Northeast Ohio Regional Sewer District

2024 Greater Cleveland Area Lake Erie Nutrient Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

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Table of Contents

List of Figures

List of Tables

Introduction

Harmful algal blooms (HABs) in freshwater systems like Lake Erie generally consist of cyanobacteria. The most common bloom-forming cyanobacteria in Lake Erie is *Microcystis* which can produce the toxin Microcystin. These cyanobacterial HABs pose a threat to human health, the economy, recreational activities, and the ecology of Lake Erie and the cities which surround it. In August 2014, an algal bloom led to a "do not drink" advisory in Toledo, Ohio impacting the drinking water of over one half a million people.

Throughout the past two decades there has been an increase in toxin-producing harmful algal blooms (HABs) in Lake Erie. Cyanobacterial blooms are known to occur annually in the western basin of Lake Erie where they are well studied. However, they have also been detected in the central basin by satellite offshore of Cleveland approximately 20% of time between 2002-2014 in July (Wynne and Stumpf, 2015). The increase in cyanobacteria blooms in Lake Erie may be attributed to eutrophication driven by increased nutrient loading particularly dissolved reactive phosphorus which is 100% bioavailable (US EPA, 2015).

In 2011, an extensive *Microcystis* bloom in the western basin spread east of Cleveland with water currents and persisted into October (Chaffin et. al., 2019). In response to the record setting bloom in 2011, the Northeast Ohio Regional Sewer District (NEORSD) began performing nutrient monitoring in Lake Erie near Cleveland in 2012.

In 2015, another record setting bloom occurred in the western basin and was detected by National Oceanic and Atmospheric Administration (NOAA) satellite imagery in the central basin (NOAA, 2015). The 2015 bloom was the largest in this century with a severity index of 10.5 (NOAA, 2015). Although the bloom was not detected via NOAA satellite imagery near Cleveland beaches, HABs were observed at Villa Angela and Euclid Beaches in the month of September 2015 during daily sampling as part of the NEORSD's beach monitoring program.

HABs in Lake Erie surrounding the Greater Cleveland area have resulted in microcystin toxin concentrations above the Public Advisory Threshold of 6 ug/L during the recreational seasons of 2013, 2015, and 2018. This has resulted in water quality advisories for HABs at Edgewater and Villa Angela Beaches and presents an ongoing potential threat to local water quality and public health. Additionally, HAB toxins have been found to be present in fillets and retained in the livers of common sport fish in Lake Erie. While toxin levels in fish tissue rarely were found to exceed World Health Organization guidelines for consumption, increases in bloom frequency and intensity may result in increased human exposure to HAB toxins through fish consumption (Wituszynski et al., 2017) (Shahmohamadloo et. al., 2023).

Global climate change may play a role in increasing the frequency and intensity of future HABs through multiple mechanisms, highlighting the need for continued nutrient and HAB monitoring in Lake Erie. Higher atmospheric carbon dioxide levels may promote HAB growth in eutrophic waters with elevated nutrient concentrations (Visser et.al, 2015). Increased water temperature may favor toxin-producing cyanobacteria, which have higher temperature optima than competing diatoms, dinoflagellates, and green algae (Visser et.al, 2015 and USEPA, 2019).

Climate change driven alterations to rainfall patterns with a shift to higher intensity rains may increase nutrient loading to receiving waters through increased runoff and stream substrate erosion (USEPA, 2019). The impact from higher intensity rainfall patterns may be further exacerbated in urban and suburban watersheds where storm sewer infrastructure results in rapid spikes in stream flow following heavy rain events. Elevated phosphorus and nitrogen export in urban watersheds during rain events has been well documented, indicating stormwater management programs and green infrastructure projects may serve as frontline tools to control eutrophication and reduce HAB frequency and intensity (Duan et al., 2012 and Yang et al., 2017).

NEORSD continued nutrient monitoring efforts in 2024. This annual Lake Erie Nutrient Study was submitted to the Ohio Environmental Protection Agency's (Ohio EPA) Credible Data Program as a Level 3 study. This study covered eight sites on Lake Erie including six sites within 2 miles of the shoreline distributed west to east from the Rocky River to Euclid Creek confluences (See Table 1 and Figure 1 for sample site locations). The remaining two lake sites included a site near the Cleveland Water Intake Crib, approximately 3.8 miles offshore, and an additional offshore control site located northwest of the Cleveland Water Intake Crib (6.7 miles offshore). River sites were added to the study in 2015 to monitor nutrient contributions from Lake Erie tributaries including Rocky River, Cuyahoga River, and Euclid Creek. This study plan was approved by the Ohio EPA on April 4, 2024. Data collected as part of daily NPDES permit-required monitoring for the three NEORSD wastewater treatment plants is also included in this report.

All sampling at lake and river sites was completed by NEORSD Level 3 Qualified Data Collectors (QDCs) certified by Ohio EPA in Chemical Water Quality Assessment as explained in the NEORSD study plan *2024 Greater Cleveland Area Lake Erie Nutrient Study*. Sample locations are shown in Figure 1 and listed in Table 1. Wastewater Treatment Plant (WWTP) samples were collected by wastewater operators using similar methods. Sample analyses were conducted by NEORSD's Analytical Services division, which is accredited by the National Environmental Laboratory Accreditation Program (NELAP).

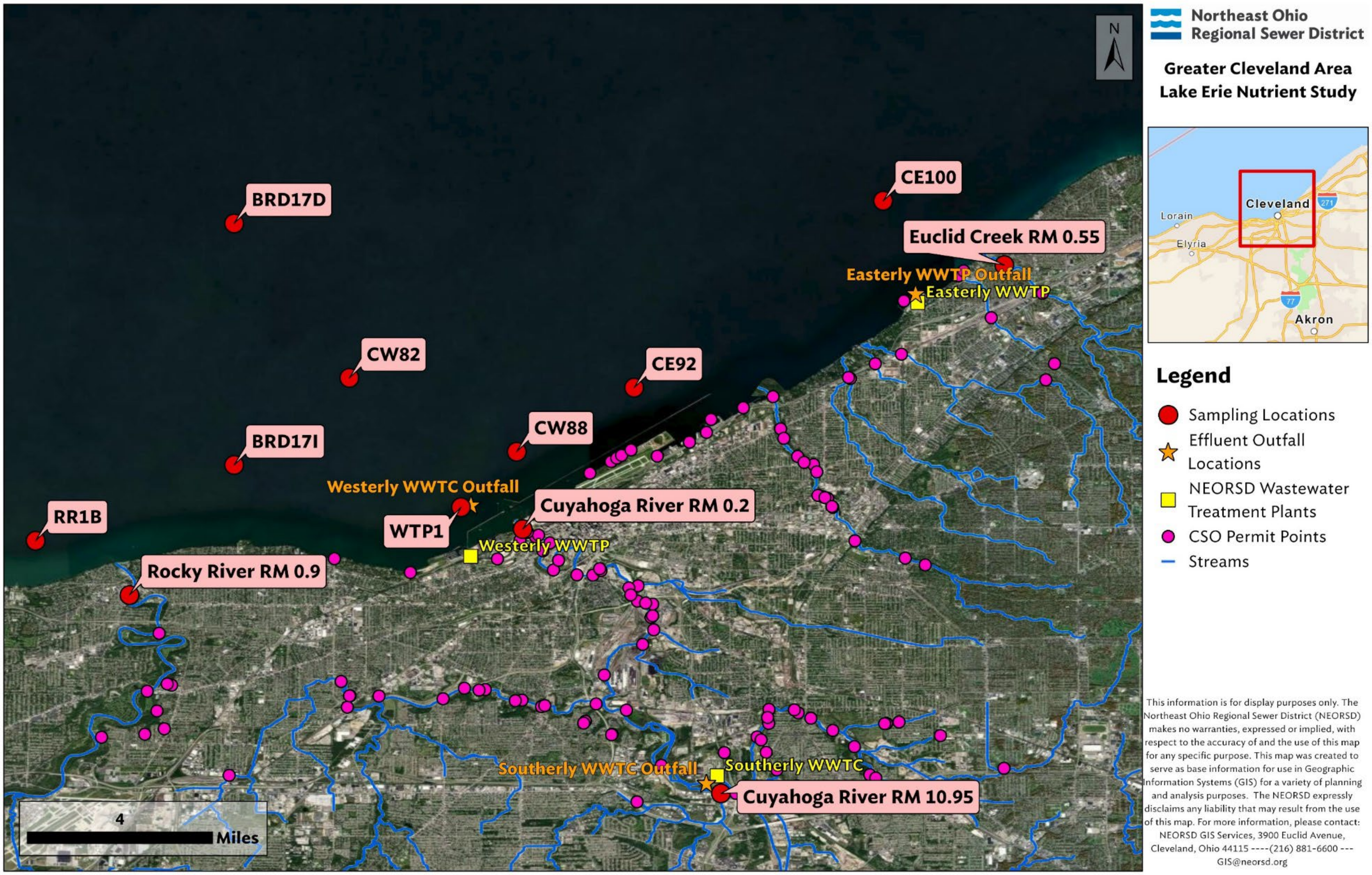

Figure 1. Sampling Locations

<table>
<tr><th colspan="7">Table 1. Lake Erie Nutrient Study Sampling Locations</th></tr>
<tr><th>Water Body</th><th>Latitude</th><th>Longitude</th><th>Station ID</th><th>Location Information</th><th>USGS HUC 8 Number -Name</th><th>Purpose</th></tr>
<tr><td rowspan="8">Lake Erie</td><td>41.49720</td><td>-81.86200</td><td>RR1B</td><td>Near Rocky River</td><td rowspan="8">04120200- Lake Erie</td><td rowspan="8">Determine trends in algal densities and nutrient concentrations in Lake Erie.</td></tr>
<tr><td>41.59630</td><td>-81.80000</td><td>BRD17D</td><td>About 7 miles offshore of Lakewood</td></tr>
<tr><td>41.52080</td><td>-81.80000</td><td>BRD17I</td><td>Near Lakewood</td></tr>
<tr><td>41.54800</td><td>-81.76400</td><td>CW82</td><td>Near Garrett Morgan Water Intake</td></tr>
<tr><td>41.50765</td><td>-81.72907</td><td>WTP1</td><td>Near Westerly WWTC Diffusers</td></tr>
<tr><td>41.52500</td><td>-81.71170</td><td>CW88</td><td>Outside the City of Cleveland's Breakwall</td></tr>
<tr><td>41.54500</td><td>-81.67500</td><td>CE92</td><td>Outside the City of Cleveland’s Breakwall</td></tr>
<tr><td>41.60333</td><td>-81.59717</td><td>CE100</td><td>2 miles north of Easterly WWTP outfall</td></tr>
<tr><td>Rocky River</td><td>41.4802</td><td>-81.8327</td><td>RRMB
RM 0.90</td><td>Upstream of Detroit Avenue</td><td>04110001 – Black/Rocky</td><td rowspan="7">Determine the contribution and effect to receiving waterbody.</td></tr>
<tr><td>Euclid Creek</td><td>41.5833</td><td>-81.5594</td><td>ECMB
RM 0.55</td><td>Downstream of Lake Shore Boulevard</td><td>04110003 Ashtabula-Chagrin</td></tr>
<tr><td>Cuyahoga River</td><td>41.5008</td><td>-81.7098</td><td>CRMB
RM 0.20</td><td>Near confluence of river in navigation channel</td><td>04110002 - Cuyahoga</td></tr>
<tr><td>Cuyahoga River</td><td>41.4182</td><td>-81.6479</td><td>CRMB
RM 10.95</td><td>Chlorine-access railroad bridge, near ash lagoons</td><td>04110002 - Cuyahoga</td></tr>
<tr><td>Easterly WWTP</td><td colspan="3">14021 Lakeshore Blvd, Cleveland, OH 44110</td><td>Treated Effluent</td><td>Discharges to 04120200- Lake Erie</td></tr>
<tr><td>Westerly WWTP</td><td colspan="3">5800 Cleveland Memorial Shoreway, Cleveland, OH 44102</td><td>Treated Effluent</td><td>Discharges to 04120200- Lake Erie</td></tr>
<tr><td>Southerly WWTP</td><td colspan="3">6000 Canal Rd
Cuyahoga Heights, OH 44125</td><td>Treated Effluent</td><td>Discharges to 04110002- Cuyahoga</td></tr>
<tr><td colspan="7">RM = river mile</td></tr>
</table>

Methods

Sample Collection and Handling

Water chemistry sampling was conducted six times for both the lake sites and river sites between May 20th and October 8th, 2024. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (Ohio EPA, 2023). These techniques were used for the lake sites and the four river sites. The effluent samples from the NEORSD wastewater treatment plants were collected as grab samples using similar techniques. Chemical water quality samples from each site were collected with one 4-liter disposable polyethylene cubitainer with disposable polypropylene lids and two 473-mL plastic bottles, one of which was preserved with sulfuric acid. An additional sample was analyzed for dissolved reactive phosphorus (DRP) and was filtered in the field using a 0.45-µm PVDF syringe filter and put into a 125-mL plastic bottle. All water quality samples were collected as grab samples at a depth of six to twelve inches below the surface. Samples collected at Westerly, Easterly, and Southerly WWTPs were collected from the final treated effluent and were analyzed for DRP. Filtering was completed at time of collection using a 0.45-µm PVDF syringe filter and put into a 125-mL plastic bottle.

Duplicate/replicate samples and field blanks (FB) were collected at randomly selected sites at a frequency of not less than 5% of the total samples collected for this study. Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and duplicate/replicate sample (Formula 1).

Formula 1: $$\text{RPD} = \left| \frac{x-y}{\left[\frac{(x-y)}{2}\right]} \right| \times 100$$

x = is the concentration of the parameter in the primary sample

y = is the concentration of the parameter in the duplicate/replicate sample

The acceptable percent RPD is based on the ratio of the sample concentration and detection limit (Formula 2) (Ohio EPA, 2023).

Formula 2: $$\text{Acceptable \% RPD} = [(0.9465x^{-0.344}) \times 100] + 5$$

x = sample/detection limit ratio

Those RPDs that were higher than acceptable may indicate potential problems with sample collection and, as a result, the data was not used in comparison to the water quality standards.

Acid preservation of the samples, as specified in the NEORSD laboratory's standard operating procedure for each parameter, also occurred in the field. Field analyses were collected by an EXO1 sonde and measured dissolved oxygen (DO), chlorophyll *a*, phycocyanin, water temperature, conductivity, and pH. Turbidity was measured using a Hach 2100Q Portable Turbidimeter.

Water column chlorophyll *a* samples were collected during each sampling event using a 1L amber glass jar. All chlorophyll *a* samples were collected as grab samples at a depth of six to twelve inches below the water's surface. Duplicate/replicate and field blank chlorophyll *a* samples were collected at randomly selected sites at frequencies of not less than 5% of the total samples collected for this study plan. After returning to the NEORSD Environmental and Maintenance Services Center (EMSC), each sample was filtered in triplicate using 47 mm glass fiber filters and a vacuum with a pressure not exceeding 6 in. Hg. Filtered samples were stored in a freezer at -37°C for storage prior to analysis.

Statistical Analysis

Data for matching parameter sets between sites were compared using a Friedman test with a 95% confidence interval. If the null hypothesis (data sets between sites have equal distributions) was rejected for a given parameter using the Friedman test, a series of one-tailed Wilcoxon signed-rank tests were performed comparing individual sites with the offshore control site BRD17D. Due to missing data, the total phosphorous, ammonia, and nitrite-nitrate samples collected on October 8, 2024 were excluded from the analysis for lake sites. The data was considered missing completely at random, therefore minimizing the risk of significant bias. For river sites, since no site was designated as a control site, Wilcoxon signed-rank tests of the individual sites were performed against the data set from the site with the lowest average concentration for that parameter. Average parameter values were calculated for all parameters. In cases where the result was below the method detection limit (MDL), the MDL was used in the average calculation for that data point.

Results and Discussion

A copy of all analyses is available upon request by contacting the NEORSD's WQIS Division.

Quality Assurance and Quality Control

Three sets of duplicate samples, two sets of replicate samples, and five field blanks were collected during the study. All QA/QC data met the quality control standards set forth in the Ohio EPA *Surface Water Field Sampling Manual* (Ohio EPA, 2023). All samples met the quality control standards in this study. Rocky River RM 0.90 was in exceedance of the Aquatic Life OMZM criteria for water temperature on May 20, 2024. No other water quality exceedances were observed throughout the course of this study.

Wastewater Treatment Plant and Collection System Phosphorus Loadings

Total phosphorus (TP) samples from NEORSD WWTPs effluent were analyzed five to seven days per week in 2024. DRP samples were analyzed twice monthly for all NEORSD WWTP effluents. Southerly discharges to the Cuyahoga River; whereas Easterly and Westerly discharge to Lake Erie. Monthly and weekly average limits of 0.7 mg/L and 1.1 mg/L TP, respectively, are implemented through the Southerly WWTP NPDES permit. Monthly and weekly average limits of 1.0 mg/L and 1.5 mg/L TP, respectively, are implemented through the Easterly and Westerly WWTP NPDES permits. No weekly or monthly TP exceedances were observed at any of the plants in 2024. No limit for DRP currently exists. However, the NPDES permits require that one grab sample for DRP be collected per month as of April 2016.

Tables 2 and 3 show annual TP and DRP averages and loadings from NEORSD discharges. The average plant flow volumes in the tables were calculated only from days for which either TP or DRP data was available. The average yearly estimate of TP and DRP in metric tons was calculated using the below formula.

$$P\ Load\ (Annual\ metric\ tons) = \frac{Average\ P\ concentration\left(\frac{mg}{L}\right)\ x\ Average\ flow(MGD)\ x\ 8.345\left(\frac{lbs}{gal}\right)x\ 365\left(\frac{days}{year}\right)}{2205\left(\frac{lbs}{metric\ ton}\right)}$$

Easterly and Westerly WWTPs contributed 21.4 and 24.8 metric tons of TP, respectively, to Lake Erie. The Lake Erie Phosphorus Task Force has recommended an annual TP loading limit of 6,000 metric tons per year to the central basin (Lake Erie Phosphorus Task Force, 2013). NEORSD WWTP discharges in 2024, including Southerly, accounted for approximately 1.9 percent of the target TP load to the central basin. In addition to the Central Basin loading target, twelve priority watersheds tributary to Lake Erie were identified and assigned target annual TP loads. These targets were designed to reduce TP loads by 40 percent of the 2008 load (Great Lakes Commission, 2021a). The annual TP target load for the Cuyahoga River is 271 metric tons per year. In 2024, the annual load of TP from the Southerly WWTP was 67.6 metric tons. Using these numbers, Southerly WWTP contributed approximately 24.9 percent of the Cuyahoga River target TP load in 2024.

In 2024, Easterly and Southerly WWTPs reduced TP discharges by 62.0 percent and 25.7 percent, respectively, compared to the 2008 load. While Southerly WWTP reduction is below the 40 percent reduction target set by the Great Lakes Commission, this is because Southerly WWTP TP already utilized advanced removal processes technology in 2008. As shown below, the Southerly WWTP had an 88.5 percent TP removal efficiency in 2024, which is similar to five-year average removal efficiencies. The 40 percent reduction goal is therefore limited by currently achievable and feasible technologies at Southerly WWTP due to the previously existing advanced treatment processes in operation since 2008. Additional phosphorus removal from NEORSD sources continues to be achieved through Project Clean Lake as further discussed below.

Westerly WWTP has historically had higher TP concentrations when compared to the other plants, requiring more ferric chloride usage to facilitate phosphorus removal. As part of a strategy to reduce overall chemical usage and decrease costs, Westerly implemented a series of controls aimed at process automation and reduction of ferric chloride usage. In 2023, Westerly had increased TP discharges by 5.9 percent when compared to the 2008 load. Westerly personnel investigated the source of the increased TP and modified the auto dosing strategy accordingly. These process control enhancements and modifications led to the reduction of Westerly WWTP TP discharges by 3.1 percent in 2024 when compared to the 2008 load.

Table 2. NEORSD WWTP and Collection System TP Loading and Related Values

Site	Year	Average TP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of TP)	n	Percent Change from 2008 (2011 for CSO)
Southerly	2008	0.51	128.5	91.0	364	-
	2017	0.42	124.3	71.5	358	-21.5
	2018	0.30	132.4	54.1	349	-40.6
	2019	0.37	125.0	64.3	360	-29.4
	2020	0.37	127.5	65.6	250	-27.9
	2021	0.41	114.0	64.6	332	-29.0
	2022	0.40	121.0	66.2	359	-27.3
	2023	0.38	120.0	62.8	360	-31.0
	2024	0.45	107.9	67.6	361	-25.7
Easterly	2008	0.41	98.6	56.3	363	-
	2017	0.37	81.9	42.0	359	-25.4
	2018	0.21	93.8	27.7	349	-50.8
	2019	0.28	89.4	34.8	355	-38.2
	2020	0.28	88.5	34.2	251	-39.2
	2021	0.26	78.1	27.9	332	-50.4
	2022	0.19	89.7	23.6	359	-58.2
	2023	0.23	92.0	30.2	359	-46.4
	2024	0.20	78.6	21.4	361	-62.0
Westerly	2008	0.630	29.4	25.6	364	-
	2017	0.657	24.1	21.9	359	-14.4
	2018	0.568	26.9	21.1	349	-17.5
	2019	0.563	25.7	20.0	360	-21.8
	2020	0.484	21.7	14.5	253	-43.3

Table 2. NEORSD WWTP and Collection System TP Loading and Related Values

Site	Year	Average TP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of TP)	n	Percent Change from 2008 (2011 for CSO)
	2021	0.626	19.4	16.7	333	-34.7
	2022	0.723	22.7	22.7	357	-11.3
	2023	0.788	26.3	27.1	359	+5.9
	2024	0.799	22.5	24.8	360	-3.1
CSO	2011	0.73	13.8	13.9	365	-
CSO	2017	0.73	16.3	16.4	365	18.0
CSO	2018	0.73	18.7	18.8	365	35.4
CSO	2019	0.73	9.0	9.1	365	34.6
CSO	2020	0.73	17.8	17.9	365	28.8
CSO	2021	0.73	8.2	8.2	365	41.2
CSO	2022	0.73	6.9	7.0	365	49.6
CSO	2023	0.73	11.8	11.9	365	14.9
CSO	2024	0.73	3.5	3.6	365	74.1

* The average volume calculation only includes flow data from days on which TP data was available.

Table 3. NEORSD WWTP DRP Loading and Related Values

Site	Year	n	Average DRP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of DRP)
Southerly	2019	24	0.28	115.3	45.0
Southerly	2020	22	0.28	117.6	43.4
Southerly	2021	24	0.33	114.0	51.4
Southerly	2022	24	0.28	106.7	39.1
Southerly	2023	24	0.29	103.8	38.3
Southerly	2024	24	0.40	92.0	46.0
Easterly	2019	24	0.28	77.8	30.5
Easterly	2020	22	0.06	78.3	6.2
Easterly	2021	24	0.07	78.1	7.3
Easterly	2022	24	0.07	78.6	6.9
Easterly	2023	24	0.06	81.1	5.6
Easterly	2024	24	0.05	70.7	4.0

Table 3. NEORSD WWTP DRP Loading and Related Values					
Site	Year	n	Average DRP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of DRP)
Westerly	2019	24	0.29	20.4	8.2
	2020	22	0.32	19.8	8.1
	2021	24	0.36	19.4	9.6
	2022	24	0.47	19.2	12.2
	2023	24	0.52	23.2	15.5
	2024	24	0.56	18.9	14.3
* The average volume calculation only includes flow data from days on which DRP data was available.					

Annual TP removal efficiencies were calculated according to the formula below and are given in Table 4. TP removal efficiencies at all three WWTPs were like the 5-year average (5ya) indicating continued good performance. Southerly WWTP had the highest 5ya TP removal efficiency at 88.9 percent.

$$TP\ Removal\ Efficiency = 100 \text{ x } \frac{(Average\ Influent\ TP\ \left(\frac{mg}{L}\right) - Average\ Effluent\ TP\ \left(\frac{mg}{L}\right))}{Average\ Influent\ TP\ \left(\frac{mg}{L}\right)}$$

Table 4. TP Removal Efficiency						
Average Influent TP (mg/L)						
	2020	2021	2022	2023	2024	5ya
Southerly	3.420	3.831	3.538	3.391	3.951	3.6262
Easterly	2.032	2.249	1.977	2.011	2.410	2.1358
Westerly	2.067	2.130	2.032	1.972	2.224	2.085
Average Effluent TP (mg/L)						
	2020	2021	2022	2023	2024	5ya
Southerly	0.373	0.410	0.396	0.379	0.453	0.4022
Easterly	0.280	0.258	0.191	0.233	0.197	0.2318
Westerly	0.484	0.625	0.723	0.788	0.799	0.6838
TP Removal Efficiency (%)						
	2020	2021	2022	2023	2024	5ya
Southerly	89.1	89.2	88.8	88.8	88.5	88.88
Easterly	86.2	88.5	90.4	88.4	91.8	89.06
Westerly	76.6	70.7	64.4	60.1	64.1	67.18

Combined sewer overflow (CSO) discharges also contribute TP to the watersheds in the NEORSD service area. The average TP concentration from CSOs during wet-weather loading has been estimated at 0.73 mg/L (Ohio EPA, 2022). Based on a combination of flow-monitoring data and model predictions with a baseline correction that removes median flows from tunnels that have dry-weather flow, approximately 1.3 billion gallons of CSO were discharged in the NEORSD service area in 2024. Using these estimates, NEORSD-operated CSOs contributed a total of 3.6 metric tons of TP to Lake Erie and Lake Erie tributary streams in 2024. This is a 74.1 percent decrease from 2011, which marked the beginning of Project Clean Lake. CSO discharges accounted for approximately 3.1 percent of the TP load from NEORSD-operated sources in 2024.

Through Project Clean Lake, the NEORSD has recently invested significant capital in CSO storage tunnel infrastructure. Implementation of CSO storage tunnel projects, including the Doan Valley Tunnel, Dugway Storage Tunnel, Euclid Creek Tunnel, and Mill Creek Tunnel, resulted in the capture of an estimated 3.0 billion gallons of CSO discharge (Table 5). This equates to a 70.0 percent capture rate for NEORSD-operated CSO sources in 2024. These captured volumes were subsequently treated at the downstream WWTPs. Using the 5-year TP removal efficiencies of these WWTPs, the NEORSD removed an additional 8.3 metric tons of TP through CSO capture in 2024. Approximately half of this CSO TP capture (3.9 metric tons) occurred during the recreational season of May through October when HABs are more likely to occur. This additional TP removal due to CSO capture equates to a 7.0 percent reduction in TP discharges from all NEORSD-operated sources compared to discharges that would have occurred in the absence of Project Clean Lake infrastructure investments.

Table 5. TP Removal by CSO Storage Tunnel Capture

	Doan Valley Tunnel	Dugway Storage Tunnel	Euclid Creek Tunnel	Mill Creek Tunnel	Total
2024 Entire Year CSO Captured Volume (MG)	709	254	211	1,822	2,996
2024 May-October Captured CSO Volume (MG)	329	154	140	810	1,433
2024 Entire Year TP Removal (Metric Tons)	2.0	0.7	0.6	5.0	8.3
2024 May-October TP Removal (Metric Tons)	0.9	0.4	0.4	2.2	3.9

Data for river sites was compared to Ohio EPA Water Quality Standards for the protection of aquatic life, as well as the Ohio EPA proposed Stream Nutrient Assessment Procedure (SNAP) (Ohio EPA, 2015). Applicable data were also compared to the Ohio EPA's proposed Nutrient Water Quality Standards for Ohio's Large Rivers, as well as the proposed summer base-flow target level of TP of 130 µg/L (Ohio EPA, 2018) (Miltner, 2017). Average parameter values for all river sites are given in Table 6 and Figures 3-7. Rocky River RM 0.90 was in exceedance of the Aquatic Life OMZM criteria for water temperature on May 20, 2024. No other water quality exceedances were observed throughout the course of this study. It should be noted that the Rocky River RM 0.90, Cuyahoga River 0.20, and Euclid Creek RM 0.55 sites are located within the lacustuary zone for these streams. These points therefore may not provide a direct measure of nutrient output from these streams as it is impossible to determine the amount of dilution influence from Lake Erie at the time of sample collection.

According to SNAP (Figure 2), concentrations of TP and dissolved inorganic nitrogen (DIN, the sum of nitrate+nitrate and ammonia concentrations) for Cuyahoga River RM 0.20 and Rocky River RM 0.90 were categorized as "levels typical of working landscapes with low risk to beneficial use". Nutrient concentrations for Cuyahoga RM 10.95 were categorized as "moderate risk to beneficial use if allied responses are elevated; increased risk with poor habitat". Nutrient concentrations for Euclid Creek RM 0.55 were categorized as "Levels typical of developed lands with little or no risk to beneficial use".

		← DECREASING RISK			
	TP Conc. (mg/l)	DIN Concentration (mg/l)			
		<0.44	0.44 < 1.10	1.10 < 3.60	3.60 < 6.70	≥6.70
DECREASING RISK ↑	<0.040	background levels typical of least disturbed conditions	levels typical of developed lands; little or no risk to beneficial uses	levels typical of modestly enriched condition in phosphorus limited systems; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition in phosphorus limited systems; moderate risk to beneficial use if allied responses are elevated	characteristic of tile-drained lands; otherwise atypical condition with moderate risk to beneficial use if allied responses are elevated (1.1% of observations)
	0.040-<0.080	levels typical of developed lands; little or no risk to beneficial uses	levels typical of developed lands; little or no risk to beneficial uses	levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition in phosphorus limited systems; moderate risk to beneficial use if allied responses are elevated	characteristic of tile-drained lands; moderate risk to beneficial use if allied responses are elevated (1.1% of observations)
	0.080-<0.131	levels typical of modestly enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges	levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges	levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges	characteristic of tile-drained lands; moderate risk to beneficial use if allied responses are elevated; increased risk with poor habitat	characteristic of tile-drained lands; moderate risk to beneficial use if allied responses are elevated (1.0% of observations)
	0.131-<0.400	levels typical of modestly enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges	levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors
	≥0.400	atypical condition (1.3% of observations)	atypical condition (1% of observations);	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors ; increased risk with poor habitat	enriched condition; generally high risk to beneficial uses; often co-occurring with multiple stressors

"allied responses" = allied response indicators (24-hour DO swing, benthic chlorophyll)

Figure 2. Table 2 of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015b)

Sestonic chlorophyll *a* and TP concentrations from the river sites were compared to the Ohio EPA's proposed target levels for large rivers. The proposed targets would apply to river sites with a drainage area greater than 500 square miles. Of the four river sites in this study, only the two Cuyahoga River sites would fall into this category. Average sestonic chlorophyll *a* concentrations were below the Ohio EPA's proposed target level of 30 µg/L for all river sites. This indicates that these sites were not in a condition of eutrophication throughout the course of the 2024 sampling season based on chlorophyll *a* concentrations. Average TP was also below the Ohio EPA's proposed target of 130 µg/L for all river sites, as well as the proposed SNAP target of 400 µg/L for small rivers and streams.

Euclid Creek RM 0.55 and Rocky River RM 0.90 had the lowest overall nutrient concentrations of all the river sites, whereas Rocky River RM 0.90 and Cuyahoga River RM 0.20 had the lowest overall chlorophyll *a* average concentrations. Cuyahoga River RM 10.95 had the most elevated average chlorophyll *a* concentrations while Cuyahoga River RM 0.20 had the most elevated nutrient concentrations of the four river sites. However, as stated above, both chlorophyll *a* and TP average concentrations were well below proposed target levels at all sites.

In conclusion, the river sites analyzed as part of this study were found to be typical of working landscapes, tile drained lands, or developed lands with respect to nutrient concentrations. These levels of nutrients pose low to moderate risk to beneficial use according to the Ohio EPA's proposed SNAP procedure. Allied response indicators were not measured in 2024, creating a potential limitation to the interpretation of risk of eutrophication based on the proposed method. However, TP, and chlorophyll *a* concentrations were below proposed targets for all river sites in 2024.

Table 6. 2024 River Site Average Values

	TP	DRP	NO_3-NO_2	NH_3	DIN	Chlorophyll *a*	TSS	pH	Conductivity	DO	Temperature	Turbidity
Site	mg/L	µg /L	mg/L	mg/L	mg /L	µg /L	S.U.	µS/cm	mg/L	°C	NTU	µg/L
Rocky River RM 0.90	0.087	0.039	2.10	0.078	2.18	2.92	7.77	8.0	627	7.7	20.93	13.58
Cuyahoga River RM 10.95	0.099	0.055	3.92*	0.073	3.99	5.29	18.57	8.0	797	8.3	20.61	9.62
Cuyahoga River RM 0.20	0.125*	0.084*	3.31	0.217*	3.53	4.13	20.65*	7.5	675	6.2*	22.49*	29.58*
Euclid Creek RM 0.55	0.062	0.037	0.25	<0.033	0.29	4.34	5.96	8.0	683	9.4	19.60	7.23
Average River Site Values	0.093	0.054	2.39	0.101	2.50	4.17	13.24	7.8	696	7.9	20.90	15.0

< - Indicates that one or more samples were found to be below the MDL. The MDL value was used in these cases to calculate the average.

* - Indicates highest average value(s) for this parameter (lowest for dissolved oxygen). Does not indicate a significant difference from other sites.

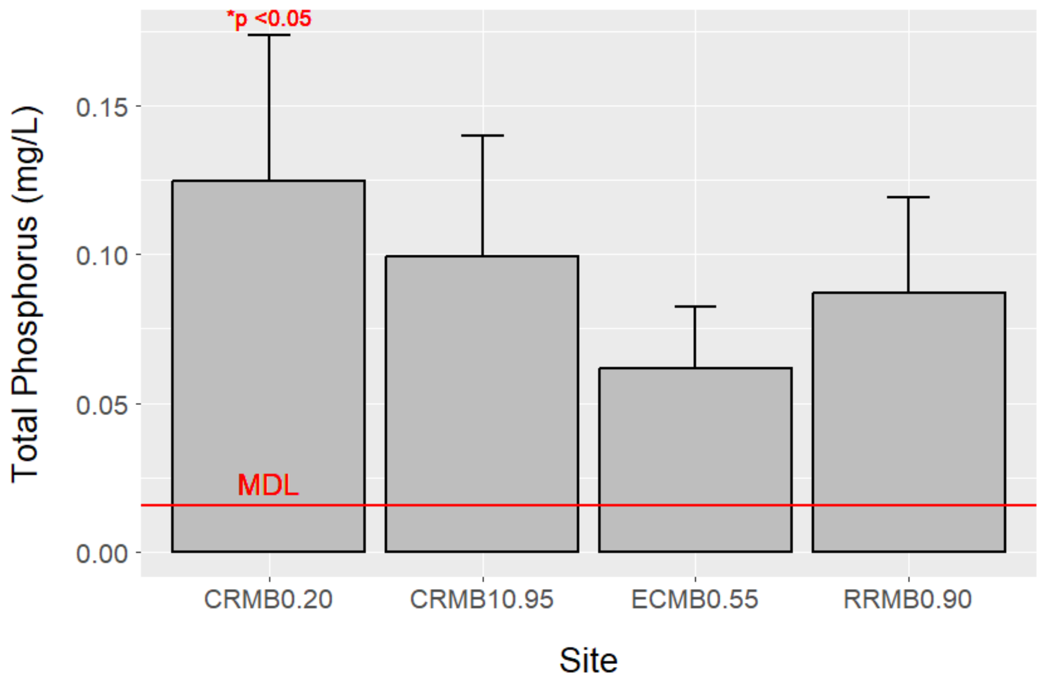

Figure 3. 2024 Average TP Concentrations at Each River Site with Standard Deviation. *Asterisks with p-values indicate sites with significant differences compared to the site with lowest average value according to the Wilcoxon signed-rank test.*

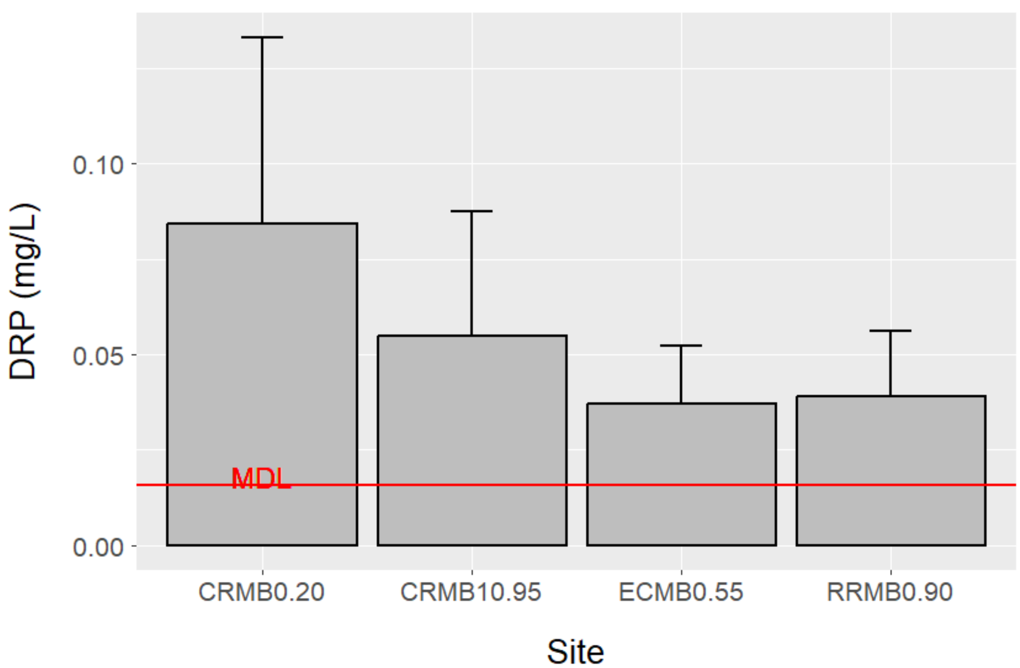

Figure 4. 2024 Average DRP Concentrations at Each River Site with Standard Deviation.

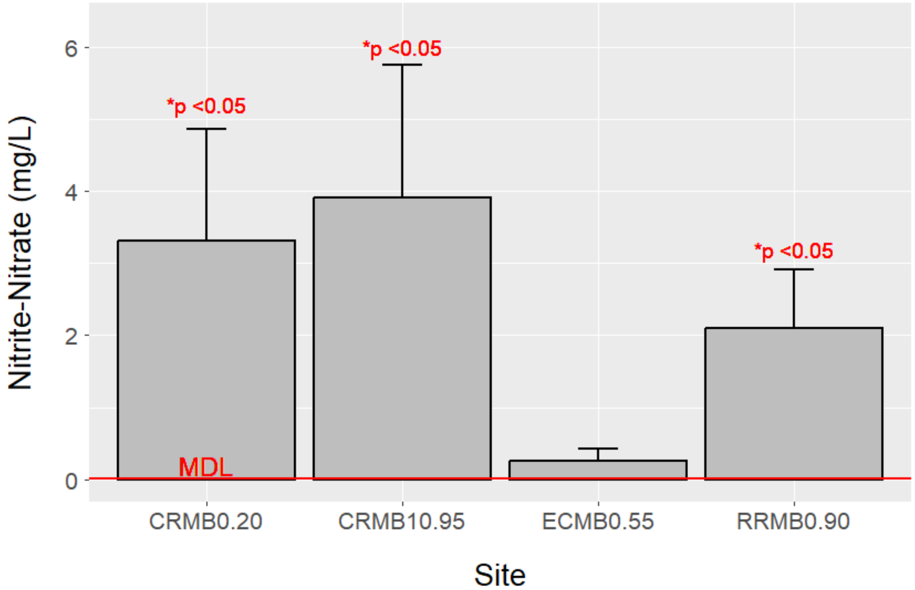

Figure 5. 2024 Average Nitrate+Nitrite Concentrations at Each River Site with Standard Deviation. *Asterisks with p-values indicate sites with significant differences compared to the site with lowest average value according to the Wilcoxon signed-rank test.*

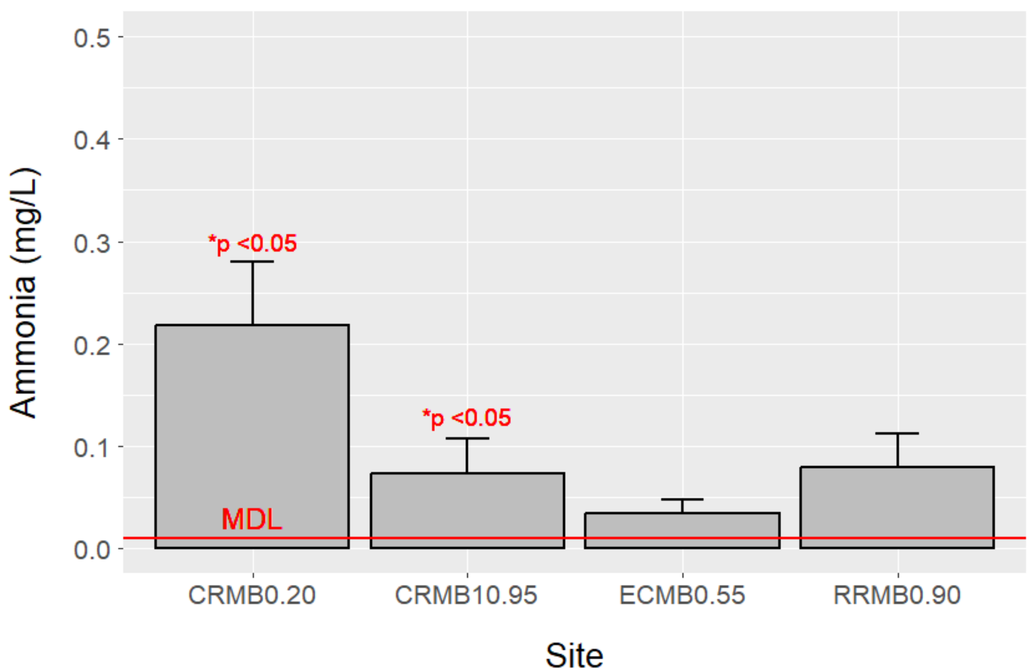

Figure 6. 2024 Average Ammonia Concentrations at Each River Site with Standard Deviation. *Asterisks with p-values indicate sites with significant differences compared to the site with lowest average value according to the Wilcoxon signed-rank test.*

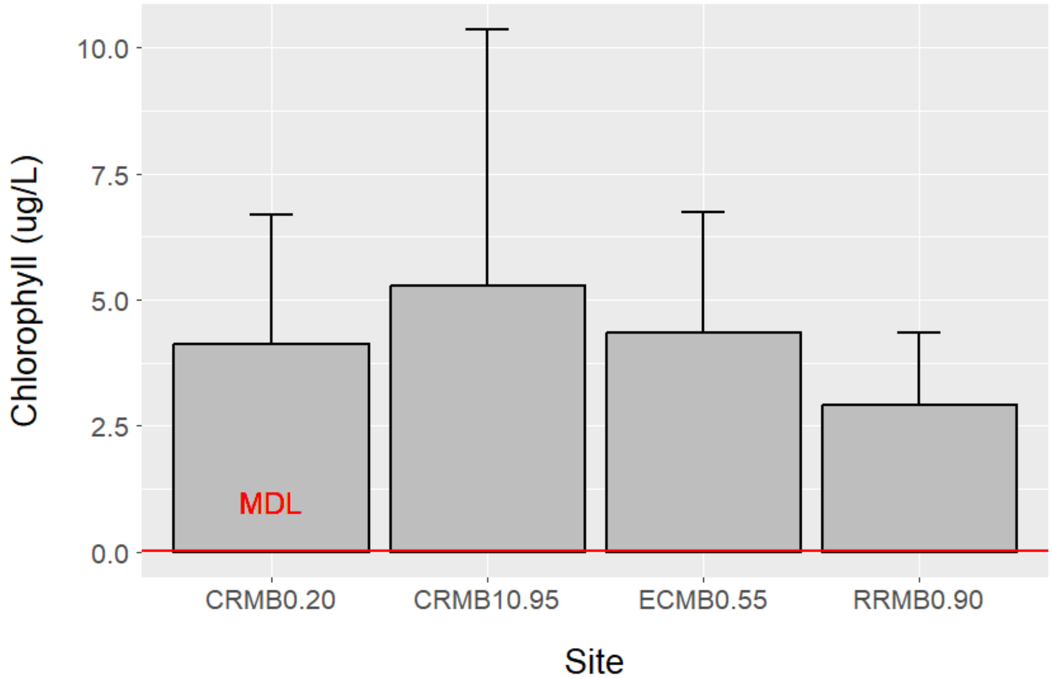

Figure 7. 2024 Average Chlorophyll *a* Concentrations at Each River Site with Standard Deviation.

Lake Site Analysis

TP for the lake sites was compared to the Interim Substance Objectives for Total Phosphorus Concentration in Open Waters (10 ug/L for Lake Erie Central Basin, represented by spring means) as set in the 2012 Great Lakes Water Quality Agreement (GLWQA). Nutrient and chlorophyll *a* data for all lake sites was also compared using the Friedman test followed by individual Wilcoxon signed-rank tests against the offshore control site BRD17D for parameters in which the null hypothesis was rejected by the Friedman test. Table 7 gives average parameter results for all lake sites. Figures 8-12 show average nutrient and chlorophyll *a* concentrations with standard deviations and significant differences from the offshore control site BRD17D.

The MDL for TP in 2024 was 15.6 ug/L, which is greater than the GLQWA objective of 10 ug/L. Of the data points analyzed for TP, approximately 30 percent of the sample set was below the MDL. No TP concentrations were found to be significantly different when compared to the offshore control site BRD17D. Average TP concentrations were higher at WTP1 (22.9 ug/L) than the offshore control site BRD17D (20.1 ug/L); however, the difference was not statistically significant.

Potential sources of phosphorus include point and nonpoint sources on the Cuyahoga River including, but not limited to, erosion and sediment transport, local stormwater runoff, CSOs, and WWTP discharges; which discharge directly to Lake Erie. The year 2024 was the warmest year on record in Ohio, the United States, and the world. It was also Cleveland’s warmest year on record dating back to the 1880s. Northeast Ohio experienced abnormally dry drought conditions that persisted throughout summer and into fall despite a few periods of intense rainfall and severe weather (Davis and Wilson, 2025). Significantly decreased precipitation and runoff due to drought may have impacted phosphorous levels in Lake Erie, leading to a higher percentage of samples below the MDL, 30% in 2024, compared to 10% in 2023.

No target currently exists for DRP, but concentrations above 6 ug/L have been associated with harmful algal blooms (Lake Erie Phosphorus Task Force, 2013). The average DRP was below this concentration at all lake sites in 2024. Individual sample results were also below this concentration in all the samples analyzed. The DRP MDL was 1.6 µg/L for the first two sampling events on May 21, 2024, and June 12, 2024. A new MDL study was performed on July 2, 2024, and the MDL was updated to 1.69 µg/L for all samples collected in the remainder of the study. DRP concentrations were below the MDL of 1.6 µg/L in approximately 66.7 percent of all analyzed samples collected on May 21, 2024, and June 12, 2024 (n=12), and were below the MDL of 1.69 µg/L in approximately 50 percent of all analyzed samples collected in the remainder of the study (n=36). No statistically significant differences in DRP concentrations were observed between the lake sites in 2024.

No statistically significant differences in nitrate+nitrite concentrations were observed between the lake sites when compared to the offshore control stie BRD17D. Average nitrate+nitrite concentrations were highest at CE92 (0.293 mg/L). However, when compared to the offshore control site BRD17D (0.168 mg/L), the difference was not statistically significant. Average nitrate/nitrite concentrations were 0.223 mg/L. These values are well below applicable water quality criteria including the protection of human health public water supply use (10 mg/L) and the protection of agricultural water supply use (100 mg/L). Like phosphorous, potential sources of nitrate/nitrite include point and nonpoint sources on the Cuyahoga River including, but not limited to, erosion and sediment transport, local stormwater runoff, CSOs, and WWTP discharges, which discharge directly to Lake Erie.

A simple linear regression analysis was used to test if TP concentrations explained chlorophyll *a* concentrations. The results of the regression indicated that TP concentrations explained 36.1% of the variation in chlorophyll *a* concentrations [$F(1,31)=17.51$, $p=0.0002$] (Figure 13). These results were significant at the $p<0.01$ level. Chlorophyll *a* concentrations are measured as a proxy for algal biomass. Drivers of algal biomass and in particular cyanobacteria in the Central Basin are likely not limited to phosphorus concentrations. Environmental factors affecting algal biomass and dynamics may include temperature, light penetration and availability, water clarity, hypoxia, physical dynamics such as mixing and stratification, runoff, and precipitation. Nitrogen and other potentially limiting nutrients may also have a role in algal biomass and algal community dynamics (Chaffin et. al., 2019).

Table 7. 2024 Lake Erie Average Values

	TP	DRP	NO_3-NO_2	NH_3	Chlorophyll *a*	TSS	pH	Conductivity	DO	Temperature	Turbidity
Site	µg/L	µg /L	mg/L	mg/L	µg /L	mg/L	S.U.	µS/cm	mg/L	°C	NTU
BRD17D	<20.1	<4.42	<0.168	<0.022	6.66	<2.2	8.3	255	9.0*	21.30	2.1
RR1B	<21.8	<4.40	<0.183	0.038	11.45*	<2.8	8.4	261	9.3	21.39	2.4
BRD17I	<19.9	<4.00	<0.204	0.041	10.28	<2.3	8.4	262	9.3	21.57*	2.0
CW82	<17.4[+]	<4.47	<0.205[+]	<0.026[+]	8.00	<2.1	8.3	258	9.1	21.33	1.8
WTP1	<22.9*	<4.85*	<0.282	0.049*	10.88	2.9*	8.4	270*	9.5	21.14	2.5*
CW88	<20.5	<4.31	<0.227	0.031	9.48	2.7[+]	8.3	263	9.2	21.22	2.0
CE92	<20.6	<3.82	0.293*	<0.029	10.78	2.6	8.3	270*	9.1	21.18	2.1
CE100	<18.3	<2.71	<0.220	0.025	9.25	2.2	8.3	263	9.2	21.10	1.6
Average Lake Site Values	20.2	<4.08	0.223	0.033	9.59	2.5	8.3	263	9.2	21.28	2.1

< - Indicates that one or more samples were found to be below the MDL. The MDL value was used in these cases to calculate the average.

* - Indicates highest average value(s) for this parameter (lowest for dissolved oxygen). Does not indicate a significant difference from other sites.

[+]n=5 for these samples

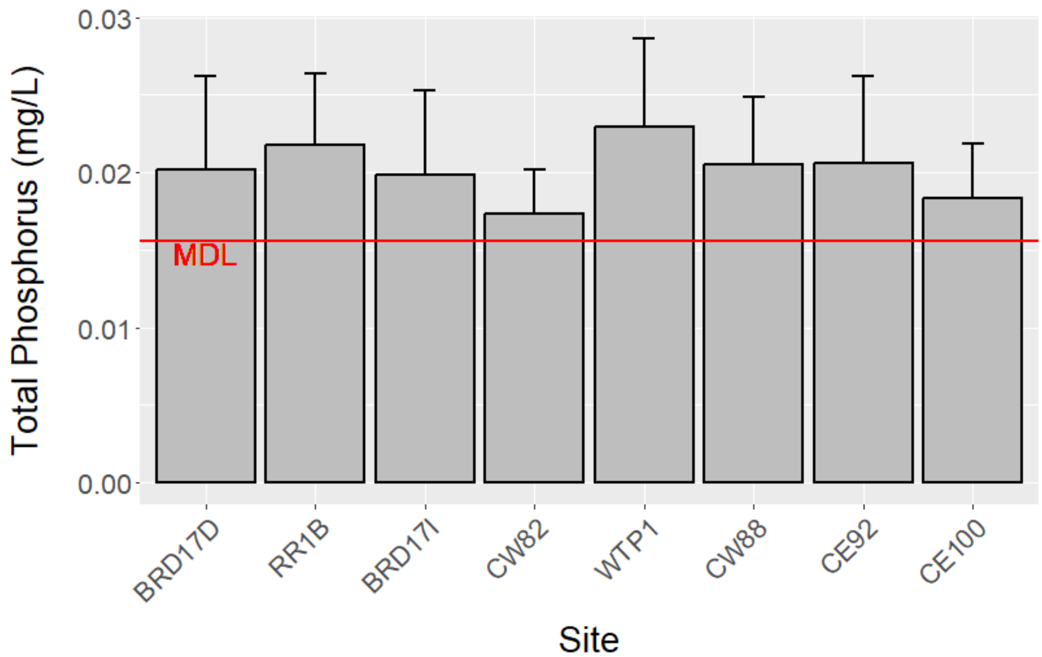

Figure 8. 2024 Average TP Concentrations at Each Lake Site with Standard Deviation.

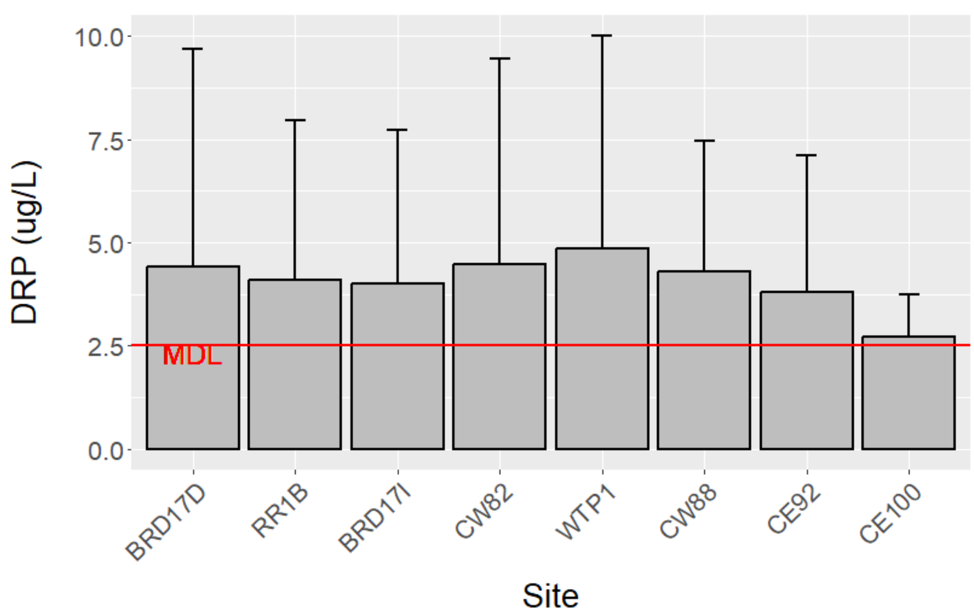

Figure 9. 2024 Average DRP Concentrations at Each Lake Site with Standard Deviation

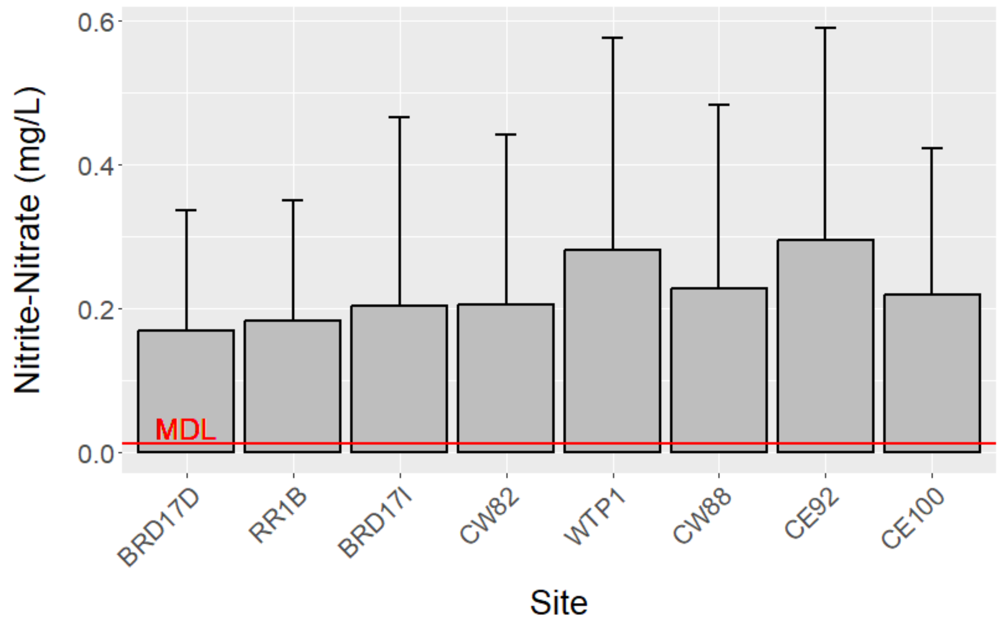

Figure 10. 2024 Average Nitrate/Nitrite Concentrations at Each Lake Site with Standard Deviation.

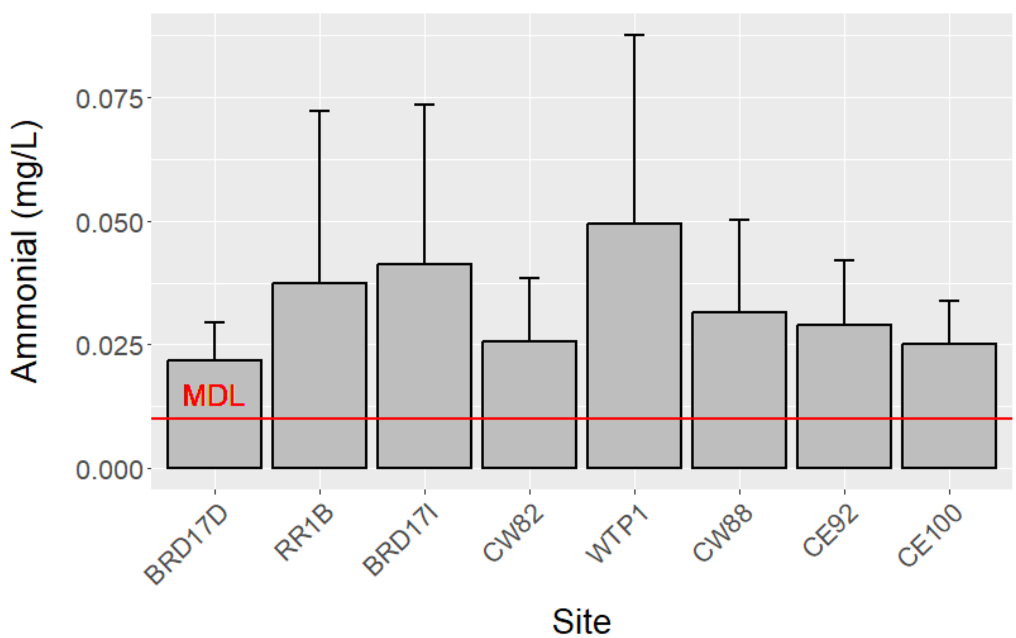

Figure 11. 2024 Average Ammonia Concentrations at Each Lake Site with Standard Deviation.

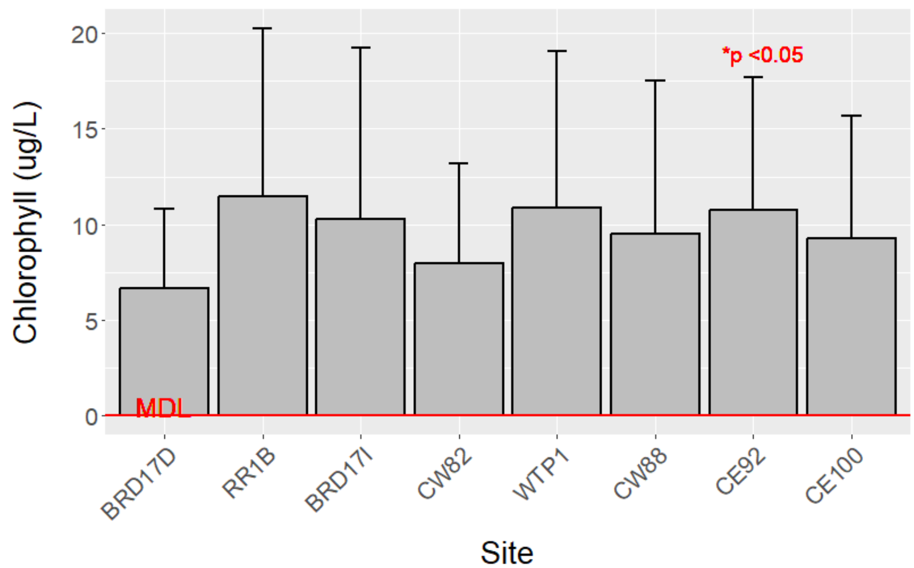

Figure 12. 2024 Average Chlorophyll *a* Concentration at Each Lake Site with Standard Deviation. *Asterisks with p-values indicate sites with significant differences compared to reference site BRD17D according to the Wilcoxon signed-rank test.*

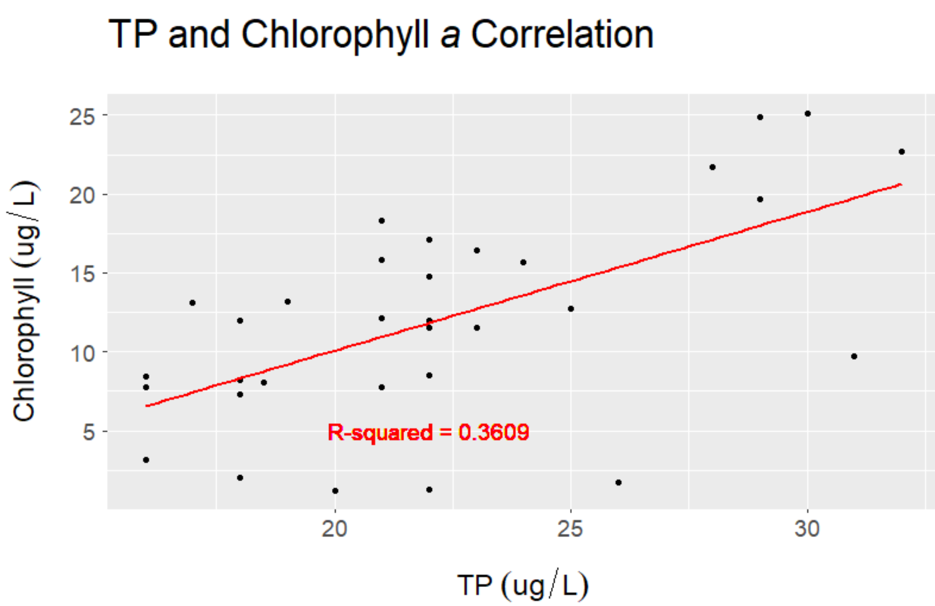

Figure 13. Linear Regression of Lake Site Chlorophyll *a* and TP. TP concentrations explained 36.1% of the variation in chlorophyll *a* concentrations.

Harmful Algal Bloom Occurrence

No HABs were observed in the study area or at Edgewater, Euclid, and Villa Angela Beaches in 2024.

Comparison to Historical Data

The NEORSD has been conducting the Lake Erie Nutrient Study annually beginning in 2012. Data collected in 2024 was compared to historical data collected since 2012 to determine trends over time. (Figures 14-17). Figure 14 shows average TP concentrations and MDLs for TP by year. In 2018, a change in the method for calculating MDLs was enacted by the USEPA through 40 CFR Part 136. This change resulted in a greater than tenfold increase in TP MDLs. Prior to this change, 100 percent of samples analyzed for TP were above the MDL. Following this change, the percentage of lake site samples above the MDL per year ranged from 45.5 percent to 98.3 percent (Figure 14). The MDL for total phosphorus in 2024 was the same as the MDL in 2023 at 0.0156 mg/L. As a result, 70.2 percent of samples analyzed including QA/QC samples were above the MDL (Figure 15). As the MDLs and percentage of samples above the MDL are inconsistent over time it is not possible to determine if statistically significant differences exist between TP concentrations in 2024 versus previous years. Plotting average values calculated by using the MDL value for samples with concentrations below the MDL, annual TP concentrations appear to remain consistent over the past twelve-year period.

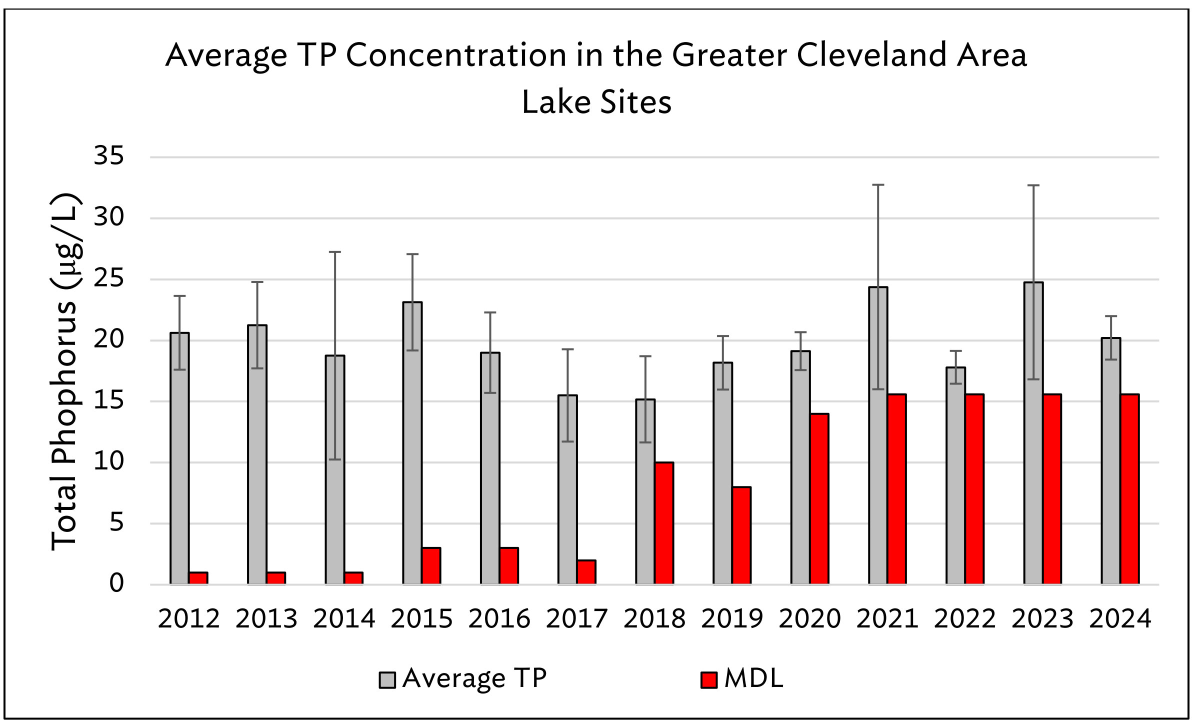

Figure 14. Average TP Concentration at All Lake Sites by Year with Standard Deviation and MDL.

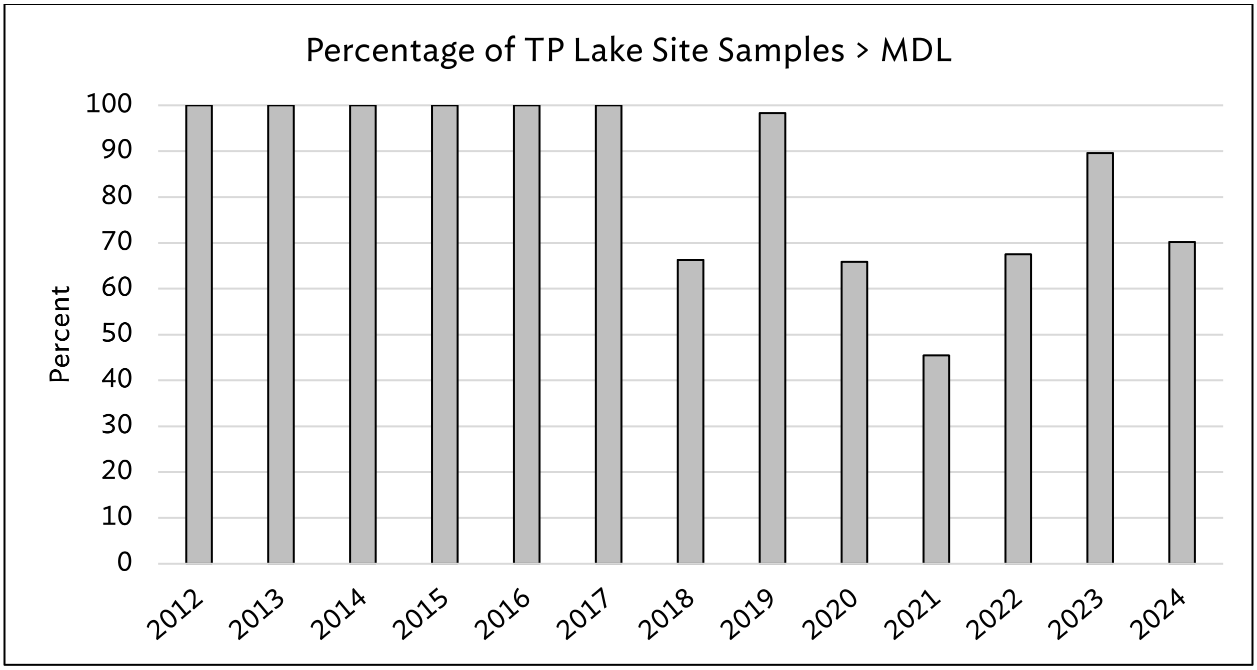

Figure 15. Percentage of TP Samples Greater Than the MDL

Average DRP concentrations have remained consistent over the past ten years (Figure 16). Ten-year peak DRP concentrations were observed in 2015. This corresponded with the record setting harmful algal bloom that also occurred in 2015 in the Western and Central Basins (Figure NOAA, 2015). DRP concentrations in 2024 were like those observed in the previous eight years. Additionally, variation in samples below the MDL occurred because DRP concentrations are typically near the MDL; a new MDL study was also performed after the first two sampling events, leading to shifts in the percentage of samples greater than the MDL.

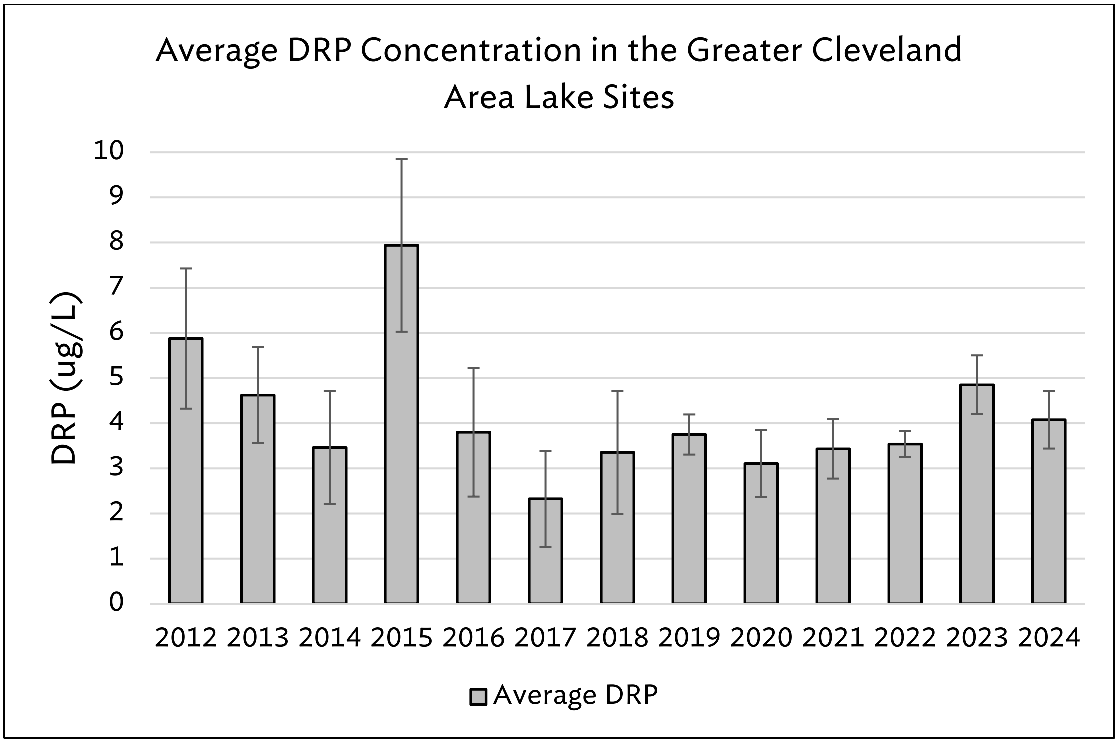

Figure 16. Average DRP Concentration at All Lake Sites by Year with Standard Deviation

Average chlorophyll *a* concentrations in 2024 were similar to previous years (Figure 17). A ten-year peak in chlorophyll *a* concentrations was observed in 2023. Chlorophyll *a* concentrations were highest on average in all samples collected on October 8, 2024; however, concentrations did not exceed 25.1 µg/L in all 48 samples analyzed. There were no incidents of surface scums or suspended algae reported to be observed on the field sheets for all sites during the sampling period.

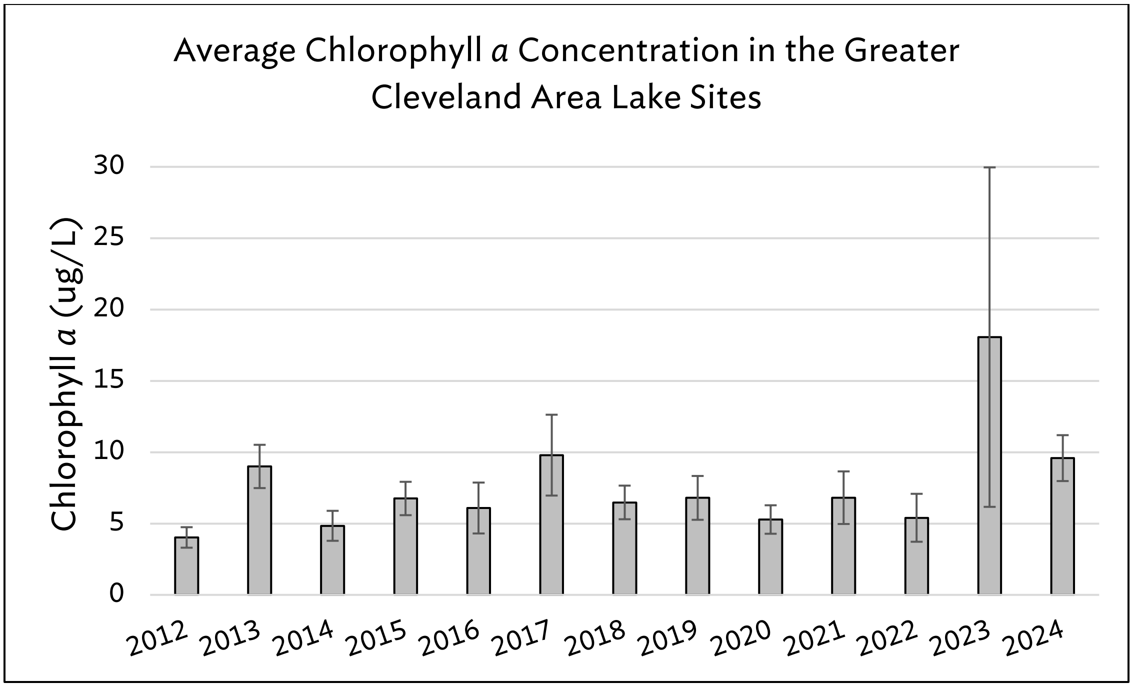

Figure 17. Average Chlorophyll *a* Concentration at all Lake Sites by Year with Standard Deviation.

The Western basin bloom severity index score was 5.3 in 2023, and 6.6 in 2024 as reported by NOAA (Figure 18; NOAA, 2024). The 2024 Western basin bloom was more intense than in 2023 and had the earliest bloom since 2002. NOAA does not report bloom severity indices or publish forecasts for the central basin of Lake Erie.

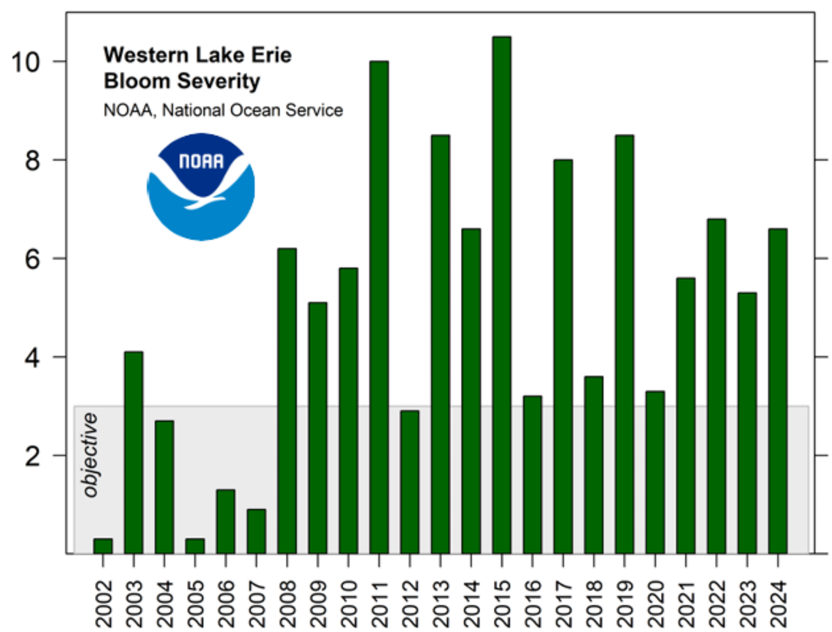

Figure 18. Bloom Severity Index as published by NOAA (NOAA, 2024).

Conclusions

Average TP concentrations at all lake sites, including the offshore control site BRD17D, were greater than the Interim Substance Objective of 10 μg/L for TP set by the GLWQA. Continued reduction of phosphorus concentrations in the Lake Erie watershed will be needed to meet the GLWQA objective. No TP, DRP, nitrite-nitrate, or ammonia concentrations were found to be significantly different when compared to the offshore control site BRD17D. Significant differences were observed in chlorophyll *a* concentrations between the offshore control site BRD17D and CE92. Despite not meeting the GLWQA TP target, no nuisance algae conditions or HABs were observed in the study area throughout the 2024 recreational season.

Nutrient concentrations at the river sites located within the lacustuary zone were found to pose a low risk to beneficial use according to Ohio EPA's proposed SNAP procedure. However, nutrient concentrations at Cuyahoga River RM 10.95 were categorized as having moderate risk to beneficial use. Additionally, all river sites were found to have average phosphorus and chlorophyll *a* concentrations below Ohio EPA proposed target limits. Nitrate+nitrite, ammonia, and total phosphorus concentrations were found to be significantly different at Cuyahoga River RM 0.20 from the other river sites; however, nutrient concentrations for Cuyahoga River RM 0.20 posed low risk to beneficial use. Additionally, nitrite-nitrate and ammonia concentrations were found to be significantly different at Cuyahoga River RM 10.95 from other river sites, nutrient concentrations for Cuyahoga River RM 10.95 posed moderate risk to beneficial use based on proposed SNAP criteria.

Phosphorus removal efficiencies of NEORSD WWTPs were like the previous 5-year averages indicating sustained high performance. The contribution of TP from CSOs in 2024 was reduced by 74.1 percent compared to 2011, prior to implementation of Project Clean Lake infrastructure improvements. The annual precipitation total in the Cleveland area was 33.62 inches in 2024 representing a historic low volume for the region, compared to 65.32 inches in 2011 (NOAA NowData). While low precipitation volume may impact the overall frequency and volume of CSO discharges, regional increases in high intensity hourly rainfall also contribute to an increased risk of CSO events.

The NEORSD continues to invest in infrastructure improvements to improve WWTP efficiency and reduce CSO discharges in the NEORSD service area. The NEORSD's investment in Project Clean Lake CSO capture tunnels resulted in the collection and treatment of approximately 3.0 billion gallons of mixed stormwater and sewage in 2024. This resulted in a 70.0 percent reduction in the 2024 CSO TP loading and an 8.3 percent reduction in all NEORSD TP source loads to Lake Erie compared to loads that would have been discharged in the absence of these CSO control structures. The NEORSD also plans to continue the work of Project Clean Lake by continuing construction of CSO storage tunnels across the region, enhancing treatment plant capacities, and piloting new technologies to improve efficiency in all processes. These investments have and will continue to reduce phosphorus discharges to surface waters in the NEORSD service area.

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