Final Technical Report

GL00E00831
A Protective Barrier to Improve Public Health at Beaches

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Project Summary

A Beach Protection Barrier was installed at Calumet Beach in Chicago on July 26, 2012 with the purpose to decrease microbial water contamination coming from offshore sources. The barrier was designed to filter the incoming water and create an embayment of low bacteria levels safe to use by the public during recreational season. The barrier was removed in October of 2012.

The barrier was a 480 ft. long, horseshoe-shaped curtain, which was anchored to the bottom of the lake floor. The furthest it reached from the shore was 200 ± 20 ft., and it contained the area of approximately 2700 square feet. Ten oz. Non-Woven Geotextile curtain consisted of 2 fabrics: an inner fabric of 0.43 mm Apparent Opening Size (AOS) and thickness of 0.7 mm, and outer fabric of 0.18 mm AOS and 2.3 mm thickness. Inner fabric was used primarily as a strength membrane but carried some filtering capabilities, and outer fabric was the primary filter. Thus, overall Barrier thickness was generally 3.0 mm, however, where the strength webbing was applied, the thickness was closer to 5.5 – 6.5 mm.

There were some changes in hydrology observed throughout the time of the barrier being present at the beach. For example, during the installment the water depth at the deepest point (portion parallel to shore) was 4.8 – 5.2 ft., and during the removal on October 23, 2012, the same point was barely 3.8 – 4.5 ft. Furthermore, there was a significant sand accumulation along the inner north portion adjacent to the shoreline transition (i.e. at least 1 – 1.5 ft. of sand). This extended from the shoreline to approximately 40 – 50 ft. towards the center of the barrier, which either was a part of, or the cause of a longer sand bar that developed just offshore predominantly closer to the north side of the barrier.

Project Outputs and Outcomes

The initial application for this project anticipated a number of outputs and outcomes that can be summarized into two categories – a reduction in beach water quality contamination and related beach advisories, and an increase in the understanding of the relationship of onshore and offshore sources of beach water quality contamination.

The project was generally not successful at reducing FIB concentrations or swim advisories at the test beach. There was not a significant difference in water quality inside and outside the barrier. Although there was evidence that the barrier excluded some offshore sources of bacteria such as algal mats and decayed organic matter, it also appeared to trap or exacerbate onshore sources of bacteria. For example, the barrier may have prevented water circulation from flushing contamination in the sediment.

Specific outputs and outcomes that were listed in the application are below.

- *Reduction in the number of pollution sources impacting Great Lakes beaches*.

The barrier was intended to limit the impact of offshore sources of Fecal Indicator Bacteria (FIB) pollution sources. Although there was evidence that the barrier did exclude offshore sources from the enclosed swimming area, the positive effects on water quality may have been counterbalanced by other negative effects, such as the barrier trapping onshore sources of FIB, or an increase in algae concentrations inside the barrier.

- *Reduction in the number of Great Lakes beach closures or advisories issued*.

The project was not successful at significantly reducing the number of closures or advisories issued at the test beach. Analysis of the data from the summer found that the beach barrier did not significantly reduce the ambient bacteria levels that are used to determine whether advisories are issued at Chicago beaches.

Interestingly, the barrier did appear to reduce the level of FIB in the sand inside the barrier. It is possible that a reduction in bacteria concentrations in the sand could have a positive impact on public health. However, sand samples are not used to make management decisions about advisories or closures at beaches.

- *Documentation of mitigation measures taken and outcomes achieved which can be applied at other Great Lakes beaches.*

This project was well documented. Results have been published in the Journal of Environmental Management and shared with the Great Lakes beach community on the beachnet listserve. The published article is attached to this report. An abstract was also accepted for presentation at the International Association of Great Lakes Researchers meeting in 2013. Unfortunately, however, US Geological Survey personnel were unable to attend the meeting due to travel restrictions resulting from the federal budget sequester.

- *Water quality is improved at Great Lakes beaches due to reductions in bacteriological, algal, and chemical contamination.*
- *Protection of public health is improved at Great Lakes beaches.*

The project was not successful at reducing concentrations of FIB or algae within the swimming barrier. Consequently, we did not find that the project had a direct impact on improving public health protection at the test beach. However, the project did provide useful information about the onshore/offshore exchange of contamination sources.

Meetings

No general public meetings were held for this project. CPD worked with lifeguards and other park staff to share information about the project goals with the public at the test beach.

Formal meetings for this project were all technical in nature and involved design and engineering or placement and anchoring of the barrier.

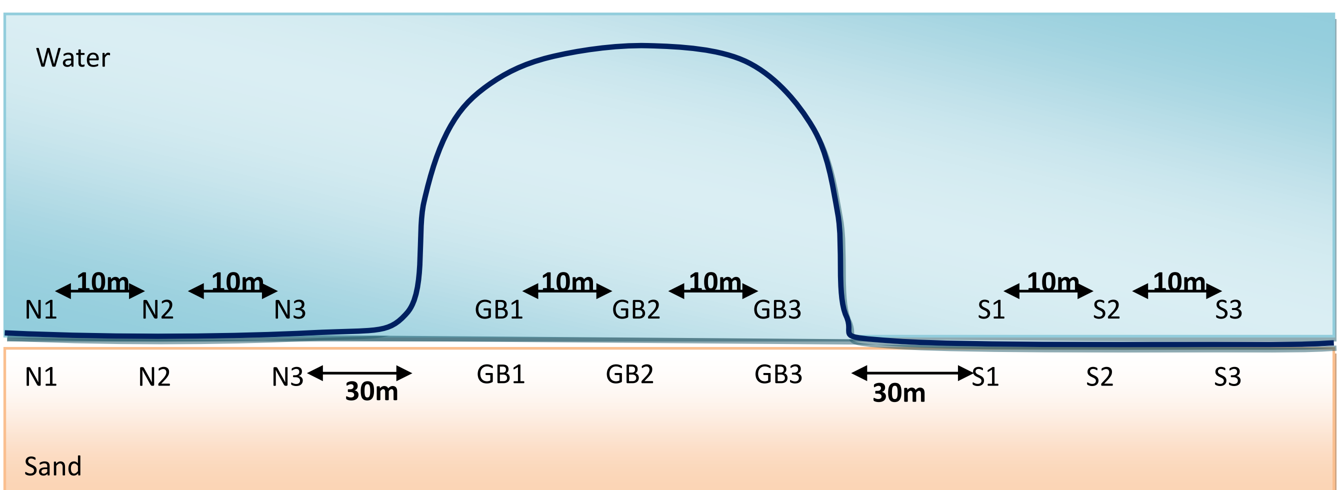
Special methodologies

The barrier was custom-built for this project and made use of specialized technology. Installation of the barrier required heavy equipment and expertise in the anchoring of large structures in the high energy nearshore environment. The Park District made use of the expertise of its harbor management contractor, Westrec Marine, for the anchoring system.

The sampling methodologies used for the project required technical expertise but were well within the norm of beach water quality research throughout the great lakes. Specifics of the sampling methodologies and results are outlined below.

Sampling strategy

Lake water and nearshore sand samples were collected 3 times a week between June and September 2012 before barrier installation (n=15 water and n=7 sand samples), and with the barrier in place (n=234 water and n=96 sand samples). Three replicated water and sand samples were collected from the following sites: within the barrier (GB) and on both sides outside of the barrier (N and S) according to the sampling diagram below.



Sampling Summary

Water samples: *n*=15 before Barrier installation at site N3 (6/26 – 7/26), and *n*=234 with Barrier in place (7/27 – 9/24)
Sand samples: *n*=7 before Barrier installation at site N3 (6/26 – 7/23), and *n*=96 with Barrier in place (7/27 – 9/24)
Water and sand samples on the north side (N), south (S), and within the Barrier (GB) were distributed every 10 m; samples collected outside of the Barrier were 30 m from the edge of the Barrier

All water samples were collected by submerging a sterile Nalgene bottle below the water surface in 45 cm deep water. Moist, subsurface sand samples (2-10 cm depth) were collected 1-2 m from the shoreline. Samples were transported to the laboratory in a cooler on ice and processed within 4 hours of collection. Water samples were analyzed individually and 3 replicates of sand samples were combined and resulting composite sand sample was analyzed for *E. coli* and turbidity. On few occasions, sand samples' replicates were analyzed individually to estimate the variation among the replicates.

Additionally, *E. coli* monitoring data, measured as most probable number (MPN)/100 ml of water, were obtained from the Chicago Park District (CPD) for the period from 5/22/2012 until 9/02/2012. Calumet Beach was sampled five days a week with duplicate water samples, of which the geometric mean was calculated for management purposes. CPD sampling locations were slightly north of the barrier; water samples were also collected inside of the embayment once the barrier was in place.

Laboratory procedures

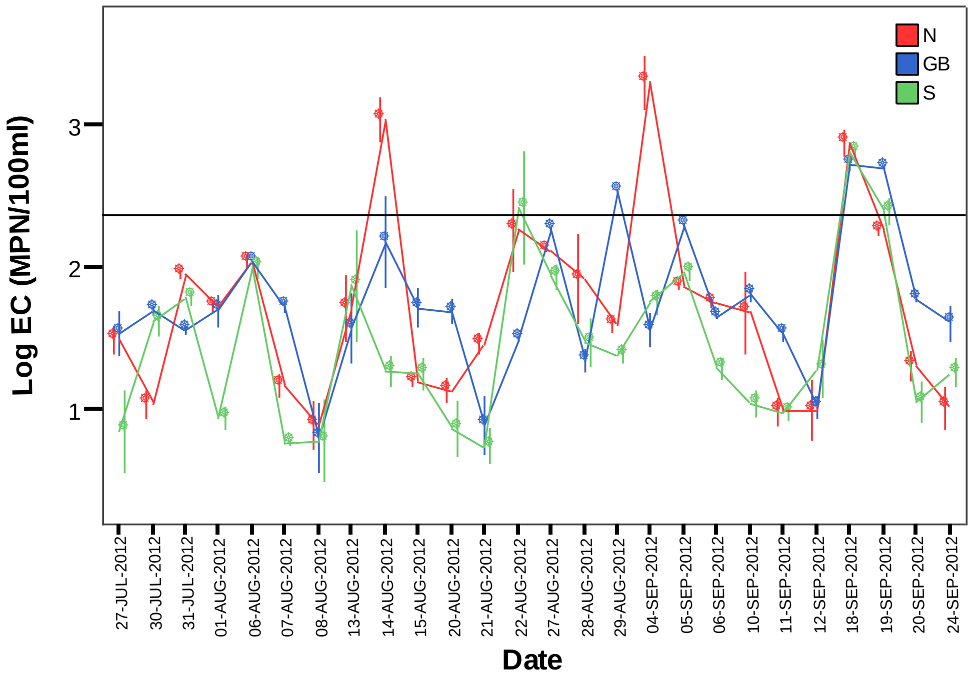
In the laboratory, sand samples were well homogenized, combined if needed, then 100 grams of sand was added to a sterile 500-ml bottle, followed by 200 ml of PBW. The mixture was shaken for 2 min, and the supernatant was used for turbidity measurements and for analysis of *E. coli*. Culturable *E. coli* concentrations were measured using Colilert-18 system (IDEXX, Inc., Westbrook, Maine) and were expressed as most probable number (MPN)/100 ml or (MPN)/1 g dry weight of sand. Turbidity measurements were performed on all water samples, as well as some of the elutriates obtained from sand (NTU; 2100N Turbidimeter, Hach Company, Loveland, CO).

Statistical analyses

Statistical analyses were performed using SPSS version 12.0. Statistical procedures were performed on $\log_{10}$-transformed *E. coli* and water turbidity data to meet parametric assumptions of equality of variance and normal distribution. Kolmogorov-Smirnov test, a non-parametric test, was used to test normality.

RESULTS

WATER *E. coli* OVERTIME
Water mean *E. coli* concentrations were lowest at S, and were significantly lower at S than at GB ($p=0.008$, $n=234$) or N ($p=0.016$, $n=234$).
E. coli was not significantly different among replicated sampling sites ($p>0.05$, e.g. N1, N2, N3 were not significantly different)
When sampling season split in half (7/27 till 8/22 and 8/27 till 9/24), overall *E. coli* concentrations at all 3 locations were significantly higher in second part of sampling season than during first part: 1.77 ± 0.06 vs. 1.5 ± 0.05, respectively ($p=0.001$, $n=234$)
By sampling site: *E. coli* was significantly higher at GB in the second part of the season vs. first: 1.9 vs. 1.58 ($p=0.005$, $n=78$), and not significantly higher at N ($p=0.198$) or S ($p=0.052$).



SUMMARY OF WATER *E. coli*

Water log *E. coli* (MPN/100ml)	Location		
	N	GB	S
N	78	78	78
Mean	1.72	1.74	1.45
Median	1.63	1.70	1.35
Std. Error of Mean	.08	.06	.07
Minimum	.60	.30	.30
Maximum	3.49	2.84	2.96

When looking at *E. coli* concentrations at sites closest together in pairs “in” and “out” of the barrier (N3 and GB1, GB3 and S1), concentrations were not significantly different

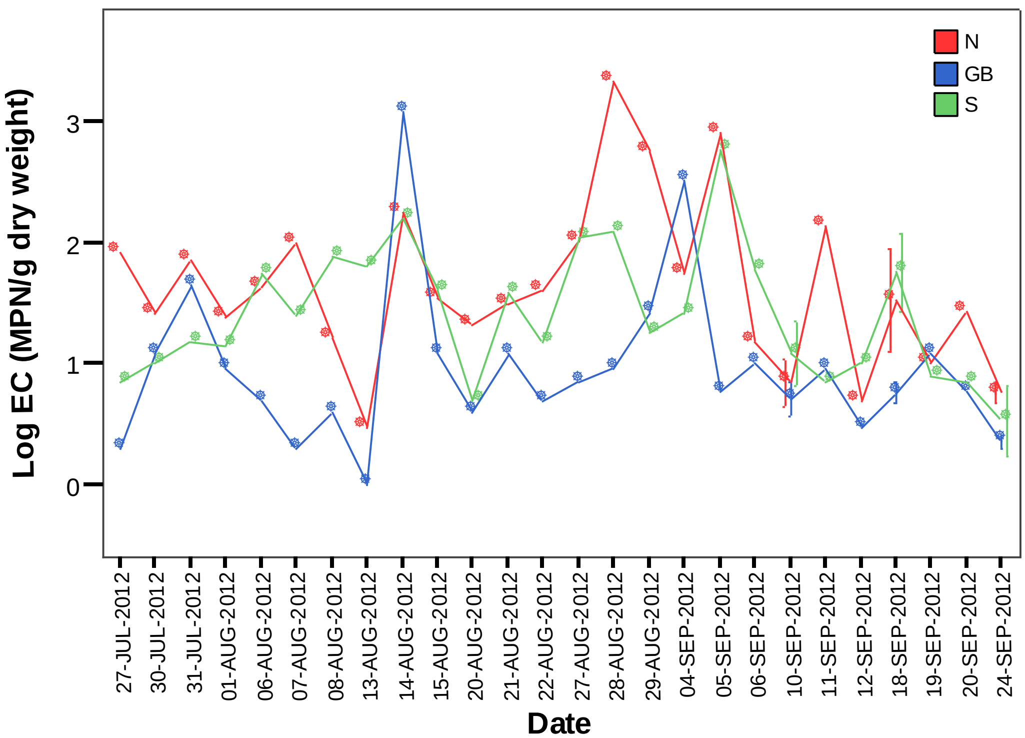
Site	N3	GB1	GB3	S1
Mean Log EC	1.73	1.77	1.74	1.45
Significance	P=0.991		P=0.336	

SAND *E. coli* OVERTIME

Sand *E. coli* was lowest at GB site (mean log *E. coli* ± SE was 0.89±0.11 MPN/g)

Sand *E. coli* was significantly lower at GB than S (p=0.012, *n*=96) or N (p<0.001, *n*=96)

Sand *E. coli* not correlated with lake *E. coli* (generally, by location, nor by season).



SUMMARY OF SAND *E. coli*

Log *E. coli* (MPN/g dry weight)	Location		
	N	GB	S
N	32	32	32
Mean	1.52	.89	1.35
Median	1.42	.78	1.22
Std. Error of Mean	.12	.11	.10
Minimum	.48	.00	.00
Maximum	3.33	3.07	2.76

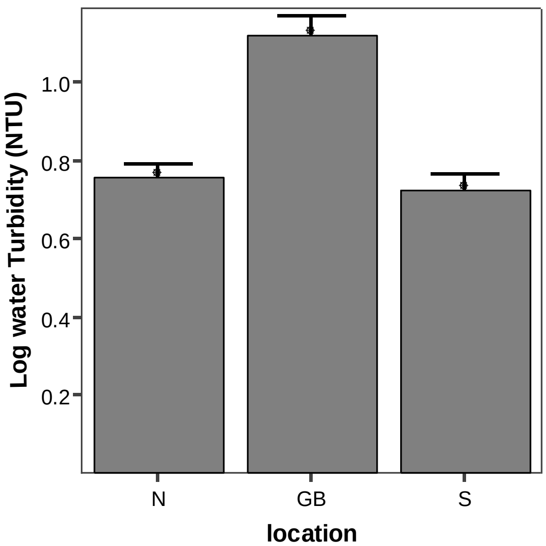
WATER AND SAND TURBIDITY

Water turbidity was significantly higher at GB than at S and N (p<0.001, *n*=233). Mean log water turbidity (log NTU ± SE) was 1.12 ± 0.05 at GB, 0.76 ± 0.03 at N and 0.72 ± 0.04 at S.

Water turbidity was increasing throughout the sampling season at all 3 locations.

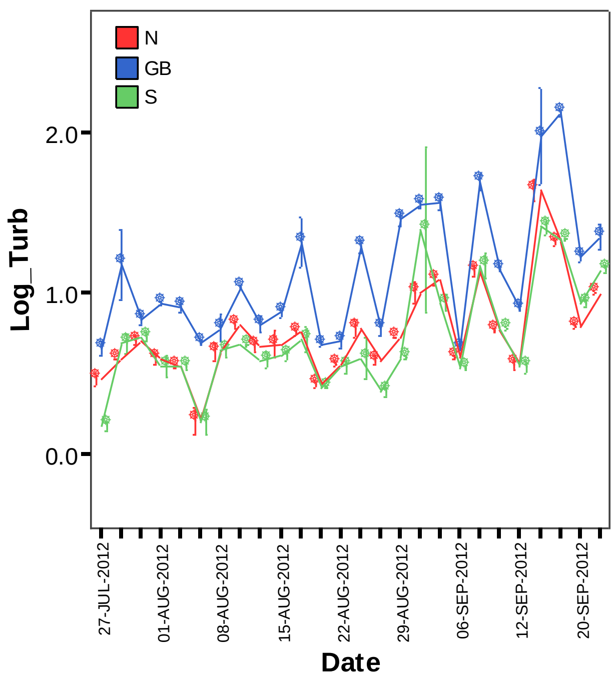
When sampling season split in half, turbidity was significantly higher in the second part of the season (8/27 – 9/24) than in the first part (7/27 – 8/22) at all 3 locations (p<0.001).

The highest increase in turbidity from first to second part of the season was at GB location (mean log NTU 0.88 vs. 1.36)



Water – Log Turbidity (NTU)	Location		
	N	GB	S
N	77	78	78
Mean	.76	1.12	.72
Median	.71	.97	.65
Std. Error of Mean	.03	.05	.04
Minimum	.12	.60	.12
Maximum	1.77	2.58	2.42

WATER TURBIDITY OVERTIME



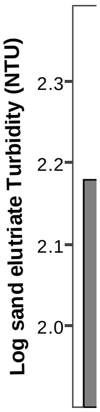
Generally, water turbidity was correlated with *E. coli* (Pearson r=0.467, p<0.001, *n*=233)
Highest correlation of water turbidity with *E. coli* was at GB location

location			Log Turbidity
N	Log E. coli	Pearson Correlation	.412(**)
		Sig. (2-tailed)	.000
		N	77
GB	Log E. coli	Pearson Correlation	.605(**)
		Sig. (2-tailed)	.000
		N	78
S	Log E. coli	Pearson Correlation	.417(**)
		Sig. (2-tailed)	.000
		N	78

When sampling season split in half, highest correlations of water turbidity with *E. coli* were recorded in the second part of the season at all 3 locations
Highest correlation of water turbidity with *E. coli* was recorded at GB (Pearson r=0.706)

			Log E. coli (MPN/100ml)		
			N	GB	S
July_Aug (7/27 – 8/22)	Log Turbidity (NTU)	Pearson Correlation	.178	.206	.351(*)
		Sig. (2-tailed)	.284	.208	.028
		N	38	39	39
Aug_Sept (8/27 – 9/24)	Log Turbidity (NTU)	Pearson Correlation	.511(**)	.706(**)	.419(**)
		Sig. (2-tailed)	.001	.000	.008
		N	39	39	39

Sand elutriate had lowest turbidity at GB, and was significantly lower at GB than at S (p=0.016, *n*=48)



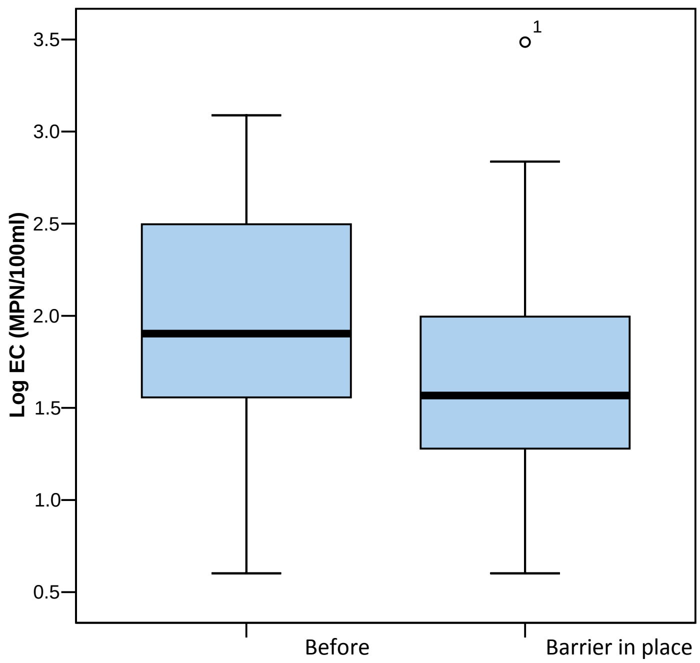
Location	Log EC
N	11
GB	10
S	7
Total	28

Sand elutriate – Turbidity (NTU)	Location		
	N	GB	S
N	16	16	16
Mean	186.17	124.69	244.20
Median	165.00	127.50	208.00
Std. Error of Mean	29.59	13.40	38.93
Minimum	48.00	48.30	35.60
Maximum	451.00	199.00	583.00

Amongst all water samples (*n*=234), 28 times *E. coli* concentrations exceeded 235 EPA standard
Highest *E. coli* concentration was recorded at N1 (3106 MPN/100 ml)
E. coli concentrations exceeded 1000 MPN/100 ml 5 times throughout the sampling season, and they all occurred at N sites
Overall, more exceedances occurred in the second part of the season (8/27 – 9/24) than in the first part (7/27 – 8/22)

date of exceedance	sites	EC
13-Aug-12	S2	357
14-Aug-12	N1	1733
	N2	1414
	N3	517
	GB3	687
22-Aug-12	N3	687
	S1	461
	S2	921
28-Aug-12	N1	326
29-Aug-12	GB1	345
	GB2	365
	GB3	298
4-Sep-12	N1	3106
	N2	816
	N3	3058
18-Sep-12	N1	1159
	N2	690
	N3	520
	GB1	615
	GB2	597
	GB3	403
	S1	545
	S2	615
	S3	775
19-Sep-12	GB1	485
	GB2	464
	GB3	550
	S1	384

COMPARISON OF *E. coli* BEFORE AND AFTER BARRIER INSTALLMENT
At site N3, water samples were collected before barrier installment (6/26 – 7/26) and with barrier in place (7/27 – 9/24)
E. coli concentrations were not significantly different at N3 site before barrier installation than when barrier was in place (p=0.316).
Log mean *E. coli* before barrier installation was 1.95±0.19 (*n*=15), and with barrier in place 1.72±0.11 (*n*=26).

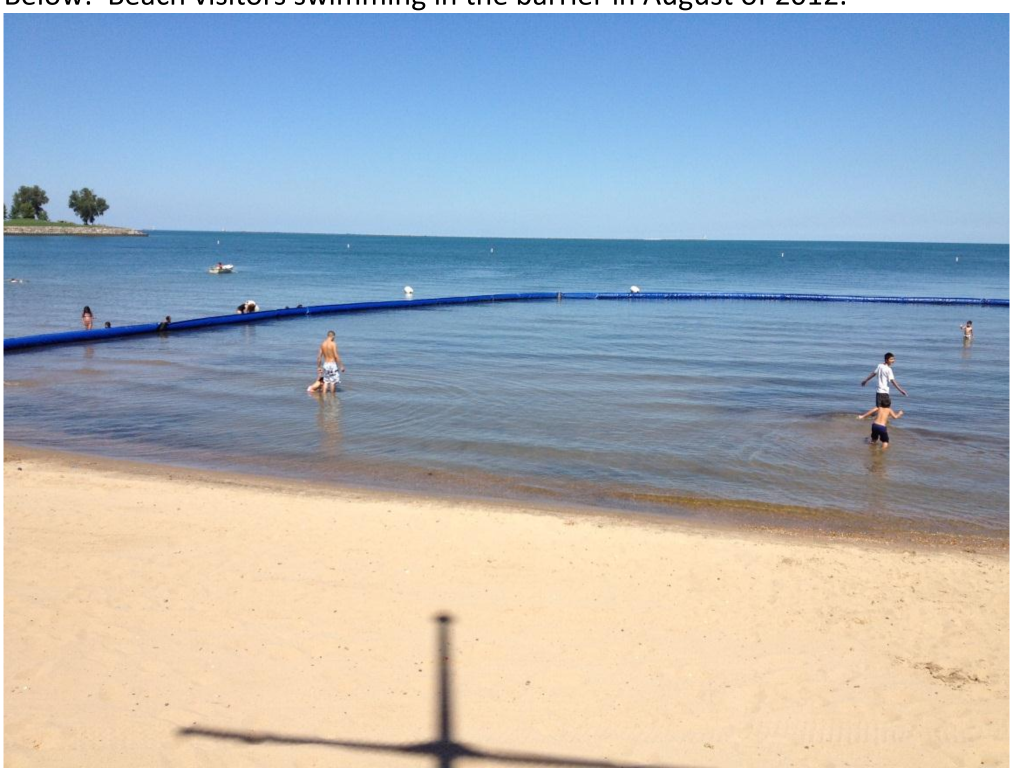


CPD *E. coli* sampling: mean log *E. coli* concentrations inside of the barrier (GB) were not significantly different from samples outside of the barrier (out) (p=0.552). Mean log *E. coli* concentrations ± SE were as follows: 1.7±0.1 (GB, *n*=30) and 1.60±0.12 (out, *n*=30)

Photos

Above: Installation of the barrier in July of 2012.

Below: Beach visitors swimming in the barrier in August of 2012.



Above: Installation of the barrier in July 2012. Floatation billets are shown in the foreground. The barrier arrived disassembled, and staff assembled the sections on site.

Above: Removal of the barrier in October of 2012. In 2012, Lake Michigan experienced record low water levels. Portions of the barrier were buried by sand due to drifting sand and receding water levels. Heavy equipment was needed to remove the large amounts of sand that accumulated on top of the barrier during the project.