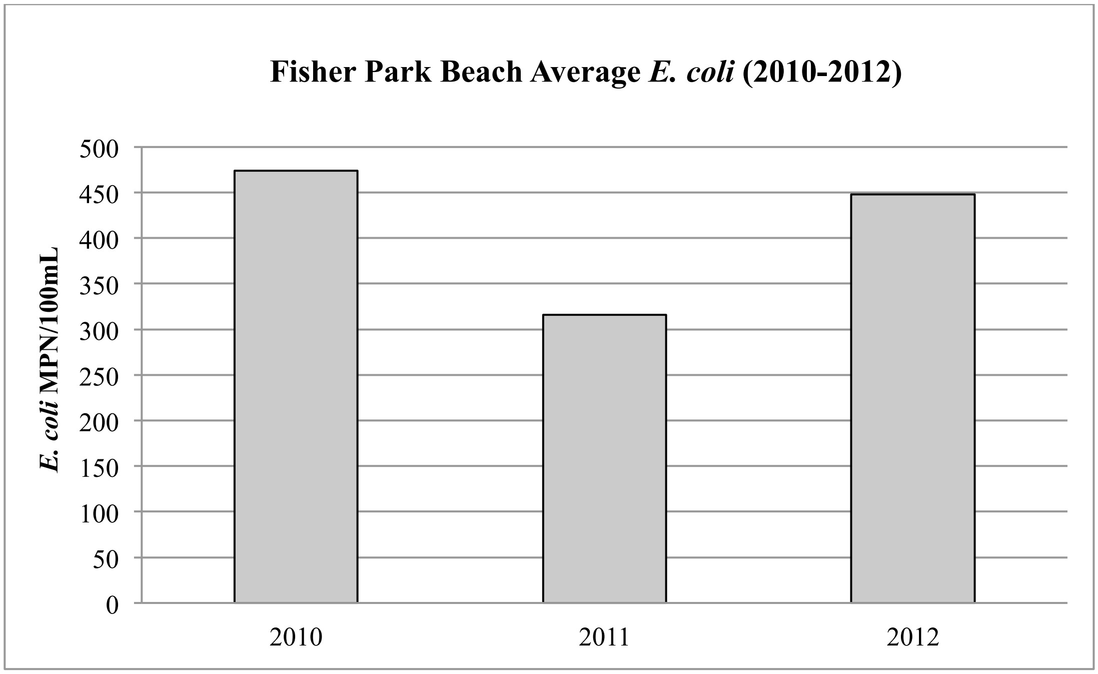


Figure A-3. Average *E. coli* (MPN/100mL) collected at the center of the beach at 24” at Fisher Park Beach in Manitowoc, Wisconsin, from 2010-2012.

Table A-11. Mean Seasonal Results 2010-2012

Fisher Park Beach Mean Results–Summer 2010 - 2012							
E. coli Center 24" (MPN/100mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)	Fisher Creek 1 *E. coli* (MPN/100mL)	Fisher Creek 2 *E. coli* (MPN/100mL
370.9	6.3	19.4	14.5	2	1	534.2	501.2
n= 53	n= 6	n= 53	n=53	n= 53	n= 53	47	45

Table A-12. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Fisher Park Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0626	0.0110	0.0040
Wind Speed (mph)	0.1183	0.0760	0.1757
Water Temperature (°C)	0.0048	0.1874	0.0083
Air Temperature (°C)	0.0897	0.0119	0.0000
Turbidity (NTU)	0.4096	0.3032	0.3071
Wave Height (ft)	0.1823	0.2355	0.2138
Within 24hr Rain (cm)	0.0145	0.0005	0.0399
Algae (1-3 scale)	x	0.0618	0.0496
Gulls (#)	x	x	x
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	x	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.1182	0.0650	0.0012
Longshore Current Direction (°)	x	0.0589	0.0964
Tributaries/Outfalls *E. coli* Fisher Creek 1	x	0.3027	0.4474
Tributaries/Outfalls *E. coli* Fisher Creek 2	x	0.6705	0.4091
Tributaries/Outfalls *E. coli* Fisher Creek Mouth	x	0.6029	x

*x indicates insufficient data collected for statistical analysis.

Kreher Park Beach

Table A-13. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Kreher Park Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	1	41	2%	40.7
2004	6	34	18%	147.2
2005	2	32	6%	85.4
2006	3	30	10%	134.2
2007	1	33	3%	57.8
2008	1	37	3%	42.8
2009	5	32	16%	150.4
2010	5	37	14%	104.7
2011	8	55	15%	144.4
2012	4	51	8%	143.8
Totals	**36**	**382**	**9%**	**105.1**

Table A-14. Summary of total *E. coli* samples collected over the duration of the study at Kreher Park Beach.

Summary of *E. coli* Samples Collected (2010-2012) Kreher Park Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	19	145	116	0	280
2011	47	144	165	36	392
2012	51	345	80	0	476
Total	117	634	361	36	1,148

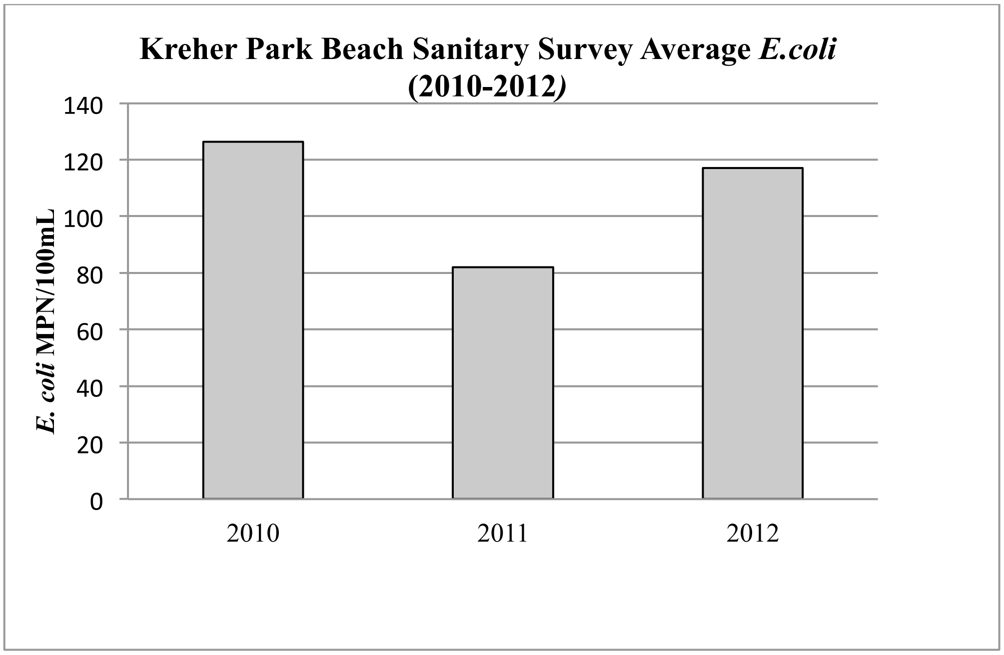


Figure A-4. Average *E. coli* (MPN/100mL) at Kreher Park Beach in Ashland, Wisconsin, from 2010-2012.

Table A-15. Mean Seasonal Results 2010-2012

Kreher Park Beach Mean Results– 2010-2012						
***E. coli* C 24" (MPN/100 mL)**	***E. coli* Sand (MPN/g)**	**Water Temp (°C)**	**Turbidity (NTU)**	**Avian (# gulls)**	**Bathers (# people)**	**Creek 1 *E. coli* (MPN/100mL)**
142.7	159.7	20.5	7.6	5.3	2.5	1118.2
n= 118	n= 37	n=139	n= 106	n= 139	n=1 39	n= 45

Table A-16. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Kreher Park Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0046	0.0076	0.0181
Wind Speed (mph)	0.1530	0.0976	0.0004
Water Temperature (°C)	0.1725	0.0428	0.0000
Air Temperature (°C)	0.1170	0.0317	0.0000
Turbidity (NTU)	x	0.1706	0.0331
Wave Height (ft)	0.0009	0.0490	0.0080
Within 24hr Rain (cm)	0.1599	0.0009	0.0027
Algae (1-3 scale)	x	x	0.0013
Gulls (#)	0.1015	x	0.0265
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	0.0118	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.0157	0.0015	0.0181
Longshore Current Direction (°)	0.0841	0.0400	x
Tributaries/Outfalls *E. coli* Creek 1	x	0.0372	x

*x indicates insufficient data collected for statistical analysis.

Maslowski Beach

Table A-17. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Maslowski Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	5	44	11%	187
2004	8	36	22%	220.2
2005	5	33	15%	164
2006	2	28	7%	98.1
2007	5	36	14%	107.8
2008	7	42	17%	137.8
2009	1	30	3%	89.1
2010	6	42	14%	201.6
2011	4	54	7%	178.8
2012	20	62	32%	280.5
Totals	**63**	**407**	**15%**	**166.5**

Table A-18. Summary of total *E. coli* samples collected over the duration of the study at Maslowski Beach.

Summary of *E. coli* Samples Collected (2010-2012) Maslowski Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	24	191	117	0	332
2011	43	144	135	195	517
2012	62	0	0	54	116
Total	129	335	252	249	965

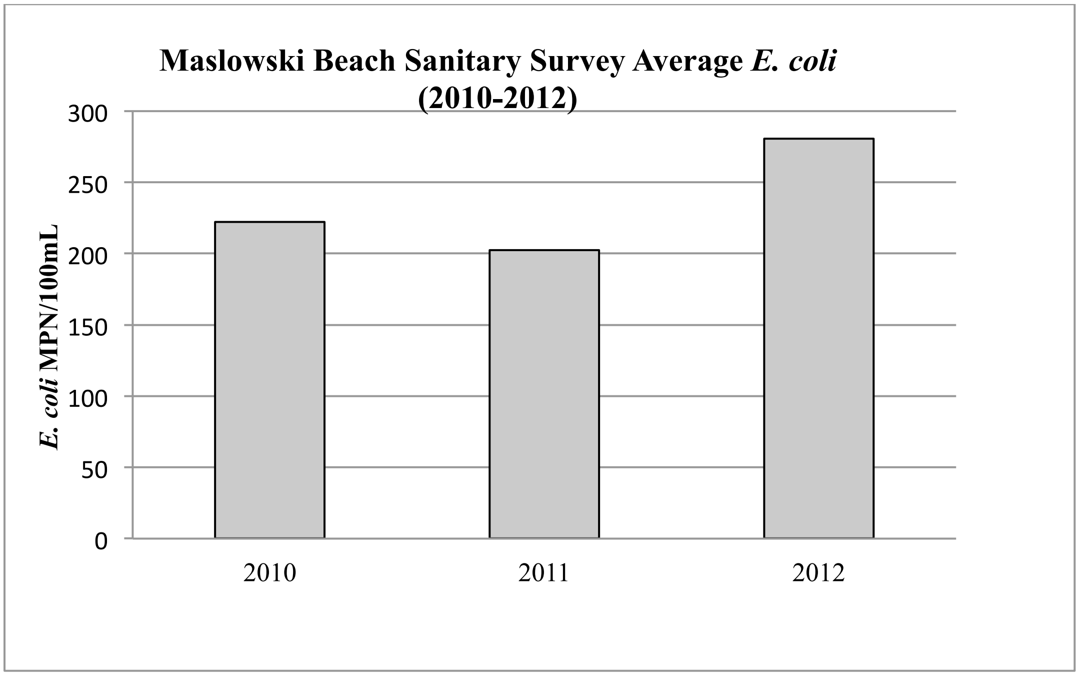


Figure A-5. Average *E. coli* (MPN/100mL) at Maslowski Beach in Ashland, Wisconsin, from 2010-2012.

Table A-19. Mean Seasonal Results 2010-2012

Maslowski Beach Mean Results– 2010-2012									
E. coli (MPN/100 mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity NTU	Avian # gulls	Bather # people	South Fish Creek *E. coli* MPN/100 mL	North Fish Creek MPN/100mL	Whittlesey Creek *E. coli* MPN/100 mL	Maslowski Pipe *E. coli* MPN/100 mL
225.3	228.7	11.4	11.4	37.7	2.6	432.7	383.0	545.1	1226.4
n=134	n=28	n=117	n=117	n=151	n=151	n=46	n=46	n=45	n=61

Table A-20. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Maslowski Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0811	0.0000	0.0027
Wind Speed (mph)	0.0152	0.0461	0.0169
Water Temperature (°C)	0.0436	0.0019	0.0199
Air Temperature (°C)	0.0992	0.0009	0.0000
Turbidity (NTU)	0.6362	0.1251	0.0169
Wave Height (ft)	0.0558	0.0045	0.0476
Within 24hr Rain (cm)	0.0221	0.0225	0.0048
Algae (1-3 scale)	x	0.0225	0.0001
Gulls (#)	0.0291	0.1148	0.0622
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	0.0004	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.0115	0.0135	0.0250
Longshore Current Direction (°)	0.0075	0.0069	x
Tributaries/Outfalls *E. coli* N Creek	x	0.0133	x
Tributaries/Outfalls *E. coli* S Creek	x	0.0056	x
Tributaries/Outfalls *E. coli* Whittlesey Creek	x	0.0070	x
Tributaries/Outfalls *E. coli* Pipe 1	x	x	0.0808

*x indicates insufficient data collected for statistical analysis.

Menominee Park Beach

Table A-21. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Menominee Park Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2010	2	33	6%	109.2
2011	2	27	7%	87.6
2012	2	37	5%	128.1
Totals	**6**	**97**	**6%**	**108.3**

Table A-22. Summary of total *E. coli* samples collected over the duration of the study at Menominee Park Beach.

Summary of *E. coli* Samples Collected (2010-2012) Menominee Park Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	33	258	107	0	398
2011	14	87	77	0	178
2012	29	174	68	0	271
Total	76	519	252	0	847

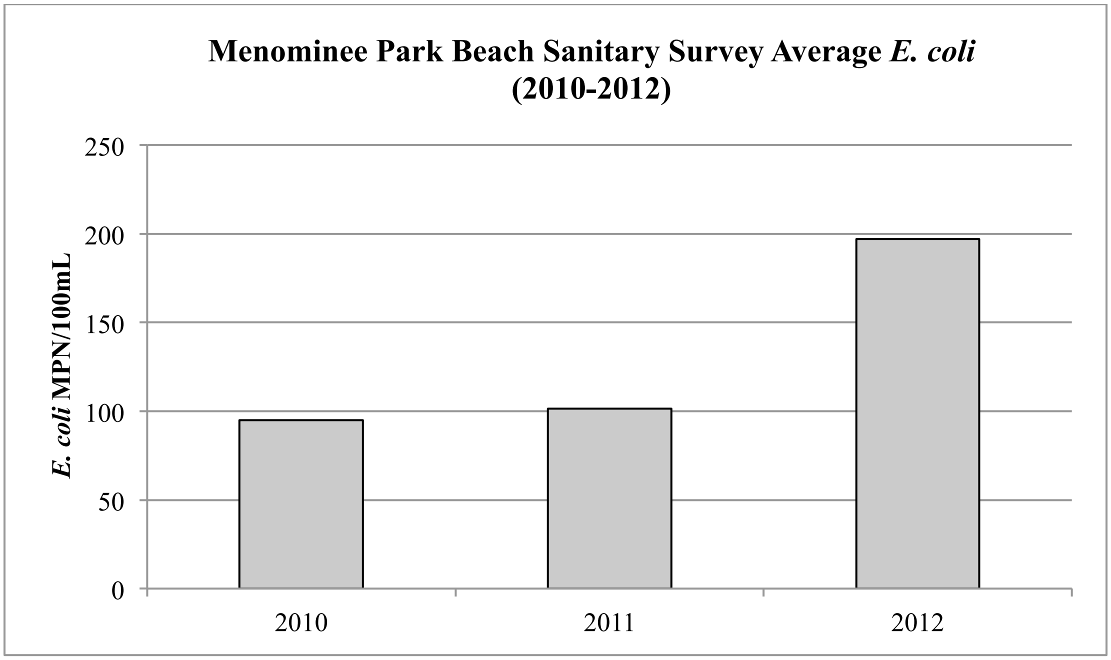


Figure A-6. Average *E. coli* (MPN/100mL) at Menominee Park in Oshkosh, Wisconsin, from 2010-2012.

Table A-23. Mean Seasonal Results 2010-2012

Menominee Park Beach Mean Results– 2010-2012					
E. coli Center 24" (MPN/100 mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)
114.9	203.2	24.4	4.2	23.2	14.2
n= 76	n= 30	n= 92	n= 58	n= 91	n= 92

Table A-24. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Menominee Park Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	x	0.1001	0.0460
Wind Speed (mph)	0.0001	0.1149	0.0100
Water Temperature (°C)	0.0501	0.0206	0.0021
Air Temperature (°C)	0.0000	0.0513	0.0327
Turbidity (NTU)	0.1851	0.0040	x
Wave Height (ft)	0.1475	0.1137	0.0565
Within 24hr Rain (cm)	0.1423	0.0679	0.2333
Algae (1-3 scale)	x	x	0.0691
Gulls (#)	0.0066	0.0507	0.0002
Geese (#)	x	0.0032	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	0.0114	0.0000
Bathers In Water (#)	x	0.0489	0.0103
Longshore Current Speed (cm/sec)	0.0500	0.2522	0.2152
Longshore Current Direction (°)	x	0.0929	0.0326

*x indicates insufficient data collected for statistical analysis.

Neshotah Beach

Table A-25. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Neshotah Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**# of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	16	35	46%	308.9
2004	10	26	38%	473.8
2005	5	20	25%	197.0
2006	13	27	48%	669.1
2007	12	41	29%	199.5
2008	16	39	41%	246.3
2009	0	25	0%	67.9
2010	2	53	4%	59.1
2011	7	53	13%	122.8
2012	1	55	2%	55.1
Totals	**82**	**374**	**22%**	**240.0**

Table A-26. Summary of total *E. coli* samples collected over the duration of the study at Neshotah Beach.

Summary of *E. coli* Samples Collected (2010-2012) Neshotah Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	50	0	0	0	50
2011	38	169	146	38	391
2012	55	346	71	64	536
Total	143	515	217	102	977

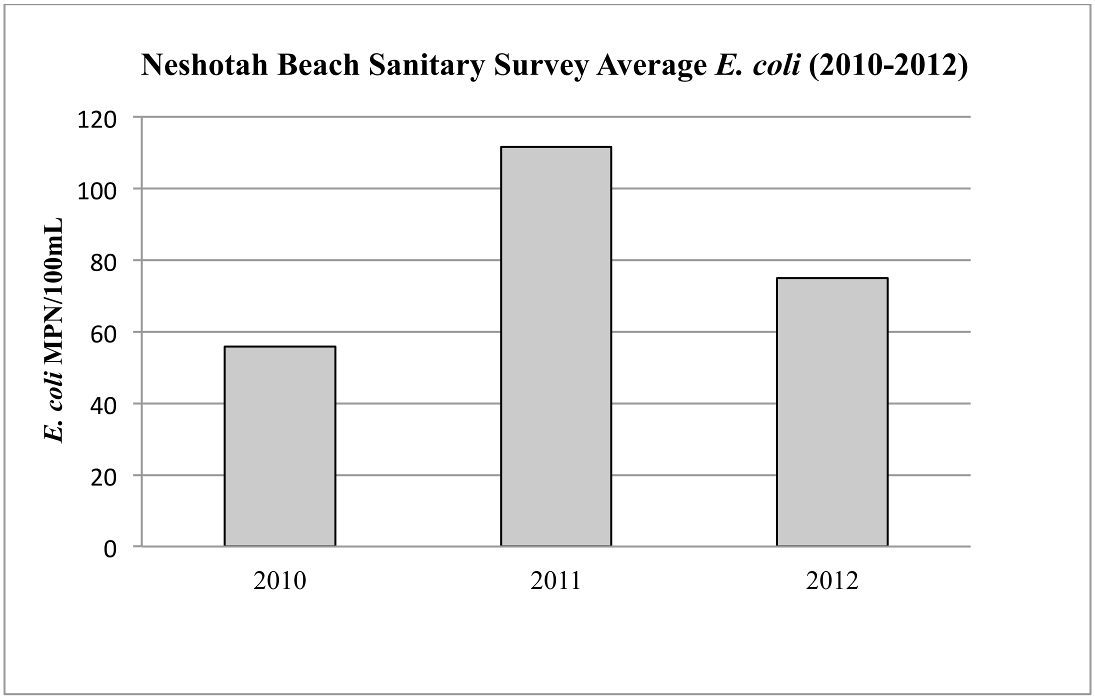


Figure A-7. Average *E. coli* (MPN/100mL) at Neshotah Beach in Two Rivers, Wisconsin, from 2010-2012.

Table A-27. Mean Seasonal Results 2010-2012

	Neshotah Beach Mean Results– 2010-2012						
E. coli Center 24" (MPN/100 mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)	Pipe N *E. coli* (MPN/100mL)	Pipe S *E. coli* (MPN/100mL)
637	68.1	18	5.2	202.9	25	108.4	234.6
n =143	n= 23	n= 151	n= 141	n= 152	n= 152	n= 61	n= 35

Table A-28. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Neshotah Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0130	0.0251	0.0342
Wind Speed (mph)	0.0000	0.1619	0.0062
Water Temperature (°C)	0.0606	0.0000	0.0147
Air Temperature (°C)	0.0000	0.0999	0.0000
Turbidity (NTU)	0.0321	0.0804	0.1424
Wave Height (ft)	0.0429	0.5893	0.0047
Within 24hr Rain (cm)	0.0295	0.0144	0.0047
Algae (1-3 scale)	x	0.0284	x
Gulls (#)	0.0000	0.1372	0.0081
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	0.0055	0.1176	0.0091
Bathers In Water (#)	0.0017	0.1483	0.0085
Longshore Current Speed (cm/sec)	0.0085	x	0.1999
Longshore Current Direction (°)	0.0158	x	0.0542
Tributaries/Outfalls *E. coli* Pipe N	x	0.5968	0.0223
Tributaries/Outfalls *E. coli* Pipe S	x	0.2431	0.0076

*x indicates insufficient data collected for statistical analysis.

Red Arrow Beach

Table A-29. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Red Arrow Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	18	35	51%	323.4
2004	10	23	43%	281.7
2005	4	19	21%	173.2
2006	14	26	54%	721.6
2007	12	33	36%	473.9
2008	13	36	36%	462.1
2009	4	27	15%	133.2
2010	23	58	40%	577.4
2011	17	58	29%	416.3
2012	14	60	23%	322.1
Totals	**129**	**375**	**34%**	**388.5**

Table A-30. Summary of total *E. coli* samples collected over the duration of the study at Red Arrow Park Beach.

Summary of *E. coli* Samples Collected (2010-2012) Red Arrow Park Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	53	0	0	0	53
2011	38	144	144	42	368
2012	60	302	58	81	501
Total	151	446	202	123	922

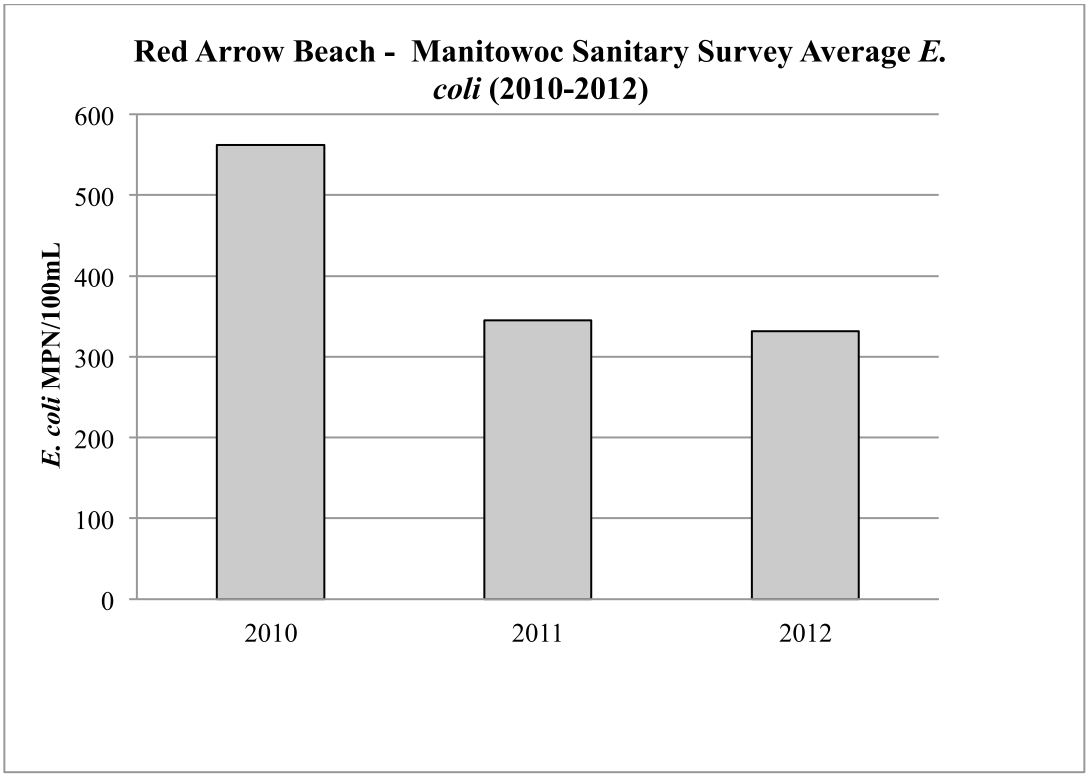


Figure A-8. Average *E. coli* (MPN/100mL) at Red Arrow Beach in Manitowoc, Wisconsin, from 2010-2012.

Table A-31. Mean Seasonal Results 2010-2012

Red Arrow Beach Mean Results–2010 - 2012						
E. coli Center 24" (MPN/100 mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)	Outfall S *E. coli* (MPN/100mL)
416.8	11.4	18.6	7.7	89.5	2.4	463.6
n= 151	n= 24	n= 160	n= 150	n= 160	n= 160	n=55

Table A-32. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Red Arrow Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0038	0.0248	0.0068
Wind Speed (mph)	0.0900	0.0087	0.0418
Water Temperature (°C)	0.0212	0.0119	0.0163
Air Temperature (°C)	0.0663	0.0332	0.0038
Turbidity (NTU)	0.1260	0.0319	0.2754
Wave Height (ft)	0.0085	0.1178	0.1252
Within 24hr Rain (cm)	0.0127	0.1260	0.1330
Algae (1-3 scale)	x	0.0082	0.0870
Gulls (#)	0.0008	0.0294	0.0738
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	x	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.1308	0.0006	0.1547
Longshore Current Direction (°)	x	x	x
Tributaries/Outfalls *E. coli* Outfall S	2010-2012: 0.2670 (n=55)		

*x indicates insufficient data collected for statistical analysis.

Thompson's West End Park Beach

Table A-33. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

Thompson's West End Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	0	17	0%	31.5
2004	1	14	7%	97.7
2005	2	16	13%	193.2
2006	7	21	33%	375.4
2007	8	44	18%	227.6
2008	3	27	11%	151.0
2009	0	16	0%	20.5
2010	9	53	17%	198.0
2011	8	56	14%	154.7
2012	4	55	7%	88.3
Totals	**42**	**319**	**13%**	**153.8**

Table A-34. Summary of total *E. coli* samples collected over the duration of the study at Thompson's West End Park Beach.

Summary of *E. coli* Samples Collected (2010-2012) Thompson's West End Park Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	23	182	124	2	331
2011	48	144	135	221	548
2012	55	0	0	108	163
Total	126	326	259	331	1,042

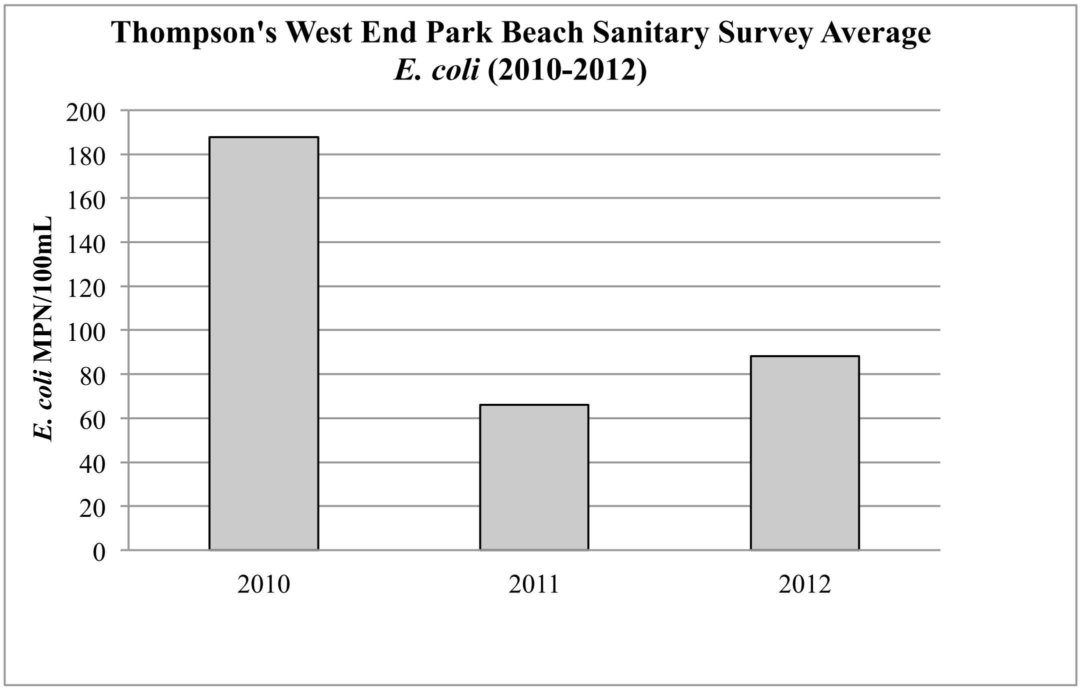


Figure A-9. Average *E. coli* (MPN/100mL) at Thompson's West End Beach in Washburn, Wisconsin, from 2010-2012.

Table A-35. Mean Seasonal Results 2010-2012

Thompson's West End Beach Mean Results–Summer 2010 - 2012								
E. coli Center 24" MPN/100 mL	*E. coli* Sand MPN/g	Water Temp (°C)	Turbidity (NTU)	Avian # gulls	Bathers # people	Creek *E. coli* (MPN/100mL)	Pipe 1 *E. coli* (MPN/100mL)	Pipe 2 *E. coli* (MPN/100mL)
136	60.9	18.9	3.2	1.2	1.1	310.4	182.2	135.8
n= 127	n= 29	n=146	n= 124	n= 144	n= 145	n= 45	n= 70	n= 66

Table A-36. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

Thompson's West End	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0820	0.0023	0.0114
Wind Speed (mph)	0.0104	0.0036	0.0481
Water Temperature (°C)	0.0883	0.0034	0.0000
Air Temperature (°C)	0.0000	0.0000	0.0078
Turbidity (NTU)	0.1716	0.1776	0.3289
Wave Height (ft)	0.1669	0.0844	0.1171
Within 24hr Rain (cm)	0.0555	0.1410	0.2475
Algae (1-3 scale)	x	0.0030	0.0087
Gulls (#)	x	x	x
Geese (#)	x	x	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	x	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	0.0031	0.0160	0.0210
Longshore Current Direction (°)	0.1149	0.0038	X
Tributaries/Outfalls *E. coli* Creek	x	0.1919	X
Tributaries/Outfalls *E. coli* Pipe 1	x	0.3146	0.3481
Tributaries/Outfalls *E. coli* Pipe 2	x	0.4238	0.4925
Tributaries/Outfalls *E. coli* Pipe 3	x	0.7170	X
Tributaries/Outfalls *E. coli* Waterfall 1	x	0.2296	X
Tributaries/Outfalls *E. coli* Waterfall 2	x	0.3184	X
Tributaries/Outfalls *E. coli* Pipe 1 Ditch	x	0.2423	X
Tributaries/Outfalls *E. coli* Stop Sign	x	0.1848	x
Tributaries/Outfalls *E. coli* Upstream from Pipe 2	x	0.0919	x

*x indicates insufficient data collected for statistical analysis.

YMCA Beach

Table A-37. Historical Water Quality (2003-2012): Routine Monitoring for BEACH Act

YMCA Beach Historical Data Number of Samples Exceeding Water Quality Standards				
Year	**Number of Exceedances**	**Total Samples**	**Percent Exceedances**	**Average *E. coli* (MPN/100 mL)**
2003	20	29	69%	567.9
2004	11	24	46%	377.5
2005	7	19	37%	315.8
2006	22	26	85%	1285.8
2007	22	40	55%	832.5
2010	x	x	x	x
2011	16	38	42%	461.2
2012	14	40	35%	465.2
Totals	**112**	**216**	**52%**	**615.1**

Table A-38. Summary of total *E. coli* samples collected over the duration of the study at YMCA Beach.

Summary of *E. coli* Samples Collected (2010-2012) YMCA Beach					
Year	**Routine Monitoring**	**Spatial Samples**	**Sand Samples**	**Investigative Samples (Tributaries, outfalls)**	***E. coli* Samples per Year**
2010	16	128	122	0	266
2011	30	143	89	48	310
2012	44	0	18	51	113
Total	90	271	229	99	689

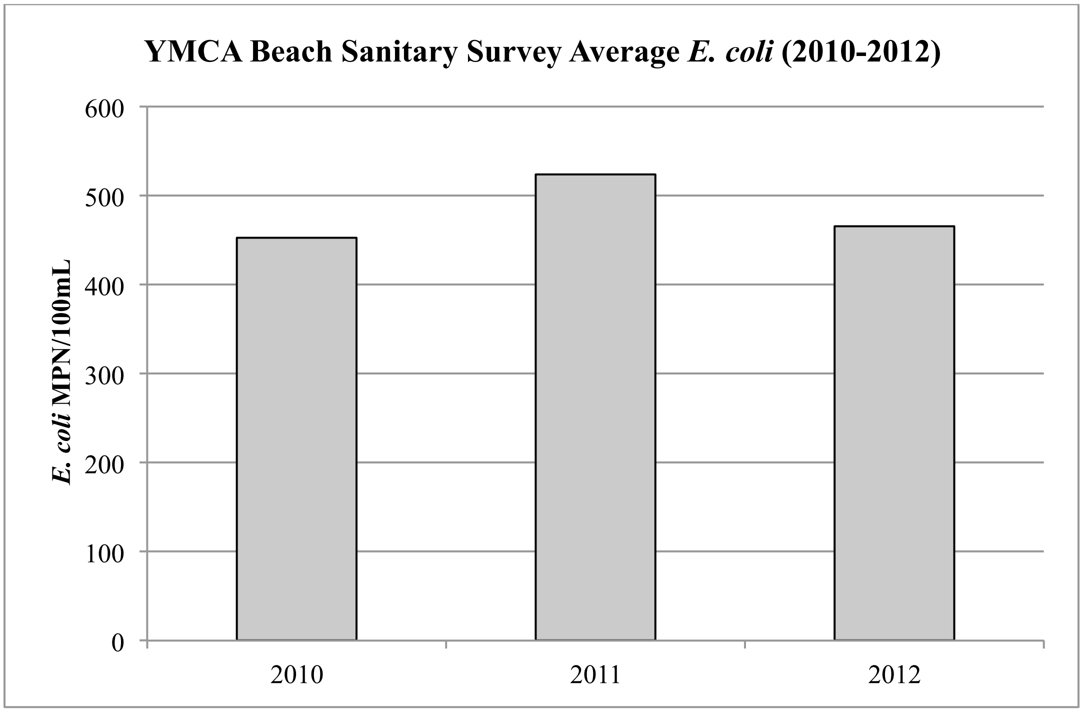


Figure A-10. Average *E. coli* (MPN/100mL) at YMCA Beach in Manitowoc, Wisconsin, from 2010-2012.

Table 39. Mean Seasonal Results 2010-2012

YMCA Beach Mean Results– 2010-2012						
E. coli Center 24" (MPN/100 mL)	*E. coli* Sand (MPN/g)	Water Temp (°C)	Turbidity (NTU)	Avian (# gulls)	Bathers (# people)	Outfall 1 *E. coli* (MPN/100mL)
485.8	124.9	19.6	7.6	7.4	0.35	297.5
n= 89	n= 24	n=130	n= 129	n= 131	n= 131	n= 32

Table A-40. Potential sources of contamination based on linear regression between biological, physical, or chemical parameters and log *E. coli* concentrations.

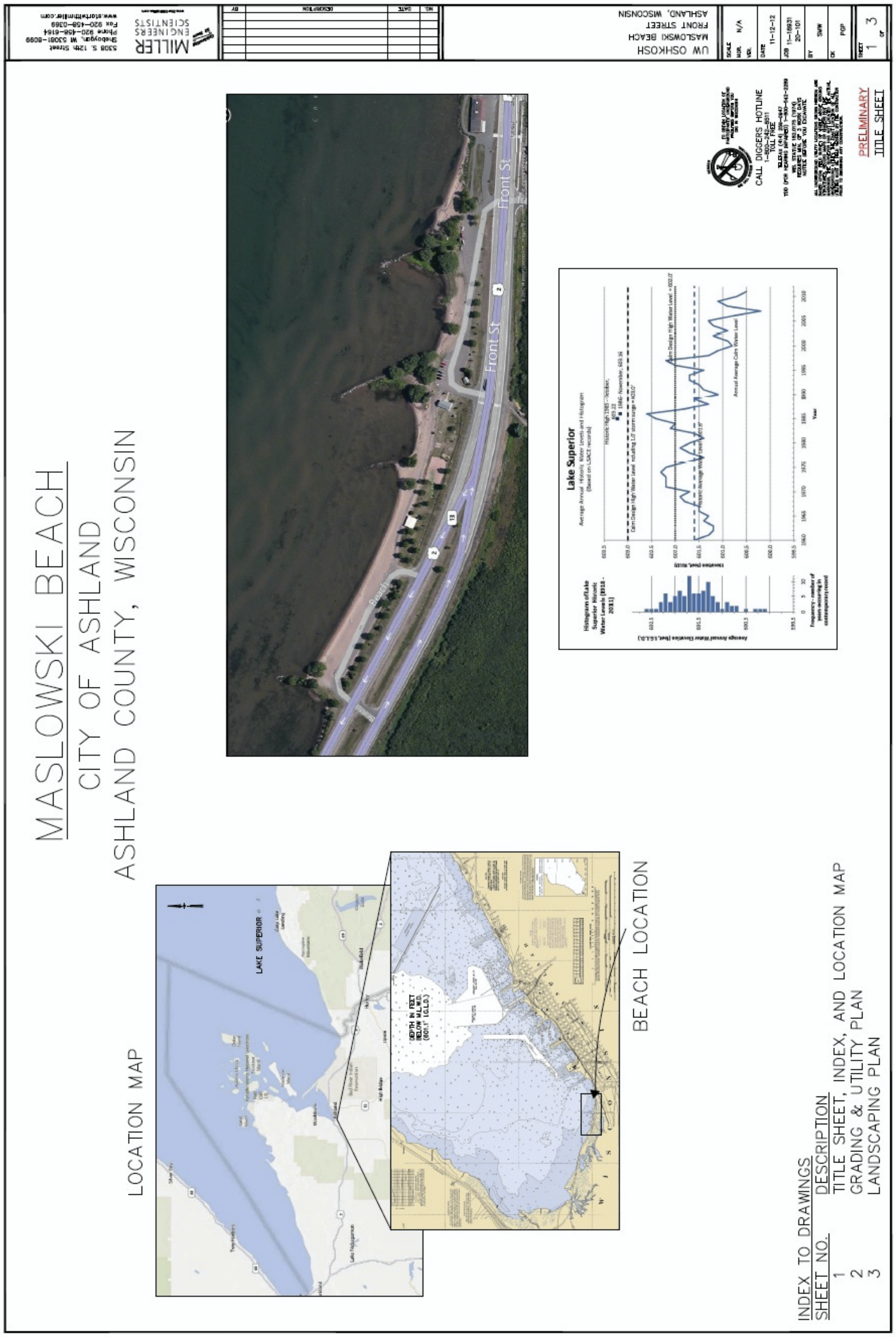
YMCA Beach	**R^2 Value**		
Physical/Chemical/Biological Parameter vs. Center *E. coli*	**2010**	**2011**	**2012**
Wind Direction (°)	0.0082	0.0545	0.0982
Wind Speed (mph)	0.2489	0.0576	0.0308
Water Temperature (°C)	0.0253	0.1010	0.0622
Air Temperature (°C)	0.1274	0.1250	0.0310
Turbidity (NTU)	0.0060	0.0734	0.0001
Wave Height (ft)	0.0034	0.1033	0.0077
Within 24hr Rain (cm)	0.0082	0.0525	0.0982
Algae (1-3 scale)	x	x	0.1173
Gulls (#)	0.4494	0.0228	0.0014
Geese (#)	x	0.0086	x
Other Avian (#)	x	x	x
Bathers at Beach (#)	x	x	x
Bathers In Water (#)	x	x	x
Longshore Current Speed (cm/sec)	x	x	x
Longshore Current Direction (°)	x	x	0.0334
Tributaries/Outfalls *E. coli* Outfall 1	x	0.1312	x

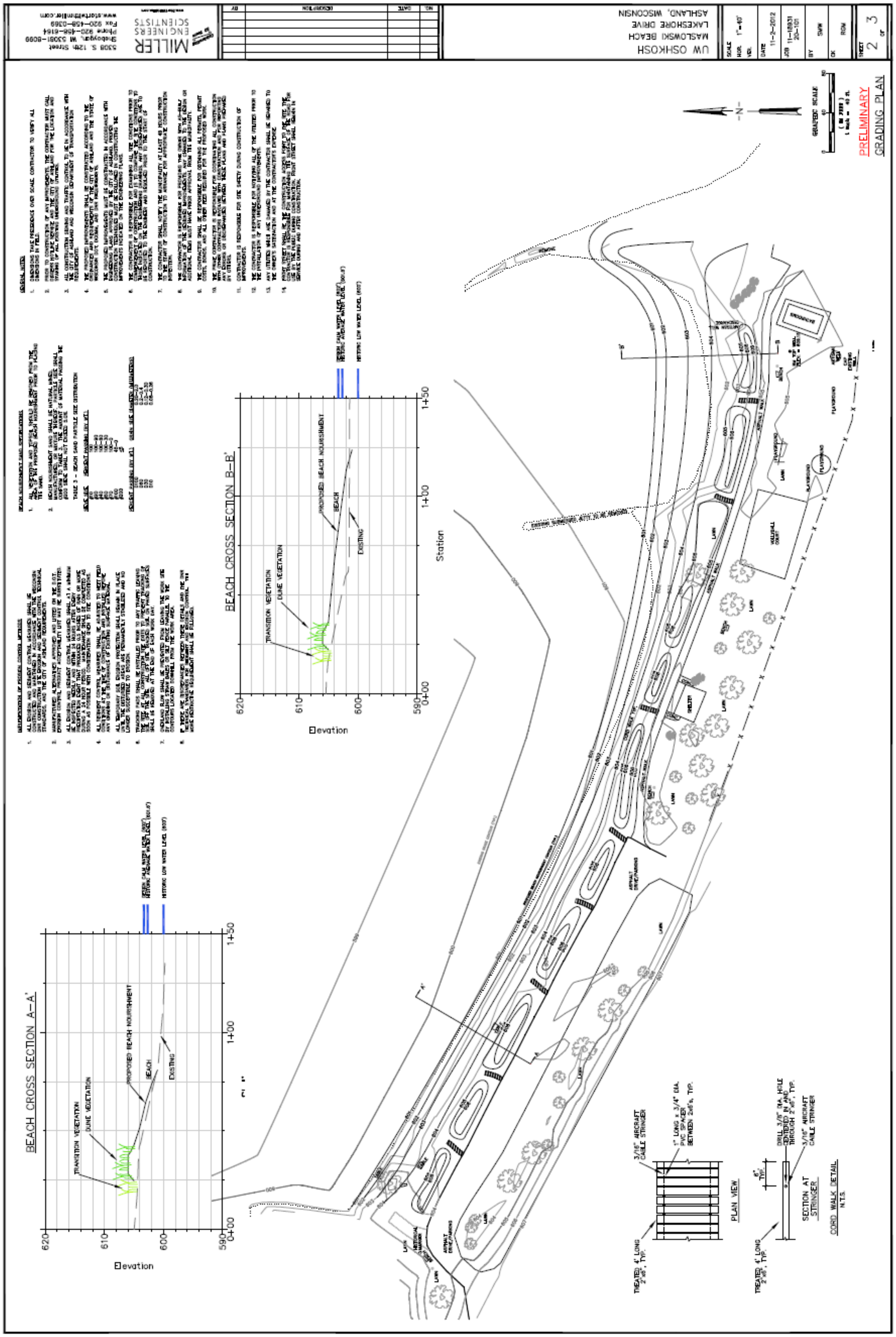
*x indicates insufficient data collected for statistical analysis.

APPENDIX B

Conceptual Redesign Plans

Maslowski Beach





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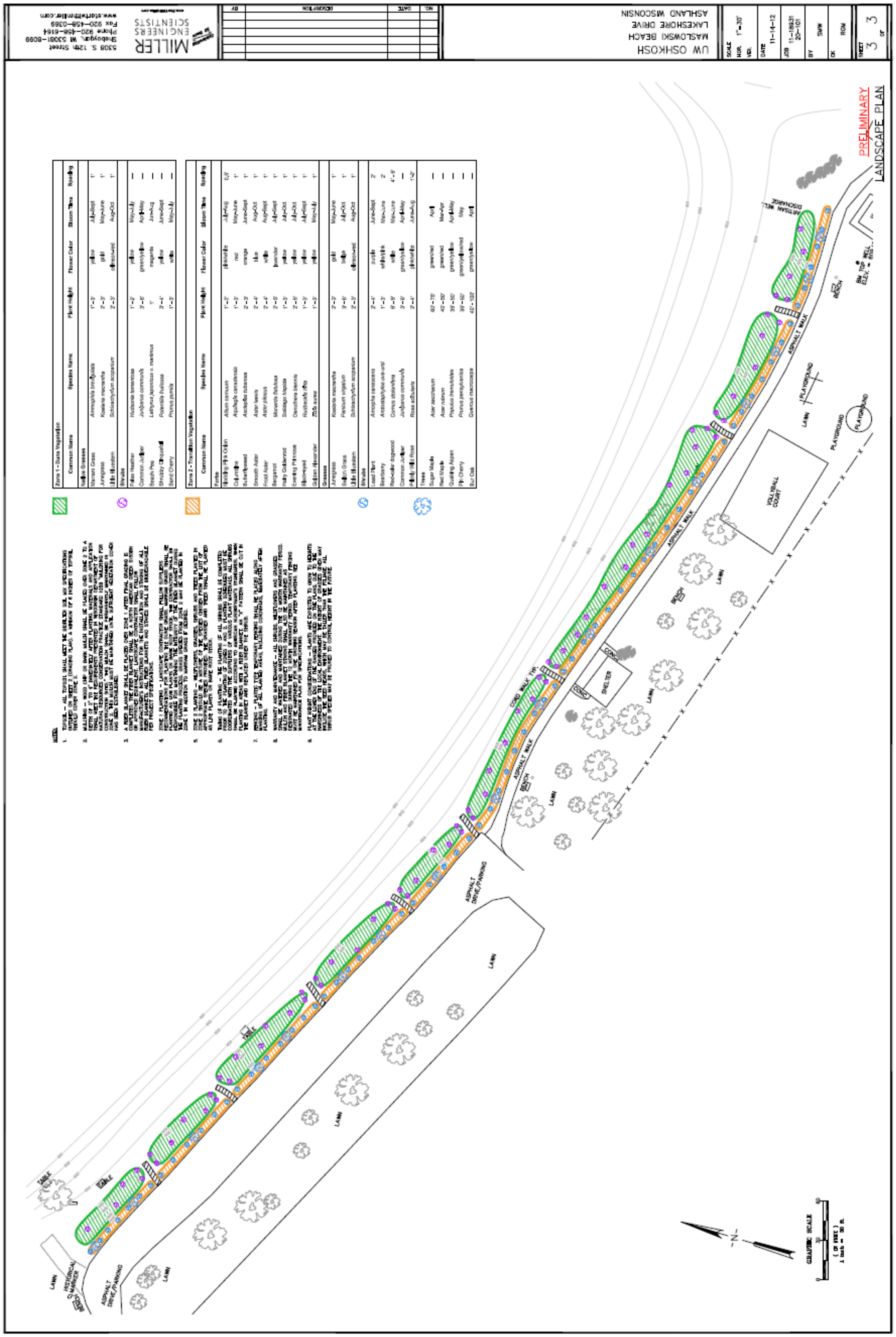
BEACH CROSS SECTION B-B'
TRANSITION VEGETATION
DUNE VEGETATION
PROPOSED BEACH NOURISHMENT
BEACH
EXISTING
Elevation
Station
PLAN VIEW
SECTION AT STRINGER
CORD WALK DETAIL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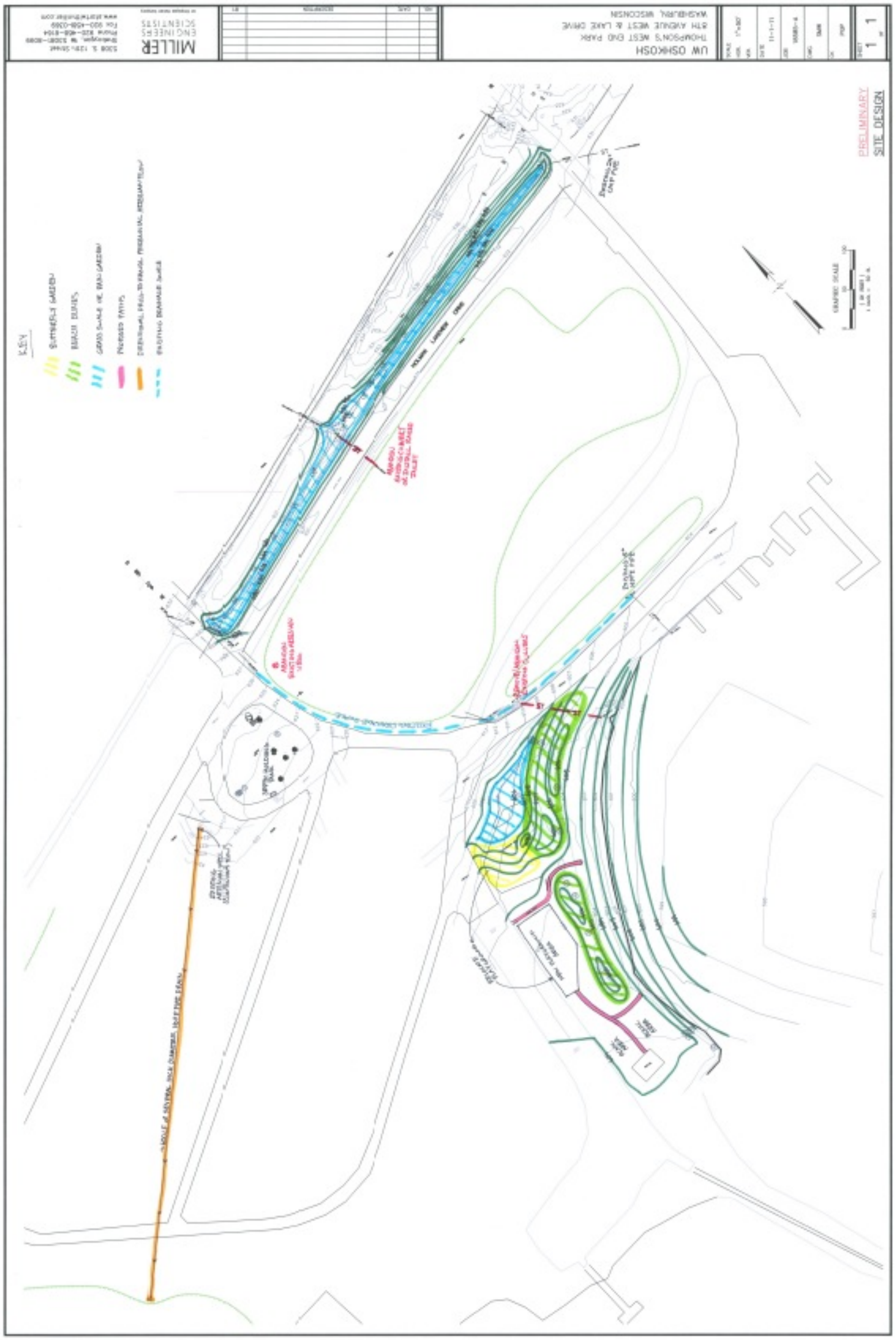
Thompson's West End Park Beach



YMCA Beach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YMCA BEACH
MARITIME DRIVE
MANITOWOC, WISCONSIN
LEGEND (Proposed Features)
BEACH DUNES
INFILTRATION TRENCH
PROPOSED FOOTPATHS
PRELIMINARY
CONCEPT
OPTIONAL
OPTIONAL

APPENDIX C

Sanitary Survey Forms

Routine Sanitary Survey Form

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

GREAT LAKES BEACHES ROUTINE ON-SITE SANITARY SURVEY (continued)

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):

Annual Sanitary Survey

GREAT LAKES BEACH ANNUAL SANITARY SURVEY

1. BASIC INFORMATION

Name of Beach:	Date(s) of Survey:
Beach ID:	Name of Waterbody:
Town/City/County/State:	Number of Routine Surveys Used:
Sampling Station(s)/ID:	Name(s) of Surveyor(s):
STORET Organizational ID:	Surveyor Affiliation:

2. DESCRIPTION OF LAND USE IN WATERSHED

Current Land Use in Watershed

Type	Residential	Industrial	Commercial	Agricultural	Other (specify):
Percentage					

Development	Describe
% undeveloped	
% developed	

How was land use measured:

Waterbody Uses: ☐ Boating ☐ Fishing ☐ Surfing ☐ Windsurfing ☐ Diving ☐ Other (specify)

Are maps of the beach area attached? ☐ yes ☐ no Are maps of the watershed attached? ☐ yes ☐ no

List maps and their sources:

Does the detailed map include locations of:

Sample Points	☐ yes	☐ no	(explain):
Hydrometric Network	☐ yes	☐ no	(explain):
Pollutant Sources	☐ yes	☐ no	(explain):
Boat Traffic	☐ yes	☐ no	(explain):
Marinas	☐ yes	☐ no	(explain):
Boat dockage	☐ yes	☐ no	(explain):
Fishing	☐ yes	☐ no	(explain):
Bathing/Swimming	☐ yes	☐ no	(explain):
Bounding Structures:			
Jetty	☐ yes	☐ no	(explain):
Groin	☐ yes	☐ no	(explain):
Seawall	☐ yes	☐ no	(explain):
Other	☐ yes	☐ no	(explain):
Sanitary Facilities	☐ yes	☐ no	(explain):
Restaurants/Bars	☐ yes	☐ no	(explain):
Playground	☐ yes	☐ no	(explain):
Parking Lot(s)	☐ yes	☐ no	(explain):
Other	☐ yes	☐ no	(explain):

Erosion/Accretion Measurements

High Watermark Location Identification	Fixed Object Description (e.g., tree, building)	Distance from Fixed Object to High Watermark	Feet or Meters?	Distance between High Watermark Locations	Feet or Meters?
A				A↔B:	
B				B↔C:	
C				C↔D:	
D (optional)				D↔E:	
E (optional)					

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Bounding Structures

Bounding Structure	Number	Description or Comment
Jetty		
Groin		
Seawall		
Natural formation		
Other (specify):		
Other (specify):		

Beach Materials/Sediments:

☐ Sandy ☐ Mucky ☐ Rocky ☐ Other:

Or, Beach Materials/Sediments Lab Analysis (attach diagram or photographs of plot locations)

Name of Lab Used:			
Date of Sample Collection:			
Plot ID	Mean Grain Size Diameter	Uniformity Coefficient	Description of Plot Location:
Average			

Describe the results and conclusion of the sediment analysis and potential effects of the sediment distribution at this beach:

Photographs Taken in the Beach Area or Surrounding Watershed

Image Number	Date/Time	File Name	Description of Photograph (Include Pictures of High Watermark Locations and Corresponding Fixed Objects)

Habitat around beach:

☐ Dunes ☐ Wetlands ☐ River/stream ☐ Forest ☐ Park ☐ Protected Habitat or Reserve

☐ Other:

3. WEATHER CONDITIONS

Examine the weather data collected over the prior beach season(s) along with bacteria sampling results.
Do the bacteria concentrations at this beach appear to correlate with any of the following?

Rainfall	☐ yes	☐ no	(explain):
Air Temperature	☐ yes	☐ no	(explain):
Water Temperature	☐ yes	☐ no	(explain):
Cloud Cover	☐ yes	☐ no	(explain):
Wind Speed	☐ yes	☐ no	(explain):
Wind Direction	☐ yes	☐ no	(explain):
Longshore Current	☐ yes	☐ no	(explain):
Wave Height or Intensity	☐ yes	☐ no	(explain):
Other Weather	☐ yes	☐ no	(explain):

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Have any statistical analyses been done to calculate the degree of correlation? ☐ yes ☐ no

Describe any analyses done, and any trends or correlations found (add lines if needed to describe in detail):

Average air temperature during beach season: ° C or ° F | Average water temperature during beach season: ° C or °F

Average wind speed and direction during beach season (e.g., E or 90° at 15 mph):

Typical weather conditions: ☐ Sunny ☐ Mostly Sunny ☐ Partly Cloudy ☐ Mostly Cloudy ☐ Overcast ☐ Rainy

Rainfall total for the beach season (in): | Average rainfall for all beach seasons (in):

Does rainfall intensity correlate with bacteria sample results? ☐ yes ☐ no Describe:

Number of significant rain events: | What constitutes "significant?" (e.g., 1 inch or more rain)

Additional Comments/Observations:

4. PHYSICAL BEACH CONDITIONS

Beach length or dimensions (indicate Z1, Z2, and Z3 on a map)

Length (m): | Width (average, in m):

Width Z1 (m): | Width Z2 (m): | Width Z3 (m):

Local water level variation: feet inches | Hydrographic influences (e.g., seiches):

Characterize any longshore or nearshore currents and their potential effects based on bacteria sampling results

Approximate beach slope at swim area: ________ %

Description and date of last beach rehabilitation (example: new sand, nourishment, dredging, etc., physical structures will be described in Sections 12 and 13):

Comments/Observations:

5. BATHER LOAD (# OF BEACH USERS)

Is bather load measured? ☐ yes ☐ no

If yes, describe how beachgoer numbers are calculated (i.e., turnstile, counting at noon, photographs):

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Beach Use

Beachgoer Category	Number of People Per Day Using the Beach: Peak Use for the Season (Daily Use)	Seasonal Average (Daily Use)	Holiday Average (Daily Use)	Weekend Average (Daily Use)	Weekday Average (Daily Use)	Off-Season Average if applicable (Daily Use)
Total people in the water						
Total people out of the water						
Total people at the beach						
Breakdown of Activities (if activities were broken down on the Routine-Onsite Sanitary Survey, summarize them here)						
Activity 1:						
Activity 2:						
Activity 3:						
Activity 4:						
Activity 5:						
Activity 6:						
Frequency of measurements (e.g., daily, weekly, monthly)						

Examine bather load data along with sampling results for the past beach season(s). Look at each sampling point. Does bather load appear to correlate with bacteria concentrations at any of these sampling points? Does the amount of people in the water or out of the water correlate with bacteria concentrations? Has a statistical analysis been done? Describe:

Comments/Observations:

6. BEACH CLEANING

Beach cleaning frequency during season:

Description of cleanup activities

	Leveling of Sand	Trimming or Removing Vegetation	Removing Debris	Removing Trash	Construction and Maintenance of a Temporary Pathway Directly to Open Water	Other (specify):
Check activities that were done						
Equipment used (if applicable)						

How often are floatables found at the beach? ☐ Never ☐ Sometimes ☐ Frequently ☐ Very frequently

Known sources of floatables:

Types of floatables found ☐ Street litter ☐ Food-related litter ☐ Medical items ☐ Sewage-related ☐ Building materials ☐ Fishing related ☐ Household waste ☐ Other:

How often is beach debris/litter found on the beach? ☐ Never ☐ Sometimes ☐ Frequently ☐ Very frequently

Known sources of debris:

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Type of Debris/Litter Found

☐ Street litter ☐ Food-related litter ☐ Medical items ☐ Sewage-related ☐ Building materials
☐ Fishing related ☐ Household waste ☐ Tar ☐ Oil/ Grease ☐ Other:

Comments/Observations:

7. INFORMATION ON SAMPLING LOCATION

Description of Sample Points (include beach water and potential pollution sources)

Sample Point Name/ID	Location	Description	Sample Frequency	Time of Day of Sample Collection

Description of hydrometric network [note that this is a network of monitoring stations that collect data such as rainfall and stream flow]

Comments/Observations:

8. WATER QUALITY SAMPLING

Name of laboratory: ____________ Distance to laboratory: ________ miles

Is there a sampling and analysis plan? ☐ yes ☐ no Is it adequate? ☐ yes ☐ no (explain):

Are the sampling staff properly trained on sampling techniques, equipment maintenance, and calibration procedures? ☐ yes ☐ no

Biological Survey Results:

Were invasive/nonnative species present? ☐ yes ☐ no (describe): ____________

Have algae blooms been observed during the beach season? (If so, specify duration and algae species) ____________

Percent of beach season where algae was present in significant amounts in the nearshore water: ☐ None ☐ Low (1–20%) ☐ Moderate (21–50%) ☐ High (> 50%)

Percent of beach season where algae was present in significant amounts on the beach: ☐ None ☐ Low (1–20%) ☐ Moderate (21–50%) ☐ High (> 50%)

List types of algae found: ____________

Colors of algae most commonly found: ____________

List any infectious snails that were found: ____________

List any dangerous aquatic organisms that were found: ____________

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Presence of Wildlife and Domestic Animals

Type	Degree of Presence (Low, Mod, High)	Does the Presence Appear to Correlate with Bacteria Results? (Yes, No, Don't Know)	Describe Further (include whether fecal droppings are seen and are a problem)
Geese			
Gulls			
Dogs			
Other (specify):			
Other (specify):			
Other (specify):			

Was a significant number of dead birds found on the beach during beach season? ☐ yes ☐ no
Describe types and numbers found and possible causes: ______

Was a significant number of dead fish found on the beach during the beach season? ☐ yes ☐ no
Describe numbers found and possible causes: ______

Bacteria Samples Collected

Do you test for *Escherichia coli*? ☐ yes ☐ no Analytical Method Used: ______
Do you test for *Enterococcus*? ☐ yes ☐ no Analytical Method Used: ______
Do you test for fecal coliform? ☐ yes ☐ no Analytical Method Used: ______
List any additional bacteria tested and associated analytical methods: ______
Do you composite any bacteria samples? ☐ yes ☐ no If yes, explain: ______

How do this past season's bacteria results compare to that of previous years'? ______

Do the bacteria results correlate to other parameters, such as water quality, weather, flow, bather load, algae, or wildlife? ☐ yes ☐ no Describe in detail analyses that were performed on the data (add additional lines as needed).

Water Quality (check all that are measured regularly)

Temperature	pH	Rainfall	Turbidity	Conductivity	Other

How does the water quality data compare to data from previous years? ______

Do any data correlate with bacteria sample results? ☐ yes ☐ no If yes, explain: ______

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Were there any unusual results, such as extremely high or low values detected, or unusual trends? ☐ yes ☐ no If yes, explain what was found and any potential causes: ______

Are water quality annual trend data attached? ☐ yes ☐ no

Comments/Observations:

9. MODELING

Are models being used? ☐ yes ☐ no

If yes, list types of models being used and a brief description of the models:

Comments/Observations:

10. ADVISORIES/CLOSINGS

List any advisories and closings that occurred, whether bacteria levels were high, and any possible reasons for advisory or closing or high bacteria level, such as stormwater runoff, sewage spill, or wildlife on the beach.

Advisory or Closing (specify one)	Start and End Dates	Length of Advisory or Closing (Days)	Did Bacteria Concentrations Exceed GM or SSM Criteria?	Reason for Advisory or Closing or Possible Contributing Factors

Total number of closings issued: ______ Total number of days under an advisory: ______

Total number of advisories issued: ______ Total number of days beach was closed: ______

Comments/Observations:

11. POTENTIAL POLLUTION SOURCES

Type of Source	Level of Concern (H, M, L, or NA)	Latitude*	Longitude*	Describe how this source might contribute to beach pollution and frequency of contribution
Wastewater discharges				
Sewage overflows				
Septic systems				
Subsurface sewage disposal				
Stormwater outfalls				
Natural outfalls				
CAFOs or AFOs				
Wildlife				
Agriculture runoff				
Urban runoff, industrial waste				
Marinas, harbors				
Mooring boats				
Domestic animals				
Unsewered areas				
Erosion-prone areas				
Landfills, open dumps				
Groundwater seepage				
Bathhouse leakage				
Drains and pipes nearby				
Stream or wetland drainage				
Vacant areas				
Other (specify):				
Other (specify):				
Other (specify):				

*If latitude and longitude are unknown, show the location on the detailed map and describe in the Comments/Observations section below.

Have potential pollution sources identified above been included on the detailed map? ☐ yes ☐ no (explain):

Did you collect bacteria samples from any potential pollution sources, such as streams or outfalls? ☐ yes ☐ no (explain):

If yes, describe any analyses performed and a summary of the results:

Are there any discharge reports available for dischargers in the watershed? ☐ yes ☐ no If yes, attach report or pertinent sections and summarize here:

GREAT LAKES BEACH ANNUAL SANITARY SURVEY (continued)

Have any sources been remediated, or have steps been taken to remediate sources? ☐ yes ☐ no (explain):

Comments/Observations:

12. DESCRIPTION OF SANITARY FACILITIES

Bathhouses: Total number of bathhouses at the beach:

Number or ID	Location	Condition (Good, Fair, or Poor)	Distance from Waterline (feet)	Frequency of Cleaning (Daily, Weekly, Monthly)

Describe further. Include number of toilets, showers, sinks, etc., and whether these facilities are adequate to support beach use.

Litterbins: Total number of litterbins at the beach:

Number or ID	Location	Condition (Good, Fair, or Poor)	Distance from Waterline (feet)	Frequency of Emptying (Daily, Weekly, Monthly)

Describe further. Include whether number and location of litterbins is adequate to support beach use.

13. DESCRIPTION OF OTHER FACILITIES

List facilities in the beach area, such as restaurants, bars, playgrounds, parking lots, and dog parks.

Facility Name/Type	Location	Condition (Good, Fair, or Poor)	Distance from Beach (feet)	How might this facility contribute to water quality problems?

Comments/Observations:

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