NORTHEAST OHIO REGIONAL SEWER DISTRICT

2015-2016 West Creek Environmental Monitoring

Prepared by

Water Quality and Industrial Surveillance Division

Introduction

During 2007 and 2008, the Northeast Ohio Regional Sewer District (NEORSD) completed baseline assessments at sites on West Creek, a tributary to the Cuyahoga River. The baseline assessments were completed to determine the conditions of the creek prior to restoration activities that started in 2009. The goals of these restoration projects were to improve existing in-stream habitat, construct additional in-stream habitat, remove or alter existing permanent structures that are preventing fish migration, and re-stabilize eroding stream banks utilizing bioengineered technology and natural channel design techniques. In 2006, sampling was also conducted on West Creek, but only consisted of habitat and qualitative macroinvertebrate evaluations. The 2007 and 2008 sampling included electrofishing, benthic macroinvertebrate, water chemistry sampling, and habitat assessments.

Completed construction of the stream restoration projects was at river miles (RM) 3.65, 2.10, 1.60 and 0.20. Stream restoration at RM 3.65 consisted of limestone boulder bank protection, and 194 cubic yards of boulder cascade over the stream bed and bank to stabilize the natural stream structure and gradient. Restoration work at RM 2.10 consisted of approximately 45 cubic yards of limestone boulder along the south bank for bank stabilization and 641 cubic yards of boulder and concrete grout covered over the stream bed to stabilize the stream gradient. Work at RM 1.60 consisted of placing 2126 cubic yards of limestone boulder and cobble in the stream bed and bank for the construction of three cascades and pools and bank stabilization. Restoration work at RM 0.20 consisted of rehabilitation of 1000 feet of stream channel with bank stabilization and construction of new deep pools and riffle features. A revegetation of the entire stream bank along West Creek was completed. Additionally, a backwater channel within the West Creek floodplain that captures overbank flows from the channel and Cuyahoga River was also constructed.

In 2013, NEORSD conducted water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys at RMs 3.65, 2.10, and 1.60 on West Creek after the completion of the stream restoration project. In 2014, an additional site located downstream of Granger Road Bridge at RM 0.20 was added to the study plan due to restoration work that took place in 2013.

In 2015, environmental assessment work (water chemistry, habitat assessments, fish/macroinvertebrate community surveys) was completed at RMs 5.30, 3.65, 2.10, 1.60, 0.20, and on West Creek Tributary 4 at RM 0.20. In 2016, environmental assessment work was conducted at the same sites, except for the one on West Creek Tributary 4 at RM 0.20. NEORSD was unable to obtain permission to access the property from the owner. Sampling was conducted by NEORSD Level 3 Qualified Data Collectors who are certified by the Ohio Environmental Protection Agency (EPA) in Fish Community and

Benthic Macroinvertebrate Biology, and Chemical Water Quality and Stream Habitat Assessments as explained in the NEORSD study plans *2015 West Creek Environmental Monitoring* and *2016 West Creek Environmental Monitoring* approved by Ohio EPA on June 17, 2015, and May 17, 2016, respectively.

Figure 1 is a map of the sampling locations on West Creek, and Table 1 indicates the sampling locations and includes river mile, latitude/longitude, description and the types of surveys conducted.

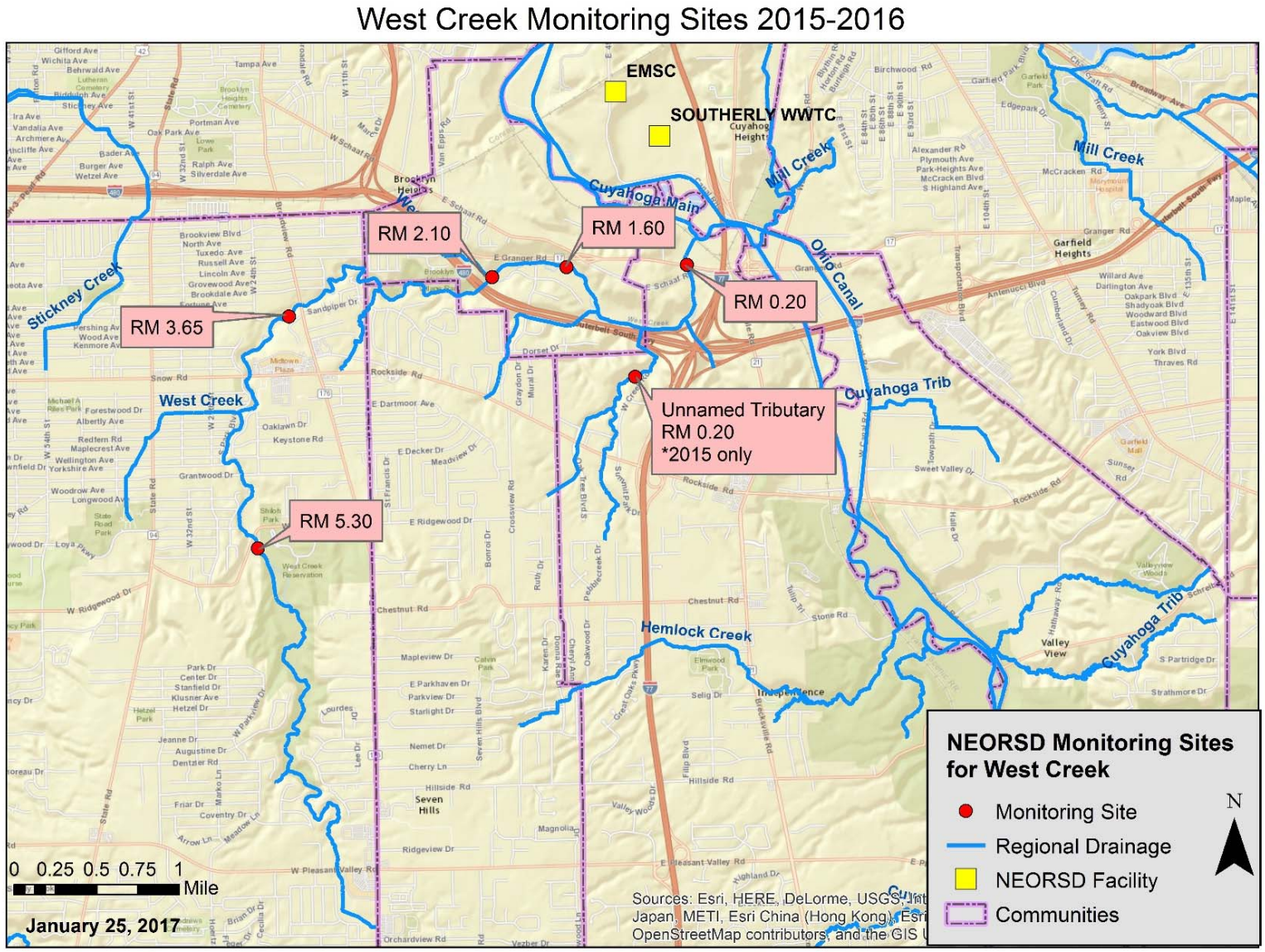


Figure 1. 2015-2016 West Creek Sampling Locations

Table 1. West Creek Sample Locations					
Waterbody	Latitude	Longitude	River Mile	Description	Purpose
West Creek, Main Branch	41.3899	-81.6982	5.30	Upstream of Ridgewood Drive	Evaluate habitat, fish, & macroinvertebrates.
West Creek, Main Branch	41.4103	-81.6943	3.65	Upstream of Broadview Road	Evaluate habitat, fish, & macroinvertebrates after completion of stream restoration work
West Creek, Main Branch	41.4136	-81.6705	2.10	Downstream from I-480	Evaluate habitat, fish, & macroinvertebrates after completion of stream restoration work
West Creek, Main Branch	41.4144	-81.6618	1.60	Downstream from Lancaster Drive Bridge	Evaluate habitat, fish, & macroinvertebrates after completion of stream restoration work
West Creek, Main Branch	41.4145	-81.6477	0.20	Downstream Granger Road	Evaluate habitat, fish, & macroinvertebrates after completion of stream restoration work
West Creek, Tributary 4	41.4047	-81.6539	0.20	Upstream West Creek Road	Evaluate habitat, fish, & macroinvertebrates.

Water Chemistry Sampling

Methods

Water chemistry and bacteriological sampling was conducted a total of ten times during 2015 and 2016. Five times were between June 17, 2015, and July 15, 2015, on West Creek at six sites, RMs 5.30, 3.65, 2.10, 1.60, 0.20, and West Creek Tributary 4 at RM 0.20. The other five times were between July 12, 2016 and August 9, 2016, on West Creek at five sites, RMs 5.30, 3.65, 2.10, 1.60, and 0.20. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2015b). Chemical water quality samples from each site were collected with a 4-liter disposable polyethylene cubitainer with a disposable polypropylene lid, three 473-mL plastic bottles and a 125-mL plastic bottle. The first 473-mL plastic bottle was field preserved with trace nitric acid, the second was field preserved with trace sulfuric acid and the third bottle received no preservative. The sample collected in the 125-

mL plastic bottle (dissolved reactive phosphorus) was filtered using a 0.45-µm PVDF syringe filter. All water quality samples were collected as grab samples. Bacteriological samples were collected in sterilized plastic bottles preserved with sodium thiosulfate. At the time of sampling, measurements for dissolved oxygen, pH, temperature, and conductivity were collected using either a YSI EXO1 or 600XL sonde. Duplicate samples and field blanks were collected at randomly selected sites, each at a frequency not less than 5% of the total samples collected. Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and duplicate sample (Formula 1).

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

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

The acceptable percent RPD is based on the ratio of the sample concentration and detection limit (Formula 2) (Ohio EPA, 2013a).

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

X = sample/detection limit ratio

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

Mercury analysis for all of the sampling events was done using EPA Method 245.1. Because the detection limit for this method is above the criteria for the Human Health Nondrinking and Protection of Wildlife OMZA, it generally cannot be determined if West Creek was in attainment of those criteria. Instead, this type of mercury sampling was used as a screening tool to determine whether contamination was present above those levels typically found in the stream.

Water chemistry analysis sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

West Creek is designated Warmwater Habitat (WWH), agricultural water supply, industrial water supply, and primary contact recreation. The Primary Contact Recreational

Use Criteria apply for *Escherichia coli* (*E. coli*). The water chemistry samples collected at each site were compared to the applicable Ohio Water Quality Standards for the designated uses to determine attainment (Ohio EPA, 2015a).

For the 2015-2016 study, two duplicate samples and two field blanks were collected each season for quality assurance and quality control (QA/QC) purposes. The duplicate samples were collected at RM 3.65 on July 1, 2015, RM 0.20 on July 15, 2015, RM 1.60 on July 26, 2016, and RM 3.65 on August 2, 2016. One parameter in the duplicate sample on July 1, 2015, titanium, was rejected based on an RPD value outside of the acceptable RPD range (Table 2). One parameter in the duplicate samples on July 15, 2015 and August 2, 2016, zinc, was rejected based on RPD values outside of the acceptable RPD range.

Table 2. Duplicate Parameter Analysis

Date	Site	Parameter	Acceptable RPD (%)	Actual RPD (%)	Qualifier
RM 3.65	7/1/2015	*Ti*	34.1	57.9	Rejected
	8/2/2016	*Zn*	62.9	74.2	Rejected
RM 0.20	7/15/2015	*Zn*	45.2	50.2	Rejected

The dates in which these samples were collected were considered wet weather[1]. Therefore, the reason for the unacceptable difference between the samples is likely due to the wet-weather conditions. Otherwise differences could potentially be attributed to lack of precision and consistency in sample collection and/or analytical procedures, environmental heterogeneity, and/or improper handling of samples.

Four field blank samples were collected for the 2015-2016 study for QA/QC purposes. One field blank sample was collected at RM 5.30 on June 17, 2015. One field blank sample was collected at RM 1.60 on June 24, 2015. One field blank sample was collected at RM 0.20 on July 19, 2016. The last field blank sample was collected at RM 5.30 on August 2, 2016. For the field blanks, there were nine 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 analysis. Table 3 lists water quality parameters that were listed as estimated, downgraded from Level 3 to Level 2 data, or rejected based on Ohio EPA data validation protocol.

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

Table 3. Parameters Affected by Possible Blank Contamination
Al (2016)
Conductivity (2015)
Cr (2015 & 2016)
DRP (2015)
NH3 (2015)
Sn (2015)
TKN (2015)
TP (2015)

Paired parameters for all samples collected were also evaluated for QA/QC purposes. The comparisons revealed no rejected data for any sampling site, and only a few parameters with estimated data (Table 4). Because there were no exceedances associated with these parameters, qualification of these results did not significantly change the overall water chemistry assessment of West Creek.

Table 4. Paired Data Parameter Analysis						
Date	Site	Parameter	Data Pair	Acceptable RPD (%)	Actual RPD (%)	Qualifier
RM 5.30	7/19/2016	*TS*	*TDS*	16.0	4.2	Estimated
RM 2.10	6/17/2015	NO_3+NO_2	NO_3	18.2	1.5	Estimated
	7/15/2015	NO_3+NO_2	NO_3	19.7	0.6	Estimated
RM 1.60	6/17/2015	*TS*	*TDS*	15.5	1.3	Estimated

The Primary Contact Recreation criteria for West Creek include an *E. coli* criterion not to exceed a Statistical Threshold Value (STV) of 410 colony-forming units per 100 milliliters (colony counts/100mL) in more than ten percent of the samples taken during any 90-day period, and a 90-day geometric mean criterion of 126 colony counts/100mL (Ohio EPA, 2015a). West Creek exceeded the primary contact recreation 90-day geomean at all sites in 2015 and 2016. STV criterion was exceeded for all 90-day periods at all sites in 2015. In 2016, STV criterion was also exceeded for most of the 90-day periods throughout the study (Table 5).

Table 5. 2016 *E. coli* STV Criterion Exceedances		
Site	Sample Date	Statistical Threshold Value (% Days >410 Colony Counts /100ml)
RM 5.30	7/12/2016	80.0
	7/19/2016	100.0
	7/26/2016	100.0
	8/2/2016	100.0
	8/9/2016	100.0
RM 3.65	7/12/2016	40.0
	7/19/2016	25.0
RM 2.10	7/12/2016	60.0
	7/19/2016	50.0
	7/26/2016	33.3
RM 1.60	7/12/2016	40.0
	7/19/2016	50.0
	7/26/2016	33.3
RM 0.20	7/12/2016	60.0
	7/19/2016	75.0
	7/26/2016	66.7
	8/2/2016	50.0

West Creek is in an urbanized area having one controlled combined sewer overflow (CSO) entering the creek at RM 2.0, Permit No. 3PA00002 063 (Ohio EPA 1997). The Ohio EPA has stated that the major chemical constraints to West Creek seem to be linked to storm water runoff, construction and failing household waste treatment systems (Ohio EPA 2003). There are approximately 700 household waste treatment systems in the West Creek Watershed (West Creek Preservation Committee [WCPC] 2005). The Ohio Department of Health (ODH) estimates a failure rate of the on-site waste treatment systems around twenty-five percent (ODH 2007). The presence of these failing systems, along with CSO 063 and any illicit discharges, may be the cause of the bacteriological exceedances that were found in West Creek. The communities surrounding West Creek are currently in the process of either eliminating the on-site waste treatment systems or are in the planning stages of connection to a sanitary collection system (WCPC 2005). These activities may help to reduce the number of exceedances in the future.

All sampling events were considered wet-weather sampling events in 2015. Two wet-weather sampling events occurred in 2016. These wet-weather events could have contributed to the elevated density of *E. coli* in the stream. The samples collected on

June 17, June 24, July 1, July 8, and July 15, 2015, are considered wet-weather sampling events because there was more than 0.10 inches of rain accumulation. Sampling events on July 19 and August 2, 2016, are considered wet-weather sampling events as well.

Copper exceeded the Protection of Aquatic Life Outside Mixing Zone Maximum (OMZM) and Tier I OMZM one time during the July 1, 2015, sampling event at RM 2.10. Copper analysis for all the sampling events was conducted using EPA Method 200.8. Potential sources contributing to the copper exceedance include geological deposits, weathering and erosion of rocks and soils, and/or improper connections to the storm sewer system.

Mercury analysis for all of the sampling events was completed using EPA Method 245.1. The detection limit for this method is above the criteria for the Human Health Nondrinking and Protection of Wildlife Outside Mixing Zone Averages (OMZA), so it generally cannot be determined if the sites were in attainment of those criteria. Instead, this type of mercury sampling was used as a screening tool to determine whether contamination was present above the detection limit. Based on the sampling that was completed, mercury was not present at levels above those normally found in the watershed (USEPA, 2004).

In 2015, the Ohio EPA Nutrients Technical Advisory Group released a proposed Stream Nutrient Assessment Procedure (SNAP) designed to determine the degree of impairment in a stream due to nutrient enrichment. SNAP assigns designations for quality of surface waters based on factors including dissolved oxygen (DO) swings, benthic chlorophyll *a*, total phosphorous, and dissolved inorganic nitrogen (Ohio EPA, 2015).

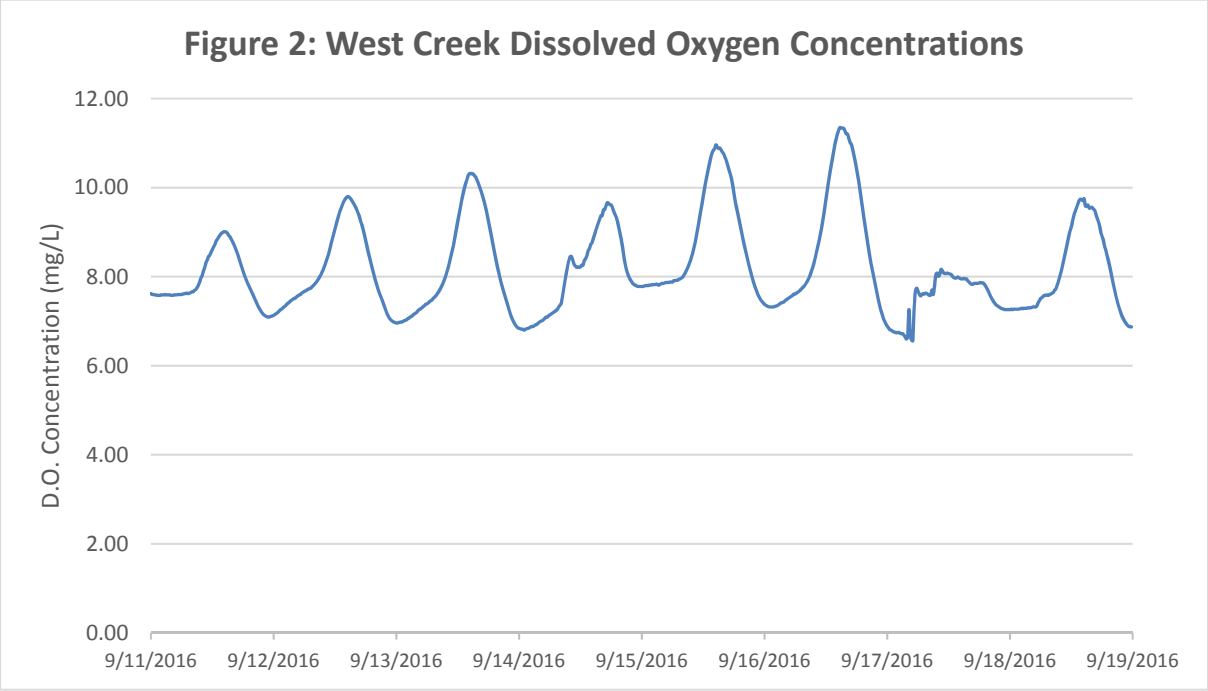
In 2016, chlorophyll *a* levels in West Creek were measured at one location in the vicinity of a long-term data sonde station. The purpose of this sampling was to provide a more comprehensive understanding of the relationship among algal production, nutrient levels, and DO diel swings in the creek. While the primary purpose of the data sonde was to collect DO data, the data sonde also recorded measurements for specific conductance, pH, temperature, and turbidity in 15-minute increments. The data sonde, a YSI 6600 sonde, is located at RM 0.25 on the downstream side of the Granger Road bridge in Cleveland, OH (Lat: 41.4138, Lon: -81.6475). This location is approximately 200 meters upstream of the site at RM 0.20. Data from RM 0.20 was also used during the SNAP analysis. The data sonde was calibrated at NEORSD Environmental and Maintenance Services Center per the manufacturer's recommendations. Upon return from the field, data was downloaded and calibrations were checked for continued accuracy.

Chlorophyll *a* samples along with nutrient samples were collected on September 14, 2016. Chlorophyll *a* was analyzed from both the benthos and water column following NEORSD SOP-EA001-01, Chlorophyll *a* Sampling and Field Filtering. For benthic chlorophyll *a* analysis, at least 15 rocks were sampled from a variety of habitats at the sample site. Water chemistry and chlorophyll *a* results are listed below in Table 6.

Table 6. 2016 Benthic Chlorophyll *a* Results from 9/14/2016 Sampling

Parameter	Result
Chlorophyll *a* (Water Column)	1.126 µg/L
Chlorophyll *a* (Benthic)	130.4 mg/m^2
Dissolved Inorganic Nitrogen	0.441 mg/L
Dissolved Oxygen Swing	2.86 mg/L
DRP	0.044 mg/L
Total Phosphorus	0.064 mg/L
TSS	2.0 mg/L

DO diel swings were also evaluated from August 30, 2016, through September 18, 2016 (See Figure 2). Daily maximum DO levels and daily minimum DO levels were calculated. The DO diel swing was calculated daily by subtracting the daily minimum from the daily maximum. DO diel swings used for SNAP evaluation were from the day of sampling (September 14, 2016); however, each day was evaluated to ensure that the swing on the day of sampling was not atypical.



Biological sampling and a habitat assessment results from 2016 were used in the assessment through SNAP (see Table 7). Per the minimum data requirements of SNAP, biological data was collected at comparable baseflows, but may have experienced changing flow events between the biological collections and chlorophyll *a* collection events. Additionally, biological sampling and the habitat assessment were performed outside the suggested range of time from chlorophyll *a* sampling. However, all data collection occurred during the normal field season during 2016.

Table 7. Biological sampling dates and scores for West Creek RM 0.20

Sample Type	Date	Score
IBI	7/22/2016	**42**
ICI	8/23/2016	*Marginally Good*
QHEI	6/17/2016	**59**

Italics=non-significant departure of the WWH biocriterion.

Bold=Meets the WWH Biocriterion.

Nutrients were assessed during the chlorophyll *a* sampling. The minimum data requirements suggest at least three samples per location to be reported as a geometric mean. One set of nutrient data was collected at the same time as the chlorophyll *a* collection on September 14, 2016. Nutrients were also assessed at RM 0.20 for watershed monitoring. Table 8 shows the results of three dry-weather results and the calculated geometric mean and standard deviation as well as the results from September 14, 2016. The nutrient concentrations used in the SNAP analysis were done so by comparing the geometric mean to the single sampling event. If the single sampling event differed outside the standard deviation, the higher of the two concentrations was used.

Table 8. Nutrient results for West Creek used for SNAP analysis

Sample Date	7/26/2016	8/2/2016	8/9/2016	**GeoMean**	**StdDev**	9/14/2016
Total Phosphorus (mg/L)	0.072	0.052	0.042	0.054	0.015	0.064
DRP (mg/L)	0.056	0.039	0.022	0.036	0.017	0.044
Dissolved Inorganic Nitrogen (mg/L)	0.416	0.382	0.042	0.188	0.207	0.441

When questions arose using these numbers, the geometric mean and the measurements taken on 9/14/16 were considered. If the same result was not the output from the tables, the worst case of the two measurements was used.

SNAP uses a variety of flow charts to determine the best course of action for a stream segment. The results of these flow charts are shown in Table 9. Some sections of the flow charts require the use of a best professional judgement and the result could be disputed. However, in the case of a dispute, often the same answer was ultimately reached by both pathways through the flow chart.

Table 9. SNAP flow chart results

Step/Question	Result/Answer
Step 1-Biological Criteria	All indices attaining or in non-significant departure.
Step 2-DO Swing	Normal or low swings (≤6.5 mg/L)
Step 3-Benthic Chlorophyll	Low to moderate (≤320 mg/m^2)
Step 4-Preliminary Assessment	Attaining use/Not threatened

The results of SNAP at West Creek determined that the best course of action with respect to nutrients is "attaining use or not threatened." Thus, nutrients do not appear to be a contribution to any impairments at this time.

Habitat Assessment

Methods

Instream habitat assessments were conducted once per year, per site, on West Creek in 2015 and 2016 using the Qualitative Habitat Evaluation Index (QHEI). The QHEI was developed by the Ohio EPA to assess aquatic habitat conditions that may influence the presence or absence of fish species by evaluating the physical attributes of a stream. The index is based on six metrics: stream substrate, instream cover, channel morphology, riparian zone and bank condition, pool and riffle quality, and stream gradient. The QHEI has a maximum score of 100, and a score of 55 or more suggests that sufficient habitat exists to support a fish community that attains the warmwater habitat criterion (Ohio EPA, 2006). A more detailed description of the QHEI can be found in Ohio EPA's *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (OEPA 2006). QHEI field sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

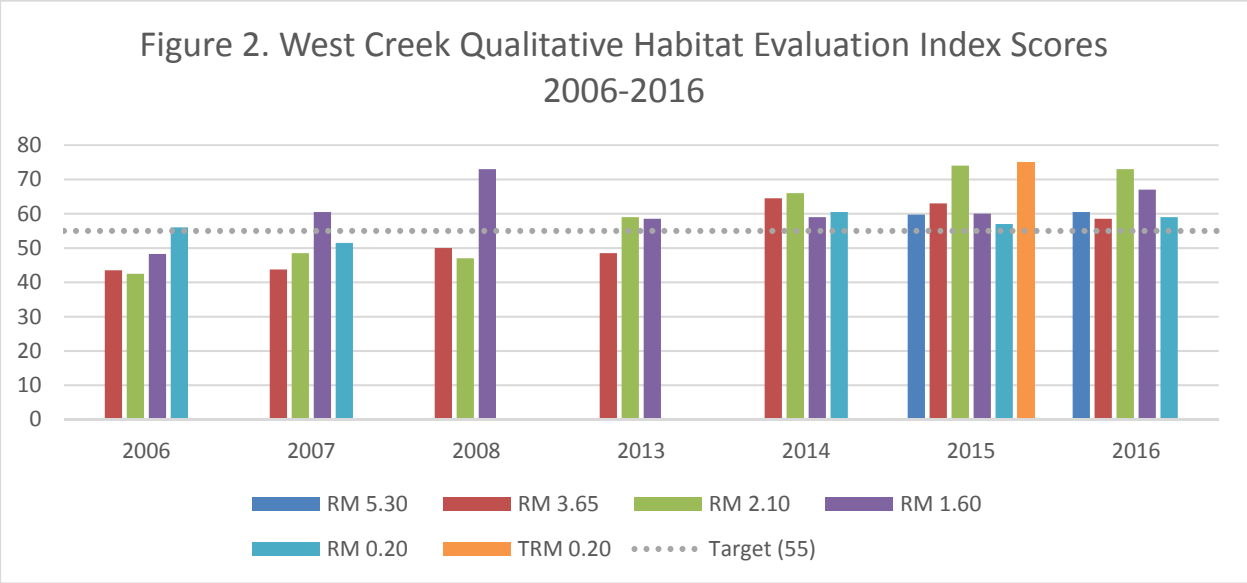
QHEI scores were determined for the six sites, West Creek RMs 0.20, 1.60, 2.10, 3.65, 5.30, and West Creek Tributary 4 RM 0.20 in 2015. Scores were determined at five sites in 2016. All sites except for West Creek Tributary 4 RM 0.20 were scored in 2016.

The narrative ratings for QHEI scoring for 2015 and 2016 were evaluated for the range for headwater sites. The QHEI results for 2006-2008 and 2013-2016 are provided in Table 10 and Figure 2.

Table 10. West Creek QHEI Scores

Year	Upstream of Ridgewood Dr. (RM 5.30)	Upstream of Broadview Rd. (RM 3.65)	Downstream of I-480 (RM 2.10)	Downstream of Lancaster Dr. (RM 1.60)	Granger & Schaaf Road (RM 0.20)	West Creek Tributary 4 (RM 0.20)
2006	n/a	43.50 (*Fair*)	42.50 (*Fair*)	48.25 (*Fair*)	56.00 (*Good*)	n/a
2007	n/a	43.75 (*Fair*)	48.50 (*Fair*)	60.50 (*Good*)	51.50 (*Fair*)	n/a
2008	n/a	50.00 (*Fair*)	47.00 (*Fair*)	73.00 (*Excellent*)	n/a	n/a
2013	n/a	48.50 (*Fair*)	59.00 (*Good*)	58.50 (*Good*)	n/a	n/a
2014	n/a	64.50 (*Good*)	66.00 (*Good*)	59.00 (*Good*)	60.50 (*Good*)	n/a
2015	59.75 (*Good*)	63.00 (*Good*)	74.00 (*Excellent*)	60.00 (*Good)*	57.00 (*Good)*	75.00 *(Excellent*)
2016	60.5 (*Good*)	58.50 (*Good)*	73.00 (*Excellent)*	67.00 (*Good*)	59.00 (*Good*)	n/a

The QHEI score at RM 5.30 was calculated at 59.75 in 2015 and 60.5 in 2016. Both scores equate to a narrative rating of "*Good*". The zone started approximately 100-feet upstream of West Ridgewood Drive. Bedrock and cobble/gravel were the most common substrates throughout the reach in 2015-2016. Instream cover was sparse, but consisted of shallows in slow water, boulders, and logs/woody debris. Moderate erosion was present on both banks of the creek.



The QHEI score at RM 3.65 was calculated at 63.00 in 2015 and a 58.50 in 2016. Both scores equate to a narrative rating of "*Good*". The zone started approximately 500-feet upstream of Broadview Road. Predominantly bedrock/slabs substrate was evident throughout the creek. The site included the two step pools from the restoration project and a pool greater than 3-feet deep. Instream cover consisted of boulders, shallows, and deep pools. Moderate amounts of instream cover were evident throughout the creek.

The QHEI score at RM 2.10 was calculated at 74.00 in 2015 and a 73.00 in 2016. Both scores equate to a narrative rating of "*Excellent*". This site begins where the creek exits the culvert under Interstate 480. The predominant substrate type in this section was bedrock and boulder/slab. The habitat of this straight channel was primarily a run/glide with sparse to moderate amounts of marginal quality instream cover types consisting of boulders, logs, deep pools and shallows. Some areas of riffle/pool complexes had fairly good development and both banks exhibited moderate erosion. Commercial development borders the riparian zone on river right. The riparian habitat along river left bank varies in width and land use and is primarily forest land.

The QHEI score at RM 1.60 was calculated at 60.00 in 2015 and a 67.00 in 2016. Both scores equate to a narrative rating of "*Good*". This site is located downstream of Lancaster Drive. Boulder and cobble were the predominant substrate types with gravel and sand also prevalent along the stream bottom. Sparse amounts of instream cover with the presence of shallows, deep pools, and boulders were evident. The bank on river right, which abuts a commercial development, was steep with areas of moderate tree removal. Tree removal was also evident on the river left bank which borders Granger Road, but offers a wider riparian habitat width of better flood plain quality. From 2007 to 2016, QHEI scores have been rated "*Good*" to "*Excellent*" at this site.

The QHEI score at RM 0.20 was calculated at 57.00 in 2015 and a 59.00 in 2016. Both scores equate to a narrative rating of "*Good*". This site begins approximately 75 yards downstream of the Granger Road Bridge and continues downstream. The predominant substrate type in this section was cobble/gravel. The habitat of this formerly straight channel had sparse to moderate amounts of marginal quality instream cover types consisting of boulders, shallows and backwaters. Some areas of riffle/pool complexes had fair development and both banks exhibited no erosion due to restoration efforts.

Fish Community Assessment

Methods

One quantitative electrofishing pass was conducted at all sites except for RM 0.20 on West Creek in 2015 as well as 2016. RM 0.20 consisted of two quantitative electrofishing passes each year. Sampling was conducted using the longline electrofishing technique and consisted of shocking all habitat types within a sampling zone while moving from downstream to upstream. The sampling zones were 0.15 kilometers. The methods that were used followed Ohio EPA protocol methods as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Fish collected during the surveys were identified and examined for the presence of anomalies including DELTs (deformities, eroded fins, lesions, and tumors). All fish were then released to the waters from which they were collected, except for vouchers and those that could not be easily identified in the field.

The electrofishing results were compiled and utilized to evaluate fish community health through the application of the Ohio EPA Index of Biotic Integrity (IBI). The IBI incorporates 12 community metrics representing structural and functional attributes (Table 11). The structural attributes are based upon fish community aspects such as fish numbers and diversity. Functional attributes are based upon fish community aspects such as feeding strategies, environmental tolerances, and disease symptoms. These metrics are individually scored by comparing the data collected at the survey site with values expected at reference sites located in a similar geographical region. The maximum possible IBI score is 60 and the minimum possible score is 12. The summation of the 12 individual metrics scores provides a single-value IBI score, which corresponds to a narrative rating of *Exceptional*, *Good*, *Marginally Good*, *Fair*, *Poor* or *Very Poor*.

Table 11. IBI Metrics (Headwater)
Total number of Native Species
Number of Darters & Sculpins
Number of Headwater Species
Number of Minnow Species
Number of Sensitive Species
Percent Tolerant Species
Percent Pioneering Species
Percent Omnivores
Percent Insectivores
Number of Simple Lithophils
Percent DELT Anomalies
Number of Fish

Results and Discussion

Table 12 shows the IBI scores that were calculated for each site along with historical data. None of the sites met the IBI WWH criterion for headwater sites except for RM 0.20 downstream of Granger Road. Two electrofishing passes were conducted each field season on RM 0.20 in 2015 and 2016. In 2015, RM 0.20 scored a 32 and 42. In 2016, RM 0.20 scored a 36 and a 40. The IBI scores from the second passes in 2015 and 2016, both met the applicable criterion of 40.

Table 12. 2007 – 2016 West Creek IBI Scores

		IBI	
River Mile	Year	Score	Narrative Rating
5.30	2010	30[a]	*Fair*
	2015	28	*Fair*
	2016	30	*Fair*
3.65	2007	31[a]	*Fair*
	2008	30	*Fair*
	2013	32	*Fair*
	2014	28	*Fair*
	2015	30	*Fair*
	2016	28	*Fair*
2.10	2007	32*	*Fair*
	2008	30*	*Fair*
	2013	30	*Fair*
	2014	28	*Fair*

Table 12. 2007 – 2016 West Creek IBI Scores			
		IBI	
River Mile	Year	Score	Narrative Rating
	2015	28	*Fair*
	2016	28	*Fair*
1.60	2007	26[a]	*Poor*
	2008	26	*Poor*
	2013	32	*Fair*
	2014	32	*Fair*
	2015	30	*Fair*
	2016	30	*Fair*
0.20	2007	27[a]	*Fair*
	2008	34	*Good*
	2014	36	*Good*
	2015	38[a]	*Good*
	2016	37[a]	*Good*
Trib 4 0.20	2015	22	*Poor*
[a]Average score *Sample Site was upstream at RM 2.40			

The site upstream of West Ridgewood Drive was electrofished in 2015 for the first time since 2010. In 2015, RM 5.30 obtained an IBI score of 28. In 2016, the IBI score increased to 30. The predominant fish species collected (99.2%) were blacknose dace, central stoneroller minnows, and creek chubs. The score increased in 2016 due to the number of individual collected compared to the 2015 score.

A score of 30 (*Fair*) was calculated at RM 3.65 in 2016 compared to 28 (*Fair*) in 2015. Once again, the predominant fish collected were blacknose dace, central stoneroller minnows and creek chubs. These fish accounted for 98% of the total catch. IBI metric scores of 5 were obtained for low proportion of DELTs, low proportion of pioneering species and low proportion of omnivores present. Predominantly bedrock/boulder substrate, moderate amounts of instream cover and no good channel development correlated to a "*Fair*" fish index score. 2015-2016 IBI scores are similar to those prior to the restoration at RM 3.65. Scores are unlikely to change here due to a concrete flume at RM 1.10 that is currently acting as a fish migration barrier to the site.

The site downstream of I-480 (RM 2.10) was electrofished for the first time in 2013 (IBI score of 30) after habitat construction restoration work was completed. In the second round of electrofishing, in 2014, the fish community remained relatively the same (IBI 28) maintaining a "*Fair*" narrative rating. In 2015 and 2016, IBI scores of 28 (*Fair*) were also found at RM 2.10. Over ninety-eight percent of the total catch was blacknose

dace, creek chubs and central stoneroller minnows. In 2016, IBI metric scores of 5 were obtained for many individuals collected (1286), low proportion of DELTs (0%), low proportion of pioneering species (7.6%) and low proportion of omnivores (1.7%) present. The bedrock substrate, straight channel development, sparse in stream cover, and downstream migration barriers are limiting factors to a more diverse fish community.

A score of 30 (*Fair*) was calculated at RM 1.60 in 2015 and 2016, down from 32 in 2013 and 2014. The predominant fish collected in 2015 and 2016 were blacknose dace, creek chubs and central stoneroller minnows. These three species accounted for 99.6% of the total catch. In 2016, IBI metric scores of 5 were obtained for low proportion of DELTs (0%), low proportion of pioneering species (3.0%), low proportion of omnivores (0.3%), and a large number of individuals collected (2966). Fish communities are limited by the same factors mentioned above at RM 2.10.

An average score of 38 (*Good*) was calculated at RM 0.20 in 2015. An average score of 37 (*Good*) was calculated at RM 0.20 in 2016. Both scores meet the IBI fish index scoring criterion and falling in the non-significant departure ($\leq$ 4 IBI units) of the applicable criterion score of 40. The predominant fish collected in 2015 and 2016 were central stoneroller minnows and these fish comprised 45% of the total fish collected. IBI metric scores of 5 were obtained during the second pass of RM 0.20 in 2016 for the number of native species (16), number of minnow species, low proportion of DELTs (0%), low proportion of pioneering species (4.6%), and low proportion of omnivores (13.6%) collected. RM 0.20 was most likely in full attainment for 2015-2016 due to proximity to the confluence of the Cuyahoga River as well as a lack of any barriers that would prevent fish migration to the site.

Macroinvertebrate Sampling

Methods

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers in conjunction with a qualitative assessment of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), also referred to as EPT taxa, inhabiting available habitats at the time of HD retrieval. HD samplers were collected at RMs 3.65 and 0.20 in 2015. HD samplers were collected at RMs 2.10 and 1.60 in 2016. Methods for sampling followed the Ohio EPA's Biological Criteria for the Protection of Aquatic Life, Volume III (1987b). The recommended period for HDs to be installed is six weeks.

The macroinvertebrate samples were sent to Third Rock Consulting of Lexington, Kentucky, for identification and enumeration. Specimens were identified to the lowest

practical taxonomic level as defined by the Ohio EPA (1987b). Lists of the species collected during the quantitative and qualitative sampling at each site are available upon request from WQIS.

The overall aquatic macroinvertebrate community in the stream was evaluated using Ohio EPA's Invertebrate Community Index (ICI) (Ohio EPA 1987a, Ohio EPA undated). The ICI consists of ten community metrics (Table 13), each with four scoring categories. Metrics 1-9 are based on the quantitative sample, while Metric 10 is based on the qualitative EPT taxa. The total of the individual metric scores result in the overall score. This scoring evaluates the community against Ohio EPA's reference sites for each specific eco-region.

Table 13. ICI Metrics
Total Number of Taxa
Total Number of Mayfly Taxa
Total Number of Caddisfly Taxa
Total Number of Dipteran Taxa
Percent Mayflies
Percent Caddisflies
Percent Tanytarsini Midges
Percent Other Dipterans and Non-Insects
Percent Tolerant Organisms
Total Number of Qualitative EPT Taxa

Results and Discussion

For West Creek RMs 5.30, 2.10, 1.60, and West Creek Tributary 4 RM 0.20, a Hester-Dendy sampler was unable to be recovered during the 2015 sampling season. For West Creek RMs 5.30, 3.65, and 0.20, a Hester-Dendy sampler was unable to be recovered during the 2016 sampling season. Therefore, a narrative assessment was designated for these sample sites based on data from qualitative sampling (See Table 14), and by utilizing the best professional judgment of the leading macroinvertebrate biologists and Qualified Data Collectors (QDCs). Factors considered in the assignment of narrative ratings include, but are not limited to: historical data from the site; total site drainage area; macroinvertebrate population composition in the qualitative sample with respect to the number of total taxa, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa, pollution sensitive taxa, and pollution tolerant taxa; and organism abundance within individual families or groups noted during sample collection.

Table 14. 2015-2016 West Creek Macroinvertebrate Assessment				
River Mile	Year	ICI Score*	Narrative	Comments
5.30	2015	-	*Fair*	HD Missing
	2016	-	*Poor*	HD Missing
3.65	2015	28	*Fair*	HD Recovered
	2016	-	*Low Fair*	HD Missing
2.10	2015	-	*Fair*	HD Missing
	2016	26	*Fair*	HD Recovered
1.60	2015	-	*Fair*	HD Missing
	2016	32	*Marginally Good*	HD Recovered
0.20	2015	48	*Exceptional*	HD Recovered
	2016	-	*Marginally Good*	HD Missing
UT 0.20	2015	-	*Marginally Good*	HD Missing
* WWH for the ICI Criterion is ≥ 34 units: Non-significant departure from attainment is ≤4 units				

West Creek RM 5.30 was assigned narrative ratings of *Fair* in 2015 and *Poor* in 2016. From the qualitative sample collected in 2015, 29 total macroinvertebrate taxa were found. Of those 29 taxa collected, seven were found to be EPT taxa. During field collection, it was noted that while there was not a large density of organisms, the most common taxa found included Baetidae, Hydropsychidae, and Chironomidae. Notably, these three taxa families accounted for 17 of the total taxa in the sample. EPT taxa found in the sample include the following: *Baetis flavistriga*, *Callibaetis sp.*, *Cheumatopsyche sp.*, *Ceratopsyche morosa*, *Ceratopsyche sparna*, and *Hydropsyche depravata group*. Regarding pollution tolerance, 27 of the 29 taxa classify as facultative to pollution tolerant according to the Ohio EPA Macroinvertebrate Taxa List. Nine of those taxa classify as moderately tolerant or tolerant. Moderate diversity of taxa, despite low density, and seven EPT taxa for a smaller drainage area (3.8 mi^2), support a narrative rating of *Fair* for the 2015 sampling season.

From the qualitative sample collected in 2016, 10 total macroinvertebrate taxa were found. Of those taxa, five were found to be EPT taxa. The most common organism found at this site was *Chimarra atterima*. Although this organism classifies as moderately intolerant of pollution, the density of the organisms found at the site were comparatively low, along with the densities of all taxa found at the site. The low taxa diversity and density was most probably an effect of the poor conditions present in the stream. There was poor quality substrate, as the substrate was heavily inundated by artifact material including shards of glass and pottery fragments. These stream conditions, and low flow related to a very dry sampling season, along with the decline of present macroinvertebrate taxa, led to the designation of West Creek RM 5.30 with the narrative rating of *Poor* for the 2016 sampling season.

In 2014, no HD sampler was retrieved at RM 3.65. In 2015, an ICI score of 28 was obtained at RM 3.65. This score failed to meet the ICI biocriterion. Prior year ICI scores in 2008 and 2013 were 36 and 34, respectively. A total of 42 taxa were collected at this site during quantitative sampling. The dominant group collected was Caecidotea, representing nineteen percent of the sample. In 2015, there were 30 taxa collected in the qualitative sample, nine of which were EPT taxa. Although total number of organisms and total number of taxa remained the same comparatively between 2013 and 2015, the quality of the taxa decreased with a greater number of pollution-tolerant organisms present in 2015.

West Creek RM 3.65 was assigned a narrative rating of *Low Fair* in 2016. From the qualitative sample collected in 2016, 20 total macroinvertebrate taxa were found. Of those taxa, six organisms were found to be EPT taxa. At the time of collection, there was a significant decline in organism density within the various taxa groups compared to previous years. The most common taxa collected during this sampling event were Hydropsychidae and Chironomidae. Most notable after taxonomic identification of the collected organisms was the presence of four different Hydropsychidae species, including *Cheumatopsyche sp.*, *Ceratopsyche morosa*, *Ceratopsyche sparna*, and *Hydropsyche depravata group*. These above-listed taxa are classified as facultative pollution-tolerant organisms, except for *Ceratopsyche* sparna, which is classified as moderately intolerant. Regarding all of the taxa collected, 13 of the 20 total taxa are classified as facultative to tolerant, with at least six of the taxa classified as moderately tolerant or tolerant.

In comparing the qualitative samples from 2015 and 2016, there is a 33% decline in taxa diversity. The evident stream degradation in the 2016 season, including bank erosion and collapse, as well as low stream flow rate, may be contributing factors to this decline. Therefore, it was determined that West Creek RM 3.65 should be assigned a narrative rating of *Low Fair* for the 2016 sampling season.

West Creek RM 2.10 was assigned a narrative rating of *Fair* in 2015. From the qualitative sample collected in 2015, 34 macroinvertebrate taxa were found. Of those 34 total taxa collected, eight were found to be EPT taxa. At the time of collection, the most common organism present were the Ephemeropteran family Baetidae. Taxonomic identification of the qualitative sample confirmed three different species present, *Baetis flavistriga* (Facultative), *Baetis intercalaris* (Facultative), and *Callibaetis sp.* (Moderately Tolerant), as representatives of this family. Regarding pollution tolerance of the organisms present, three of the 34 total taxa present are designated as moderately intolerant according to the Ohio EPA Macroinvertebrate Taxa List. The remaining 31 of the 34 total taxa range from facultative to tolerant, with 13 of the taxa designated as moderately tolerant or tolerant.

Qualitative sampling results from 2015 were compared to data collected in 2014 in order to confirm the accuracy of the narrative assessment. In 2014, West Creek RM 2.10 recorded an ICI score of 26, narratively, *Fair*. While the number of taxa collected in 2014 was significantly less in 2014 compared to 2015 (22 total taxa), the composition of the total macroinvertebrate population was similar. At the time of field collection of the 2015 sample, it was noted that most of the organisms collected were in very low densities, designated as Rare (1-10 organisms). In addition, it should be noted that at the time of collection, the site substrate was very poor, and riffle habitat was severely embedded, not allowing for quality macroinvertebrate habitat. Because of the degraded habitat, the low density of the population of the macroinvertebrate community, and the pollution tolerance of the organisms collected at the site, West Creek RM 2.10 was designated as *Fair* for the 2015 sampling season.

An ICI score of 26 was calculated at RM 2.10, failing to meet the ICI biocriterion in 2016. A total of 35 taxa were collected and the dominant group was Oligochaeta. This group accounted for twenty-eight percent of the taxa collected at this site. This site was not assessed in 2007 and 2008, and therefore, no ICI scores are available for those years. An ICI score of 44 was obtained in 2013 and 26 in 2014. The low scores in 2014 was due to a decrease in the number of taxa, percent mayflies, percent tanytarsini midges, and percent tolerant organisms. Data from 2016 confirms 2014 findings.

In 2015, West Creek RM 1.60 was assigned a narrative rating of *Fair*. While the taxa diversity and number of EPT taxa at this site were within the range of what may be expected of a site in attainment of the WWH biological criterion, the most abundant organisms present during qualitative sampling were of poor quality with respect to pollution tolerance. A total of 50 taxa were collected at this site with pollution tolerance categories ranging from moderately intolerant to tolerant according to the Ohio EPA Macroinvertebrate Taxa List. Of these 50 taxa, seven are listed in the Ohio EPA Pollution Tolerant Taxa List (Ohio EPA Biological Criteria for the Protection of Aquatic Life Volume III). Present EPT taxa included three Ephemeroptera and six Trichoptera taxa, with pollution tolerance ratings ranging from moderately tolerant to moderately intolerant. The most abundant family present at the time of sample collection in all habitats was listed as Chironomidae. Of the 24 Chironomidae taxa collected in the qualitative sample, only one species was listed as moderately intolerant. The remaining 23 range from tolerant to facultative. Additional abundant taxa present at the time of qualitative sample collection were from Class Turbellaria, followed by Families Simuliidae and Baetidae. Due to the high abundance of organisms listed as tolerant to facultative, this site was assigned a narrative rating of *Fair* in 2015. The results of this narrative evaluation were also compared to the ICI score obtained at this site in 2016. In 2016, this site obtained an ICI score of 32, narratively *Marginally Good*. Although the site had fewer taxa in the qualitative sample overall in 2016 compared to 2015, the site also had five fewer organisms from the Ohio

EPA Pollution Tolerant Taxa List, and two additional sensitive taxa. Additionally in 2016, the most abundant organism groups present at the time of qualitative sample collection were Hydropsychid caddisflies rather than Chironomid taxa as observed in 2015, demonstrating improvement at the site from the previous year.

In 2015, an HD was not recovered. In 2014, an ICI score of 28 was obtained. Forty-four taxa were collected, with the dominant taxa collected being Oligochaeta and the moderately intolerant *Cricotopus (C.) tremulus group*. These two taxa accounted for fifty-one percent of the total organisms collected. The 2016 ICI score of 32 was an increase from 2014. The increase in score was due to the HD sampler being set in better habitat conditions. In 2014, the HD sampler was moved in a pool area surrounded by pool/glide habitat conditions. In 2016, the HD sampler was installed at the beginning of a riffle that was surrounded by faster moving riffle/run habitat. Here, the HD was exposed to an area where a greater diversity and density of organisms could be collected.

In 2015, an ICI score of 48 (*Exceptional*) was calculated at RM 0.20. This resulted in attainment of the ICI criterion of 34. Forty-eight species were collected with eleven of those being EPT taxa. The Thienemannimyia group was the dominant group of the sample, representing sixteen percent of organisms collected. Quality and quantity of organisms sampled increased from 2014 to 2015. The increase in ICI score from 2014 to 2015 could be due to the colonization of organisms in and around the restored habitat at RM 0.20.

West Creek RM 0.20 was assigned a narrative rating of *Marginally Good* in 2016. From the qualitative sample collected in 2016, 33 total macroinvertebrate taxa were found. Of those 33 taxa collected, eight were found to be EPT taxa. At the time of collection, the most abundant organism noted was the Ephemeropteran family Baetidae. After taxonomic identification, it was confirmed that two different species represent this abundance, *Baetis flavistriga* and *Baetis intercalaris*. Both taxa are classified as facultative pollution tolerant organisms according to the Ohio EPA Macroinvertebrate Taxa List. Also notable at the time of sampling are organisms that met "common" population densities (11-100 organisms) from the qualitative sampling including Turbellaria, Chironomidae, Oligochaeta, Isopoda, various Zygoptera, and various Hydropsychidae. Most of the individual taxa found from these "common" groups are categorized as facultative to tolerant, with the only exceptions being *Ceratopsyche morosa* and *Cricotopus (Isocladius) absurdus*, which are categorized as moderately intolerant of pollution.

In comparing historical data for this site, it was found that West Creek RM 0.20 obtained an ICI score of 38 (Narratively – *Good*) in 2014. This score and the one from 2015 both met WWH attainment with respect to the guidelines given by Ohio EPA for the EOLP (Erie/Ontario Lake Plains). However, long stretches of dry weather and relatively poor stream channel development may have contributed to the decline of the sampling site, and the macroinvertebrate population density, in 2016. The narrative rating assigned for

West Creek RM 0.20 for 2016 is *Marginally Good*, which would normally indicate a numeric rating of 30-32 for a normal ICI score.

West Creek Tributary 4 RM 0.20 was assigned a narrative rating of *Marginally Good* in 2015. From the qualitative sample collected in 2015, 19 total taxa were collected. Of those taxa, six were found to be EPT taxa. Given that the drainage area for this site was only 1.6 mi^2, the number of present EPT taxa is notably high. In addition, all six EPT taxa found rated between moderately intolerant to facultative in pollution tolerance according to the Ohio EPA Macroinvertebrate Taxa List. At the time of collection, the most common organisms found were from the families Baetidae and Hydropsychidae. Upon taxonomic identification, it was confirmed that two representative species from the family Baetidae, *Baetis flavistriga* and *Baetis tricaudatus*, and three representative species from the family Hydropsychidae, *Cheumatopsyche sp*., *Ceratopsyche sparna*, and *Hydropsyche depravata group*, were present in the sample. Regarding pollution tolerance, five of the total 19 taxa collected were designated as moderately tolerant or tolerant. The remaining 14 taxa rated from facultative to moderately intolerant.

At the time of collection of the 2015 qualitative sample, it was evident that the stream channel had been slightly impacted, but still maintained some good macroinvertebrate habitat. Because of this channel quality, in addition to the composition of the macroinvertebrate community, it was determined that West Creek Tributary 4 RM 0.20 should be designated a narrative rating of *Marginally Good* for the 2015 sampling season.

Table 15 summarizes West Creek ICI scores from 2007, 2008, and 2013-2016.

Table 15. Invertebrate Community Index (ICI) Scores

Year	2007	2008	2013	2014	2015	2016
Site	ICI Score	ICI Score	ICI Score	ICI Score	ICI Score	ICI Score
RM 5.30	n/a	n/a	n/a	n/a	-	-
RM 3.65	40	36	34	-	28	-
RM 2.10	-	-	44	26	-	26
RM 1.60	-	30	38	28	-	32
RM 0.20	-	-	-	38	48	-
Trib 4 RM 0.20	n/a	n/a	n/a	n/a	-	n/a
"-" No HD collected						

Conclusions

Results from the bacteriological sampling, qualitative habitat evaluation assessments, and fish and macroinvertebrate assessments show West Creek may have some limiting factors and environmental stressors resulting in low fish and macroinvertebrate index scores. Bacteriological samples collected at all sites showed water quality exceedances for bacteria most of the time. The overall attainment status of West Creek is summarized in Table 16; the general water quality of West Creek at five of the six designated sample sites is "*Fair*". RM 0.20 was the one site in full attainment status of the WWH biological criterion.

Table 16. 2015-2016 West Creek Survey Results

River Mile	Aquatic Life Use Attainment Status	IBI Score (*Narrative Rating*)	ICI Score (*Narrative Rating)*	QHEI Score (*Narrative Rating)*	Water Quality Exceedances
5.30	Non	**29 (*Fair*)	2015- *(Fair)* 2016- *(Poor)*	**60.12 (*Good*)	*E. coli*
3.65	Non	**29 (*Fair*)	2015- 28 *(Fair)* 2016- *(Low Fair)*	**60.75 (*Good*)	*E. coli*
2.10	Non	**28 (*Fair*)	2015- *(Fair)* 2016- 26 *(Fair)*	**73.5 (*Good*)	*E. coli*, copper (2015)
1.60	Non (2015) Partial (2016)	**30 (*Fair*)	2015- *(Fair)* 2016- 32 *(Marginally Good)*	**63.5 (*Good*)	*E. coli*
0.20	Full	**37.5 (*Good*)	2015- 48 *(Exceptional)* 2016- *(Marginally Good)*	**58.0 (*Good*)	*E. coli*
Trib 4 0.20 (2015 only)	Non	22 (*Poor*)	2015- *(Marginally Good)*	75.0 (*Excellent*)	*E. coli*

WWH Biocriteria attainment IBI Score of 40; ICI Score of 34
Non-significant departure: $\leq$ 4 IBI units, : $\leq$ 4 ICI units.
*Narrative rating based on best professional judgment
**2015-2016 Average
N/A Not Applicable

The fish and benthic macroinvertebrate communities at RM 0.20 were in full attainment. All the other sites failed to meet the WWH IBI and ICI biocriteria and were rated "*Fair*". The lack of a diverse fish community at most of the sites may be due to a lack of extensive instream cover. Additionally, permanent instream structures are impeding upstream fish migration within the. Once these structures are removed and

home sewage treatment systems and illicit discharges within the watershed are eliminated, an improvement in the bacteria sampling results as well as macroinvertebrate and fish diversity should be noticed.

Acknowledgements

Field activities and/or report review completed by the following, except where otherwise noted:

Donna Friedman
Nya Dreyfuss
Nicole Velez
Seth Hothem
Ron Maichle
John Rhoades
Eric Soehnlen
Kelsey Amidon
Mark Matteson, Author
Mario Meany
Jill Knittle
Tom Zablotny

WQIS Interns: Julia Klepach, Bryanna Boggan, Joe Schiel, Kyle Connelly, Lyndsey Baker, Jimmy Ferritto, and Summer Student, Sarah Foley.

Analytical Services Division – Completed analysis for all water chemistry sampling

Reference List

Ohio EPA. 1987. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Monitoring and Assessment. Columbus, Ohio. Last updated: August 2008.

Ohio Environmental Protection Agency. (2013a). 2013 Updates to Biological Criteria for the Protection of Aquatic Life: Volume II and Volume II Addendum. Users Manual for Biological Field Assessment of Ohio Surface Waters. Columbus, OH: Division of Surface Water, Ecological Assessment Section.

Ohio Environmental Protection Agency. (2013b). 2013 Updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebate Communities. Columbus, OH: Division of Surface Water, Ecological Assessment Section.

Ohio Environmental Protection Agency. (2015a). *State of Ohio Water Quality Standards Ohio Administrative Code Chapter 3745-1* (Revision: Adopted October 2, 2015; Effective January 4, 2016). Columbus, OH: Division of Surface Water, Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2015b). *Surface Water Field Sampling Manual for water quality parameters and flows*. Columbus, OH: Division of Surface Water.

DeShon, J.E. 1995. Development and Application of the Invertebrate Community Index (ICI). In: Davis and Simon, editors. Biological assessment and criteria, tools for water resource planning and decision making. Boca Raton, FL: Lewis Publishers; 1995. p 217-43.

Ohio EPA. 1997. NEORSD Ohio EPA NPDES Permit No. 3PA00002*ED. Ohio Environmental Protection Agency. Columbus, Ohio. February 24, 1997

West Creek Preservation Committee. July 2005 revised December 2008. Website accessed at: http://www.westcreek.org/Final%20WSAP%2012-15-08.pdf Last Accessed on June 11, 2009. Parma, Ohio.

Ohio EPA. 2006. *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices.* Ohio Environmental Protection Agency, Division of Surface Water, Division of Environmental Services. Columbus, Ohio.

Ohio Department of Health. 2007. website: http://www.odh.ohio.gov/ASSETS/22E1223A9A9A4E5AB044E91B0A7AF61C/InfraFS.pdf Lasted Accessed on June 11, 2009. Columbus, Ohio.

Ohio Environmental Protection Agency. (2015c). *Proposed Stream Nutrient Assessment Procedure*. Columbus, OH: Division of Surface Water, Ohio EPA Nutrients Technical Advisory Group.

United States EPA. 2017. Website: https://www.epa.gov/wqc/aquatic-life-criteria-copper Last Accessed on March 22, 2017. Washington, DC.

United States Environmental Protection Agency (2004). Mercury Pollutant Minimization Program Guidance. Region 5, NPDES Programs Branch. Retrieved from http://www.epa.gov/r5water/npdestek/ pdfs/2004mercury_pmp_guidance.pdf.