NORTHEAST OHIO REGIONAL SEWER DISTRICT

2013 Nine-Mile Creek Environmental Monitoring

Prepared by
Water Quality and Industrial Surveillance
Environmental Assessment Division

Introduction

During 2013, the Northeast Ohio Regional Sewer District (NEORSD) conducted water chemistry sampling, stream habitat assessments, and fish and benthic macroinvertebrate community surveys on Nine-Mile Creek at three locations. Nine-Mile Creek is an intensely urbanized stream in Cuyahoga County which flows through the cities of University Heights, South Euclid, Cleveland Heights, Cleveland and Bratenahl before emptying into Lake Erie. The majority of Nine-Mile Creek is culverted; sampling was conducted in the open sections of the creek.

The purpose of this study was to collect general watershed monitoring baseline data in order to assess the biological health of Nine-Mile Creek and collect data prior to the completion of the construction of a relief sewer at East 140th Street and Hayden Avenue, an NEORSD capital improvement project, which should eliminate or reduce sanitary sewage to Combined Sewer Overflows (CSO) 211 and 212. These flow reductions should benefit the District's long-term CSO Control Plan's goal of four or fewer overflows per year.

Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by Ohio EPA in Fish Community and Benthic Macroinvertebrate Biology, Chemical Water Quality, and Stream Habitat Assessments as explained in the NEORSD study plan, *2013 Nine-Mile Creek Environmental Monitoring,* approved by Ohio EPA on July 10, 2013.

Refer to Figure 1 for a map of the sampling locations. Table 1 indicates the sampling locations with respect to river mile (RM), latitude/longitude, description and surveys conducted. The three sites on Nine-Mile Creek that were evaluated are designated by Ohio EPA as Warmwater Habitat (WWH), agricultural water supply, industrial water supply and Class B Primary Contact Recreation. A digital photo catalog of the sampling locations is available upon request from NEORSD's Water Quality and Industrial Surveillance (WQIS) Division.

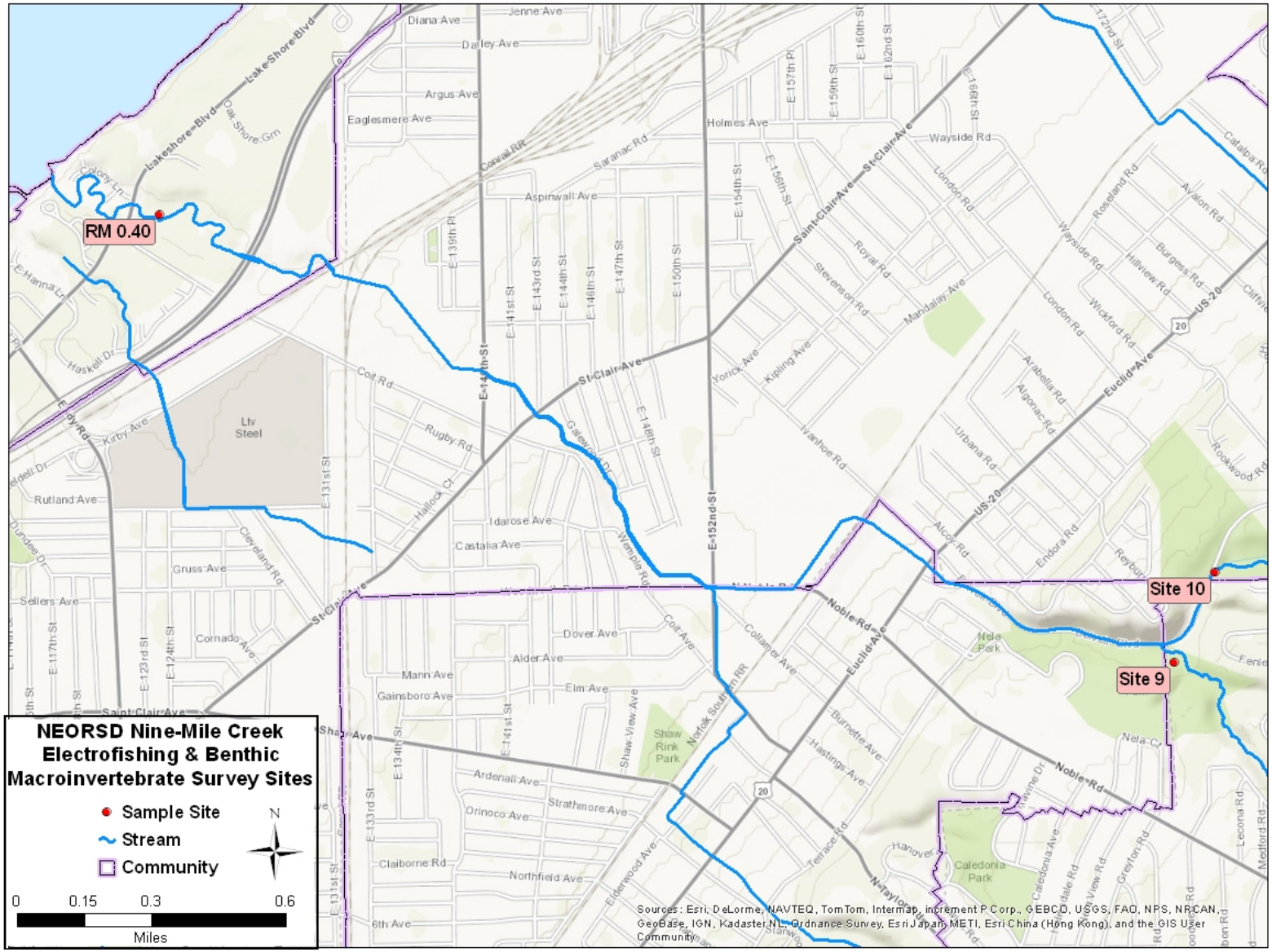


Figure 1. Map of Sampling Locations

Table 1. Sample Locations					
Location	Latitude	Longitude	River Mile	Description	Purpose
Nine-Mile Creek	41.5457	-81.5523	Site 10	South of Belvoir Boulevard	Evaluate water chemistry, fish, habitat and macroinvertebrates
Nine-Mile Creek, Nela Park Branch	41.5429	-81.5552	Site 9	South of Belvoir Boulevard on Nela Park Branch	Evaluate water chemistry, fish, habitat and macroinvertebrates
Nine-Mile Creek	41.5574	-81.5991	0.40	Upstream of Lakeshore Boulevard	Evaluate water chemistry, fish, habitat and macroinvertebrates

Water Chemistry Sampling

Methods

Water chemistry and bacteriological sampling was conducted five times between July 23, 2013 to August 20, 2013. A total of 17 samples were collected during the 2013 study, including field duplicates and field blanks. Techniques used for water chemistry sample collection and chemical analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (2013). 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 a YSI 600XL sonde. The sonde was calibrated weekly to measure dissolved oxygen, water temperature and conductivity, while pH was calibrated on a daily basis. Duplicate samples and field blanks were each collected at randomly selected sites, at a frequency not less than 5% of the total samples collected. A total of one sample duplicate and one field blank were obtained during the sampling period. The sample duplicate was collected on August 6 at RM 0.40. The field blank was collected on August 13 at Site 9. 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, 2013).

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 Nine-Mile 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 creek.

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

Results and Discussion

Each sample and sample duplicate was compared for each of the forty-three individual parameters reported on the Certificate of Analysis. After an RPD was calculated, any result greater than the acceptable difference was investigated to determine the reason for the discrepancy. A total of two potential discrepancies were found from the duplicate samples. Once the rejected data points were culled from the data set, the remaining Level 3 data was compared to the applicable Ohio EPA Water Quality Standards (OAC 3745-1) for each site. Table 2 lists the water quality parameters that were, because they did not meet Ohio EPA's requirements for level 3 data, rejected from the data set.

Table 2. Rejected Data Based on Duplicate Comparison			
Site	Date	Parameter	Action
RM 0.40	8/06/13	Al	Rejected
		Sb	Rejected

The bacteriological criteria for *E. coli* consist of two components: a seasonal geometric mean and a value not to be exceeded in more than 10% of the samples collected during a 30-day period (single sample maximum). For those streams designated Class B primary contact recreation, these criteria are 161 colony-forming units (CFU)/100mL and 523 CFU/100mL, respectively. The seasonal geometric mean criterion was exceeded at RM 0.40 and Site 10 in 2013 (Table 3). Two of the sampling dates occurred during wet weather[1], which could account for the exceedances. Potential sources of bacteria to the creek could include stormwater runoff, CSOs, sanitary sewer overflows and illicit discharges.

Table 3. 2013 Nine-Mile Creek *E. coli* Densities (colony-forming units/100mL)			
Date	RM 0.40	Site #9	Site #10
7/23/2013	5466	9580	2313
7/30/2013*	5082	9850	2776
8/06/2013	6276	11900	3610
8/13/2013*	8870	7500	5302
8/20/2013	---	---	---
Seasonal Geomean	2542	8150	500

*Wet weather event
Exceeds single sample maximum criteria for 30-day period starting on that date

Mercury exceedances of the aquatic life and wildlife outside mixing zone averages (OMZA) occurred at RM 0.40 and Site 9 during the sampling (Table 4). It is expected that the use of EPA Method 1631E, a low level method, instead of EPA Method 245.1 would have resulted in exceedances of the criteria throughout the sampling period at all of the sites. Sources of mercury contamination may be attributable to stormwater runoff, CSOs, sanitary sewer overflows, illicit discharges and atmospheric deposition.

[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 4. 2013 Nine-Mile Creek Mercury Results (ug/L)			
	RM 0.40	Site 9	Site 10
7/23/2013	j 0.008	0.058	<0.008
7/30/2013	j 0.008	<0.008	<0.008
8/06/2013	j 0.008	j 0.013	<0.008
8/13/2013	j0.012	j 0.013	<0.008
8/20/2013	j 0.008	<0.008	<0.008

Exceedance of Wildlife (0.0013 ug/L) and Aquatic Life (0.0031 ug/L) OMZAs for 30-day period beginning with that date, assuming "j" values are actual

Cadmium exceeded the Protection of Aquatic life Outside Mixing Zone Maximum (OMZM) three times and the OMZA for all 30-day periods (Table 5) at Site 9. Potential sources contributing to the cadmium non-attainment include runoff, weathering and erosion of soil and bedrock (ICA, 2009). Suspected cadmium contamination from the General Electric property to the south of Site #9 may have contributed to these exceedances. Further investigation of General Electric property is warranted to determine if cadmium contamination exists on site.

Table 5. 2013 Nine-Mile Creek Site 9 Cadmium Results (ug/L)			
	Concentration (µg/L)	Aquatic Life OMZA Criterion	Aquatic Life OMZM Criterion
7/23/2013	27.67	3.17	7.78
7/30/2013	6.37	3.06	6.07
8/06/2013	8.10	3.07	6.70
8/13/2013	5.49	2.99	6.07
8/20/2013	2.81	--	5.91
Criterion exceeded			

The Protection of Aquatic Life Outside Mixing Zone Average (OMZA) criterion for total dissolved solids (1500 mg/L) was exceeded on August 13, 2013 at RM 0.40. The result of the total dissolved solids concentration was 1523 mg/L. The total dissolved solids may have been attributed to the NEORSD Tunnel Dewatering Project which is located upstream sampling site immediately south of Interstate 90. The silt load present at the site was heavier than normal during the sampling period compared to studies that were conducted in previous years. Additionally, samples collected on August 13, 2013 were collected during a wet weather event which may have also contributed to the higher than normal solids concentration.

In 2013, the Ohio EPA released a draft Trophic Index Criterion designed to determine the degree of nutrient enrichment in a stream. Designated use and Qualitative Habitat Evaluation Index scores are used to determine nutrient target values according to the draft document. Any warmwater habitat site with a QHEI score between 12 and 64 will have targets of 0.13 mg/L for total phosphorus (TP) and 3.0 mg/L for dissolved organic nitrogen (DIN). DIN includes ammonia, nitrate, and nitrite. All other aquatic life uses and QHEI scores will have targets of 0.30 mg/L for TP and 3.0 mg/L for DIN. The nutrient concentrations for the Nine-Mile Creek sites in 2013 are shown in Table 6. Only the average TP target for Site #10 was not met during the 2013 sampling.

Table 6. 2013 Nine-Mile Creek Nutrient Concentrations

River Mile/Site	Average Total Phosphorus (mg/L)	Average Dissolved Inorganic Nitrogen (mg/L)
0.40	0.188	1.26
Site #9	0.363	1.33
Site #10	0.109	1.41

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site on Nine-Mile Creek in 2013 using the 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 headwater warmwater habitat criterion (Ohio EPA, 2003). 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)* (2006). QHEI field sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

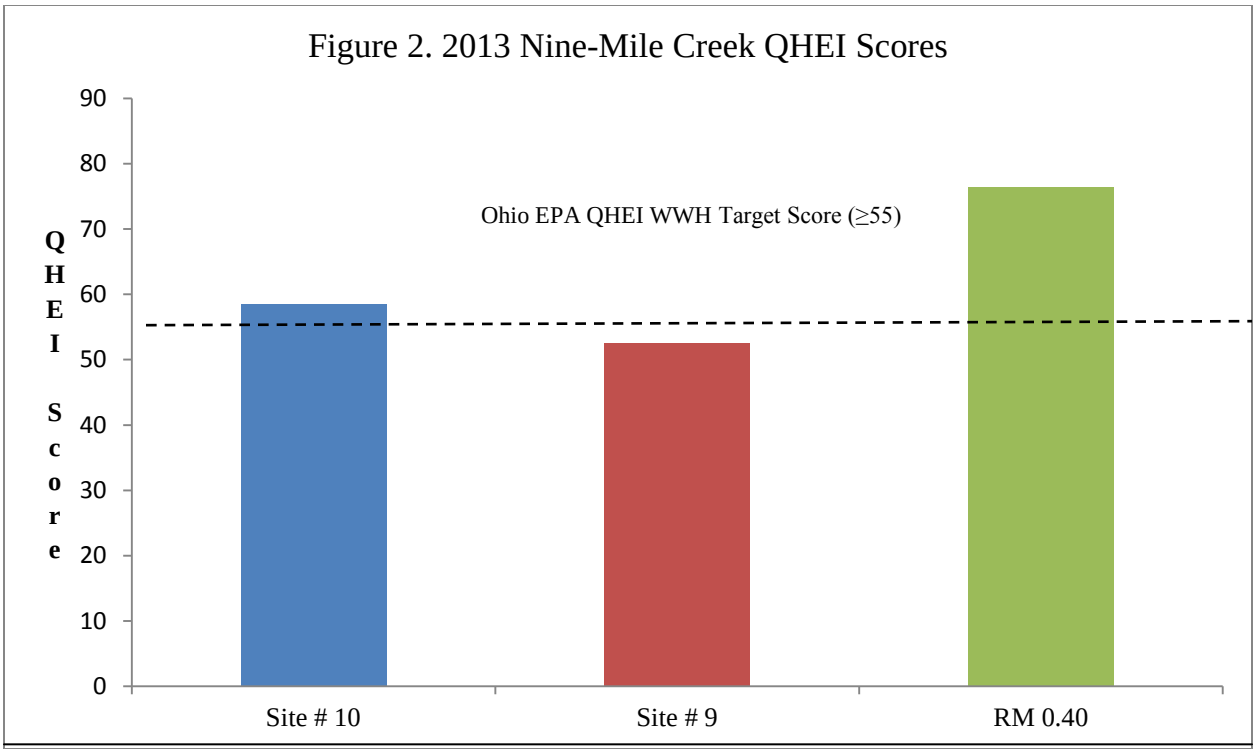
Nine-Mile Creek Site #10, south of Belvoir Boulevard, obtained a QHEI score of 58.5 (*Good*). Consisting mainly of cobble and bedrock, the site was free of silt with moderate embeddedness. Instream cover was sparse, consisting of shallows, pools (>70cm), rootwads, boulders and woody debris. Channel development was rated poor

due to low sinuosity and the lack of deep runs. Bank erosion was none to little and riparian width was wide. Although riffle areas and runs were stable to moderately stable, they tended to shift during elevated flows due to the high gradient of the stream. The site is surrounded by forest and residential/park/new field. This site exceeded Ohio EPA's target score of 55 for headwater WWH streams.

Nine-Mile Creek Site #9, which is located on the Nela Park Branch, south of Belvoir Boulevard, obtained a QHEI score of 52.5 (*Fair*). The predominant substrates were gravel and cobble with normal silt quality and normal to moderate embeddedness. Instream cover was sparse, consisting of overhanging vegetation, shallows, rootmats, rootwads, boulders, and logs or woody debris. Channel development was poor due to the lack of a functional riffle, deep pools (>70 cm) and deep runs. The channel is in a recovered state with low stability. Bank erosion was little to none and the riparian width was greater than 50 meters, consisting of forest/swamp and residential/park/new field. Site #9 did not meet the Ohio EPA target score of 55 for headwater WWH streams.

Nine-Mile Creek RM 0.40, which is located upstream of Lakeshore Boulevard, received a QHEI score of 76.5 (*Excellent*). The best substrate types were gravel and sand with moderate instream cover consisting of undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70 cm), rootwads, boulders and woody debris. Channel development was fair with deep runs and moderately stable riffles consisting of large gravel. Bank erosion was moderate, and riparian width was wide, consisting of forest/swamp and residential/park/new field. This site exceeded the Ohio EPA target score of 55 for headwater WWH streams. The QHEI scores are graphically displayed in Figure 2.

Figure 2. 2013 Nine-Mile Creek QHEI Scores



Fish Assessment

Methods

One quantitative electrofishing pass was conducted at each site in 2013. Sampling was conducted using wading electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from downstream to upstream. The sampling zone was 0.15 kilometers for each site. 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 for each pass were compiled and utilized to evaluate fish community health through the application of two Ohio EPA indices, the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being (MIwb) which is utilized at boat and wading sites. The electrofishing results for each pass were compiled and utilized to evaluate fish community health through the application of the IBI. The IBI incorporates 12 community metrics representing structural and functional attributes. 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*. The 12 metrics utilized for headwater sites are listed in Table 7. Lists of the species, numbers, pollution tolerances and incidence of DELT anomalies for fish collected during the electrofishing passes at each site are available upon request from the NEORSD WQIS Division.

Table 7. 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

Lists of the species, numbers, pollution tolerances and incidence of DELT anomalies for fish collected during the electrofishing passes at each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

The first and only sampling pass at Site #10 was performed on August 21, 2013, and consisted of one species, the creek chub (100%). Creek chubs are highly tolerant to pollution and favor a substrate of sand, gravel, boulders and bedrock (Trautman, 1981). The QHEI supports this species' habitat preference, with cobble and bedrock being the most prominent substrate types. Although the QHEI at Site #10 was slightly above the target score of 55 (QHEI=58.5, *Good*); the site was not expected to support a healthy community of warmwater habitat fish, which is evidenced by an IBI score of 20 (*Poor).* Additionally, CSO 212 (on Belvoir Boulevard, opposite Quilliams Avenue), which is approximately one half mile upstream of Site #10, averages an estimated 32 overflows

per year. This suggests that bacterial contamination and other pollutants may be preventing a healthy fish community from existing at this site.

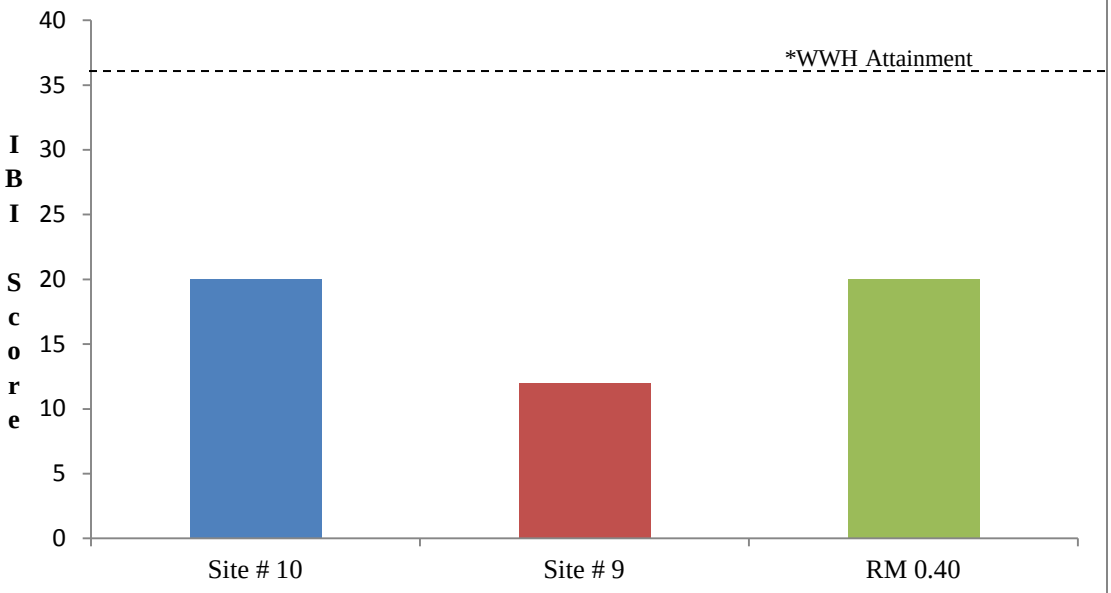
One electrofishing pass was conducted on Nine-Mile Creek Site #9 on August 13, 2013. No fish were collected at Site #9, resulting in an IBI score of 12 and a narrative rating of *Very Poor*. Habitat limitations may be a possible reason for the lack of fish; the QHEI at this site was the lowest of all three sites (QHEI=52.5 *Fair*). Site #9 lacked key habitat features including functional riffle habitat and deep pools. Water quality exceedances for mercury, bacteria, and cadmium may have negatively affected the fish community at this site. Average cadmium concentrations over the five sampling events at this site were 10.09 µg/L, much higher than the other two sites. Normal concentrations of total cadmium in rivers, streams and lakes range from 0.01 µg/L - 0.07 µg/L (NPS, 1997). It is evident that Site #9 shows higher than normal levels of total average cadmium. The high average concentration of cadmium at Site #9 may be a factor in the absent fish community.

One electrofishing pass was conducted at RM 0.40 on August 21, 2013. This sampling event yielded two species of fish totaling 110 individuals and an IBI score of 20 (*Poor*). The fish collected during this pass consisted of highly pollution-tolerant species including creek chub (98%) and white sucker (2%). Compared to the number of species collected at RM 0.40 in 2011, there was a decrease in the number of species collected at RM 0.40 in 2013. CSO 211 (east of Coit Road), which is located a little over half a mile upstream of RM 0.40, averages an estimated 77 overflows annually. Overflows from this CSO may contain pollutants that may be negatively impacting the fish community at this site. Additionally, the tunnel dewatering project taking place upstream of RM 0.40 may be impacting this site. The 2013 IBI scores are listed in Table 8 and graphically displayed in Figure 3.

Table 8. 2013 Nine-Mile Creek IBI Scores

	IBI Scores	
River Mile/Site	Score	Narrative Rating
Site #10	20	*Poor*
Site #9	12	*Very Poor*
RM 0.40	20	*Poor*

Figure 3. Nine-Mile Creek Average IBI Scores



*Nonsignificant departure (≤4 IBI units) from criterion

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. Sampling was conducted at both of the locations listed in Table 1. 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 the WQIS Division.

The overall aquatic macroinvertebrate community in the stream was evaluated using Ohio EPA's Invertebrate Community Index (ICI) (OEPA 1987a). The ICI consists of ten community metrics (Table 9), 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 9. ICI Metrics
Total number of taxa
Number of mayfly taxa
Number of caddisfly taxa
Number of dipteran taxa
Percent mayflies
Percent caddisflies
Percent Tanytarsini midges
Percent other diptera and non-insects
Percent tolerant organisms (as defined)
Number of qualitative EPT taxa

Results and Discussion

At Site #10, 12 qualitative taxa were collected. The sample consisted of two EPT taxa, while the remainder was composed of dipterans and non-insects. Two taxa (16% of the sample) were considered moderately tolerant to tolerant of pollution. Both riffle quality and margin quality were poor with a lack of suitable margin habitat to sample. Additionally, the site may not be ideal for a stable macroinvertebrate community as the substrate tends to shift during elevated flows. This may cause the macroinvertebrate community to be easily scoured, thus reducing the chances of a population to properly colonize the site.

A total of 11qualitative taxa were collected at Site #9, two of which were pollution tolerant (18% of the sample). Only two EPT taxa were collected and the rest of the sample consisted of dipteran and non-insect taxa. Site #9 had three water quality exceedances, which were for *E. coli*, cadmium, and mercury. Water pollution caused by metals may cause toxicity to macroinvertebrates through individual level responses such as mortality, decreased growth and reproduction. At the community level, reduced density and species richness may occur. Metal contamination may also cause a shift in the macroinvertebrate community to more tolerant organisms, which may be occurring at Site #9 (LeJeune et al., 2000).

At RM 0.40, a total of 16 quantitative taxa were collected. An ICI score of 8 was calculated for this site, which is below the Ohio EPA warmwater habitat biological criterion of 34. The sample consisted of one mayfly (*Baetis flavistriga)*, one tanytarsini midge (*Tanytarsus glabrescens group sp 7*), while the remainder of the sample was

composed of dipterans and non-insects. Pollution tolerant taxa made up 48.8 percent of the sample.

A total of 18 taxa were collected during the qualitative sample collection. The sample consisted of one mayfly (*Baetis flavistriga)*, one tanytarsini midge (*Tanytarsus glabrescens group sp 7*), while the remainder of the sample was composed of pollution tolerant organisms. Poor riffle and margin habitat created by shifting substrates and a heavier than normal silt load may have contributed to the relatively poor macroinvertebrate community at RM 0.40.

Conclusions

The purpose of this study was to collect baseline data on Nine-Mile Creek before construction of the relief sewer at East 140th Street and Hayden Avenue and to identify point and non-point source pollution affecting Nine-Mile Creek. The data collected in 2013 will be compared to data collected post-construction. The number of overflows per year to Nine-Mile Creek is expected to be reduced due to the construction of the relief sewer.

Water chemistry results, revealed that *E. coli* densities are elevated on Nine-Mile Creek at Site #10, Site 9 and RM 0.40. Mercury exceedances were noted at Site 9 and RM 0.40. Suspected cadmium contamination from the General Electric property may be causing the exceedances at Site #9. Further investigation of General Electric property is warranted to determine if cadmium contamination exists on site. Lastly, the elevated total dissolved solids at RM 0.40 may have been attributed to the NEORSD Tunnel Dewatering Project which is located upstream sampling site. The silt load present at this site was heavier than normal during the sampling.

Site #9 obtained a QHEI score of 52.5 (*Fair*), while Site #10 obtained a QHEI score of 58.5 (*Fair*). Both of these scores are below Ohio EPA's WWH target score of 55. RM 0.40 obtained a QHEI score of 76.5 (Excellent) and exceeded the WWH target score of 55. Although habitat scores suggest Nine-Mile Creek could support a fish community, water quality exceedances combined with the unstable nature of the substrate at all sampling locations have led to non-attainment for fish and macroinvertebrates (Table 10).

It is anticipated that the water quality and biological scores on Nine-Mile Creek will improve once construction of the relief sewer is complete. Wet weather flow relief in the collection system, as well as a reduction of overflows as a result of these projects may help to improve the biological community and water quality of Nine-Mile Creek. Further sampling will determine the effectiveness of the projects and any improvement in water quality, habitat and biological communities.

Table 10. 2013 Mill Creek Survey Results.					
River Mile	Aquatic Life Use Attainment Status	IBI Score (Narrative Rating)	ICI Score (Narrative Rating)	Habitat (Narrative Rating)	Water Quality Exceedences
Site #10	NON	20 *Poor*	---	58.5 *Fair*	*E. coli*
Site #9	NON	12 *Poor*	---	52.5 *Fair*	*E. coli*, Mercury , Cadmium
0.40	NON	20 *Poor*	8 *Fair*	76.5 *Excellent*	*E. coli*, Mercury, TDS
Warmwater Habitat Criteria		40	34		
Nonsignificant Departure from Criteria		≤4	≤4		
Target				55	
--- HDs not installed due to small drainage area					

Acknowledgments

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

Jonathan Brauer
Rachel Dannemiller
Donna Friedman
Seth Hothem
Ron Maichle
Mark Matteson, Author
Jill Novak
Ian Reider
John Rhoades
Francisco Rivera
Eric Soenhlen
Tom Zablotny
Cathy Zamborsky
Analytical Services Division – Completed analysis for all water chemistry sampling

References

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.

International Cadmium Association (ICA) (2009). Cadmium Products- The Issues and Answers. <www.cadmium.org>.

Karr, J.R. (1981). Assessment of biotic integrity using fish communities. *Fisheries, 6*, 21-27.

LeJeune, K., Podrabsky, T., Lipton, J., Cacela, D., Maest, A., & Beltman, D. (2000). Report of Injury Assessment and Injury Determination: Coeur D'Alene Basin Natural Resource Damage Assessment. Prepared for United States Department of the Interior, Fish and Wildlife Service, United States Department of Agriculture, Forest Service and Coeur D'Alene Tribe. Boulder, CO: Stratus Consulting Incorporated.

National Park Service (NPS). (1997). Environmental Contaminants Encyclopedia, Cadmium Entry. Fort Collins, CO: Water Resources Divisions, Water Operations Branch.

Ohio Environmental Protection Agency (OEPA). (1987b, updated September 1989; March 2001; November 2006; and August 2008). *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities.* Columbus, Ohio: Division of Water Quality Monitoring and Assessment.

Ohio Environmental Protection Agency (OEPA). (2006). *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI).* Columbus, Ohio: Division of Surface Water; Division of Ecological Assessment Section. Ohio EPA Technical Bulletin EAS/2006-06-1.

Ohio Environmental Protection Agency (OEPA). (2009b). State of Ohio Water Quality Standards *Ohio Administrative Code* Chapter 3745-1. Revision: Adopted July 9, 2009; Effective October 9, 2009. Columbus, Ohio: Division of Surface Water, Standards and Technical Support Section.

Ohio Environmental Protection Agency (OEPA). (2013). *Surface Water Field Sampling Manual for water column chemistry, bacteria and flows*. Columbus, Ohio: Division of Surface Water.

Rankin, E. T. (1989). *The Qualitative Habitat Evaluation Index (QHEI): rationale, methods, and application*. Columbus, Ohio: Ohio EPA, Division of Surface Water.

Trautman, M.B. (1981). The fishes of Ohio. Columbus, OH: The Ohio State University Press in collaboration with the Ohio Sea Grant Program Center for Lake Erie Area Research.