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Lakeview Park Beach
Beneficial Use Impairment Assessment
Alternatives Analysis Report

City of Lorain, Ohio

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1.0 INTRODUCTION

Lakeview Park is located approximately 1-mile west of the Black River harbor on City-owned property (Figure 1). The park is leased and operated by Lorain County Metro Parks (LCMP) who manage the park and beach area. The entire park spans 40 acres and consists of two parcels. The project study area focused on the 20-acre parcel north of West Erie Avenue and extended approximately 600 feet north of the shoreline into Lake Erie (Figure 2).

Recreational activities at Lakeview Park Beach include swimming and sunbathing, lawn bowling, beach volleyball, and picnicking. The park includes the historical rose garden, a small concert amphitheater, and space for a restaurant; however at the time of this study the restaurant was vacant. The park is also host to beach volleyball tournaments, triathlons, weddings, and outdoor symposiums focused on cycling and kayaking. Lakeview Park is one of the few public access areas along the lakeshore and is therefore considered one of the greatest assets in Lorain and the central basin of Lake Erie.

Three entities have collected water quality samples at Lakeview Beach: Ohio Department of Health (2008-2010); Cuyahoga County Board of Health (2011-2013); and the Lorain County General Health District (2014-present). Exceedances of state thresholds for fecal coliform counts from the water samples taken along Lakeview Park Beach area have been of increasing concern. Lakeview Beach has had the highest number of advisories as compared to other Ohio Lake Erie beaches since 2011. In compliance with Section 303(d) of the Clean Water Act (CWA) and the BEACH Rule Act, Ohio has set a bacterial action value for *Escherichia coli* (*E. coli)* at 235 cfu/100 mL with a 90-day geometric mean set at 126 cfu/ 100 mL for recreational waters of the state. This indicator bacteria are correlated to the presence of pathogenic bacteria harmful to humans. According to the Ohio EPA June 2018 Integrated Water Quality Report, of the 65 Ohio beaches consistently monitored, Lakeview Park Beach is one of the two Ohio beaches that have consistently failed to meet these thresholds each year between 2013 through 2017.

Recreational use of Lake Erie at Lakeview Park Beach is impaired due to high levels of *E. coli*. This poses a threat to human health based on the presence of *E. coli*, a bacterium associated with the presence of pathogenic bacteria. Coldwater Consulting, LLC (Coldwater) assisted the City of Lorain, Ohio (City) with this beneficial use impairment study at Lakeview Park Beach (Site). The purpose of this study is to characterize water and beach substrate quality and to provide conceptual design alternatives to address *E. coli* within the nearshore area. In addition, this study sought to identify potential primary and secondary sources of *E. coli*, as well as, to evaluate suspected poor circulation surrounding the beach area that may contribute to the beneficial use impairment. Based upon the analysis of these results, conceptual alternatives were developed and evaluated based on their potential to improve water quality along Lakeview Park Beach.

Figure 1: Site Vicinity Map

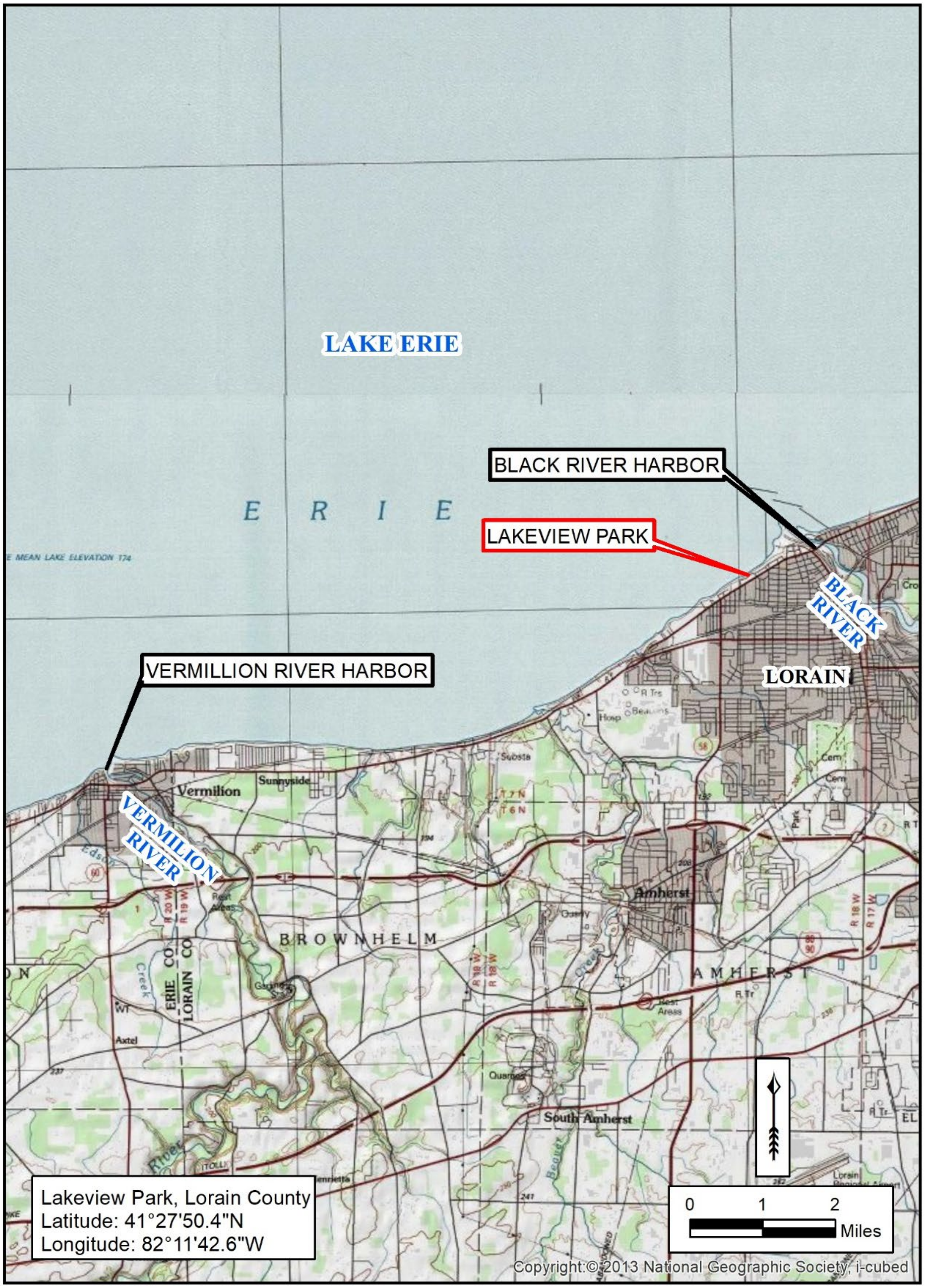
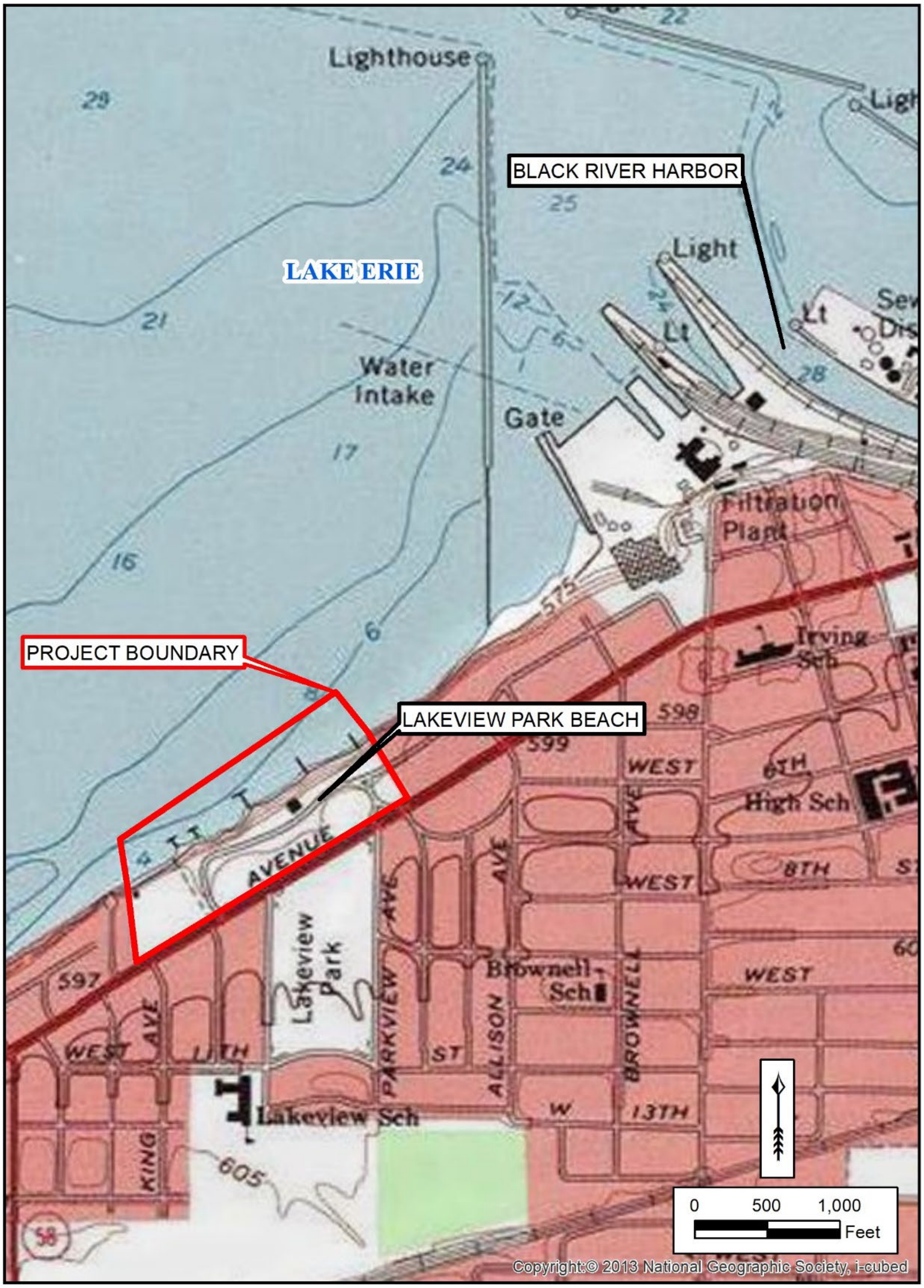


Figure 2: Site Location Map



1.1 Project Objectives

This study's objective is to help the City identify potential projects that may be implemented that will contribute to an improvement in nearshore water quality at Lakeview Park Beach. In order for potential projects to be identified, interim data objectives were deemed necessary to be collected.

- Identify sources of *E. Coli* bacteria. Based on previous investigations and sampling, it is believed that stormwater outfall pipes in the vicinity of the beach may contribute *E. coli* to the beach area. Additionally, the beach area has a significant gull population. Runoff from gull congregation areas may also contribute. The sampling program completed for this project investigated many potential sources so potential projects could focus on the primary loading sources. As part of the sampling program, Microbial Source Tracking (MST) was completed to identify species of the source bacteria. A selected sub-set of samples were subject to MST testing; this would clarify the portion of *E. coli* bacteria that the local gull population may be contributing.
- Gaining an understanding of the circulation of lake water in the nearshore swim area. Poor circulation in this area could contribute to the large number of advisories that are issued. Hydrodynamic modeling of the existing conditions was completed to meet this objective. Additionally, the hydrodynamic model may be used to assess potential projects aimed at improving circulation should it be determined that poor existing circulation contributed to the amount of beach advisories.
- Understanding the operational feasibility of potential projects based on Lorain County Metro Parks as the operator. Potential projects may likely include features added to the park and the beach, as well as configuration changes. Getting feedback from Metro Parks as the operator of the park is crucial to understanding if potential projects and park enhancements may be reasonably implemented.

1.2 Project Approach

In order to prepare this study, the project had 4 primary stages in its approach to develop potential project alternatives. These four stages included development of the sampling program, field data collection and analysis, hydrodynamic circulation modeling, and alternatives development. The study utilized sampling and monitoring data collected over the 2018 swim season (May through September) in combination with simulations from a local circulation model to develop conceptual alternatives addressing the nearshore water quality issue. Each stage is summarized here but explained in more detail later in this report.

Development of the sampling program included reviewing the storm sewersheds, historical sampling data from the three other entities, and a site visit to determine runoff pathways and potential bacteria sources. A desktop review on the local ecosystem was completed. With this information, possible sources of *E. coli* were defined, as well as, the number and location of samples to be taken. A Quality Assurance Project Plan (QAPP) was completed and approved by USEPA for the sampling program.

Field data collection was necessary to confirm sources and concentrations for the creation and calibration of the circulation model, as well as to support the sampling program. Data collected included bathymetric data for the nearshore area as well as topographic data for the breakwaters and beach area. Lake water velocity data was collected as part of the model inputs and to provide a reference for calibration. A local weather station was installed at Lakeview Park Beach to collect data for model development and calibration, as well as for correlation with the sampling program. Water and substrate quality sampling was conducted according to the sampling program; as well as, monitoring ancillary beach conditions (e.g., number of swimmer, algae, dead fish, etc.). Select samples underwent Microbial Source Tracking (MST) which was used to identify source contributors (e.g., human, avian/gull, goose, ruminant, other) to the bacteria loading issue. Further information on field data collection and the sampling program can be found Section 3.

The local, nearshore hydrodynamic circulation model was developed to assess circulation patterns in the vicinity of the beach area that may be contributing to the impaired water quality. The local model was developed and calibrated based on the hydrodynamic and bathymetric survey data, as well as, data collected as part of the beach monitoring activities. The model ran diagnostic simulations using a theoretical dye tracer as a surrogate to *E. coli*. These diagnostic simulations were used to refine the conceptual understanding of *E. coli* transport in the nearshore area of Lakeview Park Beach. Further information on the model can be found Section 4.

Potential solutions to the bacteria loading problem were identified based on the data collected, the model results, and available literature. The solutions were then assessed based on their potential and efficiency at mitigating *E. coli* issues in the nearshore area. The resulting alternatives were intended to facilitate the City's ongoing efforts to improve water quality at Lakeview Beach. Further information on potential solutions can be found in Section 5.

2.0 SITE ANALYSIS

2.1 Background and History

The park was originally bought by the City in 1917 to ensure residents had public access to the Lake. The original park frequently accommodated up to 2,000 visitors who could enjoy the beach area along with a bathhouse, diving boards, and a slide. In 1924 much of these amenities were destroyed by a tornado, including much of the bathhouse. Many efforts were made over the years to renovate the park. In 1932, the Rose Garden was dedicated by local organizations and later renovated in 2005. In 1978, the off-shore breakwaters were constructed to preserve and protect the eroding beach area. It was not until Metro Parks leased part of the land in 2007 that the remainder of the park underwent extensive renovations.

2.2 Site Features:

2.2.1 Geographic Location

This northern parcel is partially surrounded by adjoining neighborhoods to the east and west, with Lake Erie to the north and West Erie Avenue to the south. Upland, the park consists of formal drive aisles, parking areas, and walkways. Other impervious areas include the bathhouse/restaurant, fountain, pavilion, and a concrete platform for events. These areas are interspersed among a combination of open lawn space and partial tree canopy. Of the 3,000-feet of shoreline approximately 1,500-feet is dedicated to a 200-foot wide sand beach area. Three off-shore breakwaters sit approximately 200-feet from the shoreline with a 250-foot jetty to the east and two 130 jetties to the west. These armor structures provide protection against wave energy, littoral drift, beach erosion, and storm surges attributed to the site's open exposure to Lake Erie.

2.2.2 Morphology

The topography of the beach was altered in the late 1970s when 110,000 cubic yards (CY) of upland sand was brought to the site. This coincided with the construction of the three stone breakwaters and jetty. The sand was used to raise the elevation of the beach. The shoreline protection promotes the collection of sand from natural littoral processes. Since 2005, the swim area and area behind the breakwaters has been dredged twice. The dredged material was used on-site for beach nourishment.

2.2.3 Hydrology

Lake Erie water levels are dependent on changes in climate, wind, precipitation, bathymetry, as well as levels of the surrounding Great Lakes. Overall levels fluctuate in response to these changes. The Lake Erie Low Water Datum (LWD) is established at 569.2 feet, IGLD 1985. However, mean water levels are recorded at +2.8 feet and -1.6 feet from the LWD. This indicates the mean tide level is approximately 571.4 feet, IGLD 1985. According the Federal Emergency Management Agency (FEMA) a portion of the beach area is located within a regulated floodplain with a base flood elevation of 576 feet, IGLD 1985.

2.2.4 Stormwater

Stormwater is conveyed through two storm sewer outfalls that flank the outward boundaries of the beach area. These outlets service surrounding residential areas. The bathhouse rooftop conveys runoff was through a drain that discharges directly onto the beach. Erosion rills convey stormwater run-off from the parking area directly onto the beach area.

2.2.5 Climatology

The swim season for Lorain, Ohio occurs between May and September. Temperatures range between 60 degrees and 90 degrees Fahrenheit. June through August are among the hottest months. However, based on NOAA's national weather service, water temperatures typically remain about 10 degrees cooler than ambient air conditions. The average annual precipitation is approximately 39 inches. Wind speed and direction vary over the course of a year. While it has been generally thought that the predominant wind direction is from a westerly direction, review of meteorological data for the last 5 years indicates a near equal split in times with an easterly wind as a westerly wind. Winds from 2018 actually were predominately from an easterly direction. The warmer season sees average wind speeds around 8.4 miles per hour.

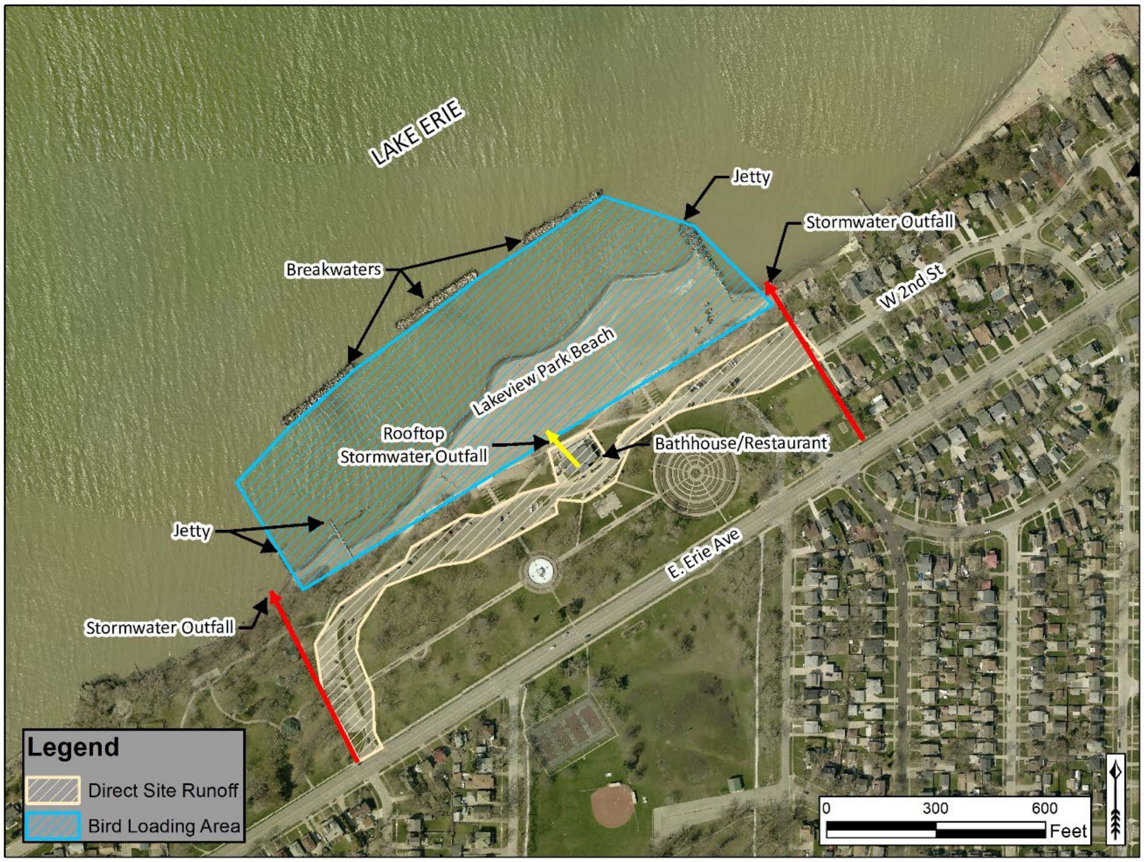
2.2.6 Ecological Habitat

The beach area sees a variety of wildlife including geese, gulls, and fish. Park patrons are allowed to fish from the far east and west reaches of the beach area, as well as, out near the breakwaters. Fish common to the nearshore lake area are walleye, bass, and perch. The park is characterized by its open space and far reaching sightlines that make it an ideal habitat for geese and gulls. Geese are often found loafing within the upland bounds of the park around the parking area, drive aisles, and walkways. Gulls flock to the beach for feeding and loafing. They are typically spotted loafing along the shore, on the breakwaters, or on the roof of the bathhouse. These two avian species are considered more a nuisance than adding to the ecological value of the surrounding area. Their fecal matter contains bacteria that pose a threat to human health. The fecal matter from the avian species present at Lakeview Park Beach has direct contact with the nearby waterway through storm runoff.

2.3 Bacteria Sources

Based upon these site features, input from stakeholders, and information from previous sampling activities, a list of potential sources that may contribute bacteria were identified. These potential sources were then the focus of the project specific sampling program to verify how each may contribute to impaired water quality at the beach. Potential sources of bacteria loading are shown in Figure 3, and include bird areas, stormwater outfalls, and direct runoff. The sampling program consisted of testing multiple locations in various media that may be subjected to bacteria loading from these sources.

Figure 3: Bacteria Source Map



3.0 SAMPLING AND MONITORING PROGRAM

To support the project, an *E. coli* sampling approach was designed to further assess the nature of the *E. coli* bacteria that has plagued the beach with advisories as well as assess potential sources of the bacteria. The general approach was presented in the approved Quality Assurance Plan Project Plan (Brown and Caldwell, 2018). The approach is presented below, along with the sampling/analytical methods employed and the results of the sampling and monitoring program.

3.1 Sampling Locations

The field investigation was designed to assess the levels of *E. coli* bacteria contamination from various possible sources under differing weather conditions. The investigation targeted those locations that are considered most appropriate and relevant to evaluate their net impact to beach conditions. Media sampled and assessed included surface water, nearby stormwater outfalls and associated manholes, surface runoff, groundwater, and beach substrate. Sampling locations are shown in Figure 4. *E. coli* sample results were compared to the Ohio Bacterial Action Value of 235 (CFU/100mL).

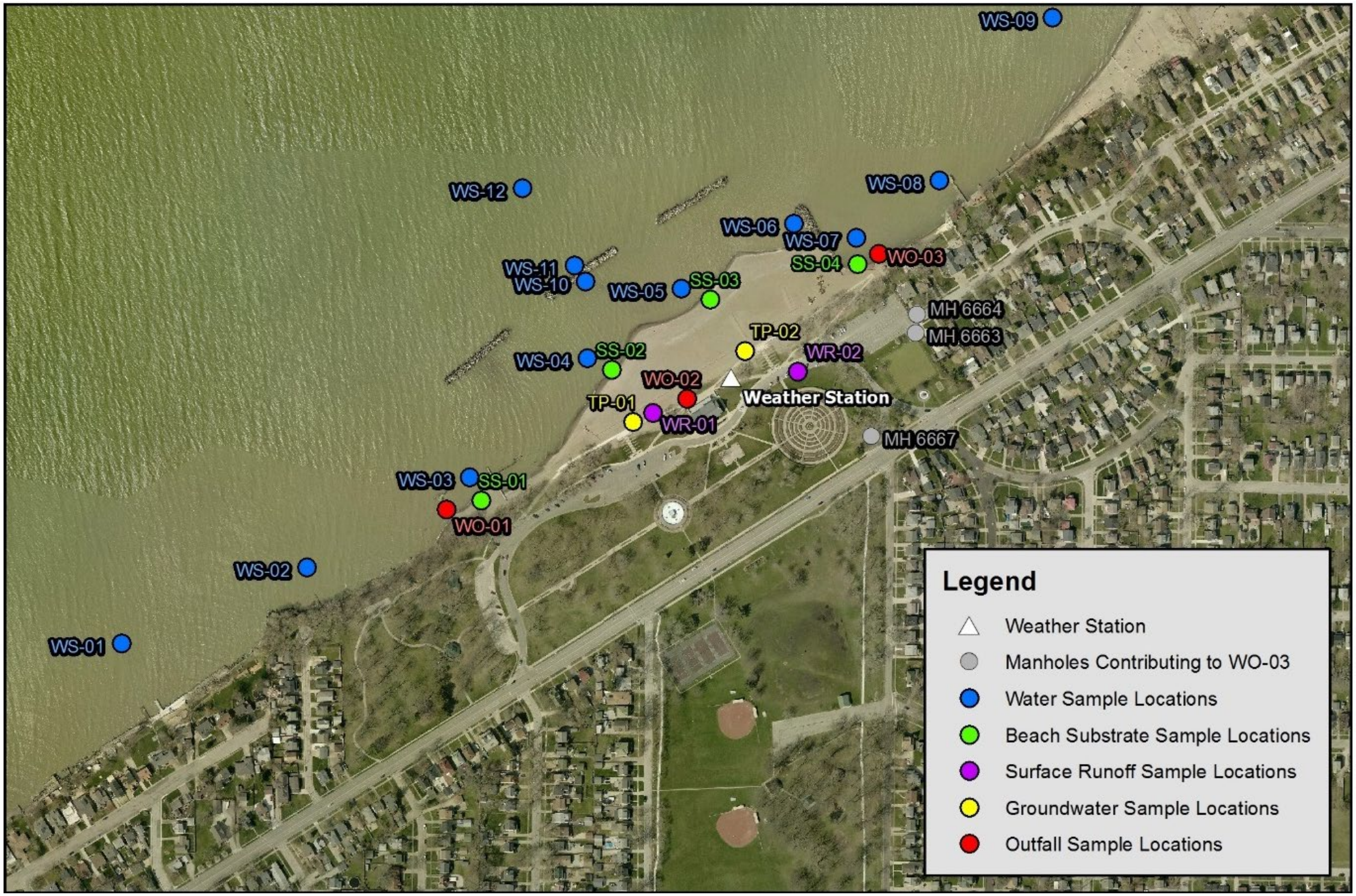
3.1.1 Lake Water Sampling

Sampling was done biweekly from June 7th to August 17th, 2018. Lake water was collected at 12 locations with an inflatable rubber raft (locations WS-01, WS-02, WS-08, WS-09, WS-10, WS-11 and WS-12) or by wading into the water (2-3 feet) (WS-03 through WS-07). The samples were collected from the upper six-inches of water regardless of the total depth of the water at the time of sampling. Field parameters measured at each location included water temperature, pH, dissolved oxygen, conductivity, turbidity, water depth and wave height.

3.1.2 Stormwater Outfalls

Three stormwater outfalls were sampled during this assessment, including two City of Lorain storm sewer outfalls located just west and east of the beach, and an outfall at the head of the beach that drains roof gutters on the bathhouse/restaurant. Runoff from the parking lot area not only sheet flows directly to the beach area, but portions also drain to either outfall. Outfalls WO-01 and WO-02 were sampled at the end of pipe by collecting the sample directly into the sample container(s). Because outfall WS-03 is located beneath a pier, the end of pipe was not accessible; therefore, three manholes that access the three tributaries to this outfall were sampled in addition to sampling the lake water just off the end of the pier. The manholes were sampled using a dedicated/disposable polyethylene cup attached to the end of a telescoping rod to retrieve the water to fill the sample container(s). Field parameters measured at each location included water temperature, pH, dissolved oxygen, conductivity, turbidity and approximate flow rate. Flow rates were estimated by observing the depth of flow in the pipe while collecting the samples.

Figure 4: Sample Location Map



3.1.3 Beach Substrate

Four beach samples locations (SS01-SS04) were sampled four times each, after or towards the end of a storm. The sand substrate composite samples were collected from the wetted zone approximately midway between the edge of the water and the inland extent of the wetted zone. The samples were composited from the upper six inches of wetted sand with a clean trowel and placed in the sample container(s).

3.1.4 Groundwater

Two one-inch diameter slotted PVC temporary piezometers (TP-01 and TP-02) were installed using a hand auger into the shallow water table. Prior to sampling, approximately three piezometer volumes were purged from the piezometer using the bailer and allowed to discharge to the ground surface. The water level within the temporary piezometer was allowed to return to equilibrium (close to the initial reading) prior to collecting the sample. The depth to groundwater was measured to the nearest 0.01 foot within the temporary piezometer using an electronic water level meter. Once the water level stabilized the groundwater was purged and sampled from the temporary piezometer using a ½-inch diameter disposable polyethylene bailer. The piezometer was sampled by bailing and placing the groundwater directly into the appropriate sample container(s). Field parameters measured included water temperature, pH, dissolved oxygen, conductivity and turbidity.

3.1.5 Surface Runoff

Two surface runoff grab locations (WR-01 and WR-2) were sampled five times from parking lot/sidewalk runoff that drained down to the beach. The samples were collected directly into the sample container(s). Field parameters measured at each location included water temperature, pH, dissolved oxygen, conductivity, turbidity and approximate flow rate.

3.2 Techniques and Approach

3.2.1 Sampling Events

Sampling events associated with this assessment were completed between June 7, 2018 and September 7, 2018 to capture data during the swimming/beach season. Sampling procedures followed those described in the approved QAPP and are generally described below for the various media sampled. The approximate sample locations were located using landmarks and a hand-held Global Positioning System (GPS) to ensure the target location could be resampled during future monitoring events. Sample locations are shown on Figure 4. Approximate longitude/latitude of the sample locations are provided in Appendix D. Samples were hand-delivered to NEORSD's laboratory in Cleveland within 1-2 hours of sampling and tested for *E. coli* and MST (certain locations). The time of sampling targeted between 8:00 a.m. and 10:00 a.m. whenever possible.

Sampling the Lake Erie water, outfall and surface runoff locations for *E. coli* during specific weather-dependent events are shown in Table 1. These included dry conditions, first-flush storm conditions, late/post-storm conditions and a specific wind condition that differed from the other weather-dependent events.

Table 1: Weather Dependent Sampling Event Types

EVENT	DESCRIPTION
Dry weather	This sampling event occurred following at least 72 hours of unmeasurable precipitation.
First Flush	This sampling event coincided with the first flush of stormwater from the conveyance system and targeted a storm event early during the 2018 beach season. The flow from the outfalls was directly observed during the storm event to attempt to sample at peak flow.
Post Storm	This sampling event coincided with late or post-storm conditions.
Wind Event	This event was intended to provide a comparative assessment between primary and secondary prevailing wind conditions. The intention was for the dry weather event to coincide with either of these wind conditions while this standalone event would capture data during whichever wind condition is not reflected during the dry weather event.

The samples collected during this assessment are summarized in Table 2. Beach water was sampled at 5 locations twice per week for eight weeks from June 27-August 17, 2018. To broaden week day coverage, these samples were taken on Tuesday and Friday or Wednesday and Saturday of alternating weeks. Beach sand was sampled within the wetted zone, and shallow groundwater sampling was at the head of the beach.

Table 2: Sampling Program Summary

TYPE OF EVENT	DATE(S) OF SAMPLES	NO. OF SAMPLES FOR *E. COLI* TESTING	NO. OF SAMPLES FOR MST TESTING
Dry Weather	June 7, 2018	12 Lake Water 1 Ambient Blank	1
First Flush	June 19, 2018	12 Lake Water 1 Stormwater Outfall 1 Manhole 1 Ambient Blank	3
Supplemental First Flush	August 29, 2018	2 Stormwater Outfall 3 Manhole 1 Roof Drain Outfall 2 Surface Runoff 1 Roof Drain Outfall	5
Late/Post Storm	June 21, 2018	12 Lake Water 1 Stormwater Outfall 1 Manhole 4 Beach Sand 1 Groundwater 1 Ambient Blank	1
Wind	August 28, 2018	8 Lake Water 1 Stormwater Outfall	1
Bi-Weekly	June 27, 2018 - August 17, 2018	80 Lake Water 2 Stormwater Outfall	1
	TOTAL SAMPLES AQUIRED	**148**	**12**

3.2.2 Supplemental Data

Lorain County Public Health (LCPH) sampled *E. coli* daily (Monday through Thursday) from one location within the swim zone at the beach through the beach season (Appendix E).

The units for the *E. coli* data generated by LCPH and the Ohio Bacterial Action Level are in colony-forming units (CFU) per 100 milliliters, or CFU/100 ml, whereas the units for *E. coli* data provided by the Northeast Ohio Regional Sewer District (NEORSD) Laboratory for this assessment were in Most Probably Number (MPN) per 100 milliliters, or MPN/100 ml. The key difference between CFU and MPN is that CFU is calculated from the bacterial and fungal colonies growing on a solid agar plate while MPN is calculated from viable bacteria growing in a liquid medium. These units are generally considered to be interchangeable and have been considered as such for this assessment.

3.2.3 Ancillary Beach Conditions

Ancillary beach conditions were recorded during each event and at each location as appropriate, and included the following:

- Field parameters for water samples at each location, including water temperature, pH, dissolved oxygen, conductivity, turbidity, flow rate (outfalls and surface runoff only), width of wetted zone of beach, water depth and wave height.
- Ambient Weather at the beach, including air temperature, rainfall, wind speed and wind direction. Prior to beach season a wireless/Wi-Fi weather station was installed at Lakeview Park to monitor climate conditions during the sampling program and beach season. Parameters continuously monitored/recorded included air temperature, humidity, barometric pressure, dew point, rainfall, rain intensity, wind speed, wind direction. In addition to the Park Manager maintaining a monitor for the weather station in his office, the weather station was also registered with Weather Underground to allow real time remote access to the weather station data any time.
- General observations of beach conditions, including quantity of gulls and/or geese and other animals (dogs, etc.), number of swimmers and non-swimmers, presence of algae on beach or in the water, and number of dead fishes, were recorded on the survey forms included in Appendix C.

3.2.4 MST Analysis

All sample locations were analyzed for *E. coli* with a selected subset of those samples also subjected to MST analysis to identify likely bacterial origins (e.g., human and avian gull). The *E. coli* data provided total bacteria counts; whereas, the MST analysis was used to speciate the bacteria. The general understanding leading up to this investigation has been that the observed elevated levels of bacteria are related to the abundant gull population that inhabits the beach area during the beach season. Therefore, the MST for this assessment initially included analysis of specific bacteria samples to determine relative counts of human bacteria, avian gull bacteria and "other" bacteria.

The process for determining which samples would be subjected to MST analysis consisted of the following:

- Upon receiving and filtering each sample, the laboratory immediately froze a portion of the sample filter for possible later MST analysis.

- Once all the *E. coli* results for the samples from the specific event were reviewed, the pre-determined number of samples were subjected to MST analysis, based on such criteria as the concentration of *E. coli* and sample location to determine both the species origin of the bacteria and the physical source, such as outfalls, surface runoff, groundwater, upwind/up-current, etc.

- Generally, when working with MST data, scientists/researches prefer to use multiple rounds of data over time to help normalize the inherent variability in sampling and testing for bacteria and subsequent speciation. However, based on the limitation of time and funding for this study, this level or rigor was not possible. However, for the purposes of this assessment there is confidence that the data collected are sufficient to provide a reasonable interpretation of site conditions.

3.2.5 Deviations from QAPP

The following are deviations from the original sampling program described in the QAPP:

- During the first flush sampling event conducted on June 19, no surface runoff from the parking areas or discharge from outfall WO-01 (bathhouse roof drain) was observed, but it was apparent that flow had occurred during the storm event. Therefore, these locations were sampled during the supplemental first flush sampling event completed on August 29.

- Only five of the originally proposed six Lake Erie water sample locations for twice/week sampling were used. One location (WS-08) was omitted from the program because it could not be accessed safely from shore.

- Outfall WO-03 (east end storm water sewer outfall) is located under a pier and could not be sampled directly. Therefore, the nearby manhole (MH-6663) for one of three storm sewer tributaries that feed this outfall was sampled, and a sample of lake water at the end of the outfall pier was also sampled. During the supplemental first flush sampling event completed on August 29 all three tributary manholes (MH-6663, MH-6664 and MH-6667) were sampled as well as the end of the pier to better evaluate this outfall.

- Only one of the originally proposed two temporary piezometers could be installed at the head of the beach (TP-02 could not be installed). After several attempts at hand-augering into the shallow water table at the western proposed location, refusal was repeatedly encountered at a depth of approximately five feet below ground surface and no shallow groundwater was encountered at that depth.

- During the wind event sampling on August 28, five Lake Erie sampling locations were not sampled due to rough water and unsafe boating conditions for the inflatable rubber raft. These locations were those located furthest offshore and from the beach and included WS-01, WS-09, WS-10, WS-11 and WS-12.

- Due to efficiencies during the sampling program, a modest budget savings was realized that afforded the ability to order additional MST testing for the ruminant (grazing animals such as deer, cattle, sheep, etc.) and goose DNA markers to aid in the *E. coli* source evaluation. Six of the 12 samples identified for MST testing were also tested for the ruminant marker, and two of these samples were also tested for the goose marker.

3.3 Results

The findings from this assessment are presented and discussed in the following subsections, including the *E. coli* results, the MST results and the subsequent summary of potential sources of the *E. coli* observed at Lakeview Beach.

3.3.1 Escherichia coli

In order to better visualize the results for the sampling program, Figures 5 through 7 show the *E. coli* results for the dry, first flush and wind events, respectively. The results from these events allowed the team to develop an understanding regarding source contributions. These observations are presented following the figures. The full *E. coli* field data generated from this assessment are summarized in the Tables included in Appendix B. These include data for lake water, outfalls, runoff, beach sand and groundwater. The *E. coli* laboratory reports are contained in Appendices F and G.

Figure 5: Sampling Event Data – Dry Weather Event (June 7, 2018)

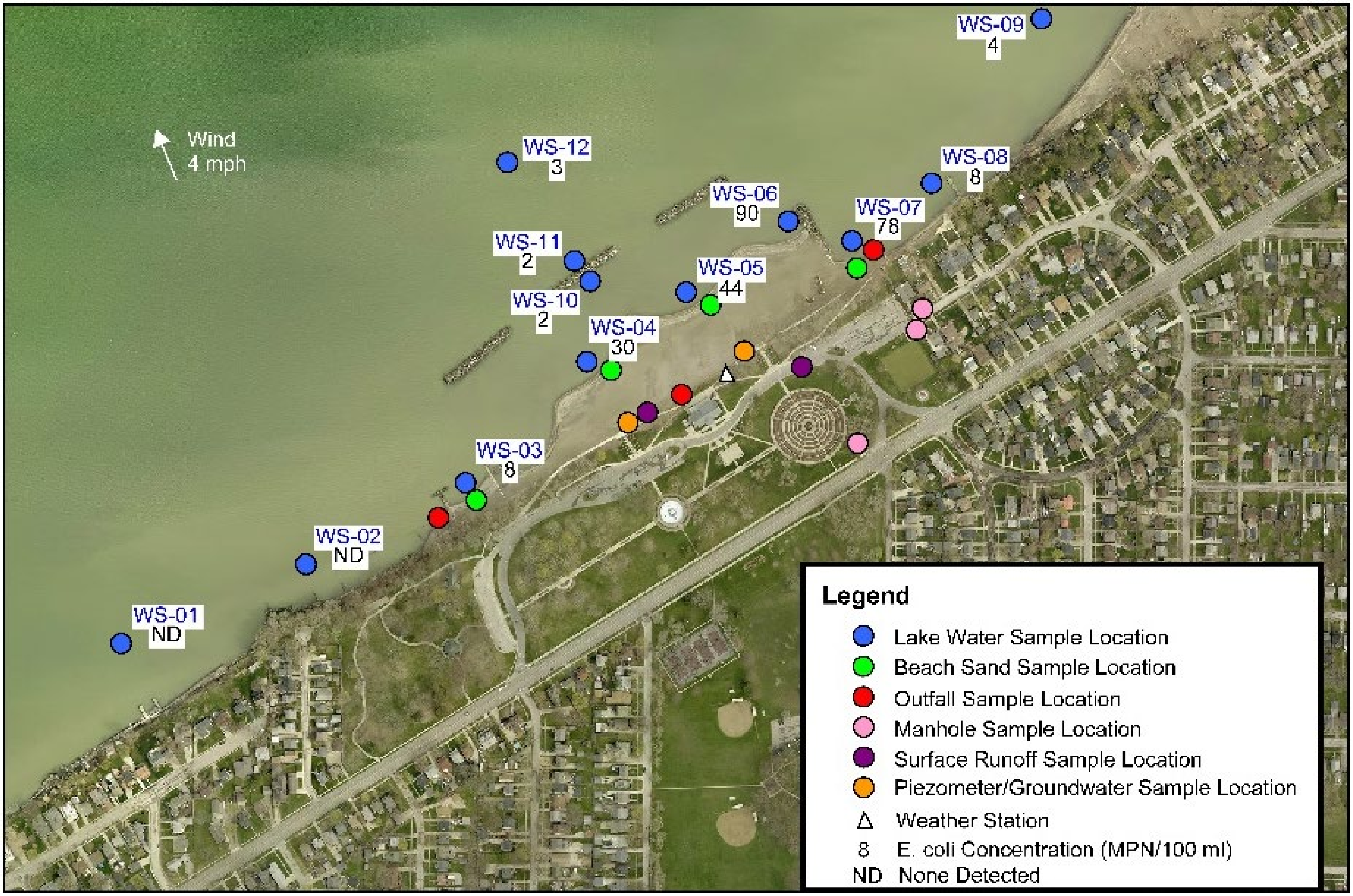


Figure 6: Sampling Event Data – First Flush Event (June 19, 2018 – Supplemental Date Aug. 29, 2018)

Figure 7: Sampling Event Data – Wind Event (August 28, 2018)

The following findings and observations were noted in the data:

- *E. coli* bacteria concentrations in the lake water were generally higher in the samples collected along the beach than those remote samples to the east and west of the beach and those to the north outside of the breakerwaters.

- Generally, *E. coli* concentrations were higher during or immediately following rain events and lower during dryer periods

- Correlating *E. coli* concentration versus wind direction was difficult since the expected westerly prevailing wind direction was rarely encountered during the sampling program. Based on the available data, in general the higher *E. coli* concentrations appear to be more related to the timing of rain events than wind direction.

- An obvious correlation between *E. coli* concentration and number of gulls/geese on the beach was not observed; however, making this comparison is complicated by the transient nature of these birds at the beach.

- The east and west storm sewer outfalls are significant contributors of *E. coli* to the near-shore lake water; however, their contribution appears to be largely limited to the first flush following significant rain events. The east end outfall (WO-03) measured 7,000 MPN/100 ml of *E. coli* during the primary first flush event; the manholes for the three tributaries to the outfall contributed *E. coli* concentrations of 1,950 (MH-6667), 5,380 (MH-6663) and 12,460 (MH-6664) MPN/100 ml for the supplemental first flush event. The west outfall measured 34,440 MPN/100 ml during the primary first flush event and 241,960 MPN/100 ml for the supplemental first flush event.

- Elevated *E. coli* concentrations ranging from 1,342 to 7,012 MPN/100 ml were reported for the four beach sand samples collected within the wetted zone along the shoreline of the beach, with the highest concentration corresponding to the active swim zone.

- Surface runoff from the parking lots and roof drain outfall from the bathhouse/restaurant are contributors to the bacteria concentrations at the beach, based on the reported *E. coli* concentrations of 1,326 and 344 MPN/100 ml for the two surface runoff samples, and 330 MPN/100 ml for the roof drain outfall. However, these locations only flow during and immediately following significant rain events, and therefore their contribution is limited in duration and to the upper portion of the beach nearly two hundred feet from the shoreline.

- *E. coli* bacteria was measured in the shallow groundwater sample collected at the head of the beach at a concentration of 148 MPN/100 ml, suggesting a minor contribution from groundwater to the beach zone. In fact, the observed concentration may be the result of surface runoff infiltration following rain events.

- The *E. coli* data generated during this assessment were compared to those data collected by LCPH for those days where both entities collected a sample from the same general location within the swim zone. That comparison is presented in Table 3. As the table indicates, the two data sets are relatively comparable, with no pattern of inconsistency apparent i.e., one data set consistently yielding much higher results than the other.

Table 3: Sampling Program vs. LCPH Sample Results

Date	Lorain County Public Health Sample Concentration (cfu/100 ml)	Brown and Caldwell Sample Concentration (MPN/100 ml)
June 7, 2018	25.9	44
June 19, 2018	>2,400	1,950
June 21, 2018	29.5	96
June 27, 2018	387.3	359
July 3, 2018	727.0	893
July 11, 2018	313.0	399
July 17, 2018	>2,400	17,820
July 25, 2018	>2,400	2,590
July 31, 2018	248.1	133
August 8, 2018	1,299.7	1,642
August 14, 2018	816.4	1,590
August 28, 2018	260.2	304

3.3.2 Microbial Source Tracking (MST)

Table 4 summarizes the MST results for those samples selected for MST analysis; full numeric results with the rational and environmental conditions for each sample including the rationale for sample selection are provided in Table 8 in Appendix B. The MST laboratory reports are provided in Appendix F. The general observations based on the MST results are summarized following Table 4.

Table 4: MST Results Summary

Area	Sample Location	Rationale for MST Testing	E. coli Conc. (MPN/100 ml or g)	MST Results (Copies per 100 ml or 0.25 g)					
				General (GenBac)	Human HF183	Human gyrB	Gull Cat 998	Ruminant (e.g. Deer)	Goose CGOF2 Bac
Swim Zone	**WS-04**	First Flush Event highest E. coli concentration	8,520	Medium	ND	ND	Low		
	WS-05	First Flush Event third highest E. coli concentration. Routinely sampled by Heath District.	1,950	Medium	ND	ND	Low	ND	ND
	WS-05	Wind Event with E. coli exceedance. Routinely sampled by Health District.	304	High	ND	ND	ND	ND	ND
	WS-06	Dry Event highest beach water E. coli concentration.	90	High	ND	ND	Medium	-	-
West Outfall	**WO-01**	First Flush Event high flow rate (200 gpm) and high E. coli concentration.	34,440	High	Medium	ND	ND	ND	-
	WO-01	Supplemental First Flush Event high flow rate (300 gpm) during rain storm and high E. coli concentration.	241,960	High	ND	Low	ND	ND	-
East Outfall	**WO-03 (End of Pier)**	Supplemental sample taken during first Biweekly Event at end of outfall pier during rain/wet period and discharge. High E. coli concentration (38,730).	38,730	High	Low	Low	Low	ND	-
	WO-03 (End of Pier)	Supplemental First Flush Event during rain storm.	2,690	High	ND	ND	ND	ND	-
	MH-6663	Supplemental First Flush Event during rain storm.	5,380	Low	ND	ND	ND	-	-
	MH-6664	Supplemental First Flush Event during rain storm.	12,460	Medium	ND	ND	ND	-	-
	MH-6667	Supplemental First Flush Event during rain storm.	1,950	Medium	ND	ND	ND	-	-
Wetted Beach Sand	**SS-03**	Post/Late Storm Event beach sand sample with highest E. coli concentration.	7,012	Low	ND	ND	Low	-	-

ND=Not Detected Low=1-100,000 copies/100 ml Medium=100,001 -1,000,000 copies/100 ml High=>1,000,000 copies/100 ml

- Only gull and non-specific bacteria were detected in the four beach water samples (WS-04, WS-05 and WS-06) and one beach sand (SS-03) sample that were subjected to MST analysis. No human bacteria was detected, and no ruminant or goose bacteria were detected in the two beach water samples tested for them. Because the non-specific bacteria copies are so much greater than the gull bacteria count, there is likely another significant source of the bacteria other than gull, human, ruminant or goose.

- Human and non-specific bacteria were detected in the west end outfall (WO-01) during first flush, with the non-specific portion again being the majority and suggesting another significant source of bacteria other than human, ruminant or gull. However, the amount of the human bacteria identified is significant and reflective of a possible sewage contribution to the storm sewer.

- Human, gull and non-specific bacteria were all detected in the east end outfall (WO-03) during a rain event on June 27 with the non-specific fraction again being the majority. No ruminant bacteria was detected in this sample. The fact that the west outfall (WO-01) had human and no gull bacteria whereas the east outfall had both is not surprising. The sample from the west outfall was from the end of pipe (EOP) before the discharge hit the lake water whereas the sample from the east outfall was from lake water at the end of the outfall pier (there is no direct access to the EOP for the east outfall), so there was some mixing among the discharge and lake water. Again, the much greater non-specific bacteria counts versus the human and gull bacteria counts suggest a significant bacteria source other than human, gull or ruminant. The sample collected from the east end outfall on August 29, during a supplemental first flush event, indicated a high non-specific bacteria count with no human, gull or ruminant bacteria detected. In addition, samples from the nearby manholes for the three sewer tributaries (MH-6663, MH-6664 and MH-6667) that feed WO-03, also collected during the supplemental first flush event, indicated significant non-specific bacteria counts but no human or gull bacteria detected.

- A significant portion of the "non-specific" bacteria identified by the MST testing remains unknown and cannot be fully accounted for by the human, gull, ruminant or goose bacteria counts, suggesting that there is at least one other significant source of the bacteria that has been detected.

3.4 Conclusions

Based on the results of the assessment, potential sources of the *E. coli* bacteria that has plagued Lakeview Beach with high bacteria beach advisories include the following:

- The storm sewer outfalls located immediately west and east of the beach.

- Gull and geese feces from the regular presence of significant numbers of these birds on the beach.

Minor contribution to *E. coli* concentrations within the swim zone at the beach may be related to the following:

- Surface runoff from the parking lot and sidewalks, and bathhouse/restaurant roof gutter discharge, during and immediately following significant rain events.

Although not directly contributing to elevated *E. coli* bacteria within the swim zone, poor circulation between the beach and breakwaters may be allowing bacteria to linger in this area rather than being flushed further out into the lake where it would dissipate. Investigations into this are covered further in this report in Section 4.

4.0 MODELING OF EXISTING CONDITIONS

Details regarding the development and of the hydrodynamic circulation model can be found in the report from Geosyntec Consultants included as Appendix A to this report. A brief summary of the model development and analysis is included here.

4.1 Approach

There is a need to evaluate the suspected poor circulation of beach water resulting from the current breakwater configuration offshore. A nearshore circulation model of Lake Erie was developed to simulate the circulation patterns in the nearshore area of Lakeview Park Beach. The model was calibrated to the surveyed velocity data to match measured data. A combined hydrodynamic model and wave model were used to evaluate both water levels and currents, as well as wind-driven waves. Various flow inputs, and *E. coli* loadings from the sources, were necessary to be included in the model to represent the movement of *E. coli* thought the model area. *E. coli* was represented as a theoretical dye tracer. This tracer does not factor into decay, only transport, therefore it may be considered a conservative representation. The results from the modeling were to be used to aid in the understanding of existing circulation patterns, as well as to aid in the evaluation of potential alternatives.

4.2 Data Collection and Acquisition

The development of the nearshore circulation model required data which were either collected at the site or acquired from existing sources. These data included bathymetry, nearshore velocity measurements, meteorology, and *E. coli* data.

Bathymetry data was used for the development of the nearshore circulation model. Offshore coarse data was obtained from the National Oceanic Atmospheric Agency (NOAA) National Geophysical Data Center. Nearshore fine resolution data was collected as part of this project. The regions of offshore and nearshore bathymetry data are shown in Figure 8.

Figure 8: Bathymetric Data Limits

Velocity data were collected in the nearshore region of Lakeview Park Beach on June 13, 2018 on the inner side of the breakwaters. Velocity data were collected from a kayak using an Acoustic Doppler Profiler (ADP) in the nearshore study area.

The circulation model metrological input data includes precipitation, air temperature, relative humidity, barometric pressure, wind speed and direction, cloud cover, and solar radiation. A weather station (station ID: KOHLORAI6)) was installed at the Lakeview Park Beach to collect meteorological data which was downloaded for the month of June to run the model during the period of measured velocity data collection.

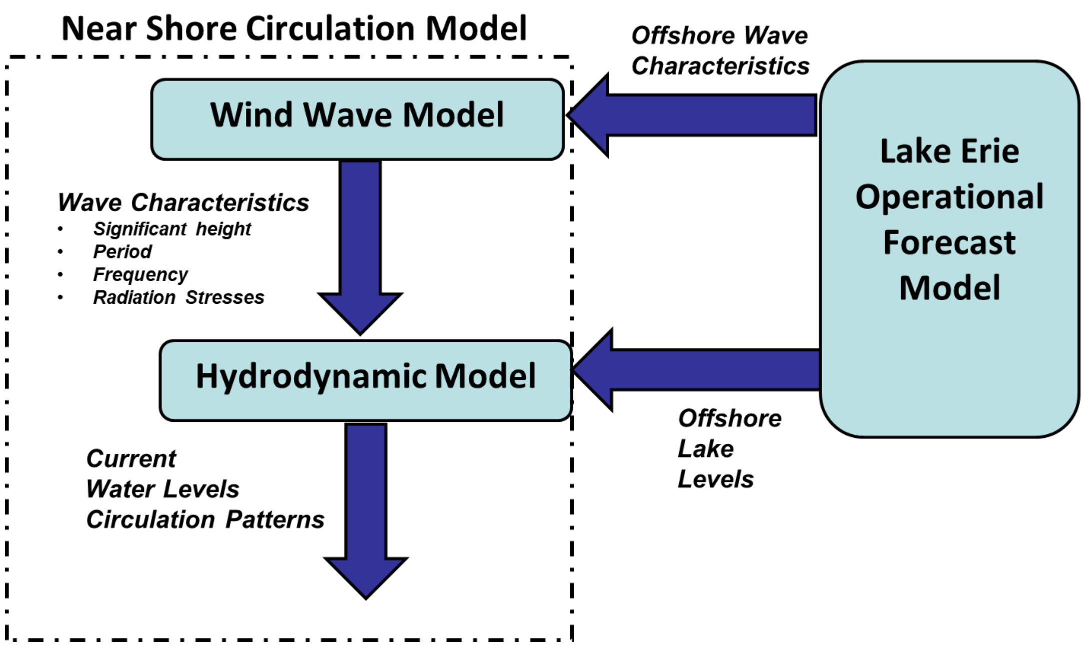
The results of the field monitoring program were used as model inputs. *E. coli* was simulated in the nearshore circulation model as a conservative dye tracer. This was a conservative assumption since the model does not account for the decay of *E. coli* in the natural environment. The major sources of *E. coli* into the nearshore area included stormwater outfalls and birds. Other sources that were included in the model were the Black River itself, and the two wastewater treatment plants (WWTP). The Black River

WWTP is located at the mouth of the Black River and the PQM plant is approximately 3.5 miles to the west.

4.3 Development

The framework for developing a nearshore circulation model consisted of a hydrodynamic model to simulate the change in water level and current, and a wave model to simulate the impact of wind-driven waves. The Lake Erie Operational Forecast Model developed by National Ocean and Atmospheric Agency (NOAA) was used to provide the boundary input for both hydrodynamic and wave model. The modeling framework is shown in Figure 9. The hydrodynamic model framework selected for this study is the Environmental Fluid Dynamics Code or EFDC. The wave model framework used for this study is Simulating Waves Nearshore (SWAN). The frameworks were coupled using the EFDC DSI Explorer Graphical User Interface (GUI) Ver 8.1.

Figure 9: Model Framework Development



In order to evaluate the existing conditions, a baseline modeling scenario was determined. The baseline scenario represents a 2-week period during the sampling period that best represents typical conditions. Therefore, a two-week time period that contained wet weather and dry weather, as well as varying wind directions was identified. Additionally, this baseline time period should include dates samples were actually taken to better provide a higher level of certainty in the *E. coli* loadings used in the model simulation. Based on these criteria the time period between June 18, 2018 and July 1, 2018 was selected as the baseline time period. Table 5 summarizes the weather conditions during this baseline time period.

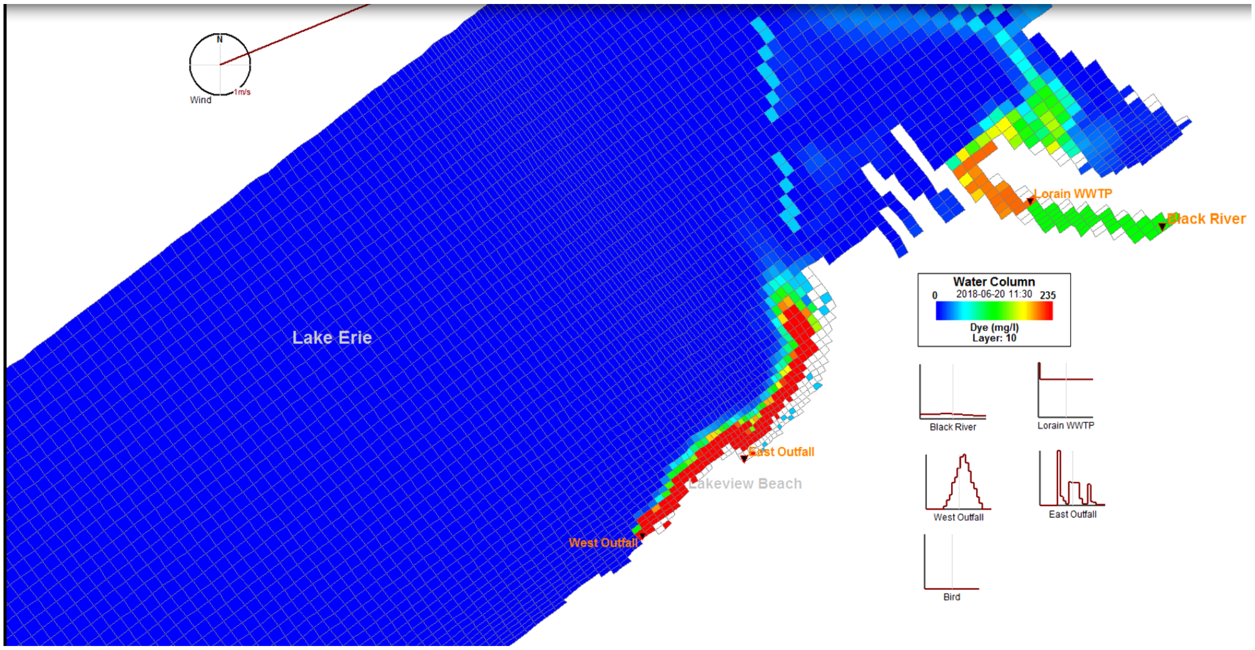
Table 5: Baseline Time Period Weather Summary

Date	Avg. Wind Speed (mph)	Wind Direction	Total Precipation (in)
6/18/2018	8.21	SW	0.28
6/19/2018	8.18	E	1.44
6/20/2018	5.47	ENE	0.21
6/21/2018	5.90	E	0
6/22/2018	4.99	ESE	0.27
6/23/2018	6.16	SSW	0
6/24/2018	9.55	SW	0
6/25/2018	7.66	ENE	0
6/26/2018	4.99	SE	0
6/27/2018	8.06	SW	0.51
6/28/2018	8.60	W	0
6/29/2018	4.36	SSE	0
6/30/2018	5.05	SSW	0
7/1/2018	4.98	SSE	0

4.4 Results

A snapshot of the Baseline Model Scenario results is shown in Figure 10 for a particular time step during a rain event and westerly wind. These results show that the loadings from the Black River and Black River WWTP do not impact E. coli levels at the Lakeview Park Beach. This is because the plume from the Black River and WWTP does not reach Lakeview Park Beach due to the restriction of breakwater structures. This was observed for both easterly and westerly winds. Stormwater outfalls and birds discharge relatively close to the beach, and hence the larger impact on the beach water quality. Flushing time for the loading from stormwater outfalls and birds is dependent on wind speed and direction and ranges from 5 hours to 37 hours based on the Baseline Model Scenario simulation. The breakwaters in front of the beach appear to have little impact on the flushing and circulation; movement appears to be primarily influenced by the predominately easterly and westerly winds. With these wind directions being relatively parallel to the breakwaters, they generate circulation though the swim area. Circulation is more limited with the less frequent northerly and southerly winds.

Figure 10: Baseline Model Scenario Results – Rain Event Snapshot



Colored cells represent E. coli concentrations. Loading from the Black River and WWTP do not enter the beach area. However, bird loadings and stormwater outfall loadings do (red cells indicate concentrations above the advisory level).

5.0 ALTERNATIVES ANALYSIS

5.1 Objectives

The primary objective of this study was to identify potential projects that may reduce the number of water quality advisories at Lakeview Beach due to elevated levels of *E. coli.* Findings from the sampling program and the baseline circulation model were used to guide the identification of potential projects. The key findings included:

- The majority of bacteria loading to the beach area was contributed by the two stormwater outfall pipes.
- Birds (gulls) contributed a significant percentage of bacteria to the beach area.
- While the Black River contributed a large load to Lake Erie, it did not contribute significantly to the water quality at the beach area; circulation modeling indicated that the existing breakwaters in the harbor prevent river discharge from reaching the beach during both easterly and westerly winds. A similar pattern was identified for the WWTP discharges.
- Circulation within the nearshore beach area is highly dependent upon the direction of the wind. The three existing breakwaters do limit circulation for northerly or southerly winds only; they have little impact on the predominantly easterly and westerly winds.

Potential project alternatives were therefore aimed to address these observations in the data. Four different types of alternatives were identified and considered in the identification and development of project alternatives. Within each of the 4 alternative types, multiple approaches or activities were considered. These are summarized in Table 6. Each type of alternative considered is briefly described in the following sections.

Table 6: Alternative Control Types

Type 1 - Stormwater Management
Onsite Treatment
Outfall Relocation
Green Infrastructure (Dunes)
Type 2 - Bird Management
Anti-Loafing Devices
Scare Tactics
Type 3 - Circulation Improvements
Pumps/Circulators
Alter Existing Structures (Breakwaters, Jetties)
Type 4 – Operations and Maintenance
Beach Management
Public Facing Activities

It should be noted that the sampling data did identify a significant human portion of *E. coli* in the storm water outfalls. The project alternatives identified in this report are not meant to address the human component of the bacteria. Actions to address the human component are beyond the scope and purpose of this study. As such, the City is pursuing other avenues to address this fact. All alternative concepts presented assume that the human component of bacteria in the stormwater has been mitigated.

5.2 Alternative Type Summary

Due to the fact that the stormwater outfalls and the birds were found to have the most impact on the water quality at the beach area, Alternative Types 1 and 2 are considered the primary approaches since these are to be applied to directly mitigate the bacteria loading. Alternative Types 3 and 4 may be considered secondary approaches. These are to be applied in conjunction with the primary types to increase the overall effectiveness at reducing bacteria counts. Each of these alternative types were presented and discussed with project stakeholders during a meeting on March 20, 2019. The merits, applicability, and feasibility of each of the types and approaches were discussed.

5.2.1 Stormwater Management

Sampling data confirmed that the east and west outfalls are major sources of indicator bacteria, therefore managing their discharge was one of the primary approaches considered for alternatives development. The stormwater discharge from the pipes could be managed through the treatment of the discharge as well as relocating the discharge to areas away from the beach. Concepts for both of these approaches are discussed below.

Although not as large of a source of bacteria loading to the beach, runoff from the park area was still found to contain *E. coli*. Local stormwater management could be improved through the use of green infrastructure techniques, particularly the construction of dunes in the beach area.

Treatment System

Improvement to water quality could come through on-site treatment of the stormwater discharge. Treatment systems would need to be installed at both the western and eastern outfalls. The system would consist of a diversion structure, a pre-treatment device and a disinfection system. The buried pre-treatment device will consist of a trash, debris and suspended solids removal system. The disinfection system could utilize an ultra-violet (UV) treatment, ozone, or an anti-microbial sponge. Finally, a small wetland area could be provided near the western outfall for tertiary treatment of the discharge.

The systems can only be sized to capture dry and smaller wet weather flows through the use of a diversion structure to divert flow into the treatment system. This could be achieved through a new 50-foot connector pipe to divert flow from the existing 36-inch pipe and to the pre-treatment system. The existing 36-inch pipe will continue to be used for high flows. High flows will bypass the treatment system by flowing over the diversion structure and to the existing outfall on Lake Erie. This is a typical safeguard to prevent overloading the treatment system. A conceptual layout for the western outfall is shown in Figure 11Since the treatment systems can only treat a small fraction of the problematic flows, they were removed from consideration due to cost, operational, and performance concerns. Therefore, treatment was not to be included in alternatives to be prepared.

Figure 11: West Outfall Treatment Concept

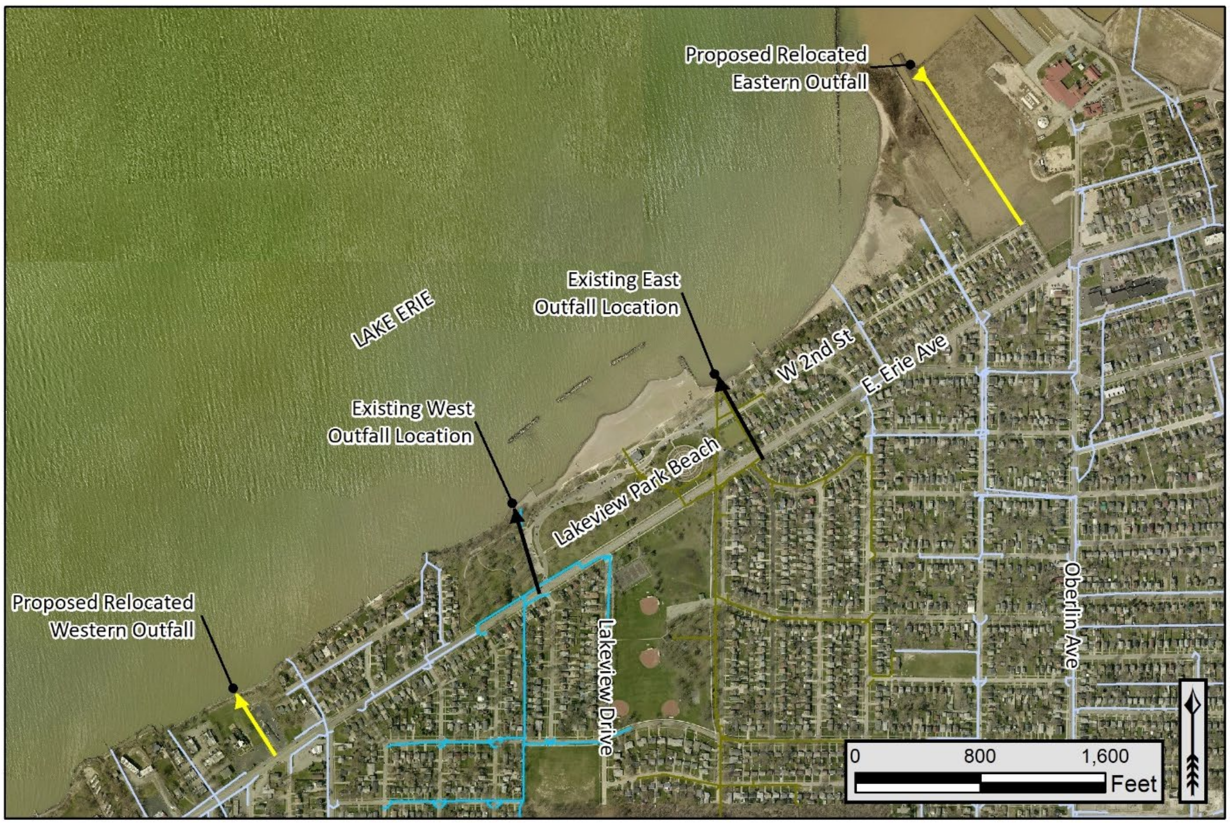
Outfall Re-location

Another approach to reducing the impact of the outfalls to the beach area would be to relocate them away from the beach. Two locations were considered for this study, one farther to the east, and one farther to the west. The location of the existing outfalls and the new potential locations are shown in Figure 12. These locations were initially screened for feasibility based upon the existing utility network's location and depths; this information was provided via historic plans and the City's GIS data. Once identified as conceptually feasible, these routes were further vetted with City engineering staff for further input to aid in the development of alternatives. It should be understood that these locations are not indicative of the final locations that may be implemented, but rather used as a tool to investigate the effects of moving the bacteria loading associated with these two outfalls.

While relocating the outfalls could potentially improve the water quality at the beach, it should be noted that relocating the outfalls to another sewershed would require further investigation to ensure no adverse environmental impacts occurred at the proposed location, as well as upstream within the sewershed. Additionally, based on the fact that human DNA markers were found in the outfall samples, an illicit or cross-connection investigation would need to be completed and implemented prior to any relocation.

Relocation of stormwater outfalls were open for further consideration. Initial modeling of relocated outfalls was completed to solicit input from the stakeholders. Based on these initial results, further advancement of the relocated outfalls concept into project alternatives was deemed warranted.

Figure 12: Stormwater Outfall Locations



Green Infrastructure

Green infrastructure is a method of managing stormwater by mimicking natural processes. There are several applicable approaches that are dependent on soil type, drainage area and groundwater table elevation. Some of these possible options include pervious parking with storage capabilities, or sand filtration systems, landscape buffers, etc. These options provide an aesthetic means to removing pollutants.

One form of green infrastructure that was considered is the creation of sand dunes on the beach area. Dunes provide several benefits to any given site including coastal resiliency, pollutant removal, and the increase of ecological diversity. Coastal resiliency is defined as a site's ability to adapt to changes both immediate and long term. Dunes increase a site's coastal resiliency by acting as a natural buffer during storm events, reducing flooding in upland areas, and acting as a sand reservoir. Dunes are typically vegetated to increase their stability. The vegetation will provide energy dissipation which together with the sand mounds will act as a buffer zone to storm surges. In addition, dunes act as natural filtration systems capable of intercepting run-off from nearby areas. Improved filtration can be achieved through an underdrain system but would require connection to an outlet structure. In this way, the dunes could serve to manage the stormwater runoff from the immediate park and beach vicinity by routing runoff through them, which should reduce the amount of bacteria entering the lake.

Another benefit of dunes is the reduction of nuisance avian species. Gulls prefer to loaf in areas with long, open sightlines, which are currently available at the beach. Vegetated dunes would offer a natural approach to breaking up the open sightlines found along the beach. To maintain the high grasses and shrubs, foot traffic must be prohibited in these areas.

The volleyball leagues and tournaments are a major recreational use of the beach and nearly all of the current open space during the summer season is utilized for volleyball. Dunes conflict with the space necessary for the volleyball leagues and tournaments. Loss of beach space usable for these events may not be desired as it may impact the beach's ability to host these events.

Dune creation as a green infrastructure feature was discussed with the stakeholders as an approach to address runoff from the site. Many of the benefits were presented, however Metro Parks expressed serious concerns about losing any available beach space that would limit the number of events they can hold. Any option for dune creation would have to allow for no reduction in the useable area.

5.2.2 Bird Management

Bird management approaches are intended to deter bird loafing along the beach, the breakwaters, and the bathhouse roof. The sampling program indicated that the gulls are a significant loading factor to the presence of *E. coli*. They are often found along beaches because they offer open sightlines to spot predatory animals approaching. Shore birds will typically congregate around flatter, partially inundated areas along the shore where small ponds form. Being scavengers, beaches with open trash containers or low maintenance/clean up can also provide additional food sources. Regularly groomed beaches turn up small insects and other invertebrates for the gulls to feed on. Gulls will also feed off smaller fish found in shallower waters or near the surface. Therefore, reducing and managing the gull population surrounding the beach should directly affect bacteria loading in the nearshore area.

Anti-loafing Devices

Anti-loafing devices are intended to obstruct flight or landing near a specified structure or area. They come in a variety of products, including plastic spikes, flags, wire systems, and spiders. Examples of some of these devices are shown in Figure 13. These types of devices could be placed on with the breakwaters, the roof of the bathhouse, or on the beach itself.

Figure 13: Examples of Bird Anti-Loafing Devices

From left to right: wire systems, flags, spikes, spiders

The breakwaters could be augmented with spikes, flags, or the spider devices. The problem with installing these approaches along the breakwaters are their durability to wave action and susceptibility to weather conditions which in turn lend themselves to constructability concerns and potential concerns about the increase to operation and maintenance costs. Additionally, due to winter ice conditions, any controls placed on them would need to be removed before winter and reinstalled in the spring.

An alternative option would be to plant the breakwaters. Due to degraded nature of the existing breakwaters there is already vegetative growth present on at least one of the breakwater structures. Vegetation if allowed to grow to increased heights helps reduce open sightlines preferred by the local bird population. The design would involve building off the existing structures to convert them into “living breakwaters”. The effect would appear to be three small islands out in the waterway. Placing sand in the middle of stone armoring and planting with plants capable of withstanding frequent inundation. However, these approaches still wouldn’t address the issue along the beach area.

On the other hand, these devices could still be a viable option for the bathhouse roof-top. They would still carry with them the additional maintenance needs. However, installation and maintenance would be much more accessible than installations on the breakwaters.

An aerial cable system is a larger scale device that would span the length of the beach. This method is known to deter gulls flying in the general area. Similar structures consist of “long galvanized fence poles placed in a grid fashion, approximately 80 feet apart in the north-south direction and 60 feet apart in the east/west direction across the lower beach and intertidal area.” The main concern with this system is the poor aesthetics that it would bring to the beach. Examples of these systems are shown in Figure 14.

Figure 14: Examples of Aerial Cable Systems

Scare Tactics

Scare tactics deter gull loafing by presenting a sense of danger. Among the available devices are water features, noise deterrents, and avian lasers.

Water features including water guns, cannons, or fountains are an engaging way to deter birds. The idea is to have some sort of water feature along the shore for kids, or adults, to play and shoot water at the birds without doing any harm.

Noise deterrents come in several forms. Chimes and sounds can be played at irregular intervals to spook birds such as gulls. However, the more effective method is to use a device called a "Squawker" which mimics the distress call of the targeted species or a known predator. Marine squawkers, such as the Phoenix Wailer IV, are floatable devices and can be deployed into the water where needed.

Avian lasers work to deterrent birds by emitting laser beams, which birds perceive as physical danger. An example is the Autonomic ® Automated Bird Repellent Laser. These devices are typically used in private agricultural fields mounted on poles; however, there are handheld options available. The device can be rigged with a power supply or ran off a combination of battery and solar power. The Autonomic has a range up to 5 square miles and can be programmed to run at certain time slots and configurations. Manual lasers may also be used. Examples are shown in Figure 15.

Figure 15: Examples of Bird Scare Tactic Systems

Chime device: Phoenix Airport Wailer Mk IV

Avian Laser: Autonomic 500 Bird Control Laser

The problem with most of these devices is that they must be periodically reinforced with an actual predator such as dogs or raptors. Raptors may be rented or a nest platform may be installed to attract them naturally to the site. Gulls will acknowledge an actual threat and eventually avoid the area. Because the intent is to scare off the birds and not to harm them, this method is legal. Studies have shown that eagles or falcons are more effective than hawks but it is suggested to use a natural predator to the specific species of gull found on-site, such as osprey. Installation of an osprey nesting stand in the vicinity of the beach may promote osprey activity in the area, which may be a deterrent to gulls. Drones may also be used as a scare tactic to simulate raptors. Additionally, Metro Parks is currently looking to buy drones for their general use. The option of drones as simulated raptors as a scare tactic was discussed.

Overall, the major constraints with all the bird deterrent techniques were installation and constructability issues, as well as, added operation and maintenance costs. A summary on the various techniques, based on feedback from the stakeholder meeting is included below. A few of the proposed bird management approaches did warrant further investigation.

- Anti-loafing devices on breakwaters – all were removed from consideration due to maintenance, installation, and durability issues.
- Aerial Cabling – removed from consideration due to aesthetic concerns.
- Water features focused on breakwaters – removed from consideration due to concerns for human safety with power supply.
- Water features along shore – removed from consideration due to concerns about spraying contaminated water (systems typically use water from the adjacent source, which in this case would be the lake). To address this concern a treatment/filtration system can be installed or instead potable water can be used in-place of the lake water. Neither of these options were considered desirable.
- Chimes (aka, squawkers) – removed from consideration due to being a noise nuisance to the public.

- Avian Lasers – Metro Parks is open to considering this option. They have previously used a small hand-held device with some reported success. They did express concerns for human safety with a larger autonomic device. Upon further investigation and coordination with product vendors, the use of the automatic system would not be appropriate in a public location such as the beach. Therefore, laser use would be relegated to manual use by Metro Parks.
- Predator Patrols – Metro Parks was open to installing an osprey nest. Metro Parks had previous coordination with the Audubon Society regarding Ospreys in the area; Metro Parks indicated they shall have additional coordination regarding the feasibility of installation. Similarly, Metro Parks indicated they could investigate further on potential applicability of drone use.

5.2.3 Circulation Improvements

There are two approaches to improving circulation: implementing a mechanical device such as a pump or circulator and/or altering existing structures. The purpose is to decrease residence times in the nearshore area and effectively flush bacteria from the beach area.

Pumps/Circulators

In order to promote improved circulation in the beach area, mechanical means may be utilized through the deployment of submersible pumps or circulators. Circulators, like pumps, have the capability of improving the circulation through the water column. Unlike the pump, circulators work by pulling water from the lower water column and dispersing it near the surface. Circulators are typically used in lakes or ponds where there is minimal wave action. Portable devices sit on the surface and use fins or pumps to create a current. An example of a floating unit for a circulator is shown in Figure 16.

The use of any mechanical system brings with it some implementation challenges. Power would need to be provided to the unit, likely from landside service, as solar powered options may not be possible. Additionally, the systems would need to be removed during the off-season, as they would not be able to be in the lake for the winter. This would add operational cost and complexity. Finally, users of the beach would need to be able to safely interact with any device and may be discouraged from use of the beach with the presence of mechanical systems in the lake.

Figure 16: Circulator System Surface Float

TORNADO® Subsurface Aerators

The current circulation model did not allow for the representation of adding pumps and circulators to gain some level of understanding regarding their potential impact. However, the concerns over providing power and maintenance and operations costs removed it from further consideration.

Alter Existing Structures

Another option to improve circulation in the beach area is to modify the existing breakwater structures. One method could be to lower them, allowing more wave action and energy to enter the beach area. Another method would be to increase the width in between them. Although the baseline model scenario demonstrated that the existing breakwaters did not limit circulation (circulation is largely dependent on wind direction), additional wave action entering the area could reduce residence times for any wind condition.

Reducing the height of the breakwaters by 2-4 feet would allow overtopping of waves, increasing wave action within the nearshore area. It has been observed that part of the gull problem is perching along the breakwaters. The additional wave action on the lowered breakwater would render this location undesirable for perching, helping to address the bird management issue as well.

Based on the original design the breakwaters are composed of 5-10 ton armor stone. Specifications call for a specific weight of 155-175 lbs. Assuming 165 lbs, this means the armor stone has typical dimensions of 3'x4'x5' (5 TN) to 4'x5'x6' (10 TN). The structure ranges from -8 FT LWD to +8 FT LWD, based on the original design. However, there has been apparent degradation on the structure, likely caused by rock movement, and no longer holds true to the original design. Please refer to Figure 17 for a conceptual cross-section for this modification. The intent would be to universally lower the top of the armor stone by approximately 2 ft. (shown in red).

The other approach would be to increase the width between the breakwaters. Armor material would be removed from the interior ends of the outer two breakwaters. This would increase the width between the structures to be approximately the same width as the structures themselves. Please refer to Figure 18 demonstrating this concept. While this may increase the wave energy to promote circulation, it does come with the added risk of additional erosion. An adequate supply of material (either natural accretion or import) would need to be available to offset this potential risk.

Figure 17: Breakwater Modification Conceptual Cross-Section

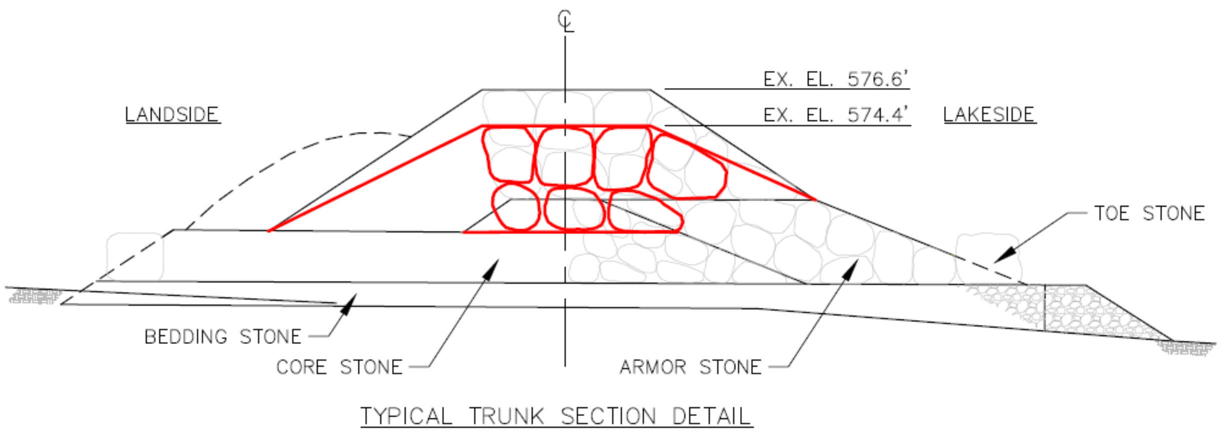
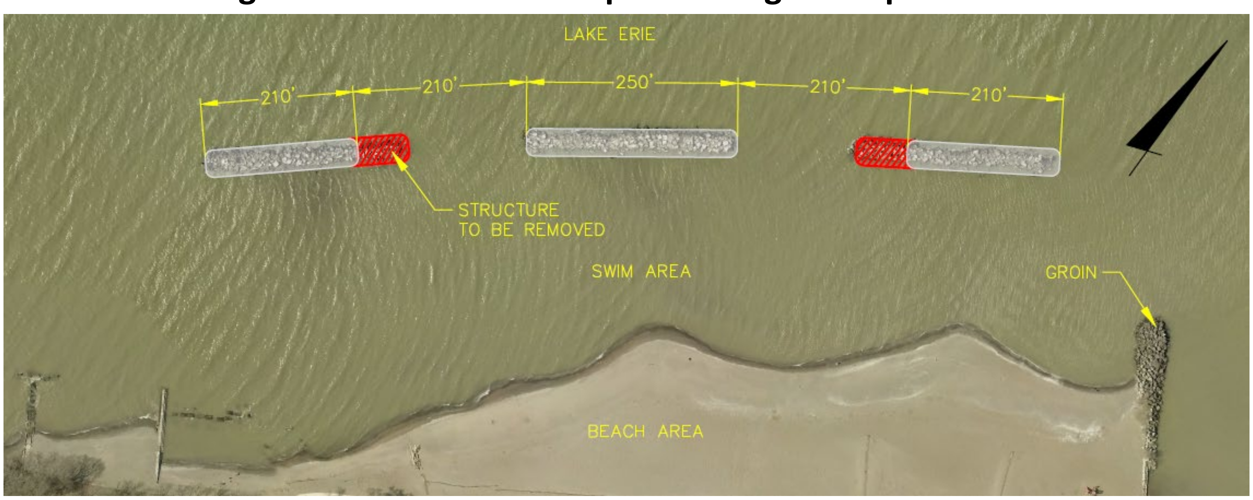


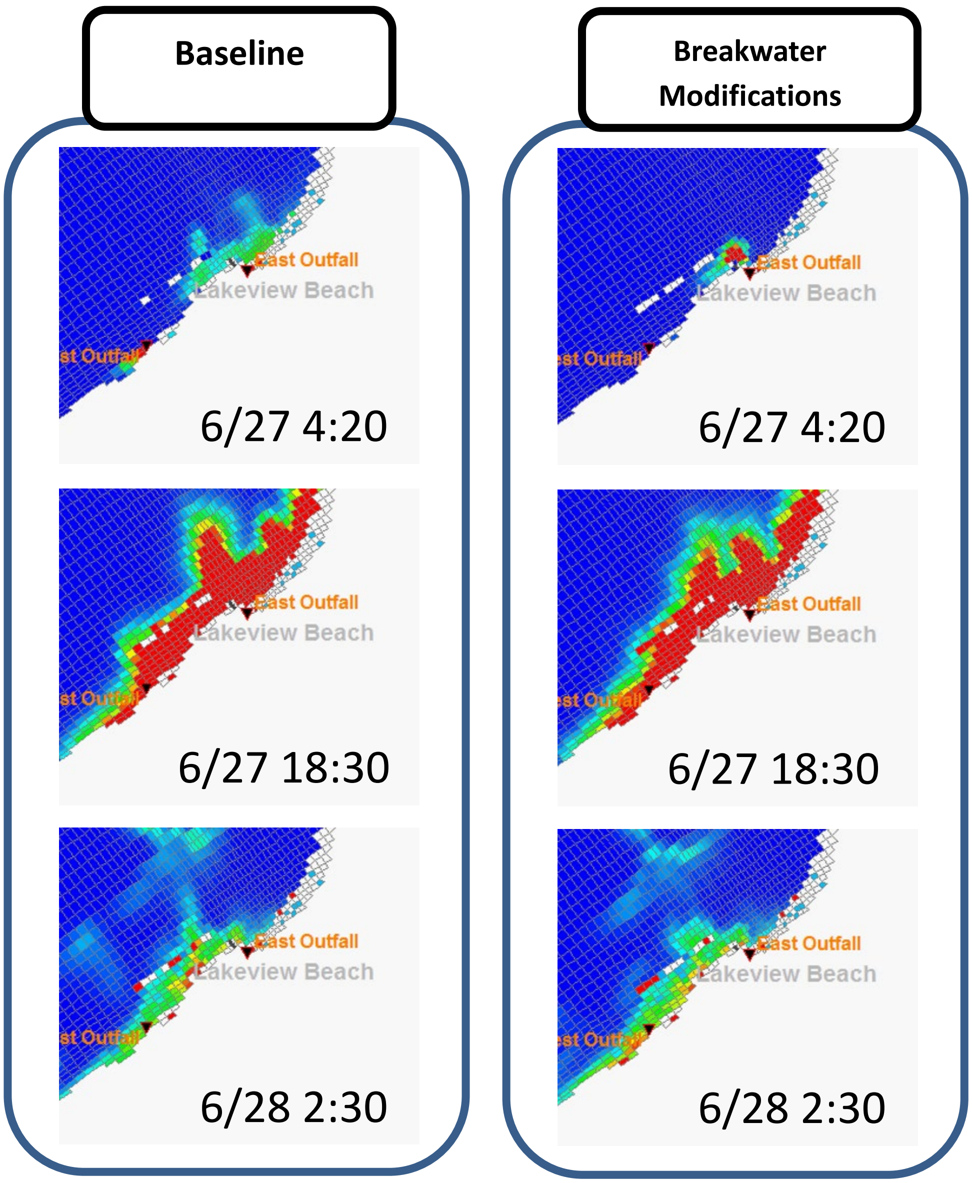
Figure 18: Breakwater Gap Widening Conceptual Plan



Initial circulation modeling was completed to support discussion regarding the lowering of the breakwaters and increasing the gap width. The results from these simulations indicated that they would be ineffective at reducing the amount of time that the nearshore area was under the advisory threshold concentration of *E. coli (*please see Appendix A for more information regarding these simulations).

Figure 19 shows results from the circulation model simulation for selected time-steps when compared to the existing conditions. Red cell shading indicated an *E. coli* concentration above the advisory threshold. As can be seen, there is little visual evidence of improvement. These results, combined with the potential for increased beach erosion, and the constructability and permitting issues involved in modifying the breakwaters, led to the decision to remove these approaches from further consideration.

Figure 19: Breakwater Gap Widening Modeling Results



5.2.4 Maintenance and Operational Improvements

Currently the park is owned by the City of Lorain and operated by Lorain County Metro Parks. There have already been efforts to address beach closures by means of dog patrol and grooming. However, additional efforts can be explored.

Grooming Techniques

Grooming should be conducted within the wetter perimeter of the beach area using long tines. Trash, debris, and vegetation racked should be properly disposed of outside of the beach area. It is currently understood that the beach is frequently groomed in an effective manner, and there may be limited opportunity for improved approaches.

Waste Management

Covered receptacles that are changed on a regular basis can help eliminate/reduce food sources for birds and other scavengers in the area. It is also important to have receptacles easily accessible to park patrons and to enforce proper trash disposal. The Metro Parks staff actively manage the covered waste receptacles so large amounts of waste are not available.

Beach Nourishment

Increasing the depth of the water on the shore side of the breakwaters and using the dredge material for beach nourishment might provide some level of improvement. Metro Parks mentioned their dredge permit was coming up for renewal. They typically dredge every 6-7 years using the sand for on-site beach nourishment. For safety reasons, Metro Parks prefers to maintain 4 feet of water depth within the swim area but are willing to consider dredging deeper outside the swim area and along breakwaters.

Dog Patrols

The goal is to patrol the beaches during peak gull hours, typically early morning and dusk, and allow the dogs to chase off the birds. If done consistently, some beaches have seen reductions up to 99%. Effective patrol ranges are around 1 dog per 600 square feet. Dog patrols have been utilized at the beach previously, however the birds eventually adapted to the presence of the dog.

Public Outreach

There are several areas of focus for public education. To reduce food sources, park patrons should be encouraged to pick up their trash and not feed the wildlife. Additional sources of bacteria can be reduced by encouraging patrons to pick up after their dog. Signs are a helpful tool but these techniques will also require enforcement.

Metro Parks indicated that they already perform many of the suggested activities to limit bacteria. Trash receptacles are covered and cleaned out twice a day; there are also signs informing the public not to feed the wildlife. Grooming is completed as well. The current approach is to groom 3 times per week, running parallel to the beach, using long tines. It was suggested by USEPA to use a zig-zag pattern, which may be more effective. Other than this suggestion, no specific project alternatives came from this control type.

5.3 Project Alternatives

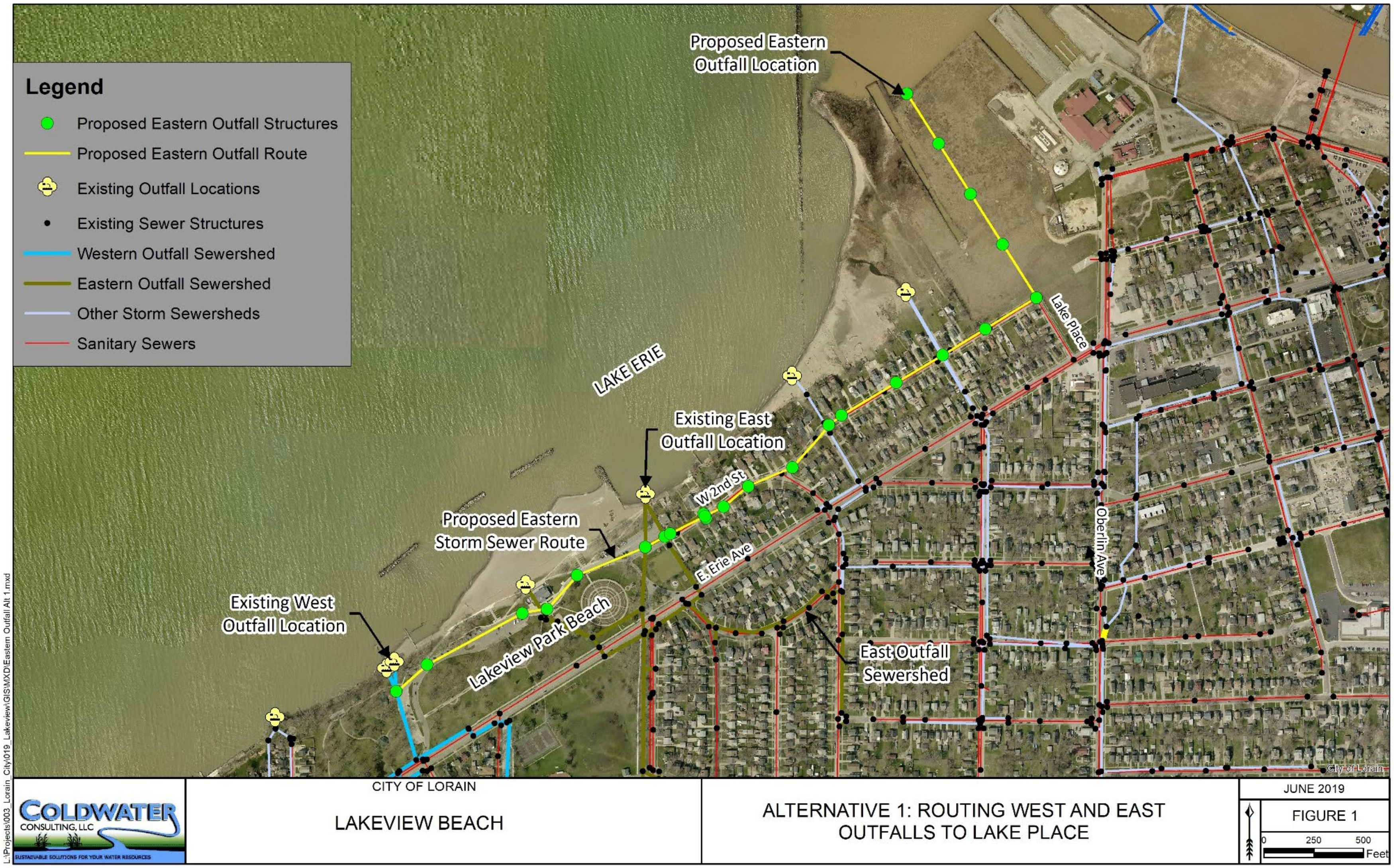
Based upon the feedback gained at the stakeholder meeting and analysis of the various approaches described above, three alternatives were developed for this study, aimed at reducing the frequency of water quality advisories within the Lakeview Park Beach area. The sampling and monitoring program indicated there were two major contributing sources resulting in elevated concentrations of *E. coli*, stormwater from the two outfalls adjacent to the beach swim area and from the nuisance avian species, specifically gulls. Therefore, Alternatives 1 and 2 focus on potential site locations for relocated stormwater outfalls, while Alternative 3 focuses on stormwater and bird management through dune creation. These alternatives are presented below.

5.3.1 Alternative 1 – Routing East and West Outfalls to Lake Place

Alternative 1 consists of combining both the existing west and east stormwater outfalls at Lakeview Park Beach and rerouting them as a single outfall farther to the East. The proposed route includes approximately 5,000 LF of storm sewer pipe, placing the proposed outfall east of the current eastern outfall. The proposed route would follow parking and drive aisle areas within the Park, then remain in the public rights-of-way of N Lakeview Boulevard and W 2nd Street, until making a turn to the north at Lake Place and continuing to Lake Erie. The route would then follow parcels that are now owned by the City of Lorain to reach the Lake. This overall route is shown in Figure 20.

Multiple outfall locations were discussed with City Engineering staff, and the location presented here was deemed the most preferable. Other potential locations to the east were near private residences with known drainage issues. Adding a new outfall near these residences may worsen the conditions there. Additionally, it was undesirable to discharge stormwater that had known elevated levels of bacteria near private residences. The proposed location has the benefit of being far away from private residences and sits behind an existing breakwater that should limit the ability for the discharge to get to Lakeview Park Beach. Since the final portion of the proposed route is through property now owned by the City, easements would not be necessary for the route and for the outfall structure itself. The City also indicated that a benefit of an eastern route would be for potential collection of other sewer improvements that may occur in the future in this vicinity. While a specific timeframe for other sewer improvements is unknown, moving it closer toward where those are likely to occur could be preferable in comparison with other locations.

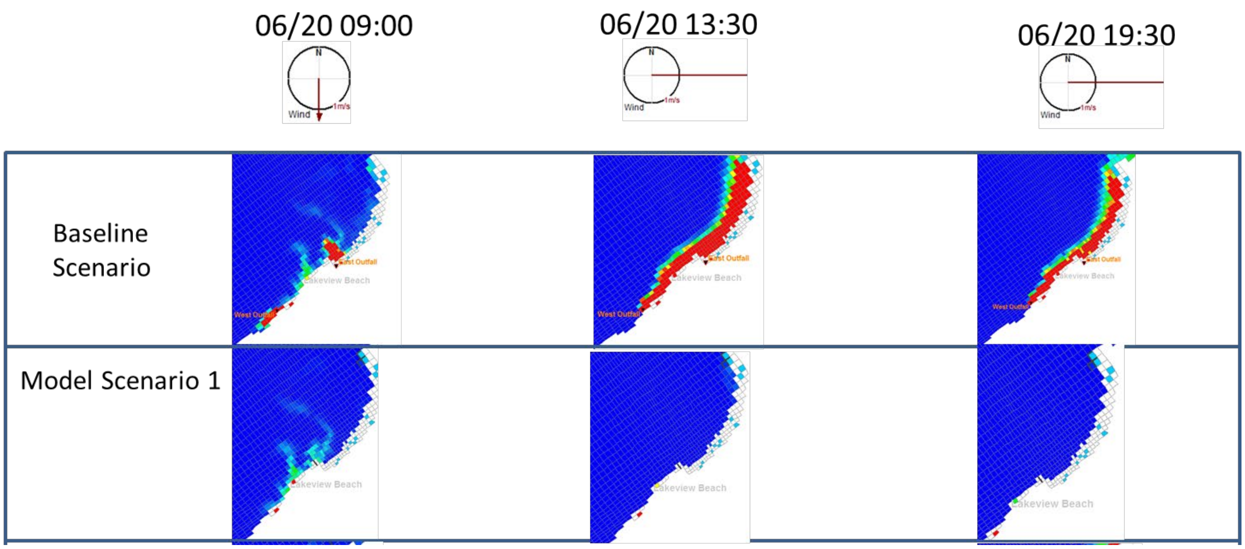
Figure 20: Alternative 1 - Routing East and West Outfalls to Lake Place



Alternative 1 was analyzed in the circulation model to identify improvements in the duration of time the Lakeview Park Beach area has a concentration above the advisory limit when compared to the baseline conditions. Figure 21 shows results from the circulation model simulation for selected time-steps when compared against the existing conditions. Red cell shading indicated an *E. coli* concentration above the advisory threshold.

Model scenario 1 was created to represent this alternative. The model scenario was run for the same time period as the baseline conditions. The results of the model scenarios were compared to the baseline model scenario to evaluate the effectiveness of conceptual alternatives to improve the water quality at the Lakeview Park Beach. Figure 21 shows a spatial time snapshot of results for Baseline scenario and Model Scenario at different times on June 20, 2018. The dominant wind direction on June 20, 2018 was towards the east. Hence, stormwater outfall discharges under the Baseline scenario resulted in increased in *E. coli* levels in the nearshore beach area. Under Model Scenario 1, the combined stormwater discharge, located at the proposed location east of Lakeview Park Beach, is flushed away from the beach area. Even under the reversed wind conditions (i.e. towards west), the discharge at the location in Model Scenario 1 has a small impact on the beach since the flow is blocked by the perpendicular breakwaters located at the end of the beach area.

Figure 21: Baseline vs. Alternative 1 Model Results



The modeling indicated that by moving the outfall to this new easterly location, the influence of the stormwater outfalls on the beach is reduced. Although this reflects the reduction for the outfalls being relocated, it does not address loading from birds. The sampling data and other modeling results indicate that the loading from birds is still a major contributor even with the outfalls being relocated. Please refer to Section 6 for more discussion on the modeling results, as well as Appendix A for more information regarding the simulations.

An engineer's opinion of probable construction cost was prepared for this alternative. Table 7 provides a summary of the costs. In addition to the installation of the new storm sewer route and outfall, many existing utilities would be disturbed and would require replacement due to conflicts or due to the high likelihood of damage due to narrow work constraints. With most of the route being in the public right-of-way, a significant amount of pavement replacement would be necessary as well. Due to the high level of unknowns at this time, a 30% contingency was placed on the cost opinion. These costs do not include engineering, nor the hydraulic analysis study that would be needed prior to implementation.

Table 7: Alternative 1 – Opinion of Probable Construction Cost

Cost Groups	Group Total Cost
Storm	$1,645,900
Sanitary	$321,400
Water	$243,600
Paving	$719,500
Other	$100,000
Subtotal	$3,030,400
Contingency - 30%	$909,100
Total	**$3,939,500**

Further analysis would be needed prior to advancement of this alternative. No hydraulic analysis or design was completed for the purpose of developing this route or cost opinion. A detailed hydraulic study of the impacted sewersheds would be needed to verify technical viability of this alternative. Additionally, the City would need to address the human bateriallogical component prior to relocating the outfalls.

5.3.2 Alternative 2 – Routing East and West Outfalls to Lakeview/Madison Avenues

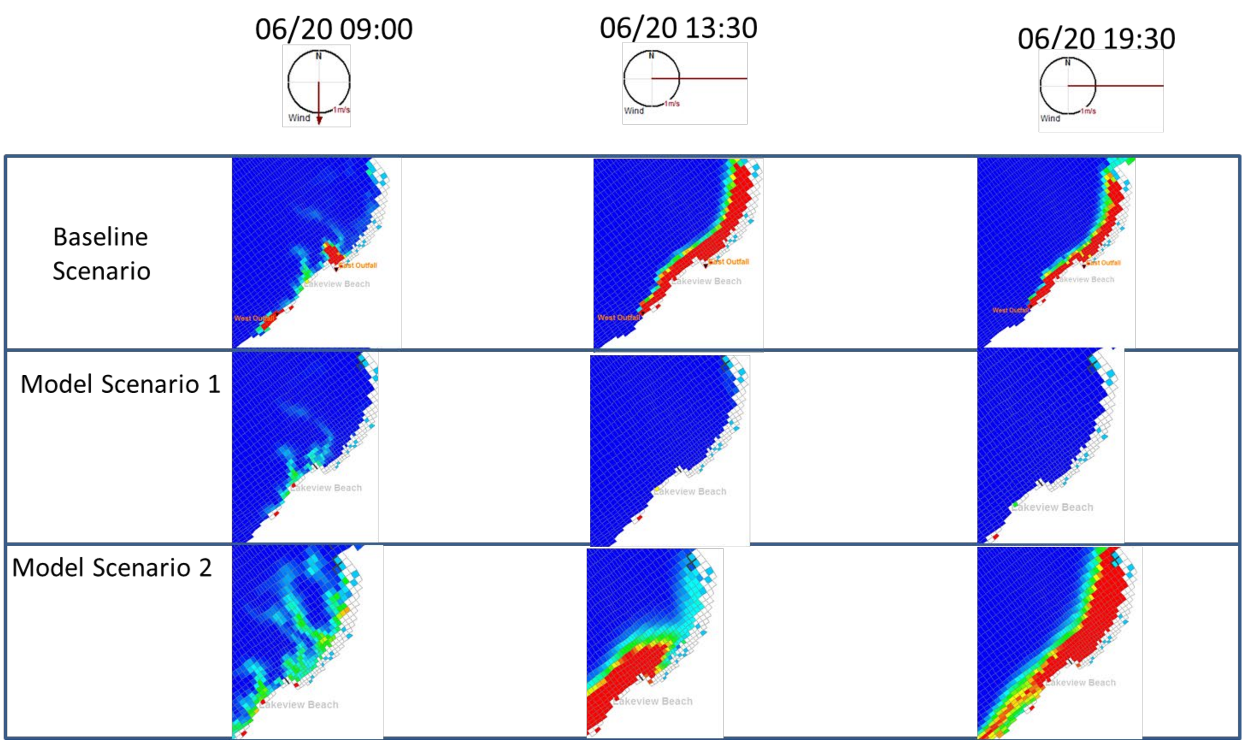
Alternative 2 is similar to Alternative 1 in that is consists of combining both the existing west and east stormwater outfalls at Lakeview Park Beach and rerouting them as a single outfall. However, this alternative proposes a new outfall to the west. The proposed route includes approximately 4,300 LF of storm sewer pipe, placing the proposed outfall west of the current western outfall. The proposed route would follow parking and drive aisle areas within the Park, then remain in the public rights-of-way of West Erie Avenue, until making a turn to the north to Lake Erie. The route would then follow through a privately held vacant parcel to reach the Lake. This overall route is shown in Figure 22.

West of Lakeview Beach, there are few access routes due to the private residences in the immediate vicinity. Based on the topography and the existing utility information currently available, the proposed outfall location is as far to the west as potentially feasible. This location would be preferable due to the fact that it is not directly at a private residence, and there is vertical drop off down to the Lake and not a beach area at this location.

Figure 22: Alternative 2 - Routing East and West Outfalls to Lakeview/Madison Avenues

Alternative 2 was analyzed as Model Scenario 2 in the circulation model to identify improvements in the duration of time the Lakeview Park Beach area has a concentration above the advisory limit when compared to the baseline conditions. Figure 23 shows results from the circulation model simulation for selected time-steps when compared against the existing conditions, as well as against Alternative 1. Red cell shading indicated an *E. coli* concentration above the advisory threshold. While alternative 1 demonstrated a reduction in concentrations, the modeling for alternative 2 indicated that there was no significant benefit. Under westerly wind conditions, an increase in *E. coli* concentrations occur. Please refer to Appendix A for more information regarding the simulations.

Figure 23: Baseline vs. Alternative 1 and Alternative 2



An engineer’s opinion of probable construction cost was prepared for this alternative. Table 8 provides a summary of the costs. In addition to the installation of the new storm sewer route and outfall, many existing utilities would be disturbed and would require replacement due to conflicts or due to the high likelihood of damage due to narrow work constraints. With most of the route being in the public right-of-way, a significant amount of pavement replacement would be necessary as well. Due to the high level of unknowns at this time, a 30% contingency was placed on the cost opinion. Considering the fact that this alternative would require major disruption of West Erie Avenue, a major road, the costs presented here may not fully capture the additional level of work needed to maintain this road during construction. Additionally, other private utilities were not located for this study. While not quantified, impacts to them must be assumed to be necessary, further inflating the costs presented here. Also, these costs do not include engineering, nor the hydraulic analysis study that would be needed prior to implementation.

Table 8: Alternative 2 – Opinion of Probable Construction Cost

Cost Groups	Group Total Cost
Storm	$1,535,400
Sanitary	$323,500
Water	$388,700
Paving	$864,400
Other	$175,000
Subtotal	$3,287,000
Contingency - Add 30%	$986,100
Total	$4,273,100

5.3.3 Alternative 3 – Dune Creation and Bird Management

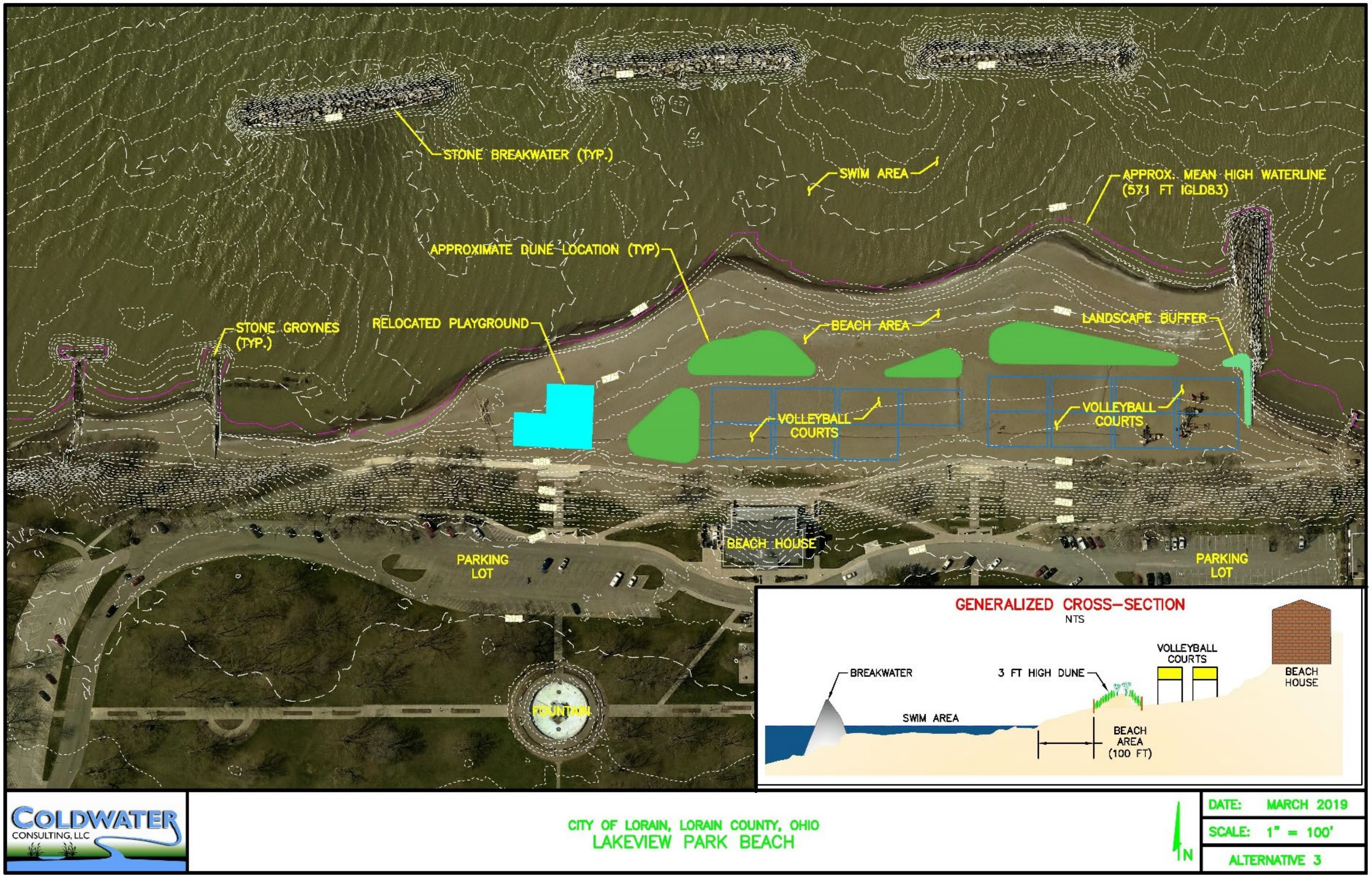
Alternative 3 focuses on providing a ecologically beneficial means of managing the avian population around the beach. This would focus on the three primary bird loafing areas: the beach area itself, the roof area, and the breakwaters.

The dune creation concept is presented in Figure 24. Approximately 1,200 cubic yards of sand will be used to create low lying, vegetated dunes interspersed along the beach. Dunes will be located approximately 100 feet from mean tide to allow for wave run-up (Mass. Sea Grant, 2008). The height of the dunes shall not exceed 3 feet so that lake views are not impeded for park patrons. The dunes will be planted with 22,500 square feet of native beach grasses and perennials. These passive features will help improve aesthetic appeal at the park while breaking up the open beach space commonly preferred by nuisance avian species, such as gulls. In addition, the dunes are naturally adaptable to changes in the environment, helping to increase the site's coastal resiliency while also improving surface water quality. Roof drain outfalls may be rerouted towards to the dunes for improved water quality.

Dune creation may address bird loafing on the beach area, other approaches may be used for the roof and breakwater areas. While anti-loafing devices placed on the breakwaters were not favorably received in the stakeholder meeting, these devices could be placed on the roof of the bathhouse/restaurant to discourage loafing there. Additionally, the use of an avian laser was not ruled out, and this could be used to discourage loafing on the breakwaters.

For the dunes to be implemented this alternative would require space currently used by the volleyball courts. This will be accommodated by relocating the playground to the west side of the beach and instead using that space for the additional court space. This layout will allow for approximately 15 volleyball courts. In addition, it is suggested a small 930 square foot hedge be placed along the jetty as a buffer from the volleyball courts since there is a 1 to 2-foot drop.

Figure 24: Alternative 3 – Dune Creation with Volleyball Courts



An engineer's opinion of probable construction cost was prepared for this alternative. Table 9 provides a summary of the costs. This cost could be mitigated by completing the project in conjunction with on-site dredging efforts. This material is would likely be deemed suitable for beach nourishment by regulating authorities. However, before utilizing this option a grain size distribution analysis would be required. It is understood that dune creation may be a type of project that would qualify for grant funding, therefore total cost to the City may be less than the total cost of the project should a grant application be deemed acceptable. These costs do not include design, permitting, nor any other analysis on the dredging reuse that would be needed prior to implementation.

Table 9: Alternative 3 – Opinion of Probable Construction Cost

DESCRIPTION	TOTAL COST
Mobilization	$50,000
Erosion and Sediment Control	$14,500
Playground Relocation	$50,000
Import Sand	$120,000
Planting dune grasses & perennials	$95,000
Planting landscape buffer (shrubs)	$15,000
Dune fence	$3,500
Anti-Loafing Devices	$25,000
SUBTOTAL	$373,000
CONTINGENCY (30%)	$111,900
TOTAL	$484,900

6.0 SUMMARY AND NEXT STEPS

The goal of this feasibility report was to develop project alternatives that have the ability to improve water quality at Lakeview Beach and reduce the number of days the beach is under a water quality advisory. To accomplish this a water quality sampling program was developed to identify sources of *E. coli* entering the beach area. A hydrodynamic circulation model was also developed to gain an understanding of existing circulation patterns and assess alternatives that may improve circulation. Input on potential project alternatives was collected from stakeholders and was combined with the data obtained during the sampling program and modeling exercises to identify 3 potential project alternatives.

6.1 Summary of Alternatives and Key Findings

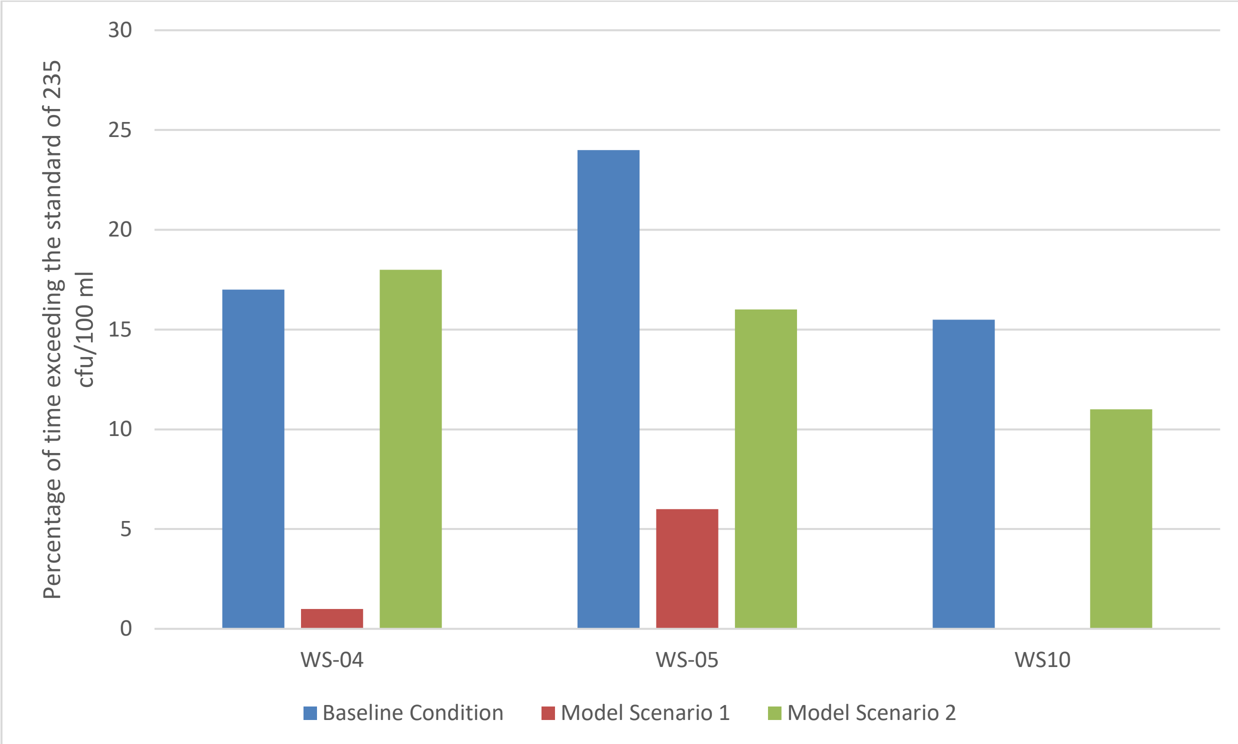
Alternatives 1 and 2 involve rerouting the two existing stormwater outfalls at Lakeview Park Beach farther to the east and to the west, respectively. Both alternatives were evaluated using the circulation model to assess potential improvements to water quality. The results indicated that moving the outfall to the east under Alternative 1 provided the better results and could be considered for further evaluation. Alternative 2 is not recommended for further evaluation as it did not provide a noticeable benefit to the beach water quality, and under westerly wind conditions worsened the condition.

Since Alternative 1 only addressed infrastructure improvement, and not birds, and Alternative 3 only addresses birds, additional evaluation of the modeling results provided more insights on how to prioritize next steps.

In order to further evaluate the effectiveness of the relocated stormwater outfalls in Alternative 1, the model results for days when there was no bird loading were reviewed to identify the amount of time above the advisory level. According to the bird count data, no birds were recorded during site visits on June 18, June 20, and June 26. As was demonstrated previously, *E. coli* loading from the Black River and the two WWTP's were shown not to affect the beach area, therefore the times above the advisory level would be solely from the stormwater outfalls.

Figure 25 identifies the percent of time during the 2-week baseline period where the *E. coli* concentration was above the advisory limit. The concentration as predicted by the model was recorded at 3 sample locations within the swim area. Figure 25 shows this percentage time for the Baseline condition, as well as for Alternatives 1 and 2 (model scenarios 1 and 2, respectively). Comparing the time above the advisory limit for the Baseline Condition (blue bars) against Alternative 1 (red bars) shows a significant reduction in time. This indicates that the relocation of the stormwater outfalls to the east is effective in reducing their contribution to water quality problems at the beach area.

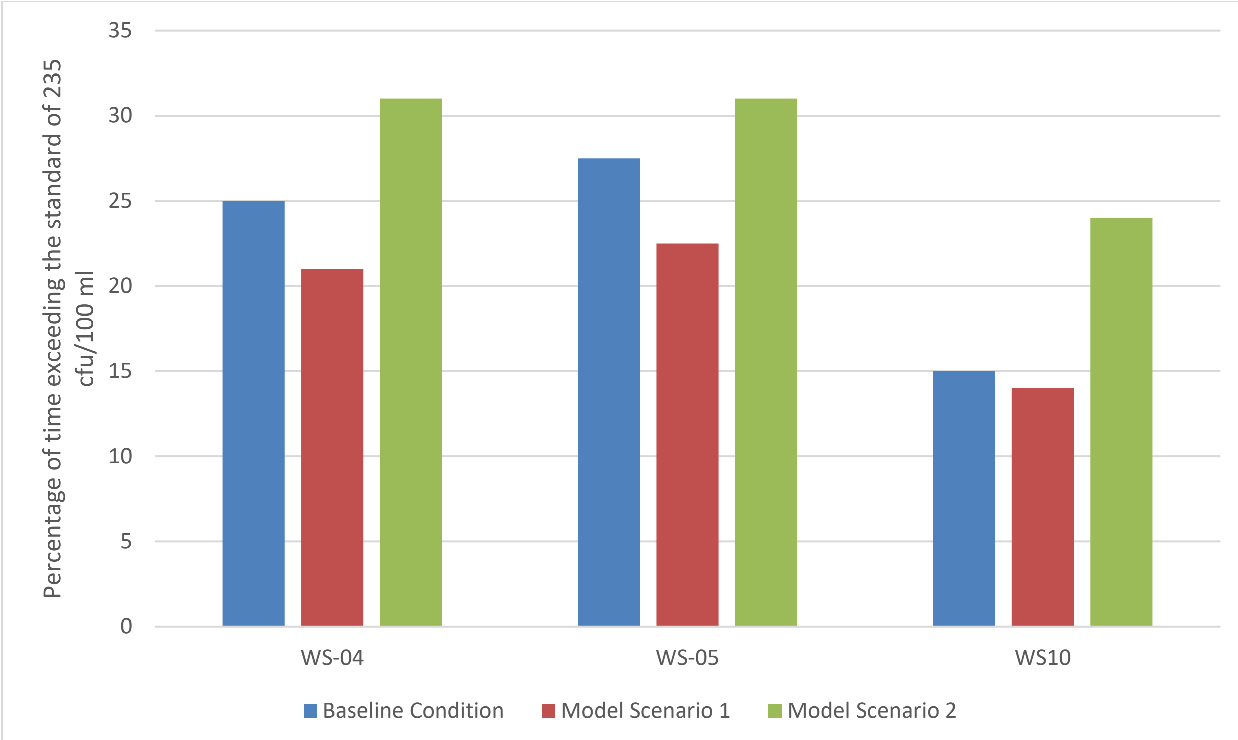
Figure 25: Percent Time above Advisory Level – Days Without Bird Loading



Another analysis completed was to review the entire two-week baseline period against Alternative 1. Figure 26 shows the time above the advisory limit for the swim area sample locations. This comparison included loading from all sources. Again, with the understanding that the Black River and the two WWTP's were shown not to affect the beach, the loading sources shown in Figure 26 are largely birds and stormwater outfalls. Two observations in the data should be noted.

- The overall time above the advisory level for the baseline period is higher in Figure 26 (birds and outfalls) than was shown in Figure 25 (outfalls only). This is a general indication of the impact of birds on the beach water quality.
- There is very little change in time above the advisory level between the baseline time period and Alternative 1. As was shown in Figure 25, moving the outfalls was effective at reducing their impact when birds aren't accounted for. Therefore, the small change between baseline conditions and Alternative 1 shown in Figure 26 further indicates that birds would still cause a significant impact on water quality even if the outfalls are relocated.

Figure 26: Percent Time above Advisory Level – 2 Weeks Baseline (All Loading Sources)



A number of other actions would need to be undertaken should it be decided to pursue Alternative 1. First, due to the presence of human markers in the MST testing, an investigation into possible sources of cross contamination from sanitary to storm sewers would need to be undertaken. At the time of this report, it is understood that the City is pursuing completing a study of this kind. Second, no hydraulic analysis regarding the feasibility of the proposed stormwater outfall relocation was completed, as it was beyond the scope of this study. As such, a detailed hydraulic analysis would need to be completed to understand the impact of routing and re-distributing flow through alternate sewersheds. Finally, Alternative 1 is an infrastructure improvement project that will not qualify for the grant funding programs that the City has successfully used in the past. Investigations into potential funding sources, and stakeholder involvement in funding the project is suggested. The project cost presented in this report does not account for costs associated with the aforementioned sanitary cross-connection study, hydraulic analysis study, nor the engineering design of the project. Bird loading was still identified as a major factor even with Alternative 1 being implemented in the model, therefore should any infrastructure improvement alternative be considered, bird management measures should also be included.

Alternative 3 may not have the same impact on beach water quality as Alternative 1 but may still warrant further consideration. The proposed dunes may reduce the amount of gull loafing, which could reduce *E. coli* loading from them. Also, it does have the ability to treat and manage the contribution from the Park itself. Furthermore, the construction cost is in a more manageable range, and could potentially qualify for grant funding assistance. However, since it would involve layout changes to the beach area, coordination and buy-in from Metro Parks would be necessary prior to further analysis or implementation. It is suggested that the City begin coordination with Metro Parks to determine their ability and willingness to consider this alternative seeing as bacteria loading from birds was identified as a major source, even with infrastructure improvements.

6.2 Limitations and Assumptions

When assessing the results of the sampling program and the results of the modeling, there are a few limitations and assumptions that went into the analysis that should be considered:

- Even after completing the MST testing for the sampling data, a very large portion of the bacteria were still not speciated. Based on the limitations of MST technology, the potential likely sources of the non-speciated bacteria could be canine or rodent, as tests for these animals were not available. The alternatives presented here do not address this component, based largely on the assumption that these could be from animals distributed widely across the sewershed/watershed.
- It was not possible to model Alternative 3 and other bird management approaches, as data on a reasonable estimate on the reduction of bird counts to be used in the model was unavailable. An additional investigation and study approach would be necessary to attempt to quantify reductions based on bird management actions.
- The modeling indicated that the birds are a major contributor to time above the advisory limit even if the outfalls are relocated. As discussed in Appendix A, the loading in the model from the birds is based on birds counts and loading per bird based on the available literature. Therefore, these results are highly dependent upon the bird count data. A more robust set of bird count data would be beneficial to enhance the model results and better define the impact from birds.

6.3 Next Steps and Action Items

Based on the results and findings from this study, the following next steps and action items are suggested:

- The City should work to complete a study to investigate the human bacteria component in the stormwater system. It is understood that programs from the US Army Corps of Engineers and Ohio EPA may be available to the City to assist with this study.
- The City should begin investigation into the feasibility of relocating the outfalls to the east as shown in Alternative 1.
- The City could begin discussion with Metro Parks regarding implementing bird management approaches and the Alternative 3 dune creation concept. The dune creation concept plan as presented would maintain the area for volleyball courts. This addresses their primary concern of losing space. If this is conceptually agreeable to Metro Parks, the City should investigate

opportunities for funding that may allow for additional study, design of dunes and implementation of the suggested bird management deterrents. This should also seek to quantify improvements from dune creation.

- The large portion of non-speciated bacteria is likely from rodent sources entering the stormwater pipes though inlet locations. To help mitigate this, the City could investigate the types of grate structures within the east and west outfall sewersheds to see if alternate grates/lids may be used to limit entry by rodents. However, this may not solve the problem, but could work as an interim measure.