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College of Engineering and Applied Science

Great Lakes WATER Institute

Ecological Study and Management Plan for Atwater Park Beach Final Report

Sponsor: Village of Shorewood

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EXECUTIVE SUMMARY

This report summarizes the results of the Ecological Study and Management Plan for Atwater Park Beach 2008-2009 performed by the University of Wisconsin-Milwaukee (UWM) College of Engineering & Applied Science (CEAS) and the UWS/UWM Great Lakes WATER Institute, with collaboration from AECOM Technology Corp. Professor Hector Bravo managed the project as Principal Investigator (PI), Dr. Sandra McLellan and Dr. Harvey Bootsma served as Co-PIs, and Jaren Hiller, P.E. and Bill Weaver, P.E. served as AECOM collaborators.

The Village of Shorewood recognized the need to address serious concerns and issues potentially degrading the quality of Atwater Beach and wanted to actively improve the beach ecosystem. Following a competitive process the Village of Shorewood was awarded a Wisconsin Coastal Management Program (WCMP) grant to evaluate the beach ecosystem and develop an Ecological Study and Management Plan to develop a baseline understanding of the issues and develop a framework for future actions. After a competitive selection process the Village of Shorewood awarded UWM and collaborators a grant to assist them in examining and reporting the beach issues. The grant awarded to UWM was funded through the WCMP grant and Village of Shorewood own funds.

The Atwater Park Beach Ecological Study addressed beach water issues, shoreline issues, and beach issues. The overall goal of this project was to take an interdisciplinary approach to examine the ecological needs and potential management strategies for Atwater Beach located in the Village of Shorewood. Each aspect of the project included collection and processing of existing information, collection and processing of new information, analysis, and formulation of findings and recommendations. The primary recommendations have been compiled in an Implementation Plan.

The complex beach issues that Atwater Beach faces are both local and regional problems that beach managers need to understand and effectively manage for both human and ecological needs. All Lake Michigan communities will be facing similar issues and should participate in active evaluation and adaptive management of their beaches and surrounding land. Based on the work from our ongoing research programs and this study, the following conclusions and recommendations can be made.

1. Water Quality and Sources of Fecal Pollution

Public Notification

a. There should be accurate signage of water quality results on the beach. The standard water quality testing notification signs (green) are often accompanied by a “today the water quality is good” (blue) signage, even when testing has not occurred in the past 24 hours.
b. The Beach Health website advisories and the signage on the beach should be consistent for reliable public notification. The Beach Health website was found to be inconsistent with advisories posted at the beach.

Monitoring

c. Beach water and stormwater outfalls should be monitored following rain events. Our data coupled with the Village of Shorewood/Whitefish Bay Health Department, shows high bacterial loads during rain events and on baseline days. These high bacterial loads are causing frequent "advisory" days or beach closures.

d. More consistent monitoring, especially during rain conditions, and public education about what beach closures mean and how they are determined could reduce the risk to human health.
e. Sewage is a known source of pathogens; therefore we recommend that until the source of contamination upstream of Outfall 1 has been determined and remediated, Atwater Beach should be preemptively closed after every rainfall. Village of Shorewood should weigh the risk to swimmers from exposure to pathogens from sewage against having the beach open.

Source Identification

f. The sources of sewage contamination at Outfall 1 should be identified and remediated. Outfall 1 has intermittent human sewage inputs and smoke testing found that there are some complicated problems in this area (e.g. not obvious cross-connections, rather leaking laterals or open joints).
g. The sources of sewage contamination at Outfall 2 should be identified and remediated. Outfall 2 has a consistent sewage signal during rain and baseflow conditions. The persistent inputs of sewage contamination at Outfall 2 and the unpredictable discharges at Outfall 1 may pose a serious human health risk.
h. The Village should implement a lateral inspection and lining program. The lack of identifiable sewage sources from a single location in the stormwater system suggests that home laterals may be the source of sewage into the stormwater.
i. The sewage contamination of the beach should be investigated until problem areas are identified. Remediation of these sources should be a priority in order to protect public health. The Village of Shorewood has extended the work of the McLellan Laboratory with additional beach water and outfall monitoring.

Beach Maintenance

j. Sand grooming and Cladophora removal should be continued, even though it may not be beneficial in terms of lowering *E. coli* counts but may be helpful in Cladophora and litter removal**.**

General Beach Management

k. General Beach Management Practices should be reviewed and evaluated to determine which practices are appropriate for Atwater Beach.
    - Bathrooms with hand washing stations should be available to beach-goers to reduce the risk of beach associated illness and the spread of contamination to others.
    - Gull roosting, a large source of *E. coli*, should be deterred. Permitting dogs on the beach during early morning and early evening hours would discourage gulls from frequenting the beach. Provide waste bags at the top of the bluff and bottom of the bluff.
    - Garbage cans should have lids at all times and litter should be continued to be regularly picked up from the beach (the Village of Shorewood removes litter 5 days a week).
    - Lifeguards would increase safety for swimmers and provide a presence on the beach to deter littering, feeding of gulls, or destruction of property. Lifeguard stations should have a first aid kit and fresh drinking water available.

- Shaded areas on the beach should be created for relief from the sun on very hot days, particularly given the physical exertion required to access the beach or return to the top of the bluff. This is particularly important for very young children or the elderly, put applies to all ages.
- The beach is currently utilized by a limited number of people. Given the serious water quality concerns, increased use of the beach or introduction of new recreational activities that involve contact with the water should not be undertaken until sewage contamination sources are identified and remediated. Long term, the Village of Shorewood, in conjunction with the residents, should ultimately identify opportunities that would enhance the quality of the beach experience without compromising the ecosystem integrity. These may include food and beverage service, family play areas, etc. New activities need to be consistent with the recommendations concerning water quality and general beach management. New activities should not reduce naturalized areas without additional assessment.

Environmental Certification

a. **Environmental certification through the Clean Beach Council should not be pursued at this time.** Sewage discharges at swimming beaches creates a serious human health risk. Until the sources of contamination at Outfall 1 and 2 are remediated, environmental certification should not be pursued.

2. Conceptual Stormwater Management Plan

a. Stormwater runoff can impact Atwater Park beach in two primary ways. The first is the runoff that is generated from rainfall landing directly on the park itself, which drains directly onto the beach from the upper terrace, and bluff. The second is the runoff that discharges into the lake from the two storm sewer outfalls discussed above.
b. <u>The source of contamination from the two stormwater outfalls is the number one priority. The impact of surface stormwater runoff on the park is likely minor but could be addressed after the stormwater outfalls are remediated.</u> Some of the Best management practices (BMPs) that can be considered are listed next (the first three are already being used by the Village): Reducing chemical applications in the park; Reducing pet waste; Use of native vegetation; Construction of upper area and lower area bioretention cells.

3. Growth of Nuisance Algae (*Cladophora*)

a. The primary factor responsible for excessive *Cladophora* growth is increased water clarity. However, water clarity is not a property that is directly amenable to management. The only management approach with potential for reducing *Cladophora* growth is reduction of dissolved phosphorus concentrations, which is usually achieved through reduction in phosphorus loading.
b. The capacity to reduce *Cladophora* growth and beach accumulation in the Atwater Beach area by reducing nutrient inputs to the lake in the immediate area is, unfortunately, very limited. Any long-term reduction of nearshore dissolved phosphorus concentration will require a concerted effort at the watershed scale to reduce phosphorus loads. However, efforts made by the Village of Shorewood to reduce phosphorus loading will contribute to any larger scale efforts, and may serve as a model for other urban communities. <u>The recommended course of action with regard to algae accumulation at Atwater Beach is to monitor the effect of any</u>

changes in groin design for a minimum of one year before determining if additional removal strategies are necessary.

c. Despite the impediments to managing *Cladophora* growth, management may still benefit from any capacity to predict *Cladophora* abundance from month to month and year to year. For example, this predictive ability might guide decisions related to equipment and labor required for beach cleaning within a given year. A numerical model is provided by the UWM Great Lakes WATER Institute that allows for *Cladophora* prediction.

4. Assessment of Groins

a. Significant damage observed in the T-heads and trunks of the groins is likely due to the advanced age of the structures as well as a design that is not ideally suited for the wave climate.

b. The flow patterns observed in aerial photographs and in the field suggest that the straight-line alignment of groin trunks and T-heads do not induce adequate wave refraction and flow circulation inside the cells, possibly contributing to poor water quality and abundance of algae at the shore. These structures would need to be significantly redesigned to induce improvements in water circulation and beach formation that could improve algae conditions.

c. Three alternatives are recommended to address the impacts of the piers on Cladophora formation, water clarity and quality, beach formation/retention, and recreational impact for swimmers, scuba divers and boaters. The three alternatives that we recommend pursuing in the next project stage, in order of decreasing preference, are:

    - *Alternative 1)* Re-design groins with a shorter, curvilinear planform to improve circulation within its cells. The waters edge of the modified beach would be curvilinear in form and would reduce stagnant corners. This will reduce the algae deposition and accumulation though not completely eliminates these deposits. A ballpark opinion of probable construction cost would likely be in the range of $1,500,000 to $2,000,000 or more depending on the scope of this option. This is the preferred alternative.
    - *Alternative 2)* Maintain the current plan view configuration of the groins, increasing the crest elevation approximately 8 ft above the mean lake level, and implement a plan for systematic cleaning of *Cladophora* from beaches – this option would involve a reconstruction of the existing groin structures in the current location. This approach would repair the deteriorated conditions, reduce the pervious nature of the groins and reduce wave overtopping essentially cutting off the direct access of longshore littoral currents to the beach. This option would not significantly reduce the algae deposits because the longshore current flow separations at the lake side ends of the groins and T-heads would not be changed. While detailed studies have not been completed, a ballpark opinion of probable construction costs would likely be in the range of $500,000 to $3,000,000 or more depending on the scope of this option.
    - *Alternative 3)* Remove groins and carry out beach nourishment as necessary. This option would reduce the size of the beach. The deposition of algae would likely be reduced by this option – but not eliminated. The reduction would be the result of the removal of water current stagnation zones that form between the existing offshore structures. We do not expect that this option will be feasible.

d. The next project stage should include a feasibility study to evaluate the optimal configuration of the selected option.

ECOLOGICAL STUDY AND MANAGEMENT PLAN FOR ATWATER PARK BEACH

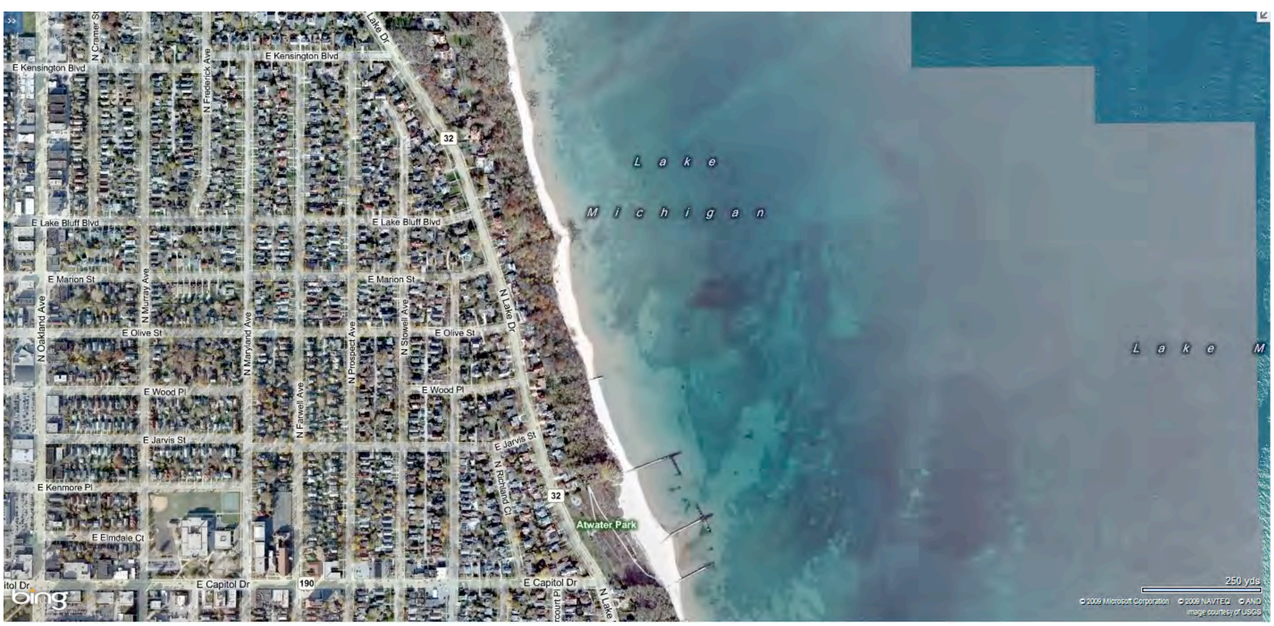
NEEDS ASSESSMENT

A healthy beach ecosystem has several benefits to the community and quality of life of its citizens. Safe swimming waters, greater utilization, and overall protection of Lake Michigan coastal areas are among these benefits. The overall goal of this project is to evaluate water quality, hydrodynamics, pollution sources, and other physical and biological parameters at Atwater Beach and provide recommendations on protecting and improving the beach ecosystem. Integral to this goal is to assure that use of this recreational area is consistent with protecting the ecological integrity of the beach.

There are many aspects for creating a healthy beach ecosystem that offers maximum benefits for citizens this includes physical maintenance, aesthetics, ecosystem protection, and public health and safety. Creating a comprehensive management plan is crucial for proper beach care and to balance ecological and human needs. Other beaches that have taken a synergistic approach to beach management such as North Beach in Racine and Bradford Beach in Milwaukee can be used as a model for implementing best management practices.

The vision for Atwater Beach as conveyed by the Friends of Atwater Beach citizens groups it to protect the ecological integrity of Atwater Beach while reclaiming its history of being a community asset for recreation, community gathering, public education, and support for local businesses.

Figure 1. View of the Village of Shorewood shoreline north of Atwater Beach Park.



This Ecological Study addresses water quality status from 2006 to 2008, identifies probable sources of pollution, and incorporates inputs from interface use (human activity) with ecological integrity goals.

1. Water quality and sources of fecal pollution

Introduction

Urban beaches face numerous water quality challenges, as they are typically located in densely populated areas and as a result are susceptible to a mixture of point and non point sources of pollution. Stormwater runoff, a form of non-point pollution, is considered one of the leading threats to surface water quality in the United States, and has been found to be linked to human illnesses from exposure to contaminated recreational waters (Gaffield et al. 2003).

Currently, *E. coli* is the United States Environmental Protection Agency (USEPA) recommended indicator of fecal contamination for recreational waters because it is present in high numbers in the gastrointestinal tracts of warm-blooded animals, and therefore is a good indicator of fecal pollution. Sources of *E. coli* that can impact beach areas are numerous and can include combined sewer overflows; sanitary sewer overflows, leaking septic systems, stormwater runoff, agricultural runoff, wildlife, and domestic pets. Generally, the presence of *E. coli* in coastal waters does not necessarily equate to a health risk however; it does “indicate” fecal contamination, which has the likelihood of harboring pathogens, and can present a public health risk.

Unfortunately, current standard techniques used to test recreational waters are not host specific, meaning that *E. coli* from animal sources such as birds and other wildlife cannot be differentiated from *E. coli* from human sources. This limitation in the monitoring procedure makes it difficult to identify the sources of bacterial contamination impacting beach sites. However, recent advances in the field of microbial source tracking have produced some methods that can assess sources of pollution. Culture-independent, molecular-based methods can be used to detect genetic targets of organisms found in a specific host. Certain species within the genus *Bacteroides* have been shown to be host specific and has been used as a genetic marker to detect fecal pollution in aquatic environments (Field et al. 2003). *Bacteroides* is a fecal anaerobe that is present in the gastrointestinal tract of humans at 1000x the amount of the fecal coliform group, making this marker a very sensitive measure of fecal pollution. Our laboratory has shown that the human *Bacteroides* genetic marker can be detected when sewage is present, even when culturable *E. coli* levels are below the USEPA recreational standard of 235 *E. coli* per 100 ml (Bower et al. 2005). One limitation of this approach is that it does not identify all of the sources present, and if multiple sources are present, does not provide information as to the major source of pollution. Despite these limitations, detection of the human *Bacteroides* genetic marker by polymerase chain reaction (PCR) appears to be a viable approach for discerning if there are human sources of fecal pollution present.

The USEPA BEACH ACT does not require that beach sand be monitored. However, data from our laboratory and others have demonstrated how the sand environment can harbor large amounts of *E. coli* (Wheeler-Alm *et al.* 2003; Whitman and Nevers 2003; Kinzelman *et al.* 2004). Recent research by us and others shows sand can act as a reservoir for *E. coli*, however, the human health risk associated with accumulation of this indicator organisms is not well documented. In some cases, *E. coli* and pathogens found in the sand have been linked to increased cases of gastrointestinal illness in beach-goers. Bacteria are ingested through hand to mouth contact or ingestion of sand. Simple hand washing can greatly reduce the human health risk linked to beach associated illness (Whitman *et al*. 2009).

1.1 Water quality

1.1.1 Village of Shorewood/Whitefish Bay Health Department Beach Monitoring Data

The Wisconsin Department of Natural Resources has deemed Atwater Beach a "medium" priority beach, so the Village of Shorewood/Whitefish Bay Health Department collects water samples from the beach at least two times a week, depending on rainfall and *E. coli* exceedances. Samples are analyzed by the City of Milwaukee Health Department in accordance with EPA standard methods. Beaches are considered unsuitable for recreational activities when levels of *E. coli* bacteria exceed 235 CFUs/100 ml and are closed when *E. coli* exceed 1,000 CFUs/100 ml. **Table 1** summarizes the monitoring data for the 2006-2008 sampling seasons. The number of days in exceedance in 2003, 2004, and 2005 were 20%, 19% and 27%, respectively. Because of these results, Atwater Beach has been listed on the 303(d) Impaired Waters List since 2006.

Table 1: Atwater Beach Monitoring Data collected by the Village of Shorewood Health Department

Year	Number of Times Sampled	% Exceedance (> 235 CFUs/100 ml)	Geo Mean *E. coli* (CFUs/100 ml)
2006	27	7%	22
2007	27	4%	28
2008	30	20%	44

1.1.2 Event Sampling by McLellan Laboratory

In addition to the routine monitoring of the beach by the Village of Shorewood Health Department, the McLellan Laboratory collected and analyzed water samples from Atwater Beach. The McLellan Laboratory collected samples during or immediately after a rainfall (>.25 inches of rain) and one baseline (0 inches of rain) sample each month. Water samples were collected from 3 sites along the beach and 2 outfalls north of the beach (**Figure 2**). An outfall is a place where a sewer, drain, or stream discharges wastewater into receiving waters. Outfall 1 is a 48-inch diameter storm sewer outfall that is approximately 600 feet north of the park. Outfall 2 is a storm sewer outfall listed as a 24x48-inch arch pipe outfall located approximately 0.5 miles (2,700 feet) north of the park. The samples were analyzed for *E. coli* and Enterococcus, using the USEPA culture based method for *E. coli* enumeration (USEPA 2000).

The McLellan Laboratory focused on sampling during rain events because this is when high *E. coli* and Enterococcus values are observed. Stormwater runoff and discharges from possible infrastructure failures upstream of the nearby outfall are potentially large contributors to bacterial loads during rainfall. Sampling during rain events allows us to capture the worst-case scenario for beach water quality.

Figure 2: Map of Sampling Sites along Atwater Beach

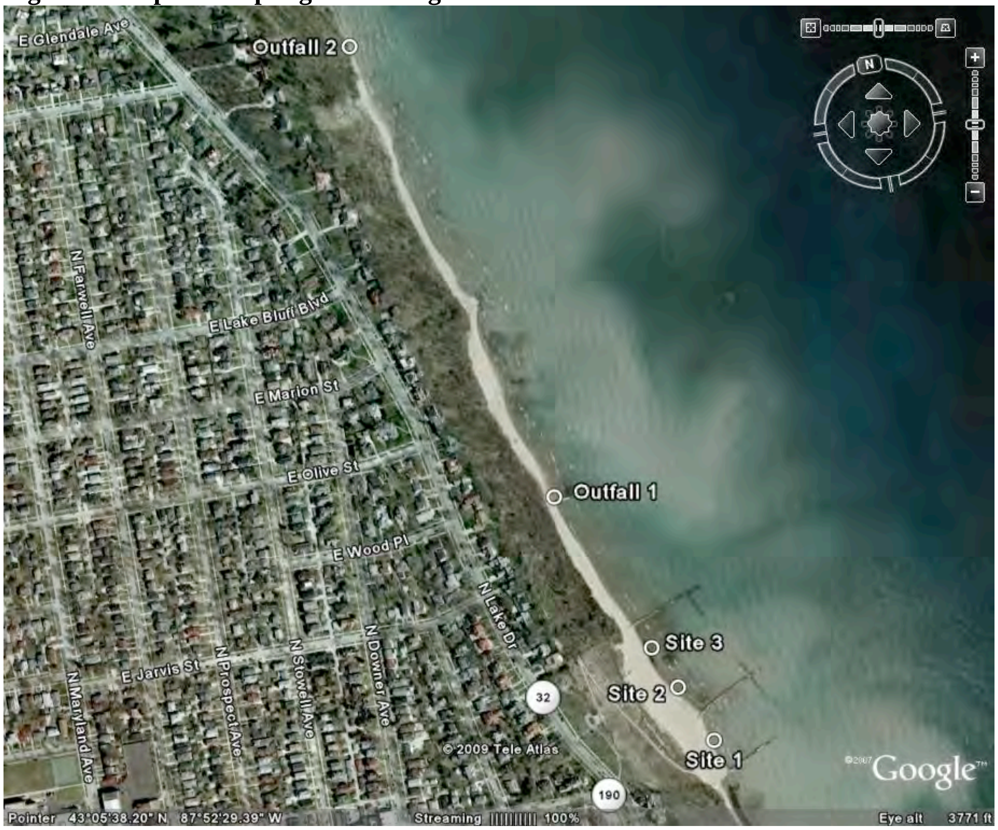


Table 2 summarizes the data collected by the McLellan Laboratory during the 2007 and 2008 sampling seasons. This data is not included because the effort is for Sea Grant and is not part of the contract. Data will be available after final publication in a peer-reviewed journal. *E. coli* levels were found to be as high as 11,600 CFUs/100 ml, two orders of magnitude higher than the standards for beach closings. In 2008, 10 out of 20 samples had *E. coli* levels over 235 CFUs/100 ml, exceeding the "Advisory" level.

In addition, Site 2 has higher levels of *E. coli* and enterococcus than sites 1 and 3 (**Table 3**). This could be due to the presence of Cladophora mats, roosting gulls, or other physical parameters related to hydrodynamics. **Tables 4 and 5** summarize the data collected from the outfalls. During rain events, the water discharged from the outfall has very high values, up to 11,400 CFUs/100 mL *E. coli* and 33,000 CFUs/100 mL enterococcus. These high bacterial loads coming from the outfall impact the beach water quality.

Table 2: Summary of beach monitoring data collected by the McLellan Laboratory

			E. coli			Enterococcus		
Year	Number of Times Sampled	% Excedance (> 235 CFUs/100 ml)	Geometric Mean (CFU/100 ml)	Average (CFU/100 ml)	Range of Values	Geometric Mean (CFU/100 ml)	Average (CFU/100 ml)	Range of Values
2007	10	60	87	291	1 to 1,550	29	357	1 to 9,700
2008	20	50	105	1,057	1 to 11,600	62	526	1 to 12,800

Table 3: *E. coli* and *Enterococcus* values for each beach water sampling site

Location	Average *E. coli* (CFUs/100 ml)	Standard Deviation (+/-)	Average Enterococcus (CFUs/100 ml)	Standard Deviation (+/-)
Site 1	646	1,676	565	1,922
Site 2	1,073	2,932	704	2,561
Site 3	423	786	198	351

1.1.3 Human Bacteroides Genetic Marker

Water samples collected at Atwater Beach are also analyzed for the human *Bacteroides* genetic marker using molecular methods. The culture based method used for *E. coli* and enterococcus allows for simple detection. However, polymerase chain reaction (PCR), a molecular based approach to detecting human *Bacteroides*, is a more sensitive test for fecal pollution. This method is currently being evaluated by the USEPA for use in microbial source tracking. The methodology has been published and used in the McLellan since 2004 (Bower 2005).

There are two outfalls that have a high probability of impacting the beach. During rainfall events, the human *Bacteroides* genetic marker was consistently detected in the water discharging from Outfall 2 during baseflow and rain conditions. The human *Bacteroides* genetic marker was intermittently detected in Outfall 1 during rain and baseflow conditions (**Tables 4 and 5**). These results suggest that there is a persistent human sewage input into the stormwater system.

In 2007 and 2008, a total of 92 beach water samples were collected and analyzed for the human *Bacteroides* genetic marker. These were found to be negative. The human *Bacteroides* genetic marker was detected in beach water samples in 2009 following a heavy rain event in April. **Levels of human Bacteroides may be too low to detect at the beach, however viruses may still be present in the water at a concentration that could pose a concern for human health.**

1.1.4 Comparison of Atwater Beach to two adjacent beaches

Water quality at Atwater Beach was compared to two adjacent beaches because we anticipated that the distant outfall on Atwater Beach may affect water quality differently than beaches that have outfalls that discharge directly onto the beach. Water quality for two adjacent beaches, known to be impacted by stormwater, was also analyzed. Bradford Beach located to the south, is also on the 303(d) Impaired Waters list and has seven outfalls that discharge directly to the beach. Big Bay Beach located to the north, is not monitored and has one outfall that discharges to the beach. Our results from two years of sampling (2007-2008) show no statistically significant difference in *E. coli* or enterococcus values between Big Bay Beach, Atwater Beach, and Bradford Beach. These results illustrate that all three beaches are impacted by stormwater to a similar extent regardless if the stormwater is discharging directly to the beach or discharging north of the beach.

Table 4: *E. coli*, Enterococcus and the human *Bacteroides* genetic marker for the Outfall 1 (node $5043), located north of Atwater Beach

Sample Date	Rainfall (inches)	Enterococcus (CFUs/100 ml)	*E. coli* (CFUs/100 ml)	Human *Bacteroides*
9/4/2008	1.96	33,000	11,400	**Positive**
9/8/2008	0.22	9,900	3,300	**Positive**
9/24/2008	0.00	1	3	BLD
9/29/2008	Trace	3	5	BLD
11/11/2008	0.26	1,300	150	**Positive**
11/12/2008	0.04	60	30	**Positive**
2/10/2009	0.00	5,000	550	Negative
2/11/2009	0.15	8,900	830	**Positive**
3/10/2009	0.59	13,700	570	**Positive**
3/24/2009	0.02	0	2	BLD
3/31/2009	0.33	15,000	330	Negative
4/9/2009	0	0	3	**Positive**
4/27/2009	1.67	160	20	BLD
4/28/2009	0.02	10	60	**Positive**
5/14/2009	0	20	3	BLD
5/28/2009	0	57	24	BLD
6/1/2009	0.14	20	120	BLD
6/3/2009	0	19	12	BLD
6/4/2009	0	0	5	BLD
6/8/2009	1.26	94	60	BLD
6/9/2009 AM	0	TNTC	43	BLD
6/9/2009 PM	0	10	3	BLD
6/10/2009	0	50	8	BLD
6/12/2009	0	18	8	BLD
6/17/09	0.09	3,000	1,300	**Weak**
6/19/09	3.61	92	400	BLD
6/22/09	0.08	42	169	BLD
6/25/09	0	4	7	BLD
6/26/09 AM	0	10	100	BLD
6/26/09 PM	0	21	136	BLD
6/29/09 AM	.01	9	6	BLD
6/29/09 PM	.01	3	5	BLD
7/9/09	0	12	13	BLD
7/15/09	0.19	147	96	Negative
7/16/09	0	23	17	BLD
7/20/09	0	82	39	BLD
7/21/09	0	100	79	Negative
7/23/09	0	34	6	BLD
8/13/09	0	14	10	BLD
8/19/09	0	3	0	BLD
10/22/09	0.5	28,000	2,400	**Positive**
10/23/09	1.5	12,000	2,600	**Positive**

*BLD = Below the Level of Detection

Table 5: *E. coli*, Enterococcus and the human *Bacteroides* genetic marker for the Outfall 2 (node #5375), located north of Atwater Beach

Sample Date	Rainfall (inches)	Enterococcus (CFUs/100 ml)	*E. coli* (CFUs/100 ml)	Human *Bacteroides*
2/11/2009	0.15	4,600	660	**Positive**
3/10/2009	0.59	7,400	520	**Positive**
3/24/2009	0.02	120	300	**Positive**
4/27/09	1.67	1,090	TNTC	**Positive**
4/28/09	0.02	130	870	**Positive**
5/1/09	0	150	50	**Positive**
5/14/09	0	290	810	**Positive**
6/1/09	0.14	1,300	11,200	**Positive**
6/8/09	1.26	2,000	5,300	**Positive**
6/10/09	0	100	6,800	**Positive**
6/17/09	0.09	3,000	1,300	**Positive**
6/19/09	3.61	9,300	12,200	**Positive**

*TNTC= Too numerous to count

1.1.5 Rainfall Impacts

During rainfall events, *E. coli* and enterococcus values are higher than baseline days. However, high levels of *E. coli* and enterococcus (>235 CFUs/100 mL) are also detected on baseline days. Two advisories were issued for Atwater Beach in 2008 when it had been dry for over 48 hours. This suggests that stormwater runoff from rainfall is a contributing factor to bacterial loads but is not the only source. Wave action may resuspend fecal indicator bacteria sequestered in the sand or sediments. The causes of dry weather advisories and their connection to wave action is the subject of ongoing research across the Great Lakes and the marine coastal regions.

1.2 Stormwater and Combined Sewer System Investigation

Based upon the strong sewage signal the McLellan Laboratory has detected in Outfall 1 and 2, stormwater and combined sewer investigations were conducted to narrow down suspect segments of the system. The locations for sampling during the storm sewer investigations were determined upon collaboration with Dr. Hector Bravo (see Appendix A for locations and site codes). Dr Bravo identified critical areas with strategic upstream and downstream nodes that would bracket the areas of possible infiltration from sewer pipes to stormwater pipes.

1.2.1 Investigation #1 on February 11, 2009

Water quality testing using microbiological and molecular methods was conducted during an investigation of the stormwater and combined sewer system to examine the potential sources of the human *Bacteroides* genetic marker consistently detected at Outfall 1. Water samples were taken on February 11, 2009 during a rain event (**Table 6**). The human *Bacteroides* genetic marker was detected at both outfalls, East Wood Place (Outfall 1, #5043) and East Kensington Blvd. (Outfall 2, #5375). The human *Bacteroides* genetic marker was not detected in upstream samples of Outfall 1 (**Figure 3**). However, the human *Bacteroides* genetic marker was detected at sampling node # 5259, along the Kensington Blvd. leg, upstream of Outfall 2 (Figure 3). A strong signal of the human *Bacteroides* genetic marker was detected at these locations, demonstrating significant human sewage contamination.

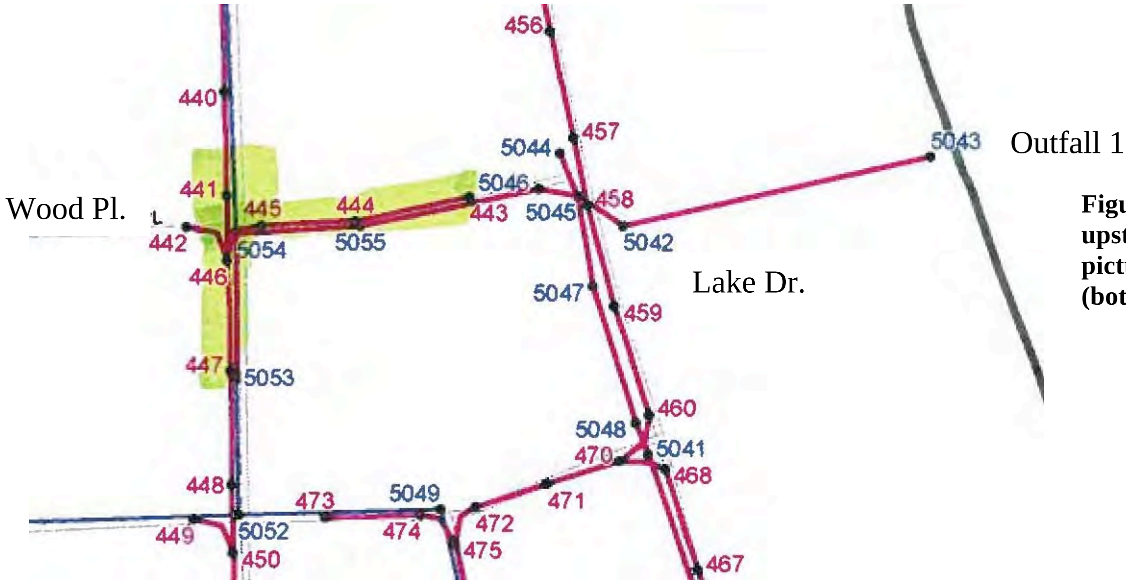
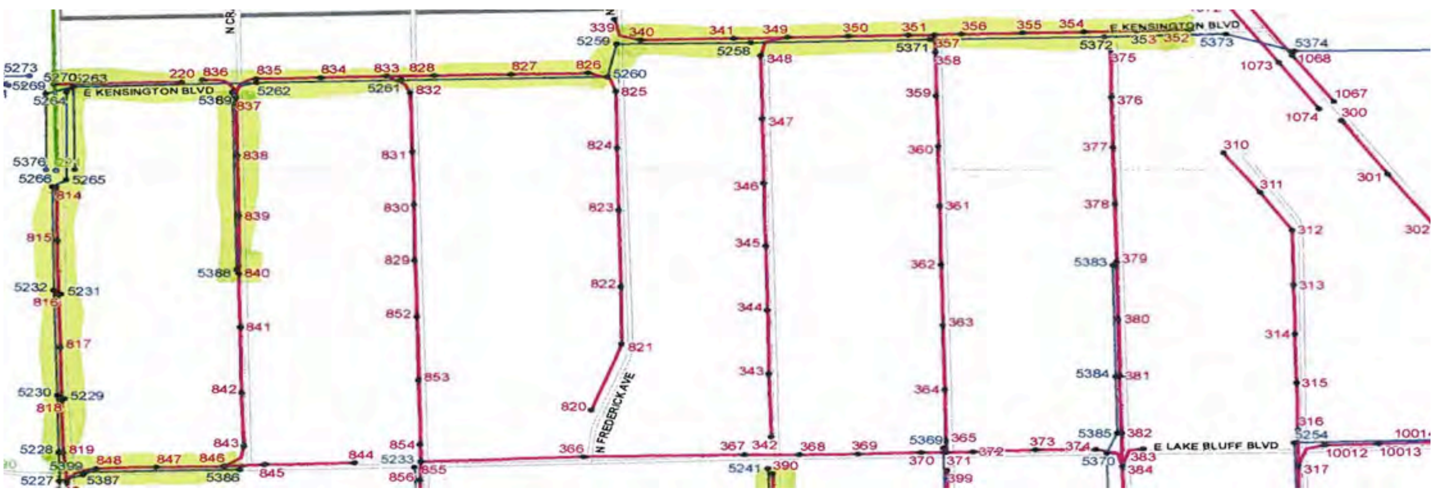


Figure 3. Sampling nodes upstream of Outfall 1 (top picture) and Outfall 2 (bottom picture).



1.2.2 Investigation #2 on March 31, 2009

An additional investigation of the stormwater and combined sewer system was conducted on 3/31/09 during a rain event to narrow or isolate the area of contamination. Dye testing was conducted using green fluorescein dye, which was injected into 2 combined sewer manholes upstream of Outfall 1 (#446 and #457). The McLellan Laboratory also tried to dye test #443 but it was not running. After the fluorescein dye is introduced into the system, downstream stormwater manholes are visually observed for the presence of the dye to determine if the combined sewer system is leaking into the stormwater system. We did not observe fluoroscein dye in the stormwater system, which does not rule out a leaking sewer system but suggests that there may not be a hard connection issue. Overall, the fluoroscein dye testing was inconclusive. Water quality monitoring was also conducted upstream of Outfalls 1 and 2 (**Table 7**). Nodes #5259, 5260, and 5389 were positive for the human *Bacteroides* genetic marker.

Table 6: Enterococcus, *E. coli*, and the human *Bacteroides* genetic marker for the stormwater and combined sewer investigation #1 on 2/11/09.

Site Code	Rainfall (Inches)	Enterococcus (CFUs/100 ml)	*E. coli* (CFUs/100 ml)	Human *Bacteroides*
5045	0.15	5,900	410	Negative
5052	0.15	7,500	1,610	Negative
5057	0.15	2,400	80	Negative
5227	0.15	1,925	190	Negative
5236	0.15	360	220	Negative
5239	0.15	3,400	810	Negative
5241	0.15	1,440	140	Negative
5247	0.15	10,300	590	Negative
5253	0.15	5,100	310	Negative
5259	0.15	4,900	410	**Positive**
5375 (Outfall 2)	0.15	4,600	660	**Positive**
5043 (Outfall 1)	0.15	8,900	830	**Positive**

Table 7: Enterococcus, *E. coli*, and the human *Bacteroides* genetic marker for the stormwater and combined sewer investigation #2 on 3/13/09.

Site Code	Rainfall (inches)	Enterococcus (CFUs/100 ml)	*E. coli* (CFUs/100 ml)	Human *Bacteroides*
5045 DEEP	0.33	2,000	630	Negative
5045 SHAL	0.33	370	70	Negative
5041	0.33	290	40	Negative
5042	0.33	24,000	790	Negative
5259	0.33	340	230	**Positive**
5260	0.33	270	290	**Positive**
5270	0.33	240	270	Negative
5389	0.33	140	210	**Positive**
5041 SUB	0.33	350	40	Negative
ATWOUT1	0.33	15,000	330	Negative

1.2.3 Investigation #3 on June 10, 2009

AECOM conducted smoke testing at locations upstream of Outfalls 1 and 2. The smoke tests were conducted under a contract between the Village of Shorewood and AECOM; that contract was separate from the agreement Village of Shorewood and UWM described herein. The memo submitted on 7/28/09 by AECOM to the Village of Shorewood is included as Appendix D.

1.2.4 Investigation #4 on June 12, 2009

During a baseflow day, the McLellan Laboratory also tested water samples from node #5045, located upstream of Outfall 1 (see **Figure 3**). Samples were taken at two different locations inside the manhole (the pipe running from the south and the shelf on the bottom). The human

Bacteroides genetic marker was detected in the water running from the pipe to the south, but not in the sample from the shelf.

1.3 Sand as a Reservoir for E. coli

Sand reservoirs of *E. coli* have been assessed at Bradford Beach since 2004. These data were compared with Atwater Beach sand reservoirs of *E. coli* to evaluate the potential for sand to act as a source of *E. coli* to the beach water. Overall, Atwater had a significantly lower sand burden of *E. coli* compared with Bradford Beach (**Table 8**). The geometric mean levels were 20 times higher at Bradford Beach at the berm region, which is the area of the beach that is subjected to wave action and is usually wetted. The backshore (e.g. dry sand) was also significantly lower for *E. coli* levels at Atwater compared to Bradford Beach. These results indicate that sand reservoirs of *E. coli* are not a likely source of fecal indicator bacteria to beach water. The submerged sand at Atwater had an *E. coli* reservoir similar to the berm region, which may be a reflection of *E. coli* originating from the water, rather than from beach runoff, as what was found at Bradford. A likely source of *E. coli* that accumulates in the submerged sand and the berm region is from the outfalls north of the beach.

Table 8: Sand levels of *E.coli* (CFU/100 g sand) at Bradford and Atwater Beach

Bradford

		Wet		Dry	
year	Site	Average	Geometric Mean	Average	Geometric Mean
2006	Berm	18,702	1,784	3,204	1,157
	Backshore	5,369,289	402	4,204	64
2007	Berm	28,243	782	11,829	1,211
	Backshore	171,075	675	5,865	48
2008	Berm	1,088	444	16,214	1,027
	Backshore	13,015	210	4,080	176

Atwater

		Wet		Dry	
year	Site	Average	Geometric Mean	Average	Geometric Mean
2007	Submerged	N/A	N/A	628	0
	Berm	728	269	825	1
	Backshore	N/A	N/A	32	0
2008	Submerged	N/A	N/A	380	144
	Berm	N/A	N/A	632	109
	Backshore	N/A	N/A	2656	8

1.4 Conclusions and Recommendations

Based up on our preliminary findings we can make the following conclusions and recommendations:

Public Notification

a. **Post accurate water quality results on the beach.** The standard water quality testing notification signs (green) are often accompanied by a "today the water quality is good" (blue) signage, even when testing has not occurred in the past 24 hours. We recommend that the blue signage not be posted unless the water has been tested in the past 24 hours. The statewide signage procedure calls for the green sign to be posted continuously which does not state that water quality is acceptable, only that the beach is monitored and if unacceptable levels are found an advisory or closure will be posted. The green sign implies testing was done and water was found acceptable.
b. **The Beach Health website advisories and the signage on the beach should be consistent for reliable public notification.** The Beach Health website was found to be inconsistent with advisories posted at the beach. At the beginning of the season, the advisory sign was posted at the beach due to sewage contamination concerns. The website shows no advisories for this time period.

Monitoring

c. **Beach water and stormwater outfalls should be monitored following rain events.** Our data coupled with the Village of Shorewood/Whitefish Bay Health Department, shows high bacterial loads during rain events and on baseline days. These high bacterial loads are causing frequent "advisory" days or beach closures. Atwater Beach has been listed on the 303(d) Impaired Waters List since 2006. The high bacterial loads are most likely from the outfalls north of the beach, which have consistent inputs when it rains, in addition to gull feces deposited on the sand and the groins. Accumulation of Cladophora exasperates the water quality problems by prolonging survival of bacterial inputs.
d. **More consistent monitoring, especially during rain conditions, and public education about what beach closures mean and how they are determined could reduce the risk to human health.** The Village of Shorewood/Whitefish Bay Health Department monitors Atwater Beach at least twice a week. Heavy rains (>1 inch in 24 hours) from June 5, 2008 caused the majority of local beaches to declare an advisory/closure from June 5 -10. Atwater Beach was listed as open the whole week until an advisory was issued on June 10, 2008. The beach did not close as a precautionary measure and was not monitored during this week.
e. **Sewage is a known source of pathogens; therefore it is recommend that until the source of contamination upstream of Outfall 1 has been determined and remediated, Atwater Beach should be preemptively closed after every rainfall.** Sewage has also been detected during dry weather (e.g. baseflow conditions); therefore dry weather does not assure that sewage contamination is not present. <u>Village of Shorewood should weigh the risk to swimmers from exposure to pathogens from sewage against having the beach open.</u> Immuno-compromised individuals (e.g. cancer patients), young children and older adults may be more susceptible to illness following exposure compared with healthy

adults. We recommend that the Village of Shorewood seek advice from the Milwaukee Health Department concerning a time frame that may be protective of human health.

Source Identification

f. **The sources of sewage contamination at Outfall 1 should be identified and remediated.** The McLellan Laboratory has continued to regularly sample Outfall 1 (#5043, East Wood Place) and 2 (#5375, East Kensington Blvd.) to monitor potential human sewage contamination discharging to the beach. Outfall 1 has intermittent human sewage inputs and smoke testing found that there are some complicated problems in this area (e.g. not obvious cross-connections, rather leaking laterals or open joints). The human *Bacteroides* genetic marker is detected during rainfall events but has only been detected in 1 sample during baseflow conditions (Note: on 4/9 and 6/17 the outfall had a strong sewage odor, both baseflow sample days). Further, evidence of sewage contamination was present on two days when no rainfall occurred. Outfall 1 is submerged in the lake (located at the end of a pier), therefore, it is possible that sewage contamination is present when there is no rainfall, but not readily detectable due to dilution from lake water during base flow conditions.

g. **The sources of sewage contamination at Outfall 2 should be identified and remediated.** Outfall 2 has a consistent sewage signal during rain and baseflow conditions. Smoke testing upstream of this outfall found numerous leaking bulkheads that should be remediated. Although these bulkheads could be contributing to the problem, this may not the primary source of contamination. Other unidentified sources likely contribute to the human sewage contamination. <u>The persistent inputs of sewage contamination at Outfall 2 and the unpredictable discharges at Outfall 1 may pose a serious human health risk.</u>

h. **The Village should implement a lateral inspection and lining program.** The lack of identifiable sewage sources from a single location in the stormwater system suggests that home laterals may be the source of sewage into the stormwater. Lining of laterals (or any sanitary sewer pipes that have lost integrity) would reduce exfiltration of sewage, which may migrate into stormwater systems.

i. **The sewage contamination of the beach should be investigated until problem areas are identified. Remediation of these sources should be a priority in order to protect public health.** The Village of Shorewood has extended the work of the McLellan Laboratory with additional beach water and outfall monitoring. An addendum to this report with additional water sampling of Outfall 1 and the 2009 beach data will be available in winter of 2009.

Beach Maintenance

j. **Sand grooming and Cladophora removal should be continued, even though it may not be beneficial in terms of lowering *E. coli* counts but may be helpful in Cladophora and litter removal.** Sand sampling at Atwater Beach did not show significant *E. coli* reservoirs. However, high levels of *E. coli* were observed at wet areas along the beach. This suggests that *E. coli* from stormwater discharge at the outfall may be constantly impacting the sand causing chronic reservoirs of *E. coli*. Accumulation of Cladophora may also prolong *E. coli* survival and contribute to elevated levels during routine testing. The Village of Shorewood grooms the beach at least twice a week.

General Beach Management

k. **General Beach Management Practices should be reviewed and evaluated to determine which practices are appropriate for Atwater Beach.**
   - Bathrooms with hand washing stations should be available to beach-goers to reduce the risk of beach associated illness and the spread of contamination to others.
   - Gull roosting, a large source of *E. coli*, should be deterred. Permitting dogs on the beach during early morning and early evening hours would discourage gulls from frequenting the beach. Provide waste bags at the top of the bluff and bottom of the bluff.
   - Garbage cans should have lids at all times and litter should be continued to be regularly picked up from the beach (the Village of Shorewood removes litter 5 days a week).
   - Lifeguards would increase safety for swimmers and provide a presence on the beach to deter littering, feeding of gulls, or destruction of property. Lifeguard stations should have a first aid kit and fresh drinking water available.
   - Shaded areas on the beach should be created for relief from the sun on very hot days, particularly given the physical exertion required to access the beach or return to the top of the bluff. This is particularly important for very young children or the elderly, put applies to all ages.
   - The beach is currently utilized by a limited number of people. Given the serious water quality concerns, increased use of the beach or introduction of new recreational activities that involve contact with the water should not be undertaken until sewage contamination sources are identified and remediated. Hence, given the quality of the water, recreation should not be a priority. Long term, the Village of Shorewood, in conjunction with the residents, should ultimately identify opportunities that would enhance the quality of the beach experience without compromising the ecosystem integrity. These may include food and beverage service, family play areas, etc. New activities need to be consistent with the recommendations concerning water quality and general beach management. New activities should not reduce naturalized areas without additional assessment.

Environmental Certification

l. **Environmental certification through the Clean Beach Council should not be pursued at this time.** Environmental certification requires beaches to uphold responsible beach practices towards water quality, beach conditions, hazards, public services, habitat conservation, erosion management, and public education. Environmental certification is an expensive and rigorous process that should not be undertaken until the quality of the beach is ensured. Sewage discharges at swimming beaches creates a serious human health risk. Until the sources of contamination at Outfall 1 and 2 are remediated, environmental certification should not be pursued.

2. Conceptual Stormwater Management Plan

Introduction

Stormwater runoff can impact Atwater Park beach in two primary ways (**Figure 4**). The first contributing load of bacteria that impacts beach water quality is the discharge into the lake from the two storm sewer outfalls discussed in Section 1 of the report. The second way is surface runoff generated from rainfall landing directly on the park itself, surface drains directly onto the beach from the upper terrace and bluff, and can also have an impact on beach water quality.

2.1 Surface Runoff

Based on topography and storm sewer system information available from the Village's online mapping tool, the only area that drains directly onto the beach itself is the ground of Atwater Park. There are no areas that drain onto the beach from offsite. Runoff from Lake Drive adjacent to the park is collected in the sewer system and conveyed north, away from the park.

The total area of the park that directly drains onto the beach is approximately five acres. The area of the park at the top of the bluff generally surface drains from the eastern edge of the Lake Drive right-of-way to the edge of the bluff. The runoff then continues down the bluff. This upper area has a width that ranges from approximately 80 to 125 feet with a slope of approximately 5-percent. The total area of the upper park is approximately 1.5 acres. The bluff is approximately 85 feet in height with side slopes the range between 2:1 to 2.5:1. The area of the bluff within the park is approximately 3.5 acres.

Figure 4: Drainage Basins. Drainage areas are designated by pink outline. Outfalls are designated by yellow lines.

Because the area of the park is relatively small compared to adjacent drainage areas, the impact of surface stormwater runoff on the park is likely minor. However, some best management practices (BMPs) could be applied. However, surface runoff BMPs should only be considered after the problems with the storm water outfalls has been remediated. Some of these BMPs that can be considered are listed here; the first three are already being used by the Village,

Figure 5: Bioretention Area at Park

2.1.1 Reduce chemical applications in Park

Minimize the amount of fertilizer, herbicides, and pesticides applied in the park area, which could ultimately reach the beach via stormwater runoff .

2.1.2 Reduce Pet Waste

The Village currently has an ordinance that addresses pet waste. To improve public awareness of the ordinance, the Village should consider increased public education (e.g. signs describing the ordinance), provide receptacles for pet waste within the park, and increased enforcement of the ordinance.

2.1.3 Native Vegetation

Maximize the use of deep rooted native vegetation, which can stabilize the soil and bluff, promote infiltration, and reduce the need for irrigation. To install native vegetation, the cost would be in the range of $25 to $50 per square yard. Further assessment, e.g., prepping site, is needed for this option.

2.1.4 Upper Area Bioretention Cells

Construct bioretention cells at the top of the bluff to catch, store, and filter stormwater from the upper park area (**Figure 5**). The existing pathway would need to be shifted to the west. To construct these cells, the cost would be in the range of $40,000 to $60,000.

2.1.5 Lower Area Bioretention Cells

Either in conjunction with the previously described BMP or alone, construct rain gardens or bioretention cells at the toe of the bluff to catch, store, and filter stormwater to prevent it from running across the beach (Figure 5). To construct these cells, the cost would be in the range of $80,000 to $120,000.

2.2 Storm Sewer Runoff

Based on the storm sewer system information available from the Village's online mapping tool, there are two storm sewer outfalls that discharge into Lake Michigan near the beach. The drainage area to Outfall 1 is approximately 90 acres of predominantly high density residential land. There is an additional 30 acres within the drainage area that drains to the combined sanitary sewer system. If all of the area that currently drains to the combined system is disconnected, the drainage area to this outfall would increase to approximately 130 acres.

The drainage area to Outfall 2 is approximately 50 acres of predominantly high density residential land with approximately 25-percent being more urban / non-residential land adjacent to Oakland Avenue. There is approximately an additional 10 acres within the drainage area that drains to the combined sanitary sewer system. If all of the area that currently drains to the combined system is disconnected, the drainage area to this outfall would increase to approximately 60 acres.

Stormwater management, with a focus on bacterial contamination, in fully built-out urban areas offers significant challenges. There are few undeveloped open spaces to construct BMPs. In addition, traditional BMPs (such as a wet detention pond or sub-surface settling device, which use sedimentation as the mechanism to remove pollutants) offer little benefit in reducing the level of bacteria because bacteria are attached to extremely small particles that cannot be settled out in the traditional BMPs. In fact, some BMPs that contain sumps with standing water can become a place where bacteria can increase in numbers. Typically, the most effective ways to manage bacterial contamination at beaches from stormwater are to prevent the stormwater from reaching the beach in the first place, filtering the stormwater with an appropriately designed filter media, and disinfecting the stormwater runoff. Both filtering, with an engineered media, and disinfection are expensive, and can typically only be applied to small drainage areas or low flows. Ultra-violet (UV) disinfection is also only effective when the water being treated is clear enough for the UV light to penetrate. These issues have limited the potential options that can be considered.

If, after addressing the cross-contamination, bacterial contamination from the storm sewer outfalls is still impacting beach water quality, then further actions should be considered. A mixing model or other analysis should be completed to further determine the potential amount and extents of impact of the outfalls. Subsequent to that analysis, some BMPs that could be considered to mitigate this impact are listed in the following sub-sections. **However, directly remediating the source of the human contamination to the outfalls should be the first priority and the recommended approach.**

Figure 6: Storm Sewer Extension and Relay

2.2.1 Outfall Extension

Extend the existing outfalls further into the lake. By extending the outfalls approximately 500 feet into the lake, the stormwater discharge has more opportunity to mix with the lake water (**Figure 6**). This not only causes the dilution of the stormwater, but increases the die-off of the bacteria in the cooler water that is further from shore. To construct these extensions, the cost would be in the range of $400,000 to $600,000 each. **This is not a preferred alternative.**

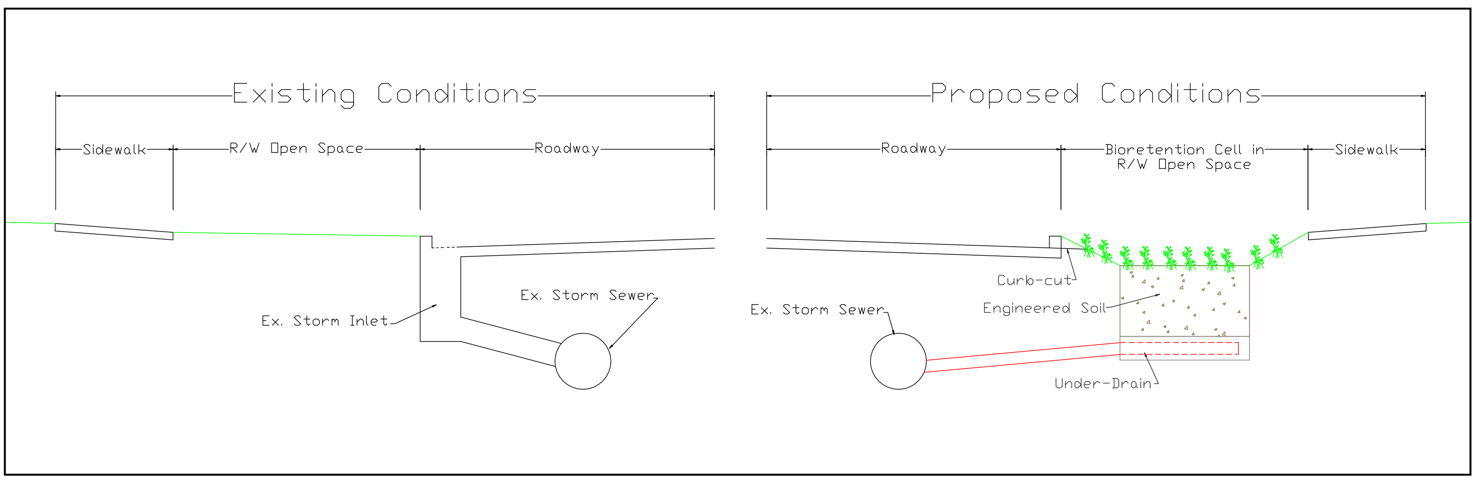
2.2.2 Storm Sewer Relay

Abandon the southern 48-inch diameter storm sewer outfall, and relay the storm sewer north in Lake Drive to the location of the existing 24x48-inch arch pipe outfall. Replace the 24x48-inch arch pipe outfall with a 60-inch diameter outfall extending 500 feet into the lake (**Figure 6**). To construct this relay, the cost would be in the range of $1,500,000 to $2,500,000. **This is not a preferred alternative.**

2.2.3 Dispersed BMPs within the Drainage Basin

Treating stormwater within the drainage basin is also an option, however is challenging because there are few opportunities to construct BMPs within the drainage basin because of the lack of open undeveloped land. Using the limited open space within Village-owned right-of-way, dispersed bioretention cells could be constructed (**Figure 7**). Because these cells would be constructed adjacent to roadways, to minimize disruption and costs, they would likely be installed at the same time roadway construction is taking place. Using this approach, it may require several years to implement an entire system of bioretention cells within the drainage basins of the two outfalls. To construct these bioretention cells, the cost would be in the range of $100,000 to $150,000 per block (800 feet). This alternative will only be effective in areas where inlets drain to the storm sewer system. **This is not a preferred alternative.**

Figure 7: Bioretention in road right-of-ways



2.2.4 Street Sweeping

Street runoff can contain high levels of bacteria, which is typically attached to fine particles. By reducing the sediment load from street runoff, the bacteria load can also be indirectly reduced.

The Village currently uses a vacuum street sweeper on the streets within the drainage basins of the two outfalls. The streets are swept once to twice monthly. This frequency could be increased to further increase the amount of sediment removed from the streets. An analysis to determine the exact water quality improve of a more aggressive sweeping schedule should be completed prior to implementing an increased sweeping program.

2.2.5 Catch-Basin Inserts

These are bag inserts that are placed in existing storm sewer inlets. They are made of a foam polymer material impregnated with an anti-bacterial substance. Most inlet filters need regular cleaning to remain effective and to prevent clogging. These types of filters, which are manufactured by Abtech Incorporated, have recently been installed by Milwaukee County on inlets adjacent to Bradford Beach. Their experience shows that the inlets need to be cleaned very frequently to remain unclogged. Once clogged, runoff is no longer filtered. At the time that this report was written, it was not immediately known the exact amount of inlets that drain to the storm sewer system. Assuming there is one inlet for each acre of drainage area, there would be 140 inlets. To install these inserts, the cost would be in the range of $175,000 to $225,000 for 140 inlets. **This is not a preferred alternative.**

2.2.6 Other Considerations

Bioretention cells to treat stormwater discharging from the storm sewer outfalls were also considered. However, in this particular situation, there is limited area available along to shoreline to construct such a device, and the property is privately owned.

3. Nuisance Algae (Cladophora) in the Atwater Beach Region of Lake Michigan

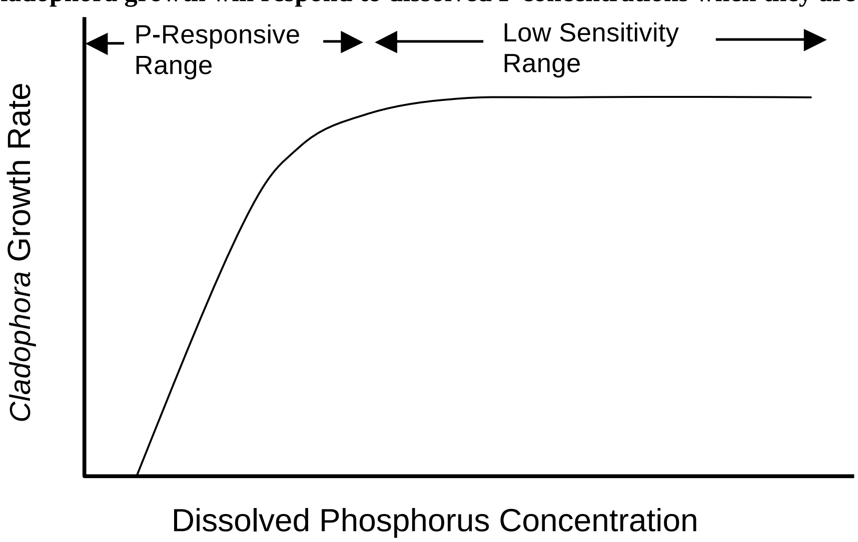
Introduction

Cladophora is an invasive species of green algae that covers the shoreline of Lake Michigan. When the conditions for Cladophora growth are optimal, large blooms occur in nearshore waters that break off and wash onto the shoreline. The decaying Cladophora on the shoreline leads to unsightly and foul-smelling beaches and create an economic burden to local communities. There are no solutions for stopping the growth of Cladophora, since there are many uncontrollable ecological factors that drive growth. Likewise, it is not feasible to manage overall growth but there are some actions that can be implemented to manage the impacts on the beach.

Within the lake there are four primary factors that control the growth of *Cladophora*:

a. Substratum. *Cladophora* is an attached algae that rarely grows in suspension. It requires a hard substratum on which to grow – usually a rocky bottom.
b. Light. *Cladophora* is able to grow over a wide range of light intensities. However, it grows more slowly at low light intensities, and growth stops at light intensities below about 50 μmol photons/m^2/s.
c. Temperature. The optimum growth temperature is between 13 and 17°C (55 – 63°F), and growth is minimal below a temperature of about 5°C (41°F).
d. Dissolved phosphorus. *Cladophora* growth increases with increasing dissolved phosphorus concentration. However, the relationship between phosphorus concentration and algal growth rate is strongly influenced by temperature and light availability. The general shape of the relationship is indicated in **Figure 8**.

Figure 8: General relationship between dissolved phosphorus concentration and Cladophora growth rate. Cladophora growth will respond to dissolved P concentrations when they are low.



3.1 Historic Trends of Excessive Algae Growth

While there is little quantitative data on historic trends of *Cladophora* in the Atwater Beach region, or any other nearshore regions of Lake Michigan, reports and observations made over the past half century suggest that the algae was very abundant in the 1960s and 1970s, diminished in the 1980s and 1990s, and resurged between the late 1990s and the present time. In the 1960s and 1970s, the problem was associated with high inputs of nutrients, especially phosphorus, to Lake Michigan. As a result, *Cladophora* abundance was particularly high near river mouths and urban centers where large amounts of phosphorus entered the lake. The implementation of phosphorus control measures as part of the Great Lakes Water Quality Agreement resulted in a decline in phosphorus concentrations in Lake Michigan, and a decrease in the abundance of *Cladophora*. The target concentration of total phosphorus in Lake Michigan, as set within the Great Lakes Water Quality Agreement, is 7 μg/L. Current open-water concentrations of total phosphorus are generally below 5 μg/L. Therefore the recent resurgence of *Cladophora* has been somewhat puzzling since phosphorous does not appear to be the primary driver of growth.

Figures 9 to 11 indicate nearshore trends of water clarity (which determines the amount of light that reaches the lake bottom, where *Cladophora* grows), temperature, and phosphorus over the past several decades. These data are collected from locations offshore of Milwaukee Harbor and the Linnwood Treatment Plant water intake, which are likely representative of trends offshore of Atwater Beach. As indicated in the figures, water clarity has increased and average summer nearshore temperature has increased. The increase in water clarity – a phenomenon that has occurred in most of the lower Great Lakes – is the result of feeding by zebra mussels and quagga mussels, which filter particles out of the water column. While total phosphorus (which includes both particulate and dissolved fractions) has generally declined over time, the concentration of dissolved phosphorus (the form required by algae) appears to have increased since the early 1990s.

Figure 9: Increasing water clarity in Lake Michigan. Temporal trend of secchi disk depths measured just south of Milwaukee, 2 km offshore (Z_{max} = 10 m). Data provided by Milwaukee Metropolitan Sewerage District.

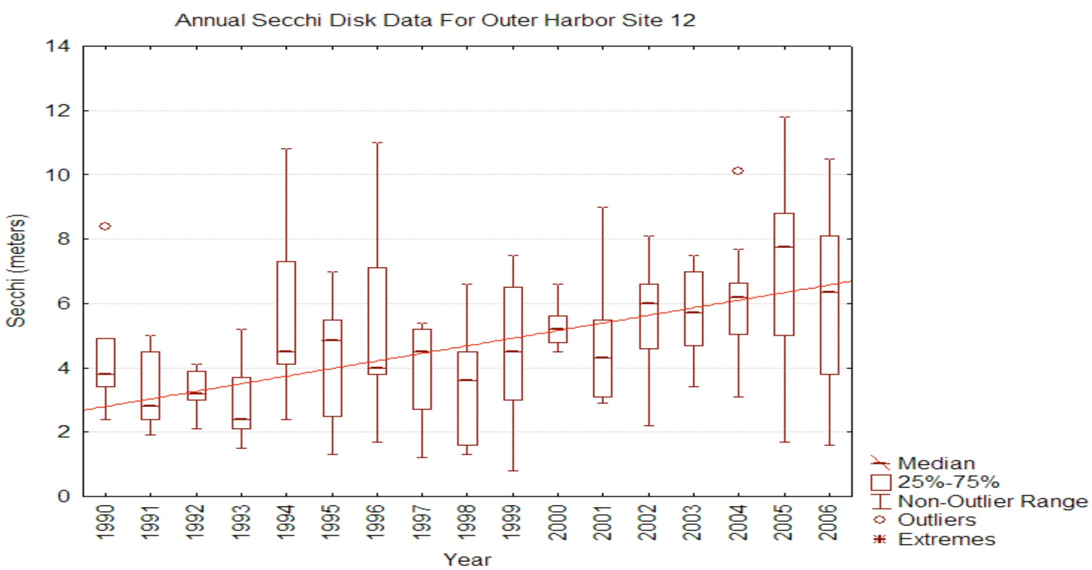


Figure 10: Increasing water temperature in Lake Michigan. Historic trend of average summer (June – August) nearshore water temperatures. Data are from the Linnwood water intake, which is positioned at a depth of 15 m.

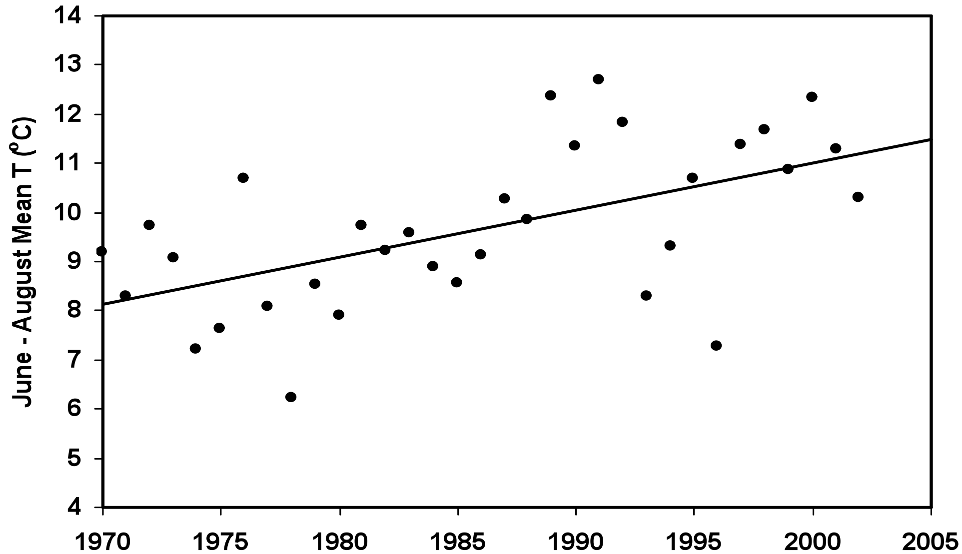
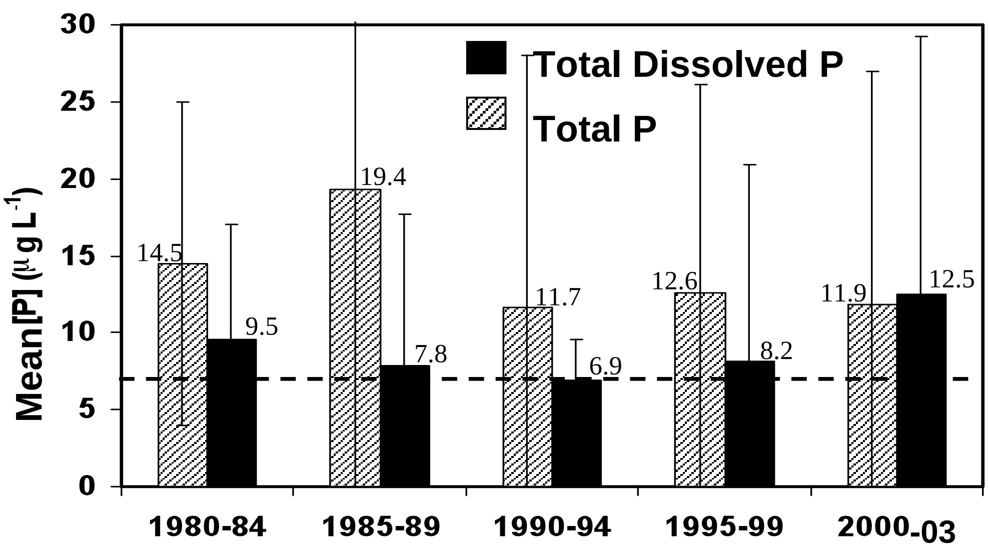


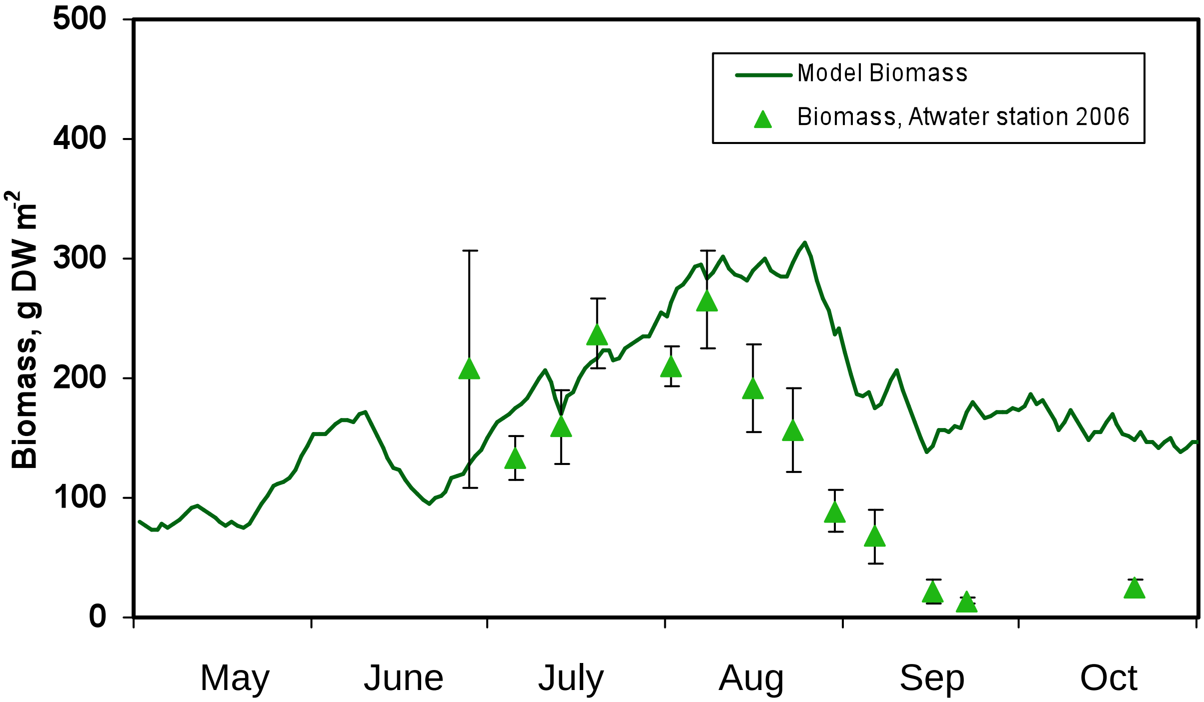
Figure 11: Increase in dissolved phosphorous at the bottom of Lake Michigan. Historic trend of near-bottom mean total dissolved phosphorus and total phosphorus concentrations at MMSD nearshore station (located approximately 1 km offshore of the north gap of the Milwaukee Harbor wall, in about 13 m of water). Data provided by MMSD. Measurements made offshore of Atwater Beach are typically lower than those for this site; the data in this figure are meant to illustrate long-term trends.



3.2 *Cladophora* Models

A model can be used to evaluate how each factor exacerbates *Cladophora* growth. This can help us determine what the critical driving forces are for *Cladophora* growth, which in turn allows us to better, predict and understand future *Cladophora* outbreaks. In order to assess the potential impact of these changes in nearshore water quality on *Cladophora*, it is necessary to have quantitative descriptions of the relationships between *Cladophora* growth and each of the water quality variables (light, temperature and dissolved phosphorus). These relationships have been previously quantified and incorporated into a numerical model developed by M. Auer and colleagues (full descriptions of the original model and the data used to develop it are available in a special issue of the Journal of Great Lakes Research [Volume 8, issue 1], published in 1982). More recent work conducted by H. Bootsma at the UWM Great Lakes WATER Institute has provided field data that was used to revise and validate the model so that it is applicable to Lake Michigan. The model simulates *Cladophora* growth and biomass as a function of light, temperature and dissolved phosphorus concentration. The results of a model simulation for the summer of 2006, along with actual measurements of *Cladophora* biomass made offshore of Atwater Beach in that year, are presented in **Figure 12**. The comparison indicates that, although the model does not accurately predict the timing of the *Cladophora* biomass decrease in late summer, it is reasonably good at simulating the growth phase of *Cladophora* between June and early August. Therefore the model can be used as a tool to investigate how *Cladophora* growth might respond to changes in temperature, light and dissolved phosphorus.

Figure 12: Comparison of modeled (——) and measured (▲) *Cladophora* biomass for the period May – October, 2006, 9 m depth, Atwater Station. Model input included in situ temperature measurements, in situ light measurements, and soluble reactive phosphorus measurements.



Using the *Cladophora* model, the influence of the long term changes in temperature, light and dissolved phosphorus shown in figures 9 to 11 on *Cladophora* biomass was determined. The results indicate that the increase in average summer nearshore temperatures likely had an insignificant effect on algal biomass, but the increases in dissolved P and light (i.e. water clarity) had a significant influence. In particular, the increase in water clarity has affected total biomass in two ways: 1) It has resulted in increased growth rates at shallow depths; 2) It has doubled the depth range over which *Cladophora* can grow (**Fig. 13**). As a result of the increase in water clarity and the increase in dissolved P concentration, the maximum total biomass of *Cladophora* in the waters immediately offshore of Atwater Beach is estimated to be approximately five times greater than it was in the late 1980s, before the arrival of zebra mussels and quagga mussels (**Fig. 14**).

Figure 13: Modeled effects of changes in water clarity (light effect) and soluble reactive P concentration on the mid-summer depth distribution of *Cladophora* biomass offshore of Atwater Beach.

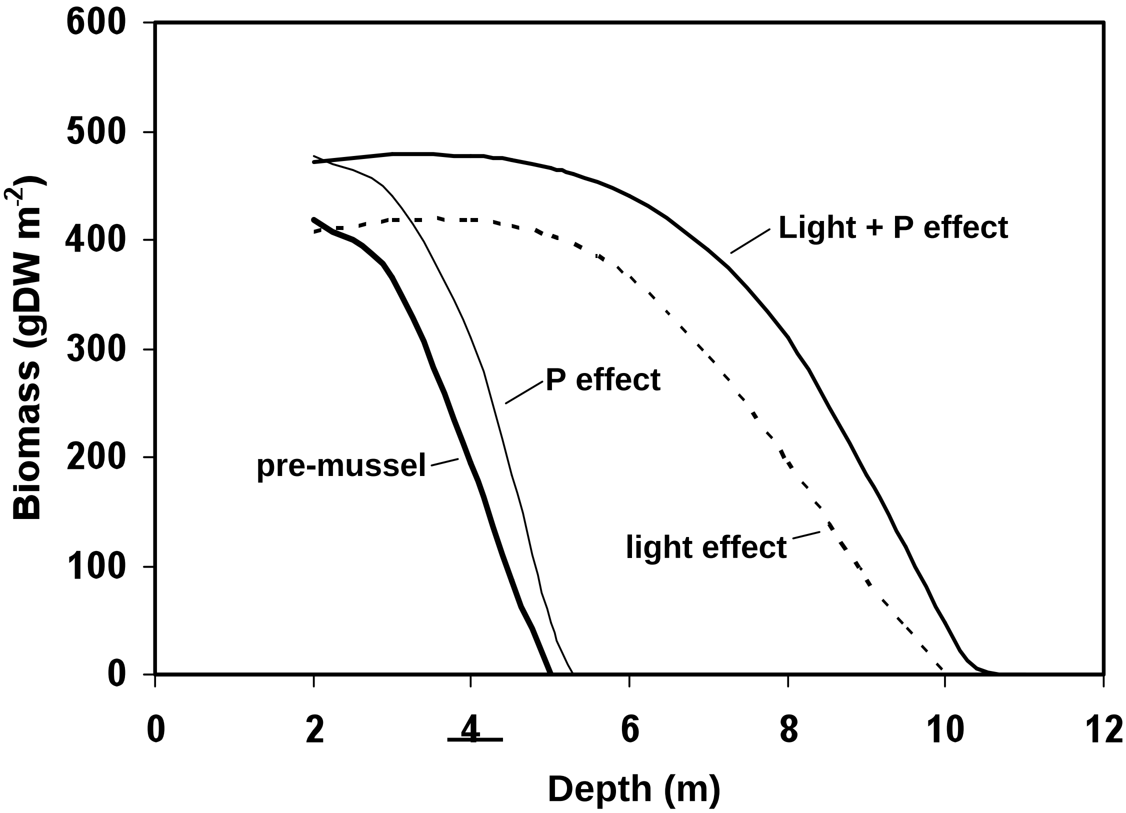
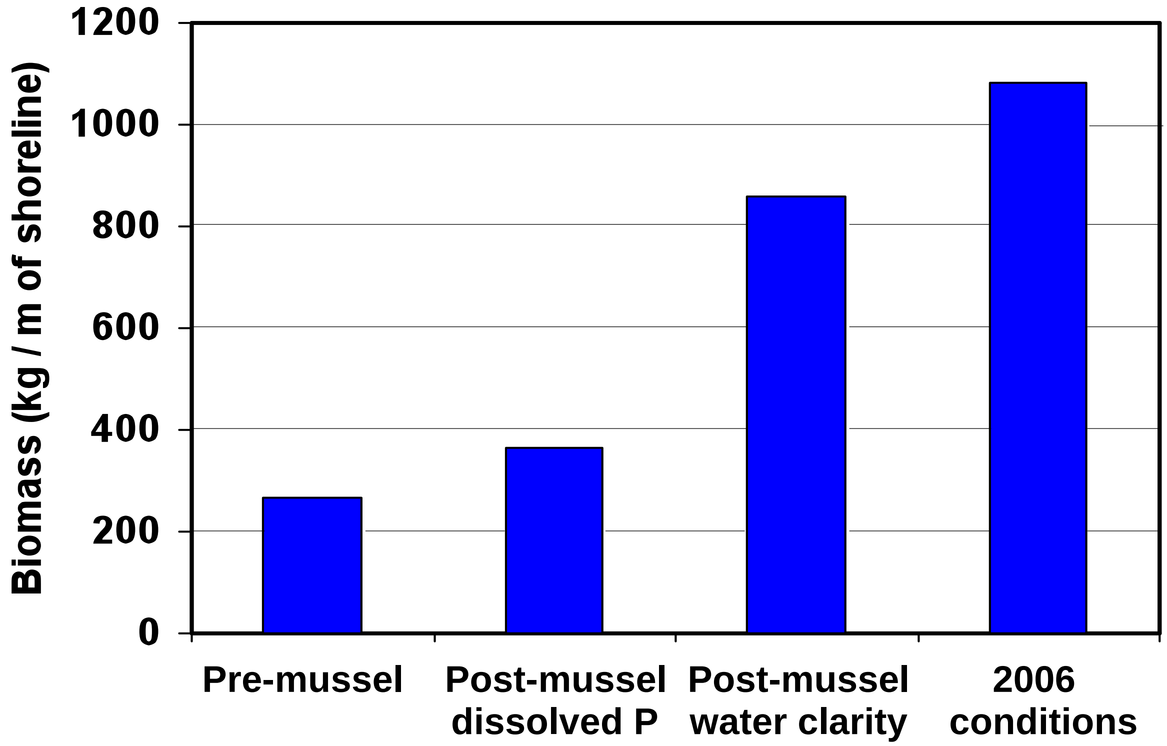


Figure 14: Modeled maximum *Cladophora* accumulation under the four phosphorus / light scenarios used for Fig. 13, illustrating the effects of long-term changes in water clarity and dissolved phosphorus concentrations on *Cladophora* biomass in the Atwater Beach region. Depth-integrated biomass was calculated using a nearshore lake bottom slope of 1:250, determined from regional bathymetric maps.

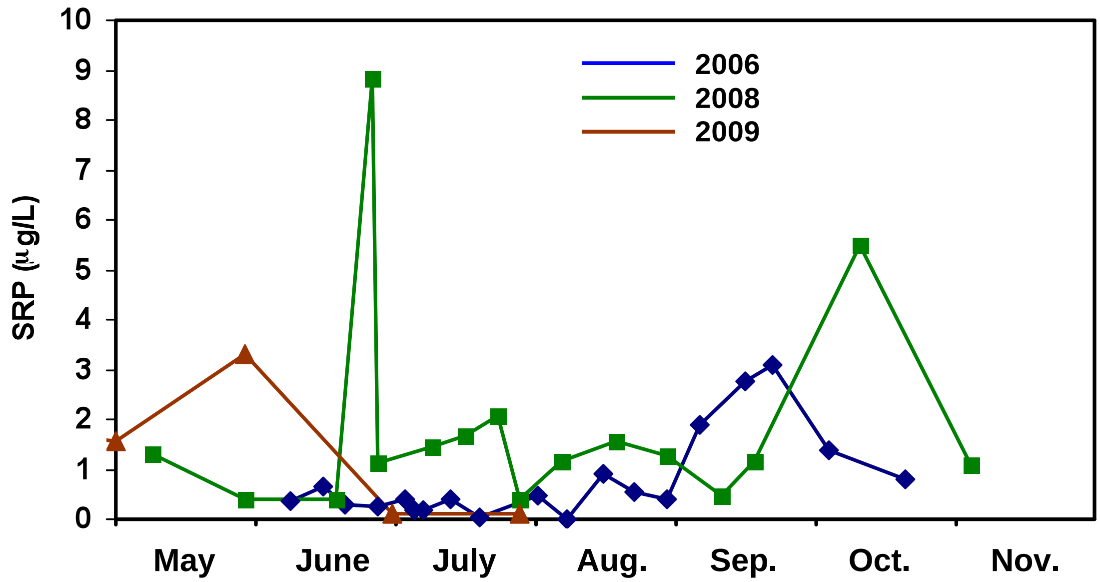


3.3 Options for Managing Cladophora Growth

3.3.1 Phosphorous

The primary factor responsible for excessive *Cladophora* growth is increased water clarity. However, water clarity is not a property that is directly amenable to management. The only management approach with potential for reducing *Cladophora* growth is that which has been used for the past half century in lakes with excessive algal production: reduction of dissolved phosphorus concentrations, which is usually achieved through reduction in phosphorus loading. While phosphorus concentrations near Milwaukee Harbor are often higher than the target concentration of 7 μg/L set for Lake Michigan (see **Fig. 11**), the dissolved phosphorus concentrations near Atwater Beach are generally much lower (**Fig. 15**). These concentrations were previously low enough to prevent nuisance growth of *Cladophora*, but the increase in water clarity has countered these low nutrient concentrations, so that nearshore concentration targets need to be set even lower to result in acceptable *Cladophora* biomass.

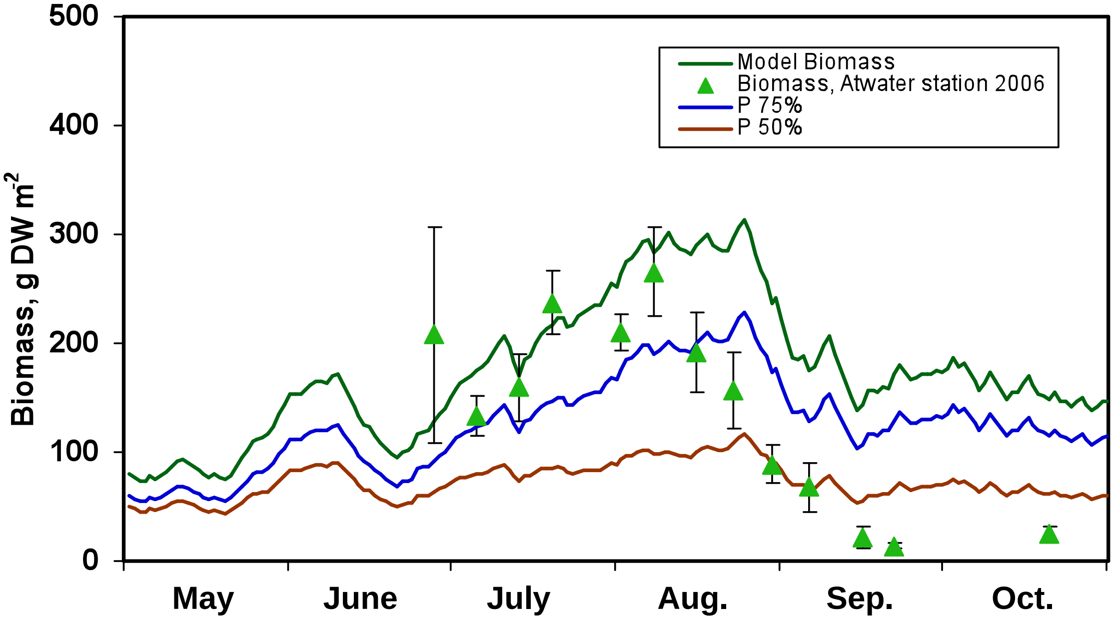
Figure 15: Soluble reactive phosphorus (SRP) concentrations directly offshore of Atwater Beach (lake depth = 10 m).



The *Cladophora* model can be used to explore the potential *Cladophora* response to different management scenarios. The mean soluble reactive concentration for the months of May - July 2006 (the year for which the *Cladophora* model was originally validated for Lake Michigan) was 0.6 μg/L. These three months are the period during which most biomass accrual occurs. **Figure 16** illustrates the potential reduction in *Cladophora* biomass that might be expected if soluble reactive phosphorus concentrations were reduced to 75% and 50% of current values. A phosphorus reduction to 50% of current concentrations is predicted to result in a reduction in peak biomass to about one third of current values. It is important to note that the effect of nutrient reductions will vary with depth, because the phosphorus – growth relationship varies with light intensity. For example, at a depth of 5 m, the model predicts that a 50% phosphorus reduction would result in a decrease of algal biomass to about 80% of current biomass. It is relatively simple to alter parameters and variables for the *Cladophora* model, and therefore the ramifications of any change in environmental conditions (water clarity, phosphorus concentration, temperature) can be fully explored with the model.

The above analysis suggests that a 50% reduction in dissolved P concentration may lead to a significant reduction of *Cladophora* biomass. Within the Atwater Beach region, dissolved P concentrations are sufficiently low that *Cladophora* growth is in the P-responsive range, i.e. changes in dissolved P concentration will result in changes in *Cladophora* growth. From a management perspective, the obvious question is: can this goal be achieved? For the Atwater Beach nearshore region, there are three major impediments to achieving this goal. First, there is the challenge of reducing P loads to a level low enough to result in significant reductions in nearshore phosphorus concentrations. Over the past four decades significant efforts have gone into reducing phosphorus loads to Lake Michigan. These have included improvements in sewage treatment, agricultural practices, and the removal of phosphorus from laundry detergents. While further load reductions are achievable and desirable from a *Cladophora* management perspective, these reductions will only be achieved through the reduction of non-point phosphorus sources. These include agricultural and urban non-point sources. While a detailed phosphorus management plan for the Village of Shorewood would require a thorough study of phosphorus sources and transport mechanisms, the most likely sources to be targeted include lawn fertilizer application, soil erosion from construction sites, and other nutrient sources (e.g. leaves, animal waste) that contribute to the nutrient load of storm sewers that drain directly to the lake.

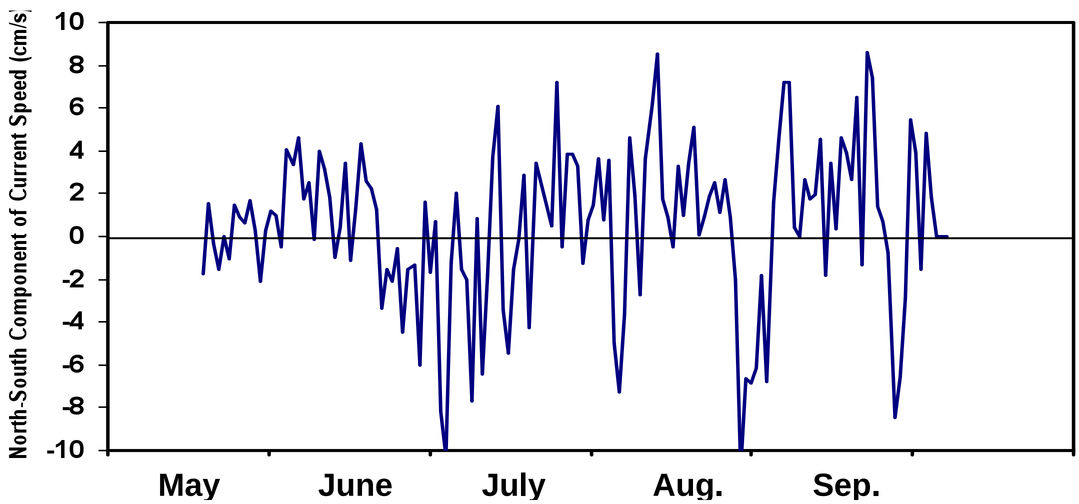
Figure 16: Model simulation of *Cladophora* biomass (9 m depth) under current dissolved phosphorus concentrations, and scenarios in which dissolved phosphorus concentrations are 75% and 50% of current values.



3.3.2 Nutrient Transport along Shoreline

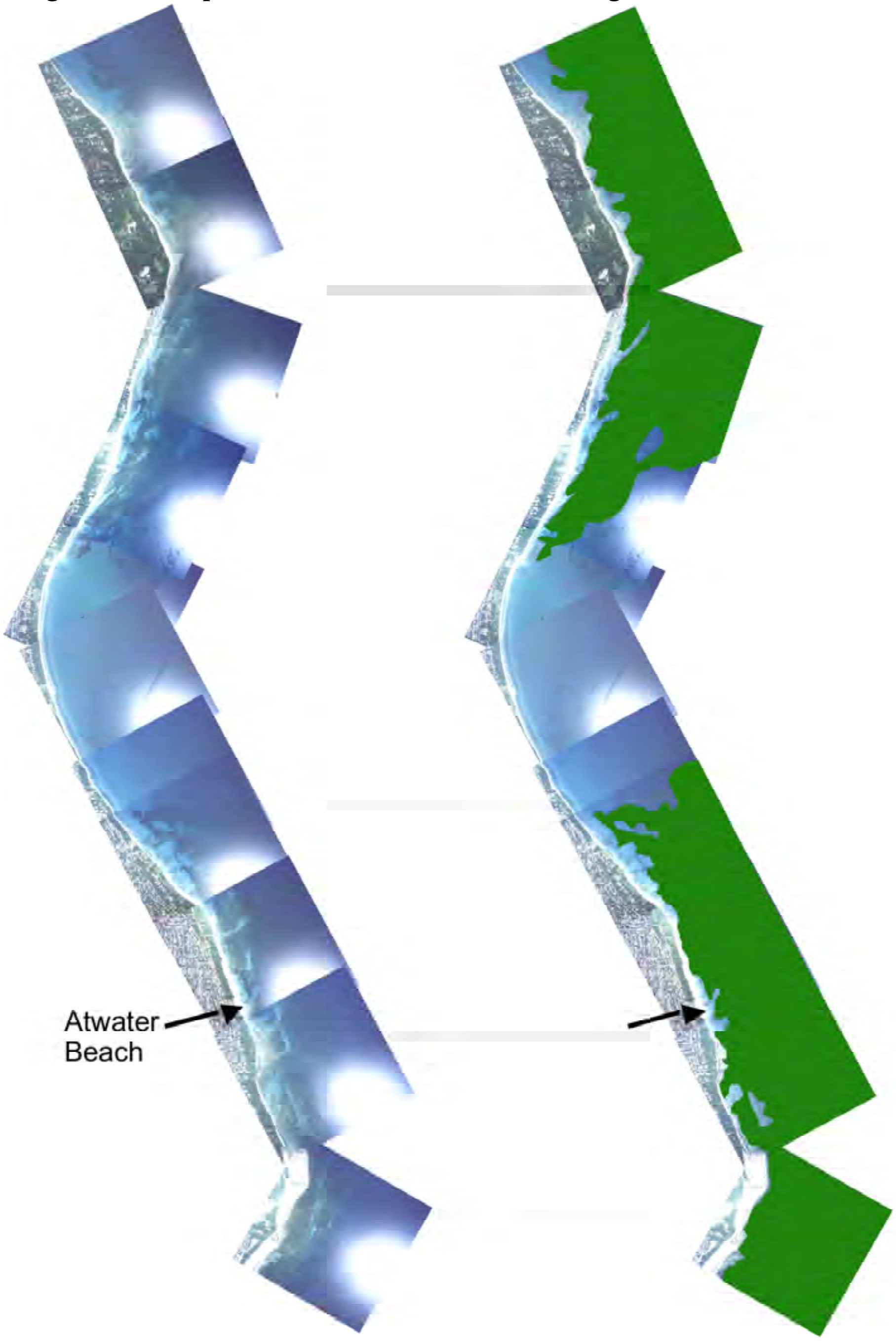
Even if significant reductions in phosphorus loads from the Village are achieved, a second impediment is that of nutrient transport along the Lake Michigan shoreline. Because no major rivers enter Lake Michigan in the Atwater Beach region, this shoreline area is likely not a major source of nutrients to the nearshore zone. Rather, it is influenced by water that is transported along the shoreline from the south and the north. Current speeds were measured at this location in the summer of 2008 using an acoustic Doppler current profiler (ADCP). The results are shown in **Fig. 17**. Depth-averaged current speeds in the north-south direction averaged 4 cm/s, and were occasionally as high as 10 cm/s. At the average speed of 4 cm/s, nearshore water masses will move 3.5 km (2.1 miles) per day, and 24 km (14.5 miles) in a week. Hence, any efforts to minimize nutrient loading in the immediate Atwater Beach region will have a very small effect on *Cladophora* growth in the region, because nearshore nutrient concentrations are determined by land use and nutrient loads over long stretches of shoreline. This is not to say that nutrient mitigation by the Village of Shorewood is not worth pursuing. Indeed, a reduction in nearshore nutrient concentrations in Lake Michigan requires that such action be taken by numerous communities within the Lake Michigan watershed.

Figure 17: North-South component of nearshore depth-averaged current speed off of Atwater Beach, 2008. Average current speed for the period was 4 cm/s. Positive values represent currents flowing to the north, negative values represent currents flowing to the south.



Nearshore currents can transport *Cladophora* as well as nutrients. As a result, *Cladophora* accumulation on Atwater Beach results in part from *Cladophora* growth in other nearshore areas to the north and south of Atwater Beach. An approximate picture of *Cladophora* distribution in the larger region surrounding Atwater Beach can be obtained from aerial photographs (**Fig. 18**). In general, *Cladophora* grows in the nearshore zone wherever there is a suitable, hard substratum. With the exception of Whitefish Bay, much of the nearshore region to the north and south of Atwater Beach is dominated by rocky bottom. Algae growing in this region usually reaches its peak around late July or early August (**Fig. 12**), after which it begins to brake off and drift. The fate of this sloughed algae will depend largely on current speed and direction, which will determine how far along the shore it is transported, and whether its final destination will be the lake's open waters, or the beaches and rocky areas that make up the shoreline.

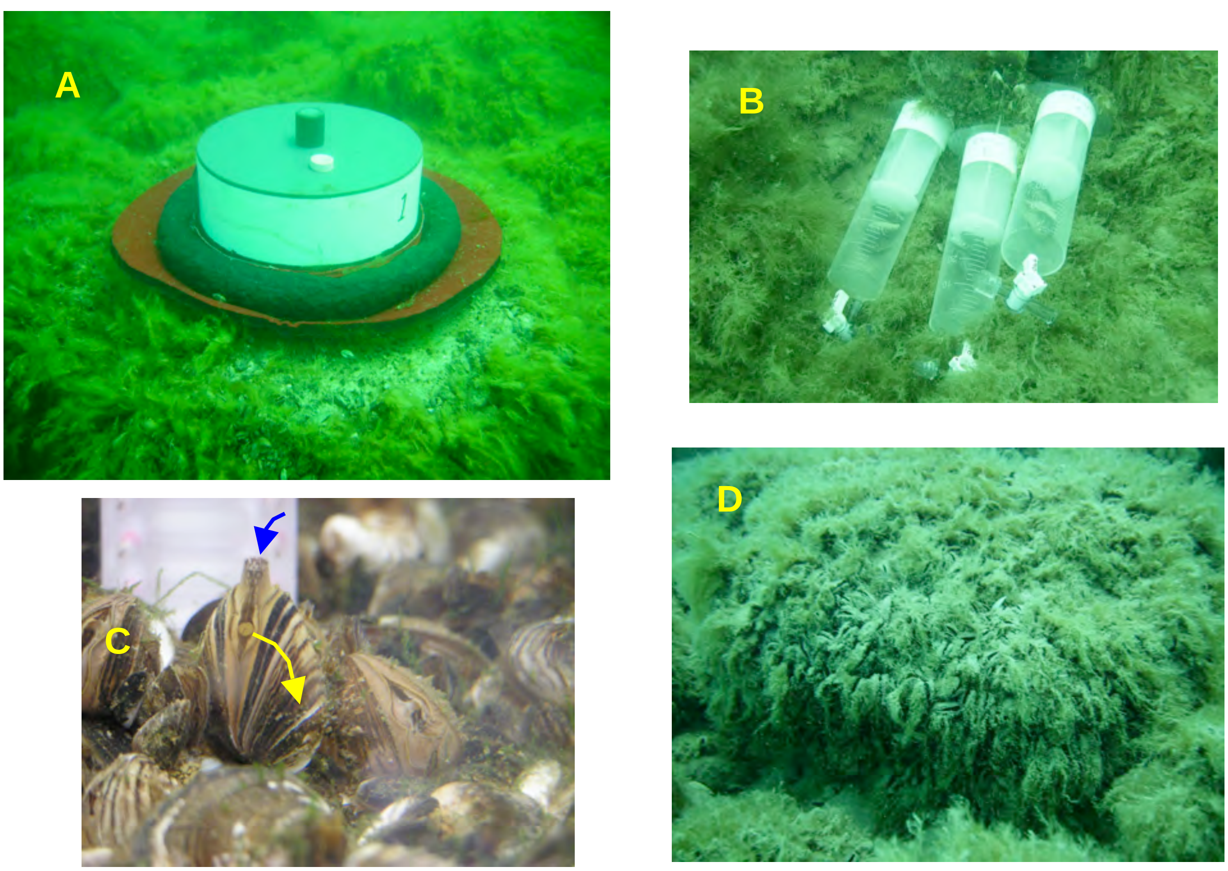
Figure 18: Left: Aerial image composite of nearshore Lake Michigan north of Milwaukee. Right: The same image, with *Cladophora* dominated areas indicated in green.



3.3.1 Mussels

A third factor making the management of nearshore dissolved phosphorus concentrations difficult is phosphorus recycling by dreissenid mussels – the zebra mussel and the more numerous quagga mussel. In the summer of 2008 we made numerous measurements of quagga mussel phosphorus excretion by conducting experiments offshore of Atwater Beach (**Fig. 19**). Measurements made on seven dates resulted in excretion rates ranging from 0.2 to 1.2 mg $P/m^2/hr$. These rates were compared with phosphorus loading from the Milwaukee River by applying them to the region between Wind Point (south of Milwaukee) and Fox Point. For this region, P loading from the Milwaukee River is approximately 1.3 mg $P/m^2/day$, compared with a mussel excretion rate of 5.5 mg $P/m^2/day$. As a result of high P excretion rates by mussels, it is unclear at this point whether reductions in external phosphorus loads will have any immediate impact on nearshore dissolved phosphorus concentrations. Rather, nearshore phosphorus concentration (and therefore, *Cladophora* abundance) appears to be controlled more by mussel abundance and mussel metabolic rates, which in turn are controlled by food supply in the form of plankton.

Figure 19. A: Chamber used to make in situ measurements of mussel phosphorus excretion rates. B: Mussel P excretion was also measured by incubating mussels in large syringes. C: Close-up image of mussel showing inhalant siphon in blue (through which food enters) and exhalant siphon in yellow (through which dissolved P is excreted). D: Rock on lake bottom near Atwater Beach, showing mussels covered by *Cladophora*.



3.4 Cladophora Prediction

The capacity to reduce *Cladophora* growth and beach accumulation in the Atwater Beach area by reducing nutrient inputs to the lake in the immediate area is, unfortunately, very limited. Any long-term reduction of nearshore dissolved phosphorus concentration will require a concerted effort at the watershed scale to reduce phosphorus loads. Alternatively, nearshore nutrient concentrations and *Cladophora* abundance would also likely respond to changes in the distribution and/or density of quagga mussels. This is unlikely to occur as the result of any direct human intervention, but natural processes such as disease and predation may result in future increases or decreases in mussel abundance that are not predictable.

Despite the impediments to managing *Cladophora* growth, management may still benefit from any capacity to predict *Cladophora* abundance from month to month and year to year. For example, this predictive ability might guide decisions related to equipment and labor availability within a given year. A comparison of *Cladophora* biomass trends near Atwater Beach in three separate years indicates that monthly patterns were very similar in 2006 and 2008, but in 2009 biomass was significantly lower (**Fig. 20**; no monitoring was conducted in 2007). A comparison of other water quality variables for these years indicates that light intensity was lower in 2009. In addition, while dissolved P concentrations were high in the spring of 2009, they were very low in June and July (**Fig. 20**). The effect of this low light availability and low dissolved phosphorus concentration on *Cladophora* biomass can be tested using the *Cladophora* model. In **Fig. 21** model simulation results for 2006 and 2009 are compared. The maximum biomass predicted by the model is very similar to the observed maximum biomass. Both the model and the observed data support the conclusion that low light and dissolved P in 2009 resulted in relatively low *Cladophora* biomass. The reason for the relatively low dissolved P concentrations in June and July of 2009 is not clear. However, nearshore currents during this period were primarily from the north (**Fig. 17**). The nearest major tributary to the north of Atwater Beach is the relatively small Sauk Creek in Port Washington, 35 km (21 miles) away, followed by the Sheboygan River which is 70 km (42 miles) to the north. These long distances allow nearshore water to mix with nutrient-depleted offshore water, and so currents from the north can be expected to have lower dissolved phosphorus concentrations than currents from the south, which are supplied with nutrient-rich water entering the lake through the Milwaukee Harbor.

Regardless of the cause of low dissolved phosphorus concentrations in June and July of 2009, the results presented in **Fig. 15** indicate that the model has potential for predicting *Cladophora* growth within a given summer if water quality data are available. While the data presented here suggest that measurements of current speeds and directions may eventually prove useful for predicting *Cladophora* growth near Atwater Beach, a longer multi-year time series of data would be necessary to confirm this relationship and refine its description. The more immediate controllers of *Cladophora* growth – especially light and nearshore dissolved phosphorus concentrations – will likely result in more accurate predictions of *Cladophora* growth in the Atwater Beach region.

Figure 20: Monthly trends of *Cladophora* biomass and water quality variables offshore of Atwater Beach in 2006, 2008 and 2009. Temperature and light values are monthly averages. Vertical bars in biomass plot represent standard deviations of replicates.

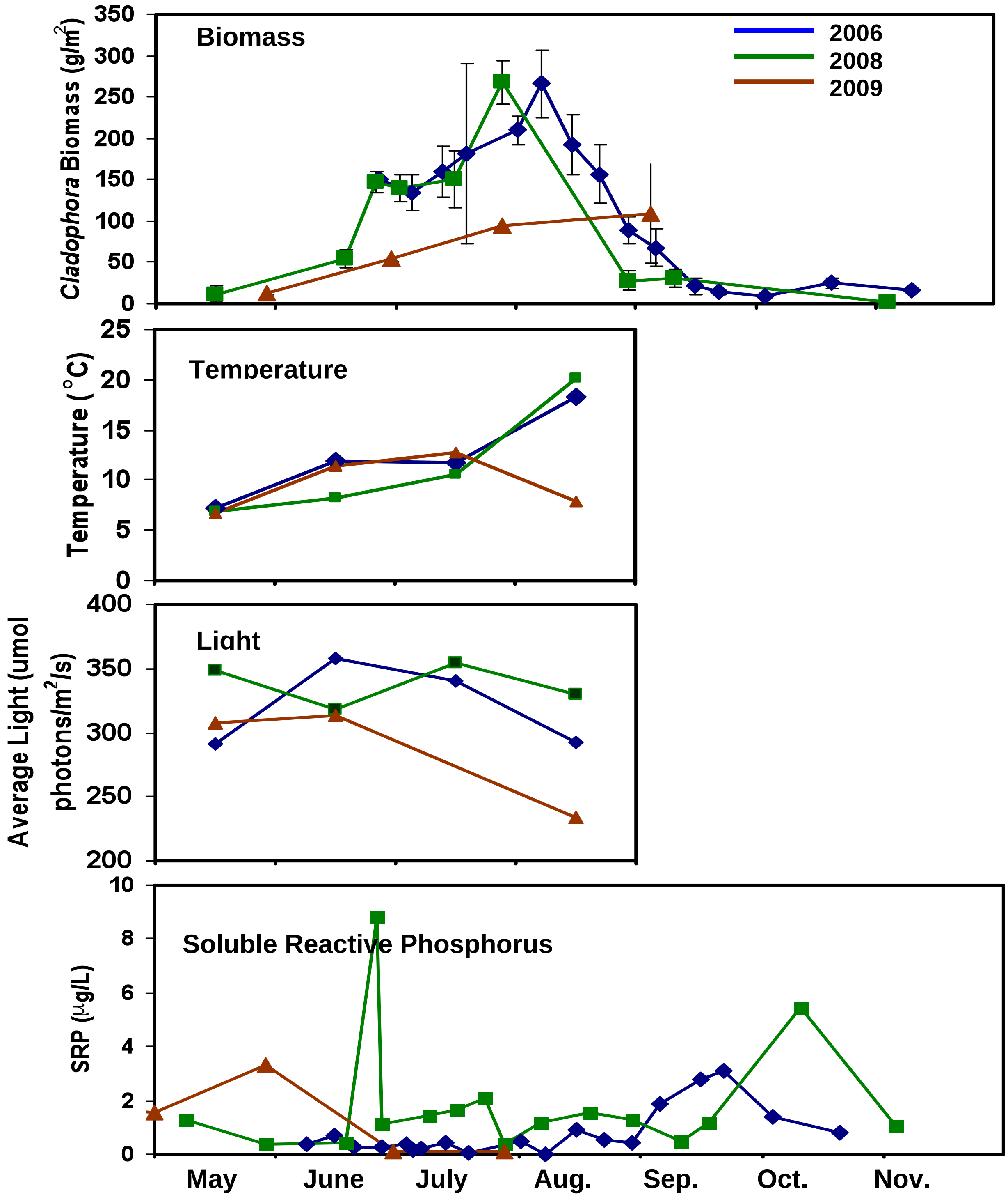
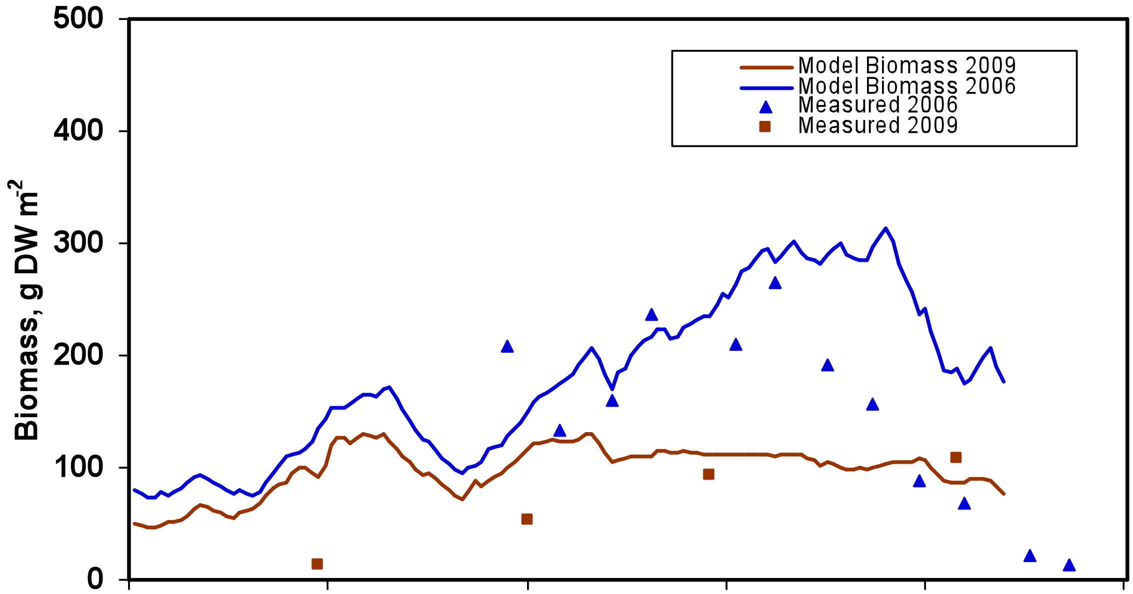


Figure 21: Model simulations of *Cladophora* biomass at 9 m depth in 2006 and 2009. The lower biomass in 2009 is due to relatively low light availability and low dissolved phosphorus concentrations during June and July.



3.5 Conclusions and Recommendations

Cladophora management can be considered at three levels: 1) Reduction of *Cladophora* growth within the lake; 2) Prevention of *Cladophora* accumulation on the beach; 3) Removal of *Cladophora* after it has accumulated on the beach.

a. **Level 1: Reduction of *Cladophora* growth within the lake**. Both in-lake observations and the *Cladophora* model indicate that the primary factors controlling *Cladophora* growth in the lake are light (as determined by water clarity) and dissolved phosphorus concentration. Light is not a variable that can be managed. Phosphorus can be managed by controlling phosphorus inputs to the lake via tributaries. However, in the immediate Atwater Beach region there are no major tributaries entering the lake. Nearshore dissolved phosphorus concentrations in this region are primarily a function of loading from large tributaries, including the Milwaukee River, and phosphorus recycling by quagga mussels (which consume plankton and other particulate material that contains phosphorus, and then excrete the phosphorus in dissolved form). Therefore the ability of the Village of Shorewood to reduce *Cladophora* growth in the lake is very limited. This does not mean that a phosphorus reduction program is not worth pursuing. The large scale phosphorus reductions necessary to reduce *Cladophora* growth in Lake Michigan require that communities around the lake consider ways in which phosphorus loads can be reduced, and there is a need for the development of programs in smaller communities that can be used as models for other parts of the watershed. Specific actions that can be pursued include:
    1. Using low-phosphorus dishwashing detergents. (In October 2009, the Wisconsin State Legislature passed a bill to limit the phosphorus content of dishwashing detergents. The bill is expected to take effect in 2010).

2. Applying lawn fertilizers conservatively, and using low-phosphorus fertilizers (most soils in southeastern Wisconsin have phosphorus concentrations greater than those required for a healthy grass turf). The State of Wisconsin has put in place a bill banning the use of phosphorus-containing fertilizers on lawns, which is to take effect in 2010.
3. Reducing runoff from construction sites (following guidelines defined by the Wisconsin Pollution Discharge Elimination System (WPDES) Permit Program).

b. **Level 2: Prevention of *Cladophora* Accumulation on the Beach.** Algal accumulation on the beach is determined by: 1) the amount of algae that is detached (sloughing) from the lake bottom; 2) the transport of algae within the lake; 3) nearshore hydrodynamics which determine whether the sloughed algae get stranded on the beach. Nearshore hydrodynamics are influenced by shoreline structure. In the case of Atwater Beach, a challenge is to select a structure that inhibits algal stranding while still allowing for sand retention. An alternative strategy for preventing algal stranding is to create a "porous dike" – a rock wall that separates the lake proper from the beach. This approach has been adopted by WE Energies to prevent fouling of cooling water intakes at the Port Washington power plant. While this approach may limit algal accumulation on the beach, it has disadvantages, including clogging by debris, provision of a growth substrate for quagga mussels, and retention of bacteria and other contaminants within the enclosed area when water exchange between this area and the open lake is slow.

c. **Level 3: Removal of Stranded *Cladophora*.** For most areas of the Great Lakes where beach fouling by *Cladophora* is a problem, this is the solution that has been adopted. This approach is also applied to marine shorelines where algal stranding is a problem. Options for algae removal range from manual removal to fully mechanized removal. For small beaches, manual removal or removal with light beach grooming equipment, such as that provided by BeachTech®, is feasible. For example, the city of Hamilton, Ontario (Canada) uses manual raking to groom its beaches on Lake Ontario, while the city of Racine, WI, uses larger mechanized groomers. Options for disposal of collected algae include: 1) Disposal in a land fill; 2) Composting; 3) Biodigestion. Option 3 is not economically viable at this time, as transportation distance to a bio-digester will be greater than to a land fill or compost facility. Few attempts have been made to use *Cladophora* as compost. However, preliminary research at the University of Wisconsin-Oshkosh indicates that a mixture of 75% *Cladophora* and 25% wood chips results in compost with a high available nitrogen content.

In view of the above options, **the recommended course of action with regard to algae accumulation at Atwater Beach is to monitor *Cladophora* accumulation on the beach for one year after any change in groin design, to confirm the efficacy of a reconfigured groin in minimizing beach stranding of the algae.** The recommended monitoring method is to collect frequent images of the beach (ideal frequency is daily, using a digital camera mounted at a fixed location above the beach), along with notes to accompany each image regarding smell, presence of algae in water, etc. If possible, imagery should also be collected before any groin reconfiguration, to provide baseline data with which to compare data collected after groin reconfiguration. During any monitoring period, measurement of algal biomass on the lake bottom should also be made, to determine whether the observations made in the monitoring period apply to a “typical” year. Following the monitoring period, if it is determined that algae accumulation is still a problem, beach grooming with a light- to medium-duty beach groomer is recommended, with disposal in a land fill or a composting facility.

4. Assessment of groins

4.1 Introduction

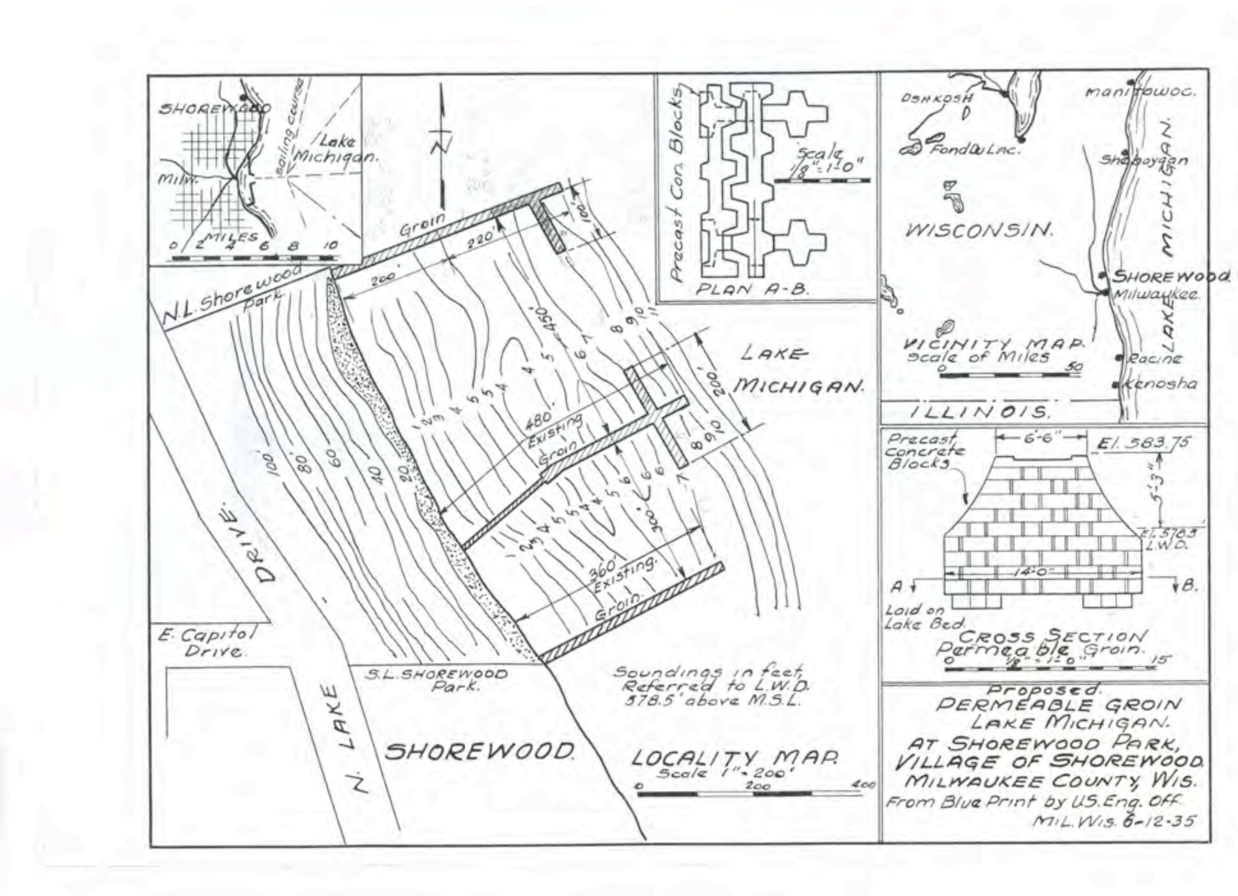
According to the Sponsored Service Agreement (SSA), the Ecological Study and Management Plan for Atwater Park Beach "will include recommendations that address the impacts of the piers on Cladophora formation, water clarity and quality, beach formation/retention, and recreational impact for swimmers, scuba divers and boaters. The impact of the removal and modification of the piers shall also be included."

The main concerns expressed by the Village of Shorewood during meetings before and after the signing of the SSA were the following:

- Reduction in the frequency of beach closures
- Improvement of beach water quality
- Reduction in the occurrence of Cladophora at the beach
- Access to the groins by beach users

The tasks completed in the assessment of groins consisted of the collection and processing of existing information, the collection and processing of new information, the overall analysis of information, and the formulation of recommendations.

Figure 22: Groin drawing, dated 1935, showing plan view, cross section and structure type.



4.2 Collection and processing of existing information

The existing information that was collected and processed included maps and drawings, aerial and bird's eye photographs, information on lake levels, currents and waves, and information on coastal structures at neighboring beaches.

4.2.1 Maps and drawings

The groin maps, dated 1935, that show plan view, cross section, and type of structure were digitized, geo-referenced by the UWM American Geographical Society Library (AGSL), and superimposed on the aerial photographs described below.

4.2.2 Aerial photographs

Aerial photographs taken in 1937, 1956, 1963, 1985, 1995, 2000, 2005 and 2008 were obtained from the UWM AGSL. AGSL superimposed the aerial photographs on the digitized and geo-referenced map of the groins to assess the evolution of the beach and the groins since their construction. The composite map/ aerial photographs are shown in **Figures 23-30**.

Figure 23: 2008 aerial photograph with groin map superimposed. Mean annual lake level: 577.59 ft.

Figure 24: 2005 aerial photograph with groin map superimposed. Mean annual lake level: 577.74 ft.

Figure 25: 2000 aerial photograph with groin map superimposed. Mean annual lake level: 577.36 ft.

Figure 26: 1995 aerial photograph with groin map superimposed. Mean annual lake level: 579.20 ft.

Figure 27: 1985 aerial photograph with groin map superimposed. Mean annual lake level: 580.79 ft.

Figure 28: 1963 aerial photograph with groin map superimposed. Mean annual lake level: 577.33 ft.

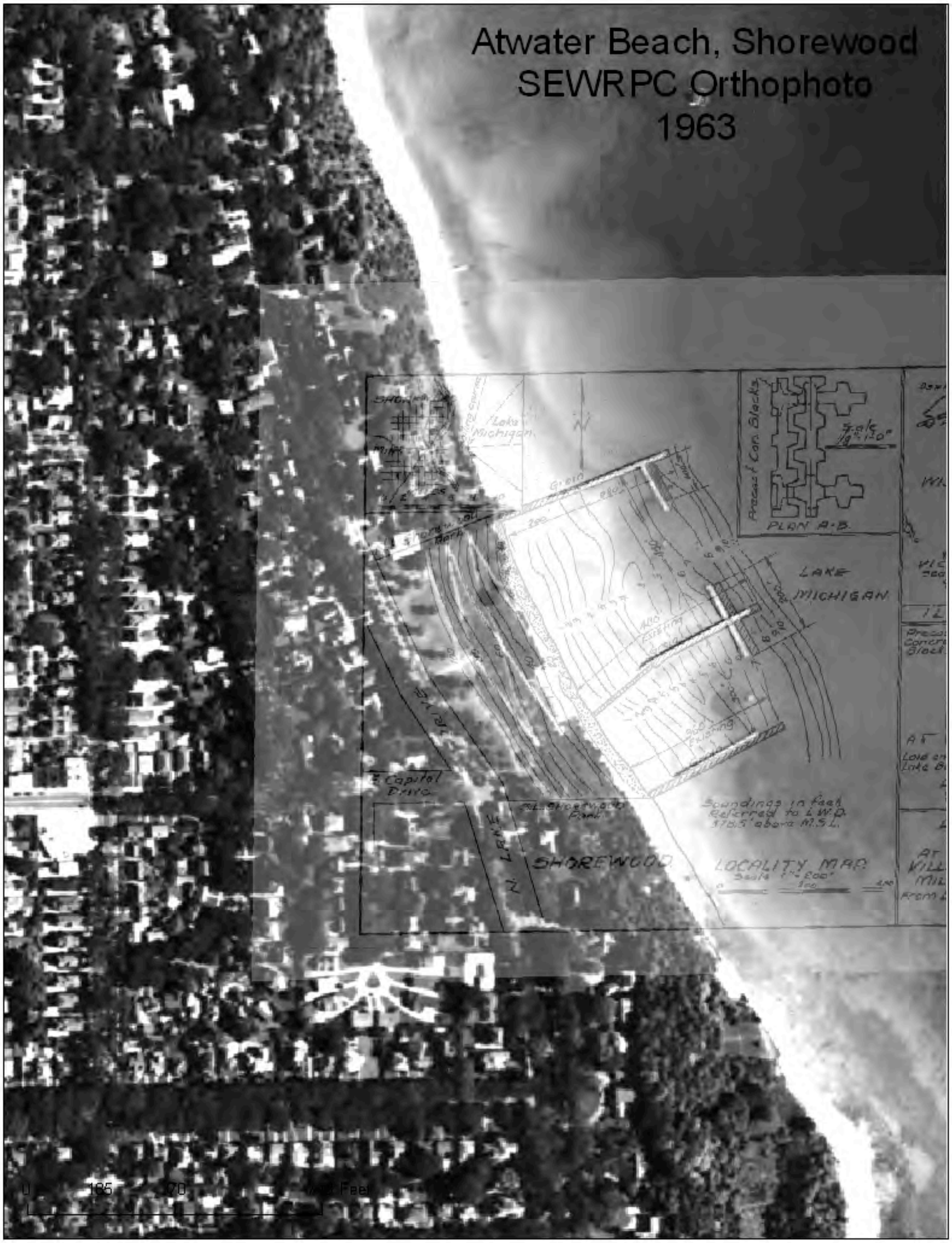
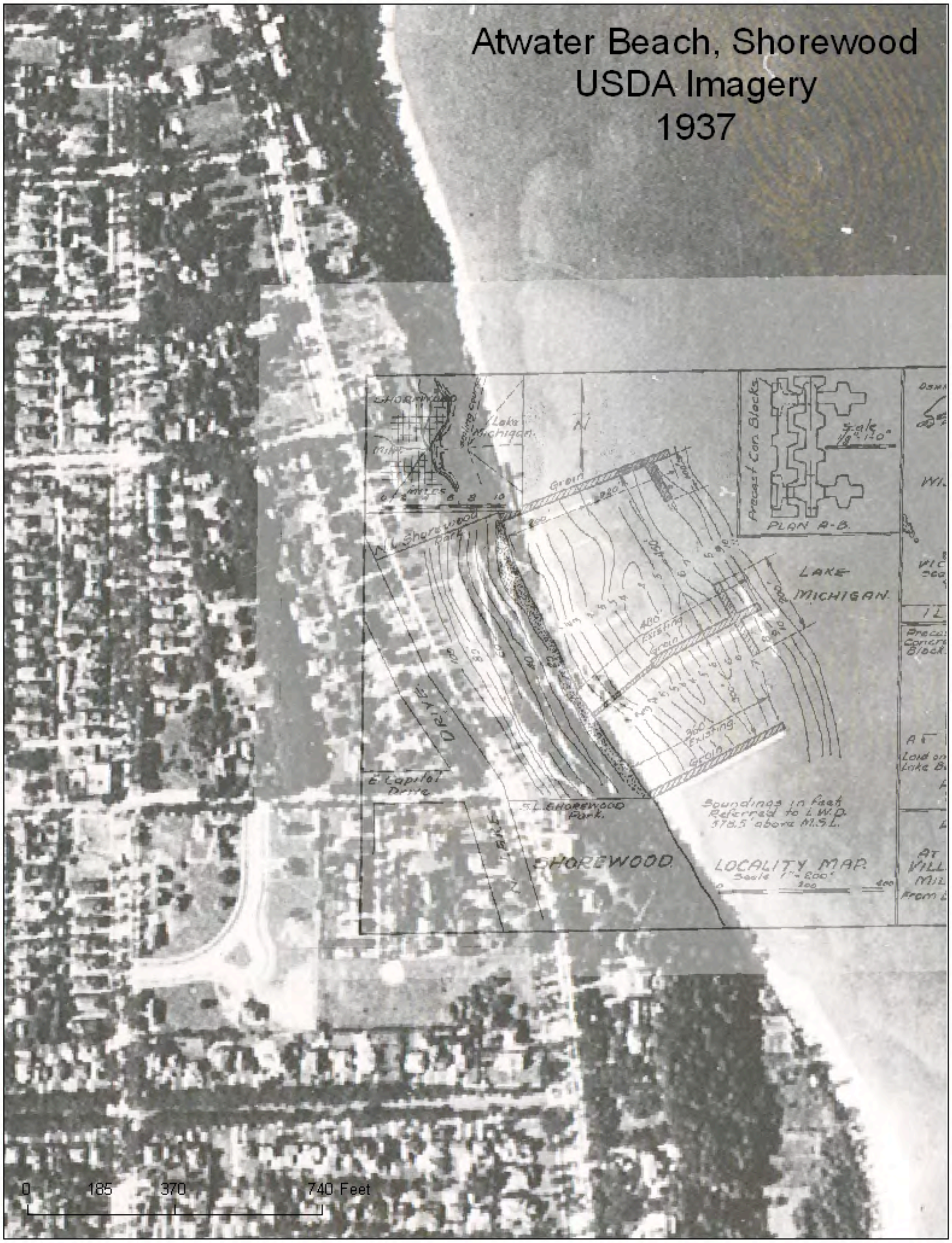


Figure 29: 1956 aerial photograph with groin map superimposed. Mean annual lake level: 579.00 ft.

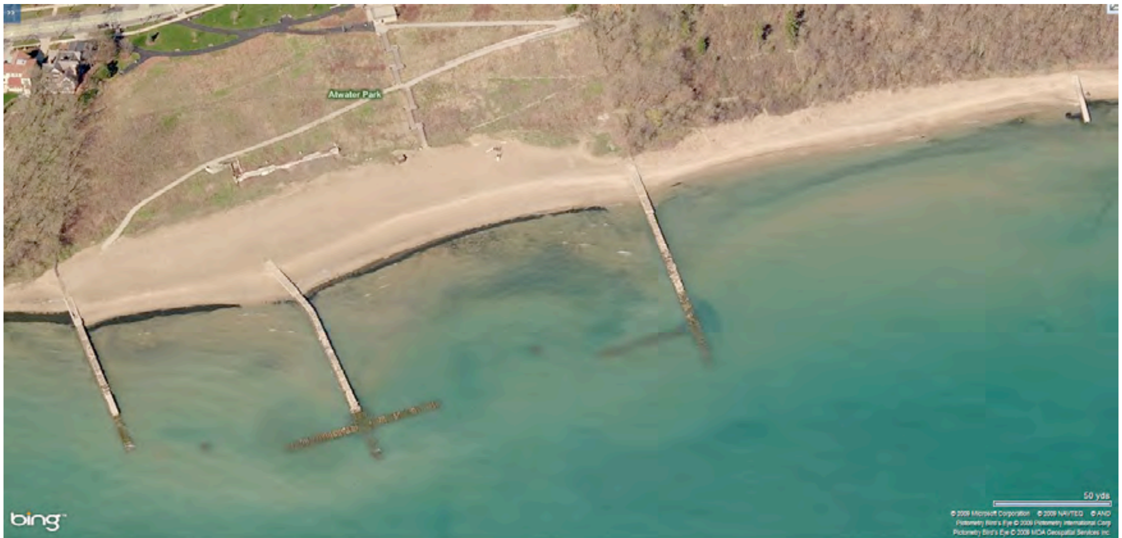
Figure 30: 1937 aerial photograph with groin map superimposed. Mean annual lake level: 577.27 ft.

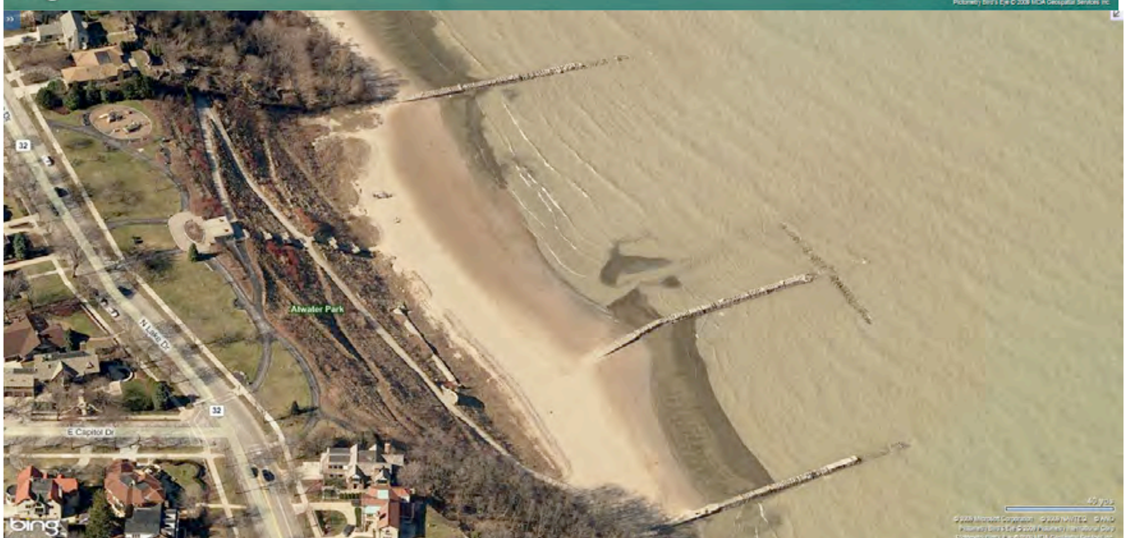


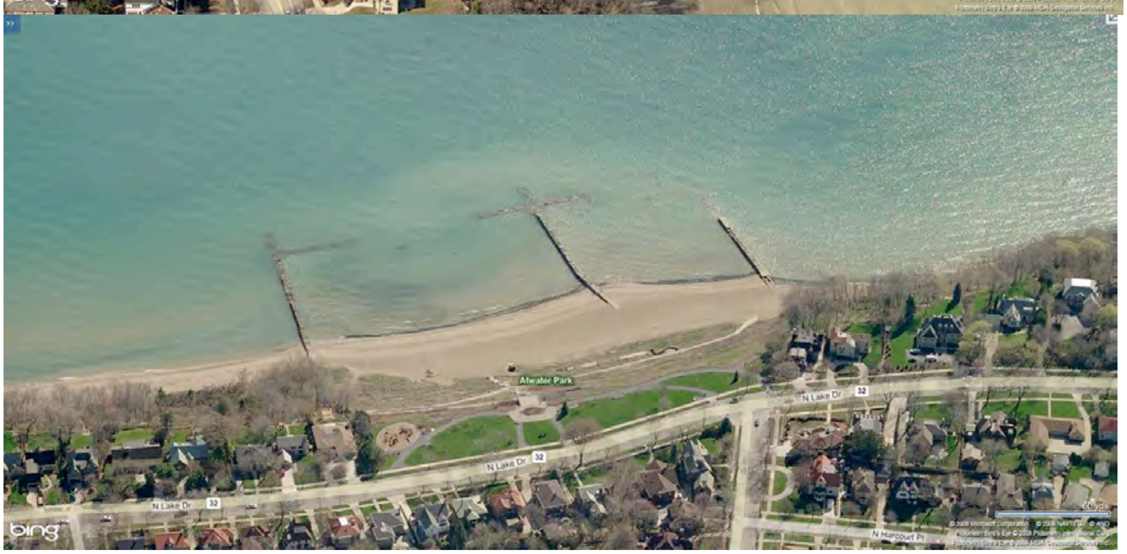
4.2.3 Bird’s eye images of Atwater Beach

The Bing images shown in **Figure 31** (http://www.bing.com/maps/) are birds’ eye views of Atwater Beach. The images show Atwater Beach in plan view, from the north, east, south and west, respectively.

Figure 31: Bird's eye images of Atwater Beach (2009)


Atwater Park
bing
50 yds

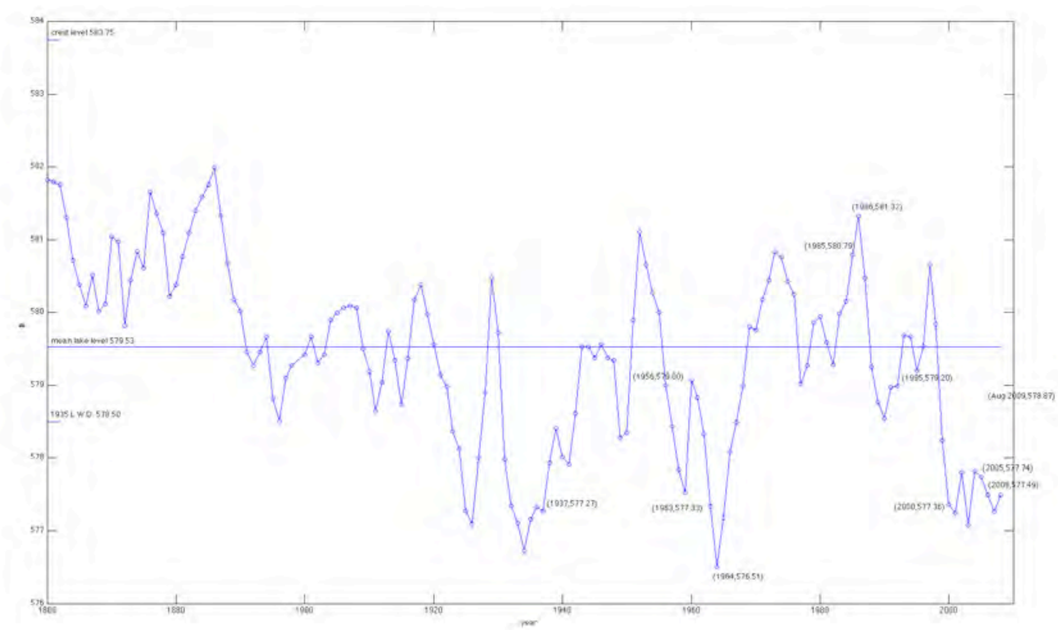

Atwater Park
N Lake Dr
E Capitol Dr
32
bing


Atwater Park
N Lake Dr
N Harcourt Pl
32
bing

4.2.4 Lake levels

Information on Lake Michigan levels was obtained from the National Oceanic and Atmospheric Administration (NOAA) website: ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-083/UpdatedFiles/. A plot that summarizes our analysis is shown in **Figure 32**.

Figure 32. Lake Michigan levels since 1860



Between 1860 and 2008 the mean annual lake level was 579.53 ft, the maximum annual lake level was 581.99 ft (year 1886), the minimum annual lake level was 576.51 ft (year 1964), and the range was 5.48 ft. The lake levels for the years when aerial photographs were taken are given in the **Table 9**.

Table 9: Lake Michigan level for years with existing aerial photograph

Year	Mean annual lake level (ft)
1937	577.27
1956	579.00
1963	577.33
1964	576.51
1985	580.79
1986	581.32
1995	579.20
2000	577.36
2005	577.74
2008	577.49
(August) 2009	578.87

4.2.5 Waves

The source of existing information on waves are the Wave Information Studies (WIS) completed by the US Army Corps of Engineers Coastal & Hydraulics Laboratory, which produced wave climate information generated by numerical simulation of past wind and wave conditions, a process called hindcasting. The available data consists of multi-year time series of the bulk wave parameters of significant wave height, period, direction, and wind speed and direction. Lake Michigan WIS Stations located near Atwater Beach are shown in **Figure 33** and the table below.

Figure 33: USACE WIS wave hindcast sites located near Atwater Beach

STATION	LATITUDE	LONGITUDE	DEPTH (m)	AVAILABILITY
M0008	42.83	87.70	18.	1/56 - 12/87
M0009	42.98	87.70	46.	1/56 - 12/87
M0010	43.12	87.68	82.	1/56 - 12/87

A statistical analysis of the data set is shown graphically in Appendix B through boxplots of significant wave height, period, direction, wind speed and direction, for each month of the year over the period of availability referenced in the table above. Each boxplot shows the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation (sample maximum).The WIS gives the wave periods as integer numbers in seconds (**Figure 35**). The convention used for the wind and wave direction (**Figures 33 and 36**) is 0° = N, 90° = E, 180° = S, and 270° = W.

4.2.6 Information on coastal structures at neighboring beaches

The Bing images shown in Figure 34 (http://www.bing.com/maps/) are birds' eye views of Klode Beach in Whitefish Bay, and of Bradford Beach and McKinley Beach in Milwaukee. These coastal structures are discussed, along with Atwater Beach structures, in Section 4.3.

Figure 34: Bird's eye images of Klode Beach, Bradford Beach and McKinley Beach, respectively.

4.3 Collection and processing of new information

The collection and processing of new information included numerous visits to the sites, taking photographs, information on currents and waves, information on size distribution of beach sand, and water quality sampling as described above.

4.3.1 Photographs taken at Atwater Beach

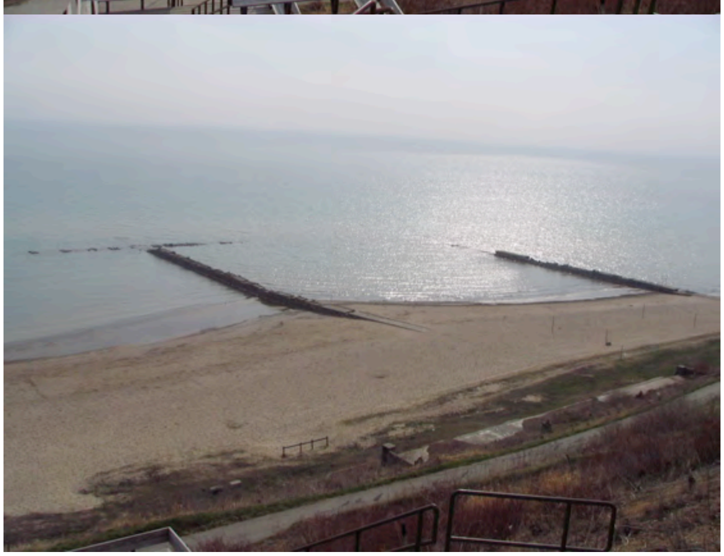
The first four photographs in **Figure 35** show the beach and groins as seen from the top of the bluff, starting with the north groin and moving to the south. The last three photographs in Figure 35 show the north cell, the south cell, and the damaged central groin.

Figure 35: Photographs taken at Atwater Beach

North groin as seen from the top of the bluff.

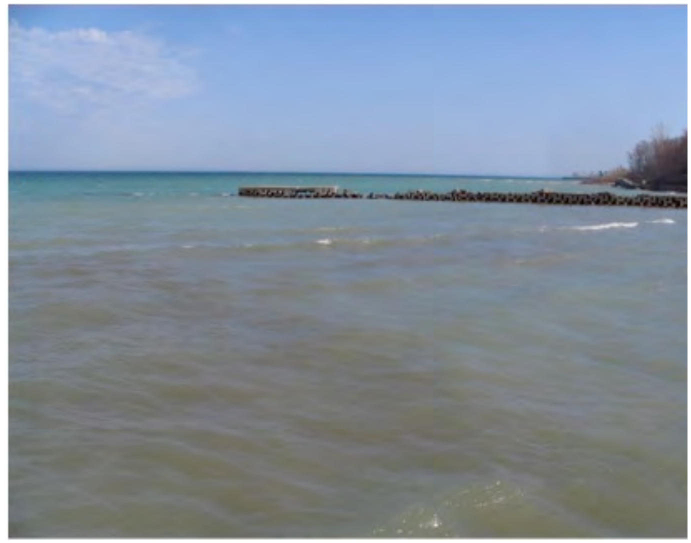
North cell as seen from the top of the bluff.

Central groin as seen from the top of the bluff.



South cell as seen from the top of the bluff.

North cell as seen from the central groin.



South cell as seen from the central groin.

Central groin.

4.3.2 Currents and waves

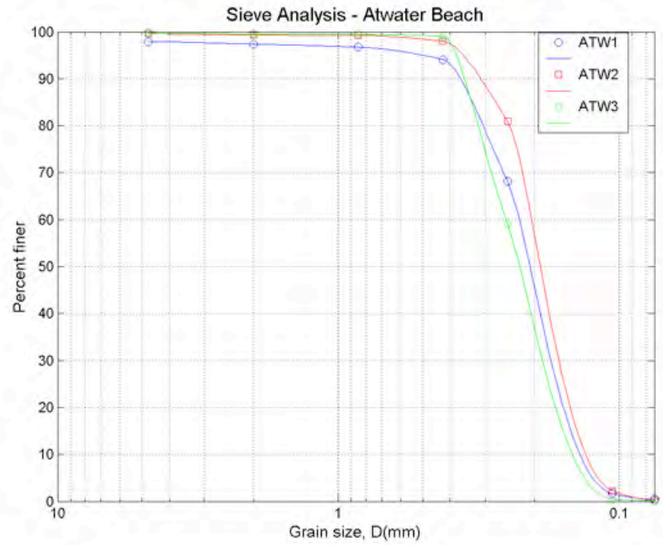
Currents and wave measurements were taken at the following depths: 10 m (33 ft), 6 m (20 ft) and 1.5 m (5 ft), at the sites shown in **Figure 36**. The results of current and wave measurements made during the present study are shown in Appendix C.

Figure 36: Location of wave measurements

4.3.3 Size distribution of beach sands

Figure 37 shows the location of sand sampling and the corresponding size distributions. Two samples were taken at the north cell and one sample in the south cell. All samples showed a median diameter D_{50} of approximately 0.2 mm.

Figure 37: Locations of beach sampling and size distributions



4.3.4 Aerial photographs of Cladophora distribution (Drs. Janssen and Bootsma, WCMP funding)

Drs. John Janssen and Harvey Bootsma collected the aerial photographs shown in **Figures 38-40** in a previous project supported by Wisconsin Coastal Management Program.
Figure 38 shows Klode Beach in Whitefish Bay, **Figure 39** shows Atwater Beach in Shorewood, and **Figure 40** shows Bradford Beach and McKinley Beach in Milwaukee. The photos do a good job of showing where Cladophora is (the dark areas). Drs. Janssen and Bootsma estimate that the photos allow us to see the bottom to a depth of around 20 to 25 feet. Beyond that, it is not possible to distinguish dark bottom from deep water. But at shallower depths, one can see the differences in bottom types. So the images can be used to reveal spatial differences in Cladophora distribution.

Figure 38: ***Cladophora*** **distribution offshore from Klode Beach, Whitefish Bay**

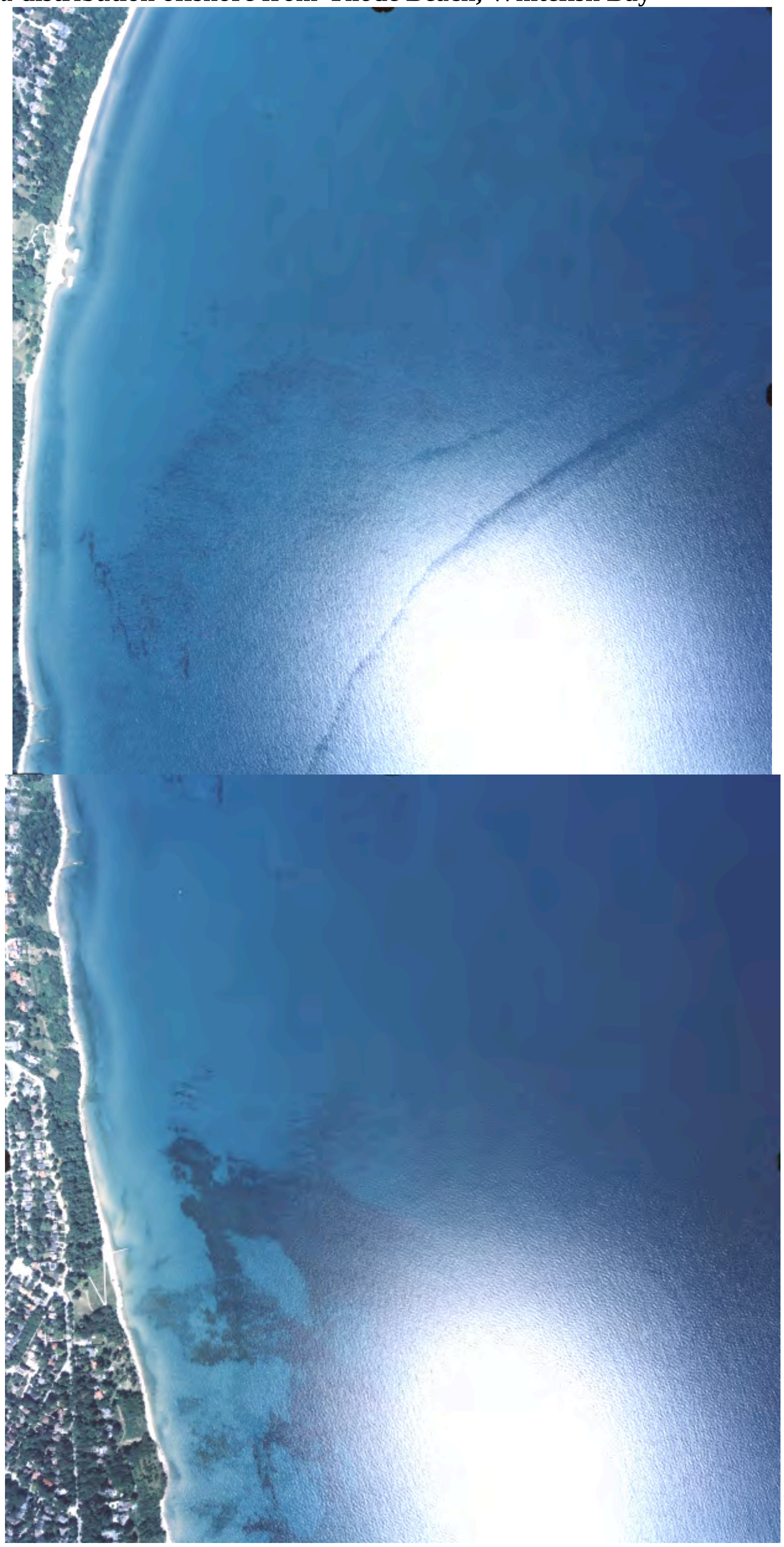
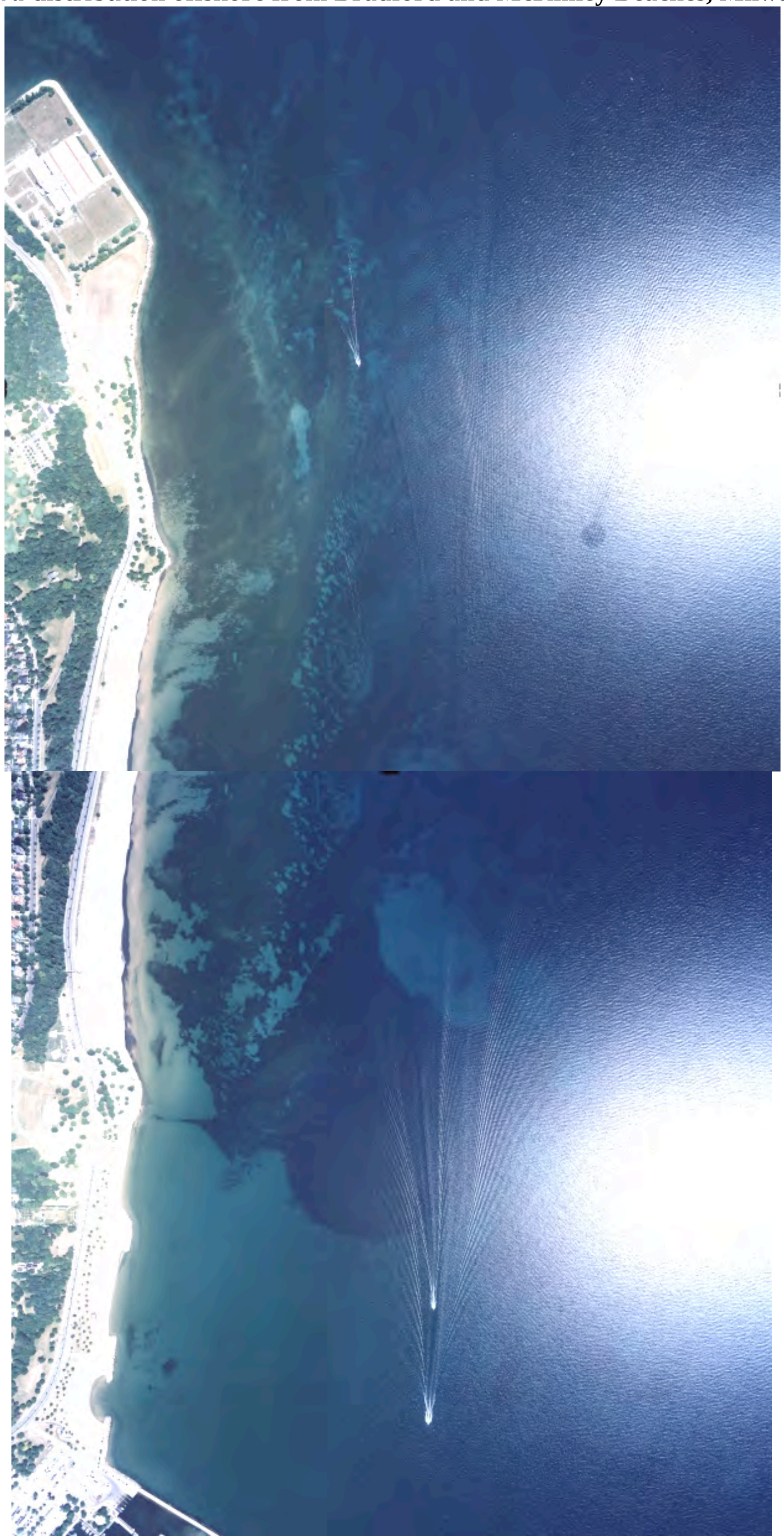


Figure 39: ***Cladophora*** **distribution offshore from Atwater Beach, Shorewood**

Figure 40: *Cladophora* distribution offshore from Bradford and McKinley Beaches, Milwaukee

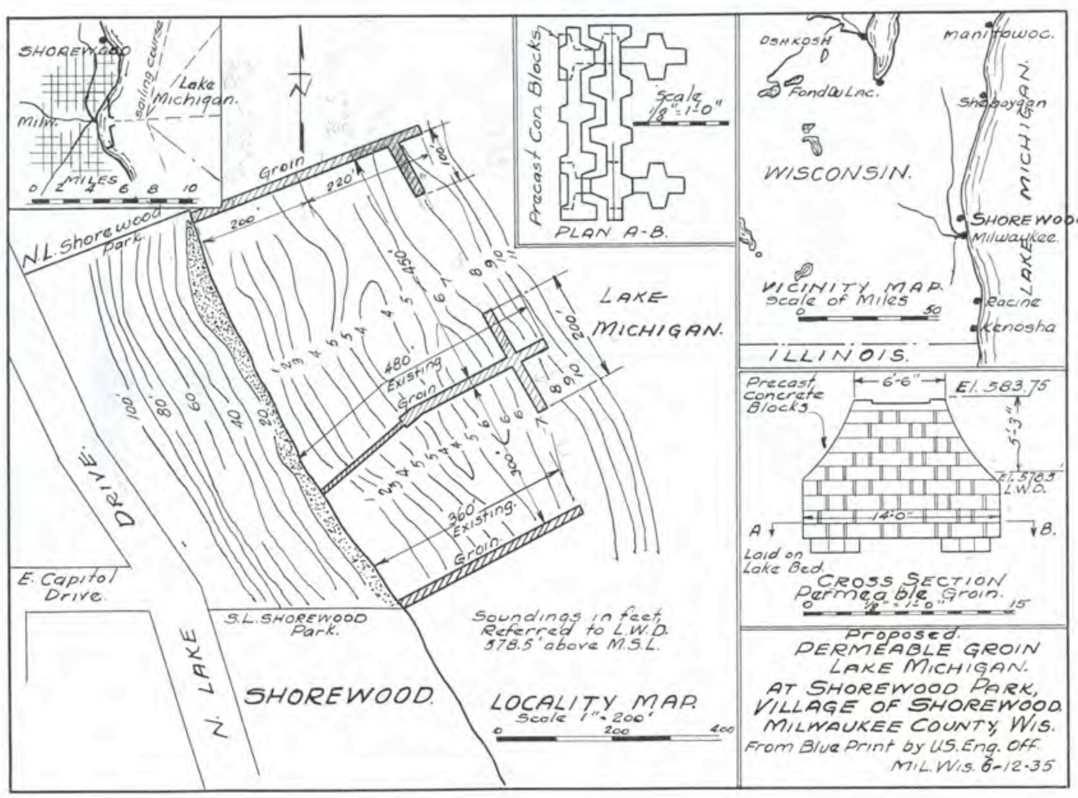


4.4 Analysis

4.4.1 Existing groins

The Atwater Beach coastal structures consist on three permeable concrete-block groins that form two cells (**Figure 41**). The north and central groins have a T-head parallel to the shore. The south groin has a trunk shorter than the north and central groins and no T-head. The 1935 drawings show a single crest elevation of 583.75 ft, but the crest elevation of the T-heads is lower than that of the groin trunks, at least at the present time.

Figure 41: Groin drawing, dated 1935, showing plan view, cross section and structure type.



The north cell gap is approximately 240 feet long and parallel to the shore, i.e., oriented approximately 20° counterclockwise from the north. The south cell gap is oriented in the NS direction and is approximately 180 ft long in the direction parallel to the shore.
The difference in elevation between the crest elevation given in the drawings (583.75 ft) and the mean lake level (579.53 ft) is only 4.22 ft. If one considers the lake level in 1986 (581.32 ft), then that difference in elevation is only 2.43 ft.
All aerial photographs shown in **Figures 22-29**, except the 1985 photograph, were taken with lake levels below the mean level. The 1985 photograph shows the smallest beach width (some 100 ft)

and the 1963 and 2000 photographs show the largest beach width (some 160 ft). In other words, the variation in beach width was some 20 times larger than the variation in lake level. The lake level was also low in 1937, but that photograph shows the beach still in formation.
The beach formation limit is dependant to a large extent on lake level and the characteristics of the groins. Groins that effectively block long shore currents will hold more sand. The groins at this beach are permeable and their low top elevations allow some long shore currents to pass over and through the structures. Therefore, the beach formation relative to the long lengths of these structures is not as aggressive as other beach cells in the region. During periods of low water, wave energy within the beach cells is reduced as large waves break farther offshore due to the relatively shallow near shore conditions. The sand formation migrates lakeward and is generally in proportion to the natural sand profile slope that can form under water. The slope is affected by the grain size of the sand. At this site, the slope is in the range of 15 to 25 feet for every one foot of water level rise or fall; therefore, a one foot drop in water level can cause approximately a 20 foot reduction in beach width.

4.4.2 Effects of lake levels, shoreline changes, currents and waves

The design of groin in the final design phase will require the following dataset: water level, waves, longshore sand transport, offshore bathymetry, shoreline changes, sediment budget, and geotechnical data for analysis of pier foundations (Ram et al., 2003). For the structural design, it will be necessary to have the characteristic wave height associated with a given frequency of occurrence. For the pier functional design, the time series of wave height, period, and direction are necessary to estimate the amount of alongshore sediment transport. The present study provides information on water level, waves, and shoreline changes.

Consider the wave height hindcast at the WIS stations shown in Appendix B, at depths between 18 and 82 m (between 59 and 269 ft). The wind speeds are higher in winter than in the summer, and the wind direction is mostly from the W-SW in winter and from the S-SE in summer. The model-predicted wave direction is mostly from the SW in winter and from the S in the summer. The significant wave height is larger in winter than in the summer. The winter median and upper quartile are approximately 0.8 m (2.6 ft) and 1.2 m (3.9 ft), respectively, and values up to 6 m (20 ft) were predicted for the winter months. The summer median and upper quartile are approximately 0.5 m (1.6 ft) and 0.75 m (2.5 ft), respectively.
Consider now the wave measurements taken during this project, shown in Appendix C. At a depth of 33 ft (10 m) the median and upper quartile are approximately 0.5 m (1.6 ft) and 0.8 m (2.6 ft), respectively, and waves up to 2 m (6.6 ft) were measured almost every month between October 2008 and April 2009. At a depth of 20 ft (6 m) waves up to 0.5 m (1.6 ft) were measured during a three-week period in July 2009. At a depth of 5 ft (1.5 m) waves up to 0.4 m (1.4 ft) were measured during a week in June 2009 and two weeks in August 2009. During those weeks waves were approaching predominantly from the NE.
The difference in elevation between the crest level of the groins and lake level is 4.22 ft for the mean lake level. The T-head groins and much of the trunks of these structures are regularly overtopped. Wave statistics for this region indicate that waves exceeding 6 to 8 feet in height occur frequently at this site. Therefore, the groin structures are regularly overtopped by wave action. This explains the mild beach cell formation between these groins. The long length of the groins would produce a much wider beach if not for the low elevation of the crest. While the low crest elevations could explain to a certain extent some of the damage to the groin structures over

the years, this configuration also reduces stress on the groins by allowing some of the wave energy to pass over the structure. In any event, these structures have been in place for many years and while they have taken on a lot of damage and in places have essentially failed, they continue to function essentially as they have since the time of their original construction.

Consider now the geometry of the groins and its implications on flow within the cells. The Atwater Beach Bing images included above show that the north cell has a more symmetric pattern of wave refraction, better circulation, and smaller abundance of algae near the shoreline than the south cell for waves approaching from the northeast. The smaller distance between the groins in the south beach cell as well as the wave "shadow" effect caused by the T groin reduces wave energy in that cell. The rectangular shape of the beach cell structures helps to set up flow current separations that can cause strong eddy currents out at the ends of the structures. The currents near the shoreline are subdued and stagnant zones can form. Thus, floating algae tends to congregate along the beach. The accumulation of algae varies in each cell depending on the direction of wave approach. When waves approach from the northeast, onshore wave attack in the north cell causes more aggressive flow circulation than in the south cell that is partially sheltered from these waves. The opposite is true for waves approaching from the southeast. However, the more narrow distance between the groins in the south cell results in less wave energy at the shoreline and reduced currents.

4.4.3 Comparison with coastal structures at neighboring beaches

The coastal structures at Klode Beach, shown in **Figure 34**, consist in three T-head groins and two cells. The distance between the north and south groins is approximately 400 ft, i.e. about one half the corresponding distance in Atwater Beach. The short groin trunks are made up of steel and the T-heads are rock structures. These structures are also constructed well above the Stillwater level of the lake thereby causing a pronounced reduction in longshore littoral drift potential. Finally, the offshore stone structures are located closer to shore in water that is shallower than that which exists at Atwater Beach. This helps in the formation of sand within the beach cell. The aerial photographs show a smooth pattern of wave refraction; the shoreline has a log-spiral geometry, and the beach seems to suffer less abundance of algae than Atwater Beach. The scalloped beach formation pattern encourages participation of the entire beach cell area in the onshore-offshore flow pattern. This pattern reduces areas of flow stagnation where algae can accumulate.

The coastal structure at McKinley Beach, shown in **Figure 34**, consists of two T-head groins and one cell. The total beach length is about 600 ft and aerial photographs show a smooth pattern of wave refraction; the shoreline has a log-spiral geometry, and the beach seems to suffer less abundance of algae than Atwater Beach. This beach is similar to Klode Beach in that the breakwater and groin structures are located in water that is shallower than that at Atwater Beach, and the gap widths between the breakwater structures are much smaller. This configuration is much more efficient in terms of beach formation and also reduces the amount of stagnant flow zones.

Bradford Beach, shown in **Figure 34**, is approximately 2,000 ft long, lacks any coastal structures, and was built between two stable points at its north and south ends. The record of algal abundance at Bradford Beach is a mixed one. Water currents along this stretch of beach include both long shore and offshore components, which differentiates this site from the other beaches discussed above.

In addition to the details of coastal structures, the presence of algae depends on other important factors, such as the substrate and regional availability of nutrients. The three sets of figures that show the distribution of Cladophora to a depth of approximately 20 m offshore from Klode Beach, Atwater Beach, and both Bradford and McKinley Beaches suggest that changes in groin geometry do not guarantee an automatic reduction in the presence of algae.

4.5 Findings and recommendations

Following is a summary of observations and analysis for the existing lake front structures at Atwater Beach:

- Significant damage observed in the T-heads and trunks of the groins is likely due to the advanced age of the structures as well as a design that is not ideally suited for the wave climate.
- The crest elevation of the T-heads is low relative to the water level. While this can reduce stress on the structure as some of the wave energy passes over the structure, erosion on the back side can cause shifting and settling of the structure that can also affect durability.
- The structures are also constructed in an inefficient configuration in terms of beach sand formation potential, and water current stagnation potential.
- The long groin structures place the "T-head portions of the structure in deep water with lake bed bottom elevations of 568.5 to 569.5 ft International Great Lakes Datum, 1985 (IGLD 1985). The crest elevations of the structure ends and the profile of the groins are regularly overtopped by wave action, and the structures are pervious. As a result, the longshore currents are not completely deflected from the beach and sand deposition potential is reduced accordingly. The long widths between the lake side ends of the groin and breakwater structures allow significant amounts of wave energy to enter the beach cells. This configuration reduces beach formation potential.
- The rectangular shape of the groins and beach cells encourages longshore flow and current separations that form strong eddy currents for waves approaching from the north and south. This configuration can create zones of significant stagnation along the shoreline and especially in the shore side corners of the beach areas.

The flow patterns observed in aerial photographs and in the field suggest that the straight-line alignment of groin trunks and T-heads do not induce adequate wave refraction and flow circulation inside the cells, possibly contributing to poor water quality and abundance of algae at the shore. These structures would need to be significantly redesigned to induce improvements in water circulation and beach formation that could improve algae conditions. While it would not be possible to completely eliminate the algae deposits along the beach by simply reconstructing the offshore beach cell structures, it would be possible to significantly improve this condition.

Three alternatives are recommended to address the impacts of the piers on Cladophora formation, water clarity and quality, beach formation/retention, and recreational impact for swimmers, scuba divers and boaters. The three alternatives, in order of decreasing preference, are:

- Alternative 1) Re-design groins with a shorter, curvilinear planform to improve circulation within its cells. This option would include the abandonment of the existing groin and T-head structures. The structures would not necessarily need to be completely eliminated. It might make sense that the structures should be dismantled down to the normal water elevation with the materials beneficially reused as core material in the new groins. New stone groins would be constructed and would terminate in shallower water – perhaps 75 percent of the distance to the existing T-head groin locations. Water bottom elevations are more in the range of 571.5 to 572.5 ft IGLD 1985 at the new lake side end locations. The new stone groin structures would be constructed approximately 8 ft above low water datum and would be much more efficient at forming a scallop shaped beach. The groins would be curvilinear in shape to encourage bypassing of longshore currents around the beach cell. It is possible that the central groin would be replaced with a short shore parallel segmented stone breakwater without connection to shore. The beach sand would form a wider beach immediately behind this breakwater; however, the sand would not necessarily be designed to form all the way out to the stone structure. The shape of the groins would also reduce the dynamics of the flow separation as these currents pass by the groin ends. This in turn should reduce the entrainment of algae in the beach cell. The waters edge of the modified beach would be curvilinear in form and would reduce stagnant corners. This will reduce the algae deposition and accumulation though not completely eliminates these deposits. A ballpark opinion of probable construction cost would likely be in the range of $1,500,000 to $2,000,000 or more depending on the scope of this option.

- Alternative 2) Maintain the current plan view configuration of the groins, increasing the crest elevation approximately 8 ft above the mean lake level, and implement a plan for systematic cleaning of Cladophora from beaches – this option would involve a reconstruction of the existing groin structures in the current location. This approach would repair the deteriorated conditions, reduce the pervious nature of the groins and reduce wave overtopping essentially cutting off the direct access of longshore littoral currents to the beach. The onshore offshore flows would remain essentially unchanged; however, the beach formation would likely increase due to the reduction in longshore currents. Beach formation north of the groins would also increase. This option would require the pre-nourishment of the beach zone with sand to compensate for the removal of sediment from the near shore environment in the expanded beach areas. This option would not significantly reduce the algae deposits because the longshore current flow separations at the lake side ends of the groins and T-heads would not be changed. While detailed studies have not been completed, a ballpark opinion of probable construction costs would likely be in the range of $500,000 to $3,000,000 or more depending on the scope of this option.
- Alternative 3) Remove groins and carry out beach nourishment as necessary. This option would reduce the size of the beach. The deposition of algae would likely be reduced by this option – but not eliminated. The reduction would be the result of the removal of water current stagnation zones that form between the existing offshore structures. Beach nourishment by itself would not last for significant durations of time between nourishment events. Sand introduced to the water without some type of offshore retention structure would be transported in the long shore currents to up and downdrift areas fairly quickly. We do not expect that this option will be feasible.

The next project stage should include a feasibility study to evaluate the optimal configuration of the selected option. Wave climate and transformation studies would be performed to help in the design development and refinement of likely project costs. Detailed computer modeling of currents and waves in the proposed designs would be recommended to better understand the potential to improve water quality conditions. The modeling work should consider several scenarios that combine lake levels, wave conditions (for example winter and summer conditions), and wind setup with different probabilities of occurrence and evaluate the subsequent implications on flow and circulation.

The chances of public funding for any alternative should improve if the design can demonstrate improvements in the environmental impact. The project should include the development of water quality improvement features as well as habitat creation to improve the potential for grant funding opportunities.

5. Acknowledgements

Several researchers and students contributed to this study. We would like to acknowledge Daniel Talarczyk, Patricia Bower, Colin Peck, Marcia Silva, and Erin Wilcox for contributing to engineering, field and laboratory studies. The foundation for these recommendations and the primary data used in the assessment was funded through several grants including a grant from the University of Wisconsin Sea Grant Institute under a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Federal grant number NA06OAR4170011, Project Number R/UC-2. This work was also supported by a grant from the Wisconsin Coastal Management Program grant number AD06014-007.09 and AD86003-006.08.

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IMPLEMENTATION PLAN FOR ATWATER BEACH ECOLOGICAL STUDY

Water Quality

1. Identify and remediate sources of sewage contamination at Outfall 1. Outfall 1 has intermittent human sewage inputs. Stormwater testing, dye testing, smoke testing, and televising the system has not found an obvious problem. Continued stormwater testing and evaluation at the outfall and upstream of the outfall is recommended. **This is a high priority** due to the potential of human viruses and pathogens present in swimming water. It is strongly recommended that this be completed before the next swimming season or earlier. The cost is dependent on the type of monitoring and the actions needed to remediate the problem such as lining pipes or replacing pipes. A one year investigative study to sample for bacteria and molecular markers of sewage throughout the entire system would be $30,000 to $85,000. Televising the entire system is expected to cost significant staff time. These costs do not account for any repair costs to remediate the problem. Remediation cost could reach greater than $2 million dollars for sewer line lining or repair of sewer lines. This estimate does not consider home laterals.

2. Identify and remediate sources of sewage contamination at Outfall 2. Outfall 2 has persistent human sewage inputs. Storm sewer water testing and smoke testing identified leaking bulkheads that could be contributing to the contamination. The stormwater system was televised by the Village of Shorewood which found a leaking lateral. Additional monitoring of the stormwater system and outfall after remediation of the lateral is recommended. **This is a high priority** due to the potential of human viruses and pathogens present in swimming water. It is strongly recommended that this be completed before the next swimming season or earlier. The cost is dependent on the type of monitoring and the actions needed to remediate the problem such as lining pipes or replacing pipes (see above recommendation for cost estimates).

3. Implement a sewer lateral inspection and lining program. A likely source of sewage to the beach is from home sewer lateral that are leaking or in some cases, collapsed. A village wide inspection program will document the extent of this problem. This problem is not unique to older urban areas, but Shorewood has a direct impact on Lake Michigan since stormwater (containing sewage from leaking laterals) is directly released to these waters. There is also a very high potential to impact the health of the Village residents and visitors since Outfall 1 is located near the beach. There are model programs around the country that structure the costs of repair so that they are on a community wide level rather than solely the burden of the homeowner. This recommendation is a high priority. The estimated cost for an inspection program is $300 per property (Gonwa et al., 2004), lining of a lateral is $500 to $1000, and complete replacement for collapsed laterals can be a high as $7000.

4. Review procedures for posting notifications at the beach and on the Beach Health website and revise as necessary to provide accurate and consistent public notification. Inconsistencies were found between the signs posted on the beach and the beach health website. Consistent postings and updates on the Beach Health website are recommended for standardized and reliable notification to the public. **This is a high priority** that would be no cost. It is recommended that this be completed before the next swimming season or earlier.

Stormwater Management

5. Review Best Management Practices (BMPs) in Atwater Park to reduce chemical and bacterial loading to the beach. Reducing human sewage contamination should be the highest priority but surface runoff can also be a source of chemicals and bacteria. BMPs such as reducing chemical application to park and reducing pet waste come at little or not cost and therefore should be implemented by next swimming season. Planting native vegetation on the bluff to reduce surface runoff should be considered but this is a low priority and should be incorporated into a master plan for bluff restoration. We do not recommend pursuing rain gardens at this time until there is a master plan for bluff restoration.

6. Review BMPs for stormwater management in the stormwater drainage area serviced by outfall 1 and outfall 2 and explore new BMPs for controlling stormwater in this area. The stormwater system that discharges to Outfall 1 and Outfall 2 contains bacteria, sediments, nutrients, metals, herbicides, car exhaust, among other non-point source pollutants. The link between stormwater and beach water quality needs to be included in Village planning and in education activities. The Village should review street sweeping practices and increase frequency if deemed inadequate by Public Works staff. We recommend that the Village utilize the Conservation Committee to explore innovation approaches to reducing these pollutants in stormwater discharge and request that that committee provide suggestions to be considered in long term planning activities. Even with the remediation of sewage sources from the stormwater system, the non-point pollutants (including fecal indicator bacteria) will continue to impact the beach. The conservation committee may also be helpful with conducting pubic education on what residents can do to reduce pollutants in stormwater on their properties. The Village has some BMPs in place, but larger scale efforts to reduce stormwater from entering Lake Michigan needs to be addressed during all Village planning activities (repairing roadways, development decisions). Essentially, the Village should include some evaluation of the stormwater impact, or the opportunity to reduce stormwater volumes in all of their project plans. There should be no cost for investigating new potential BMPS since the Conservation Committee is already in place.

Cladophora Growth

7. Continue beach maintenance. *Cladophora* will continue to grow at Atwater Beach until larger regional management issues are addressed. Reducing the amount of *Cladophora* on the beach through grooming will significantly reduce the problems associated with *Cladophora* such as nuisance smells, murky water and bacteria growth. **This is a high priority** and would be a low cost strategy since the Village of Shorewood already operates a groomer. Costs would include operator time and maintenance. The Village already regularly grooms the beach, and it is recommended that this be continued during the entire beach season. If the damaged groins are replaced the effect on algal accumulation should be monitored. Following the monitoring period, if it is determined that algae accumulation is still a problem, beach grooming with a light- to medium-duty beach groomer is recommended, with disposal in a landfill or a composting facility.

8. Reduce phosphorous concentrations. Analyses show that a 50% reduction in phosphorous may lead to a significant reduction in Cladophora. A reduction in phosphorous needs to be addressed at a larger regional level, but all the nearshore communities should participate in a phosphorous reduction program to take part in mitigating the issue. Outfalls that discharge stormwater directly to Lake Michigan, e.g. Outfall 1 and 2 in the Village of Shorewood) have the potential to add high phosphorous loads to the lake locally. Phosphorous can be reduced by using low-phosphorus dishwashing detergents, applying lawn fertilizers conservatively and using low-phosphorus fertilizers, and reducing runoff from construction sites. This is a medium priority at no cost.

Assessment of groin structures

9. Select the alternative groin design to develop in the final design phase. Residents and stakeholders should be involved in the selection of alternative. **This is a high priority.** This process should be started as soon as possible. Three alternatives are recommended, in order of decreasing preference.

1) Re-design groins with a shorter, curvilinear planform to improve circulation within its cells. New stone groins would be constructed and would terminate in shallower water – perhaps 75 percent of the distance to the existing T-head groin locations, constructed approximately 8 ft above low water datum. The groins would be curvilinear in shape to encourage bypassing of longshore currents around the beach cell and to reduce the entrainment of algae in the beach cell. It is possible that the central groin would be replaced with a short shore parallel segmented stone breakwater without connection to shore. The waters edge of the modified beach would be curvilinear in form, would reduce stagnant corners and algae deposition and accumulation though not completely eliminate these deposits. A ballpark opinion of probable construction cost would likely be in the range of $1,500,000 to $2,000,000 or more depending on the scope of this option.

2) Maintain the current plan view configuration of the groins, increasing the crest elevation approximately 8 ft above the mean lake level, and implement a plan for systematic cleaning of Cladophora from beaches – this option would involve a reconstruction of the existing groin structures in the current location. This approach would repair the deteriorated conditions, reduce the pervious nature of the groins and reduce wave overtopping essentially cutting off the direct access of longshore littoral currents to the beach. This option would require the pre-nourishment of the beach zone with sand to compensate for the removal of sediment from the near shore environment in the expanded beach areas. This option would not significantly reduce the algae deposits. While detailed studies have not been completed, a ballpark opinion of probable construction costs would likely be in the range of $500,000 to $3,000,000 or more depending on the scope of this option.

3) Remove groins and carry out beach nourishment as necessary. This option would reduce the size of the beach. The deposition of algae would likely be reduced by this option – but not eliminated. The reduction would be the result of the removal of water current stagnation zones that form between the existing offshore structures. Beach nourishment by itself would not last for significant durations of time between nourishment events. Sand introduced to the water without some type of offshore retention structure would be transported in the long shore currents to up and downdrift areas fairly quickly. We do not expect that this third option will be feasible.

10. Complete final design of groins. The final design phase should include a study of wave climate and transformation studies to help in the design development and refinement of likely project costs. Detailed computer modeling of currents and waves in the proposed designs are recommended to better understand the potential to improve water quality conditions. The modeling work should consider several scenarios that combine lake levels, wave conditions (for example winter and summer conditions), and wind setup with different probabilities of occurrence and evaluate the subsequent implications on flow and circulation. The chances of public funding for any alternative should improve if the design can demonstrate improvements in the environmental impact. The project should include the development of water quality improvement features as well as habitat creation to improve the potential for grant funding opportunities.

Facilities

11. Provide bathroom facilities with hand washing capacity during beach season. Bacteria are ingested through hand to mouth contact after being in contact with beach water and/or sand. Simple hand washing can greatly reduce the human health risk linked to beach associated illnesses. **This is a high priority.** Existing bathroom facilities are available, and costs would entail maintenance, supplies; lifeguards could carry out supervision of the facility. It is recommended that this be completed before the next swimming season.

12. Review no pet policy and modify rules as necessary. The presence of dogs deters roosting gulls which are a large source of *E. coli*. Dog hours (6 am-10 am and 5 pm-close) could be established when beach goers are less likely to be at the beach. This is a medium priority. The cost would be extra garbage cans and a pet waste center with signs. It is recommended that this be completed before the next swimming season or earlier.

13. Provide lifeguards during the beach season. Other beaches, such as Bradford Beach in Milwaukee and North Beach in Racine, can be used as a model for implementing best management practices. Lifeguards protect human health and deter misuse of the beach. This is a medium priority which can cost up to $20,000 per season. It is recommended that this option be pursued before the next swimming season.

Possible funding sources

14. Potential funding sources for the implementation of the project may include the following.

- Wisconsin Coastal Management Program
- Multiple grants being generated through the Great Lakes Restoration Initiative. This is an ongoing program: http://epa.gov/greatlakes/glri/index.html
- Wisconsin DNR grant programs
- Wisconsin Beach Program: http://dnr.wi.gov/org/water/wm/wqs/beaches/
- WDNR grant programs that specifically deal with stormwater projects:
- Urban Nonpoint Source and Storm Water grant program: http://dnr.wi.gov/org/caer/cfa/EF/NPS/urbannps.html
- Targeted Runoff Management grant program: http://dnr.wi.gov/org/caer/cfa/EF/NPS/nonpoint.html
- WDNR's Clean Water Fund Program: http://dnr.wi.gov/org/caer/cfa/el/section/clean.html
- A list of all of the WDNR programs is listed here: http://dnr.wi.gov/org/caer/cfa/Grants/index.html

APPENDICES

Appendix A: Village of Shorewood Sewer System Map provided by Dr. Hector Bravo

Appendix B: Statistical analysis of 1956-1987 wave direction, height and period, wind direction and speed measured at WIS stations M0008, M009 and M010

Figure 42: Wave directions at WIS stations M0008, M009 and M0010

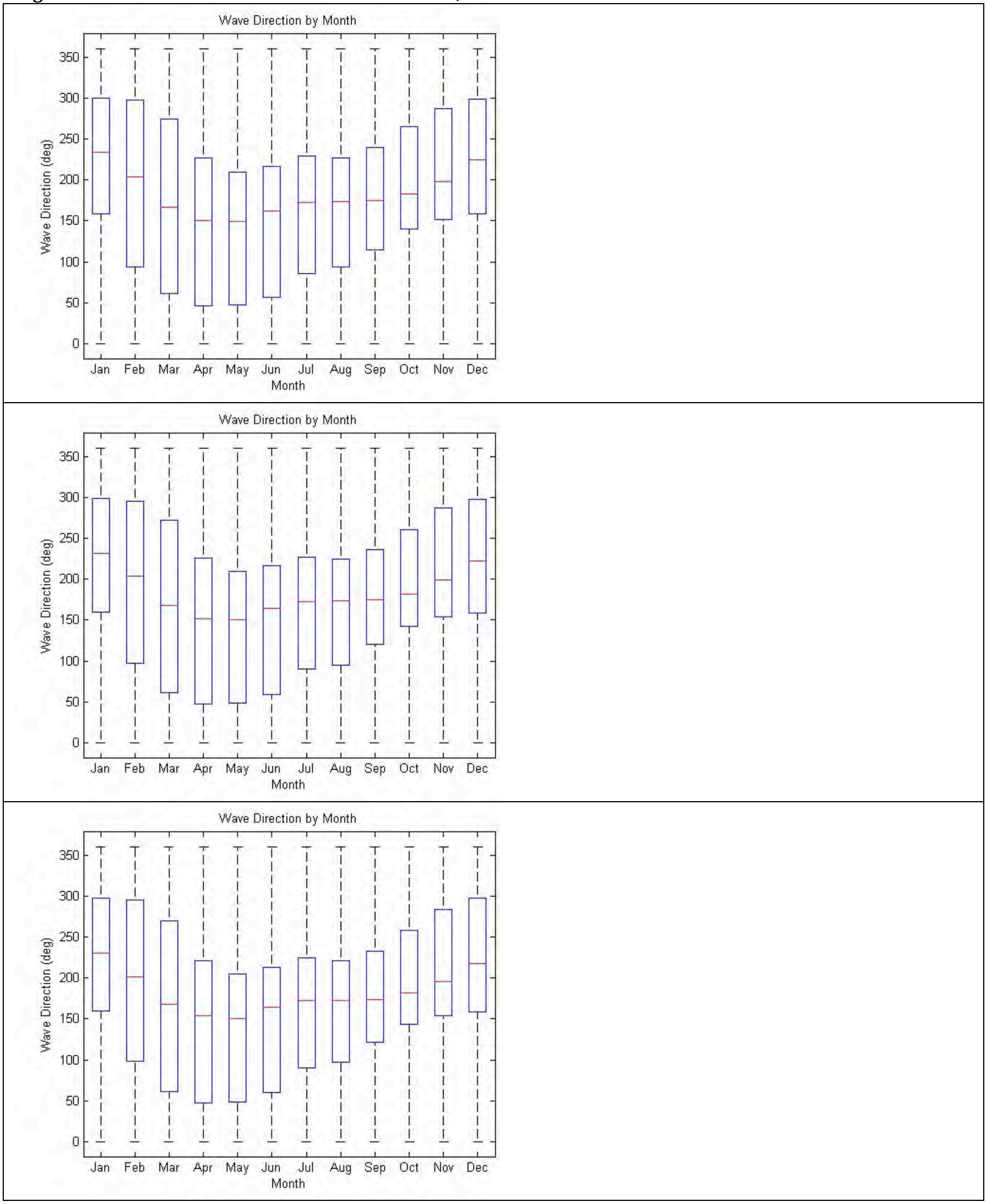


Figure 43: Wave height at WIS stations M0008, M0009 and M0010

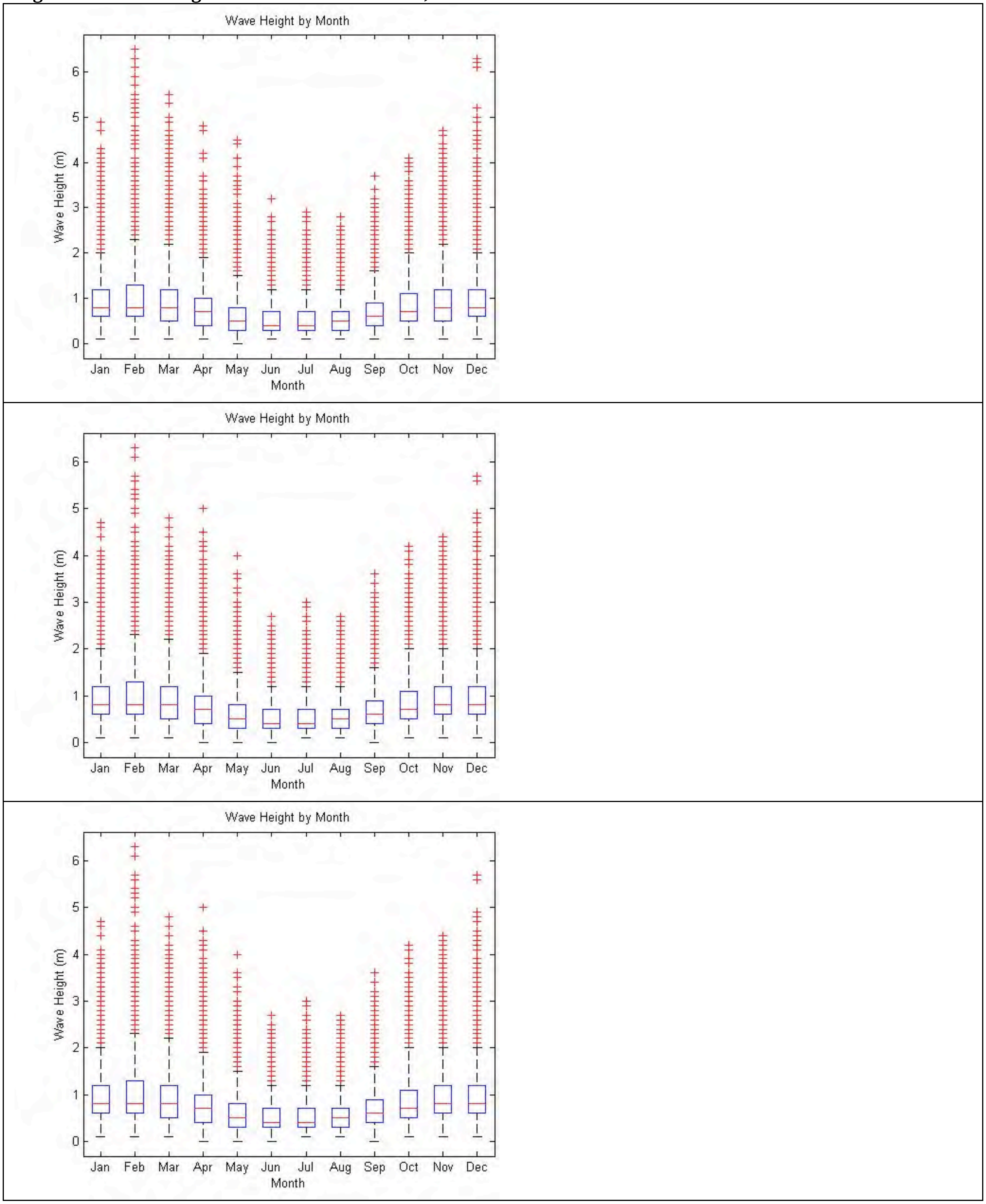


Figure 44: Wave period at WIS stations M0008, M0009 and M0010

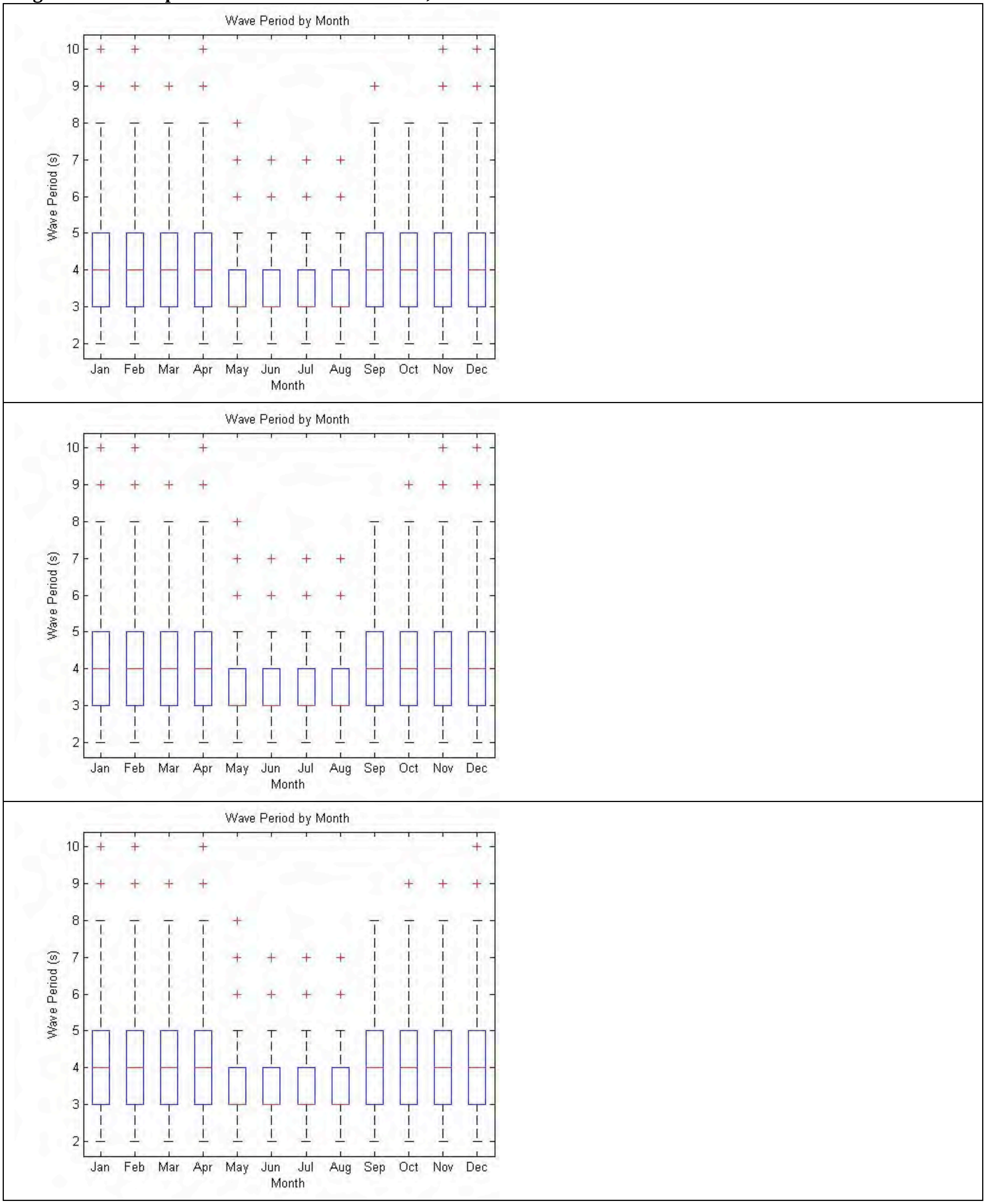


Figure 45: Wind direction at WIS stations M0008, M009 and M0010

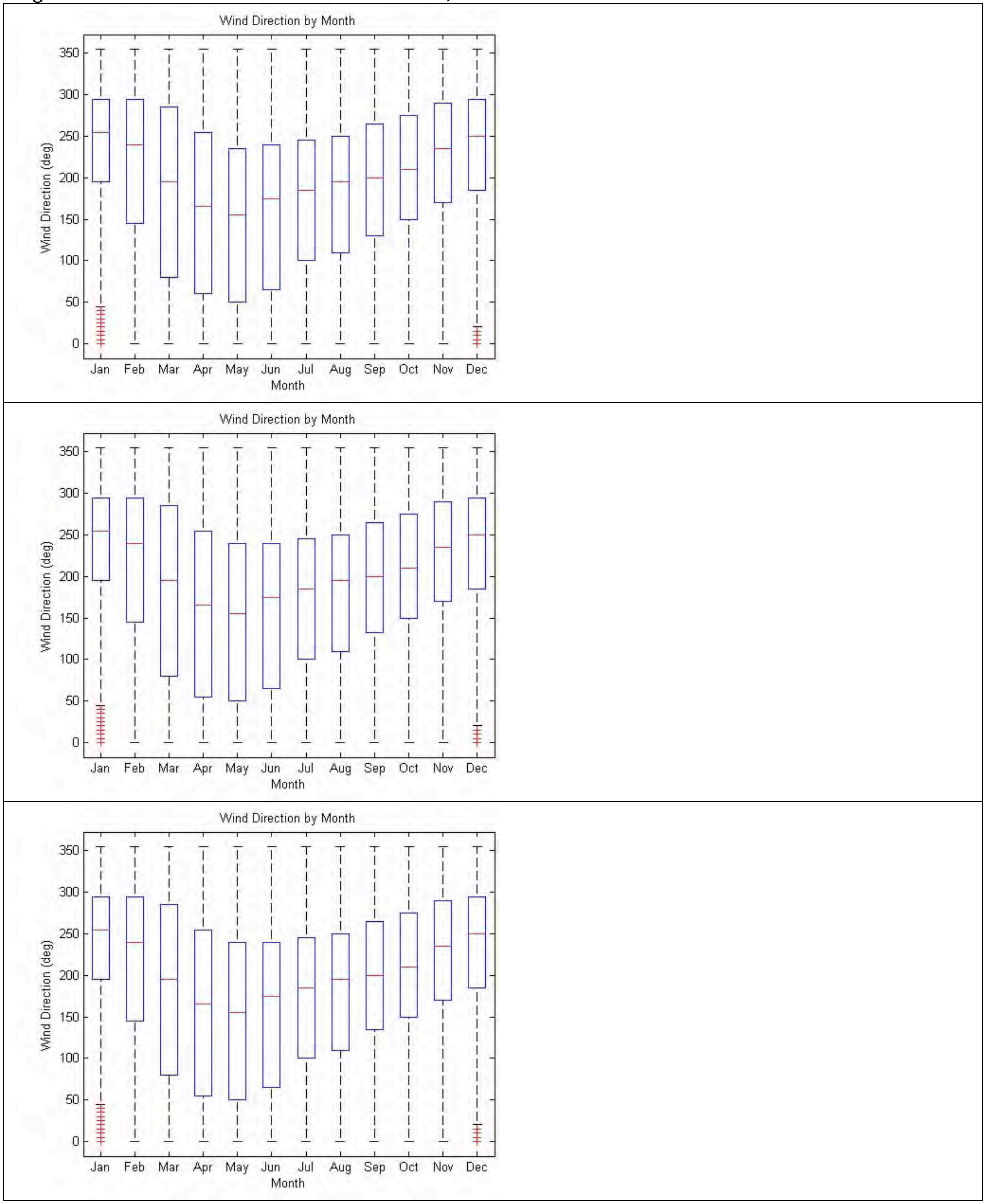
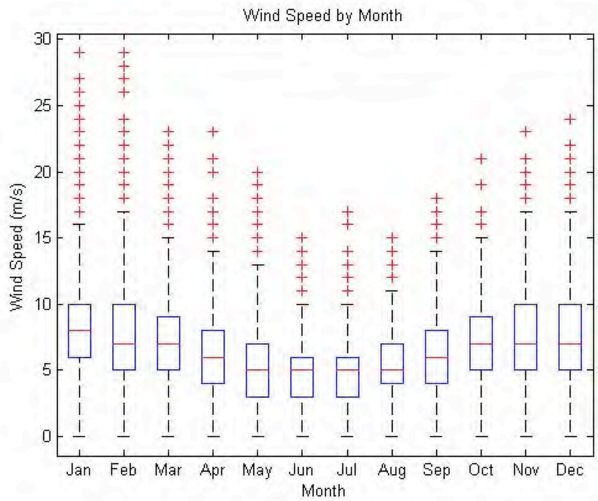
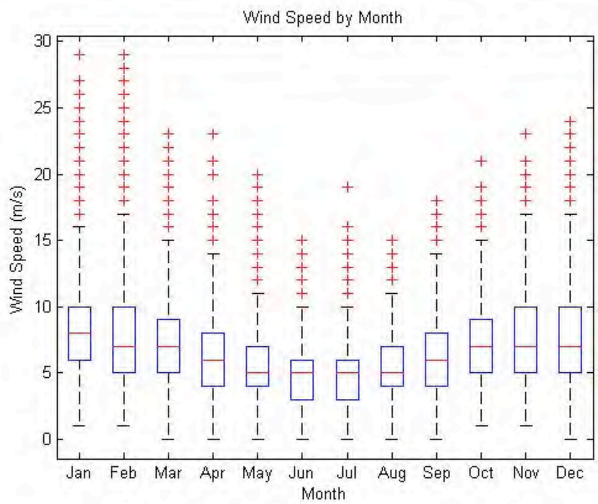
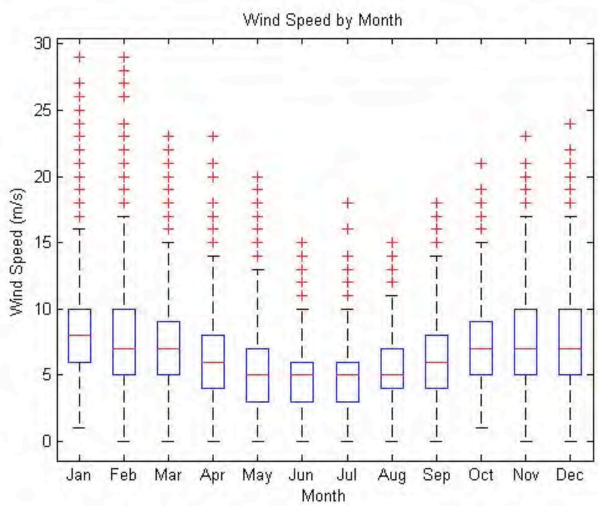


Figure 46: Wind speed at WIS stations M0008, M009 and M0010





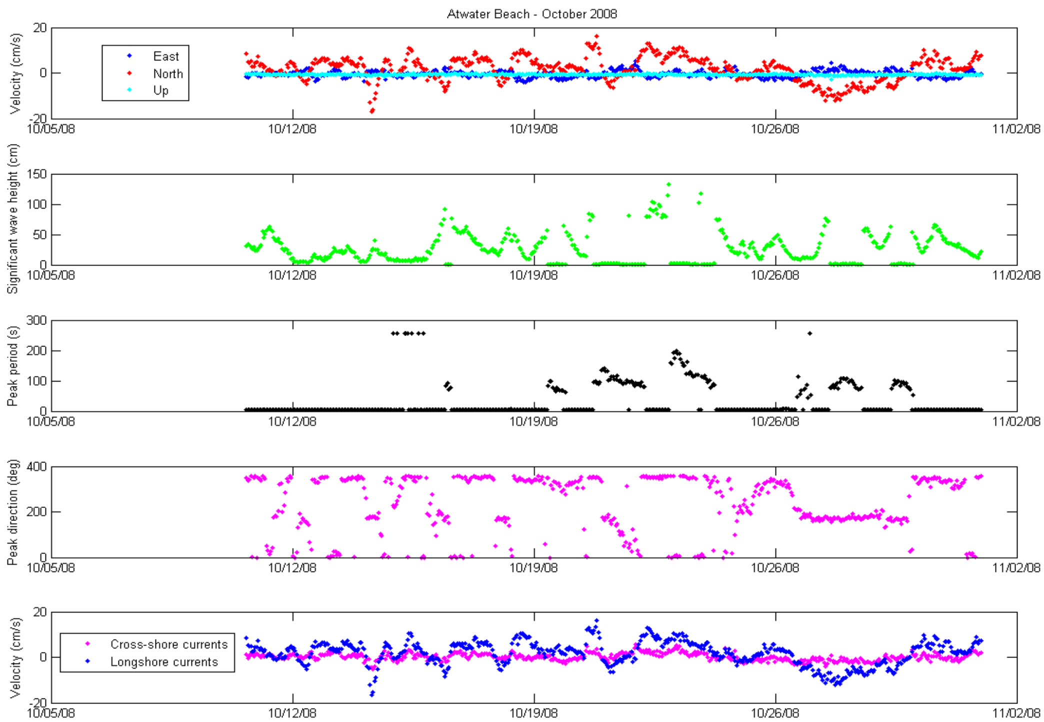


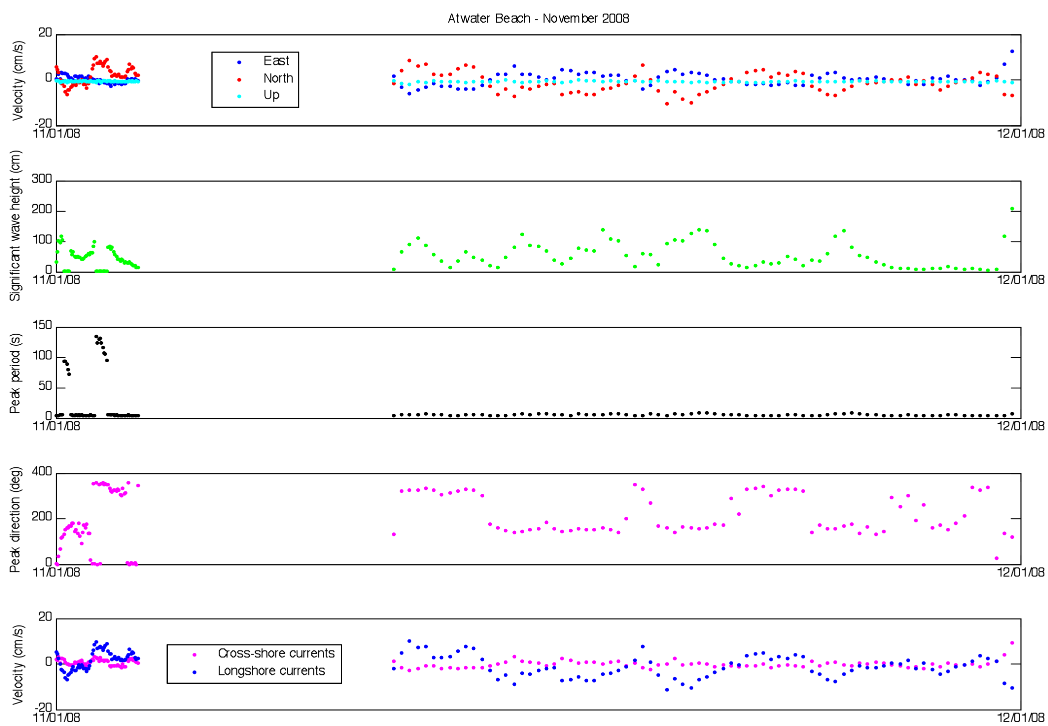
Appendix C: Current and wave measurement made during the present study

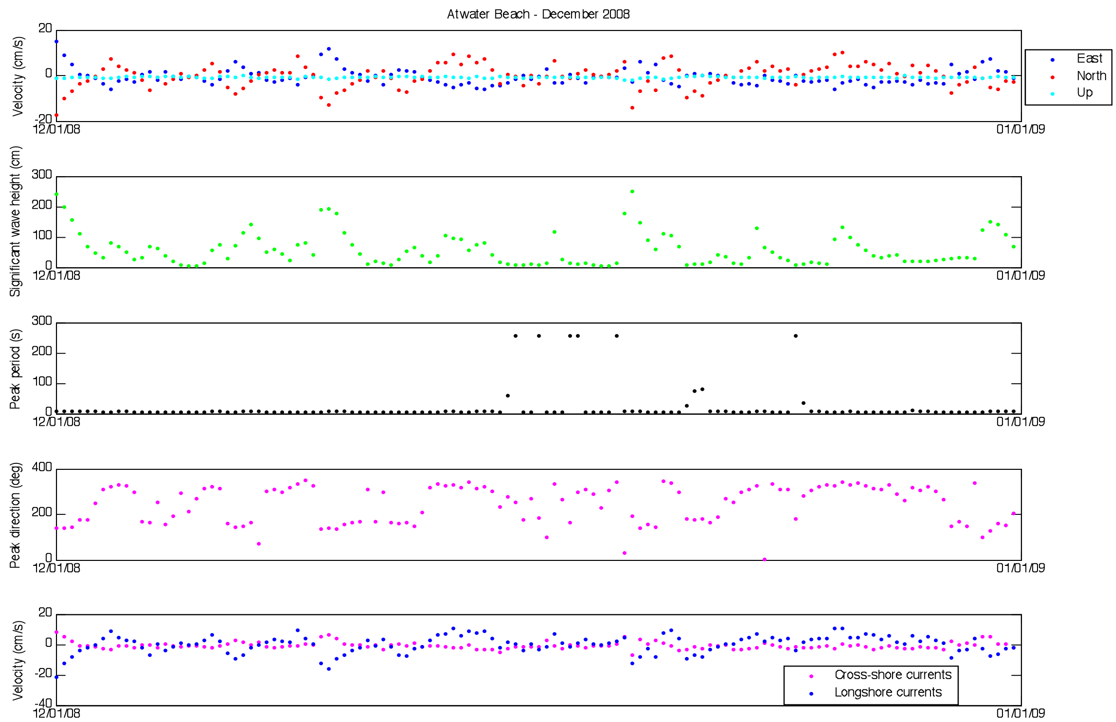
Measurements made at 10 m (33 ft) depth

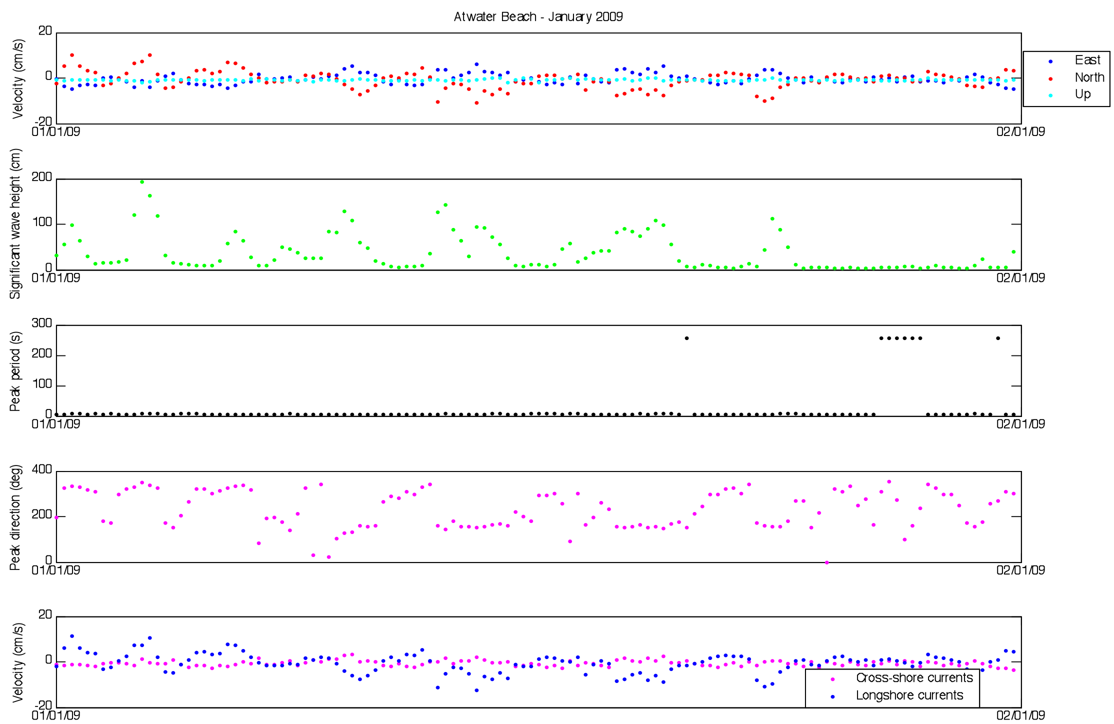
Figure 47 is based on measurements made by Dr. Bootsma's laboratory between October 2008 and April 2009 at longitude W87.86385° and latitude N43.0957433°. The first seven groups of five figures each show wave data for the months of October 2008 to April 2009.. The individual figures in each group shown current velocities (east, north, vertical), significant wave height, wave peak period, wave peak direction, and current velocities (re-plotted as longshore and cross components). The last five figures show, for the October 2008 to April 2009 period, boxplot statistics of significant wave height, wave peak period, wave peak direction, and current velocities (longshore and cross components.)

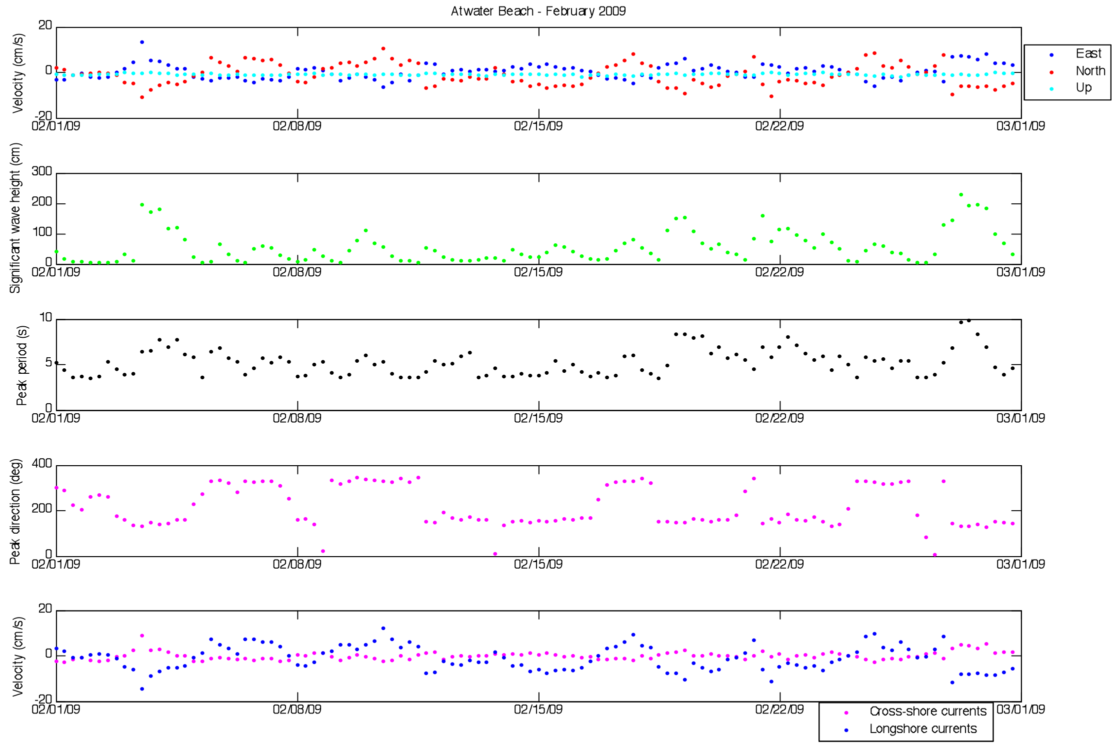
Figure 47: Wave and current measurements taken at 10 m (33ft) depth

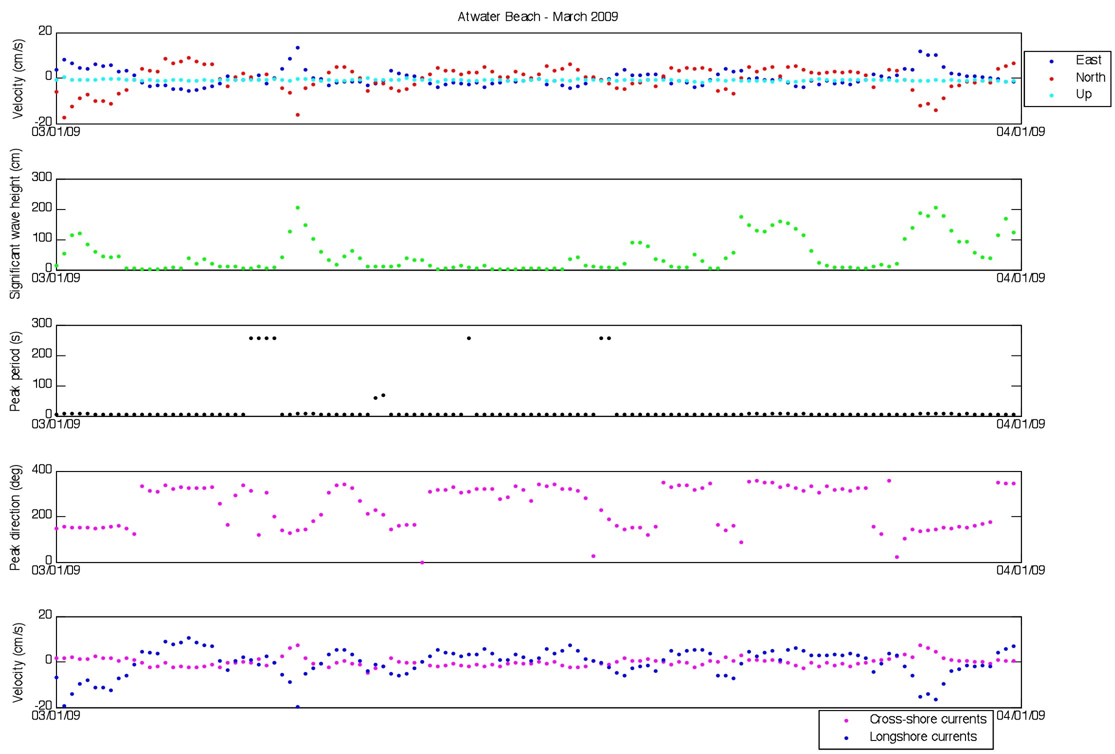


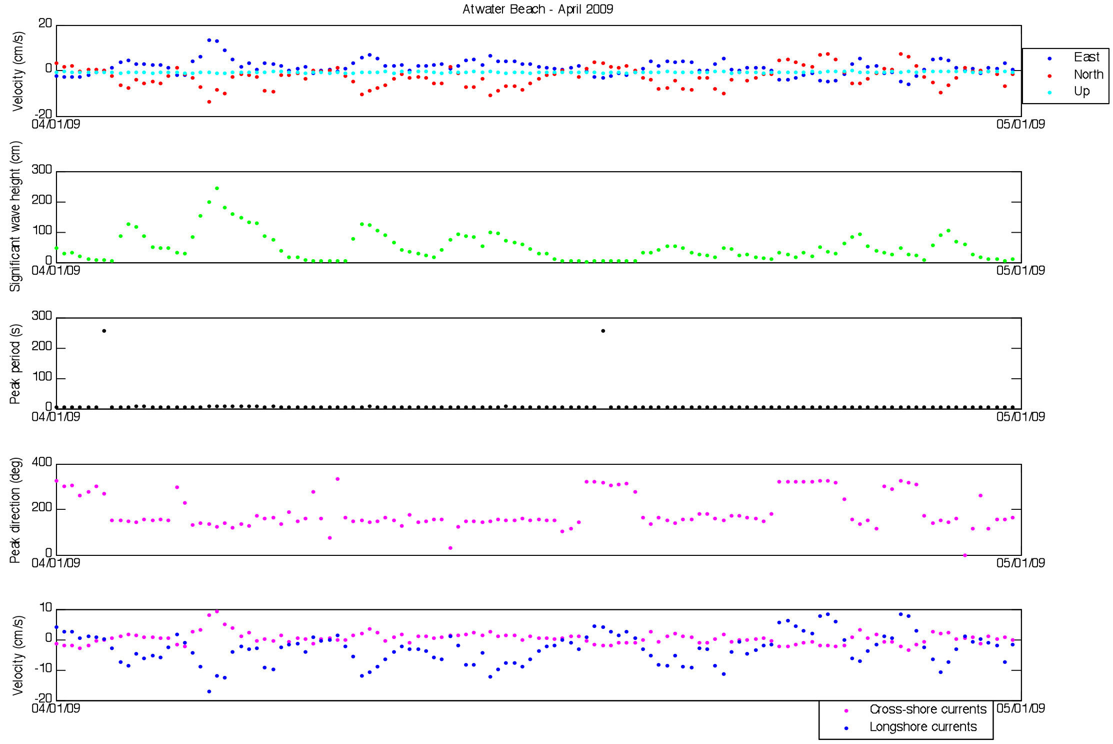


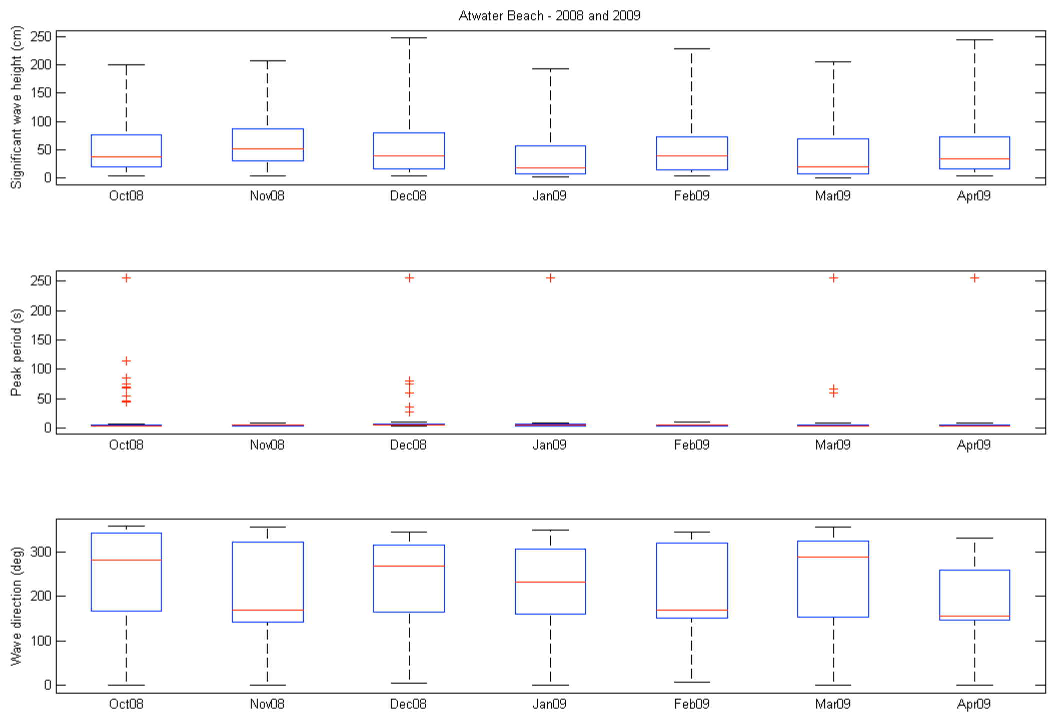

Atwater Beach - December 2008
Velocity (cm/s)
East
North
Up
Significant wave height (cm)
Peak period (s)
Peak direction (deg)
Cross-shore currents
Longshore currents
12/01/08
01/01/09

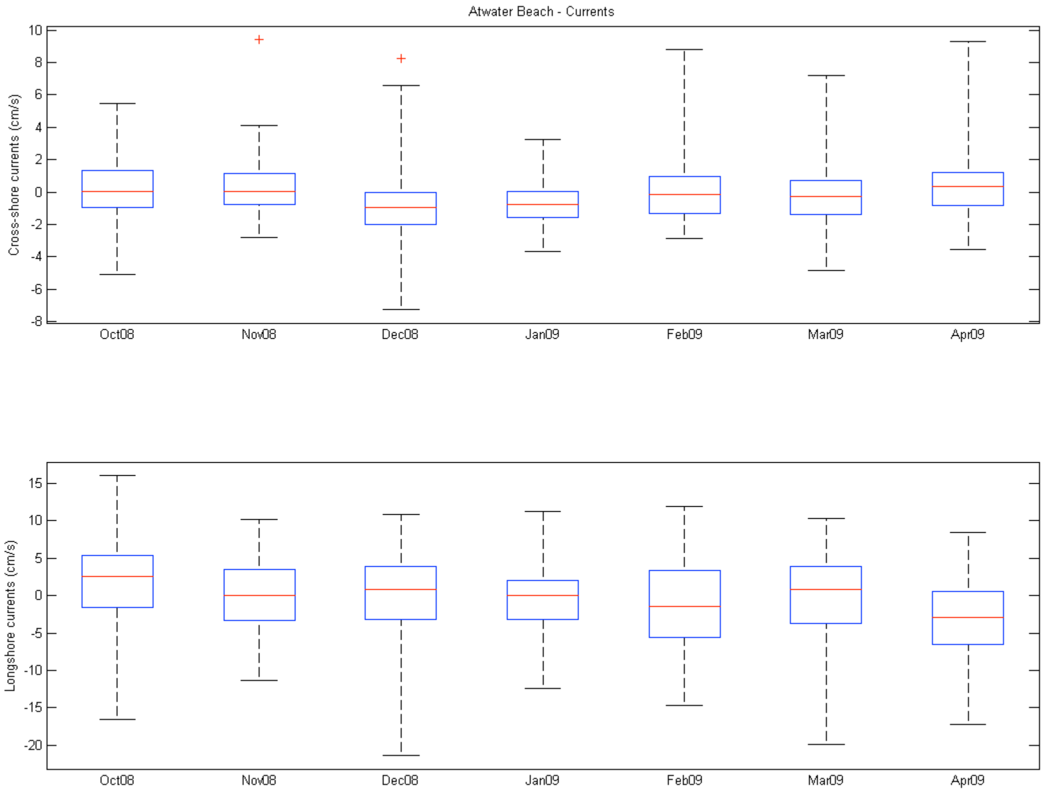

Atwater Beach - January 2009
Velocity (cm/s)
East
North
Up
Significant wave height (cm)
Peak period (s)
Peak direction (deg)
Cross-shore currents
Longshore currents
01/01/09
02/01/09


Atwater Beach - February 2009
Velocity (cm/s)
East
North
Up
Significant wave height (cm)
Peak period (s)
Peak direction (deg)
Velocity (cm/s)
Cross-shore currents
Longshore currents
02/01/09
02/08/09
02/15/09
02/22/09
03/01/09


Atwater Beach - March 2009
Velocity (cm/s)
East
North
Up
Significant wave height (cm)
Peak period (s)
Peak direction (deg)
Velocity (cm/s)
Cross-shore currents
Longshore currents
03/01/09
04/01/09


Atwater Beach - April 2009
Velocity (cm/s)
East
North
Up
Significant wave height (cm)
Peak period (s)
Peak direction (deg)
Velocity (cm/s)
Cross-shore currents
Longshore currents
04/01/09
05/01/09

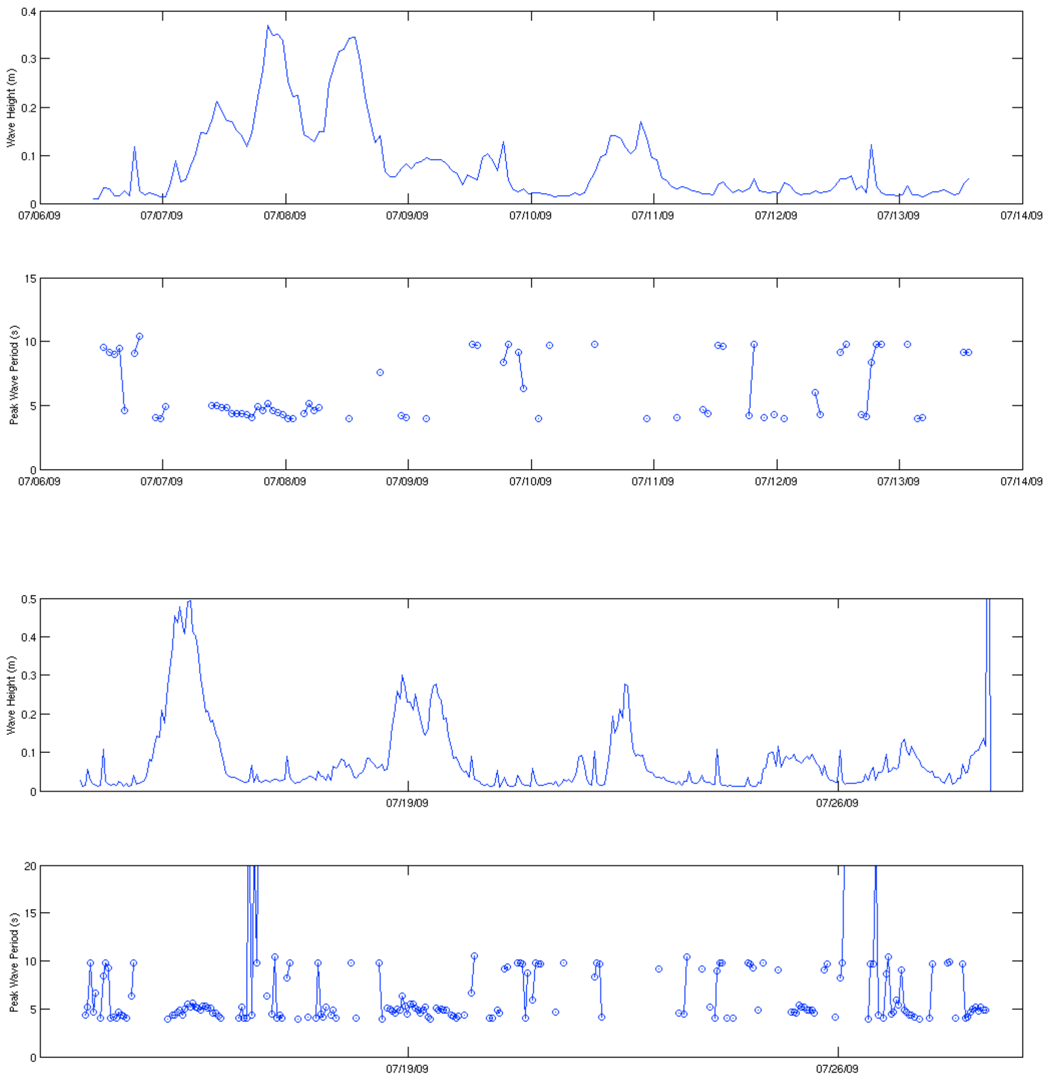

Atwater Beach - 2008 and 2009
Significant wave height (cm)
Peak period (s)
Wave direction (deg)
Oct08
Nov08
Dec08
Jan09
Feb09
Mar09
Apr09



Measurements made at 6 m (20 ft) depth

Figure 48 is based on measurements made by Dr. Bravo's laboratory between July 6 and July 28, 2009, at a site located at longitude W-87.87125 and latitude N43.0899. Each group of two figures each shows significant wave height and wave peak period. The first group shows data collected between July 6 and 13, 2009. The second group shows data collected between July 13 and July 28, 2009.

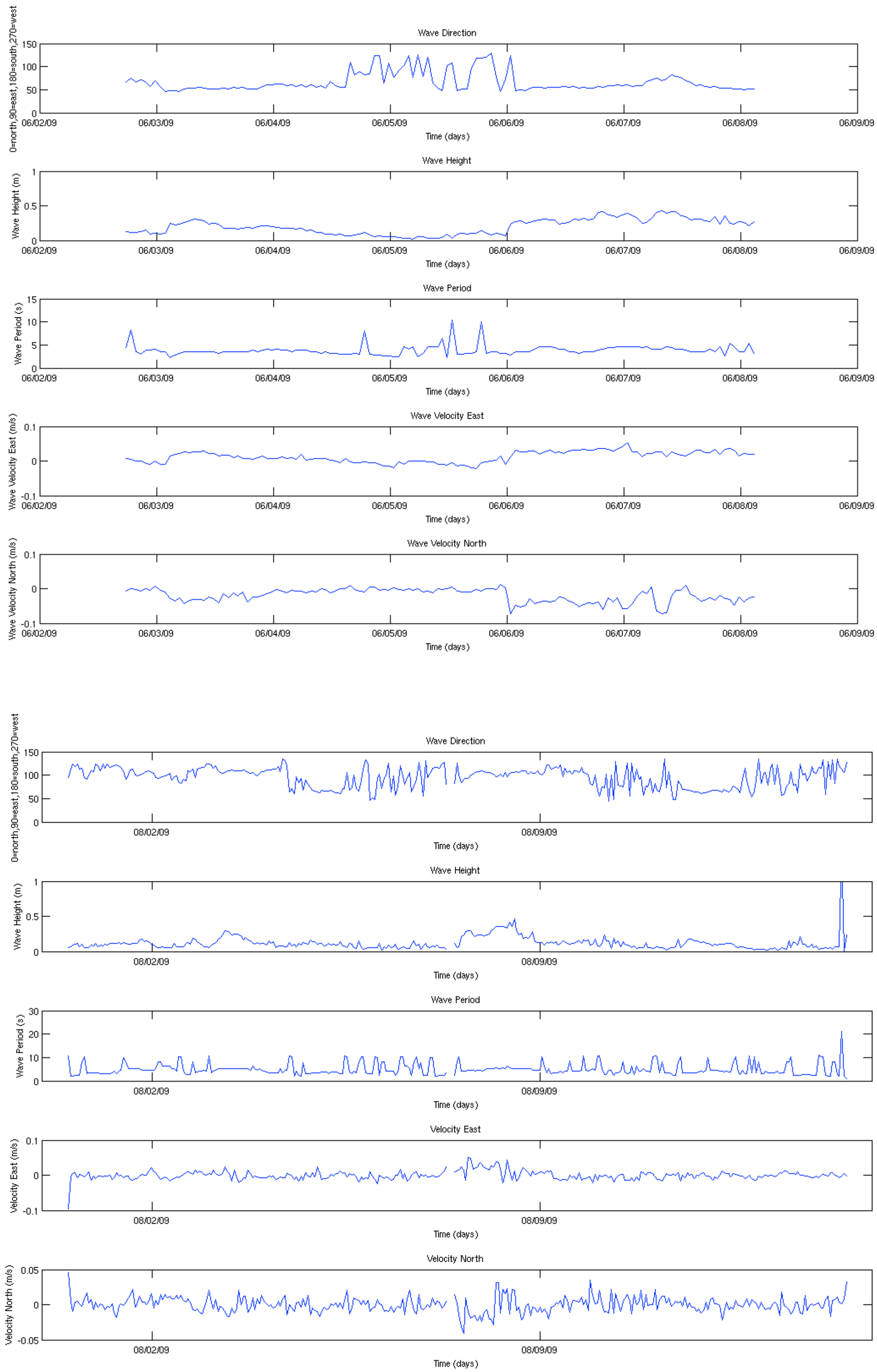
Figure 48. Measurements taken at 6 m (20 ft) depth



<u>Measurements made at 1.5 m (5 ft) depth</u>

Figure 49 is based on measurements made by Dr. Bravo's laboratory between June 2 and June 8, 2009, and between July 31 and August 14, 2009 at a site located near the center of the south gap between the groins, at longitude W87˚52.312' and latitude N43˚05.404'. Each group of five figures each shows wave direction, significant wave height, wave period, and current velocity components (east and north, respectively.)

Figure 49: Measurements taken at 1.5 m (5 ft) depth



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Memorandum

Date:	July 28, 2009
To:	Mrs. Leeann Butschlick, Director of Public Works
From:	Mr. Thomas J. Nejedlo, PE – Project Engineer
Subject:	Combined Sewer Smoke Testing (113272)

The Great Lakes Water Institute conducted storm water sampling in the Village of Shorewood at two outfalls to Lake Michigan that identified human tracers in the water sample. To identify the source of human tracers, the Great Lakes Water Institute conducted additional sampling and dye testing to narrow down the potential areas that are contributing the human tracers. The testing identified two (2) areas that are potentially responsible for the human markers. Because AECOM has considerable experience with smoke testing and sewer studies in general, a preliminary meeting was held with the Great Lakes Water Institute, UWM, and AECOM to discuss the most likely method to identify the specific source of human tracers.

To identify the specific source of the human tracers, the Great Lakes Water Institute in conjunction with the University of Wisconsin – Milwaukee (UWM), the Village of Shorewood, and AECOM decided to smoke test the sewers in the suspect areas. Two areas were smoke tested as follows:

- N. Lake Drive at E. Wood Place
- N. Cramer Street at E. Kensington Boulevard

The scope of services, findings, and recommendations for this effort are presented below and on the following pages.

Smoke Testing Scope of Services

Smoke testing was undertaken to identify potential defects or illegal connections. Three (3) separate smoke testing set-ups were completed in the area of N. Lake Drive and E Wood Place (see Figure 1). Two (2) set-ups were completed at N. Cramer Street and E. Kensington Boulevard as a shown in Figure 2.

Services for the smoke testing will be provided as follows:

1. Smoke testing was performed by forcing a non-toxic, non-staining gray smoke into the combined sewer system with a portable air blower (minimum capacity of 1,750 cubic feet per minute). For this project, Smoke #3C by Superior Signal Company was utilized.

2. AECOM's standardized smoke testing forms were completed for each set-up and observed defects documented. The smoke testing data report includes the following information:

   - Technicians performing the test
   - Date of the test
   - Manhole into which smoke is introduced into the sanitary sewer system

- A sketch of each test site including:
  - Street names
  - Manhole numbers
  - Actual emission locations
  - Potential emission locations
- Photographic documentation

3. Individual handouts were distributed two to three days prior to the smoke testing by Village personnel and local fire and police departments were notified of the testing.

4. Indications of defects or improper connections were noted on field forms as observed. The field forms completed during the testing are included in Appendix A.

5. This technical Memorandum was prepared showing the results of the smoke testing investigations. The memorandum describes the methods used, locations of smoke testing sites, investigation summarization, and identification of system defects that may be responsible for the human tracers.

Investigation and Findings

N. Lake Drive and E. Wood Place (Figure 1)

Three (3) smoke testing set-ups were conducted in the area. Smoke was introduced into the following combined sewer manholes:

- Manhole Number 456, N. Lake Drive, north of E. Wood Place
- Manhole Number 459, N. Lake Drive, south of E. Wood Place
- Manhole Number 444, E. Wood Place, west of N. Lake Drive

Moderate to heavy smoke was observed in storm manhole number 5044 due to a poorly bulkheaded pipe between combined sewer manhole 457 and storm sewer manhole 5044. The bulkheaded pipe in the combined manhole is 3 to 4 feet above the crown of the combined sewer pipe. If the sewer in this area would surcharge to the level of the bulkheaded pipe, sanitary flow could get into the storm sewer and eventually discharge to Lake Michigan. However, following discussions with Shorewood personnel, this does not appear to occur and is most likely not responsible for the human tracers. There is also no evidence of surcharging in combined sewer manhole 547.

Trace or light smoke was observed in storm manhole 5045. The smoke into this manhole is probably due to cracked pipe in the combined sewer system in the area and/or defective laterals. The exact source of the smoke could not be determined. A water curb stop was observed smoking on the north side of E. Wood Place during the set-up at manhole number 444. Because laterals were previously installed in the same ditch that water system services were installed, this is a good indication that the laterals in the area are cracked or have open joints, potentially allowing flow to enter the storm sewer system.

N. Cramer Street at E. Kensington Boulevard (Figure 2)

Two (2) smoke testing set-ups were conducted in the area. Both tests were conducted from the same manhole, but the second test was conducted to check pipes further downstream than the first test. Smoke was introduced into the following combined sewer manhole:

- Manhole Number 837, N. Cramer Street at E. Kensington Boulevard

Heavy smoke was observed in storm manhole 5262, located in the southeast corner of N. Cramer Street and E. Kensington Boulevard. Smoke was entering this storm manhole from two sources. The bulkheaded pipe between storm manhole 5262 and combined sewer manhole 835 had moderate to heavy smoke (Please note that our maps did not have numbers for all manholes, so the numbering system shown in Figure 2 is the numbering system used for calling out manhole numbers in this memorandum). This pipe is bulkheaded and appears to be an abandoned overflow from the combined system. The bulkheaded pipe that leaves the combine manhole (manhole number 835) is located on the bench of the manhole and appears to be below the crown of the combined pipe. Therefore, flow that reaches the level of the bench could flow into the storm manhole accounting for the human tracers identified in the earlier sampling.

A catch basin located in the northeast corner of N. Cramer Street and E. Kensington Boulevard has a lead that runs directly to storm manhole 5262. This lead was smoking heavily during the testing. The heavy smoke in the catch basin lead indicates severely cracked pipe or open joints in both the catch basin lead and the combined sewer pipe in the area of the catch basin lead. This is the most likely source of the human tracers identified during the sampling.

The second test at this site identified moderate to heavy smoke from a bulkheaded cross connection between combine sewer manhole number 833 and storm sewer manhole number 5261, located at the intersection of N Murray Avenue and E. Kensington Boulevard. The bulkheaded pipe between the combined sewer and storm sewer has a very similar configuration as the storm and combined sewers at N. Cramer Street and E. Kensington Boulevard. The bulkheaded pipe leaves the combined sewer manhole at the bench in the manhole. If flow rises above the bench in the combined sewer manhole, flow can potentially enter the storm manhole from this source. This may also contribute human tracers to flow in the storm sewer.

Figure 1
N. Lake Drive and E. Wood Place

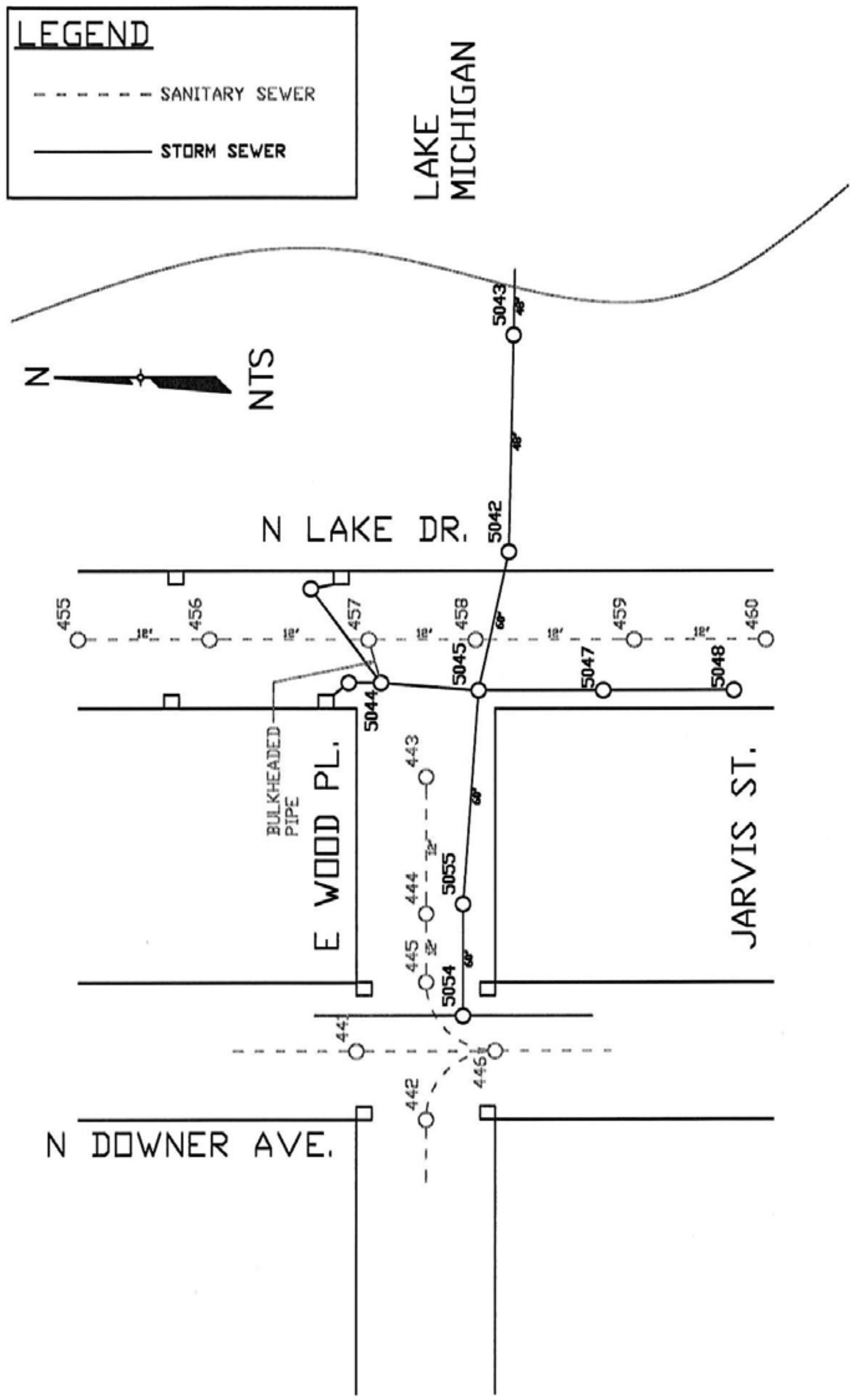
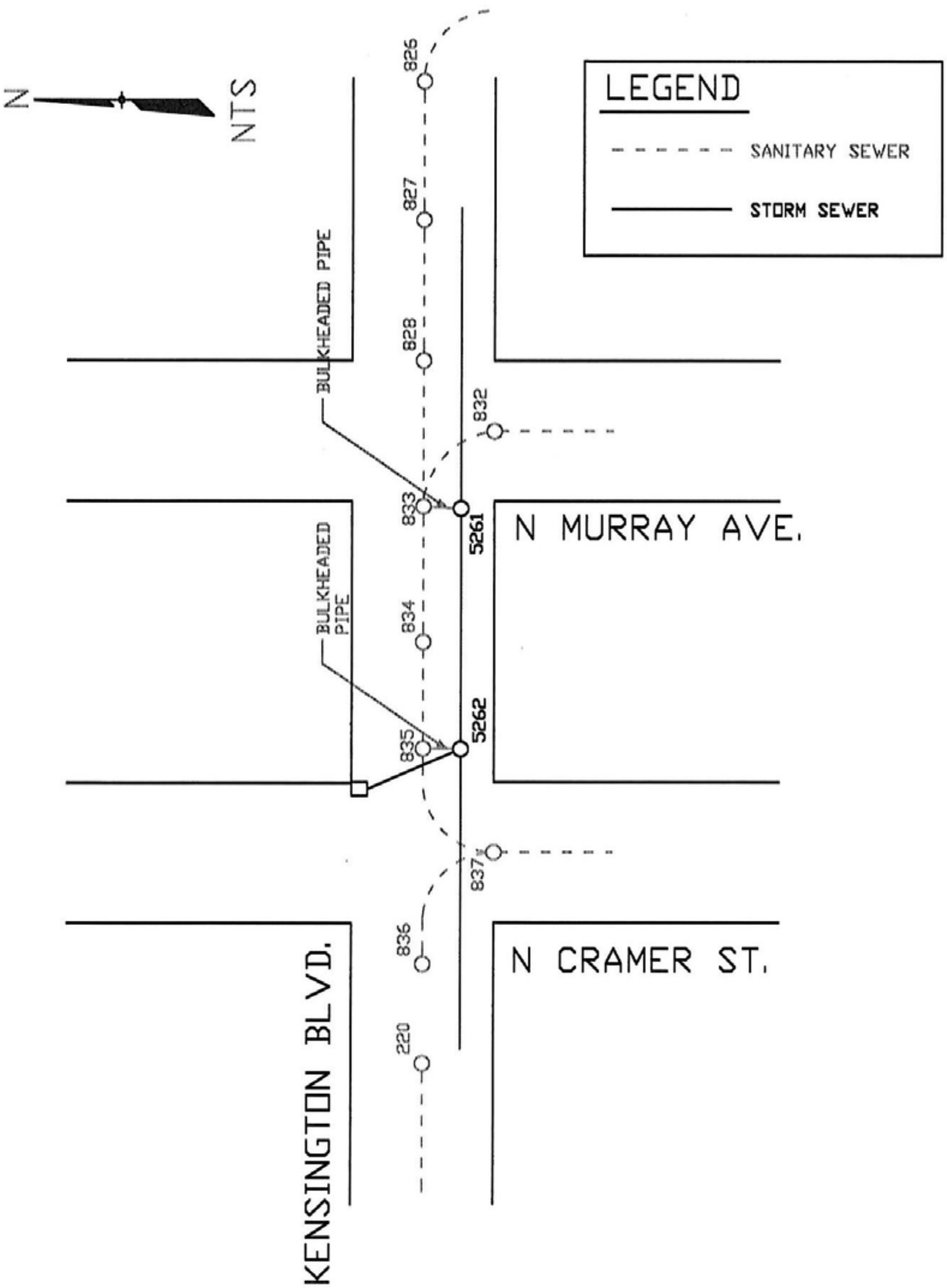


Figure 2
N Cramer Street and E. Kensington Boulevard



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Recommendations

N. Lake Drive and E. Wood Place

Smoke testing did not identify specific defects allowing for the transference of human tracers from the combined sewer to the storm sewer and eventually Lake Michigan in this area. It appears that the transfer may occur due to cracks or open joints in the combined and storm sewers as well as potentially from laterals connected to the combined sewer.

Lining or grouting of the mainline combined sewer may eliminate the transference of human tracers, although laterals may also be responsible for the transference. Televising the mainline combined sewer between manhole numbers 456, south to manhole 459 may identify specific problems such as cracks and/or open joints in the combined sewer that could be repaired with lining or grouting. Village personnel indicated that a defective joint just south of manhole 458 may be responsible for the transference. This should be discussed with sewer maintenance personnel or televised to identify the severity of the defect. This defect appears to be directly over the top of the 60-inch storm sewer between storm manholes 5045 and 5042.

Where possible, televising house laterals in the area may identify defects that are responsible for the transference of human tracers. Repair of defect laterals could involve complete replacement, spot repairs, or lateral lining.

N. Cramer Street at E. Kensington Boulevard

Three (3) specific defects were identified at this location that may be responsible for the human tracers in the storm sewer.

1. The pipe connecting the catch basin in the northeast corner of N. Cramer Street and E. Kensington Boulevard to the storm manhole in the south east corner of the intersection was smoking heavily, almost as if this was a direct connection. The catch basin lead is probably severely cracked or there is a significant open joint in the lead as well as severe cracks or open joints in the combined sewer in the area of the catch basin lead. Televising the combined sewer and the catch basin lead would further identify the severity of this defect. The catch basin lead could be repaired or lined to eliminate the potential for the transference of human markers. This lead is the most likely source of human tracers in the storm sewer.

2. The bulkheaded pipe between the combined sewer and storm sewer manholes at N. Cramer Street and E. Kensington Boulevard should be repaired or eliminated, as this may be responsible for the human tracers in the storm sewer.

3. The bulkheaded pipe between the combined sewer and storm sewer manholes at N. Murray Avenue and E. Kensington Street should be repaired or eliminated, as this may also be responsible for the human tracers in the storm sewer.

4. There are numerous locations on E Kensington Blvd and N Oakland Ave where this type of vacated bypass mechanism exists. Additional smoke testing should be conducted to confirm the extent of the problem.

Appendix A

Smoke Testing Field Forms

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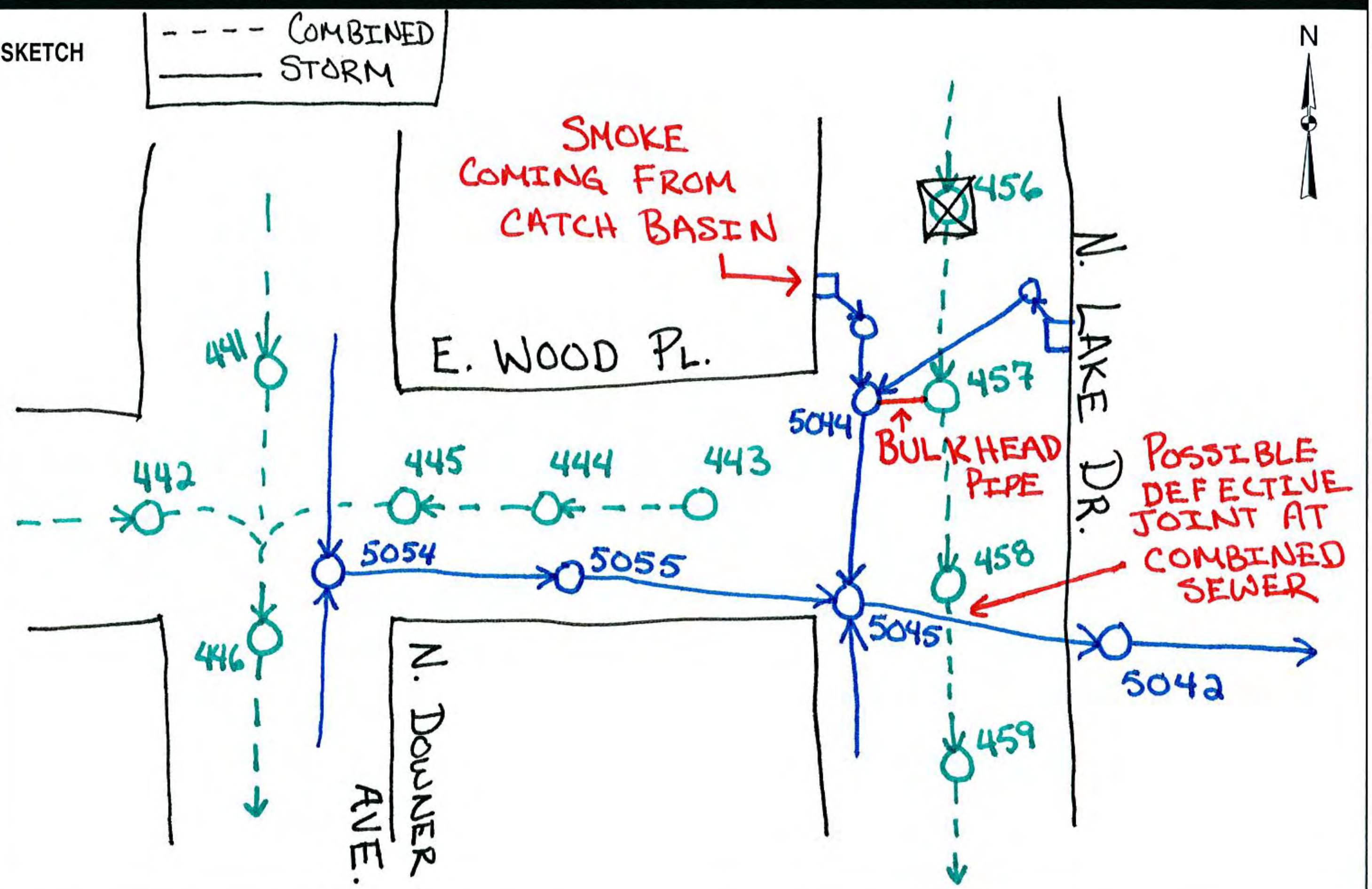
SMOKE TEST DATA REPORT

CLIENT: SHOREWOOD	DATE: 6-10-09
PROJECT NO: 113272	BASIN:
CREW: TN, DA, AM	SMOKE INTO MANHOLE: 456

SKETCH



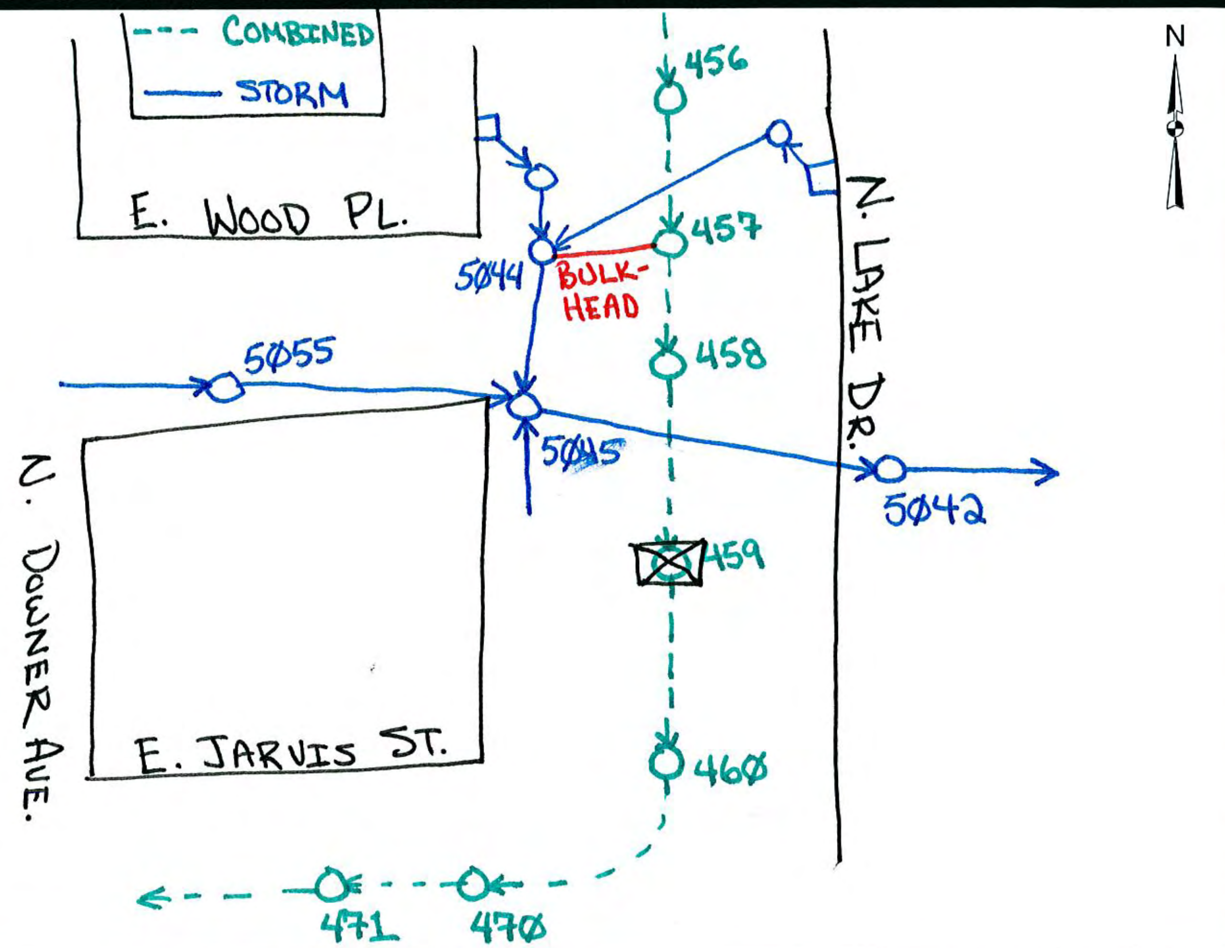
REMARKS: SMOKE COMING FROM	FILM – PICTURE:
CATCH BASIN DUE TO	
BULKHEADED PIPE FROM STORM	
MH # 5044 AND COMBINED	
SEWER MH # 457	

AECOM

SMOKE TEST DATA REPORT

CLIENT: SHOREWOOD	DATE: 6-10-09
PROJECT NO: 113272	BASIN:
CREW: TN, DA, AM	SMOKE INTO MANHOLE: 459

SKETCH



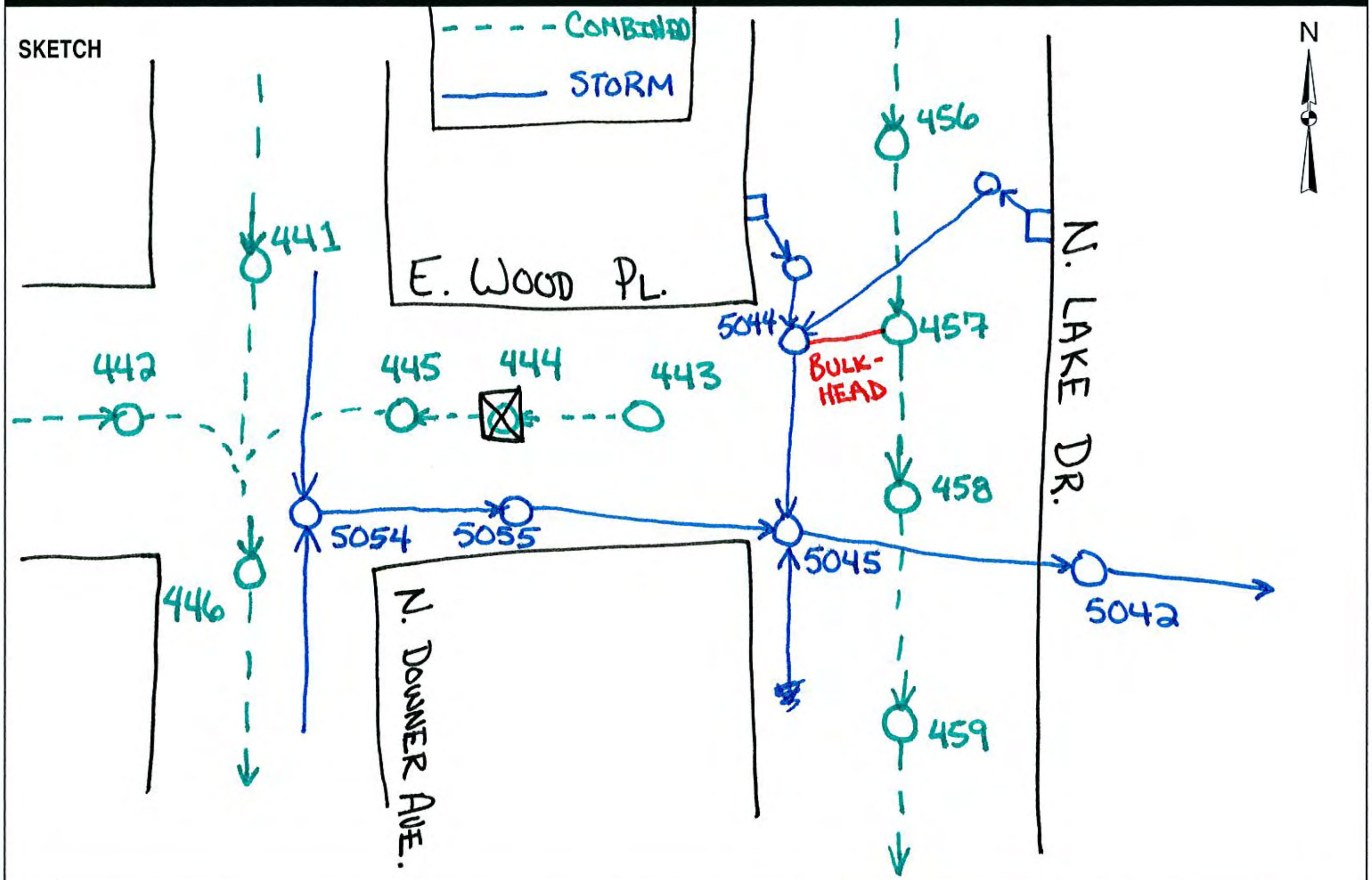
REMARKS: NOTHING IRREGULAR	FILM – PICTURE:
FOUND	

AECOM

SMOKE TEST DATA REPORT

CLIENT: SHOREWOOD	**DATE:** 6-10-09
PROJECT NO: 113272	**BASIN:**
CREW: TN, DA, AM	**SMOKE INTO MANHOLE:** 444

SKETCH



REMARKS: NOTHING IRREGULAR	**FILM – PICTURE:**
FOUND	

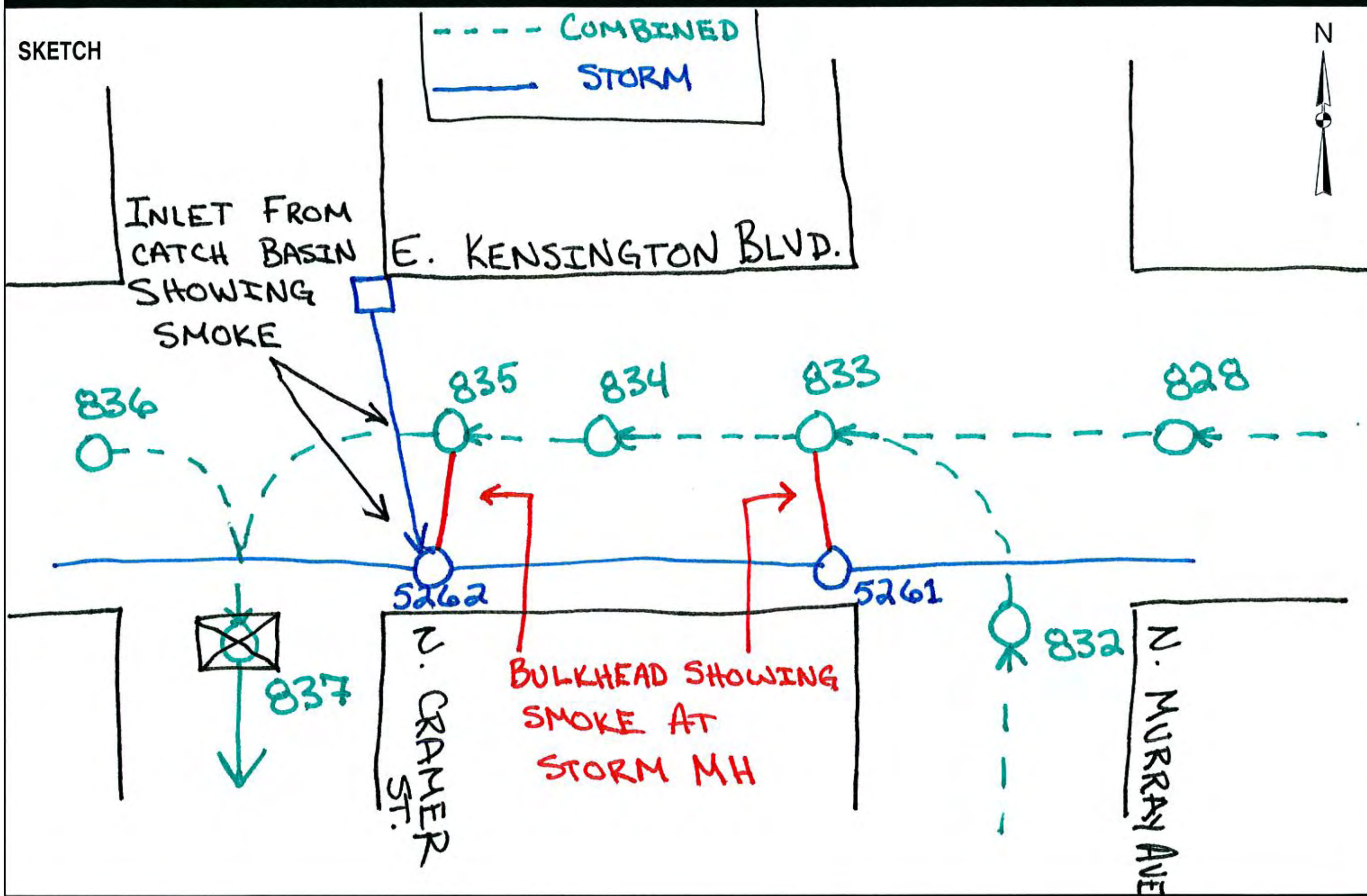
L:\library\Dept\ENG\-NEW- AECOM blank Documents\Smoke Testing\Sample Smoke Testing Form.doc KMA 10/2008

AECOM

SMOKE TEST DATA REPORT

CLIENT:	SHOREWOOD	DATE:	6-10-09
PROJECT NO:	113272	BASIN:	
CREW:	TN, DA, AM	SMOKE INTO MANHOLE:	837

SKETCH



REMARKS: POSSIBLE CRACK AT	FILM – PICTURE:
STORM SEWER PIPE AND	
SANITARY PIPE ~~NEAR~~ @	
CROSSING NEAR E SANITARY	
MH # 835	