

Recreational Bathing Beach Water Quality Testing & Surveillance Recommendations for Wisconsin's Inland Lakes

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Overview

This document provides background on the history and practice of beach water quality testing in Wisconsin and describes recent innovations and research related to beach monitoring. Overall, this document was designed to provide guidance for local health departments interested in monitoring recreational bathing beach water quality during the outdoor swimming season.

Introduction and Background

During the 1960's and 70's, testing of beaches was mandated by Wisconsin Department of Health and Family Services (DHFS) administrative codes. Even though testing was required in the code, the reality was that testing was done only sporadically. This was the era of environmental protection where a paradigm shift from emphasis on microbial disease to concern for chemical threats was occurring. As funding at local health departments (LHDs) and the DHFS moved towards testing for formaldehyde, asbestos and PCB's, the funding to test beaches for microbial contaminants became marginal. In order to reflect this reality, the statute requiring beach testing was replaced with a model ordinance that left the decision to require monitoring of beaches to local health departments. Few local health departments have adopted the model ordinance and, for the last three decades, beach testing in Wisconsin has been minimal. This trend reversed in 2002 with the enactment of the 2000 Federal Beaches Environmental Assessment and Coastal Health (BEACH) Act. The BEACH Act, administered by the Wisconsin Department of Natural Resources (WDNR), funds regular fecal testing at all Great Lakes coastal beaches. The testing has led to an increase in health advisories and beach closures as well as a renewed interest in beach health by the media. This increase in public awareness resulted in an increased pressure by the public to also test inland beaches.

Federal Guidelines

For the past 40 years, Wisconsin public health practitioners responsible for monitoring beaches have looked to the United States Environmental Protection Agency (US EPA) and its predecessors for guidance. Prior to 1986, the US EPA recommended the use of fecal coliforms as the indicator organism of choice to protect people from gastrointestinal illness due to exposure to recreational waters. The pre-1986 criteria encouraged weekly or more frequent sampling for fecal coliforms. Beach closures were based on calculating a geometric mean on 30 days of fecal coliform enumeration data. Beaches were closed if this value exceeded 200 colony forming units (CFU)/100milliliter (mL), and also could be closed if more than 10% of the total samples taken during the 30-day period exceeded 400 CFU/100mL.

In 1986, the US EPA published "Ambient Water Quality Criteria for Bacteria-1986." This document revised the US EPA's recommended water quality criteria aimed at protecting people from gastrointestinal illness resulting from recreational water activities where the accidental ingestion of fecally contaminated water could occur. The US EPA based the 1986 criteria on levels of the indicator bacteria *Escherichia coli* (*E.coli*) and/or enterococci, moving away from the fecal coliform standard used previously. The US EPA derived the new criteria from US EPA sponsored epidemiological studies that evaluated the use of several potential microbiological indicators, including fecal coliforms, *E. coli*, and enterococci. The US EPA subsequently recommended the use of *E. coli* or

enterococci for evaluating fresh recreational waters and enterococci for marine recreational waters. The studies documented that elevated levels of these organisms more accurately predicted acute gastrointestinal illness in swimmers than levels of fecal coliforms. The 1986 US EPA guidelines recommended a single sample maximum of 235 CFU/100mL for *E. coli* and a maximum of 61 CFU/100mL for enterococci as the levels where beach closures should be considered.

*Note: the single sample maximum criteria is for use in making beach advisory decisions, the geometric mean is for making ambient water use designation decisions. The geometric mean is a type of mean or average more typically used in risk assessment, which indicates the central tendency of a set of numbers. It is similar to an arithmetic average, except that instead of adding the set of numbers and dividing the sum by the count of numbers in the set, n , the numbers are multiplied and then the n th root of the resulting product is taken.

In late 2004, the US EPA published "Water Quality Standards for Coastal and Great Lakes Recreation Waters" in the Federal Register: November 16, 2004, Volume 69, Number 220, Rules and Regulations, Page 67217-67243. This document set the ambient water criteria for microbiological monitoring of beaches for all coastal and Great lakes waters. This 2004 standards kept the 1986 US EPA guidelines which recommended values for *E. coli* and for enterococci where beach closures could be considered. Additionally the guidance offered a chart (Table 1) for interpretations to be made on the basis of single sample test results. The chart stratified the single sample criteria based on the intensity of beach use. Based on this chart, most inland beaches in Wisconsin may be classified as high use beaches. While many waters are suitable for recreation of some sort, there are circumstances where classification as moderate or light use recreation water, where less intensive testing is performed might be appropriate. Examples here might include waterways where most participants would have very little direct contact with the water such as when wading, canoeing, motor boating or fishing, or where ingestion of water is unlikely. Another example might be intermittent recreation use in situations where water quality criteria associated with contact recreation are not attainable during wet weather events. Classifying a beach area or waterway as moderate use may result in decreased surveillance coupled with a relaxation of the microbial standards used to close the swimming area.

These numbers cannot be used as geometric mean value standards for beaches in the various categories because the numbers are statistically derived values that, if exceeded on a one time basis, predict a high likelihood that the geometric mean of several samples collected from the same beach would exceed the primary standard.

*Note: The geometric mean alone was not intended for use in beach closure and advisory decisions. Instead it is to be used to determine if water quality is meeting the recreational water designation. Beaches are being closed and advised based on the single sample maximum of 235 CFU/100mL. For high priority beaches that are collecting daily samples or sampling 5 times per week, a running geometric mean can be used to make beach advisory decisions. Otherwise the geometric mean will not be valid for those who are sampling once or twice per week.

The 2004 US EPA standards allowed states to set their own standards providing the state could provide data demonstrating that their proposed standard is at least as protective of swimmer health as the US EPA criteria. For example, the state of Washington collected a large amount of data demonstrating that a fecal coliform level of 14 CFU/100 mL is equivalent to an *E. coli* level of 126 CFU/100 mL and therefore the US EPA has granted them permission to use this standard in lieu of the US EPA criteria. Additionally the US EPA will not allow a state to raise the level of the criteria based on the fact that the beach operators can document that the fecal contamination is from domestic or wild animals and thus not as much of a risk as human fecal contamination.

As of January 2005, the WDNR had not requested a deviation from the US EPA criteria. In early 2004, the WDNR convened a work group to create Wisconsin-specific criteria. The work group met several times; however, no state-specific criteria were developed.

Wisconsin Department of Natural Resources Coastal Beach Program

The BEACH Act was passed in October of 2000, requiring States that border coastal or Great Lakes waters to develop beach monitoring and public notification programs. The BEACH Act also authorized the US EPA to provide grants to States that have beaches bordering these coastal waters for the purpose of developing and implementing monitoring and public notification programs. The WDNR and its partners were awarded program development grants for use in 2001 and 2002 resulting in a total of \$287,090. During the 2003 through 2007 swimming seasons, roughly \$225,000 per year was used for the implementation of the Wisconsin Great Lakes Beaches Monitoring and Notification Program.

193 beaches were identified along the Lake Michigan and Superior shores. The WDNR contracts with local health departments to implement the monitoring program.

Ashland County Health Department	Kewaunee County Health Department
Bayfield County Health Department	Manitowoc County Health Department
Brown County Health Department	North Shore Health Department
City of Milwaukee Health Department	Ozaukee County Health Department
Door County Health Department	City of Racine Health Department
Douglas County Health Department	Sheboygan County Human Services
Iron County Health Department	Shorewood/Whitefish Bay Health Department
Kenosha County Division of Health	UW Oshkosh Department of Biology

The 193 beaches identified during 2002 were grouped into three categories or tiers which in turn dictated the level of monitoring activity necessary. Information including bather and waterfowl loads, the potential for impacts from storm water runoff, and the location of outfalls and farms was used to rank and classify beaches as “high,” “medium,” or “low” priority (Table 2).

The implementation of the monitoring and notification program has resulted in not only a number of beach closures, but an increase in public awareness about beach safety. The biggest public concern is source identification and reduction. Many communities feel it is a waste of time to continue to monitor, but then not do anything to identify and control the source of contamination.

The BEACH Act grant has resulted in the creation of standard practices regarding coastal beach monitoring. The WDNR encourages these same standard practices for inland lake monitoring at State Parks.

Beach Water Sampling & Collection

To assure consistency in collecting samples for analysis, the following procedures are described. A tutorial video is available at the Wisconsin State Laboratory of Hygiene website <http://www.slh.wisc.edu/wps/wcm/connect/extranet/ehd/pamphlets/index.php>

- 1) Specific sites will be designated for collecting samples during the bathing season. Samples will be collected consistently at these sites for the duration of the sampling period.
- 2) Sample bottles will be prepared and provided by the laboratories charged with conducting bacteria analyses.

General Rules of Sampling

- Take extreme care to avoid contaminating the sample and sample container.
- Do not remove bottle covering and closure until just prior to obtaining each sample.
- Do not touch the inside of the sample container.
- Do not rinse the sample container.
- Do not put caps on the ground while sampling.
- Do not transport the samples with other environmental samples.
- Adhering to sample preservation and holding time limits is critical to the production of valid data.
- Samples should be labeled, iced or refrigerated at 1 - 4 degrees C immediately after collection and during transit to the lab.
- Care should be taken to ensure that sample bottles are not totally immersed in water from melted packing ice during transit or storage.
- Samples should arrive in the lab no later than 24 hours after collection. Whenever possible, samples should arrive at the lab on the day of collection, preferably before 2 p.m.
- The sampler will complete 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

- (1) Carefully move to the first sampling location. Water should be approximately knee deep. While wading slowly in the water.
- (2) Open a sampling bottle and grasp it at the base with one hand and plunge the bottle mouth downward into the water to avoid introducing surface scum.
- (3) The sampling depth should be approximately 6 to 12 inches below the surface of the water.

- (4) Position the mouth of the bottle into the current away from your hand. If the water body is static, an artificial current can be created by moving the bottle horizontally with the direction of the bottle pointed away from you.
- (5) Tip the bottle slightly upward to allow air to exit and the bottle to fill.
- (6) Make sure the bottle is completely filled before removing it from the water.
- (7) Remove the bottle from the water body and pour out a small portion to allow an air space of 2.5 cm (1/4 inch) for proper mixing of the sample before analyses.
- (8) Tightly close the cap and label the bottle.
- (9) Store sample in a cooler filled with ice or suitable cold packs immediately.

Analytical Methods

Enzymatic most probable number (MPN) tests for *E. coli*:

- LTB EC-MUG (Standard Methods 9221B.1/9221F)
- ONPG-MUG (Standard Methods 9223B, AOAC 991.15, Colilert, Colilert-18,

Membrane filter tests for *E. coli*:

- MEndo, LES-Endo, or mFC followed by transfer to NA-MUG media (Standard Methods 9222B/9222G or 9222D/9222G)
- MI Agar or broth, EPA Method 1604,
- M-ColiBlue24 Broth
- Modified mTEC Agar, US EPA Method 1603
- mMTEC Agar, Standard Methods 9213D

Posting Beach Advisories

High Priority Beaches

High priority beaches shall post advisory signs (Figure 1) under the following conditions:

- whenever the sample results for *E. coli*, exceeds 235 CFU/100mL as a single sample maximum
- and/or whenever the sample results for *E. coli*, exceeds 126 CFU/100mL as a *geometric mean of at least 5 samples collected over a 30-day period.

*The **geometric mean** is a type of mean or average more typically used in risk assessment, which indicates the central tendency of a set of numbers. It is similar to an arithmetic average, except that instead of adding the set of numbers and dividing the sum by the count of numbers in the set, *n*, the numbers are multiplied and then the *n*th root of the resulting product is taken.

Medium Priority Beaches

Medium Priority beaches shall post beach advisory signs whenever the level of *E. coli* in the beach water sample exceeds 235 CFU/100mL.

Low Priority Beaches

Monitoring at low priority beaches and the posting of signs will be determined on a case-by-case basis. Low priority beaches that are required to monitor weekly shall post

advisory signs whenever the level of *E. coli* in the beach water sample exceeds 235 CFU/100mL.

Removing Advisory Signs

Beach advisory signs may be removed when the sample results of two consecutive days of sampling are below the established criteria (<235 CFU/100mL)

Posting Beach Closures

All beaches shall be closed under the following conditions:

- Whenever a human health hazard exists as determined by the local health department (i.e. reported illnesses).
- After a major pollution event where potential exists that indicator levels may be expected to exceed standard (sewage leak, spill)
- After a significant rainfall event that determined to impact a beach area

All beaches shall post closure signs (Figure 2) whenever the level of *E. coli* in the beach water sample exceeds 1000 CFU per 100 mL.

Re-opening Beaches

Beach closure signs may be removed when the sample results of two consecutive days of sampling are below the established standard.

Signage

It is recommended that LHDs (local health departments) adopt the signage currently used by the WDNR's Coastal Beach program. The following signage examples are available for purchase from BSI (Badger State Industries), 3099 East Washington Ave., Madison, WI 53709, phone 608 240 5207 (www.buybsi.com).

Current Research and Potential for Future Monitoring Tools

2004 Beach Workshop

The enactment of the BEACH Act has precipitated a flurry of research activities, some of which were highlighted at the 2004 National Beaches Conference. For example, not previously considered in regard to beach contamination problems were ubiquitous windrows of seaweed, kelp and floating algae that accumulates on land or in the water near the shore. Such windrows are regularly visited by avian and terrestrial vermin that subsequently inoculate the windrows with feces. The *E. coli* from the feces can actually multiply in the plant detritus and be distributed via wave action. Dr. Greg T. Kleinheinz of the University of Wisconsin at Oshkosh determined that *E. coli* survive in swash sand (located at land / water interface) at much higher numbers than in upland sand, submerged sand, or beach water (Zehms et al., 2008). These high levels of *E. coli* can be washed back into the beach water by rain or wave action, resulting in *E. coli* levels high enough to close the beach. Research done in Racine WI (Kinzelman et al. 2004) studied the effect of routinely raking the windrows from the beach as well as raking the sand areas to encourage sunlight disinfection of the sand. Raking was found to be effective.

Another recurring theme from the conference was the observation that elevated *E. coli* concentrations in a body of water were often restricted to the immediate beach area. That

is, transect sampling of a water body would have high counts in the beach area but much lower levels some yards out from the beach. This repeated finding has led a number of researchers to conclude that beach contamination is not coming from large contamination events of the greater water body, but from the immediate area contingent to the beach (Kleinheinz et al. 2006). These immediate area contamination sources could include terrestrial wildlife, waterfowl, storm sewers, parking lot run-off, the swimmers themselves, leaking sewers, or windrows. This work underlines the importance of doing sanitary surveys (see Sanitary Survey section) of beaches to clearly understand the potential pollution sources.

Indicator organism variability also occurs in relation to varying water depths. The predominant trend is that indicator levels increase significantly closer to shore, where children usually spend their swimming time in relatively shallow water. Thus, Wisconsin changed sampling depths from chest deep to knee-deep, with the collection bottle submerged just six to 12 inches below the surface. Given the data demonstrating that shallow water samples have generally higher counts, this decision has most likely resulted in more beach closings.

2007 Beach Workshop

In March, 2007, another beach workshop was convened entitled “Experts Scientific Workshop on Critical Research Needs for the Development of New or Revised Recreational Water Quality Criteria” (US EPA 2007). Among other issues, the workshop assessed the current state of knowledge and identified future research that would result in rapid, reliable beach testing and closing criteria. Attendees focused on methods with promise of availability within the next 3 years. The following sections describe some methods currently under consideration, and the advantages and limitations of each.

Traditional indicator organisms

The traditional fecal indicators (*E. coli* or enterococci) were discussed and evaluated.

Although relatively easy to detect, *E. coli* or enterococci are inadequate because

1. They may not correlate well with the presence of some pathogens (Blatchley et al., 2007; Wiedenmann et al. 2006),
2. Some point pollution discharges such as paper mills may contain high numbers of *E. coli* or enterococci from non fecal sources (Degnan, 2008)
3. Different methodologies for detecting *E. coli* or enterococci (enzymatic, culture, or PCR-based) may target different strains, resulting in inability to compare and standardize results (Barnes and Gordon, 2004).
4. The length of time required for obtaining results from enzymatic or culture-based assays diminishes the effectiveness of testing, so far as public health is concerned. PCR-based testing is problematic because it is unable to differentiate viable from non-viable cells, and it requires a high level of technical capability and equipment.

Alternative indicator organisms

Sulfite-reducing *Clostridium perfringens* (SRC) are under consideration as an alternative bacterial indicator of fecal pollution. SRC are common and numerous in feces from warm blooded animals and are not believed to grow or multiply in aquatic environments such as

paper mills. Therefore its presence would more reliably indicate the presence of fecal material. One possible drawback is that SRC can persist much longer in the environment than most pathogens and would not necessarily indicate recent fecal contamination events (Payment and Franco 1993).

Bacteroides species generally do not survive well in the environment, and some may be strictly associated with human feces and therefore have potential for microbial source tracking (MST) to human waste. These features are attractive for indicating recent events and for assigning risks per exposure to recreational waters. However, data have shown that both human and animal feces contain such diverse populations of *Bacteroides* spp. as to complicate simple MST. Molecular methods for detecting *Bacteroides* promise hope for analyses of beach water samples as methods are sufficiently specific and rapid (Gawler et al., 2007; Walters et al., 2007).

Pathogen Indicators

Pathogen indicators, or the methods of targeting pathogens (*E. coli* O157:H7, *Salmonella*, *Listeria*, etc.) directly in lieu of indicator organisms, have been considered. However, pathogen numbers are generally too low relative to those of indicators, thus requiring higher sample volumes, which is more costly. Also, the number of pathogens practically targetable is limited.

Bacteriophages

Bacteriophages (viruses) that infect bacterial pathogens are under scrutiny for use as indicator organisms. Phage characteristics that are positive for use as indicators include the relatively high concentrations in sewage, the persistence throughout water treatment plants, and ability to be detected in relatively modest (≤ 1 liter) samples. Phages which infect *E. coli* (coliphages) have been scrutinized more closely than the types which infect *Bacteroides* spp. as potential indicator organisms. There are four distinguishable groups of coliphages, two of which (groups I and IV) are associated with animal fecal waste, and two of which (groups II and III) are associated primarily with human fecal waste. Although Colford et al. (2007) found that coliphages were the only microbial indicator associated with risks in a swimming-associated illness, they also reported that they were not predictive of human health risks from bathing in marine recreational waters. Also, *Bacteroides* are anaerobic bacteria, and would therefore require a more complicated laboratory culturing procedure.

Chemical bio-markers

Chemical bio-markers (CBM) are also considered as indicators of fecal contamination. CBM are non-microbial, chemical-based substances which generally originate from the intestinal tract of warm-blooded animals. There are several CBM that are specific to humans, such as cholesterol, caffeine, and optical brighteners, such as fluorescent whitening agents in tooth pastes. Because of the high sensitivity of equipment used in detecting CBM's, such markers would provide high resolution information in source tracking (Hagedorn et al. 2005; Peeler et al. 2006).

Tool Box

The Tool Box and/or Tiered Tool Box (TTB) are names for an approach to beach water testing that combines some or all of the various methods previously described in an investigative approach. The TTB not only relies on bacterial counts from water sampling, but also considers sanitary surveys, animal/avian presence, weather effects (rain, temp., etc), and/or bacterial characterization (i.e. antibiotic sensitivity), to assess the health risks to recreational bathers. Dr. Greg T. Kleinheinz of the University of Wisconsin-Oshkosh presents compelling evidence for the use of TTB, but cautions that there are disadvantages as well. There is no “one size fits all” for beach testing and TTB approach is best suited when each site is evaluated individually. However, a large amount of data are required as well as the skills to interpret the data, and cost, objectives, and local concerns must factor into decision-making (Kleinheinz et al. 2007).

Predictive modeling

Predictive modeling proposes the use of a mathematical formula to assess the health risk in real time to recreational bathers, based on a prediction of *E. coli* levels. The real time evaluation provides the advantage of advising swimmers based on immediate risks, instead of the delays necessitated when using “next day” testing methods. Studies have shown that predictive modeling agreed with traditional *E. coli* -based methods in up to 80% of testing (Francy et al. 2003). Predictive modeling is endorsed by the BEACH Act for circumventing the lag time associated with current methods but as yet is not a replacement for laboratory-based tests.

Although several models are in development for predictive beach water quality (Peden 2003; Nevers and Whitman 2005; U.S. EPA 2006; Lis 2007), the following example was designed by Dr. Greg Olyphant of the Indiana Geological Survey (Olyphant 2005). Parameters used in the equation consist of wind direction, wave height, water temperature and water turbidity (Table 3), among others. Each parameter is assigned a numerical value so that solution of the equation results in units of *E. coli* per 100 ml of beach water. The numerical product is then compared with the US EPA recommendations for beach water quality. Development of a statistical equation is complex, incorporating such parameters as autocorrection coefficients, error correlations, random error values, and/or multiple correlation coefficients. However, with these statistical correlations incorporated into a program, the end user (beach health technician) need only enter easily obtained values of water temperature, wind speed, wave height, etc., to obtain a statistical prediction of *E. coli*/100 mL water. Predictive modeling for monitoring beach water quality would not only provide real-time data but could facilitate testing at multiple time intervals throughout any given day.

The following equation is an example from Dr. Olyphant's studies, and parameters contained within the equation are defined in Table 3. In theory, the EC_t value would be used much as the *E. coli* count currently is used, that is, comparing the EC_t value to the limits set by the EPA and pertaining to the category best describing your beach.

$$EC_t = Hw + Wa + (Hw * R * Wo) \text{ } \ddagger + (B * Ta * UV) + Tw$$

Table 3. Parameters considered in calculating the model equation predicting *E. coli* levels in beach waters.

VARIABLE	SYMBOL	Units
Rainfall	R	cm
Wind (onshore)	Wo	m/s
Wind (alongshore)	Wa	m/w
Wave Height	Hw	cm
UV index	UV	--
Air temperature	Ta	°C
Water temperature	Tw	°C
Water turbidity	tt	NTU
Bird Counts	B	--

Sanitary Survey

Sanitary surveys refer to an on-site inspection of swimming waters, the surrounding terrain, sanitary facilities, daily activities, and maintenance of a swimming beach (US EPA 2002; Pitt 2006). To begin, a shoreline survey is a comprehensive investigation of coastal properties to determine whether there are pollution sources impacting water quality at beach management areas. The first step in conducting a survey is to become familiar with the area. This can best be done by obtaining and studying 1:24,000 scale maps of the area. Topographical maps overlaid with dwellings and land use designations are needed. These maps can be obtained on line form sources such as “Google Earth” <http://earth.google.com/> or from the United States Geological survey <http://topomaps.usgs.gov/> Maps can also be acquired form local units of government. Locally acquired maps of sanitary and storm sewerage locations can be particularly useful. Other preliminary information may also be obtained such as archived water quality data, location and license status of discharges, and location of sewage treatment plants. Once the maps have been studied and other preliminary information has been acquired a determination is made of the geographical area to be field surveyed. A typical shoreline survey could include the following field activities.

Assessing privately owned lakeshore dwellings should be first approached from the road looking for an indication of the name of the residents. Knock on the door, and if someone is home, introduce yourself and explain why you are conducting the survey. Ask questions and record information about, location, age and problems related to septic systems and holding tanks. Ask for permission to make a cursory inspection. If no one is home, check for access to the shoreline. If you can approach the shoreline by walking around the house without violating privacy, do so. Using indications such as the location of septic system vent pipes and ground terrain to determine where a septic system might be located. Make observations for possible discharge pipes. Although illegal, there are

numerous remnant straight pipe discharges of untreated wastes or gray water emptying directly into the water still found in Wisconsin. Signs of discharge pipe usage include disturbance in vegetation directly below the pipe as compared to vegetation to either side, or, in some cases, a green or rust colored slimy.

Sump pump discharges generally run out of cellars or crawl spaces onto lawns and are sometimes buried after leaving the basement. Look for flexible tubing coming out of a window or more rigid pipes coming out of the foundation. Sometimes dwellings will have what looks like a cellar drain but may actually be draining a washing machine or other gray water source located in the dwelling.

Malfunctioning septic systems are of primary concern as direct fecal contamination sources. You can usually tell a failing system by: odor; presence of swamp species such as cattails in an otherwise normal vegetation area, seepage from the tank or leech field area, mushy areas near the system, indents in the ground or other signs that the cover or tank might have collapsed, or leakage around the base of mound systems.

Outhouses need to be checked to determine if they are in use and whether they are being maintained well. Outhouses without proper containment pits and maintenance can be pollution sources. Also, if the outhouse has been built in an unsuitable soil area, it may contaminate groundwater or seep constantly into nearby streams or lakes. Also, after large rainstorms, these systems may become flooded and overflow to the ground surface.

Domestic animal holding areas such as dog pens, horse barns, riding trails and pastures should be documented as direct fecal material sources. Observations should also be made for evidence of wildlife fecal contamination.

Storm water removal from a developed site requires the use of gutters, pipes, swales and culverts to assist drainage around buildings and other man-made structures. It is not uncommon for storm sewer systems to have constant flows even during extended dry periods. These sources are termed dry weather flows. Sources of some of this water can be attributed to legal NPDES (National Pollutant Discharge Elimination System) discharges to the storm drainage system. However, these flows usually come from other sources, including illicit and/or inappropriate entries to the storm drainage system. Unfortunately, stormwater systems have not received the scrutiny and regulation that point dischargers have, and thus, these entries can account for a significant amount of the pollutants. Careful examination of these discharges can be useful in the identification and elimination of potential beach closing pollution sources. They can originate from private homes, apartment buildings, commercial, industrial, or institutional establishments such as gas stations, automobile dealerships, car washes, auto body and repair shops, construction site dewatering, plating shops, manufacturers, carpet cleaners, private service agencies and wholesale/retail establishments. Often these base flows account for only 10 % of the total stormwater flows, but greater than 80 % of the annual load of toxic and microbial contaminants. These outfalls can range in size from just a few inches to several feet in diameter. It should be noted that dependence on maps for locating outfalls must be supplemented with on-site observations.

Illicit outfalls are seldom documented on maps. Therefore, it will be necessary to “walk” the beach area shoreline as well as nearby creeks searching for outfalls. Creeks should be waded in a downstream direction. If the creek cannot be waded, a small boat or canoe can be used to look for outfalls above the water. Submerged outfalls are more difficult to find and require more careful examinations for storm drain man-holes or grates along the shore. In many cities, streets following the banks of creeks or drainage canals that contain outfalls. It may be possible to carefully search the opposite bank from a moving automobile

Once stormwater outfalls have been identified using maps and physical inspection of the site, further activities may be indicated. Observations of the dry weather discharges for floatables, turbidity, oil sheens, smells, color and coarse solids should be performed and recorded. Identifiable floatables such as animal fats, animal hair, vegetable particles, packing materials, condoms and non biodegradable diaper wipes can be indicative of industrial or raw sewage discharges. Oil sheens can point towards businesses associated with auto and truck service. Smells can be suggestive of industries using gasoline, oils, solvents, or detergents. Sour smells and rotten egg smells can be associated with food product production or food preparation.

Laboratory analysis of dry weather flow samples for tracer parameters can be useful in identifying a source, or determining the sanitary significance of a flow. Simple microbiological and chemical testing may be warranted. For example, tests for *E. coli* can be performed. Flows of groundwater contaminated with only 5% raw sewage can look and smell fairly clean, but still contain high levels of *E. coli*. Chemical tests for fluorides, potassium, ammonia, and surfactants can also be useful. Fluoride indicates the presence of municipal tap water, assuming the municipality fluoridates. Methylene blue active substances (MBAS) are indicative of surfactant detergents in the sample. This test is usually performed in a laboratory. Fluoride in the presence of detergents detected by the MBAS test and elevated ammonia indicates a probability of sewage contamination, as the detergents are a major constituent of laundry soap and shampoos. Fecal wastes also add ammonia to sewage. Therefore ammonia is useful in differentiating sewage sources from industrial wash waters that may contain surfactants.

Table 4 may be useful in choosing analyses and interpreting results. There are numerous certified commercial, university and wastewater laboratories throughout Wisconsin capable of performing these tests. Contact the laboratory for specific instructions on sample collection, handling and shipping. The laboratories will supply acceptable sample bottles. It is mandatory that the proper bottles be used. Alternatively, some investigators choose to use portable testing equipment such as those marketed by the Hach Chemical Company (<http://www.hach.com>) or LaMotte Chemical (<http://www.lamotte.com>) to perform testing in the field for parameters such as fluoride, MBAS and ammonia. Successful operation and maintenance of these field test kits requires a significant time commitment and expertise. In addition to the simple chemical testing listed here, there are many more complex approaches aimed at identifying contamination sources. These include microbial source tracking, fecal sterols, caffeine, Microtox™, metals analysis and genetic finger printing.

Infiltration of relatively clear water to the stormwater system is common and of course is less of a public health risk than other sources. The most common source is groundwater leaks into the storm water pipes through poorly sealed joints when pipes are installed below the groundwater level. Another common source of clear water is from undetected underground municipal water system leaks. Unimproved natural drainage ways may also provide an entry point for high groundwater levels in the form of flowing springs and seeps. Excessive landscape watering can also be a source of clean water. The potential for clear water intrusions to pick up pollutants from failing septic systems, surface spills or leaking underground storage tanks must be considered. Sometimes the dry weather flows in an outfall may be intermittent, particularly from industrial sources that may discharge only once per day, for example when a shift change occurs, or at the end of a production run. Intermittent flows can be detected by constructing a temporary one inch high dam on the bottom of a pipe using quick drying caulk.

In conducting a beach sanitary survey, it is helpful to prepare a criterion list in order to ensure a thorough evaluation. Table 5 presents an example of a prepared beach sanitary survey form.

Cyanobacteria or Blue green algae

Cyanobacteria (also known as blue-green algae) can also be of concern in many Wisconsin's lakes, ponds and rivers (Perkins, 2007). Under high ambient temperatures and nutrient conditions, these organisms are capable of proliferating very quickly to form blooms, surface scums and mats. The blooms typically appear blue-green in color and have an unpleasant odor. Health concerns arise because some species of cyanobacteria can produce naturally occurring toxins (called cyanotoxins) that may be harmful to humans and animals that come in contact with them. Illness and other health effects may occur through direct skin contact with cyanobacteria blooms or ingestion of the cyanotoxins while being produced. Cyanotoxins generally fall into three categories: dermatotoxins, hepatotoxins and neurotoxins. Dermatotoxins can cause allergy-like skin and mucous membrane irritations such as a rash or hives. Hepatotoxins primarily affect the liver and other organs by triggering severe hemorrhaging and neurotoxins affect the central nervous system by impacting the normal operation of nerve cells.

Scientists have not determined what triggers toxin production in freshwater cyanobacteria, so specific laboratory tests must be conducted to ascertain whether or not toxins are present in a water body. The World Health Organization has established a drinking water guideline of 1 µg/L for one cyanotoxin, called microcystin-LR. The U.S. Environmental Protection Agency has not established guidelines for any of the toxins freshwater cyanobacteria can produce.

Symptoms of exposure to cyanobacteria may include: skin rash, hives, runny nose, throat irritation and/or eye irritation. Symptoms of ingestion of cyanobacteria may include: nausea, vomiting, diarrhea, headache, throat irritation, muscle/joint pain, seizures/convulsions, paralysis, cardiac failure, respiratory failure and death. Persons thinking they are experiencing any of these symptoms should immediately contact their physician or the poison control center (1-800-222-1222). If a pet or animal is experiencing any of these symptoms after water exposure, contact a veterinarian immediately. A sign for posting areas affected by cyanobacteria is presented below.

For more information on cyanobacteria and the toxins they may produce, please see the following:

1. The Wisconsin Department of Health and Family Services website:
<http://dhfs.wisconsin.gov/eh/Water/index.htm>
2. The Wisconsin Department of Natural Resources website:
<http://dnr.wi.gov/org/land/parks/safety/bluegreenalgae.html#pubs>
3. "Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management."
http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/index.html

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Tables

Table 1. Federal guidelines for indicator organism levels in beach water samples.

	High Use	Moderate Use	Light Use	Infrequent Use
CFU <i>E. coli</i> /100mL	235	298	409	575
CFU Enterococci/100mL	61	78	107	151

Table 2. Parameters describing high, medium, or low priority beaches in Wisconsin.

High Priority Beaches

<i>Basic Sampling</i>	<i>Additional Sampling</i>	<i>Where to Sample</i>	<i>Depth to Sample</i>
<ul style="list-style-type: none"> Begin sampling at least one week prior to the swimming season Sample at least 5 times per week during the swimming season 	<ul style="list-style-type: none"> After heavy rainfall (generally ¼ to ½ inch- depending on local conditions) After a major pollution event where potential exists that indicator levels may be expected to exceed standard (sewage leak, spill) Immediately following the exceedance of the water quality standards 	<p><i>Depends on characteristics of the beach</i></p> <ul style="list-style-type: none"> Middle of typical bathing area For longer beaches, one sample for every 500m of beach 	<ul style="list-style-type: none"> Knee depth Where 24-30 inch depth is first encountered, take sample 6-12 inches below surface of water Other as you feel is necessary for your beach (e.g., <i>surface of water, waist depth, sediment</i>)

Medium Priority Beaches

<i>Basic Sampling</i>	<i>Additional Sampling</i>	<i>Where to Sample</i>	<i>Depth to Sample</i>
<ul style="list-style-type: none"> Begin sampling at least one week prior to the swimming season Sample at least 2 times per week during the swimming season 	<ul style="list-style-type: none"> After heavy rainfall (generally ¼ to ½ inch- depending on local conditions) After a major pollution event where potential exists that indicator levels may be expected to exceed standard (sewage leak, spill) Immediately following the exceedance of the water quality standards 	<p><i>Depends on characteristics of your beach</i></p> <ul style="list-style-type: none"> Middle of typical bathing area For longer beaches, one sample for every 500m of beach 	<ul style="list-style-type: none"> Knee depth Where 24-30 inch depth is first encountered, take sample 6-12 inches below surface of water

Low Priority Beaches

<i>Basic Sampling</i>	<i>Additional Sampling</i>	<i>Where to Sample</i>	<i>Depth to Sample</i>
<ul style="list-style-type: none"> Begin sampling at least one week prior to the swimming season Sampling frequency at low priority beaches should be determined by state and local authorities, taking into account resource constraints and evaluation of risk factors at individual beaches. 	<ul style="list-style-type: none"> After a major pollution event where potential exists that indicator levels may be expected to exceed standard (sewage leak, spill) Immediately following the exceedance of the water quality standards 	<p><i>Depends on characteristics of your beach</i></p> <ul style="list-style-type: none"> Middle of typical bathing area 	<ul style="list-style-type: none"> Knee depth Where 24-30 inch depth is first encountered, take sample 6-12 inches below surface of water.

Table 4. Expected ranges of indicator parameters in various environments.

Parameter	Municipal Tap Water	Natural lakes & streams	Sewage	Septage	Wash water*
<i>E. coli</i>		10-1000 per 100 mL	10 ⁶ /100mL	10 ⁷ /100mL	none
Fluoride	1 mg/L		0.2-0.4mg/L		
Ammonia	<0.1mg/L	0-1mg/L	12-50 mg/L	20-120mg/L	
Detergents (MBAS)	<0.01mg/L		1-2 mg/L		10-100mg/L

*water from car washes and industrial cleanup procedures.

Table 5. Survey list of criteria and significance thereof (unknown, low, or high) in conducting a beach sanitary survey (Summer, 2006).

CRITEREON	UNKOWN (0 points)	LOW PRIORITY (2 points)	HIGH PRIORITY (4 points)
Reported health issues	No reports or data not available	up to 2 reports	3 or more reports per year
Historical exceedence	None or data not available	1-5 exceedences	>5 exceedences
<i>Cyanobacteria</i> advisory	None or data not available	<2 days	>2 days
Mean number of days under advisory	Data not available/not applicable	<2 days	>2 days
Wildlife present on beach	None or data not available	Present at 50% inspections	Present at >50% inspections
Town ordinance regarding domestic animals on beach	Data not available	No	Yes
Mean high water temperature	Data not available	<60oF	≥60oF
Average precipitation (annual)	Data not available	<25 inches	≥25 inches
Significant rainfall events (>3 inches)	None or data not available	1 event	2 or more events
Rainfall vs. bacteria counts	No risk or data not available	Low detected risks	moderate or high detected risks
Fecal contamination source within 1 mile of beach	None or data not available	1 or more potential sources	1 or more actual sources
Point sources: industrial waste within 1 mile of beach	None or data not available	1 or more potential sources	1 or more actual sources
Estimated # septic systems within 1 mile	None or data not available	<25	≥25
Boat mooring sites within 1 mile of beach	None or data not available	<10	≥10
Mean number of days bathing season	Data not available	<50	>50
Mean % of beach-goers who enter the water	Data not available	<50%	>50%
Extraneous criteria			

Figures

Figure 1. Beach Swimming Advisory Sign example.

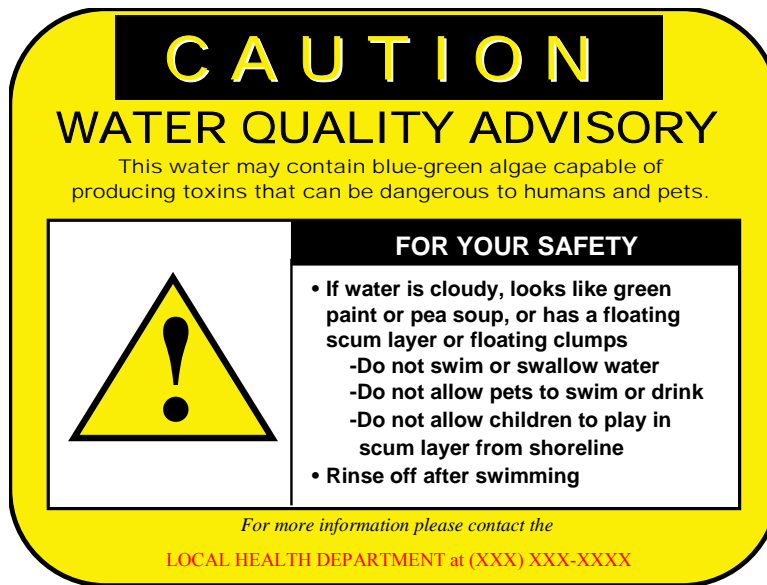


Figure 2. Beach Closure Sign Example.



Figure 3. Beach Default Informational Signage Example

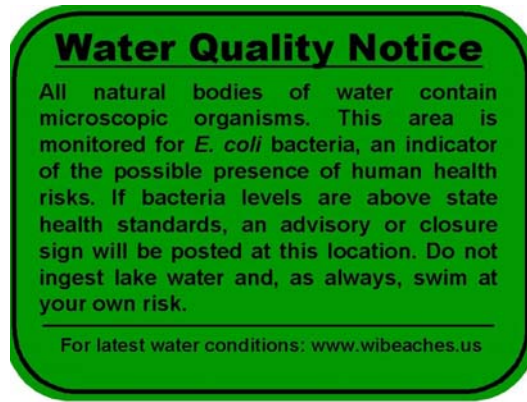


Figure 4. Beach Closure Sign Example in Spanish.



Figure 5. Beach Closure Sign Example in Hmong

