NORTHEAST OHIO REGIONAL SEWER DISTRICT

2015 Greater Cleveland Area Lake Erie Nutrient Study

Prepared by
Water Quality and Industrial Surveillance Division

Introduction

In 2011, an algal bloom, the majority of which consisted of *Microcystis,* spread east of Cleveland and persisted there until the middle of October. The increase in algae throughout the lake is thought to be due to increases in dissolved reactive phosphorus (Ohio EPA, 2011) coupled with favorable weather conditions. The algal bloom which occurred in 2014 left residents in the City of Toledo without drinking water for three days. The algae bloom in 2015 was the largest in this century according to the National Oceanic and Atmospheric Academy (NOAA, 2015). Northeast Ohio Regional Sewer District (NEORSD) facilities, such as its wastewater treatment plants and the combined sewer overflows (CSOs), are a source of nutrients to the lake. The extent to which these potential sources, along with other ones within the study area, are contributing to the problem is not well known.

The purpose of the 2015 study was to continue to monitor the levels of nutrients and algae in Lake Erie near the greater Cleveland area from April through October and further attempt to establish temporal and spatial trends and potentially relate them to level of precipitation. In 2015, two additions were made to the study. First, the major tributaries to Lake Erie in the Cleveland area were sampled, including the Rocky River, Euclid Creek, and the Cuyahoga River. Second, samples were collected at the District's three wastewater treatment plants for dissolved reactive phosphorus (DRP). Chlorophyll *a* was measured as a means of determining the total quantity of algae present. Nutrient analyses included both phosphorus and nitrogen. Other water quality parameters that may influence algal production were also measured. Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by Ohio Environmental Protection Agency (EPA) in Chemical Water Quality as explained in the NEORSD study plan *2015 Greater Cleveland Area Lake Erie Nutrient Study* approved by the Ohio EPA on June 17, 2015.

Figure 1 is a map of the sampling locations evaluated during the study, and Table 1 indicates the sampling locations with respect to latitude/longitude and description. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's Water Quality and Industrial Surveillance Division (WQIS).

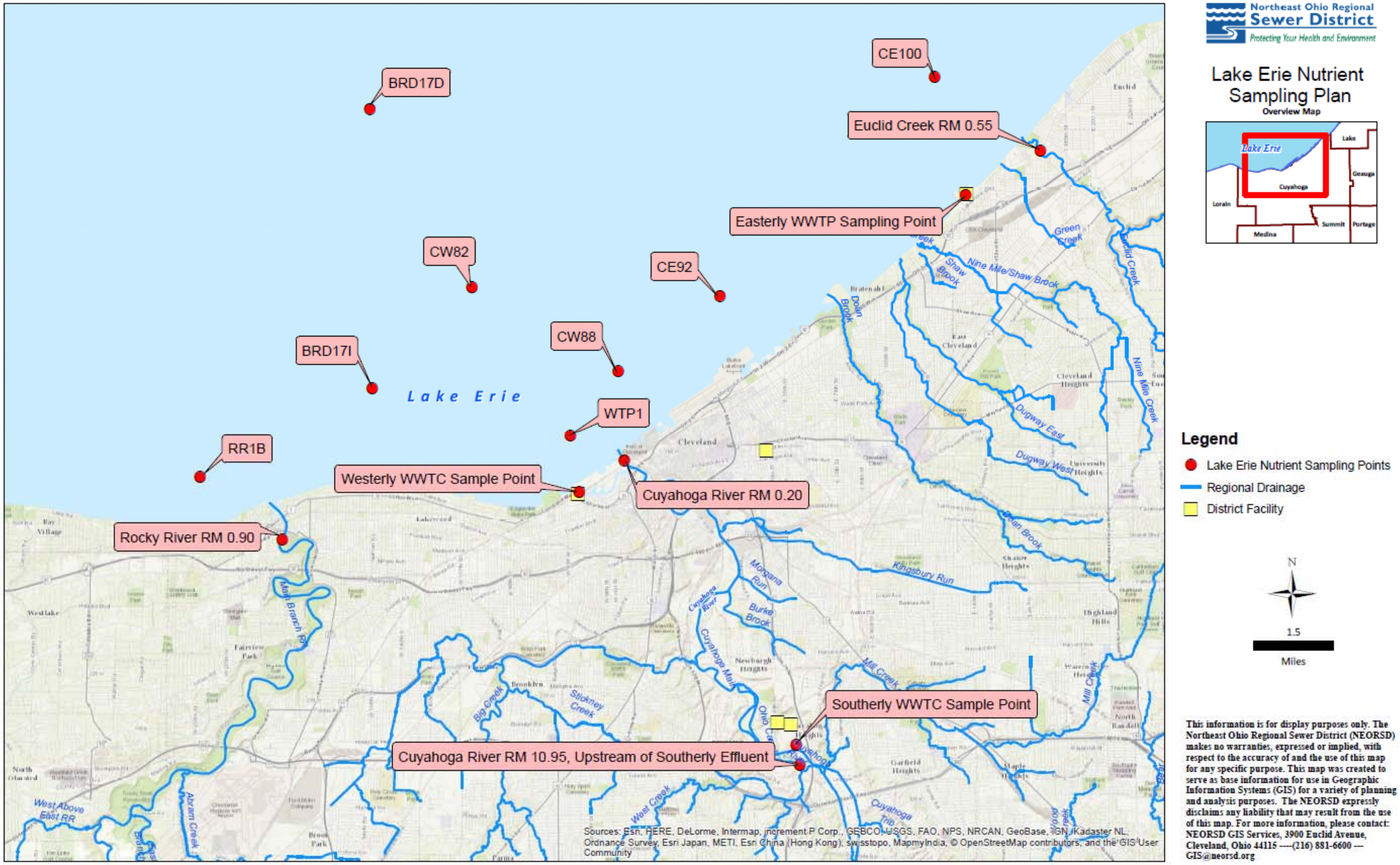


Figure 1. Sampling Locations

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 WWTP 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	

Water Chemistry Sampling

Methods

Water chemistry sampling was conducted at most of the sites thirteen times between May 4th and October 19th. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (2013). These techniques were used for the lake sites and the three river sites. The effluent samples from the NEORSD wastewater treatment plants were 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 is 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 at Westerly, Easterly, and Southerly Treatment Plants were collected from the final treated effluent and were analyzed for DRP. Filtering was done 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 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 a YSI 600XL or EXO1 sonde and measured dissolved oxygen (DO), water temperature, conductivity and pH. Turbidity was measured using either a Hach 2100P IS Portable Turbidimeter or a Hach 2100Q Portable Turbidimeter.

Water column chlorophyll *a* samples were collected during each sampling using a 1L glass amber-colored jar. All chlorophyll *a* samples were collected as grab samples at a depth of six to twelve inches below the 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. An error in filter size occurred during the first three weeks of sampling and therefore, the DRP values generated were discarded. Filtered samples were stored in a freezer at -37°C for storage prior to analysis.

Microcystin samples were collected for four different analyses: microscope ID and enumeration, EPA 545 for Cylindrospermopsin and Anatoxin-A by LC/MS/MS1, EPA 544 for Microcystins and Nodularin by LC/MS/MS2, ISO 20179 Determination of Microcystins using SPE and HPLC with UV3, and ELISA (Enzyme-Linked-Immunosorbent Assay) protocol. These samples were collected Lake Erie site CW82.

Results and Discussion

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

Compliance and Quality Control

Eleven sets of duplicate samples and thirteen field blanks were collected during the study. For the field blanks, there were three parameters that showed possible contamination. It is unclear how the field blanks became contaminated and may be due to inappropriate sample collection, handling, contaminated blank water and/or interference during chlorophyll *a* analysis. Table 2 lists water quality parameters that were rejected, estimated, or downgraded from Level 3 to Level 2 data based on Ohio EPA data validation protocol.

Table 2. Parameters affected by possible blank contamination
DRP
NH_3
TP

Nine instances occurred in which the RPD between duplicate samples was greater than acceptable, with six of them for ammonia (Table 3). There may be numerous reasons for why these parameters were rejected, such as a lack of precision and consistency in sample collection and/or analytical procedures, improper handling of samples and/or environmental heterogeneity.

Table 3. Duplicate samples with greater than acceptable RPDs

Site	Date	Parameter	Acceptable RPD (%)	Actual RPD (%)
Cuyahoga River RM 10.95	7/29/2015	NH_3	56.1	148.9
BRD17D	5/5/2015	NH_3	39.1	139.1
CE100	7/28/2015	DRP	99.7	107.7
		NH_3	63.8	66.7
CW88	7/1/2015	NH_3	28.1	75.9

Table 3. Duplicate samples with greater than acceptable RPDs

Site	Date	Parameter	Acceptable RPD (%)	Actual RPD (%)
		Chlorophyll *a*	10.7	11.1
RR1B	10/6/2015	NH_3	46.5	128.5
		Chlorophyll *a*	10.6	11.8
WTP1	9/1/2015	NH_3	99.7	165.2

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 total phosphorus (TP) and DRP fell into this category. During the sampling that was conducted in 2015, there was one instance in which these parameters needed to be qualified due to the subset parameter being greater than the other one (Table 4).

Table 4. Paired Parameter samples with greater than acceptable RPDs

Site	Date	Parameter	Acceptable RPD (%)	Actual RPD (%)	Qualifier
CE100	7/28/2015	TP/DRP	72.5	22.2	Estimated

Ohio EPA Exceedance

For the rest of the parameters measured, there was an aquatic life OMZA (outside mixing zone average) exceedance of temperature over a thirty-day period on the Rocky River (Table 5). Otherwise, all other parameters at the lake or river sites were acceptable for human health nondrinking, aquatic life, and agricultural criteria.

Table 5. Aquatic Life OMZA Exceedance

Site	Date	Parameter	30-Day Average (ºC)
Rocky River RM 0.90	9/1/2015-9/30/2015	Field Temperature	24.5

Microcystin Analysis at CW82

Samples collected at lake site CW82 were analyzed for microcystin, a toxin which can be produced by cyanobacteria. CW82 was chosen due to its proximity to one of the City of Cleveland's main water intake location. Microcystins come in different forms (congeners) based on the location and type of the amino acids on the main structure. NEORSD analyzed for seven congeners for several of the sampling dates. The state guideline for the Recreational Public Health Advisory is 6 µg/L microcystin (Ohio Department of Health, *Harmful Algal Bloom*, 2016). By adding the seven congeners together, a rough minimum estimate could be made of the amount of microcystin in a sample. The highest sample was collected on September 22, 2015, and the sum of the congeners was approximately 1.19 µg/L. All other dates were below 1.0 µg/L with the next highest sampling on September 9, 2015, measuring approximately 0.134 µg/L.

Data Analysis: Dissolved Reactive Phosphorous and Total Phosphorus

Wastewater Treatment Plant Analysis

In 2015, DRP measurements were collected at Southerly, Westerly, and Easterly WWTPs (Table 6). Southerly discharges to the Cuyahoga River. Easterly and Westerly WWTPs discharge to Lake Erie. There is a current limit of 0.7 mg/L for TP implemented through NEORSD's NPDES permits, but no limit specifically for DRP is imposed by the Ohio EPA. In April 2016, one grab sample every month to monitor DRP was added to Southerly WWTP's NPDES permit requirements. Phosphorus has many anthropogenic and natural sources. It usually is a limited nutrient in a water body and increases can accelerate growth rates of algae and plants. While Westerly WWTP had the lowest average value of DRP, it also had the highest collected value. Samples were not collected from the WWTPs last year, so a comparison cannot be made, but the study in 2016 will continue to have these sites.

Table 6. 2015 Dissolved Reactive Phosphorus Values at Effluent

WWTP	Average Value (mg/L)	Highest Collected Value (mg/L)
Southerly	0.378	0.647, August 10
Westerly	0.246	0.844, October 19
Easterly	0.357	0.822, August 24

Lake and Land Site Analysis

Most of the highest average parameters of concern were at Cuyahoga RM 10.95, which is upstream of the Southerly WWTP, and therefore not impacted by the effluent. Similarly, WTP1 of the lake sites had the highest values on average. This site is the closest to the Cuyahoga River mouth and so the findings of the river sites are consistent with what was collected on the lake. Since the rivers are the major arteries of flow to the lake, it is expected that the levels would be highest before diluting into the lake. Elevated parameters are not inherently negative; however, it is important to monitor for changes in the ecosystem to see how it affects its function, especially when those changes are man-made. Parameters like TP, ammonia, total suspended solids and conductivity increase due to erosion, fertilizers and CSOs. When in combination with the weather, their increase may lead to a casual sequence involving chlorophyll *a* and algae blooms.

Currently, a target of 0.01 mg/L exists for TP in the central basin of Lake Erie (Lake Erie Nutrient Science Task Group, 2009). The average concentration at all the river sites and lake sites were above this target in 2015 (Table 7). The overall average in 2015 of the lake sites was 0.0231 mg/L for TP (Table 8). This is higher than 2014 when the average was 0.0186 mg/L. Although no concentration targets currently exist for DRP, harmful algal blooms have been found at concentrations around 0.006 mg/L (Lake Erie Phosphorus Task Force, 2013). All the sites averaged above this value on the lake, except for CE100, located furthest east of the sites. The river sites were higher than the lake sites and the Cuyahoga River at RM 10.95 was the highest overall. Cuyahoga RM 10.95 also had the highest total suspended solids (TSS), which was more than double the other rivers. TSS can be reflective of runoff and eroded soils in the water, which carry phosphorus. Based on these measured phosphorus concentrations, it could be expected that elevated chlorophyll *a* levels may be found in the lake, and this was the case.

Table 7. 2015 River Sample Average Values													
	TP	DRP	NO_3-NO_2	NH_3	Alkalinity	TSS	pH	Conductivity	DO	Temperature	Chlorophyll *a*	Turbidity
Site	mg/L	mg/L	mg/L	mg/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	ºC	ug/L	NTU
Euclid Creek RM 0.55	0.049	0.0221	0.26	0.0367	109.88	7.55	7.75	829.8	8.90	17.9	2.75	8.13
Cuyahoga River RM 0.20	0.130	0.0578	3.17	0.225	118.50	30.7	7.53	840.3	5.98	21.6	6.86	26.02
Rocky River RM 0.90	0.083	0.0196	2.09	0.063	121.11	41.17	7.94	816.6	8.23	20.0	8.55	42.85
Cuyahoga River RM 10.95	0.132	0.0378	2.98	0.158	132.56	88.38	8.00	848.1	9.04	19.8	11.38	62.34

= Highest average value for that parameter

Table 8. 2015 Lake Erie Average Values												
	TP	DRP	NO_3-NO_2	NH_3	Alkalinity	TSS	pH	Conductivity	DO	Temperature	Chlorophyll *a*	Turbidity
Site	mg/L	mg/L	mg/L	mg/L	mg/L CaCO3	mg/L	S.U.	uS/cm	mg/L	ºC	ug/L	NTU
RR1B	0.024	0.0078	0.31	0.035	85.76	4.00	8.33	258.7	9.4	19.76	7.90	5.67
BRD17D	0.020	0.0099	0.20	0.062	85.60	3.13	8.31	241.0	9.5	18.35	4.99	4.41
BRD17I	0.022	0.0096	0.24	0.032	85.62	3.35	8.36	253.6	9.5	19.72	7.36	4.81
CW82	0.020	0.0072	0.22	0.068	85.74	4.05	8.34	244.6	9.5	19.35	6.46	4.81
WTP1	0.029	0.0102	0.39	0.060	87.00	4.33	8.23	272.24	9.2	19.72	8.39	5.63
CW88	0.029	0.0077	0.35	0.039	86.35	4.44	8.28	272.23	9.3	19.68	7.05	5.75
CE92	0.022	0.0065	0.27	0.094	85.48	3.28	8.30	254.7	9.4	19.58	6.50	4.32
CE100	0.019	0.0046	0.26	0.044	86.10	3.08	8.23	253.31	9.3	19.52	5.39	3.15

= Highest average value for that parameter

When comparing standardized[1] graphs of DRP to chlorophyll *a*, many of the sites had a recognizable and repeated trend seen below (Figure 2-3). The chlorophyll *a* increases in the summer as the water warms and the algae begin to grow, creating chlorophyll *a*. DRP decreases as it is absorbed and used by the algae. As fall begins and temperatures decrease, the algae die and are no longer using and converting DRP, creating a rise in DRP and a decrease in chlorophyll *a*. This trend was noticeable on the lake and the river sites with many of the lake sites looking like Euclid Creek and CW88 below. The same standardization will be completed on 2016 data to see if this is a reoccurring seasonal transition. This is a hypothesis as it stands. The same analysis was completed for chlorophyll *a* and TP, but no recognizable trend was identified

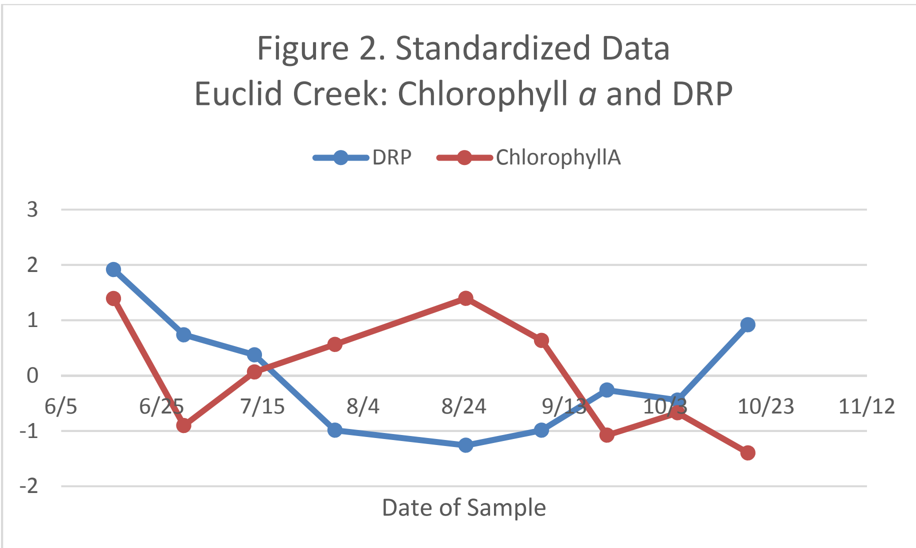
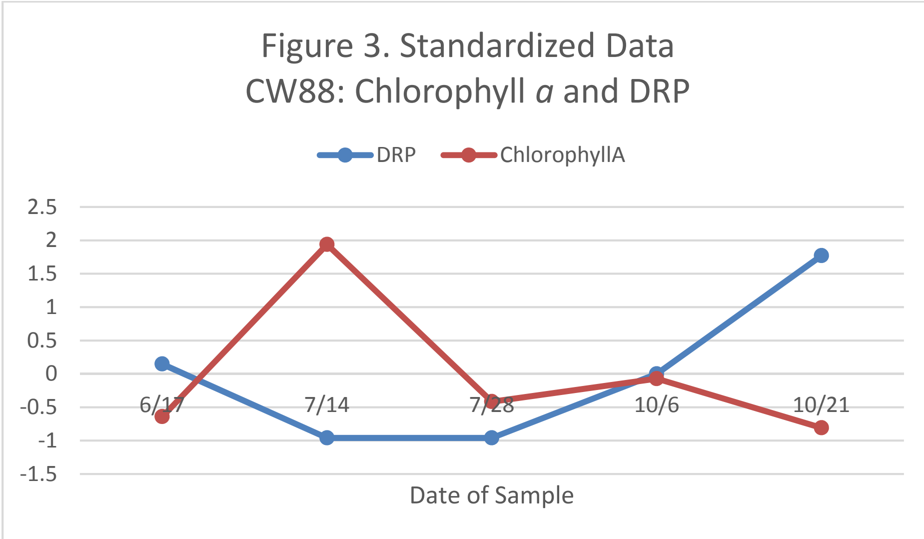


Figure 2. Standardized Data
Euclid Creek: Chlorophyll *a* and DRP

[1] Standardizing variables is a way of representing data which would normally be on different scales (e.g. ug/L and mg/L or ft^3/second and mg/L) on the same scale, thereby making trends comparable. This is done by calculating the z-score of each measurement in a data set. The z-score is the original value minus the mean of the data set, divided by the standard deviation of the data set.



Lake Erie Chlorophyll a *Concentrations*

As in the 2012-2014 studies, chlorophyll *a* concentrations measured at site WTP1 averaged the highest in 2015 (Table 9). Overall, the average concentrations per site in 2015 were higher than the previous year, but lower than in 2013 (Figures 4-6). In 2013, northeast Ohio received much more rain than normal, which most likely contributed to those elevated levels. In 2015, all averages exceeded the Great Lakes Water Quality Agreement target of 2.6 ug/L chlorophyll *a* (Lake Erie Nutrient Science Task Group, 2009). Some individual samples did meet this target; they are shaded below (Table 9).

The chlorophyll *a* averages from 2013-2015 were used in Figures 4-6. Overall, yearly increases and decreases are expected and not enough data has been collected to suggest an overall trend. However, the data helps to monitor chlorophyll *a* levels and keep records for reference when algal blooms are an issue for northeast Ohio. When they are present, water quality data can be compared to other summers when blooms were occurring. In addition, as practices involving fertilizer use, manure storage, and no-till farming change, sediment and phosphorous loading in the western basin may also change, which could affect the central Lake Erie basin as well.

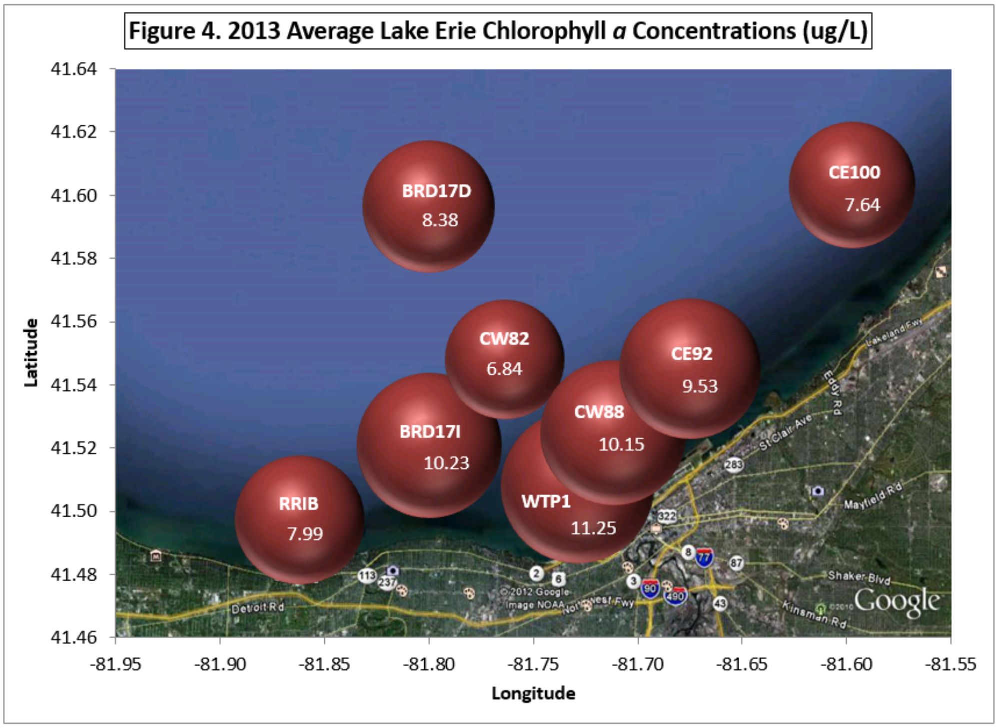


Figure 4. 2013 Average Lake Erie Chlorophyll *a* Concentrations (ug/L)
BRD17D
8.38
CE100
7.64
CW82
6.84
CE92
9.53
CW88
10.15
BRD17I
10.23
WTP1
11.25
RRIB
7.99
Latitude
41.64
41.62
41.60
41.58
41.56
41.54
41.52
41.50
41.48
41.46
-81.95
-81.90
-81.85
-81.80
-81.75
-81.70
-81.65
-81.60
-81.55
Longitude

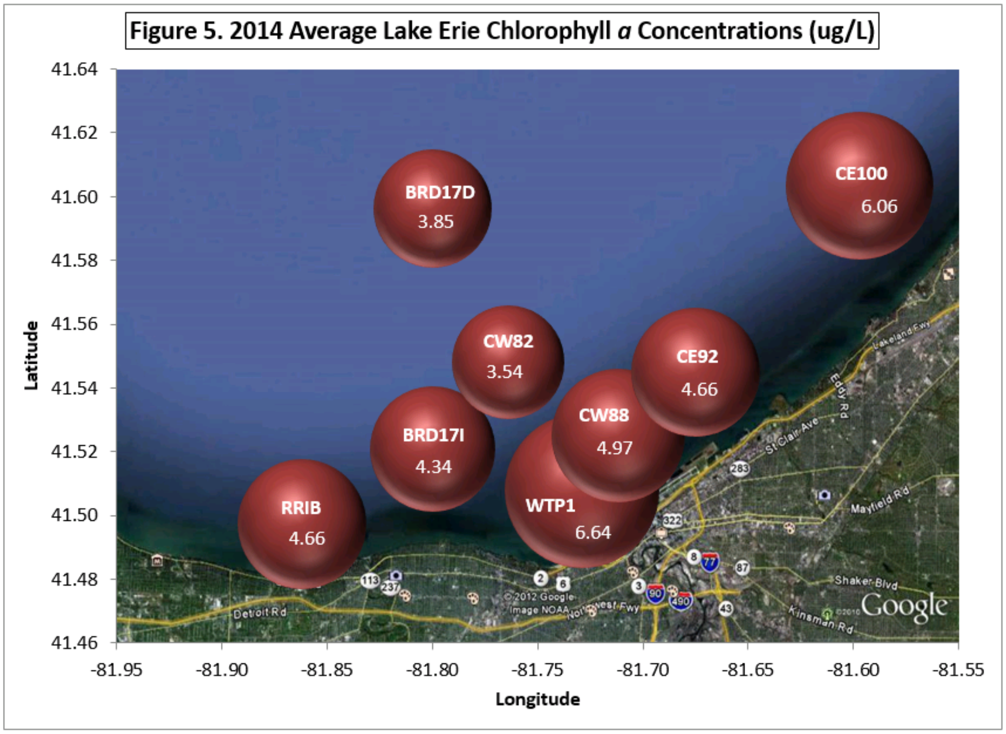


Figure 5. 2014 Average Lake Erie Chlorophyll *a* Concentrations (ug/L)
BRD17D
3.85
CE100
6.06
CW82
3.54
CE92
4.66
CW88
4.97
BRD17I
4.34
WTP1
6.64
RRIB
4.66
Latitude
41.64
41.62
41.60
41.58
41.56
41.54
41.52
41.50
41.48
41.46
-81.95
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-81.60
-81.55
Longitude

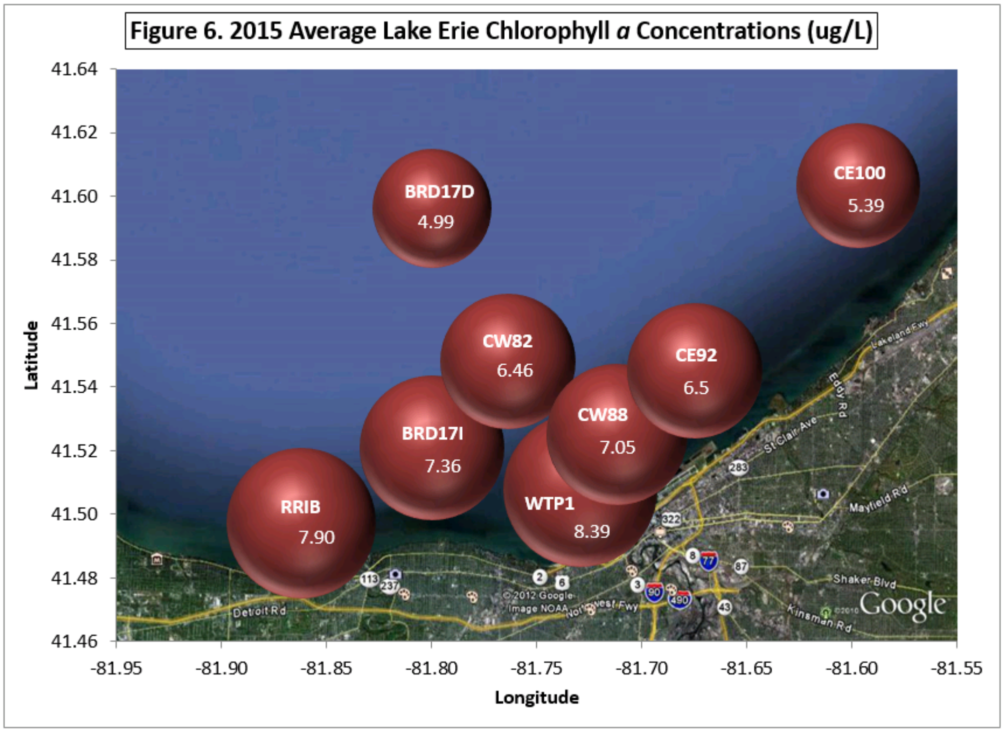


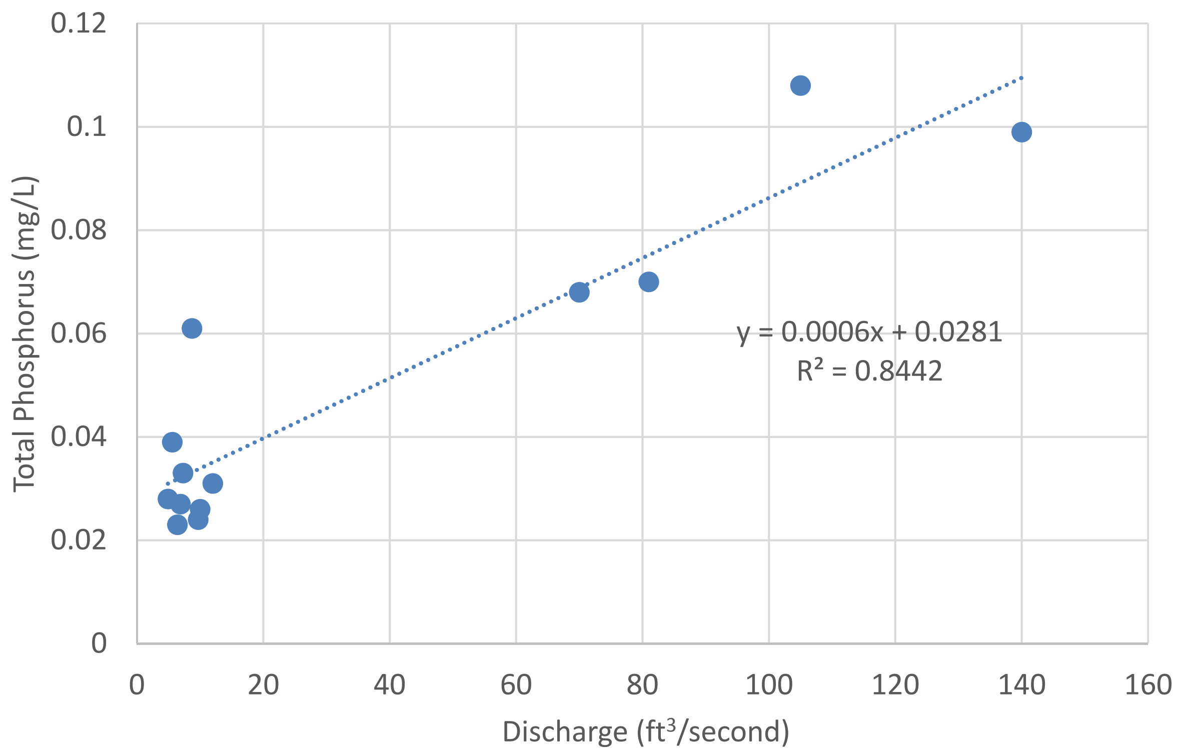
Table 9. 2015 Chlorophyll *a* Concentrations (ug/L)									
	RR1B	BRD17D	BRD17I	CW82	WTP1	CW88	CE92	CE100	**Average**
5/5/2015	3.75	1.29*	2.70	1.76	5.42	4.18	5.27	3.54	3.80
5/21/2015	8.95	2.33	8.40	2.80	6.30	8.80**	9.38**	7.55**	5.76
6/4/2015	1.15	2.09	2.01	2.07*	1.30	0.62	0.41	0.54	1.16
6/17/2015	3.64	1.72	3.71	1.93	3.09	3.09	3.51	2.54	2.90
6/30/2015	12.93	9.44	17.17	13.11	8.14	---	5.96	4.82	10.22
7/14/2015	12.64	5.08	10.89	7.02	15.61	12.63	8.20	10.68	10.34
7/28/2015	3.65	3.76	4.78	5.00	7.70	3.92	4.59	3.88	4.66
8/11/2015	10.61	---	8.57	7.47	14.30	13.70	13.71	8	10.91
9/1/2015	10.15	6.45	11.00	8.77	12.15*	10.64	9.42	6.35	8.97
9/9/2015	8.30	10.47	6.63	6.85	8.42	5.66	6.24	4.42	7.12
9/22/2015	16.87	5.67	10.86	13.98	22.23	15.45	12.16	8.27	13.19
10/6/2015	---	5.34	6.40	6.54	5.90	5.19	5.77	5.82	5.85
10/21/2015	2.10	2.54	2.51	2.25	2.22	2.47	2.81	5.85	2.84
Average	7.90	4.99	7.36	6.46	8.39	7.05	6.50	5.39	6.75

Shaded values meet GLWQA Target
*Average of duplicate and sample
** taken 5/19/15

River Discharge and Total Phosphorous

Data of stream discharge and TP was analyzed at Euclid Creek near RM 0.55. This showed a significant correlation with an r^2 value of 0.8442. (Figure 7). The same analysis was done for the Rocky River site with a similar correlation found and an r^2 value of 0.9711 (Figure 8). The distance between the flow gauge and the site is much greater than at the Euclid Creek site. This creates a level of discrepancy in the data; however, the results are like those of Euclid Creek. Flow data was not available close enough to the other river sites to be considered relevant, but this data is reflective of what other researchers have been observing (for other sources, see lakeeriealgae.com, a site hosted through Heidelberg University). When discharge increases during storm events, TP also increases.

Figure 7. Euclid Creek RM 0.55: Discharge vs Total Phosphorus



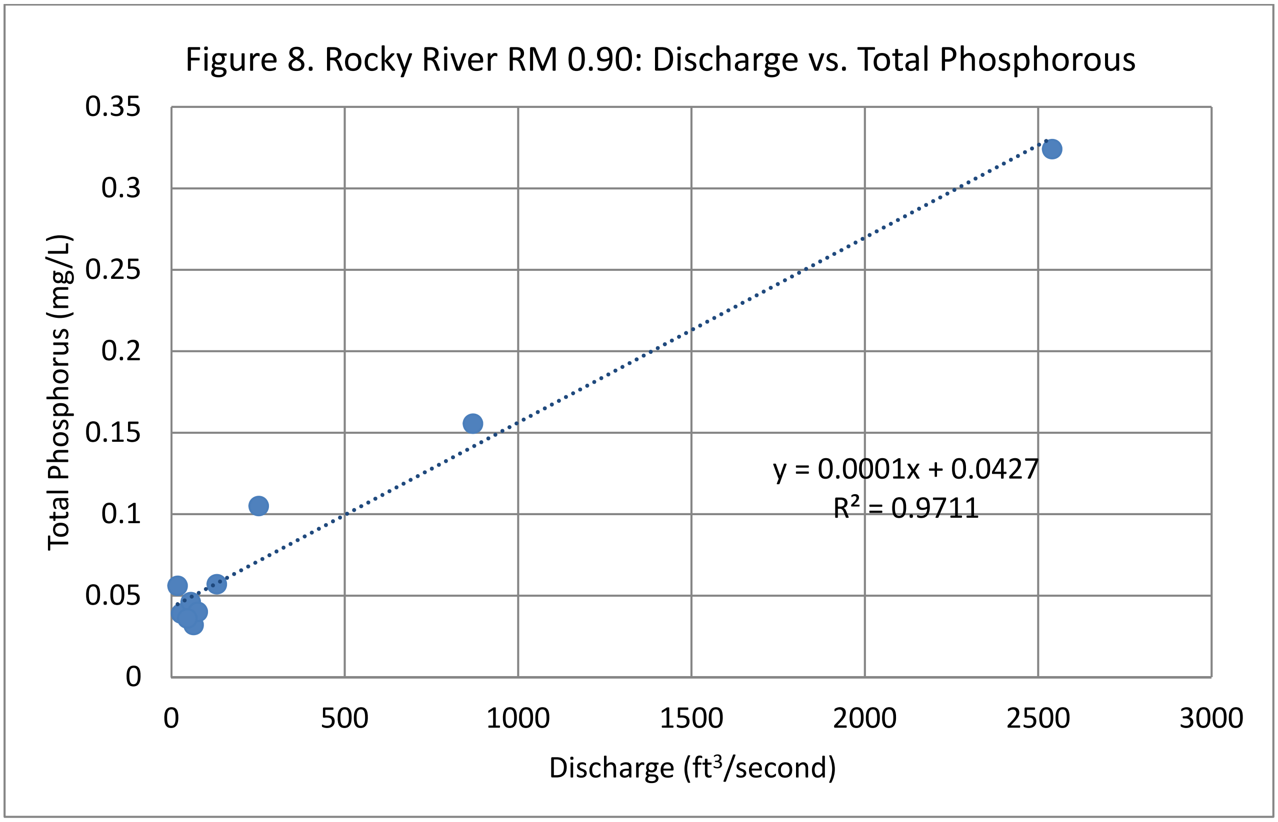


Figure 8. Rocky River RM 0.90: Discharge vs. Total Phosphorous
Total Phosphorus (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
y = 0.0001x + 0.0427
R² = 0.9711
0
500
1000
1500
2000
2500
3000
Discharge (ft³/second)

Conclusions

The study conducted in 2015 differed from past studies in that data was collected from the wastewater treatment plants and from several sites on major tributaries to determine how they contribute to nutrient loading to the lake. There were no major parameter exceedances in 2015 and microcystin levels remained well below the health advisory limit during all sampling events. Dissolved reactive phosphorus was higher downstream of the Southerly WWTP, which could be due to the plant's effluent, the added effects of about 10 river miles between the sites, or a combination of the two. Of the WWTPs, Southerly has the highest average DRP input per liter as well as the highest effluent rate. There is no limit for DRP for the WWTPs, only for TP.

As in past years, sampling conducted in 2015 showed that generally, chlorophyll *a* concentrations in Lake Erie were above targets set by the Great Lakes Water Quality Agreement. For TP and DRP, both had concentrations that were above set targets and those levels that have been found when harmful algal blooms are present. While no correlation was found between TP and chlorophyll *a*, there did seem to be a relationship between chlorophyll *a* and DRP. Chlorophyll *a* increased as DRP decreased and the opposite occurred in the fall as the algae were dying off and unable to consume the DRP. When river flow increases, it seems that phosphorus also increases, most likely from eroded sediment and runoff.

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Analytical Services Division – Completed analysis for all water chemistry sampling

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