NORTHEAST OHIO REGIONAL SEWER DISTRICT

2018 Greater Cleveland Area Lake Erie Nutrient Study

Prepared by
Water Quality and Industrial Surveillance Division

Introduction

Throughout the past decade there has been an increase in toxin producing harmful algal blooms (HAB) in Lake Erie, particularly in the Western Basin. In 2011, a record setting HAB extended beyond the Western Basin, into the Central Basin, along both the United States and Canadian shorelines. The southern portion of the bloom extended well east of Cleveland, where it persisted throughout the month of October (NOAA, 2011). In response to this record setting bloom, the Northeast Ohio Regional Sewer District (NEORSD) began performing nutrient monitoring in Lake Erie near Cleveland in 2012.

Since that time, HABs have continued to be an environmental concern in Lake Erie. In 2014, another HAB fouled the drinking water supply of the City of Toledo, leaving residents without drinking water for three days. 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). Although the bloom did not appear to be near Cleveland beaches by NOAA satellite imagery, 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.

The NEORSD continued nutrient monitoring efforts in 2018. This annual Lake Erie Nutrient Study was submitted to the Ohio Environmental Protection Agency's 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). Additional 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 Environmental Protection Agency (Ohio EPA) on February 20, 2018. Data collected as part of daily NPDES permit required monitoring for the three NEORSD wastewater treatment plants was 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 *2018 Greater Cleveland Area Lake Erie Nutrient Study*. 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.

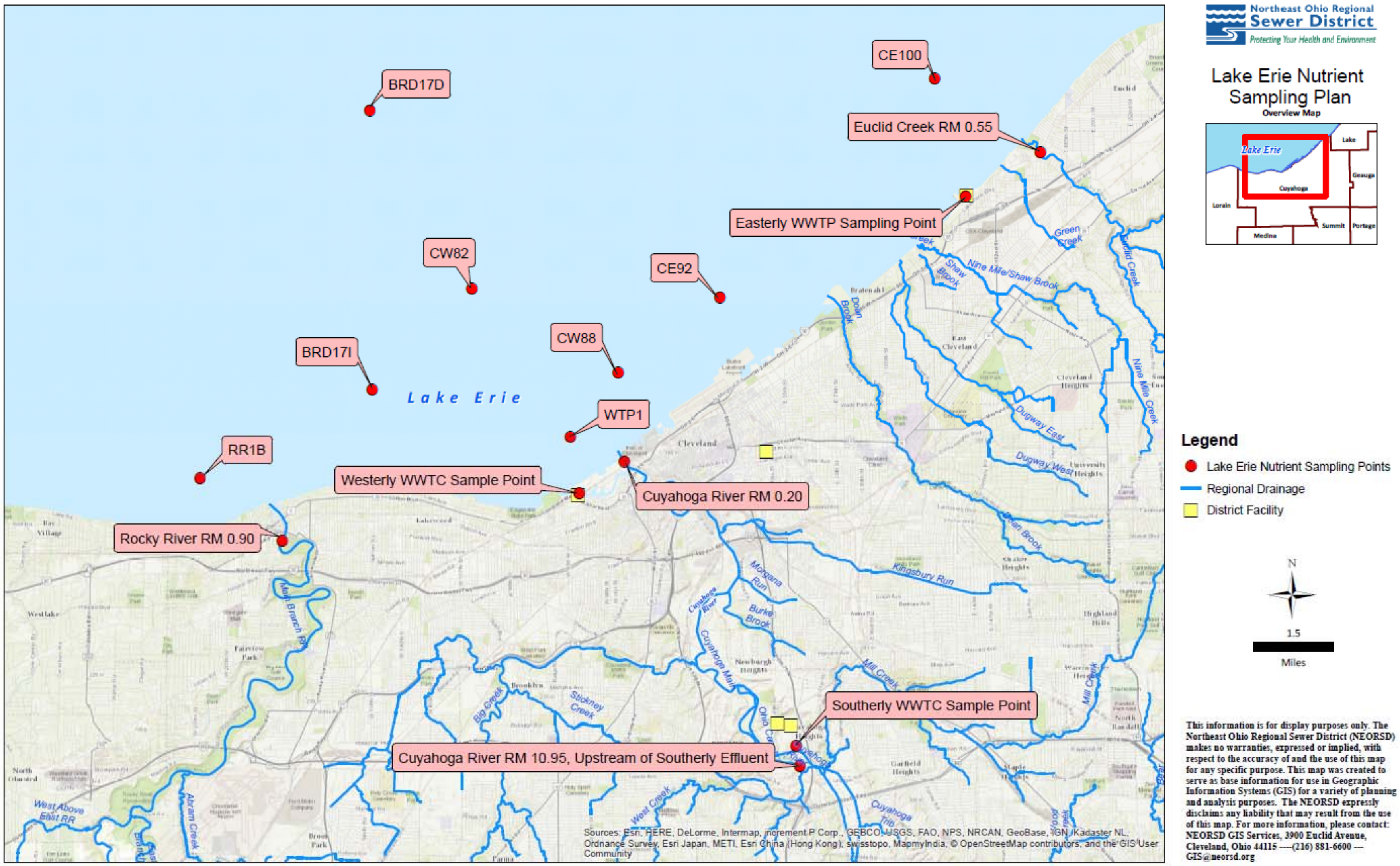

Figure 1. Sampling Locations

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

Methods

Sample Collection and Handling

Water chemistry sampling was conducted ten times at the lake sites and twelve times at the river sites between May 7th and October 22nd. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (Ohio EPA, 2018a). 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 which was preserved with sulfuric acid. An additional sample was analyzed for 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 Wastewater Treatment Plants (WWTP) 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 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. The acceptable relative percent difference (RPD) for field duplicate samples was less than or equal to $[(0.9465x^{-0.344})*100]+5$, where x = sample result/detection limit; results above this range were rejected. 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, 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. One duplicate chlorophyll *a* sample was collected at randomly selected sites at a frequency of not less than 5% of the total samples collected for this study plan. After returning to the NEORSD Environmental and Maintenance Services Center, 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 Kruskal-Wallis 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 Kruskal-Wallis test, a series of one-tailed Wilcoxon rank-sum tests were performed comparing individual sites with the offshore control site BRD17D. For river sites, since no site was designated as a control site, Wilcoxon rank-sum tests of the individual sites were performed against the data set from the site with the lowest average concentration for that parameter, with the exception of dissolved oxygen for which the site with the highest average concentration was selected for comparison against the other sites.

Results and Discussion

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

Quality Assurance and Quality Control

Nine sets of duplicate samples and nine field blanks were collected during the study. Data which did not meet quality control standards set forth in the Ohio EPA *Surface Water Field Sampling Manual* (Ohio EPA 2018a) were qualified as rejected, estimated, or Trend (downgraded from Level 3 to Level 2 data) based on Ohio EPA data validation protocol.

All duplicate samples collected in this study met quality control standards. Thirty-one sample results were qualified based on low ratios of sample to field blank results. Table 2 gives the results for parameters that were rejected, estimated, or downgraded from Level 3 to Level 2 (Trend) based on Ohio EPA data validation protocol for field blank comparison. One chlorophyll, 15 DRP, 8 ammonia, and 7 nitrate/nitrite results were qualified as estimated, trend, or rejected for reasons listed in Table 2. Most field blank results associated with qualified data were below the practical quantitation limit (PQL) with the exception of the parameter DRP for the field blank collected on September 27, 2018. DRP was detected in this field blank at concentrations greater than 2x the PQL indicating contamination of the blank. It is unclear how the field blank became contaminated. This may have occurred due to incorrect sample collection, handling, contaminated blank water and/or analytical error.

The final QA/QC check for the samples that were collected was for paired parameters, or those parameters in which one of them is a subset of the other. For this study, only TP and DRP fell into this category. During the sampling that was conducted in 2018, TP and DRP data from the Cuyahoga River RM 10.95 site collected on June 4, 2018, was qualified as estimated. On this date the TP result was less than the DRP result, but within acceptable RPD, resulting in the estimated qualifier (Table 3).

Table 2. Field Blank Data Qualifications									
Site	Parameter (Units)	Date	MDL	PQL	Sample Result	Field Blank Result	Sample/Blank Ratio	QA/QC Code	Reason
BRD17D	Chlorophyll a (µg/L)	7/24/2018	0.007	0.1	0.064	0.008	8.00	J	< 5x Sample ≤ 10x FB
CE92	DRP (µg/L)	9/27/2018	1.11	2.5	12.43	1.255	9.90	J	< 5x Sample ≤ 10x FB
WTP1	DRP (µg/L)	9/27/2018	1.11	2.5	12.01	1.255	9.57	J	< 5x Sample ≤ 10x FB
CE100	DRP (µg/L)	9/27/2018	1.11	2.5	9.561	1.255	7.62	J	< 5x Sample ≤ 10x FB
BRD17D	DRP (µg/L)	9/27/2018	1.11	2.5	5.83	1.255	4.65	Trend	< 3x Sample ≤ 5x FB
CW82	DRP (µg/L)	9/27/2018	1.11	2.5	5.064	1.255	4.04	Trend	< 3x Sample ≤ 5x FB
RR1B	DRP (µg/L)	9/27/2018	1.11	2.5	5.043	1.255	4.02	Trend	< 3x Sample ≤ 5x FB
BRD17I	DRP (µg/L)	9/27/2018	1.11	2.5	4.262	1.255	3.40	Trend	< 3x Sample ≤ 5x FB
BRD17D	DRP (µg/L)	9/12/2018	1.11	2.5	10.56	5.588	1.89	R	Sample ≤ 3x FB
CW88	DRP (µg/L)	9/12/2018	1.11	2.5	8.942	5.588	1.60	R	Sample ≤ 3x FB
CE92	DRP (µg/L)	9/12/2018	1.11	2.5	7.95	5.588	1.42	R	Sample ≤ 3x FB
CE100	DRP (µg/L)	9/12/2018	1.11	2.5	6.494	5.588	1.16	R	Sample ≤ 3x FB
WTP1	DRP (µg/L)	9/12/2018	1.11	2.5	6.118	5.588	1.09	R	Sample ≤ 3x FB
RR1B	DRP (µg/L)	9/12/2018	1.11	2.5	5.092	5.588	0.91	R	Sample ≤ 3x FB

Table 2. Field Blank Data Qualifications

Site	Parameter (Units)	Date	MDL	PQL	Sample Result	Field Blank Result	Sample/Blank Ratio	QA/QC Code	Reason
BRD17I	DRP (µg/L)	9/12/2018	1.11	2.5	4.749	5.588	0.85	R	Sample ≤ 3x FB
CW82	DRP (µg/L)	9/12/2018	1.11	2.5	4.718	5.588	0.84	R	Sample ≤ 3x FB
BRD17D	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.027	0.017	1.59	R	Sample ≤ 3x FB
WTP1	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.026	0.017	1.53	R	Sample ≤ 3x FB
CE100	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.025	0.017	1.47	R	Sample ≤ 3x FB
RR1B	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.024	0.017	1.41	R	Sample ≤ 3x FB
BRD17I	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.024	0.017	1.41	R	Sample ≤ 3x FB
CW88	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.02	0.017	1.18	R	Sample ≤ 3x FB
CE92	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.015	0.017	0.88	J	System Uncertainty
CW82	NH_3 (mg/L)	9/27/2018	0.01	0.02	0.015	0.017	0.88	J	System Uncertainty
CW88	NO_3/NO_2 (mg/L)	9/12/2018	0.009	0.02	0.087	0.009	9.67	J	< 5x Sample ≤ 10x FB
CW82	NO_3/NO_2 (mg/L)	9/12/2018	0.009	0.02	0.085	0.009	9.44	J	< 5x Sample ≤ 10x FB
BRD17I	NO_3/NO_2 (mg/L)	9/27/2018	0.009	0.02	0.085	0.009	9.44	J	< 5x Sample ≤ 10x FB
BRD17D	NO_3/NO_2 (mg/L)	9/12/2018	0.009	0.02	0.082	0.009	9.11	J	< 5x Sample ≤ 10x FB

Table 2. Field Blank Data Qualifications									
Site	Parameter (Units)	Date	MDL	PQL	Sample Result	Field Blank Result	Sample/Blank Ratio	QA/QC Code	Reason
BRD17I	NO_3/NO_2 (mg/L)	9/12/2018	0.009	0.02	0.077	0.009	8.56	J	< 5x Sample ≤ 10x FB
RR1B	NO_3/NO_2 (mg/L)	9/12/2018	0.009	0.02	0.076	0.009	8.44	J	< 5x Sample ≤ 10x FB
BRD17D	NO_3/NO_2 (mg/L)	9/27/2018	0.009	0.02	0.075	0.009	8.33	J	< 5x Sample ≤ 10x FB
R - rejected J- estimated Level 2 – downgraded from Level 3 to Level 2 data All units in mg/L									

Table 3. Paired Parameter Data Qualifications							
Site	Parameter (Units)	Date	Result	Acceptable RPD	RPD	QA/QC Code	Reason
Cuyahoga River RM 10.95	TP (mg/L)	6/04/2018	0.162	42.5	31.7	J - estimated	TP < DRP
Cuyahoga River RM 10.95	DRP (mg/L)	6/04/2018	0.223			J - estimated	TP < DRP

Ohio EPA Water Quality Standards Exceedance

No exceedances of the Ohio EPA Water Quality Standards were observed during the course of this study. Dissolved oxygen concentrations as low as 3.0 mg/L were observed in the Cuyahoga River at RM 0.20. However, this site is located within the Cuyahoga River Ship Channel and is therefore designated as a limited resource water. The minimum dissolved oxygen concentration for this portion of the Cuyahoga River is listed as 1.5 mg/L (OAC-3745-1-26(E)(3)(b)).

Wastewater Treatment Plant Phosphorus Loadings

In 2018, TP was collected daily and DRP was collected twice monthly at Southerly, Easterly, and Westerly WWTPs. Southerly discharges to the Cuyahoga River. Easterly and Westerly discharge to Lake Erie. A monthly average limit of 0.7 mg/L TP is implemented through the Southerly WWTP NPDES permit. A monthly average limit of 1.0 mg/L TP is implemented through the Easterly and Westerly WWTP NPDES permits. 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. Phosphorus has many anthropogenic and natural sources. It usually is a limited nutrient in a water body and concentration increases can accelerate growth rates of algae and plants. Tables 4 and 5 show average concentrations and loading values of TP and DRP, respectively. The average TP values for all three WWTPs met the NPDES permit limit of 0.7 mg/L. 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.

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

The average annual load of TP in the Cuyahoga River for 2013 through 2017 was reported as 308.6 metric tons (Ohio EPA, 2018c). The annual load of TP from the Southerly WWTP was 54.1 metric tons in 2018. Using these numbers, the Southerly WWTP contributed approximately 17.5% of the annual TP load of the Cuyahoga River in 2018, down from 23.2% in 2017. Easterly and Westerly WWTPs contributed 27.7 and 21.1 metric tons of TP, respectively, to Lake Erie.

Table 4. NEORSD WWTP TP Loading and Related Values						
Site	Year	Average TP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of TP)	n	Highest Collected Value (mg/L)
Southerly	2016	0.488	115.0	77.6	360	1.292, January 5
	2017	0.417	124.3	71.5	358	1.406, February 15
	2018	0.296	132.4	54.1	349	0.837, February 11
Easterly	2016	0.456	71.7	45.2	360	1.928, August 25
	2017	0.371	81.9	42.0	359	2.126, August 16
	2018	0.214	93.8	27.7	349	1.977, March 30
Westerly	2016	0.530	24.8	18.1	360	1.246, December 18
	2017	0.657	24.1	21.9	359	3.239, November 18
	2018	0.568	26.9	21.1	349	1.484, September 6
CSO	2018	2.19	11.0	33.2	-	-
* The average volume calculation only includes flow data from days on which TP data was available.						

Table 5. NEORSD WWTP DRP Loading and Related Values						
Site	Year	Average DRP Value (mg/L)	Average Volume * (MGD)	Average Yearly Estimate (metric tons of DRP)	n	Highest Collected Value (mg/L)
Southerly	2016	0.385	96.7	51.5	29	0.579, June 13
	2017	0.310	129.1	55.4	22	0.561, August15
	2018	0.186	150.5	38.7	24	0.652, December 18
Easterly	2016	0.472	58.5	38.1	12	1.093, July 26
	2017	0.322	79.8	35.5	23	1.978, June 15
	2018	0.162	86.1	19.3	23	1.628, August 15
Westerly	2016	0.348	19.4	9.10	12	0.603, August 8
	2017	0.337	21.8	10.1	23	0.893, August 15
	2018	0.232	23.0	7.4	24	0.461, September 5
* The average volume calculation only includes flow data from days on which DRP data was available.						

Annual DRP and TP loadings from the Westerly WWTP remained fairly consistent in 2018 compared to the previous two years. Loads from the Easterly and Southerly WWTP were both reduced compared to the previous two years. These load reductions were due to a decrease in phosphorus concentration in the plant effluents rather than total plant flow, as flows were actually elevated in 2018 compared to the previous two years. Annual TP removal efficiencies were calculated according to the below formula and are given in Table 6. TP removal efficiencies were improved at Easterly and Southerly WWTPs in 2018 compared to previous years. This suggests that the decreases in TP loads from these plants are due to improvements in plant performance rather than to decreases in influent phosphorus concentrations. This improved phosphorus removal efficiency resulted in a combined decrease in annual TP load of 32.5 metric tons. This is a 19.3% reduction in TP load from NEORSD sources including CSO and WWTP discharges compared to 2017.

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

Table 6. TP Removal Efficiency			
Average Influent TP (mg/L)			
	2018	2017	2016
Southerly	3.396	3.817	2.291
Easterly	2.039	2.288	2.231
Westerly	2.175	2.327	2.174
Average Effluent TP (mg/L)			
	2018	2017	2016
Southerly	0.296	0.417	0.488
Easterly	0.214	0.371	0.456
Westerly	0.568	0.657	0.530
TP Removal Efficiency (%)			
	2018	2017	2016
Southerly	91.3	89.1	78.7
Easterly	89.5	83.8	79.6
Westerly	73.9	71.8	75.6

Combined sewer overflow (CSO) discharges also contribute TP to the watersheds in the NEORSD service area. Average TP concentration from CSOs has been estimated at 2.19 mg/L (Ohio EPA, 2018c) and it is estimated, based on model predictions, that approximately 4.0 billion gallons of CSO discharges occurred in the service area in 2018. Using these estimates, CSOs in the NEORSD service area contributed a total of 33.2 metric tons of TP to Lake Erie in 2018. In 2011, the NEORSD entered into a \$3 billion, 25-year consent decree program called Project Clean Lake to reduce annual Lake Erie pollution from CSOs by 4 billion gallons by 2036. It is estimated that by 2025, the construction of CSO storage tunnels and other projects will have reduced the volume of CSO discharges to 1.97 billion gallons annually. This would result in the additional treatment of 2 billion gallons of wastewater with an average TP loading of 16.6 metric tons annually. Using the average TP removal efficiency for all three NEORSD operated WWTPs from 2016-2018 (81.5%), this would result in an estimated decrease in TP load to Lake Erie of 13.5 metric tons annually. For comparative purposes this reduction in CSO TP would be equal to 64% of the annual TP load of the Westerly WWTP and 4.4% of the annual TP load of the Cuyahoga River.

River Site Analysis

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 total phosphorus of 130 µg/L (Ohio EPA, 2018b) (Miltner, 2017). 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 do 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. They instead provide information concerning relative nutrient content upstream of each stream confluence with Lake Erie. Average parameter values for all river sites are given in Table 7. No exceedances of the criteria for the protection of aquatic life were found for all river sites for the parameters in this study.

According to SNAP, concentrations of TP and dissolved inorganic nitrogen (DIN, the sum of nitrate/nitrate and ammonia concentration) for Cuyahoga River RMs 0.20 and 10.95, and Rocky River RM 0.90 were categorized as "levels typical of working landscapes with low risk to beneficial use". Nutrient concentrations for Euclid Creek RM 0.55 were categorized as "Levels typical of modestly enriched condition in nitrogen limited systems; low risk to beneficial use".

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 2018 sampling season. Additionally, average total phosphorus was below the Ohio EPA's proposed target of 130 µg/L for all river sites.

Euclid Creek RM 0.55 had the lowest overall nutrient and chlorophyll *a* average concentrations of the four sites, with the exception of DRP, which was lowest at Rocky

River RM 0.90 (Figures 2-6). TP and DRP were significantly elevated at both Cuyahoga River sites compared to the sites with the lowest values for these parameters. Despite having the lowest concentration of DRP of all sites, Rocky River RM 0.90 had the most elevated average chlorophyll *a* concentration. However, as stated above, both chlorophyll and total phosphorus 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 or moderately enriched with respect to nutrient concentration. These levels of nutrients pose low risk to beneficial use according to the Ohio EPA's proposed SNAP procedure. In addition, total phosphorus and chlorophyll *a* concentrations were below proposed targets for all river sites.

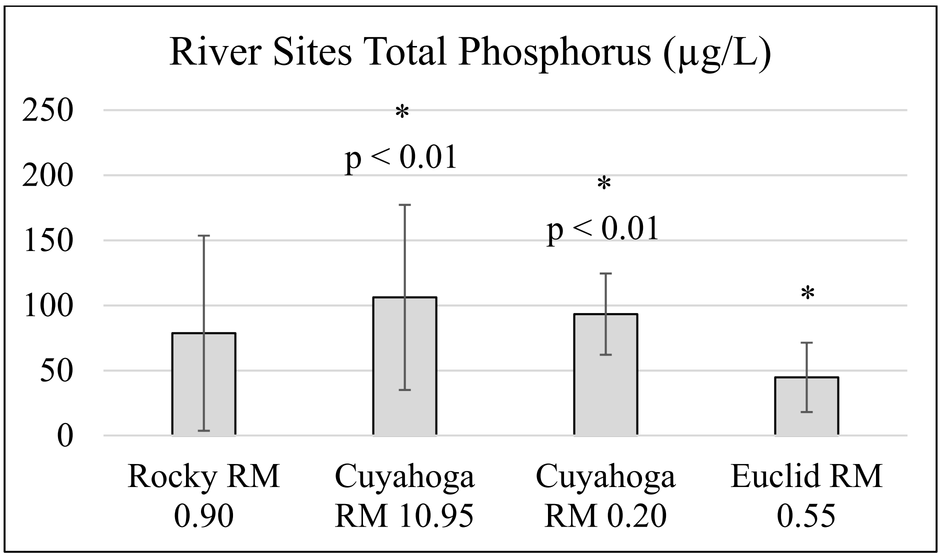

Figure 2. 2018 average TP concentrations at each river site with standard deviation. Cuyahoga River RMs 0.20 and 10.95 were found to have significantly elevated TP concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

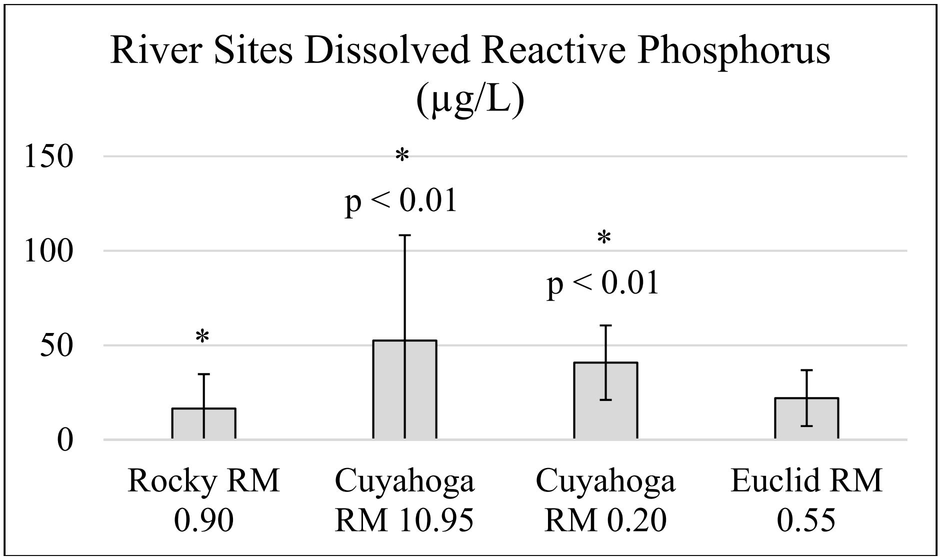

Figure 3. 2018 average DRP concentrations at each river site with standard deviation. Cuyahoga River RMs 0.20 and 10.95 were found to have significantly elevated DRP concentrations compared to Rocky River RM 0.90 according to the Wilcoxon rank-sum test.

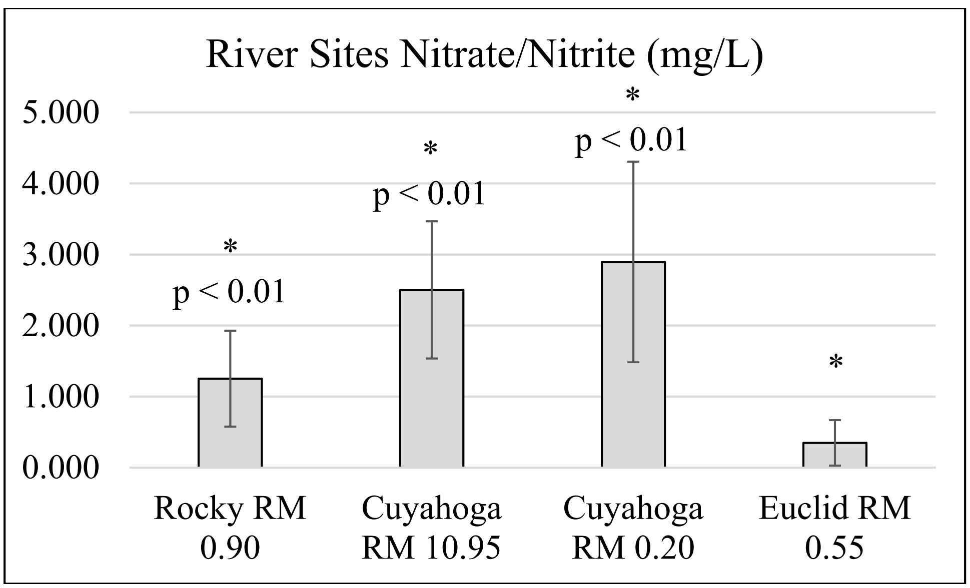

Figure 4. 2018 average nitrate/nitrite concentrations at each river site with standard deviation. All other sites were found to have significantly elevated nitrate/nitrite concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

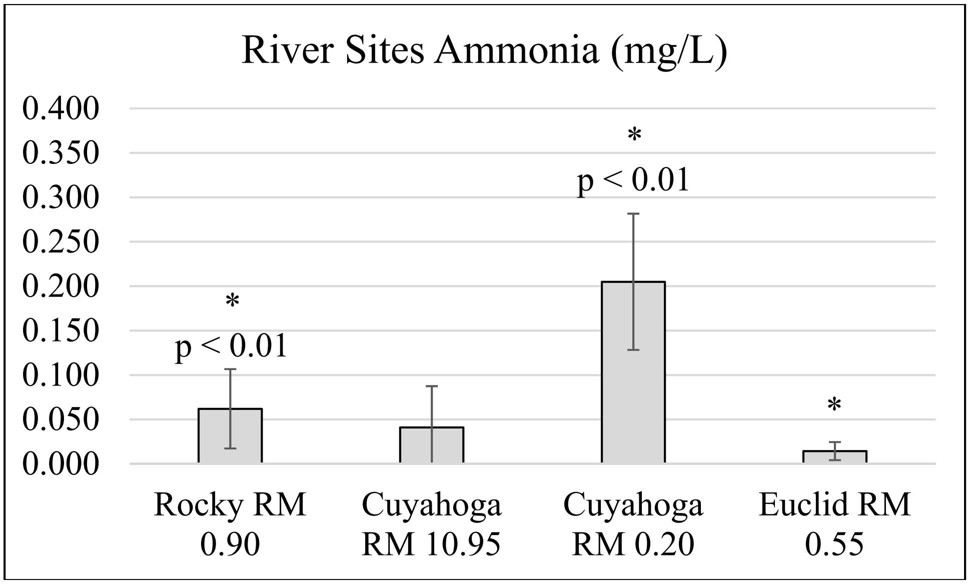

Figure 5. 2018 average ammonia concentrations at each river site with standard deviation. Cuyahoga River RM 0.20 and Rocky River RM 0.90 were found to have significantly elevated ammonia concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

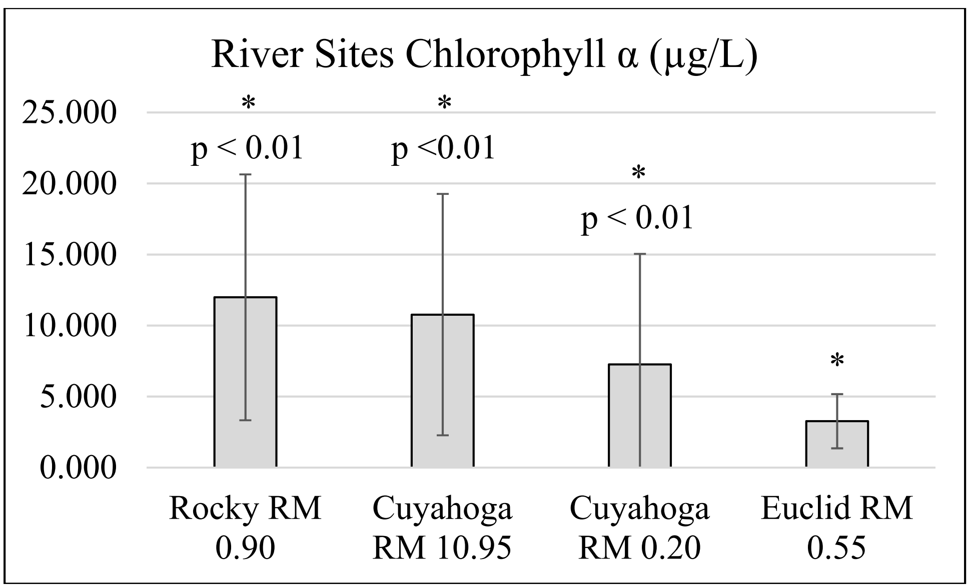

Figure 6. 2018 average chlorophyll *a* concentrations at each river site with standard deviation. All other sites were found to have significantly elevated average chlorophyll *a* concentrations compared to Euclid Creek RM 0.55 according to the Wilcoxon rank-sum test.

Table 7. 2018 River Site Average Values												
	TP	DRP	NO_3-NO_2	NH_3	Chlorophyll *a*	Alkalinity	TSS	pH	Conductivity	DO	Temperature	Turbidity
Site	ug/L	ug/L	mg/L	mg/L	ug/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	ºC	NTU
Rocky River RM 0.90	79	<17	1.252	<0.062	11.987*	123.5	43.9	8.0*	767	8.1	20.3	57.0*
Cuyahoga River RM 10.95	106*	<53*	2.502	<0.041	10.769	135.1*	45.7*	8.0*	855	8.7	20.8*	30.4
Cuyahoga River RM 0.20	93	41	2.895*	0.205*	7.269	116.4	23.0	7.6	773	6.3	21.5	24.5
Euclid Creek RM 0.55	45	<22	0.349	<0.014	3.267	115.4	8.1	7.9	899*	9.5*	18.6	9.3
Average River Site Values	81	<33	1.750	<0.081	8.323	122.6	30.2	7.9	823	8.2	20.3	30.3

< - 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.
Highlighted – Indicates that the data from this site was significantly elevated (reduced for dissolved oxygen) compared to the data of the site with the lowest average value for this parameter (highest average value for dissolved oxygen) according to a Wilcoxon rank-sum test with 95% confidence.
* - Indicates highest average value for this parameter. Does not indicate a significant difference from other sites.

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) as set forth in the 2012 Great Lakes Water Quality Agreement (GLWQA). Nutrient and chlorophyll *a* data for all lake sites was also compared using a Kruskal Wallis test followed by Wilcoxon rank-sum tests comparing all sites to offshore control site BRD17D. Table 8 gives average parameter results for all lake sites. Figures 7-11 show average nutrient and chlorophyll *a* concentrations with standard deviations and significant differences compared to offshore control site BRD17D.

The average total phosphorus concentrations for all sites in 2018 were greater than or equal to the 10 µg/L objective set by the GLWQA. BRD17D had the lowest total phosphorus concentration of all sites at 10 µg/L. Average total phosphorus concentrations were elevated up to two-fold at the remaining sites, but these differences were not significant according to the Kruskal Wallis test with a 95% confidence interval. For DRP, no target currently exists, but concentrations above 6 ug/L have been associated with harmful algal blooms (Lake Erie Phosphorus Task Force, 2013). Average DRP was below this concentration at all sites in 2018. WTP1, CW88, CE92, CE100, and CW82 had significantly elevated average DRP concentrations compared to BRD17D according to the Wilcoxon rank-sum test.

Despite having the most elevated average total and dissolved reactive phosphorus concentrations, WTP1 chlorophyll *a* concentrations were not significantly elevated compared to BRD17D. No significant differences in chlorophyll *a* concentrations were observed among the sites according to the Kruskal Wallis test.

No correlation was observed between TP and chlorophyll *a* ($R^2 = 0.21$) or DRP and chlorophyll *a* ($R^2 = 0.05$) in 2018 (Figures 12 and 13). This suggests that TP and DRP are not the primary factors influencing algal growth in the Greater Cleveland area. Additional factors that may influence algal growth in the Greater Cleveland area include, but are not limited to, weather conditions including sunlight and rain, lake conditions including wave height and currents, lake turbidity, and seeding from HABs in the western basin.

Table 8. 2018 Lake Erie Average Values

	TP	DRP	NO_3-NO_2	NH_3	Chlorophyll *a*	Alkalinity	TSS	pH	Specific Conductivity	DO	Temperature	Turbidity
Site	ug/L	ug/L	mg/L	mg/L	ug/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	ºC	NTU
BRD17D	10	<1.326	0.355	0.010	4.886	90.6	2.2	8.3	284	9.4*	19.6	2.73
RR1B	<16	<2.566	0.473	0.017	8.174*	91.3	3.4	8.3	292	9.2	20.3	4.42
BRD17I	<14	<2.400	0.430	<0.009	6.565	90.4	<2.5	8.3	289	9.2	20.4*	3.70
WTP1	20*	5.506*	0.620*	<0.035*	7.739	91.8	4.2*	8.1	317*	8.9	20.1	5.00*
CW88	<14	<3.691	0.466	<0.013	7.298	91.9*	3.0	8.2	297	9.3	19.9	3.83
CE92	20*	4.098	0.462	0.019	5.976	91.3	2.6	8.2	294	9.1	19.7	3.36
CE100	<13	4.601	0.438	<0.024	5.252	90.6	<2.0	8.2	292	9.0	19.6	2.85
CW82	<13	<2.658	0.430	<0.012	5.940	90.1	2.8	8.3	290	9.2	20.1	3.77
Average Lake Site Values	15	3.356	0.459	0.017	6.479	91.0	2.8	8.2	294	9.1	20.0	3.71

< - 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.
Highlighted – Indicates that the data from this site was significantly different from BRD17D offshore control site by a Wilcoxon rank-sum test with 95% confidence interval.
* - Indicates highest average value for this parameter. Does not indicate a significant difference from other sites.

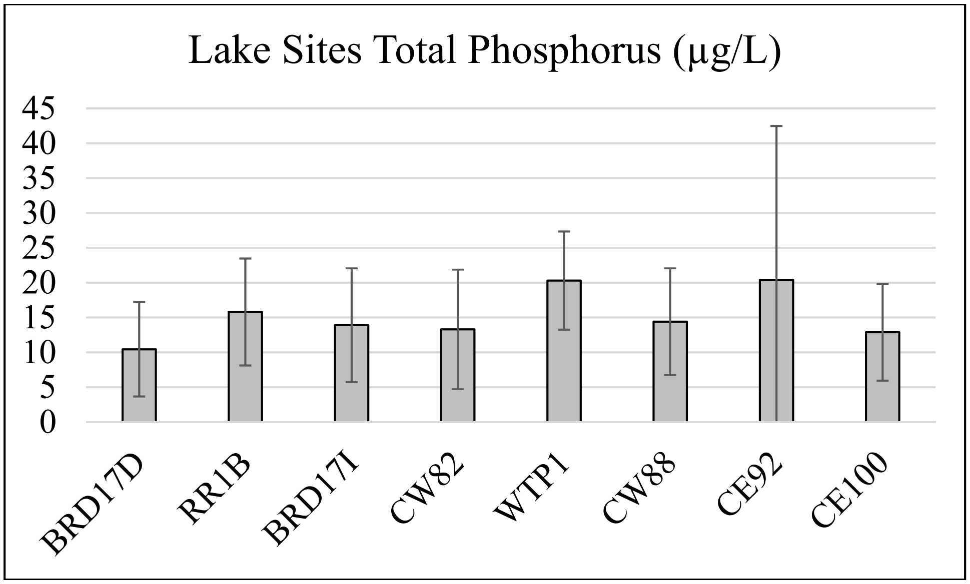

Figure 7. 2018 Average TP concentrations at each lake site with standard deviation. No significant differences among sites were observed according to the Kruskal Wallis test with a 95% confidence interval.

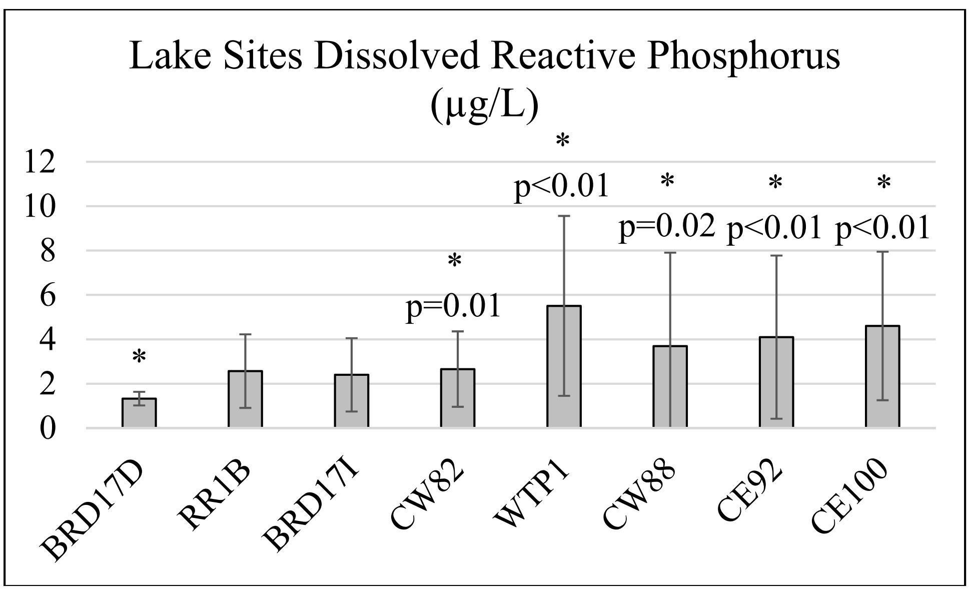

Figure 8. 2018 average DRP concentrations at each lake site with standard deviation. WTP1, CW88, CE92, CE100, and CW82 were found to have significantly elevated average DRP concentrations compared to offshore control site BRD17D according to Wilcoxon rank-sum tests.

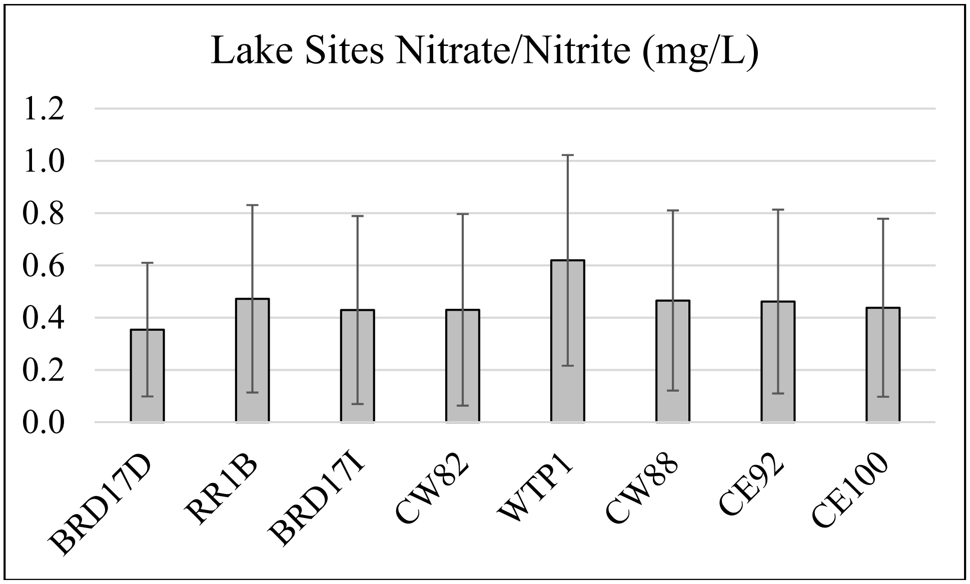

Figure 9. 2018 average nitrate/nitrite concentrations at each lake site with standard deviation. No significant difference among the lake sites was observed with respect to nitrate/nitrite according to the Kruskal Wallis test with a 95% confidence interval.

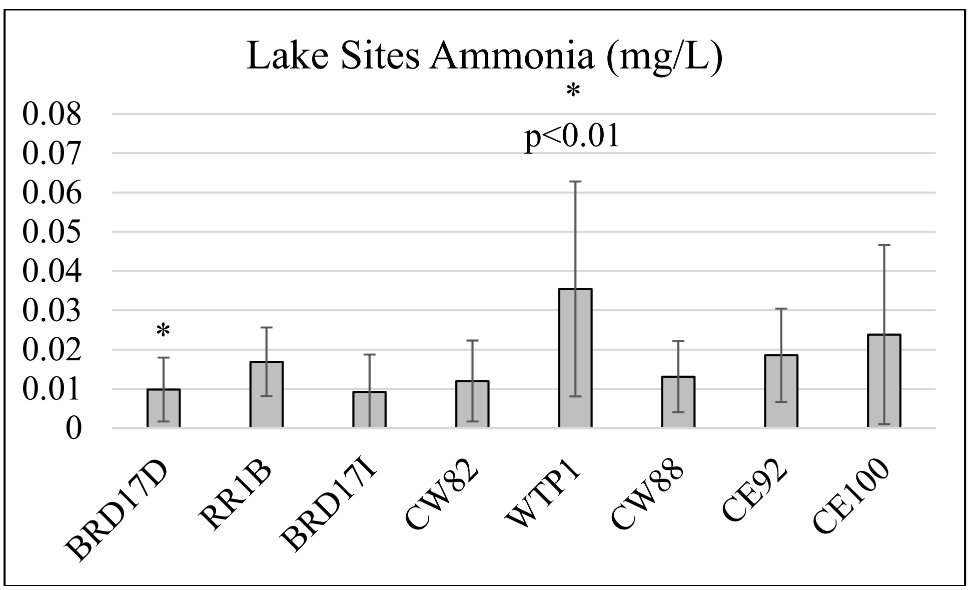

Figure 10. 2018 average ammonia concentrations at each lake site with standard deviation. WTP1 was found to have significantly elevated average ammonia concentration compared to offshore control site BRD17D according to the Wilcoxon rank-sum test.

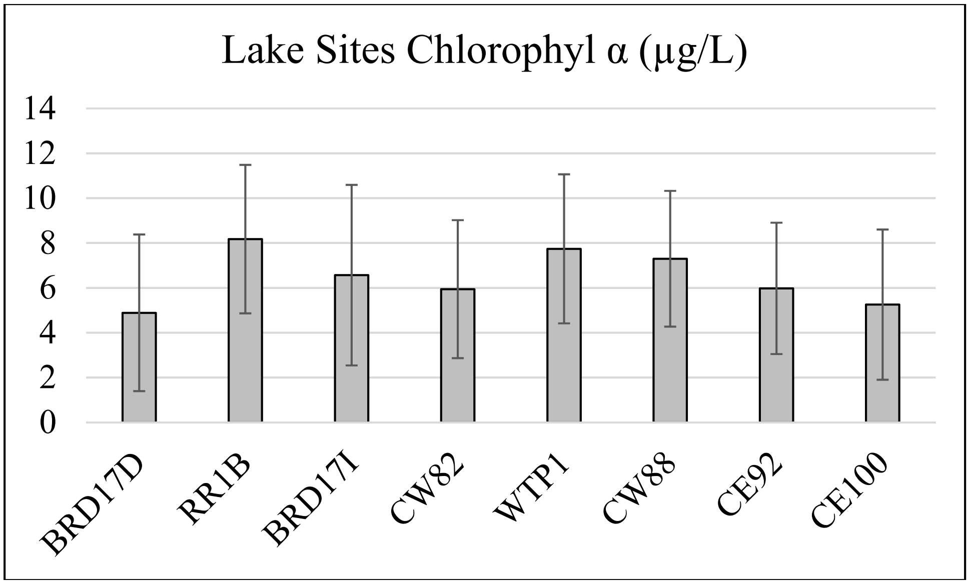

Figure 11. 2018 average ammonia concentrations at each lake site with standard deviation. No significant differences among sites were observed according to the Kruskal Wallis test with a 95% confidence interval.

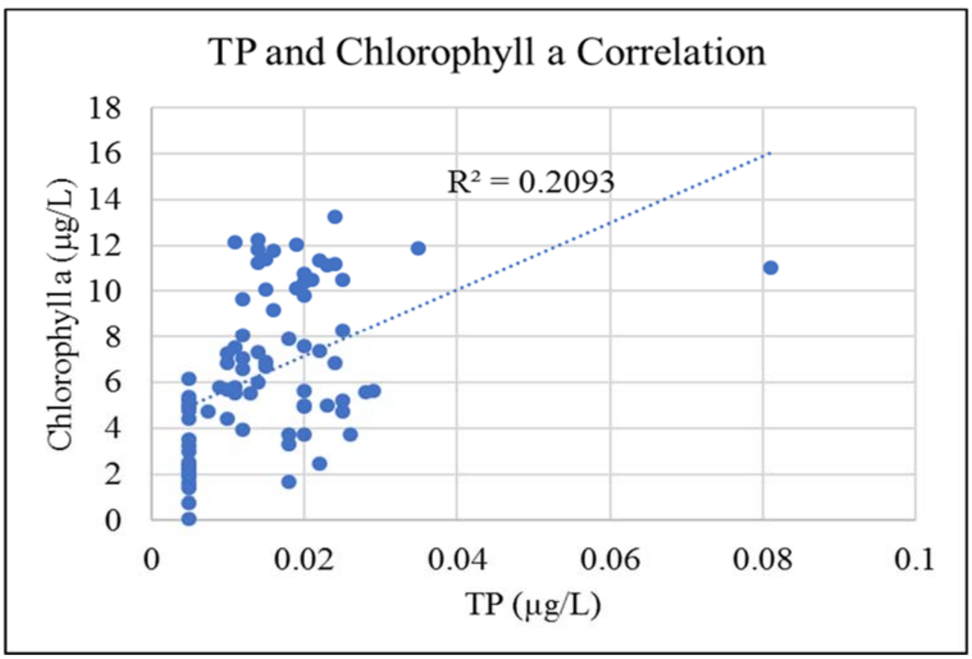

Figure 12. TP and chlorophyll *a* correlation. No correlation was observed between TP and chlorophyll *a* in 2018.

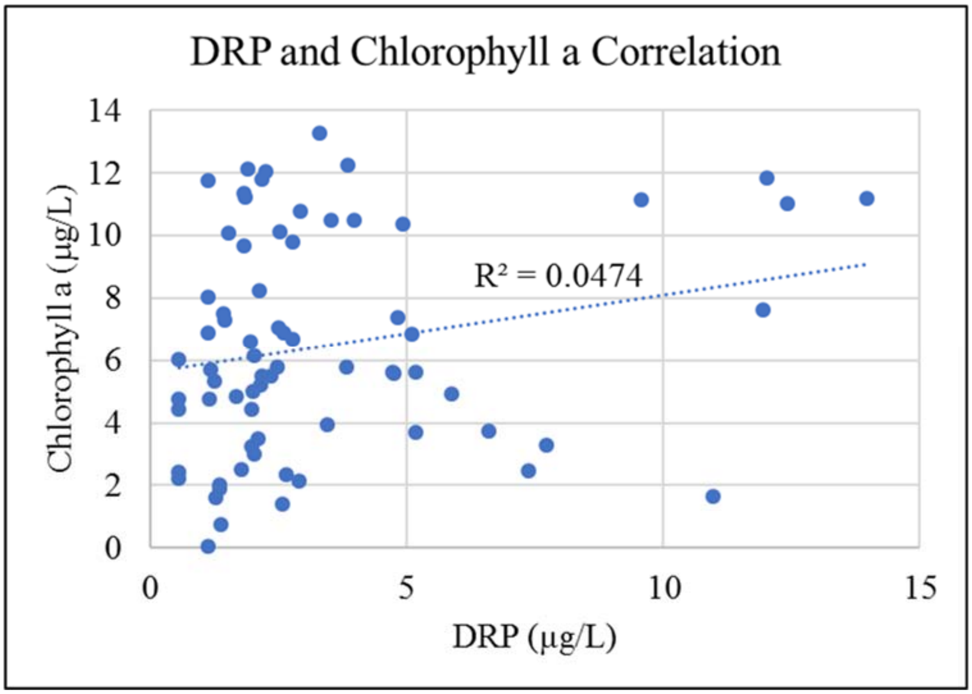

Figure 13. DRP and chlorophyll *a* correlation. No correlation was observed between DRP and chlorophyll *a* in 2018.

Harmful Algal Bloom Occurrence

A single HAB occurred during the 2018 recreational season in the Greater Cleveland Area. On June 29, 2018, Cleveland Metroparks staff noticed a green color at Edgewater Beach at approximately 1200 hours. NEORSD was contacted by Cleveland Metroparks for assistance with HAB monitoring at 1336 hours. The bloom spanned the majority of the Greater Cleveland area from Edgewater Beach to Villa Angela Beach, but was particularly concentrated at Edgewater beach along the eastern shoreline. NEORSD performed daily HAB monitoring at both beaches from June 29-July 8, 2018, throughout the course of the bloom. Only a single sample at Edgewater Beach was found to have microcystin toxin above the public advisory threshold of 6 ug/L (June 29, 11.55 µg/L). Additional offshore samples were collected at the nutrient study lake sites on July 3, 2018. Algal floc was visible at all sites except for offshore sites BRD17D and BRD17I. Microcystin toxin was below the minimum detection limit (MDL, 0.14 µg/L) for all sites with the exception of WTP1, at which toxin concentration was estimated between the MDL and practical quantitation limit (0.30 µg/L). The bloom was short-lived and was not visible after July 8, 2019.

Comparison to Historical Data

The NEORSD has been conducting the Lake Erie Nutrient Study annually beginning in 2012. Data collected in 2018 was compared to historical data collected since 2012 in order to determine trends over time. (Figures 14-16). Average TP concentration in the Greater Cleveland area lake sites was at an all-time low in 2018 at 15.2 µg/L. Average DRP concentrations were slightly elevated compared to 2017, but were still lower compared to all other previously monitored years. Chlorophyll *a* concentrations were reduced compared to 2017. No clear relationship was observed between yearly chlorophyll *a* trends and yearly trends of either form of phosphorus. The chlorophyll *a* trend does follow the same basic trend as the annual Western Lake Erie Bloom Severity Index presented in Figure 17 (NOAA, 2018). This would be expected, as annual conditions in the central basin would be fairly similar to the western basin for each respective year.

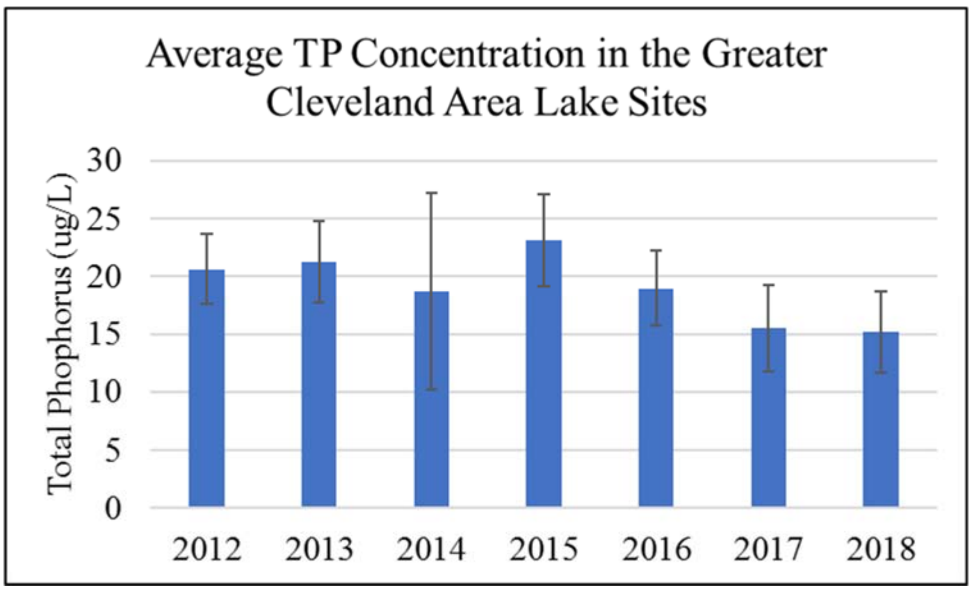

Figure 14. Average TP concentration at all lake sites by year with standard deviation. Average TP concentrations in 2018 were at an all-time low compared to previously monitored years. No clear relationship was observed between TP trends and chlorophyll *a* trends.

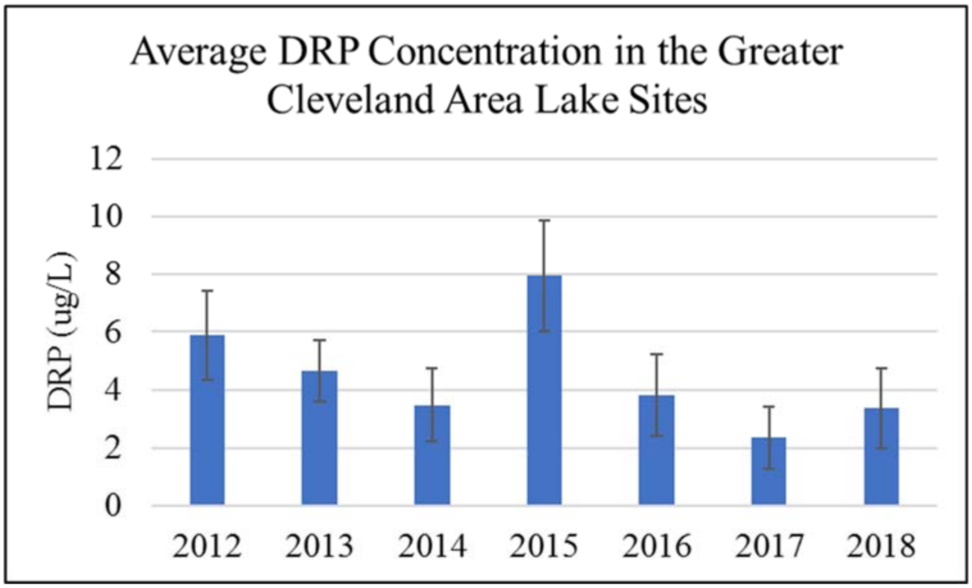

Figure 15. Average DRP concentration at all lake sites by year with standard deviation. Average DRP concentrations were at the second lowest since monitoring began in 2012. No clear relationship was observed between DRP trends and chlorophyll *a* trends.

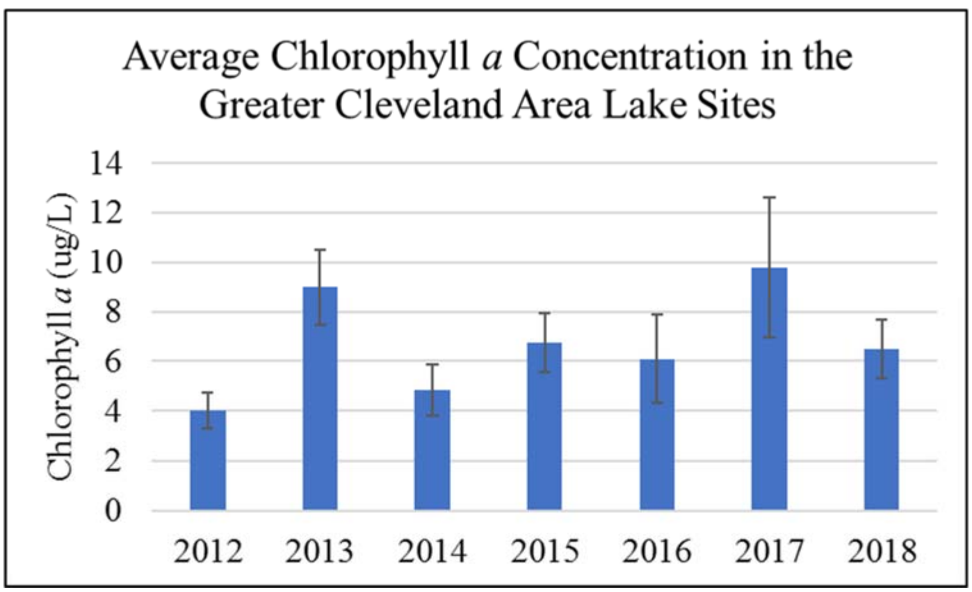

Figure 16. Average chlorophyll *a* concentration at all lake sites by year with standard deviation. Basic year to year trends correspond to NOAA Bloom Severity index.

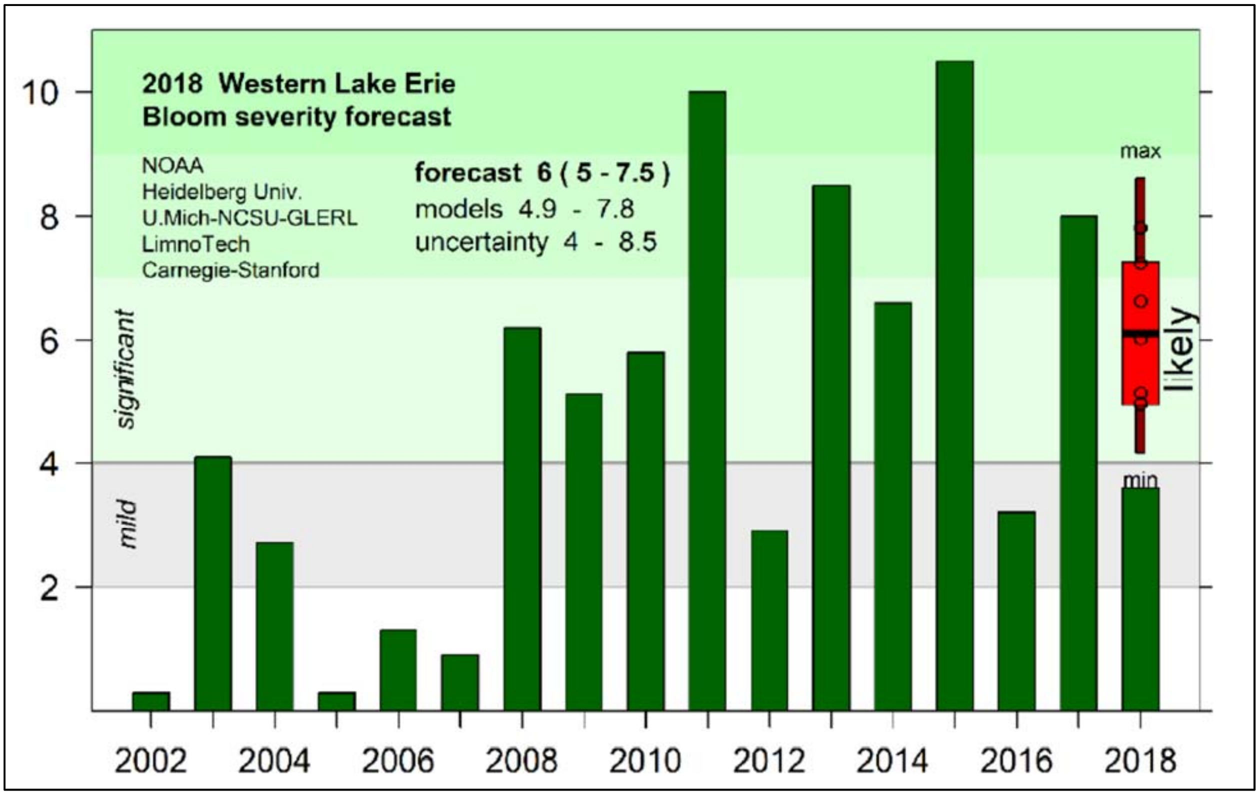

Figure 17. Bloom Severity Index as of October 2018 as published by NOAA (NOAA, 2018).

Conclusion

Average TP concentrations in 2018, from Lake Erie surrounding the Greater Cleveland area, were at a historical low since nutrient monitoring by the NEORSD began in 2012. Despite this, average TP concentrations at all lake sites, including the offshore control site, were still equal to or above the Interim Substance Objective of 10 µg/L for TP set by the GLWQA. A single HAB was observed in the Greater Cleveland area, resulting in public advisory postings for a period of ten days at local beaches. Continued reduction of phosphorus concentrations in the Lake Erie watershed will be needed in order to meet the GLWQA objective and prevent future HAB occurrences. Major streams in the NEORSD service area were found to have phosphorus concentrations below Ohio EPA proposed target limits, suggesting that efforts to reduce phosphorus contributions to Lake Erie may provide greater results if directed towards watersheds with more elevated phosphorus concentrations.

The NEORSD continues to invest in improvements to wastewater treatment and collection system infrastructure. These investments have and will continue to reduce phosphorus discharges to surface waters in the NEORSD service area. Phosphorus loading contributions from NEORSD operated sources were decreased in 2018 compared to previous years despite increased rainfall and plant flow in 2018. This suggests that improvements in plant performance have resulted in increased phosphorus removal efficiency at NEORSD operated facilities. TP loads from NEORSD discharges decreased in 2018 by 32.5 metric tons, a 19.3% decrease compared to 2017. Future improvements to NEORSD operated WWTPs and sewage collection systems as part of Project Clean Lake are expected to result in further reductions of nutrient loads from NEORSD operated sources.

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