Northeast Ohio
Regional Sewer District

2022 Lake Erie Beach Monitoring

Water Quality and Industrial Surveillance

Environmental Assessment Group

May 2023

Table of Contents

List of Figures ii
List of Tables ii
Introduction 1
Methods 3
Results and Discussion 4
Recreational Use Attainment Status 4
Comparison with Historical Data, Rainfall, and CSO Occurrence 10
Harmful Algal Bloom Monitoring 20
Conclusions 21
Acknowledgements 22
References 22

List of Figures

Figure 1. Map of Sampling Sites 2
Figure 2. 2022 Edgewater Beach East Site - Attainment of Bathing Water STV Criterion 5
Figure 3. 2022 Edgewater Beach East Site - Attainment of Bathing Water 90-Day Geomean Criterion 5
Figure 4. 2022 Euclid Beach East Site - Attainment of Bathing Water STV Criterion 6
Figure 5. 2022 Euclid Beach East Site - Attainment of Bathing Water 90-Day Geomean Criterion 7
Figure 6. 2022 Villa Angela Beach East Site - Attainment of Bathing Water STV Criterion 8
Figure 7. 2022 Villa Angela Beach East - Attainment of Bathing Water 90-Day Geomean Criterion 8
Figure 8. 2022 Euclid Creek RM 0.55 - Attainment of Primary Contact Water STV Criterion 9
Figure 9. 2022 Euclid Creek RM 0.55 - Attainment of Primary Contact Water 90-Day Geomean Criterion 9
Figure 10. Proximity of CSO Outfalls to Edgewater Beach. 14
Figure 11. Proximity of CSO Outfalls to Euclid and Villa Angela Beaches 14
Figure 12. Boxplot showing the distributions of recreation season E. coli densities before, during, and after construction of the ECT. 17
Figure 13. Smooth density plots of the Euclid Creek discharge volume at the USGS gage station at Lakeshore Boulevard. 17
Figure 14. ANCOVA Analysis of E. coli as a function of Euclid Creek flow before and after ECT installation. No significant difference was observed before and after installation..... 18
Figure 15. LOESS analysis of E. coli as a function of Euclid Creek flow before and after ECT installation. No change in the relationship between wet-weather flows and E. coli was observed. 19
Figure 16. NOAA Forecasted Bloom Severity Index for 2022. 21

List of Tables

Table 1. List of Lake Erie and Euclid Creek Sampling Sites 1
Table 2. Edgewater Beach Historical Recreational Use Criteria Exceedances 10
Table 3. Euclid Beach Historical Recreational Use Criteria Exceedances 11
Table 4. Villa Angela Beach Historical Recreational Use Criteria Exceedances 11
Table 5. Euclid Creek Historical Recreational Use Criteria Exceedances 12
Table 6. Total Rainfall (Inches) from May 1st to October 31st 13
Table 7. CSO Events from May 1 to October 31 15

2022 Lake Erie Beach Monitoring
May 3, 2023

Introduction

Since 1992, the Northeast Ohio Regional Sewer District (NEORSD) has conducted bacteriological sampling on Lake Erie at Edgewater Beach, Villa Angela Beach, and Euclid Beach to monitor bacteriological densities at the beaches. In 2005, sampling at Euclid Creek was added to determine the impact the creek may have on the water quality at Villa Angela and Euclid Beaches.

In 2022, the NEORSD continued these sampling efforts by monitoring the *Escherichia coli* (*E. coli*) densities at Edgewater, Villa Angela, and Euclid Beaches and Euclid Creek. The purpose of this sampling was to communicate beach conditions to the public and evaluate water quality standards attainment. This report will evaluate water quality standards attainment using the results from each sample site.

Sampling was completed by either NEORSD Level 3 Qualified Data Collectors (QDCs) certified by the Ohio Environmental Protection Agency (Ohio EPA) in Chemical Water Quality Assessment or other individuals in the Water Quality and Industrial Surveillance Division trained by Level 3 QDCs as explained in the NEORSD study plan *2022 Lake Erie Beach Monitoring*, which was approved by Ohio EPA on May 9, 2022. Sample analyses were conducted by NEORSD's Analytical Services division, which is accredited by the National Environmental Laboratory Accreditation Program.

Table 1 indicates the sampling sites with respect to location, site or river mile (RM), latitude/longitude and description. Figure 1 is a map of the sampling locations at Edgewater, Euclid and Villa Angela Beaches and Euclid Creek.

Table 1. List of Lake Erie and Euclid Creek Sampling Sites

Location	Site	Latitude	Longitude	Description	Quadrangle	Purpose
Edgewater Beach	East	41.4893	-81.7392	Eastern half of the beach. In line with the brick stack on the other side of the freeway	Cleveland South	• Public notification of water quality conditions at bathing beaches • Determination of water quality standards attainment • Evaluation of the impact of point and non-point sources
Villa Angela Beach	East	41.5851	-81.5677	Eastern half of beach, mid-distance between the 3rd and 4th break walls	East Cleveland	
Euclid Beach	East	41.5843	-81.5686	Eastern half of beach in line with the East side of the pile of stones on the beach	East Cleveland	
Euclid Creek	RM 0.55	41.5831	-81.5594	Downstream of Lakeshore Boulevard	East Cleveland	

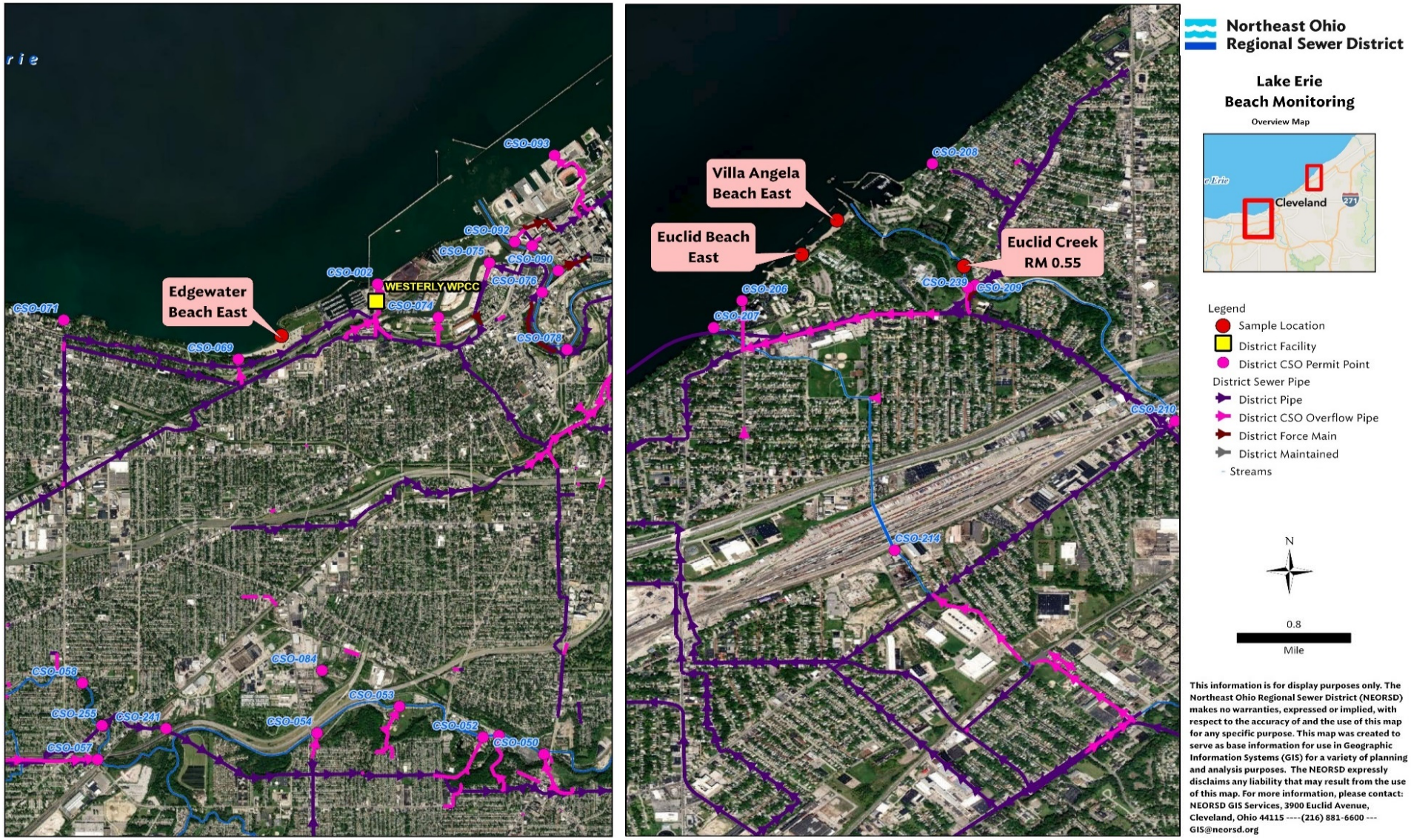

Figure 1. Map of Sampling Sites

Methods

Bacteriological sampling was conducted from May 2, 2022, to September 29, 2022. From May 2 through May 12, water samples were collected from each beach and Euclid Creek RM 0.55 (further referred to simply as Euclid Creek) four days a week (Monday through Thursday). Beginning May 16, and lasting through September 4, samples were collected at each beach and Euclid Creek seven days a week. From September 5 through September 29, sampling at all sites returned to four days a week (Monday through Thursday). A total of 134 samples were collected at each site. Overall, a total of 569 samples including 33 replicates were collected throughout the course of this study.

Field analysis included the use of a Hanna HI 98129 meter to measure pH, water temperature, and specific conductance. The Hach 2100Q Portable Turbidimeter was additionally used to obtain field turbidity measurements. An in situ YSI EXO2 sonde installed along the eastern breakwall of Edgewater Beach collected field measurements of chlorophyll *a* and phycocyanin pigments, pH, turbidity, temperature, and turbidity. The data sonde was primarily used as a real-time predictive tool for HAB monitoring by utilizing the ratio of chlorophyll *a* vs phycocyanin pigments measured by the EXO Total Algae PC Sensor. All water samples, field parameters and analyses were collected as specified in the most current NEORSD Beach Sampling Standard Operating Procedure (*SOP-EA016-19*) and Ohio EPA's *Surface Water Field Sampling Manual for water quality parameters and flows* (Ohio EPA, 2021).

Bacteriological grab samples were collected in a 250-milliliter sterilized polypropylene container. Samples at each location were collected approximately 6-12 inches below the surface, in water that was approximately three feet deep. At the time of sample collection, field parameters were measured, and field observations and water conditions were documented at each beach site. All data collected was recorded on an NEORSD Beach Sampling Field Data Form. All samples were placed in a cooler with ice and stored in a locked NEORSD vehicle until the samples were transferred to NEORSD's Analytical Services sample receiving with a Chain of Custody. All Beach Sampling Field Data Forms, Chains of Custody and Certificates of Analysis are available upon request from the Water Quality and Industrial Surveillance Division, and the Analytical Services Division.

The quality assurance and quality control of bacteriological water sample collections included field replicates that were collected at a frequency not less than 5% of the total samples collected. Since field blanks are not required by method SM 9223 or by the National Environmental Laboratory Accreditation Conference (NELAC) for bacteria analysis, no bacteriological field blanks were collected during the study. Analytical Services has procedures in place which are required by NELAC to demonstrate that the sample containers are clean and sterile.

Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and replicate sample (Formula 1).

Formula 1: $$RPD = \left(\frac{|X-Y|}{((X+Y)/2)} \right) * 100$$

X= is the concentration of the parameter in the primary sample
Y= is the concentration of the parameter in the replicate sample

For bacteriological samples, the acceptable RPD is 133.3%. Those RPDs that are higher than acceptable may indicate potential problems with sample collection and, as a result, the data would not be used for comparison to the water quality standards.

Statistical Analysis was performed using either RStudio version 4.2.1 or Microsoft Excel Office 365. Euclid Creek flow data from 2013-2022 was obtained from the United States Geological Survey (USGS) gage station on Euclid Creek located at Lakeshore Boulevard, Cleveland (gage number 04208700). Euclid Creek bacteriological data was taken from historical sampling on Euclid Creek at RM 0.55 by the NEORSD from Level 3 Credible Data studies from 2013-2022 during the recreational season.

Results and Discussion

The *E. coli* results from each beach site were compared to the Ohio Water Quality Standards to determine recreational use attainment. From May 1st to October 31st, the three beaches are designated as Bathing Waters for the Protection of Recreational Use, while Euclid Creek is designated as a Primary Contact Recreation stream (Ohio EPA, 2021). Both the Bathing Waters and Primary Contact Recreation criteria for *E. coli* include a statistical threshold value (STV) criterion not to exceed 410 colony counts units per 100 milliliters (colony counts/100mL) in more than ten percent of the samples collected during any 90-day period and a 90-day geometric mean criterion of 126 colony counts/100mL. The Bathing Waters criteria also maintain the use of the previous single sample maximum limit of 235 colony counts/100mL as the beach action value for the purpose of posting daily water quality advisories.

Throughout the study, a total of 33 replicate samples were collected for a final replicate frequency of 6%. No replicate samples collected at any of the four sites were outside of the acceptable RPD during the 2022 season.

Recreational Use Attainment Status

Edgewater Beach

Water Quality Standards attainment status of Edgewater Beach for Bathing Water recreational use criteria are shown in Figures 2 and 3. Edgewater Beach was in non-attainment of the geomean criterion for seven of the 90-day periods, a frequency of 5.2%, and in non-attainment of the STV criterion for 35 of the 90-day periods, an exceedance frequency of 26.1%. Single samples exceeded the Beach Action Value of 235 colony counts/100mL for 16 of the 134 sampling events,

a frequency of 11.9%. Fifteen of the 16 exceedances of the Beach Action Value (94%) occurred within 48 hours of a rain event with a total rainfall greater than 0.10 inches.

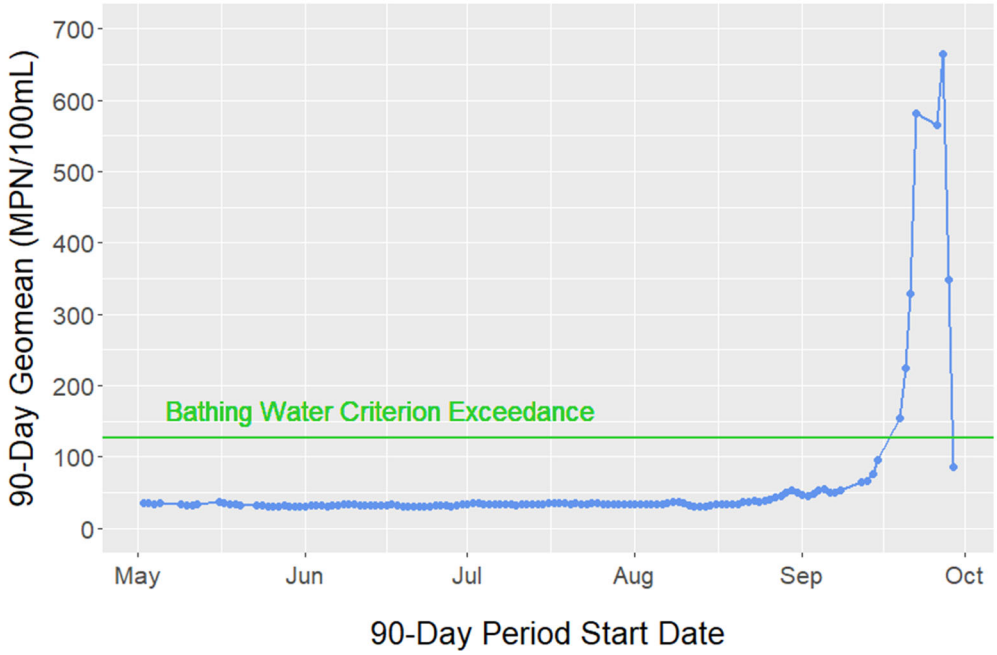

Figure 2. 2022 Edgewater Beach East Site - Attainment of Bathing Water STV Criterion

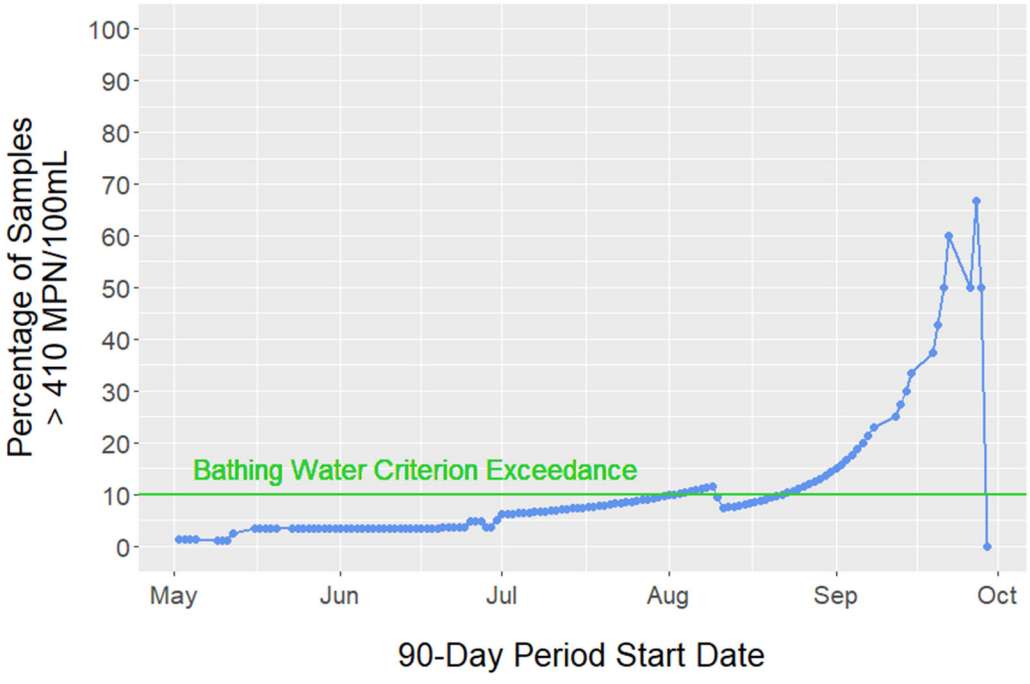

Figure 3. 2022 Edgewater Beach East Site - Attainment of Bathing Water 90-Day Geomean Criterion

Euclid Beach

Euclid Beach was in non-attainment of the Bathing Water recreational criteria for most of the recreation season in 2022 (Figures 4 and 5). Euclid Beach was in non-attainment of the STV criterion for 89.6% of the 90-day periods. Euclid Beach was also in non-attainment of the geometric mean criterion for 10 of the 90-day periods, an exceedance frequency of 7.5%. Single samples exceeded the Beach Action Value of 235 colony counts/100mL for 32 of the 134 sampling events, a frequency of 23.9%. Twenty-two of these 32 exceedances (68.8%) occurred within 48 hours of a rain event with a total rainfall greater than 0.10 inches.

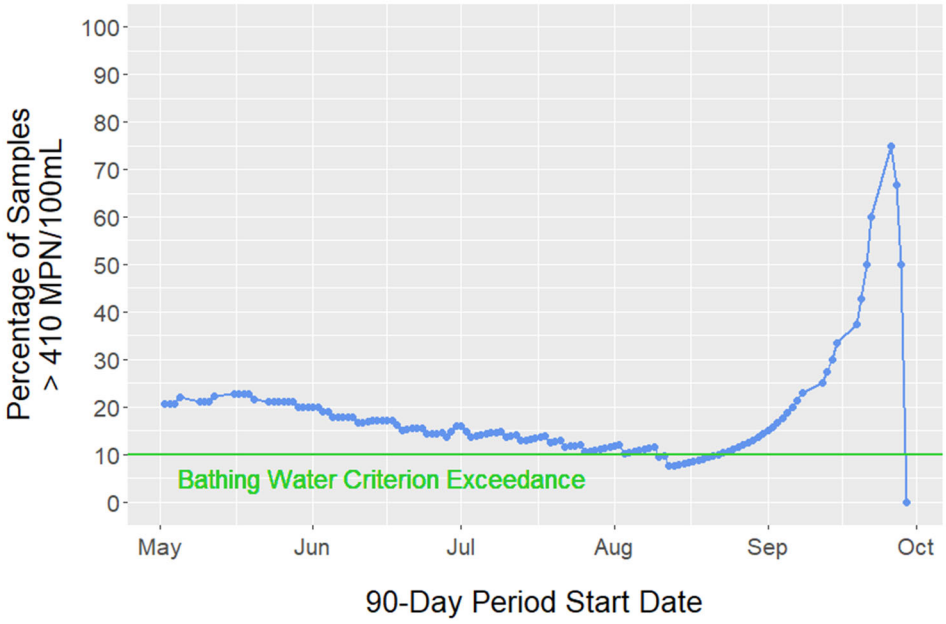

Figure 4. 2022 Euclid Beach East Site - Attainment of Bathing Water STV Criterion

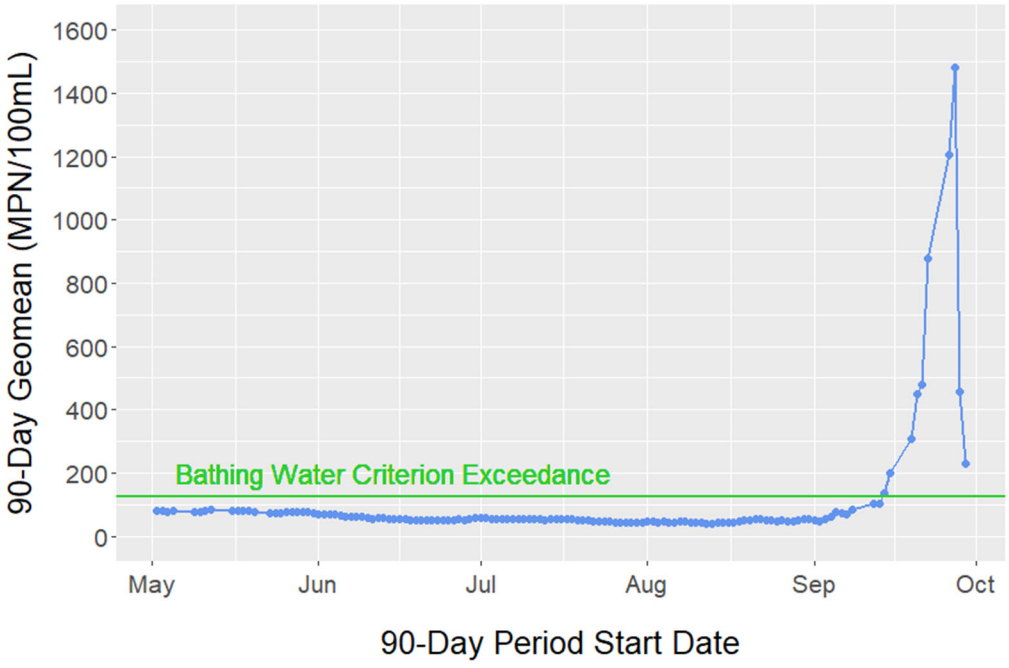

Figure 5. 2022 Euclid Beach East Site - Attainment of Bathing Water 90-Day Geomean Criterion

Villa Angela Beach

Villa Angela Beach was also in non-attainment of the Bathing Water recreational use criteria for most of 2022 (Figures 6 and 7). Villa Angela exceeded the STV criterion for 99.3% of the 90-day periods and exceeded the geomean criterion for 9.7% of the 90-day periods in 2022. Single samples exceeded the beach action value of 235 colony counts/100mL for 35 of the 134 sampling events, a frequency of 26.1%. Twenty-five of these 35 exceedances (71.4%) occurred within 48 hours of a rain event with a total rainfall greater than 0.10 inches, and 21 of the 35 exceedances (60%) occurred within 72 hours of a rain event with a total rainfall greater than 0.25 inches.

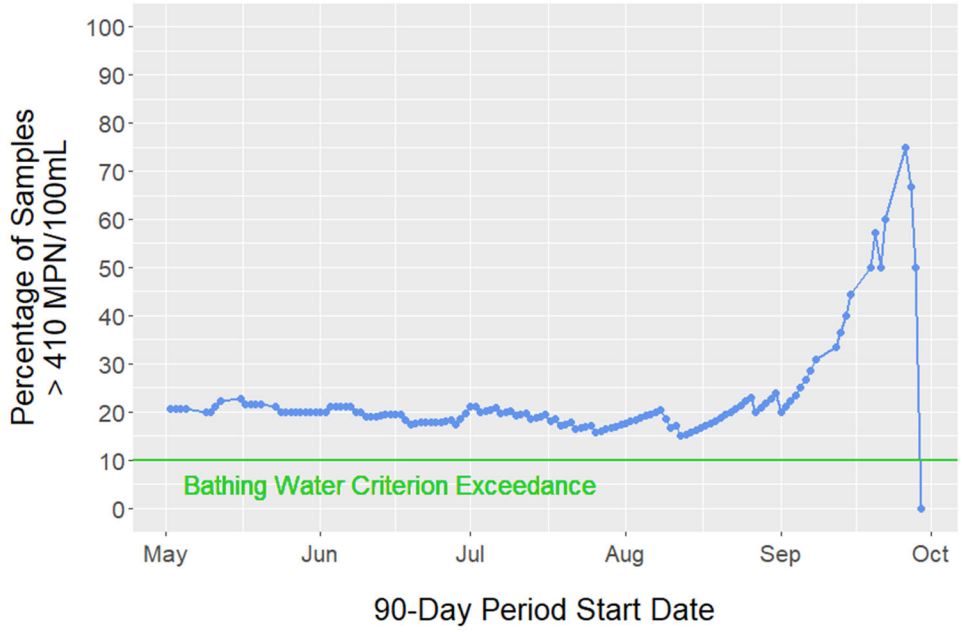

Figure 6. 2022 Villa Angela Beach East Site - Attainment of Bathing Water STV Criterion

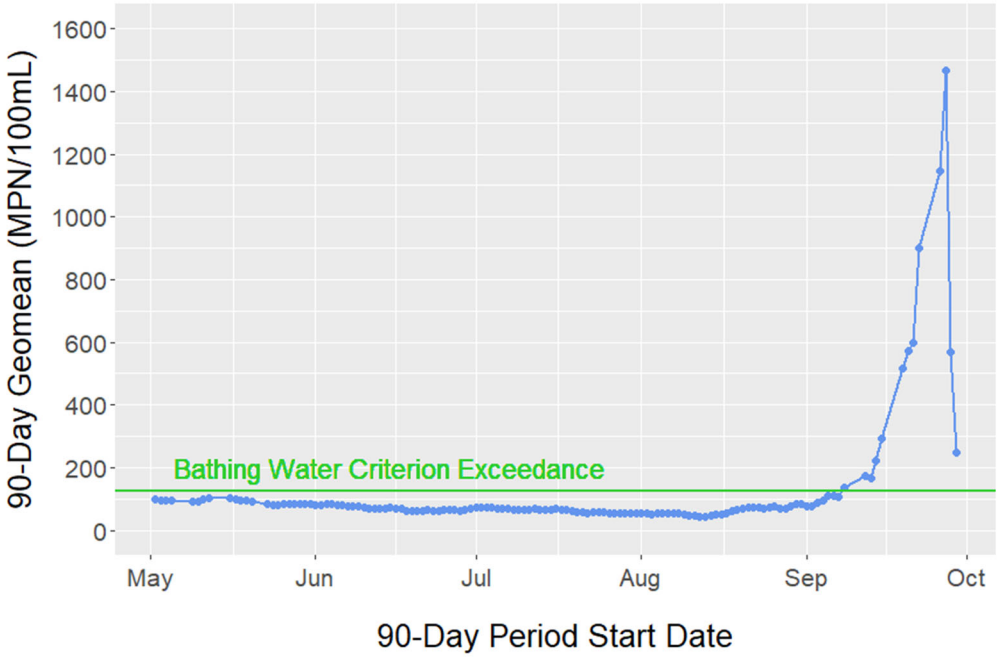

Figure 7. 2022 Villa Angela Beach East - Attainment of Bathing Water 90-Day Geomean Criterion

Euclid Creek RM 0.55

Euclid Creek was in non-attainment of both Primary Contact recreational criteria in 2022 (Figures 8 and 9). Euclid Creek exceeded both the STV and geomean criterion for 100% of the 90-day periods. As further discussed below, Euclid Creek RM 0.55 has displayed this degree of exceedance for as long as monitoring has been performed by the NEORSD.

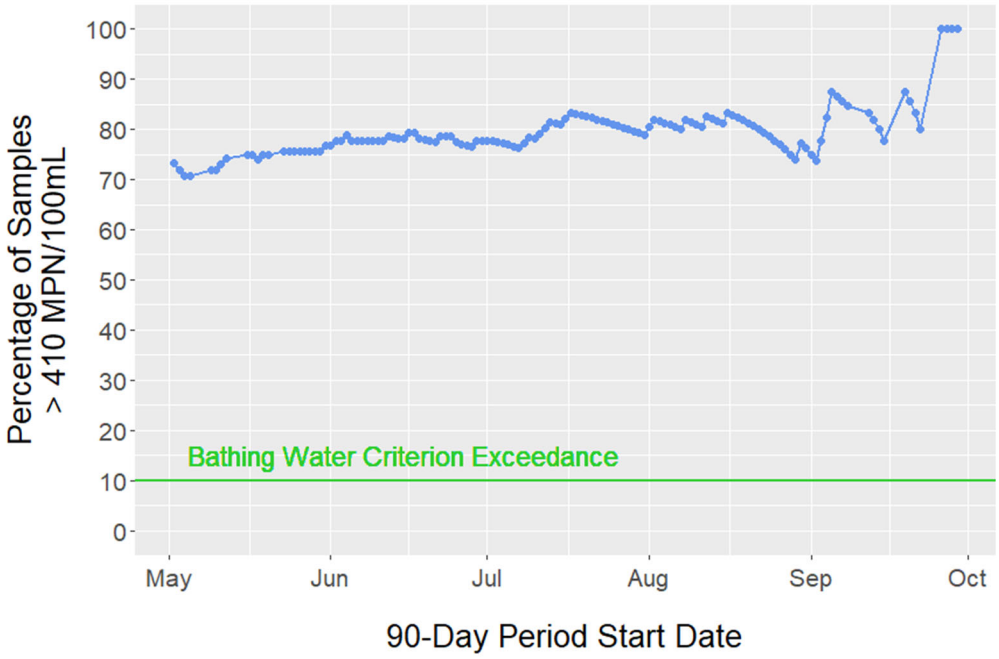

Figure 8. 2022 Euclid Creek RM 0.55 - Attainment of Primary Contact Water STV Criterion

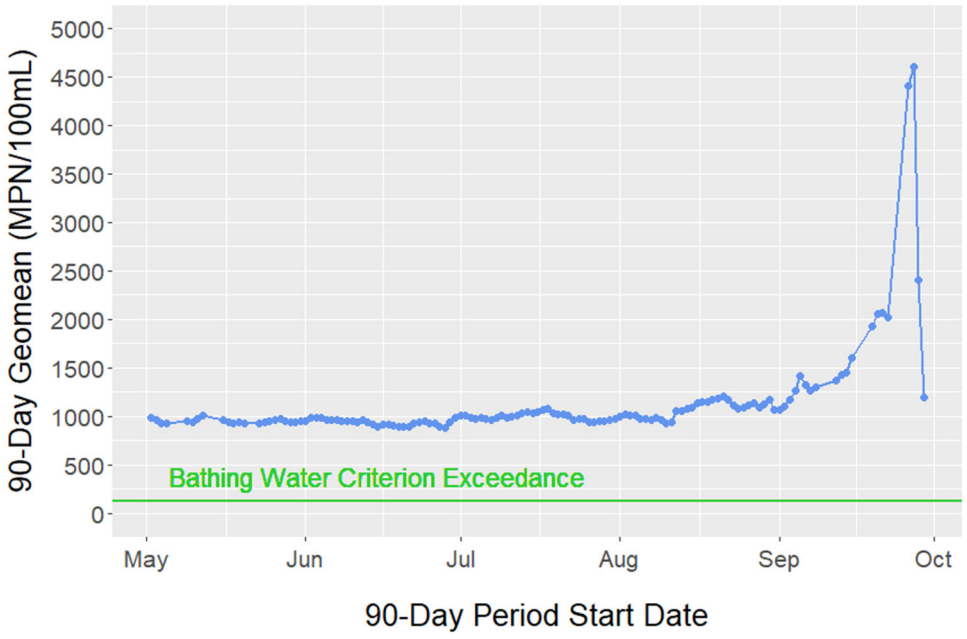

Figure 9. 2022 Euclid Creek RM 0.55 - Attainment of Primary Contact Water 90-Day Geomean Criterion

Comparison with Historical Data, Rainfall, and CSO Occurrence

Tables 2-5 present historical data on the recreational use criteria exceedances for all the sites included in this study. The NEORSD began submitting beach monitoring data to the Ohio EPA Credible Data Program in 2009. Therefore, prior data is not included in this comparison. It should be noted that the recreational use criteria have been modified within the presented timeline. From 2009 to 2014, the applicable Bathing Waters recreational use criteria included an *E. coli* criterion not to exceed a single sample maximum (SSM) of 235 colony counts/100mL in more than ten percent of the samples collected during any 30-day period, and a seasonal geometric mean (SGM) criterion of 126 colony counts/100mL (Ohio EPA, 2010). The current 90-day STV and geometric mean criteria took effect in 2015. The data presented in Tables 2-5 represent exceedances of the criteria that were applicable at the time of sample collection. For comparative purposes only, the SGM *E. coli* density was also calculated from data collected from 2015-2022, even though it does not apply to data collected from these years. Additionally, the beach action value of 235 colony counts/100mL used to post public advisories has remained constant for the entire period of record. The seasonal percent exceedance of the beach action value for each beach site is also presented in Tables 2-5 for historical comparison.

The SSM/STV value percentages, geometric mean, and beach action percentages were all higher at Edgewater Beach compared to the previous year (Table 2).

Table 2. Edgewater Beach Historical Recreational Use Criteria Exceedances

Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value % Exceedance	SGM
2022	26.1	5.2	11.9	34*
2021	3.8	0	7.5	33*
2020	0	0	12.6	30*
2019	3.8	0	13.7	52*
2018	91.4	1.6	13.6	35*
2017	0.0	0.0	6.9	30*
2016	0.0	0.0	8.3	35*
2015	34.8	0.0	18.8	77*
2014	93.0	N/A	20.0	60
2013	66.0	N/A	13.9	53
2012	58.6	N/A	11.6	41
2011	92.2	N/A	26.6	98
2010	73.0	N/A	13.3	56
2009	90.6	N/A	28.1	107
Average	*45.2*	*0.9*	*14.8*	*54.4*

Exceedances of historical SGM criterion in **Bold (>126 colony counts per 100mL)**
*SGM does not apply. Calculated for comparative purposes only.

The geometric mean, SSM/STV value percentages, and beach action percentages were all lower at Euclid Beach compared to the previous year (Table 3). Additionally, the SSM/STV value percentages and geometric mean were found to be higher at Villa Angela Beach compared to the previous year (Table 4). There was an increase in high intensity rain events in 2022 compared to 2021. This may be the cause of the observed increase in exceedances at Edgewater and Villa Angela Beach as further discussed below.

Table 3. Euclid Beach Historical Recreational Use Criteria Exceedances

Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value % Exceedance	SGM
2022	89.6	7.5	23.9	65*
2021	94.7	9.0	25.6	89*
2020	79.3	3.7	17.1	68*
2019	89.4	15.2	26.5	63*
2018	98.6	2.0	29.8	84*
2017	66.1	1.5	25.4	79*
2016	89.5	0.0	24.8	71*
2015	97.8	33.8	37.7	**136***
2014	98.0	N/A	32.2	126
2013	97.0	N/A	41.1	**144**
2012	99.3	N/A	36.9	118
2011	100	N/A	43.6	**149**
2010	90.0	N/A	36.3	110
2009	100	N/A	36.6	112
Average	*92.1*	*9.1*	*31.3*	*101*

Exceedances of historical SGM criterion in **Bold (>126 colony counts per 100mL)**
*SGM does not apply. Calculated for comparative purposes only.

Table 4. Villa Angela Beach Historical Recreational Use Criteria Exceedances

Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value % Exceedance	SGM
2022	99.3	9.7	26.1	78*
2021	94.0	6.8	30.7	87*
2020	74.8	3.7	20.0	77*
2019	84.1	20.5	28.8	100*
2018	98.6	0.0	30.5	93*
2017	79.2	8.4	29.2	89*
2016	91.7	5.3	33.1	99*
2015	97.8	51.8	46.4	**181***
2014	96.0	N/A	34.4	**147**
2013	91.0	N/A	41.7	**141**
2012	100	N/A	41.5	110

Table 4. Villa Angela Beach Historical Recreational Use Criteria Exceedances				
Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value % Exceedance	SGM
2011	100	N/A	46.0	**174**
2010	100	N/A	34.9	**128**
2009	100	N/A	43.8	**172**
Average	*93.3*	*13.3*	*34.8*	*120*
Exceedances of historical SGM criterion in **Bold (>126 colony counts per 100mL)** *SGM does not apply. Calculated for comparative purposes only.				

The geometric mean and SSM/STV value percentages at Euclid Creek RM 0.55 remain unchanged throughout the historical period of record (Figure 5).

Table 5. Euclid Creek Historical Recreational Use Criteria Exceedances				
Year	SSM/STV % Exceedance	Geometric Mean % Exceedance	Beach Action Value % Exceedance	SGM
2022	100	100	N/A	**909***
2021	100	100	N/A	**1185***
2020	100	100	N/A	**1168***
2019	98.5	99	N/A	**1241***
2018	100	100	N/A	**1006***
2017	100	100	N/A	**1510***
2016	100	100	N/A	**907***
2015	100	100	N/A	**1246***
2014	100	N/A	N/A	**1617**
2013	100	N/A	N/A	**1092**
2012	100	N/A	N/A	**973**
2011	100	N/A	N/A	**1351**
2010	100	N/A	N/A	**1047**
2009	99.3	N/A	N/A	**852**
Average	*99.8*	*99.9*	*N/A*	***1120***
Exceedances of historical SGM criterion in **Bold (>126 colony counts per 100mL)** *SGM does not apply. Calculated for comparative purposes only.				

Table 6 presents total rainfall in inches during the past eleven years of recreational seasons (May 1st to October 31st) as measured at the Division Avenue (located near Edgewater Beach) and Easterly WWTP rain gauges (located near Euclid and Villa Angela Beaches and Euclid Creek). Total rainfall in 2022 was measured two inches higher at Division Avenue and one inch higher at the Easterly WWTP rain gauges during the recreation season compared to 2021. During the recreation season in 2021, there were 17 days where precipitation exceeded 0.5 inches in 24 hours, and in 2022 there were 25 days were precipitation exceeded 0.5 inches in 24 hours. Significant wet-

weather[1] events and runoff are often associated with elevated microbial densities at Great Lakes Beaches. Point and non-point source contaminants are flushed into surface water from inflow and infiltration in common trench sanitary/storm sewer systems, combined sewer overflows (CSOs), urban stormwater including sediment, nutrients, pet and wildlife waste, sanitary sewer overflows, and illicit cross connections (Chaganti et. al, 2022).

Table 6. Total Rainfall (Inches) from May 1st to October 31st

Year	Division Ave Rain Gage (West Side)	Easterly Rain Gage (East Side)
2022	26.01	25.43
2021	24.00	24.60
2020	29.50	26.30
2019	31.80	27.70
2018	27.56	25.32
2017	16.56	20.30
2016	13.87	16.23
2015	23.40	23.41
2014	24.50	25.12
2013	21.35	28.31
2012	26.46	24.80
Average 2012-2022	**24.09**	**24.32**

Contributions of CSO discharges may have influenced criteria exceedances at Edgewater, Euclid, and Villa Angela Beaches in 2022. Figures 10 and 11 show the proximity of nearby CSO outfalls to the three beaches. Table 8 shows the number of overflow events and total volume of discharge from the listed CSOs from May 1 to October 31. CSO discharge and capture volumes were provided by the NEORSD Engineering and Construction department and include both modeled and direct flow measurements.

In the proximity of Edgewater Beach, 20 overflow events occurred during the 2022 recreational season. Thirteen of these events occurred from CSO-002, the Westerly Wastewater Treatment Center Overflow, two from CSO-069, and five from CSO-071.

Twenty-five overflow events occurred in the proximity of Euclid and Villa Angela Beaches in 2022, down from 80 overflow events in 2019. These events among other contributing factors most likely influenced the elevated *E. coli* densities observed at these beaches.

[1] Wet-weather sampling events: greater than 0.10 inches of rain but less than 0.25 inches, samples collected that day and the follow day are considered wet-weather samples; greater than 0.25 inches, the samples collected that day and the following two days are considered wet-weather samples.

Figure 10. Proximity of CSO Outfalls to Edgewater Beach.

Figure 11. Proximity of CSO Outfalls to Euclid and Villa Angela Beaches

Table 7. CSO Events from May 1 to October 31									
Outfall ID	Nearest Beach	Number of Overflow Events (Total Overflow Volume (Million Gallons))							
		2022	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**
CSO-002	Edgewater	13 (278.3)	16 (250.2)	14 (466.1)	15 (155.8)	19 (277.7)	8 (180.3)	9 (125.3)	16 (235.2)
CSO-069	Edgewater	2 (0.1)	1 (0.3)	3 (1.7)	2 (0.2)	2 (0.1)	0 (0.0)	0 (0.0)	3 (6.5)
CSO-071	Edgewater	5 (NA)	2 (NA)	3 (NA)	0 (0.0)	3 (NA)	0 (0.0)	0 (0.0)	5 (NA)
CSO-001	Euclid/Villa Angela	22 (992.3)	19 (394.3)	21 (637.9)	19 (294.8)	23 (670.5)	17 (614.6)	28 (1,346.7)	31 (2301.9)
CSO-206	Euclid/Villa Angela	0 (0.0)	0 (0.0)	0 (0.0)	49 (21.0)	18 (65.3)	22 (37.4)	13 (18.3)	13 (50.7)
CSO-239	Euclid/Villa Angela	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	27 (033.5)	31 (18.0)	39 (26.7)	46 (60.0)
CSO-242	Euclid/Villa Angela	3 (0.9)	1 (2.5)	3 (1.2)	12 (21.8)	6 (10.5)	5 (4.5)	7 (9.0)	17 (20.7)

Impact of Euclid Creek and the Euclid Creek Storage Tunnel on Recreational Use Attainment Status

The Euclid Creek Storage Tunnel (ECT), a CSO storage tunnel designed to capture CSO discharges, was brought partially online in July 2018, and was fully operational for the 2021 and 2022 recreational seasons. As a result of this, there were zero overflow events at CSO-239 and CSO-206 between May 1 and October 31 from 2020-2022. In total, the Euclid Creek Storage Tunnel captured 210.82 million gallons of mixed sewage and stormwater during that period.

Euclid Creek RM 0.55 is located downstream of all NEORSD CSOs. The site therefore serves as an excellent monitoring location to determine the effectiveness of the Euclid Creek Tunnel in improving recreational water quality criteria parameters on Euclid Creek following CSO control. To determine if the Euclid Creek Tunnel successfully reduced *E. coli* densities in Euclid Creek, daily sampling results from the past 10 years' recreational seasons were compared. The data were grouped into three-time spans. The "No Tunnel" time span includes data from 2013-2017 before the completion of all portions of the ECT. The "Partial" time span includes data from 2018-2020 during the construction of the ECT when CSOs may have been partially controlled. The "Tunnel" time span includes data from 2021-2022 following completion of the ECT.

The *E. coli* density distributions of the three-time spans, shown as box plots in Figure 12, were compared using a series of Wilcoxon rank-sum tests. There was no significant difference between the "No Tunnel" and "Partial" time periods. *E. coli* densities were significantly reduced in the "Tunnel" period compared to both the "No Tunnel" ($p = 0.005$) and "Partial" ($p = 0.002$) time periods. However, a comparison of the distribution of Euclid Creek discharge volumes for these three time periods suggests that this difference may be due to variation in weather patterns between these time periods. Figure 13 shows the distributions of the Euclid Creek discharge volumes for the three time periods at the USGS gage station at Lakeshore Boulevard (USGS monitoring location 04208700). The "Tunnel" period had an increased distribution of low flow events, which may have been the cause of the decreased *E. coli* densities rather than the impact from the CSO capture by the ECT.

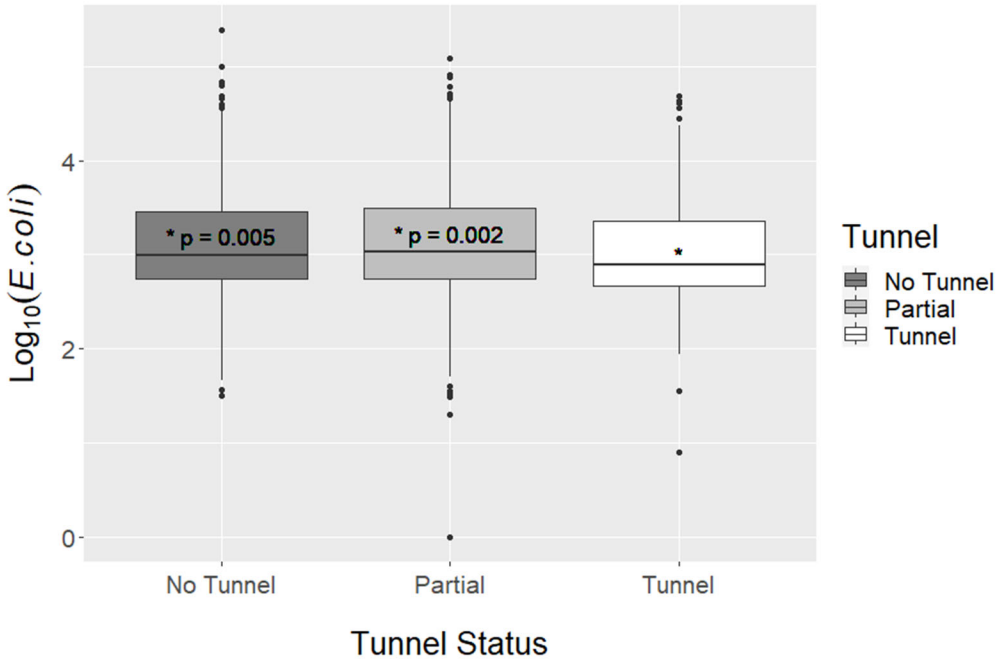

Figure 12. Boxplot showing the distributions of recreation season *E. coli* densities before, during, and after construction of the ECT.

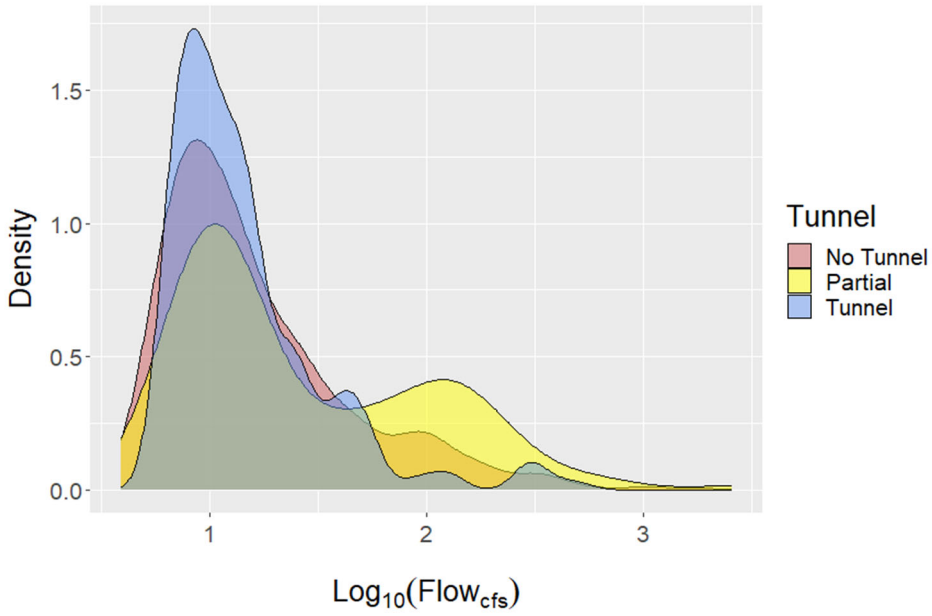

Figure 13. Smooth density plots of the Euclid Creek discharge volume at the USGS gage station at Lakeshore Boulevard.

To control for the impact of weather variation, the relationship between stream flow and *E. coli* was compared between "No Tunnel" and "Tunnel" time periods. Stream flow was chosen because there is a strong correlation between Euclid Creek stream flow and *E. coli*. CSO discharges occur during wet-weather events in periods of high stream flow. Therefore, CSO capture would be expected to result in a decrease in the slope of the relationship between stream flow and in-stream *E. coli* densities. Figure 14 shows linear regression models for the relationship between Euclid Creek flow measured at Lakeshore Boulevard (USGS gage 04208700) and *E. coli* at ECMB RM 0.55, just downstream of Lakeshore Boulevard. No change in the relationship between stream flow and *E. coli* was observed as determined using the analysis of covariance model (ANCOVA model p = 0.161, Figure 14). This indicates that the ECT had no impact on weather-dependent increases of *E. coli* in Euclid Creek.

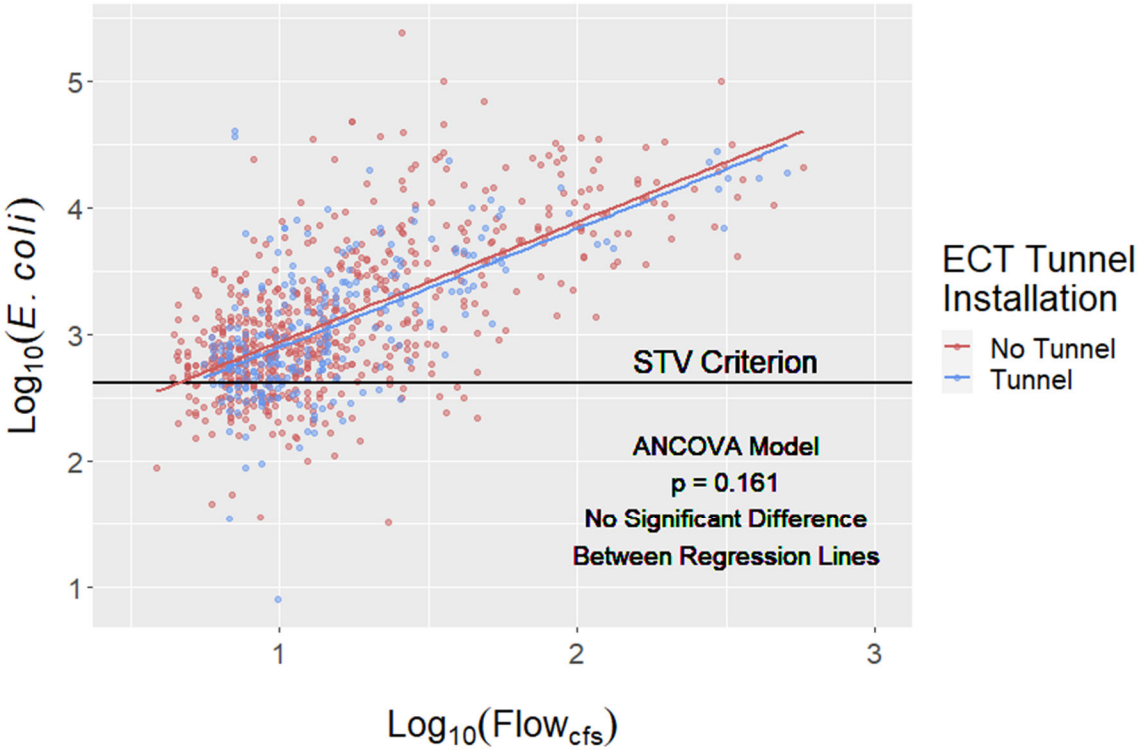

Figure 14. ANCOVA Analysis of *E. coli* as a function of Euclid Creek flow before and after ECT installation. No significant difference was observed before and after installation.

In addition to linear modeling used in ANCOVA, the data was also fitted using locally estimated scatterplot smoothing (LOESS). This was performed to determine if there were changes in the relationship between *E. coli* and flows during peak flows when CSO events were likely to occur. LOESS curves for both the "No Tunnel" and "Tunnel" data sets were nearly identical. This suggests that the ECT capture of 100% of NEORSD CSO discharges had no impact on the reduction of *E. coli* densities in Euclid Creek when variations in weather patterns are accounted for. This indicates that NEORSD-operated CSOs were not a major contributing factor to recreational use

criteria impairments that worsen during wet-weather events when compared to other wet-weather sources of *E. coli*. While CSO control may have had some minor impact on *E. coli* densities during wet-weather conditions and high stream flow, the major causes of recreational use criteria impairment to Euclid Creek remain unaddressed.

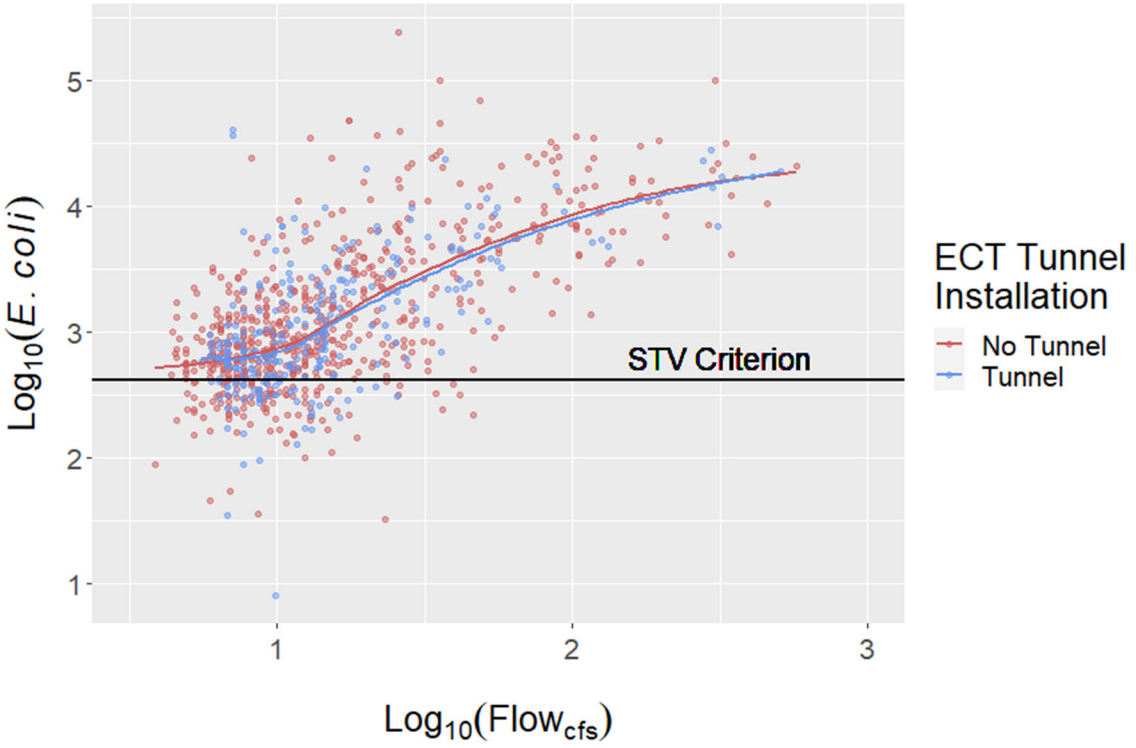

Figure 15. LOESS analysis of *E. coli* as a function of Euclid Creek flow before and after ECT installation. No change in the relationship between wet-weather flows and *E. coli* was observed.

Previous studies have also indicated that NEORSD CSO discharges are not the major contributor to recreational criteria exceedances in Euclid Creek. The NEORSD 2018 Villa Angela Beach Microbial Source Study demonstrated that *E. coli* densities were equally elevated both upstream and downstream of NEORSD-operated CSOs while the CSOs were discharging (NEORSD, 2019). The NEORSD 2019-2021 Euclid Creek Bacteriological Study utilized microbial source tracking to demonstrate that human sewage contamination was present throughout the entirety of the Euclid Creek watershed including reaches upstream of both NEORSD and City of Euclid CSOs (NEORSD, 2022). This human sewage contamination increased significantly during wet-weather events and was as elevated upstream of CSOs as it was downstream. *E. coli* loading calculations performed in the 2019-2021 study demonstrated that, while removal of CSO discharges eliminated a small volume (~3% of Euclid Creek's total discharge volume) of highly contaminated flow, the remaining 97% of the Euclid Creek flow was still highly contaminated from upstream sources. These sources may include but are not limited to common trench sewer inflow and infiltration, sanitary sewer overflows, urban stormwater runoff, wildlife fecal contamination, and illicit discharges. While capture of CSO discharges is a necessary step in the improvement in water quality in the

region, the amount of upstream contamination in Euclid Creek remains the major hurdle for meeting the recreational criteria. Until these issues are addressed, the positive impact from the ECT may remain masked by upstream sources.

Harmful Algal Bloom Monitoring

On July 15, 2022, WQIS personnel received a report of a possible harmful algal bloom (HAB) at Villa Angela Beach. A phytoplankton identification sample was collected and analyzed as specified in Ohio's *State of Ohio Harmful Algal Bloom Response Strategy for Recreational Waters* (State of Ohio, 2020). Cyanobacteria genera capable of producing cyanotoxins were detected; however, the density and cell count were below the HAB threshold of 4,000 cells/mL (State of Ohio, 2020). The potential risk of cyanobacterial surface and sub-surface scum formation in central Lake Erie was also low during this time (NOAA, 2022). Recommendations, data, and best professional judgement were utilized to determine that no advisory or further sampling events were required.

The YSI EXO2 sonde deployed at Edgewater Beach detected no potential warning indicators of a HAB during the recreation season. No other possible and/or confirmed HABs were visually detected by or reported to WQIS personnel during the 2022 recreational season.

The National Oceanic and Atmospheric Administration (NOAA) conducted a bloom analysis and determined that the cyanobacteria bloom in the western basin of Lake Erie was considered moderately severe (Figure 16). The 2022 bloom in the western basin was less extensive than in 2021, but more severe due to higher bloom concentrations. The 2022 bloom persisted later in the season lasting longer than usual. However, it did not spread east to the central basin, so the beaches monitored during this study were not impacted.

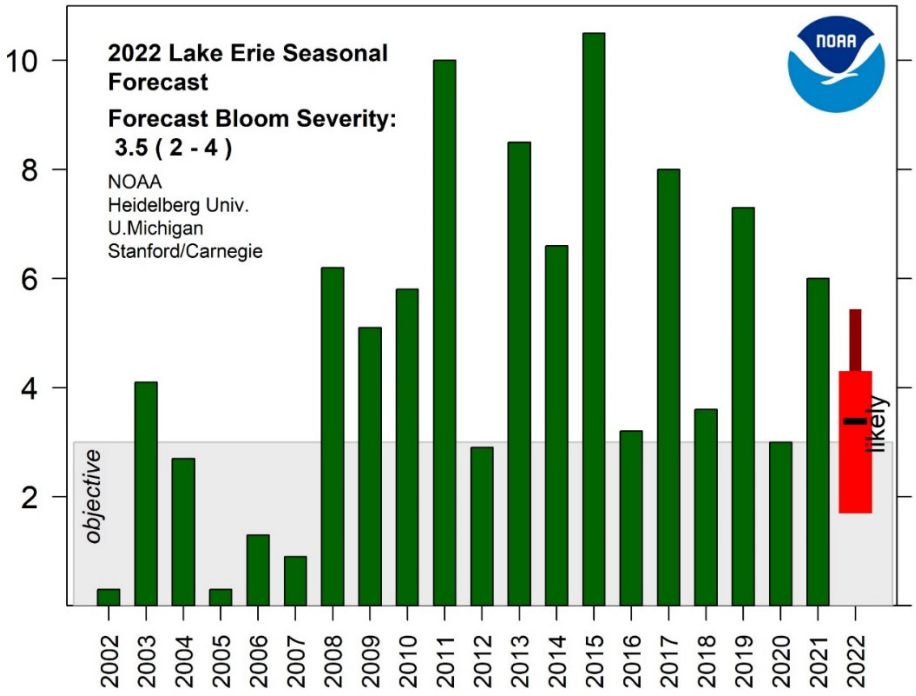

Figure 16. NOAA Forecasted Bloom Severity Index for 2022.

Conclusions

In 2022, Edgewater Beach was found to be in attainment of the bathing water recreational criteria for a majority of the season, attaining the geometric mean criterion for 95% and for STV criterion 74% of the time of record. Euclid and Villa Angela Beaches were in attainment of the geometric mean criterion for 93% and 90% of the season. However, Euclid and Villa Angela Beaches were in non-attainment of the STV criterion for 90% and 99% of the season. Exceedances of the water quality criteria were often related to high intensity wet-weather events. Potential point and non-point sources of contamination from CSOs, urban stormwater including sediment, nutrients, pet and wildlife waste, sanitary sewer overflows, common trench sewer inflow and infiltration, and illicit connections can lead to elevated *E. coli* densities during wet weather. An increase in the exceedance frequency of the STV criterion was observed at Edgewater Beach in 2022 compared to 2019-2021. This was likely to related to high intensity wet-weather events later in the recreation season. The Euclid Creek Tunnel System continued to capture all overflow events from CSO-239 and CSO-206 and eliminated 210.82 million gallons of sewage and storm water between May 1 and October 31, 2022. Water quality may continue to improve at Euclid Creek and Euclid and Villa Angela Beaches because of infrastructure investment and upgrades but will likely continue to be limited by widespread bacteriological contamination in the Euclid Creek watershed. During the 2022 recreational season, a potential HAB was reported at Villa Angela Beach. A sample was collected and cyanobacteria genera capable of producing cyanotoxins were detected; however, the density and cell count were below the advisory value criteria determined by the State of Ohio.

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