GLRI Beach Sanitary Survey Project
Olbrich Park Beach (Madison, WI)

2007 – 2012

Adrian Koski, BS

Sarah Wright, BA

Julie Kinzelman, Ph.D., MT (ASCP)

Public Health MADISON & DANE COUNTY Healthy people and places

RACINE ON THE LAKE City of Racine, Wisconsin

Great Lakes RESTORATION

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City of Racine Health Department Laboratory

730 Washington Avenue, Room 8

Racine, WI 53403

(262) 636-9501

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INTRODUCTION

The main goal of the Clean Water Act (CWA) is to make all water bodies fishable and swimmable. Protecting water from pathogenic microbe contamination is critical at water bodies used for recreation and community water supplies in order to safeguard public health (Simpson et al, 2002). From 1971 to 2000, over 7,500 cases of illness and 116 disease outbreaks associated with ponds and lakes have been reported to the Center for Disease Control (CDC). However, it is suspected that a large number of cases go unreported (Craun et al; 2005). The majority of disease outbreaks associated with recreational use have been linked to inland water bodies; 19 out of 20 disease outbreaks associated with non-*Vibrio* agents from 2005 to 2006 were associated with inland water bodies (Yoder et al, 2008). The association of waterborne illnesses with inland waters has been apparent in past reports as well. All 19 disease outbreaks from the 2003-2004, and 11 disease outbreaks from the 2001-2002, CDC reporting periods associated with recreational waters occurred at inland waters (Dziuban et al, 2006; Yoder et al, 2004). Diseases associated with recreational water include gastroenteritis, dermatitis and respiratory infections amongst others (Craun et al, 2005; Seyfried et al, 1985). Potential pathogens in recreational waters include *Cryptosporidium, Giardia, Shigella* and *Salmonella* (Coupe et al, 2006; Keene et al, 1994; Koopman et al; Makintubee et al, 1987). Increased contact with water, particularly around the head and face area, enhance an individual's risk of illness (Seyfried et al, 1985). The risk of developing an illness after exposure to recreational waters is dependent upon a variety of factors including the presence and concentration of pathogens in the water, the strength of an individual's immune system and type of exposure.

Currently, pathogens are not directly measured to gauge water quality, partially due to the expense and the elusiveness of pathogens in the environment (Field, 2008). Instead, fecal indicator bacteria (FIB) are measured. Fecal indicator bacteria such as *enterococci* and *Escherichia coli* (*E. coli*) are normal gut flora of several species, including humans, are harmless (with the exception of noted pathotypes such as O157:H7),easy to enumerate from the aquatic environment and are, therefore, useful as indicators of recent fecal contamination. *E. coli* and enterococci have been show to correlate to increased risks of gastro-intestinal illnesses and are approved indicators of fecal contamination in freshwater systems (Dufour, 1984; US EPA 1986). Great Lakes coastal beaches in Wisconsin are placed under water quality advisories (recommended avoidance of water contact, particularly if one has a compromised immune system) when *E. coli* concentrations exceed 235 colony forming units per 100 milliliters (CFU/100ml) and beaches are closed (contact prohibited) when *E. coli* concentrations exceeds 1,000 CFU/100ml. Previously, national recreational water quality criteria did not encompass inland beaches (US EPA 1986); however some communities chose to adopt coastal recreational water standards as a public health protection measure. When coastal recreational standards are applied to inland lakes, they are thought to be at least as protective of public health as when they are applied to coastal beaches (Dorevitch et al, 2010). Recently released revisions to the US EPA 1986 criteria have now extended recreational water quality standards to all bodies of water, including inland lakes (US EPA 2012). The City of Madison, an inland community with several public bathing beaches, has historically monitored recreational waters and used a beach closure criterion of 1,000 *E. coli* CFU/100ml, in line with coastal water quality standards as adopted by the State of Wisconsin and enforced by the WI DNR.

Potential Sources of Fecal Indicator Bacteria (FIB)

Multiple sources and portals of entry exist for *E. coli* and associated pathogens to enter into recreational waters. *E. coli* and pathogens are present in the digestive tract of warm blooded animals, including humans, and are excreted in feces. Once excreted, bacteria can be transported to local water ways via direct contributions, tributaries, stormwater runoff (both agricultural and urban), stormwater infrastructure and sewage overflows (Gannon and Busse, 1989). Additional non-point sources of bacteria pollution include beach sediments, aquatic macrophytes or species of algae. Macro-algae species, such as *Cladophora*, have been identified as sources of water quality impairments at Great Lake beaches (Byappanahalli et al, 2007; Byappanahalli et al, 2009; Englebert et al, 2008; Whitman et al, 2003). Although it is unlikely that *Cladophora* blooms would be observed at inland lakes, other species of algae or macrophytes may behave as a source of/or point of attachment for FIB. The majority of studies examining sources of FIB in freshwater systems have been conducted on Great Lake beaches. Although there are similarities between coastal and inland waters, some assumptions must be made when considering the application of source tracking tools developed for coastal waters to inland water bodies including hydro-geochemical differences and the potential impact on the transportation and fate of fecal indicator bacteria and associated pathogens.

Stormwater. Stormwater in urban and rural environments has been found to contain FIB concentrations exceeding primary recreational standards regardless of surrounding land use (Clary et al, 2008; Novotny et al, 1985). Rainfall flows over land and transports pollutants including bacteria that had previously been deposited on surfaces towards receiving bodies; eventually this water and associated pollutants are conveyed into local water bodies through overland flow, stormwater infrastructure or tributaries where they can pose a threat to public health. For example, water samples collected during precipitation events from a variety of surface area types (lawns, streets, driveways and parking lots in residential, commercial and industrial locations) all exceeded a geometric mean of 1,500 CFU/ fecal coliforms (Madison, Wisconsin; Bannerman et al 1993). Of these, samples collected from residential areas had the highest geometric means with 34,000, 42,000 and 56,000 CFU/100ml fecal coliforms in water samples collected from driveways, lawns and streets respectively. High concentrations of fecal coliforms, of which *E. coli* is a subset, on streets and driveways are particularly troublesome as these surfaces are hydrologically active. (i.e. they are impervious surfaces which store small amounts of water while the rest is conveyed towards waterways). Pervious surfaces such as lawns, forests, and green areas can absorb larger amounts of water reducing runoff volumes and associated pollutants. Land use, watershed population and the percentage of impervious surface inside watersheds have all been positively associated with the amount of fecal indicator bacteria observed in tributaries (Mallin et al, 2009). Runoff from agricultural areas can also pose a risk to water quality. Sources of contamination from agricultural areas include manure deposited on pastures, manure slurry applied to fields(either injected or surface application), animal feeding operations (AFOs and CAFOs), fields, barns and the erosion of soil (Abu-Ashour and Lee, 2000; Heinonen-Tanski and Uusi-Kämppä, 2001; Gerba and Smith, 2005). Agricultural soils, even in temperate climates, have the ability to serve as a reservoir for *E. coli*. One of the major transportation methods of bacteria from fields is through soil erosion and water that is discharged from field drainage tiles (Ishii et al, 2006; Jamieson et al, 2002).

Animals. Local wildlife and domestic animals can directly contribute fecal matter to surface water or load upland, riparian, or shoreline associated sediments as an intermediate which may later be transferred to aquatic environments, following precipitation events, as surface runoff. Some of the most prevalent avian species in nearshore environments are ring billed (*Larus delawarensis*) and herring seagulls (*Larus argentatus*). From 1976 through 1990, ring billed seagull populations have increased from 56,000 to 283,000 pairs along the Canadian portion of the lower Great Lakes (Blokpoel and Tessier, 1991). Seagull populations may have increased in other areas as well due to ecosystem modifications that promote large populations. The rise in seagull population is believed to be caused by increases in anthropogenic food sources, such as landfills, uncovered waste containers, and the increased availability and use of urban nesting sites (Dwyer, 1996). Seagull feces contains between 10^5 – 10^9 CFU *E. coli* per gram of feces. This gives gulls the ability to produce a staggering amount of FIB when considering the number of resident gulls a beach may attract and the amount of waste each gull can produce per day (Fogarty et al, 2003). As an example, seagulls were baited to a beach with food to determine their impact on water quality at a location in Quebec with normally pristine water quality. After attracting seagulls using food, the population increased in the study area from none present to 30 seagulls. After two days with seagulls present, water quality was impaired beyond government water quality standards (Lévesque et al, 1993). In addition to gulls, geese have the potential to impact water quality. However, while the average fecal dropping of geese weighs 15 times more than the weight of gull droppings they contain smaller concentrations of fecal coliforms (Alderisio and DeLuca, 1999). While it is likely that local wildlife impacts water quality, it may be difficult to assess and attribute the amount of fecal loading at a beach to the presence of wildlife alone. In a Door County, Wisconsin study, *E. coli* densities in water did not correlate to either the density of fecal matter observed at the beach or the numbers of animals present at most locations (Kleinheinz et al, 2006). The impact wildlife has on recreational water is difficult to predict and is dependent on multiple factors, some of which include the intrinsic properties of the beach (e.g. beach sediment grain size, uniformity, topography, etc.).

Beach Sands. Sediments are an important reservoir for FIB. *E. coli* concentrations in sediments have been observed ranging from 3-38 times higher in the top layer of beach sand than in adjacent surface water samples (Alm et al, 2003). Sediments provide an ideal environment for bacteria because they are protected from inactivation due to sunlight, protozoan grazing and are provided with nutrients (Davies et al, 1995; Alm et al, 2003). Indicator bacteria can survive at high concentrations in sediments throughout the swimming season and it is suspected that bacteria reproduce to some degree inside sediments (Obiri-Danso and Jones, 1999; Beversdorf et al, 2007). It has been hypothesized that the amount of FIB in surface water attributed to sediments may be greater at inland lakes than in coastal waters due to a larger ratio between sediment surface area and lake volume (Dorevitch et al, 2010). Therefore, sediments may be a more significant source of fecal loading at inland lakes than coastal waters.

Fecal indicator bacteria may be transferred from sediments to adjacent waterways following precipitation (via surface runoff) or during periods of intense wave activity as a function of bed shear stress and wave run-up (Kinzelman et al, 2004a, Ge et al, 2010). In addition, sediments interact with nearshore waters via Aeolian deposition (windblown), although it is unclear how much bacteria transfer may occur under these scenarios. Although no current regulatory standards exist, beach sediments, even in the absence of water exposure, may pose a risk to public health (Heaney et al, 2009). Pathogens in sediments can be transferred from ones hand with subsequent ingestion resulting in illness (Whitman et al, 2009). In one study examining the impact of bacteria in sediments on human health, beach patrons with significant exposure to beach sand had a 20- 50% greater risk of developing gastrointestinal illness than individuals who were not exposed (Heaney et al, 2009).

Factors Influencing Bacteria Die Off

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

Beach Sanitary Surveys

Beach sanitary surveys are a low cost technique designed to determine sources of FIB and associated environmental conditions resulting in bacteria loading to recreational waters. In essence, sanitary surveys are a unified, reliable and replicable data collection method. Ambient environmental and beach conditions that have the potential to impact water quality are recorded on each day that sample collection occurs using a routine on site sanitary survey form (Appendix-A). Conditions recorded include: recent rainfall amounts, water and air temperature, the amount of algae present in water, the amount of algae washed ashore, wave height, turbidity, the number and type of wildlife present, and the amount of people at the beach. In addition to examining highly variable environmental conditions, local infrastructure and the watershed in which the beach is located may also be evaluated, e.g. stormwater outfalls or other potential point sources. Data collected as part of the sanitary survey process characterizes potential sources of bacteria, conditions that may increase the amount of bacteria introduced from non-point sources, environmental conditions that can alter bacteria die off rates and factors that affect the transportation of bacteria once in the nearshore environment. Annual sanitary surveys provide additional information including: topographical characteristics, the location of municipal infrastructure (i.e. stormwater outfalls), surrounding land uses and the number/location/condition of restrooms near the beach. Through the interpretation of this information, sources and pathways of bacteria which influence the nearshore environment can be identified. The use of sanitary surveys has been effective at identifying sources of contamination and guiding remediation efforts at beach in the past (Kinzelman and McLellan, 2009). The collection of this information can also be used to generate predictive models that can (empirically) estimate water quality conditions before laboratory results are available.

Although *E. coli* currently is the most widely used indicator in freshwater systems, existing analytical methods require at least 18 hours for quantification of microorganisms to occur. Water conditions at a beach can change rapidly, often while water samples are incubating. As a result, beach managers are forced to make regulatory beach action decisions when lab results may not reflect current water quality conditions. In effect they are posting based on conditions of the previous day. Rapid analytical methods or predictive models, which utilize environmental factors to predict water quality, will reduce the number of erroneous management decisions made by identifying event based pollution at the time of its occurrence. Models may help to safeguard public health by decreasing errors associated with current beach monitoring efforts (i.e. the persistence method). One such means of collecting data to generate predictive models are through beach sanitary surveys.

Point and Non-point Pollutions Sources Impacting the Study Site

Point sources identified as potentially influencing water quality included Starkweather Creek to the north west of the beach (Figure-1) and a stormwater outfall that discharges 120 meters east of the beach (Figure-2).

Starkweather Creek. The Starkweather Creek watershed is predominantly urban, draining a 62 km^2 sub-basin of the larger Yahara River-Lake Monona watershed. The creek discharges 450 meters to the north-west of Olbrich Park Beach. It is estimated that nearly 3,000 acres of wetlands existed in this watershed prior to development (Mollenhoff, 2003). Today, approximately 900 acres of wetlands remain (WRMP, 2005). The majority of wetlands have been drained through channelization and further development. The watershed by surface area is 18% residential, 31% industrial, 8% commercial, 2% government and institutional, 5% recreational areas and 36% agricultural. It is estimated that the watershed is composed of 33% impervious surfaces. The high amount of impervious surfaces and destruction of wetlands has lead to conditions that may mobilize contaminants, including bacteria, during precipitation events. Impairments of concern within this watershed include sediments, excess nutrients and bacteria.

Figure 1. Location of Olbrich Park Beach and nearby infrastructure.

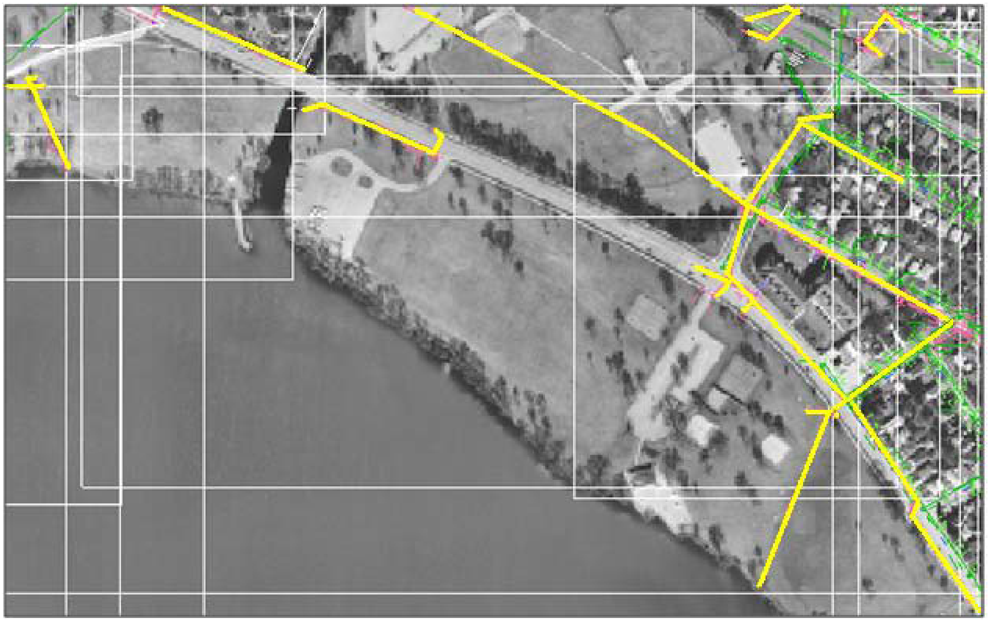

Figure 2. Stormwater infrastructure near Olbrick Park. Yellow lines represent stormwater infrastructure and green lines represent sanitary sewers.

These impairments may be attributed to multiple land use areas and portals of entry. Beyond stresses to the watershed related to water quality impairments, creek base flow volumes have decreased significantly due to lowering of the groundwater table through municipal pumping and less infiltration (caused by increases in impervious surface) (WRMP, 2005). When these conditions are combined with low gradients in the stream channel and excess nutrients, this leads to slow flowing stagnant water that promotes algal growth (Figure-3).

Figure 3. Examples of algal blooms present near the mouth of Starkweather Creek on October 10th, 2010.

In addition to Starkweather Creek, there are *non-point pollution sources* that may negatively influence surface water quality at Olbrich Park Beach. A statistical analysis was conducted on data collected at Olbrich Park from 2002 through 2008. Elevated bacteria concentrations were positively associated with antecedent precipitation and increased wave height. Large waves may introduce bacteria into the water from non-point sources such as stranded algae and/or sediments via wave run up, re-suspend micro-organisms from bottom sediments into the water column, and increase the amount of point source mixing with the nearshore water.

There was also frequent evidence of localized runoff discharging directly onto the beach area (Figure-4, A and B). The amount of impervious surface adjacent to the beach (parking lot and roof of structure), the steep slope of the beach and the poor grade of the adjacent turf grass all contribute to erosion. An eroded beach face may contribute to the rain mediated delivery of bacteria released from sediments to the water. Other potential pollution sources include: wrack deposited on the shoreline (Figure 4 C), aquatic macrophytes, bather shedding, and fecal droppings from pets, gulls, geese and other forms of local wildlife (Figure-4 D).

Figure 4 (A – D). **A.** A channel created by localized runoff on the west side of the beach. **B.** A channel caused by localized runoff on the east side of the beach. **C.** Evidence of wrack accumulation on the beach. **D.** Animal feces and wrack accumulated on the beach.

<u>2010 – 2012 Great Lakes Restoration Initiative Beach Sanitary Survey Project</u>

The intent of the 2010 – 2012 Great Lakes Restoration Initiative (GLRI) project was to determine the adaptability of coastal tools, such as sanitary surveys, to inland waters. Therefore, the remainder of this report will: 1) detail the sanitary survey methods used to collect surface water and sediment samples, generate water quality data, examine surrounding infrastructure and ambient environmental conditions that could contribute to poor water quality at Olbrich Park Beach, 2) explore potential pathways of direct and indirect pollution, 3) draw conclusions, and 4) recommend actions to improve water quality at this inland beach.

<u>METHODS</u>

Multiple sampling events occurred over the course of several years in order to identify sources of bacterial contamination. Samples were collected by three different agencies. The Madison Dane County Public Health Department (MDCPH) conducted routine sanitary surveys numerous times over a 6-year period (n=100, 2007-2012). The United States Geological Survey (USGS) has conducted a series of sampling events on Starkweather Creek. The City of Racine Health Department (RHD) assisted with expanded spatial sampling to determine bacteria concentrations in both sediments and water on three occasions (October 12, 2010; September 23rd, 2011; October 2nd, 2012), as part of the annual sanitary survey process. On these occasions, sediment cores and multi-depth surface water samples were collected across three equally distributed transects in an attempt to further characterize the terrestrial and aquatic beach environment. The slope, width and length of the beach were also determined.

The following section describes methods the RHD and MDCPH used to collected information. The methods used by the RHD were similar to those previously employed by MDCPH when collecting data. However, exact definitions or descriptors used by MDCPH may differ from those of the RHD and other agencies. The dataset examined includes data collected by the RHD, MDCPH and USGS.

Surface Water Sample Collection

<u>Sampling Locations</u>

Surface water samples were collected at Olbrich Park Beach (Lat: 43.08749^o, Long: 89.33029^o) by the RHD (n=3 sampling events) and MDCPH (100 sampling events, 2007 to 2012). Additional, multi-depth samples were taken by the RHD at the time of the annual surveys.

The USGS, RHD and MDCPH collected surface water samples from Starkweather Creek (USGS: 9/16/2009 – 3/23/2011, MDCPH: 7/8/2009 – 3/23/2011). Tributary samples were collected by all organizations near the point where the creek discharges into Lake Monona (Lat: 43.09114^o, Long: 89.33404^o) (Figure 1).

Three water samples were also collected from the stormwater outfall located to the east of the beach (Lat: 43.086900^o, Long=89.32900^o) by the RHD during the annual surveys (2010 – 2012).

<u>Collection of Surface Water Samples – RHD, MDCPH and USGS</u>

Olbrich Park Beach. Surface water samples were collected at various depths ranging from 0.3 to 1.2 meters in depth. A field technician would wade out to the desired depth of water while being careful not to disturb sediments or algae on the bottom of the lake. Facing parallel to the direction of the longshore current, the seal on top of the sampling vessel (Whirlpak™ bag) was removed, the vessel opened using the tabs located on the side of bags and a water sample was collected from approximately 0.3 meters below the water surface (depending on the depth of water) by submersing the bag and upending away from the sampler's body to avoid contaminating the adjacent water with *E. coli* present on the sampler's body. Upon collection of the sample, the bag was sealed and placed in a cooler on ice packs where samples were chilled to 4^{o}C until analysis for *E. coli* could be conducted, generally within one hour of sample collection.

Stormwater outfall. A single grab sample of stormwater outfall discharge was collected by the RHD at the time of the annual sanitary survey in each year that it was conducted (2010 – 2012). Samples were collected following the same protocol as for Olbrich Park Beach samples.

Starkweather Creek. Tributary surface water samples were collected by the USGS and MDCPH from Starkweather Creek (adjacent to Olbrich Park) at various points throughout the study period (May 24th 2007 – September 23rd, 2011). Wet weather (only) samples were collected by the USGS from September 16th 2009 to March 23rd 2011 (n=141) using *in situ* sampling devices that did not cool water samples; these samples were not intended for biological purposes and the lack of refrigeration may have influenced FIB concentrations. MDCPH collected tributary samples once monthly from July 8th, 2009 to March 14th, 2011 (n=16); the majority of these samples were not associated with rain events. The mean daily discharge volume of Starkweather Creek was determined via a permanent USGS monitoring station (gauging station 05428668) located adjacent to where this tributary discharges into Lake Monona (http://waterdata.usgs.gov/usa/nwis/uv?05428668). This gauging station is located near Atwood Avenue (Figure 1).

Routine Beach Sanitary Surveys

Routine on-site beach sanitary survey forms were employed for data collection on each day that sampling occurred (RHD and MDCPH only) to provide replicable and consistent data quality (Appendix-A). The use of sanitary survey forms also provided an organizational system which improves the ease upon which data can be processed. Beach conditions described and quantified when possible included: cloud cover, water temperature, air temperature, antecedent precipitation, the amount of algae or other macrophytes present (both washed ashore and submerged in the water), longshore current direction, wave height, wave intensity, turbidity, any odors present at the beach, the presence of local wildlife, the presence of beach litter, the number of people at the beach, activities people were engaged in and tributary or stormwater outfall discharge data.

Insolarity can attenuate the presence of fecal indicator bacteria in the nearshore environment. Cloud cover was estimated upon initial arrival at the site and was described as sunny (no cloud coverage), mostly sunny (1/8 to ¼ cloud coverage), partly sunny (3/8 to ½ cloud coverage), mostly cloudy (5/8 to 7/8 cloud coverage) or cloudy (total cloud coverage).

Air temperature was measured initially upon arrival at a site using a calibrated alcohol thermometer. Temperature was expressed in degrees Celsius.

Precipitation. Rainfall received in the 24-hour period prior to sample collection was noted each day that a routine sanitary survey was performed. Rainfall information was obtained from City of Madison Water and Wastewater Utility or Madison/Dane County Regional Airport and recorded in cm per 24-hour period.

Turbidity. Both the RHD and MDCPH estimated turbidity at the time of sample collection. The RHD qualitatively described the turbidity of the nearshore water as clear, slightly turbid, turbid or opaque. For statistical analysis purposes, this data was converted into ordinal values. (i.e. clear=1, slightly turbid=2, turbid=3, opaque=4). In a similar fashion, MDCPH uses an ordinal scale between zero and five to describe turbidity. A value of zero described water clarity when a field technician collecting water samples could see their feet in knee deep water with little distortion (clear), a value of one described when a field technician could vaguely see their feet in knee deep water (slightly turbid), a value of two described when a field technician could see past the middle of their calf in knee deep water (turbid), a value of three described when a technician could see down to approximately mid calf in knee deep water (turbid), a value of four described when a technician could not see their feet in ankle deep water (opaque) and a value of five described when a technician could not see their feet in water two inches deep (opaque). Due to differences in turbidity descriptors used between RHD and MDCPH, direct turbidity comparisons were not made between datasets. Water color was also noted.

Water temperature was measured by placing a calibrated alcohol thermometer in the water adjacent to point where water samples were collected. The thermometer was always placed down current of where water samples were collected to avoid potential contamination issues. Temperature was expressed in degrees Celsius.

The ***longshore current*** direction at beaches was described for sampling events conducted by the RHD only. Longshore current direction was determined by observing the angle waves broke parallel to the shoreline. For example, if one section of a wave broke to the north first, then towards the south, the longshore current direction would be towards the south. If this method of determining longshore current was indeterminate, an object would be tossed into the water and the direction the object travelled parallel to the shore would be recorded.

Wave height* and *intensity is measured as a proxy of bed shear stress. MDCPH used an ordinal scale to describe wave height. A value of zero describes when no waves were present, a value of one describes surface ripples, a value of two described wave height of two to four inches, a value of three described wave height between four and six inches, a value of four described wave height between six and 12 inches and a value of five described wave height greater than 12 inches. During the 2010 to 2012 annual sanitary surveys, the RHD estimated wave height by averaging the height (measured from trough to crest) of the three largest out of ten waves. Wave intensity was estimated based upon the frequency that waves hit the shoreline and was described as calm, normal or rough. Statistical analysis was conducted on wave height but not intensity due to the limited number of dates for which this data was available (n = 3).

Algae and aquatic macrophytes. The color, type, presence, condition and amount of algae in the nearshore water and washed ashore water was described on each day that samples were collected. The color of the algae was described as either light green, bright green, dark green, yellow, brown, other or any combination thereof. The amount of algae washed ashore was quantified the RHD as a percent surface coverage on the berm crest and described as low (1-20% coverage), moderate (21-50% coverage) or high (>50% coverage). The amount of algae in the water was also quantified as low, moderate or high based upon surface area coverage near the sampling location. Alternatively, MDCPH used an ordinal scale to estimate the amount of algae observed in the water and washed ashore. A value of zero represented no algae present, a value of one described when algae was present but difficult to detect, a value of two described when a slight amount of algae was present, a value of three described when algae was clearly present but not excessive, a value of four described when large amounts of algae were present and a value of five represents when extreme amounts of algae were present. In the same manner as the RHD, the location of the algae, either in the water or washed ashore, was also recorded. The amount of macrophytes or "weeds" observed in the water was described by MDCPH using ordinal descriptors. A value of zero was used to describe when no weeds were present, a value of one was used to describe when a few scattered weeds were present throughout the swimming area, a value of two was used to describe when the swimming area was slightly weedy, a value of three was used to describe when the presence of weeds was obvious but not excessive, a value of four described when the swimming area was very weedy and weeds were present in the water and on the bottom with less than one inch of accumulation and a value of five was used to describe when the swimming area was extremely weedy with weeds in the water and on the bottom with over 1 inch of weed accumulation. The RHD did not quantify aquatic macrophytes during its annual sanitary survey visits.

***Wildlife*.** The location, species and number of animals observed were enumerated, as actual numbers present, at each beach transect at the time of sample collection.

***Debris*.** The amount of debris in the water and on the beach was estimated as either low, moderate or high based upon percent surface coverage. Classification of waste types included: street litter, food related waste, medical items, sewage related waste, building materials, fishing related litter, household waste or other types of waste.

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

Annual Beach Sanitary Surveys

<u>Collection of Sediment Samples</u>

Sediments cores were collected from each of the three sampling transects at the following locations: the berm crest (the area actively influenced by waves), the middle beach (10 m behind the berm crest), and the back beach (20 m behind the berm crest), and submerged (at the depth of regulatory sample collection).

All sediment samples were collected manually with an AMS stainless steel slotted soil recovery probe (Art's Manufacturing and Supply, American Falls, Idaho, US) with a 2.8 cm bore and sterilized butyrate liners with end caps. The sterilized butyrate liners were pre-labeled at the laboratory using removable tape, one for each sample to be collected, and placed in clean Ziploc bags (S. C. Johnson, A Family Company, Racine, WI, US). At the site of collection, a liner was removed from the Ziploc bag and placed within the soil recovery probe whose interior had been previously coated with a light layer of silicone spray to aid in the successful removal of the liner. The sample was collected by holding the apparatus parallel to the beach sand, firmly pressing the soil recovery probe into the sediment and then removing it in the same manner. After sample collection the liner was extracted by removing the handle and grasping the exposed exterior edge of the liner being careful not to disturb the core or contaminate the sample. Once a sufficient portion of the liner had been withdrawn from the probe an end cap was placed on the exposed end, the probe up-ended and the liner withdrawn completely and capped on the opposite end. The soil recovery probe was then rinsed with water and the procedure was repeated once for each sample to be collected. All samples were obtained between 10:00 am and 12:00 pm and returned to the laboratory on ice packs. Analysis for *E. coli* concentration in sediments was conducted within four hours of sediment sample collection.

Beach Slope and Size Measurements

Beach length and width were measured using a 60 meter tape measure. Beach length was defined as the measure of the dimension of the beach parallel to the shoreline. Beach width, the measurement of the dimension of the beach perpendicular to the shoreline, was measured both from the high-water mark to the edge of the beach and from the current position of the berm crest (on the day sites were assessed) to the edge of the beach. The change in elevation along the beach width was measured using two wooden poles, a pair of line levels and a high tension string. One wooden pole was placed at the edge of the beach and the other wooden pole was placed at the high water mark (determined by the edge of debris field left from receding water or by personnel observation). The high tension string was attached to both poles and pulled taut to increase tension on the string. The height of the string was adjusted until the string was deemed level using the pair of line levels. The length between the sediments and the height of the string were measured on each wooden pole. The difference between the height of the string on the wooden pole at the high water mark and the height of the string on wooden pole at the edge of beach represented the change in elevation over the beach width. The change in elevation across the beach width was divided by the width of the beach and multiplied by 100% to determine the slope of the beach (reported as % grade).

Laboratory Methods

E. coli Enumeration from Surface Water Samples

E. coli was enumerated in water samples using IDEXX Colilert-18® or IDEXX Colilert® (IDEXX, Inc., Westbrook, ME), a selective cultural identification method utilizing bacterial enzymatic activity and differential substrates, for the detection of *E. coli* according to previously established laboratory protocols. In brief, water samples were processed either undiluted (100 ml) or diluted, either 1:10 (10 ml of sample + 90 ml sterile distilled water) or 1:100 (1.0 ml sample + 99 ml of sterile distilled water) based on visual inspection of the sample (using sample cloudiness as an estimation of gross turbidity). The sample to be tested was then mixed with reagent and placed in a Quanti-Tray/2000 according to manufacturer's instructions (Colilert-18® product insert, IDEXX Laboratories, Westbrook, ME, US). Quanti-Trays were sealed using an IDEXX Quanti-Tray® sealer and placed in a 35 ºC ± 0.5 ° C incubator for 18 hours (Colilert-18®) or 24 hours (Colilert®). A quality control organism (*E. coli* ATCC #25922) was run once daily to validate (qualitative) test performance, i.e. a positive test reaction. Following incubation, Quanti-Tray wells were read for yellow color indicating onitrophenyl ß-D-galactopyranoside (ONPG) hydrolysis (confirmatory for the presence of total coliforms) and fluorescence, indicating 4-methyl-umbelliferyl ß-D-glucuronide (MUG) cleavage (confirmatory for the presence of *E. coli*), with the aid of a UV light box (366 nm). Wells producing fluorescence in the absence of yellow color were determined to be false readings (*E. coli* would be classified as a total coliform and therefore should be detected by this method as such, according to the manufacturer). The number of wells producing fluorescence was compared to the provided MPN table to enumerate *E. coli* as MPN/100ml (Most Probable Number of *E. coli* per 100ml). *E. coli* concentrations below the detection limit were reported as half of the detection limit, the reciprocal of the dilution factor, i.e. <10 MPN/100 ml was reported as 5 MPN/100 ml (most dilutions were 10ml of sample with 90ml of sterile water and the detection limit was 10 MPN/100ml *E. coli*).

Enumeration of E. coli in Sediment Samples

Sediment cores were weighed (expressed in grams) and the length of cores where measured (in cm) upon arrival at the laboratory. After measuring the weight and length of sediment cores, the entire sediment core was aseptically transferred into a sterile container and 99 ml of sterile phosphate buffer with $MgCl_2$ (Hardy Diagnostic or Hach®, pH 7.2 +/- 0.2) was added. Samples were mechanically agitated for 30 seconds to suspend sediment attached *E. coli* into the phosphate buffer solution. The use of Colilert-18 ® was employed to determine *E. coli* concentrations in sediments as per above. Serial dilutions of the sediment - phosphate buffer solution were performed to yield a 100 ml total volume using sterile deionized water, generally 1 – 5 ml of sediment-buffer suspension to 99 or 95 ml of water. The enumerated *E. coli* concentration (expressed as MPN/100 ml) was multiplied by the dilution factor employed, and divided by the sediment core weight to express *E. coli* concentration as MPN per gram of sediment wet weight. The MPN/gram wet weight was then divided by a factor determined by drying each individual sample to convert the concentration into MPN/gram dry weight (data not shown).

Sediment Moisture Content, Grain Size and Uniformity Coefficient

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

Once composited, sediment grain size analysis was conducted using method ASTM C 136-05 (ASTM, 2006) at the University of Wisconsin-Parkside Geosciences Department Laboratory. In brief, samples were placed into a stack of progressively finer sieves that allow sediments finer then 8, 4.76, 1, 0.5, 0.21, 0.125, 0.074 millimeters to pass through. This stack of sediments sieves was then placed onto a mechanical shaker for at least three minutes to separate sediments into size fractions. Following mechanical agitation, the fraction of sediments remaining on each sieve was weighed. The mean grain diameter and uniformity coefficient were calculated using standard graphical techniques based on the proportion of sediments retained on each sieve (Folk and Ward, 1957; Hazen, 1900). Mean grain size was determined using equation Eq (1), where Φ (phi) was determined by equation 2 Eq (2). In Eq (2), d represents the diameter of a particle in millimeters. Φ_{16}, Φ_{50} and Φ_{84} were determined through graphical methods. Φ_{16}, Φ_{50} and Φ_{84} represent the phi size of the particles distributed at the 16th, 50th and 84th percentile respectively. The uniformity coefficient (C_u) was determined using equation Eq (3). D_{60} and D_{10} represent the diameter of particles for which 60 and 10% of particles are finer then. A C_u less than four is considered a well sorted sediment sample and a C_u greater than six is considered a poorly sorted sediment sample. Combined sediment samples were further described using the Unified Soil Classification System (ASTM, 2011).

Equations used to calculate grain size and uniformity:

$$\text{Eq.1} \quad \text{Mean grain size } (\Phi) = \frac{\Phi_{16} + \Phi_{50} + \Phi_{84}}{3}$$

$$\text{Eq.2} \quad \Phi = -\log_2(\mathrm{d})$$

$$\text{Eq.3} \quad \mathrm{C_u} = \frac{\mathrm{D_{60}}}{\mathrm{D_{10}}}$$

Statistical Analysis

A number of basic statistical analyses were conducted to determine conditions impacting water quality. All *E. coli* concentration data was log-normalized to partially satisfy statistical conditions of normality and equal variance. All qualitative variables, such as degree of cloud cover were converted into ordinal values (given a ranking compared to other possible qualitative variables). Other qualitative variables generally expressed as either present or absent, i.e. "odor present/absent), were assigned binary values of 1 (condition present) or 0 (condition absent). The amounts of gulls, geese, or ducks (individually) were sometimes converted into a binary variable of 1 or 0 which denoted the presence of the bird. This was due to the fact that the counted numbers of birds was highly variable and tallies observed were only comprised of a single observation at the time of sample collection and are not reflective of the total potential fecal loading capacity that might be present at the study site. For example, it is possible that high numbers of birds could have been at a specific transect on the beach prior to the arrival of the technician and hence were not accounted for in the sanitary survey due to the limited temporal variation. This may be the case for other variables as well; artifacts related to potential variation in water quality may have been short lived in some situations and may have not been observable when sanitary surveys were conducted.

Microsoft® Office Excel data analysis ToolPak was used to calculate descriptive statistics of every variable collected throughout the sampling season and was used to compute Pearson's Product Moment correlation coefficient (*r*- value) between every possible combination of variables. Minimum significant *r* values (α <0.05, p<0.05) were identified for every pair of variables based upon the degree of freedom present in the analysis. Trend analysis was accomplished through the generation of scatter plots and the application of linear regression analysis (R^2 value), in particular targeting variables with significant *r* values. If any variable, such as long shore current or wind direction, appeared to be explanatory for total *E. coli* concentrations (i.e. a southerly wind), SigmaPlot® (Systat Software, Inc., San Jose, CA) was used to determine if the averages or means were significantly different. SigmaPlot® processes data through normality tests such as the Shapiro-Wilk test and equal variance tests to determine if parametric or non-parametric tests were indicated based upon data distribution. P values of <0.05 were considered significant, unless otherwise noted. When comparing the means of multiple groups, analysis of variance (ANOVA one way) was employed. Test for normalcy and equal variance were used to determine what post-hoc treatments including Tukey-Kramer Method, Bonferroni-Dunn test, and Kruskal-Wallis method amongst others. The type of test or post-hoc analysis performed is specified throughout the discussion and results of this report.

RESULTS

Surface Water Quality

Olbrich Park Beach. *E. coli* concentrations were determined in 100 surface water samples collected at Olbrich Park Beach (center of the beach) by MDCPH from 2007 through 2012. *E. coli* concentrations did not vary based upon the year samples were collected (p=0.708). Log mean *E. coli* concentrations averaged 2.24 (σ=0.67) (geometric mean= 175 MPN/100ml). Overall, 39 and 16 percent of samples collected from 2007 through 2012 exceeded *E. coli* concentrations of 235 and 1,000 MPN/100ml respectively. A single surface water sample collected by the RHD as part of the annual sanitary process exceeded recreational water quality standards (>235 MPN/100ml but < 1,000 MPN/100ml) (Figures-5 and 6).

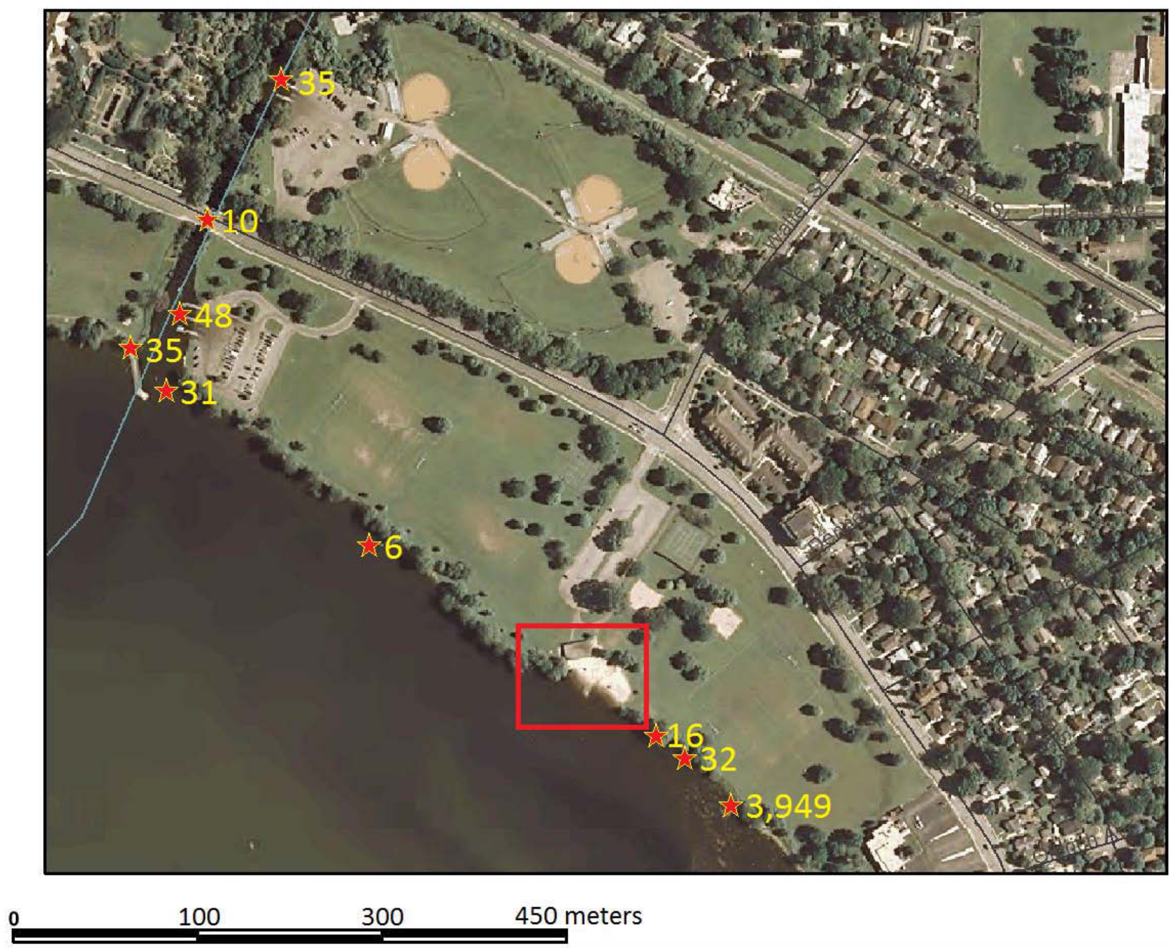

Figure 5: Geometric mean of RHD sampling results. The stormwater outfall is designated by red star at the far right of the figure. Results for the area highlighted by the red square are in Figure 6.

Stormwater Outfall. Three grab samples were collected adjacent to the outfall east of the beach during dry weather events; one each in 2010 2011 and 2012. The *E. coli* concentrations were 41

MPN/100ml in 2010, 173,329 MPN/100ml in 2011 and 8,664 MPN/100ml in 2012 (GM = 3949 MPN/100ml, Figure-5). The single sample maximum of *E. coli* samples collected in 2011 and 2012 exceeded water quality standards. Surface water samples collected by RHD did not show any significant trends or gradients regarding the distribution of *E. coli* in the nearshore environment as a function of stormwater outfall discharge (Figure 6). However, the outfall was partially submerged on all dates samples were collected and concentrations may not have been reflective of the effluent discharged from the outfall as there was no evidence of discharge. Dense, partially decayed, macrophytes were present surrounding the discharge location (Figure-7) which may have influenced *E. coli* concentrations; this was not the case in 2010.

Figure 6. Geometric mean of RHD sampling results near the beach area of Olbrich Park.

Figure 7: Stormwater outfall east of Olbrich Park Beach on September 23rd, 2011. Dense partially decayed macrophytes were present near the discharge point. Similar conditions were present on October 2nd, 2012.

Starkweather Creek. *E. coli* concentrations in monthly samples (July 2009 through March 2011) collected by MDCPH (dry weather events) ranged in concentration from 20 to 460 MPN/100ml (n=16);

the geometric mean was 73 MPN/100ml. Three samples collected were preceded by rainfall (0.03, 0.17 cm and 0.25 cm); associated *E. coli* concentrations were 224, 68 and 23 MPN/100ml respectively. Water samples collected by the USGS during wet weather flow events (n=141) contained significantly greater amounts of *E. coli* ($p < 0.001$). *E. coli* concentrations ranged from 10 MPN/100ml to above the detection limit (>24,192 MPN/100ml) with a geometric mean of 1,290 MPN/100ml. When samples exceeded the maximum detection value, they were treated as the maximum detection value (24,192 MPN/100 ml) for statistical purposes.

Routine Beach Sanitary Survey Data

Insolarity and air temperature. There was no relationship between *E. coli* concentrations and the amount of cloud cover or air temperature (data not shown).

Precipitation. Precipitation events of 0.13cm (0.05") or greater occurred prior to sampling on 23 days. The largest precipitation event preceding water sample collection was 4.96 cm (1.95" on July 5th, 2007). The mean log normalized *E. coli* concentration in surface water samples following precipitation events of 0.13 cm or greater was 2.47 MPN/100ml (n=23, σ=0.65). The mean log normalized *E. coli* concentration for dry weather sampling events was 2.18 MPN/100ml (n=77, σ=0.68); a non-significant difference (p=0.070).

Turbidity. Turbidity was described by MDCPH as zero (30 days), one (20 days), two (20 days), three (19 days), four (8 days), and five (3 days) (increased turbidity is associated with higher ordinal value; see Methods section). There was a positive correlation between the log normalized *E. coli* concentration in surface water samples and ordinal turbidity values (n=100, r=0.458, $p<0.001$). Of the samples that exceeded 1,000 MPN/100ml, zero (0.0%), one (5.0%), three (15.0%), four (21.1%), five (62.5%) and three (100%) were associated with turbidity values of zero, one, two, three, four and five respectively. *Water color*, on days that sampling occurred, was described as being clear (n=53), brown (n=32) or green (n=12). When the water was described as clear the mean log normalized *E. coli* concentration was 2.11 MPN/100ml (n=53, σ=0.66), 2.44 MPN/100ml (n=32, σ=0.68) when brown, and 2.44 MPN/100ml (n=12, σ=0.66) when green. *E. coli* concentrations did not differ significantly based upon water color (p=0.0607).

Water temperature. There was no relationship between *E. coli* concentrations and the amount of cloud cover or air temperature (data not shown).

Longshore current. There was no relationship between *E. coli* concentrations and the amount of cloud cover or air temperature (data not shown).

Wave height and intensity. Wave height was described using ordinal values of zero (16 days), one (53 days), two (21 days), three (3 days), four (4 days), and five (1 day) (increased wave height is associated with higher ordinal value; see Methods section). A statistically significant positive correlation between ordinal wave height and log normalized *E. coli* concentrations was present (n=98, r=0.293, p=0.003). One (6.3%) three (5.7%), seven (33.3%), two (66.7%), three (75.0%) and zero (zero out of one) samples exceeded water quality standards (>1,000 MPN/100ml) when waves were described using values of zero, one, two, three, four and five respectively. There was also a positive correlation between the observed wave height (estimated) and ordinal turbidity values (n=98, r=0.417, $p<0.001$). There was insufficient data to conduct statistical analyses on wave intensity.

Algae and aquatic macrophytes. The amount of *macrophytes* ("weeds") present, on the dates samples were collected, was described as zero (34 days), one (41 days), two (13 days), three (8 days), four (3 days) and five (1 day) between 2007 and 2012 (an increasing ordinal value indicates a greater amount of vegetation present; see Methods section). There was a statistically significant correlation between log normalized *E. coli* concentrations and ordinal macrophyte values (n=100, r=0.229, p=0.022). Eight (23.5%), two (4.9%), zero (0.0%), four (50.0%) one (33.3%) and one (100.0%) sample(s) exceeded water quality standards when the amount of weeds were described with values of zero, one, two, three, four and five respectively.

The amount of ***algae stranded on the beach*** was described using ordinal values of zero (70 days), one (11 days), two (8 days), three (7 days), four (4 days) and five (0 days) (an increasing ordinal value indicates a greater amount of algae present; see Methods section). Mean log normalized bacteria concentrations did not differ when algae was noted as stranded on the beach (n=30, mean= 2.29, σ=0.67) versus when absent (n=70, mean=2.22, σ=0.69) (p=0.651, ANOVA).

The ***amount of algae in the water*** was noted using ordinal values of zero (51 days), one (14 days), two (19 days), three (12 days), four (4 days) and five (0 days) (an increasing ordinal value indicates a greater amount of algae present; see Methods section). There was no a difference in mean log normalized bacteria concentrations when algae was noted as present in the water (n=49, mean= 2.13, σ=0.66) versus when absent (n=51, mean=2.35, σ=0.69) (p=0.106).

Animals. Wildlife species data was available for 2010 through 2012. On 38 sampling dates over this period, there were on average 144, five and 124 ducks, gulls and geese respectively. Other unspecified types of wildlife (50 observed on 10 separate days) and animal feces (observed on 31/38 days) were also present on the beach on. *E. coli* concentrations did not correlate with the type (each species, p>0.05) or number (p>0.05) of wildlife present. With limited data sets regarding the number of wildlife present on each date during this time period, it was not possible to determine the significance of any trends with confidence.

Debris. Debris noted at Olbrich Park Beach consisted primarily of wrack, i.e. leaves, sticks, algae, aquatic macrophytes, and animal feathers/feces. Low amount so anthropogenic waste were noted at the time of the annual sanitary surveys and included: toys, articles of clothing, shoes, and food-related waste.

Beach Usage. Olbrich Park averaged approximately three people per day from 2007 – 2012. Of those, one third was in the water and two-thirds were on the beach. Due to the low beach usage, bather shedding is unlikely to be a significant source of contamination. The time of day when data was collected varied and the number of people observed may not be reflective of actual beach usage. Additionally, other factors may influence beach usage including day of week, (i.e. weekends and holidays), weather and beach conditions. Since these values represent weekday, early morning data, they likely do not represent peak or overall beach usage.

Annual Beach Sanitary Survey Data

Beach sands. Seventeen sediments samples were collected by RHD and *E. coli* enumerated on each of three dates from 2010 – 2012: October 12th, 2010, September 23rd, 2011 and October 2nd, 2012. Both submerged sediment samples (n = 5) and onshore samples were collected: berm crest (n=6), ordinary high water mark (n=2), mid- beach (n=2, 10 meters from the berm crest), and back beach (n=2, 20 meters from the berm crest). Sediment sample collection locations were evenly distributed between the two lobes of the beach; east (n=8) and west side (n=8). A single sample was collected from the center of the beach (off the promontory, n=1). Samples from 2010 were analyzed to determine dominate grain size and uniformity coefficients. Sediments at Olbrich Park Beach were well sorted and described primarily as sands although some locations had the inclusion of small amounts of gravel (<10% gravel by weight) (Table-1). Uniformity coefficients were all below four (well sorted) and mean sediment grain size ranged from 0.18 to 0.43 mm. Sediment composition did not change from 2010 to

2012. Therefore, the 2010 grain size and uniformity coefficients were considered representative of conditions throughout the study period. The color of some submerged sediment samples changed from yellow to a gray color at a depth of approximately 2.5 cm (1") in samples collected in each year; this may indicate increasing anoxic conditions with depth.

E. coli concentrations were higher in berm crest sediments (n=18, log mean=3.45_CFU/100g, σ=1.00) than in submerged samples (n=10, log mean= 2.52, σ=0.62, p=0.019), however not statistically different (Table-1). *E. coli* concentrations in submerged sediments were low at all times/locations except for one occasion in 2010. *E. coli* density in samples collected from the back beach, middle beach and the ordinary high water mark (combined data, n=18, log mean= 2.80 CFU/100g, σ=1.06) were also not significantly from either the berm crest (p=0.124) or submerged samples (p=0.94) *E. coli* concentrations did not differ in samples collected on the east versus west side, all positions (p=0.085 – 0.937).

Location	n	Uniformity Coefficient	Mean Sediment size (mm)	Sediment Description	*Log E. coli* (MPN/100grams sediment dry weight)					
					2010		*2011*		*2012*	
West End of Beach					*Mean*	*σ*	*Mean*	*σ*	*Mean*	*σ*
Berm Crest	3	2.47	0.33	Well sorted sand with trace gravel (SP)	3.68	0.45	3.56	1.22	3.06	0.65
Middle Beach	1	2.67	0.29	Well sorted Sand (SP)	3.45	---	2.03	---	1.83	---
Back Beach	1	2.48	0.18	Well sorted Sand (SP)	1.77	---	2.13	---	1.78	---
High Water Mark	1	2.53	0.41	Well sorted sand with few gravels (SP)	2.31	---	3.04	---	2.97	---
East End of Beach										
Berm Crest	3	3.50	0.43	Well sorted sand with trace gravel (SP)	3.59	0.17	4.97	0.70	3.64	0.81
Middle Beach	1	3.37	0.22	Well sorted Sand (SP)	3.44	---	3.20	---	1.77	---
Back Beach	1	2.50	0.21	Well sorted Sand (SP)	1.72	---	3.11	---	1.73	---
High Water Mark	1	2.50	0.43	Well sorted sand with trace gravel (SP)	1.71	---	4.92	---	2.10	---
In Water (depth)										
West (0.3 m)	1	2.08	0.23	Well sorted sand with trace gravel (SP)	2.42	---	2.41	---	2.57	
West (0.6 m)	1	2.50	0.23	Well sorted Sand (SP)	2.82	---	2.06	---	1.67	
East (0.3m)	1	2.00	0.27	Well sorted Sand (SP)	2.35	---	2.11	---	2.39	
East (0.6m)	1	2.50	0.33	Well sorted sand with few gravels (SP)	4.45	---	2.24	---	2.43	
Promontory (0.6m)	1	3.18	0.27	Well sorted sand with few gravels (SP)	2.90	---	2.73	---	2.27	

Table 1. Mean sediment grain size, uniformity coefficient, sediment description and *E. coli* concentrations.

Physical Attributes of Olbrich Park Beach. Olbrich Park Beach is divided into two separate lobes, an eastern and western lobe, separated by a rocky promontory (Figure-8). The length of the beach, the measurement of dimension parallel to the water, was 49.7 meters. The eastern lobe was 30.8 meters in length and the western lobe was 18.9 meters. The width of the beach, measured from the water to the interface between the beach sand and the turf grass, was 29.6 meters on the western side and 25.2 meters on the eastern side of the beach. Beach slopes were 7.0 and 6.2% gradient on the west and east side of the beach respectively. On the west side of the beach, it was 8.1, 9.8, 17.2 and 61.0 meters from the shore line to where water depth was 0.3, 0.6, 0.9 and 1.2 meters respectively. On The east side of the beach it was 6.7, 9.8, 20.4 and 47.0 meters from the shoreline to where water depth was 0.3, 0.6, 0.9 and 1.2 meters respectively.

The physical configuration of Olbrich Park Beach could impact water quality. Lobed, or teacup shaped, beaches may prevent adequate flushing of nearshore areas due to interrupted longshore currents.

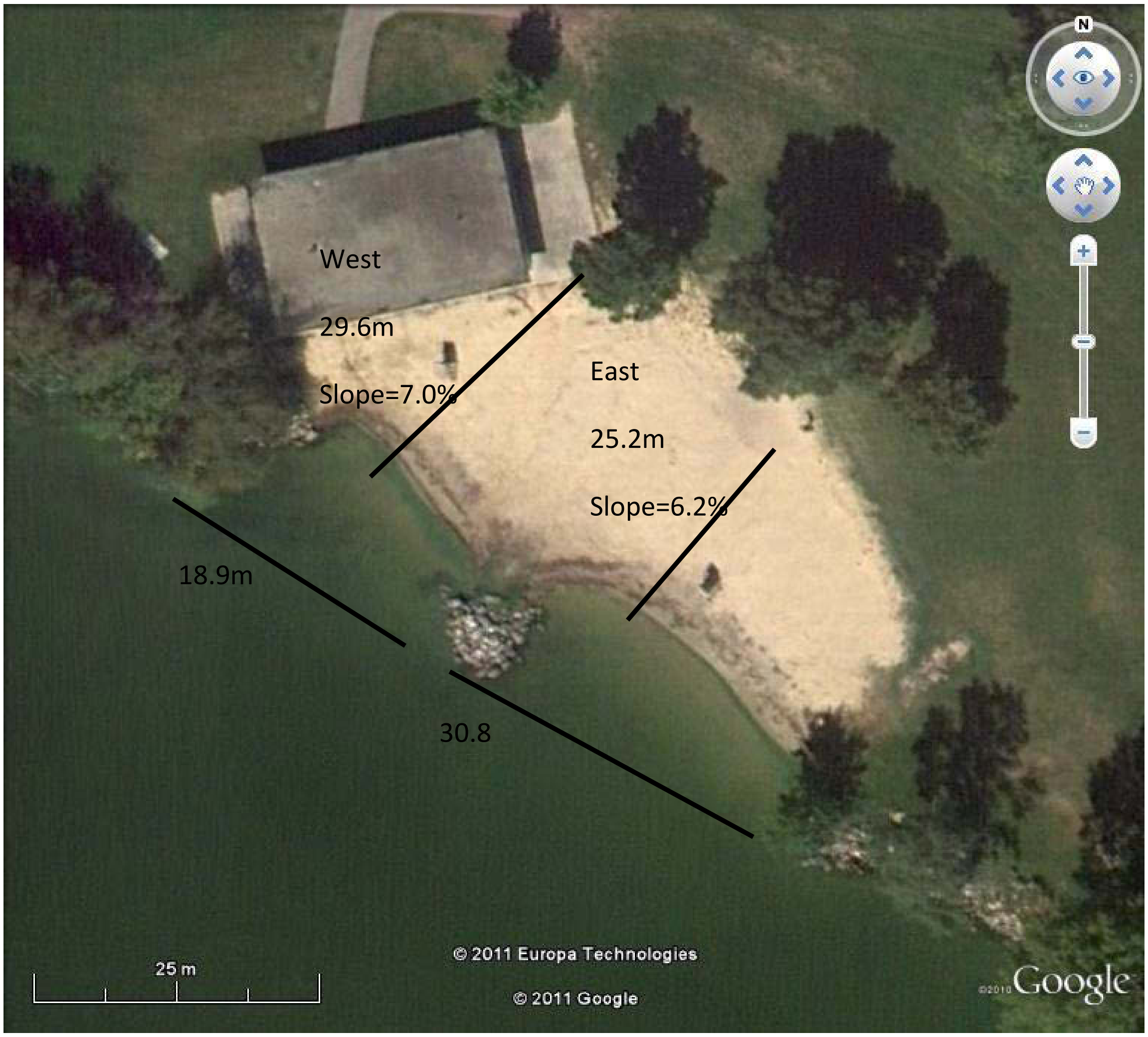

Figure 8. Average beach slope measurements and dimensions of Olbrich Park obtained during the annual sanitary surveys by the RHD (2010 – 2012).

CONCLUSIONS

Point sources that potentially influenced water quality at Olbrich Park include Starkweather Creek and a stormwater outfall 120 meters to the east of the beach.

E. coli concentrations were significantly higher in samples from Starkweather Creek collected by the USGS during wet weather events when compared to dry weather samples collected by MDCPH. However, some of the variation maybe explained by the protocols used by the USGS during sample collection (i.e. samples were not intended for biological purpose). *E. coli* concentrations in Starkweather

Creek during precipitation events were potentially high enough to negatively influence water quality at Olbrich Park Beach based upon USGS data. However, the presence of an active point source does not indicate water quality impairment. Additional hydrodynamic studies must be conducted to determine if conditions are favorable to promote mixing during high flow conditions. At the time of this study, the hydrodynamics following precipitation events are not known. Low *E. coli* concentrations in samples collected from Starkweather Creek during dry weather suggests this is not a significant source of bacteria under low flow conditions.

Water samples collected adjacent to the stormwater outfall east of the beach during dry weather had a low *E. coli* concentration on one occasion and highly elevated *E.* coli concentrations on two other occasions. No noticeable discharge was present from the outfall on any of the dates. On the dates elevated *E. coli* concentrations were present, high densities of macrophytes were noted adjacent to the outfall, which may have influenced *E. coli* concentrations (high densities of macrophytes in beach water were associated with higher *E. coli* concentrations). With few samples and a large variability in sample results it is unclear the influence this outfall has on adjacent water quality, although there was not any distinguishable trends of high bacteria concentrations near this outfall on dates when intensive sampling was conducted by RHD. It is not clear if this outfall behaves as a source of water quality impairment during precipitation events; further event-based monitoring is required to further characterize this potential source.

Non-point source pollution is also likely to have an adverse impact on water quality at Olbrich Park Beach. Associations between environmental conditions and FIB concentrations can help determine the relative contribution when it is significant.

Multiple environmental factors appeared to explain a portion of the elevated bacteria concentrations at Olbrich Park Beach. An analysis conducted on ambient water quality results from 2002 through 2008 (n=252) indicated a statistically significant relationship between increasing *E. coli* concentrations and precipitation events. Analysis of data from 2007 through 2012 did not yield the same relationship when examining precipitation events of greater than 0.13 cm (0.05") in the 24-hour period prior to sample collection. However, a greater rate of beach closures (*E. coli* >1,000MPN/100ml) was associated with prior precipitation (21.7%) compared to dry weather (10.4%). Therefore, rainfall may partially explain decreased water quality; however, the majority of instances with poor water quality were not associated with precipitation. Large amounts of impervious surface adjacent to the beach, steep slopes on the beach, and evidence of localized runoff may amplify the influence of precipitation.

Turbidity measures the ability of a medium to scatter light; this is a measurement of water clarity. Several processes can increase the amount of turbidity in the nearshore area including high amounts of suspended algae in the nearshore water, increased wave activity that may introduce fine particles into the water column and point sources such as tributaries or stormwater outlets. Increased turbidity decreases the amount of bacteria that is deactivated by sunlight. Increased turbidity and wave intensity were both associated with poor water quality during the study period. All water samples in exceedance of water quality standards were associated with higher ordinal turbidity values (greater than zero). Additionally, wave intensity and turbidity were related. Elevated turbidity values were associated with increased wave height likely due to the re-suspension of particles with increased wave action. Turbidity may also serve as an indicator of increased sediment, algae and water interactions. If turbidity levels can be associated with direct (point) sources, the delineation of a plume may represent the geospatial extent of contamination associated with that source. Elevated bacteria levels within the delineated area would confirm the association between that source and water quality impairment.

Changes in water color, from clear to either green or brown, were not significantly associated with elevated bacteria concentrations. However, the presence of aquatic macrophytes washed ashore or in the water was significantly associated with elevated bacteria concentrations. Macrophytes may provide a potential source for *E. coli* to attach and prevent inactivation due to sunlight exposure. Macro algal species such as *Cladophora* have been associated with higher *E. coli* concentrations in the Great Lakes (Englebert et al, 2008; Byappanahalli et al, 2007; Byappanahalli et al, 2009). Additionally, the presence of excess macrophytes may deter beach users. Stranded or submerged algae were not associated with elevated bacteria concentrations. However, depending upon the species of algae present in the water (*Microcystis* or other harmful algal blooms), health concerns associated harmful algal blooms may be of greater public health concern.

Insufficient (none) data existed to conduct water quality comparisons in relation to the presence of wildlife from 2007 through 2009. Wildlife and the presence of feces were observed on numerous dates during 2010 through 2012; poor water quality was not associated with the presence of feces or wildlife. However, evidence of fecal matter may have been present on some dates but not obvious. Short turf grass surrounding the beach with little topographical relief may promote an environment favorable for wildlife such as geese, gulls and ducks. Previous studies conducted by the RHD demonstrated a correlation between the evidence of gulls and increased FIB concentrations in foreshore sands (Koski and Kinzelman, 2009). Further, water samples collected near areas where wildlife frequent often contains evidence of wildlife markers and elevated *E. coli* concentrations (Lu et al, 2011).

The number of bathers in the water at the beach was generally low and likely did not contribute directly to the elevated FIB concentrations observed.

Although only a limited number of sediment sampling event occurred during the study period, if the results were representative of relative conditions, higher bacteria concentrations were present in sediments collected at the berm crest. Considering the active transport mechanisms at play at the land/water interface, this may suggest that water-washed bacteria may enter the lake thereby adversely influencing nearshore water quality. Submerged sediments generally had low bacteria concentrations, possibly due to anoxic conditions in sediments at depth, and therefore re-suspension of submerged sediments is likely not a significant influence on surface water quality.

RECOMMENDATIONS

Sources of water quality impairments should continue to be investigated. Through the proper identification of sources of water quality impairments, effective remediation strategies can be developed resulting in improved public health and increased recreational opportunities. Point sources that may influence water quality include a stormwater outfall adjacent to the beach and Starkweather Creek. Current monitoring suggests these are not sources during dry weather conditions. It is not clear if the outfall adjacent to the beach contributes to elevated bacteria concentrations following precipitation events; further sampling is recommended. Starkweather creek may behave as a source of FIB following precipitation events; however, uncertainties exist concerning whether hydrodynamics favor mixing following precipitation. Until these sources are further characterized, it is unclear if and under what conditions they may influence recreational water quality at Olbrich Park.

Elevated *E. coli* concentrations in berm crest sediments and in water with increased wave height and turbidity suggests elevated concentrations may be partially explained by bacteria introduced to the nearshore waters from sediments. Concentrations in sediments can be reduced, possibly enabling a reduction in water *E. coli* concentrations, by implementing a shoreline grooming strategy. Numerous companies sell mechanical beach grooming products; however, due to the relatively small size of the beach, grooming the beach near the shoreline with a thatching rake, available at local hardware or gardening store, would suffice. Removal of wrack/debris and deep grooming of wet or damp sediments to facilitate drying has been shown to decrease sediment bacteria concentrations (Kinzelman et al, 2004b; Kinzelman et al, 2003). Conversely, compacted sands may provide a more favorable environment for the persistence or replication of sediment associated FIB. A reduction of shoreline wrack and litter may also reduce wildlife numbers by removing a food source. It may be possible to engage with local environmental groups or have life guards (if actively used) facilitate these efforts.

Modifications made to structures and areas surrounding the beach may result in water quality improvements. Repairs made to the gutter system of the structure adjacent to the beach, the redirection of surface runoff from the rooftop, sidewalks and adjacent parking lot to a rain garden/vegetated swale and/or rain barrels may reduce erosion of the beach face and reduce runoff. Grading or terracing the beach to reduce the slope of the beach may also reduce runoff and improve aesthetics, Further, allowing native grasses, rather than turf grass, to grow adjacent to the beach may reduce nuisance wildlife (geese, gulls, ducks) habitation of the beach, reduce runoff, improve aesthetics and serve as an extension to adjacent gardens.

Works Cited

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Appendix A

US EPA Routine On-site Sanitary Survey Form for the Great Lakes

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

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):