Northeast Ohio
Regional Sewer District

2022 Stream Restoration Projects

Biological, Water Quality, and Habitat Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

April 2023

Table of Contents

List of Figures

List of Tables

Introduction

In 2022, the Northeast Ohio Regional Sewer District (NEORSD) monitored environmental and biological conditions at three sites to determine the effectiveness of recently completed restoration projects in improving water quality conditions, habitat, and fish and macroinvertebrate communities. Sites on Stickney Creek and Mill Creek were assessed as part of post-project monitoring. Site surveys were conducted by the Environmental Assessment (EA) group of the NEORSD Water Quality and Industrial Surveillance (WQIS) Division.

In Brooklyn, Ohio, the Stickney Creek Restoration project was completed on November 29, 2019. This restoration project restored more than 1,000 feet of urban stream where erosion exposed and threatened the integrity of sanitary sewer infrastructure. Additionally, restoration efforts reestablished floodplain storage, slowed stream velocities, and created more in-stream habitat.

In Warrensville Heights, Ohio, the Mill Creek Stream Stabilization project was completed in November 2016. This project restored more than 4,300 feet of stream at Highland Park Golf Course. This project resulted in the permanent placement of stream fill in over 3,500 feet in Mill Creek and an un-named tributary. Additionally, the restoration included a 1.2-acre floodplain wetland depression in place of a previously existing pond and created 6.6 acres of restored floodplain and 8.4 acres of a vegetated buffer, which included the planting of 540 trees, 1,500 shrubs, and 960 herbaceous perennial plants (Mill Creek Watershed Partnership, 2022).

Although the data was not submitted to the Ohio Environmental Protection Agency (EPA) as part of the Credible Data Program, sampling was conducted by NEORSD Level 3 Qualified Data Collectors (QDCs) certified in Fish Community Biology, Benthic Macroinvertebrate Biology, Chemical Water Quality, and Stream Habitat Assessments using Level 3 methodology as explained in the NEORSD project study plan *2022 Stream Restoration Projects Environmental Monitoring*. All sampling and environmental assessments occurred between June 15, 2022 and September 30, 2022 (through October 15 for fish sampling assessments), as required in the Ohio EPA *Biological Criteria for the Protection of Aquatic Life Volume III* (1987b). The results gathered from these assessments were evaluated using the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI), Index of Biotic Integrity (IBI), and the Invertebrate Community Index (ICI). Water chemistry data was validated per methods outlined by the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2021) and compared to the Ohio Water Quality Standards for their designated use to determine attainment (Ohio EPA, 2022). An examination of the individual metrics that comprise the IBI and ICI was used in conjunction with the water chemistry data and QHEI scores to assess the health of the stream.

Figure 1 shows a map of the sampling locations, and Table 1 indicates the sampling locations with respect to river mile (RM), latitude/longitude, description, and surveys conducted. A digital photo catalog of the sampling locations is available upon request by contacting the WQIS Division.

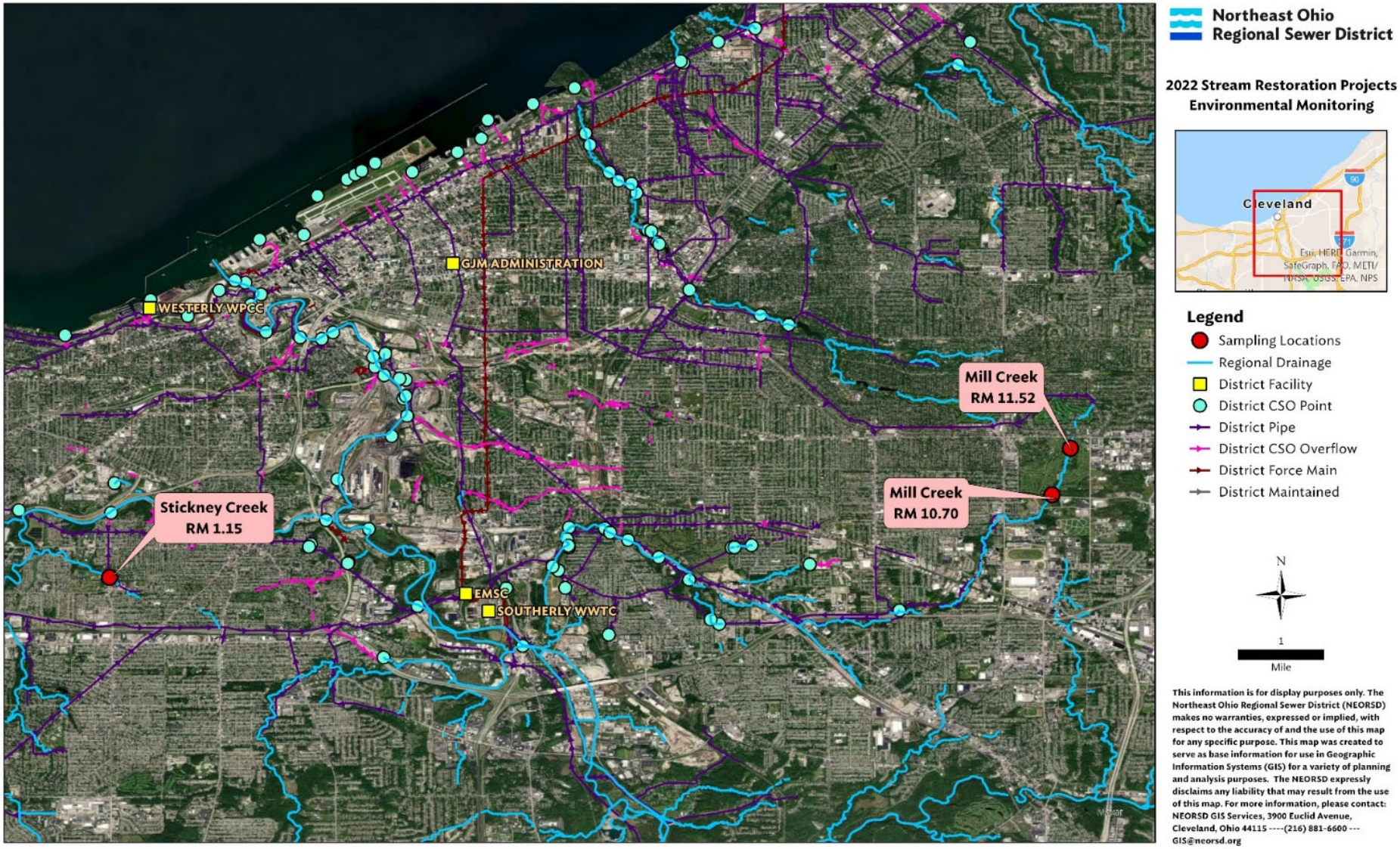

Figure 1. 2022 Stream Restoration Project Sampling Locations

Table 1. 2022 Stream Restoration Project Sampling Locations

Location	Latitude	Longitude	River Mile	Station ID	Drainage Area (sq. mi)	Sampling Conducted
Stickney Creek	41.4334	-81.7351	1.15	303948	3.15	F, M, C (Post)
Mill Creek	41.4621	-81.5214	11.52	301194	1.17	F, M, C (Post)
Mill Creek	41.4518	-81.5255	10.70	301195	1.8	F, M, C (Post)

F = Fish community biology (includes habitat assessment)
M = Macroinvertebrate community biology
C = Water chemistry

The Ohio EPA assigns designated uses to establish minimum water quality requirements for surface waters. These requirements represent measurable criteria for assessing the chemical, physical, and biological integrity of Ohio's surface waters consistent with Clean Water Act requirements. The beneficial use designations for the 2022 Restoration Projects are listed below in Table 2 (Ohio EPA 2022).

Table 2. Beneficial Use Designations for 2022 Restoration Projects

Stream	**Beneficial Use Designation**												
	Aquatic Life Habitat (ALU)							Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Stickney Creek		+							+	+		+	
Mill Creek		+							+	+		+	

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat;
MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat;
LRW = limited resource water
PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply;
BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted five times between June 23, 2022 and July 20, 2022, at the sites listed in Table 1. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2021). 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 one 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 and preserved with sodium thiosulfate. At the time of sampling, measurements for dissolved oxygen, dissolved oxygen percent, pH, temperature, conductivity, and specific conductance were collected using a YSI EXO1 sonde. Replicate samples and field blanks were each collected at randomly selected sites, 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 replicate 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 replicate sample

The acceptable percent RPD is based on the ratio of the sample concentration and detection limit (Formula 2) (Ohio EPA, 2019).

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

X = sample/detection limit ratio

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

Water chemistry analysis sheets for each site are available upon request from the NEORSD WQIS Division. Dates of water chemistry sampling compared to Mill Creek flow data (USGS 04208460) are shown below in Figure 2. There is no flow data available for Stickney Creek.

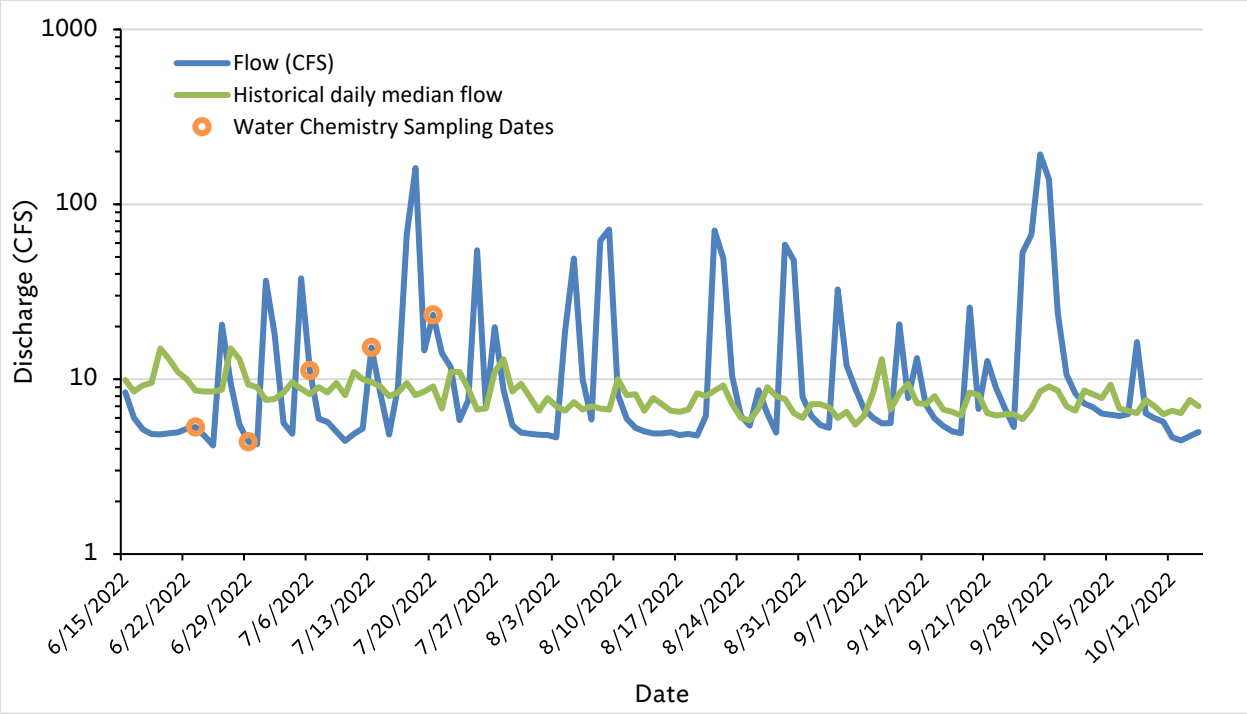

Figure 2. Daily mean discharge for Mill Creek at USGS Station 04208460. Shown are the daily mean discharge for 2022 and the historic median discharge (2001-2022). Orange circles indicate water chemistry sampling dates.

Results and Discussion

One replicate sample and one field blank were collected in support of quality assurance and quality control (QA/QC) guidelines for field sampling. The replicate sample was collected at Mill Creek RM 10.70 on July 20, 2022. The chemical parameter total dissolved solids (TDS) was rejected based on RPD values outside of the acceptable RPD range for this sample (Table 3).

Table 3. Replicate Samples with RPDs Greater than Acceptable

Site Location	Date	Parameter	Acceptable RPD	Actual RPD
Mill Creek 10.70	7/20/2022	Total Dissolved Solids	24.5%	128.0%

The field blank sample was collected on July 06, 2022, at Stickney Creek RM 1.15. Results from that sampling indicate that no parameters were affected by possible field blank contamination.

Paired parameters, wherein one parameter is a subset of another, were also evaluated in accordance with QA/QC protocols for all samples collected at each Stream Restoration Projects

site (Table 4). On July 13, 2022, Mill Creek RM 11.52 had a total phosphorus (TP) concentration less than a dissolve reactive phosphorus (DRP) concentration; therefore, the TP concentration is qualified as a "J" estimated. Based on the sampling data, no additional exceedances in paired parameters were identified in the 2022 Stream Restoration Projects data set.

Table 4. Paired Parameter Qualifiers

Site Location	Date	Pair Parameter	Acceptable RPD	Actual RPD	Qualifier
Mill Creek 11.52	7/13/2022	TP/DRP	78.8%	51.7%	J
J= Data estimated					

Attainment of the PCR designated use is determined using *Escherichia coli* (*E. coli*), a fecal indicator bacteria commonly found in the intestinal tract and feces of warm-blooded animals (USEPA, 2012). The PCR criteria includes an *E. coli* criterion not to exceed a Statistical Threshold Value (STV) of 410 colony counts or most-probable number (MPN) per 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 or MPN per 100mL (Ohio EPA, 2022). In accordance with Ohio EPA procedure and practice to qualify *E. coli* exceedances for the PCR criteria, the geometric mean and STV are only calculated and compared when a minimum of five bacteriological samples have been collected.

Approximately 86 percent of the samples collected exceeded the STV of 410 colony counts/100mL, resulting in PCR impairment at all sampling sites in 2022. Additionally, all sites exceeded the 90-day geometric mean criterion of 126 colony counts/100mL (Table 5). One of the five sampling dates was a wet-weather event, which may lead to elevated *E. coli* densities due to urban runoff and potential sanitary sewer overflows; however, no sanitary sewer overflows were documented in Mill Creek or Stickney Creek in 2022. *E. coli* exceedances may also have been a result of domestic and/or wild animal waste and improper sanitary sewage connections to stormwater outfalls upstream of the sampling locations. NEORSD has identified numerous active improper sanitary connections in the city of Parma tributary to this section of Stickney Creek in 2017. NEORSD confirmed that improper connections are still present in May 2022.

Table 5. 2022 *E. coli* Densities (MPN/100mL)

Date	Stickney Creek RM 1.15	Mill Creek RM 11.52	Mill Creek RM 10.70
6/23/2022	1,300	2,420	378
6/29/2022	2,850	2,420	411
7/6/2022*	21,620	5,654	2,595
7/13/2022	1,986	770	649
7/20/2022	3,080	494	230.5
90-day Geomean	3,451.7	1,659.7	570.3

Exceeds statistical threshold value of 410 MPN/100mL
Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL
*Wet-weather Event: 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.

Mercury analysis for all 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 Outside Mixing Zone Averages (OMZA), 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 those levels typically found in the stream. Mercury was not detected above detection limits in any of the samples collected.

TDS and specific conductance exceeded Aquatic Life OMZA and Tier I OMZA standards at Mill Creek RM 11.52 on multiple sample dates. TDS exceeded the Aquatic Life OMZA and Tier I OMZA standard of 1,500 mg/L at Mill Creek RM 11.52 on three of the five sampling dates. Specific conductance exceeded the Aquatic Life OMZA and Tier I OMZA standard of 2,400 micromhos/cm at Mill Creek RM 11.52 on four of the five sampling dates. According to the Lake Erie Basin Aquatic Life and Human Health Tier I Criteria, dissolved solids exceedance values are the equivalent of the specific conductance exceedance values. The TDS and specific conductance exceedances are believed to be cause by urban runoff.

Based on the sampling that was conducted, no additional exceedances of water quality standards were found for the other parameters that were monitored at these sites in 2022.

Temporal Water Quality Trends

The 2009 Mill Creek at Highland Heights study showed similar TDS trends at RM 11.52 as the 2022 Stream Restoration Project Monitoring study. The 2009 study showed elevated concentrations of TDS at Mill Creek RM 11.52; however, the concentrations did not exceed the

Aquatic Life Use (ALU) criterion. In 2022, TDS concentrations exceeded ALU criterion on three of the five days sampled. Figure 3 shows TDS concentrations at Mill Creek RM 11.52 from past NEORSD studies. Elevated concentrations of potassium and sodium are driving the elevated concentrations of TDS. Additionally, field conductivity and field specific conductance levels were elevated confirming the presence of dissolved salts in the stream. Mill Creek is a highly urbanized watershed, so it is likely that the cause of the TDS exceedances is urban runoff.

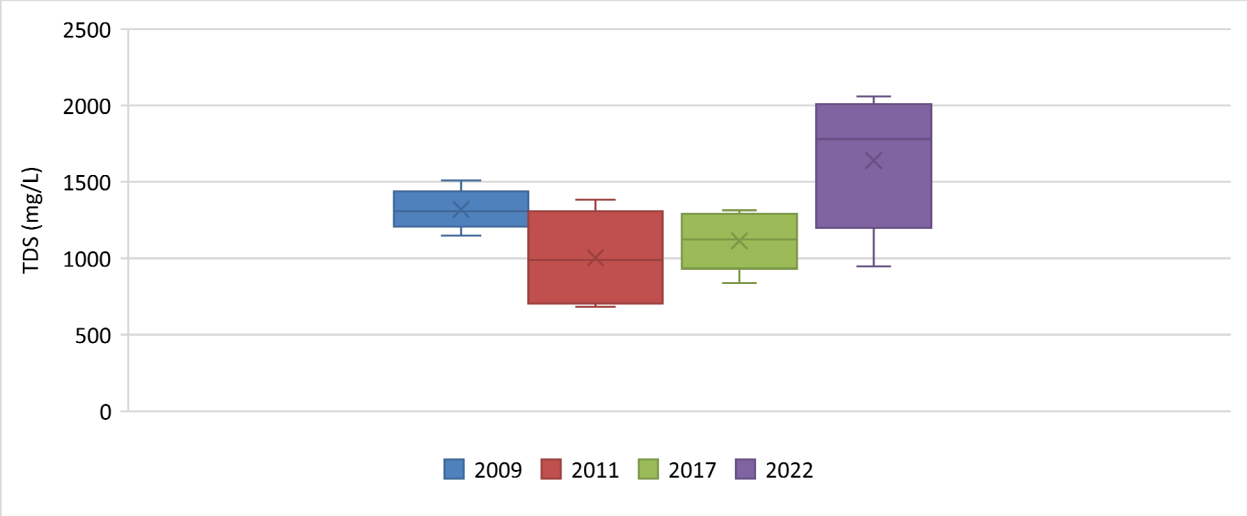

Figure 3. Total Dissolved Solids Concentrations at Mill Creek RM 11.52

Stream Nutrient Assessment

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). NEORSD did not assess DO swings or benthic chlorophyll *a* in 2022; however, nutrients were assessed.

Table 6 shows the 2022 nutrient concentrations for the Stream Restoration Projects sampling sites. The results of dissolved inorganic nitrogen (DIN) and TP were compared to Table 2 listed in the SNAP document (Figure 4) and applicable nutrient concentrations and narrative level can be seen in Table 7. Stickney Creek was the only site that showed an enriched condition. Stickney Creek at RM 1.15 lacks a developed riparian buffer, which is an important component in the detention and removal of nutrients in headwater streams (Ohio EPA, 1999). Increased TP was the primary driver for the nutrient enrichment at Stickney Creek RM 1.15, and there is a statical relationship between mean TP concentrations in headwater streams greater than 0.12 mg/L and decreases in IBI and ICI scores (Ohio EPA, 1999). Table 6 shows TP concentrations at Stickney Creek RM 1.15 greater than 0.12 mg/L.

Table 6. Nutrient Analysis (Geometric Means)					
Waterbody	River Mile	DIN (mg/L)*	NO_3-NO_2 (mg/L)	DRP (mg/L)	TP (mg/L)*
Stickney Creek	1.15	1.050	0.962**	0.142	0.235
Mill Creek	11.52	0.611	0.475	0.055	0.072**
	10.70	0.559	0.486	0.038	0.081
* Data used in Table 2 of SNAP (Ohio EPA 2015) ** Data used contains "J" qualified data					

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

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

Figure 4. Table 2 of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015b)

Table 7. Applicable SNAP Analysis with Narrative Level (Geometric Means)				
Waterbody	River Mile	DIN Range	TP Range	Narrative Level
Stickney Creek	1.15	0.44<1.10	0.131<0.400	Levels typical of enriched condition; low risk to beneficial use if allied responses are withing normal range
Mill Creek	11.52	0.44<1.10	0.04<0.08	Levels typical of developed lands; little or no risk to beneficial uses
	10.70	0.44<1.10	0.04<0.08	Levels typical of developed lands; little or no risk to beneficial uses

Similarly, Stickney Creek showed an enriched condition in 2021, which is believed to be caused by the numerous illicit discharges upstream contributing to the elevated nutrient load. Figures 5 through 8 show temporal changes in nutrients concentrations from previous NEORSD studies. Even though Stickney Creek has been designated as having an enriched condition, all nutrients analyzed have decreased from 2021.

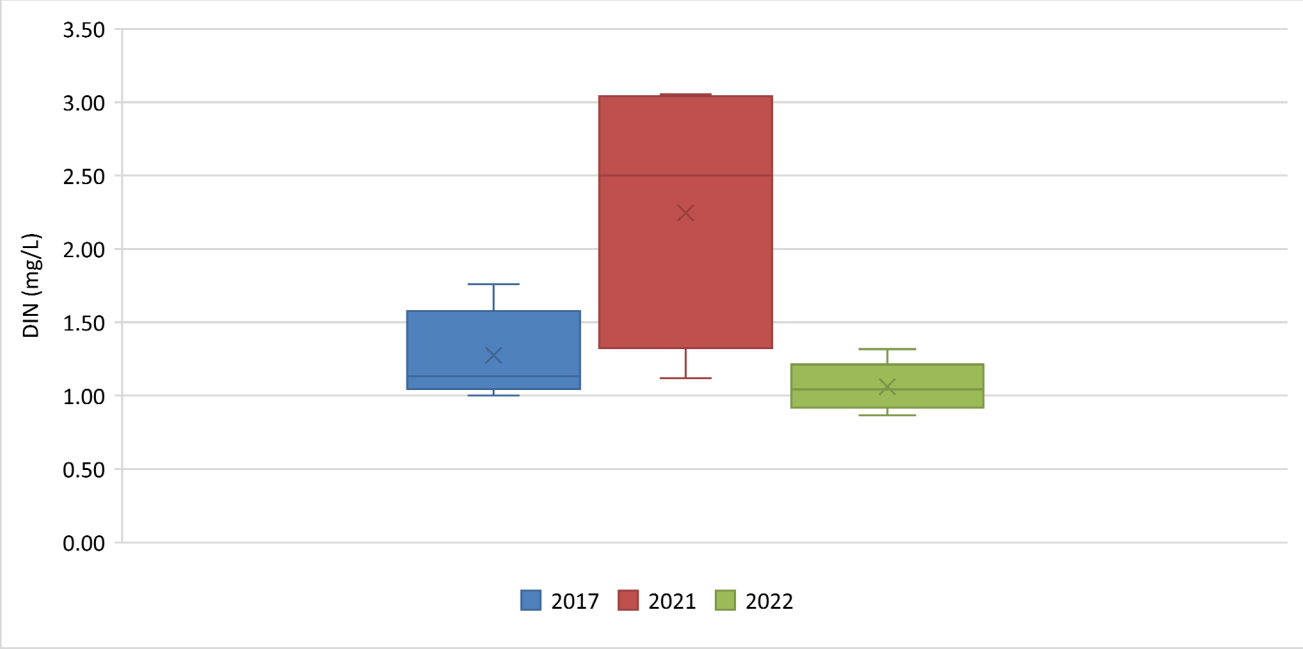

Figure 5. Stickney Creek RM 1.15 DIN Concentrations

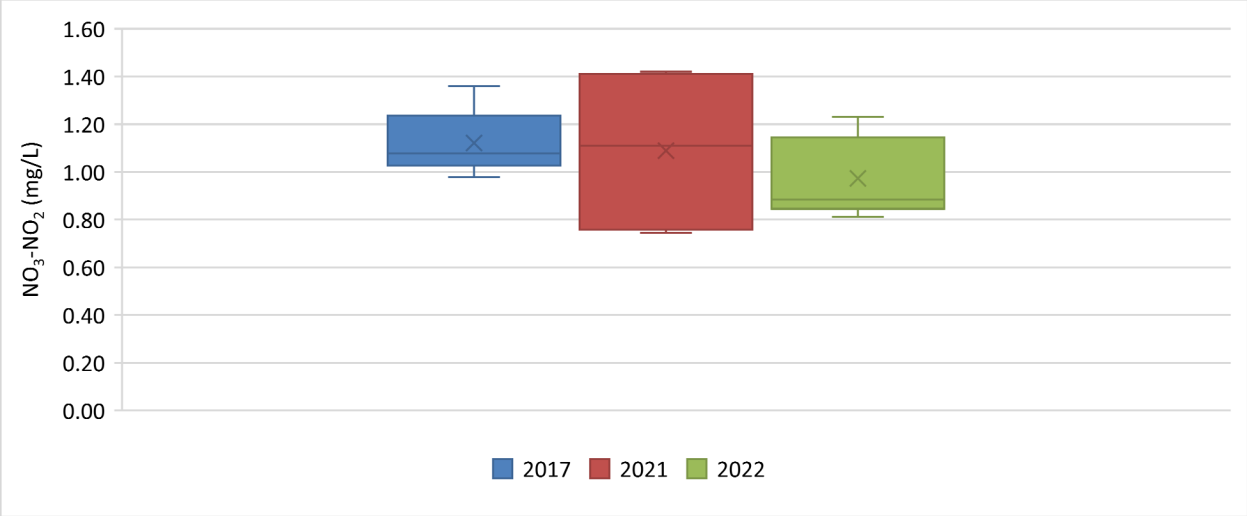

Figure 6. Stickney Creek RM 1.15 Nitrate-Nitrite Concentrations

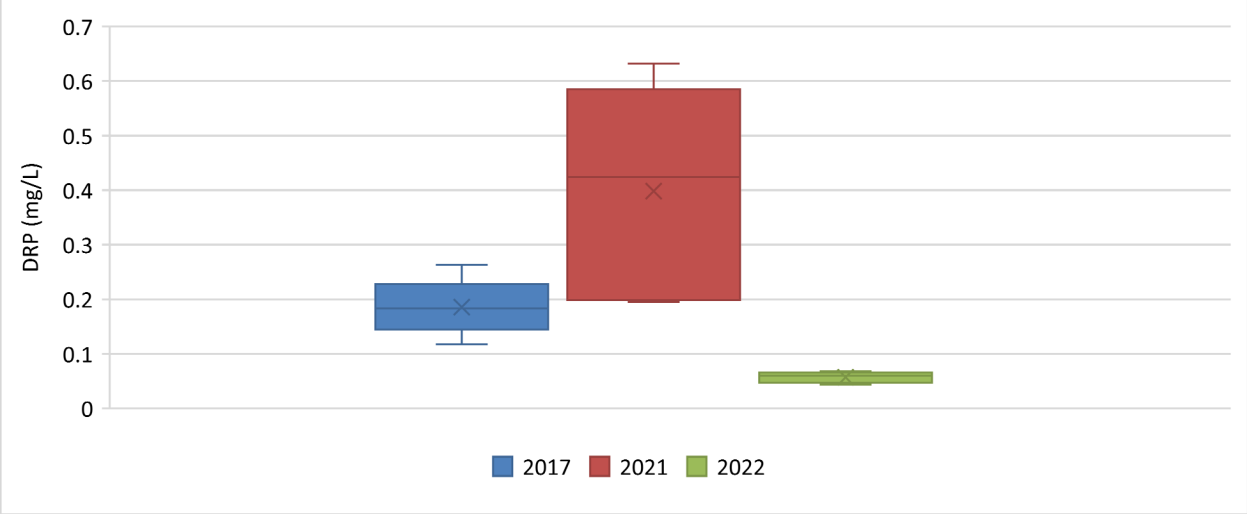

Figure 7. Stickney Creek RM 1.15 Dissolved Reactive Phosphorus Concentrations

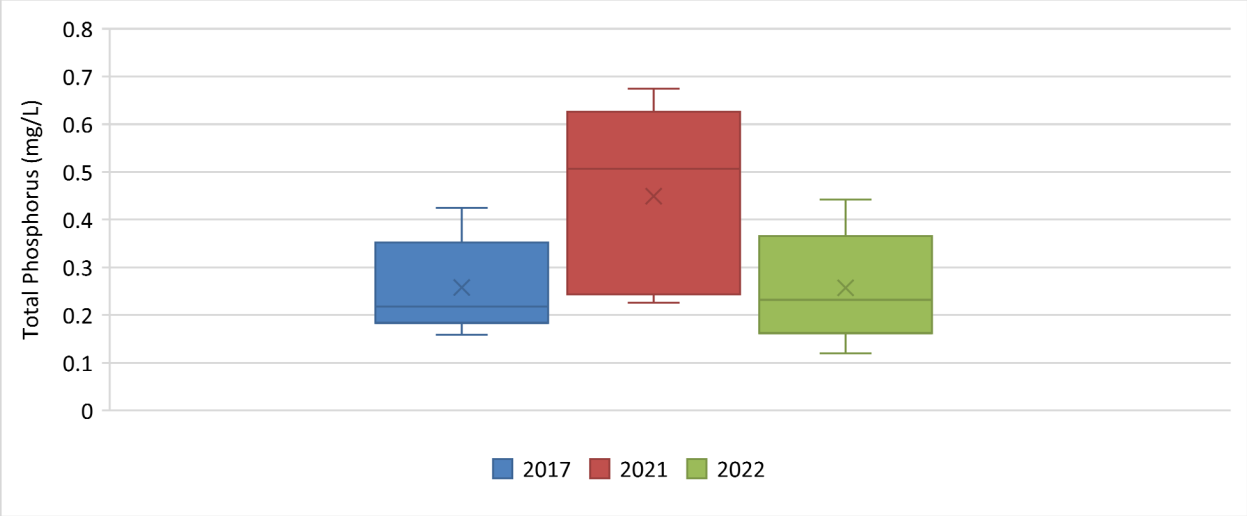

Figure 8. Stickney Creek RM 1.15 Total Phosphorus Concentrations

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site in 2022 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 greater than 55 for streams with less than 20 mi^2 which applies to all three sites, suggests that sufficient habitat exists to support a fish community that attains the warmwater habitat criterion (Ohio EPA, 2006). Scores greater than 75 frequently demonstrate habitat conditions that have the ability to support exceptional warmwater faunas. 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

One of the three 2022 Stream Restoration Projects sampling sites achieved the Ohio EPA Warmwater QHEI target score of 55 for headwater streams. Figure 9 shows an overview of each stream location assessed during the 2022 field season.

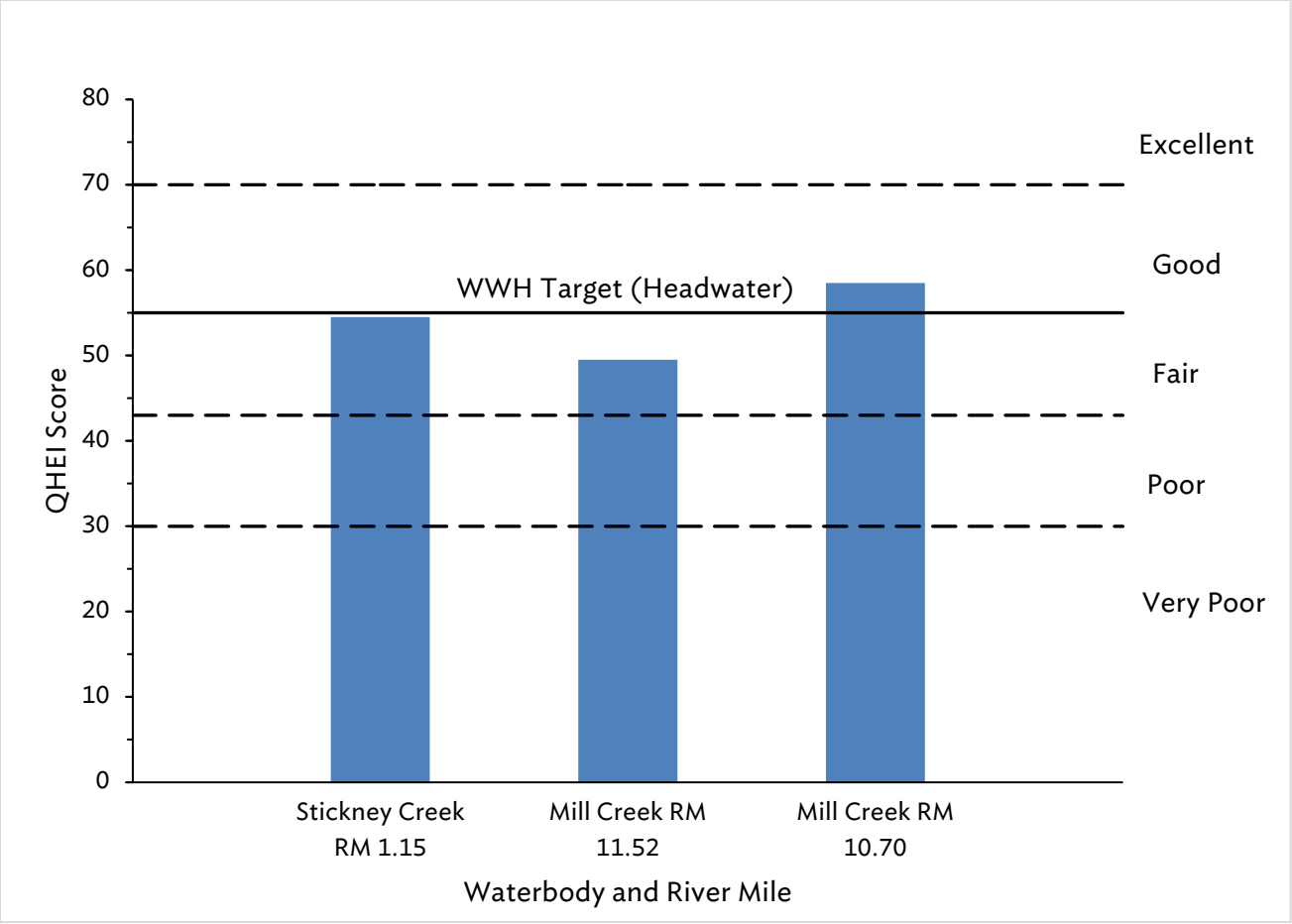

Figure 9. QHEI Scores for Each Site Monitored in 2022

Stickney Creek RM 1.15

The habitat for the stream segment at Stickney Creek RM 1.15 was assessed on July 7, 2022. The QHEI assessment was calculated at 54.5 (*Fair*), which fell just short of the headwater target score of 55. The most prominent types of substrate present consisted of cobble and gravel with a "normal" silt narrative. The reach had mostly recovered in terms of disturbance caused by the restoration project and was characterized by additional morphology features of high sinuosity and fair to good development. Development of the riffle/pool complexes was good; however, the reach lacked depth in pools. A sparse amount of instream cover only included two distinct habitat types, overhanging vegetation and boulders, which was a key factor in reducing the QHEI score for the reach. The sample site at RM 1.15 is one of the only non-culverted sections of Stickney Creek, as the upstream sections are almost completely culverted and void of habitat. It is understood that the riparian width metrics played a significant role in the decreased QHEI score; however, it is believed that over time as trees and woody vegetation grow, the score will increase.

A post-construction QHEI assessment at Stickney Creek RM 1.15 was conducted on June 23, 2021, and was calculated at 67.5, which exceeded the headwater target score of 55. The 2021 post-construction QHEI assessment scored higher than the 2022 QHEI assessment in every metric except for gradient, which both assessments scored the same. The 2021 assessment scored much higher in the instream cover category due to having a moderate amount of instream cover, pools greater than 70 centimeters, and logs and woody debris. The decrease in the score for the instream cover metric is likely due to the stream segment beginning to stabilize post-construction.

Figure 10 below shows QHEI scores from the 2022 field season and previous NEORSD assessments. The first NEORSD assessment was completed in 2017, as part of pre-construction monitoring. The 2017 QHEI score was calculated at 59.75 (*Good)*. Similarly to the 2021 assessment, instream cover metrics scored much higher than in 2022. The 2022 assessment was the first time since NEORSD has monitored Stickney Creek RM 1.15 where the stream segment did not meet the warmwater habitat target score of 55. However, as the instream cover and riparian zones continue to stabilize it is likely that QHEI scores will reach the target score of 55 in future assessments.

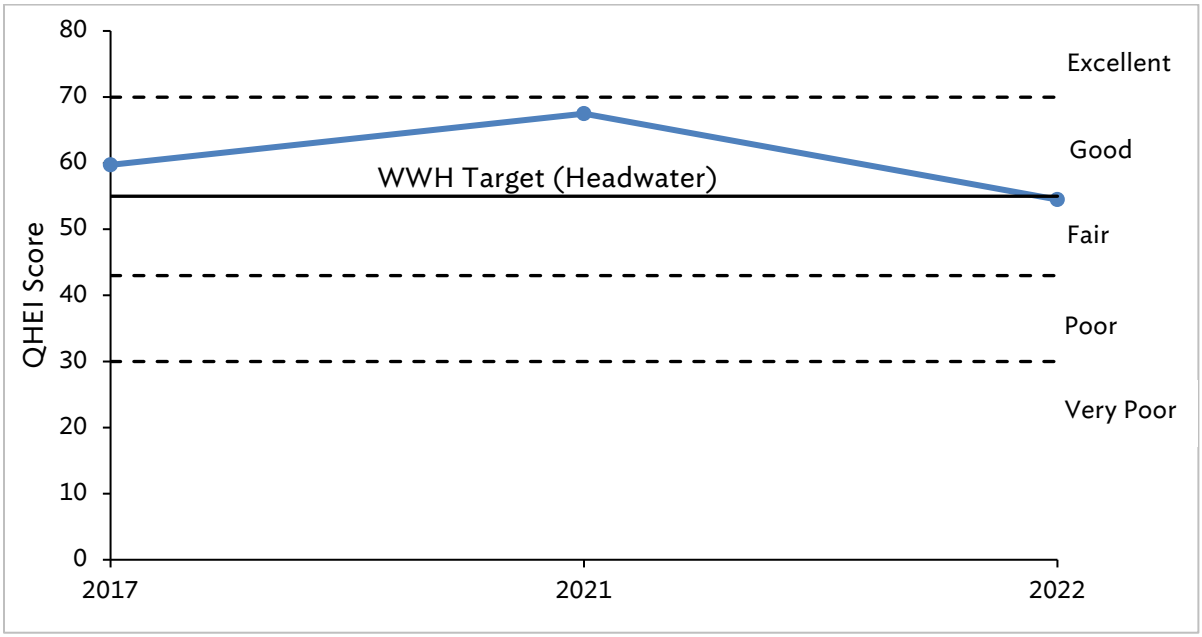

Figure 10. Historical Stickney Creek RM 1.15 QHEI Scores

Mill Creek RM 11.52

The habitat for the stream segment assessment at Mill Creek RM 11.52 was completed on June 30, 2022. The QHEI assessment at Mill Creek RM 11.52 was calculated at 49.5 (*Fair*), which did not meet the headwater target of 55 and suggests that there is not sufficient habitat to support a healthy warmwater fish community. The most prominent types of substrate present consisted of cobble and gravel with a "normal" silt narrative. The reach did not display features of channelization and was characterized by additional morphology features of moderate sinuosity, fair development, and moderate to high stability. Development of the riffle/pool complexes was fair with some pool depth variations; however, the reach did not have a functional riffle with a depth less than 5 centimeters. A sparse amount of instream included overhanging vegetation, root mats, boulders, and aquatic macrophytes, which was a key factor in reducing the QHEI score for the reach. Mill Creek RM 11.52 failed to meet the target scores for the QHEI; it could be expected that the reach may not be able to sustain healthy biological communities due to the small drainage area (approximately 1.5 sq. miles).

A post-construction QHEI assessment at Mill Creek RM 11.52 was conducted on June 29, 2017, and was calculated at 59, which exceeded the headwater target score of 55. The prominent substrates were boulder and cobble in 2017; whereas the prominent substrates were cobble and gravel in 2022, resulting in a lower QHEI score. Additionally, the pool/glide and riffle/run quality scored higher in 2017 than in 2022. Pool and riffle depth were greater in 2017 and there was no functional riffle present in 2022, which lowered the QHEI score. The lack of functional riffles

appears to be the primary contributing factor to the lower QHEI score in 2022; however, this is likely due to the very low flow observed during the assessment.

Figure 11 below shows QHEI scores from the 2022 field season and previous NEORSD assessments. The first NEORSD assessment was completed in 2009 as part of pre-construction monitoring. The 2009 QHEI score was calculated at 48.25 (*Fair*), which did not meet the headwater target of 55; however, the 2011 and 2017 QHEI assessments did meet the headwater target score of 55. As mentioned previously, the lack of functional riffles is the primary contributing factor to the lower QHEI score in 2022.

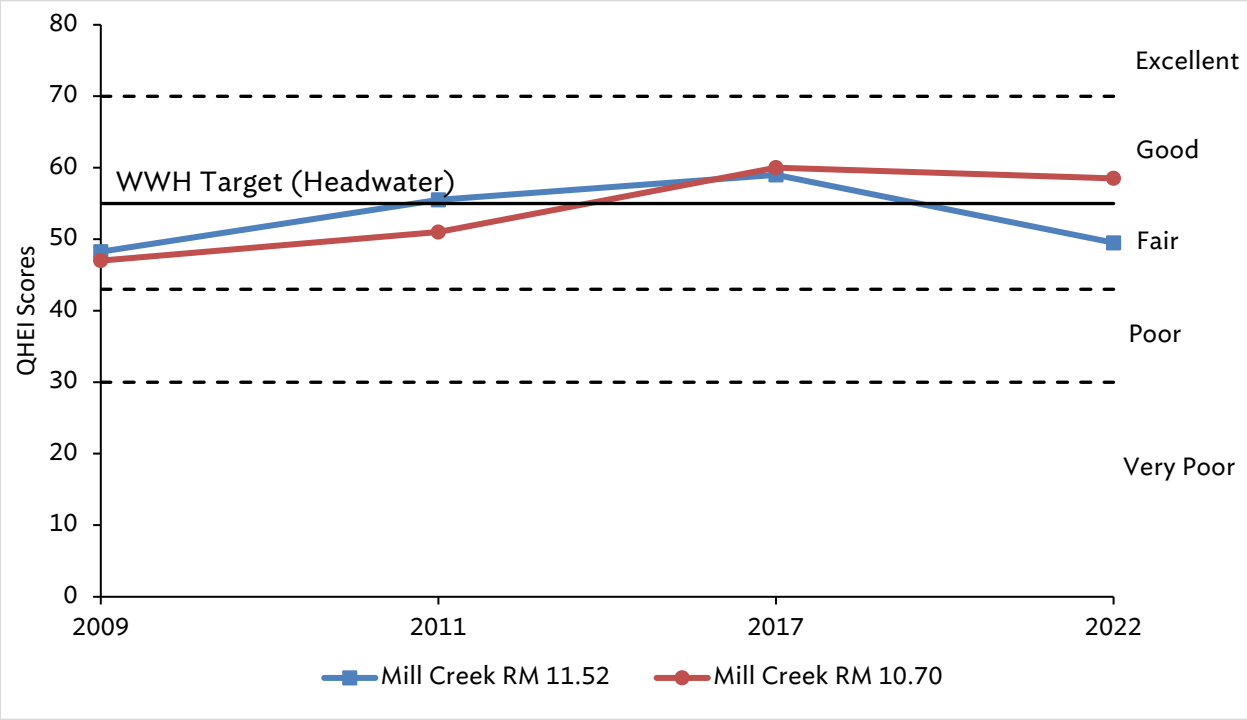

Figure 11. Historical Mill Creek QHEI Scores

Mill Creek RM 10.70

The habitat for the stream segment at Mill Creek RM 10.70 was assessed on June 29, 2022. The QHEI assessment at Mill Creek RM 10.70 was calculated at 58.5 (*Good*), which exceeded the headwater target of 55 and suggests that sufficient habitat exists to support a warmwater fish community. The most prominent types of substrate present consisted of cobble and gravel with a "moderate" silt narrative. The reach displayed features of recovered to no channelization and was characterized by additional morphology features of moderate sinuosity, good to fair development, and high stability. Development of the riffle/pool complexes was good; however, the reach lacked depth in pools greater than one meter. A sparse amount of instream cover only included three distinct habitat types which included overhanging vegetation, pools greater than 70 centimeters, and boulders. The minimal amount of instream cover was a key factor in reducing the QHEI score

for the reach.

The 2017 post-construction QHEI assessment for Mill Creek RM 10.70 was similar to the QHEI assessment calculated in 2022. The QHEI score for 2017 was calculated at 60, which exceeds the headwater target score of 55. Similarly to the 2017 and 2022 QHEI assessments for Mill Creek RM 11.52, boulder and cobble were the primary substrates observed at the site in 2017 and cobble and gravel were the primary substrates observed at the site in 2022. Since the QHEI assessment from 2017 scored very closely to the assessment in 2022, it is reasonable to believe that the habitat has stabilized post restoration.

Figure 11 above shows QHEI scores from the 2022 field season and previous NEORSD assessments. The first NEORSD assessment was completed in 2009 as part of pre-construction monitoring. The 2009 QHEI assessment was calculated at 47 (*Fair*), which did not meet the headwater target of 55.

Individual components of the QHEI can also be used to evaluate whether a site is capable of meeting WWH designated uses. This is done by categorizing specific attributes as indicative of either a WWH or modified warmwater habitat (MWH) (Rankin, 1995). Attributes that are considered characteristic of MWH are further classified as being a moderate or high influence on fish communities. The presence of one high or four moderate influence characteristics has been found to result in lower IBI scores, with a greater prevalence of these characteristics usually preventing a site from meeting WWH attainment (Ohio EPA, 1999).

Table 8 describes QHEI scores and physical attributes for each stream segment and determines the influence each parameter has on the QHEI score. Stickney Creek RM 1.15 and Mill Creek RM 11.52 had a total of five WWH attributes and Mill Creek RM 10.70 had seven WWH attributes. Each segment shared the following WWH attributes: boulder/cobble/gravel substrates, moderate/high sinuosity, and pools with a max depth greater than 40 centimeters. Additionally, all three sites contained one high influence MWH attributes, sparse/no cover, which negatively impacted the QHEI scores. Additionally, Stickney Creek RM 1.15 had five moderate influence MWH attributes, Mill Creek RM 11.52 had four, and Mill Creek RM 10.70 had six. Stickney Creek RM 1.15 had MWH attributes that outnumbered WWH attributes; however, both Mill Creek sites had equal MWH and WWH attributes.

Table 8. 2022 Qualitative Habitat Evaluation Index Scores and Physical Attributes.

				WWH Attributes											**MWH Attributes**																
															High Influence						Moderate Influence												
Stream	**River Mile**	**QHEI Score**	**Narrative Rating**	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max. Depth >40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or no Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW sites)	**Total High Influence Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total Moderate Influence Attributes**	**(MWH-H.I.+1) / (WWH+1) Ratio**	**(MWH M.I.+1) / (WWH+1) Ratio**
Stickney Creek	1.15	54.5	*Fair*		x		x	x		x		x		**5**				x		**1**	x			x		x			x	x		**5**	0.3	1.0
Mill Creek	11.52	49.5	*Fair*	x	x			x			x	x		**5**				x		**1**			x	x				x			x	**4**	0.3	0.8
Mill Creek	10.70	58.5	*Good*	x	x		x	x			x	x	x	**7**				x		**1**		x	x	x				x	x	x		**6**	0.3	0.9

Additionally, Figures 12 through 14 show each segment pre- and post-construction site photos. Figure 12 depicts Stickney Creek RM 1.15 pre- and post-construction. Prior to construction the stream banks were eroding into the sewer. Post-construction, stream bank erosion was addressed, higher quality in-stream habitat was established, and more natural hydrological function was restored. Some of the primary goals for the restoration project was to reestablish floodplain storage, slow stream velocities, and create more in-stream habitat. Figures 13 and 14 depict Mill Creek RMs 11.52 and 10.70 pre- and post-construction. Prior to construction, the stream segments provided little instream cover and were highly channelized. Post-construction photos show that the stream segments have been dechannelized, riparian zones are beginning to become established, and improved in-stream habitats have been created.

Figure 12. Stickney Creek RM 1.15 in 2017 (left) and 2022 (right)

Figure 13. Mill Creek RM 11.52 in 2009 (left) and 2022 (right)

Figure 14. Mill Creek RM 10.70 in 2009 (left) and 2022 (right)

Fish Community Biology Assessment

Methods

Two quantitative electrofishing passes were conducted at each site in 2022. A list of the dates when the surveys were completed, along with approved flow measurements from the United States Geological Survey gage station at available locations are shown Table 9. Sampling was conducted using longline 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 and followed the Ohio EPA 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, weighed, 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.

Table 9. Sampling Dates and River Flows

Date	Sites sampled (RMs)	Daily Mean Flow (CFS)
6/29/2022	Mill Creek RM 10.70	4.39
6/30/2022	Mill Creek RM 11.52	4.24
7/7/2022	Stickney Creek RM 1.15	---
10/10/2022	Mill Creek RM 10.70	5.98
	Mill Creek RM 11.52	
	Stickney Creek RM 1.15	---

The electrofishing results were compiled and utilized to evaluate fish community health. The Index of Biotic Integrity (IBI) incorporates twelve community metrics representing structural and functional attributes (Table 10). The structural attributes are based upon fish community aspects such as fish abundance and diversity. The 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 10. IBI Metrics
Number of indigenous fish species
Number of darter species
Number of headwater species
Number of minnow species
Number of sensitive species
Percent tolerant species
Percent omnivore species
Percent insectivore species
Percent pioneering species
Number of individuals (minus tolerants)
Number of simple lithophilic species
Percent DELT anomalies

The 2022 Stream Restorations sites are located completely within the Erie-Ontario Lake Plains (EOLP) ecoregion and follow the EOLP IBI metric scoring. The WWH IBI scoring criterion in the EOLP ecoregion is 40 and sites are considered to be within non-significant departure if the score falls within 4 IBI units of the criterion (Table 11). Lists of the species diversity, abundance, 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 11. Fish Community Biology Scores for Headwater Sites in the EOLP Ecoregion							
Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
IBI Score	12-17	18-27	28-35	36-39	40-45	46-49	50-60
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Results and Discussion

Stickney Creek RM 1.15

Electrofishing sampling surveys were conducted two times at RM 1.15 of Stickney Creek in 2022. The sampling events for RM 1.15 were calculated to have an average IBI score of 37, narratively *Marginally Good*; therefore, this stream segment was in non-significant departure of the IBI WWH designated use criterion. Results for the electrofishing surveys for Stickney Creek RM 1.15 site can be seen in Table 12 below.

Table 12. 2022 Stickney Creek Fish Community Assessment Scores

Waterbody	River Mile	1st Pass	2nd Pass	Average
		IBI	IBI	IBI
Stickney Creek	1.15	36 ns	38 ns	37ns

*Significant departure from biocriterion (>4IBI; >0.5 MIwb units). Underlined scores are in the *Poor* or *Very Poor* narrative range
ns non-significant departure from biocriterion (≤4IBI; ≤0.5 MIwb units)
E Exceptional WWH score

The first electrofishing pass on RM 1.15 was conducted on July 7, 2022. The fish assemblage collected consisted of five species, four of which are listed as pollution tolerant. No pollution-intolerant species or darter species were collected. The central stoneroller minnow (*Campostoma anaomalum)* was the most abundant of the fish collected, contributing to nearly 67.6% of the sample population and is not considered pollution tolerant; this allowed for the percent tolerant metric to positively contribute to the overall IBI. Additional positive scoring came from the low percentage of pioneering and omnivorous species and total number of fish collected. No DELTs were found to be present on the fish collected.

The second electrofishing pass occurred on October 10, 2022. The fish assemblage collected was almost identical; however, one bigmouth shiner (*Notropis dorsalis)* was present. Additionally, a larger ratio of central stoneroller minnows characterized the sample population (72.1%). The total number of fish collected during this survey was increased by 66.1% with IBI scoring of the individual metrics increasing to 38, narratively *Marginally Good*. No DELT anomalies were observed during the second survey.

From the results of the habitat assessment, the QHEI score of 54.5 falls just short of reaching the target score of 55 for warmwater habitat. Although this stream segment did not meet the QHEI target score of 55, it was in non-significant departure of the IBI WWH designated use criterion. The Stickney Creek watershed is highly developed and was greatly altered from its naturally free flowing state prior to restoration. The SNAP assessment for Stickney Creek indicated that the nutrients in the reach were typical of an enriched condition; however, the "enriched" condition has a low risk to beneficial use if allied responses are within a normal range. Connectivity from Stickney Creek to the lower Big Creek and the Cuyahoga River was once lost due to the John Nagy drop structure that acted as a fish barrier at Big Creek RM 2.10 but was only recently reestablished through the Big Creek Stabilization and dam removal project. Additionally, Stickney

Creek is extensively culverted upstream of RM 1.15 and provides little to no habitat to support aquatic life beyond this reach. The sampling zone at RM 1.15 did show an improvement from the previous fish community assessments conducted in 2017 and 2021 (Table 13 and Figure 15).

Table 13. Stickney Creek RM 1.15 Historical IBI Results

Year	Score
2017	35*
2021	32*
2022	37^{ns}

*Significant departure from biocriterion (>4IBI units).
Underlined scores are in the *Poor* or *Very Poor* narrative range
^{ns} non-significant departure from biocriterion (≤4IBI units)

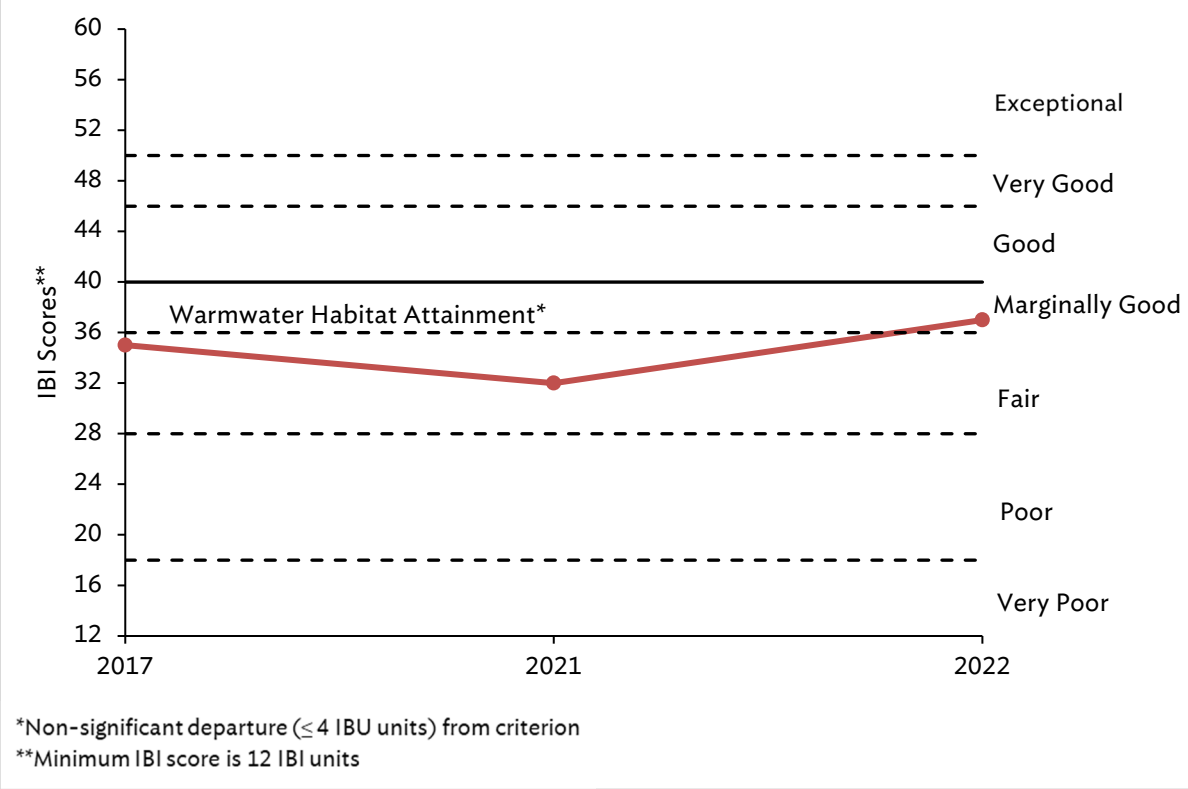

Figure 15. Historical Stickney Creek RM 1.15 IBI Scores

Mill Creek RMs 11.52 and 10.70

Electrofishing sampling surveys were conducted two times in each stream segment at RMs 11.52 and 10.70 of Mill Creek in 2022. The sampling events for RM 11.52 were calculated to have an average score of 22, narratively *Poor;* therefore, this stream segment was not in attainment of the IBI WWH designated use criterion. Additionally, the sampling events for RM 10.70 were

calculated to have an average score of 21, narratively *Poor*; therefore, this stream segment was also not in attainment of the IBI WWH designated use criterion. Results of the electrofishing surveys for both Mill Creek sites are listed below in Table 14. Additionally, historical IBI scores for both Mill Creek sites can be seen in Figure 16.

Table 14. 2022 Mill Creek Fish Community Assessment Scores

Waterbody	River Mile	1st Pass	2nd Pass	Average
		IBI	IBI	IBI
Mill Creek	11.52	22	22	22
Mill Creek	10.70	20	22	21

*Significant departure from biocriterion (>4IBI; >0.5 MIwb units). Underlined scores are in the *Poor* or *Very Poor* narrative range
ns non-significant departure from biocriterion (≤4IBI; ≤0.5 MIwb units)
E Exceptional WWH score

The first electrofishing pass at Mill Creek RM 11.52, conducted on June 30, 2022, resulted in an IBI score of 22 with a narrative rating of *Poor.* The sampling event had a species composition that consisted of 100% pollution-tolerant species. A total of 13 fish were collected from two species. The fish assemblage collected during the survey included blacknose dace (*Rhinichthys atratulus*) and creek chub (*Semotilus atromaculatus*). No DELTs were present in the sample population. RM 11.52 exhibited no key fish species collected during the sampling event under sensitive and darter species metrics for the IBI, which resulted negatively on the overall score.

On October 10, 2022, a second electrofishing pass was completed at Mill Creek RM 11.52, which resulted in an IBI score of 22 with a narrative rating of *Poor.* The sampling event had a species composition that consisted of 100% pollution-tolerant species. A total of 268 fish were collected from two species. The two species collected during the survey included blacknose dace and creek chub. No DELTs were present in the sample population. Similarly to the first pass, RM 11.52 exhibited no key fish species collected during the sampling event under sensitive and darter species metrics, which resulted negatively on the overall IBI score.

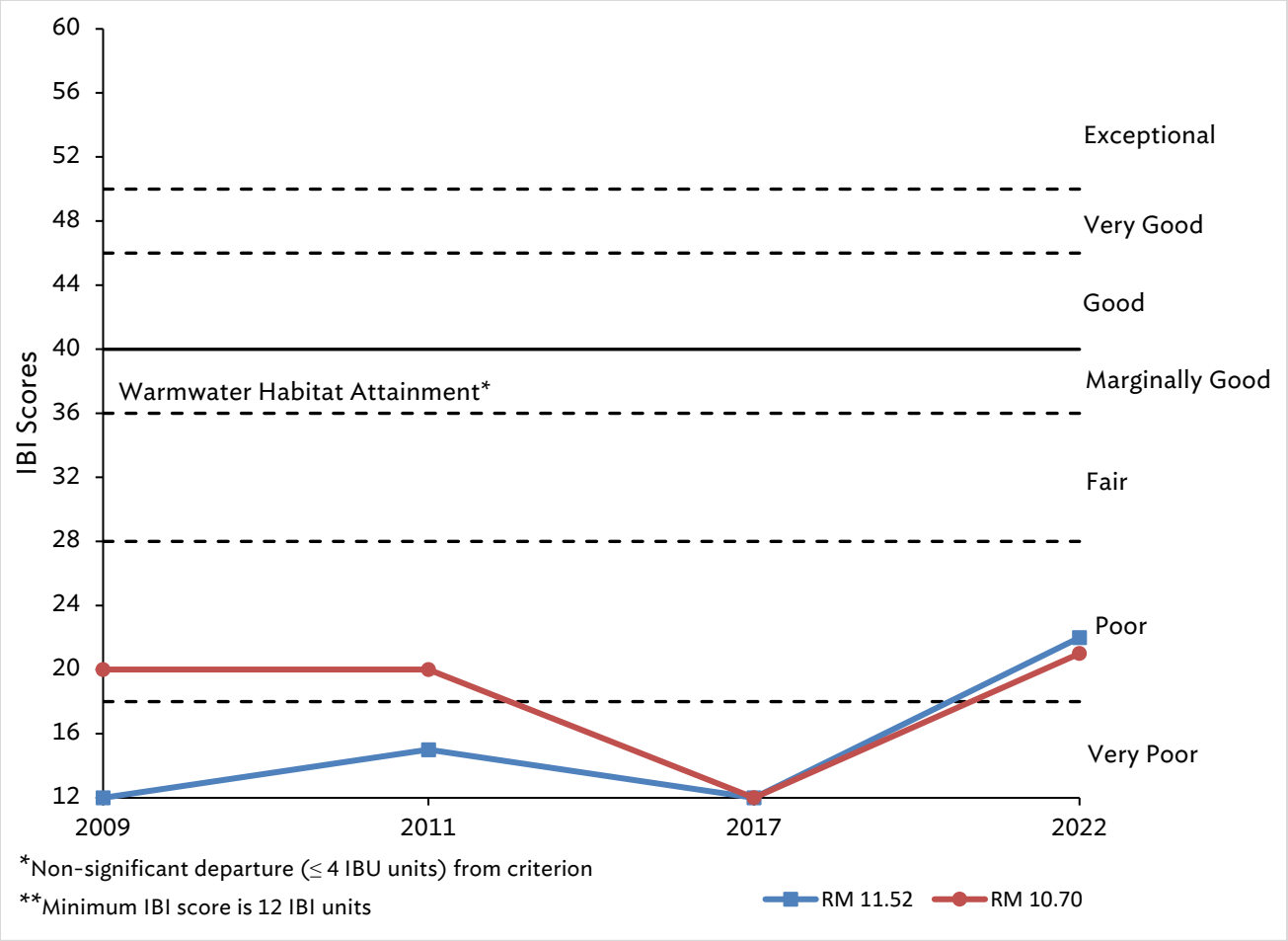

Figure 16. Historical Mill Creek IBI Scores

One electrofishing pass was completed as part of post-construction monitoring at Mill Creek RM 11.52 on June 29, 2017. The electrofishing pass resulted in a narrative rating of *Very Poor* with an IBI score of 12, which is the lowest possible score. During the pass only nine goldfish (*Carassius auratus)* were collected.

Two electrofishing passes were completed as part of pre-restoration monitoring at Mill Creek RM 11.52 in 2009 and 2011. The average IBI score was 12 and 15 with a narrative rating of *Very Poor*. Only two species and a total of 34 fish were collected between the two passes. The two species collected included creek chub and goldfish. Creek chub comprised approximately 42% percent of the population, whereas goldfish comprised approximately 58% percent of the population. Both species are pollution tolerant.

From the results of the habitat assessment, the QHEI score of 49.5 suggests that sufficient habitat does not exist to support a warmwater fauna. However, there may be additional factors contributing to the poor IBI score. This section of Mill Creek is located on a golf course and the reach has been historically channelized. Natural and artificial barriers downstream also prevent fish migration into this section of Mill Creek.

The first electrofishing pass at Mill Creek RM 10.70, conducted on June 29, 2022, resulted in an IBI score of 20 with a narrative rating of *Poor.* The sampling event had a species composition that was characterized as 100% pollution tolerant. A total of 257 fish were collected from two species. The fish assemblage observed during the survey included blacknose dace and creek chub. No DELTs were present in the sample population. RM 10.70 exhibited no key fish species collected under sensitive and darter species metrics, which negatively impacted the IBI score.

On October 10, 2022, a second electrofishing pass was conducted at Mill Creek RM 10.70, which resulted in an IBI score of 22 with a narrative rating of *Poor.* The sampling event had a species composition that was characterized as 100% pollution tolerant. A total of 524 fish were collected from two generalist taxa. The fish assemblage observed during the survey included blacknose dace and creek chub. No DELTs were present in the sample population. Similarly to the first pass, RM 10.70 exhibited no key fish species collected during the sampling event under sensitive and darter species metrics for the IBI.

On July 29, 2017, one electrofishing pass was completed at Mill Creek RM 10.70 as part of post-construction monitoring. Similarly to Mill Creek RM 11.52, Mill Creek RM 10.70 obtained the lowest possible IBI score of 12 with a narrative rating of *Very Poor*. Only pollution-tolerant species were collected, which included three creek chub and two blacknose dace.

Two electrofishing passes were completed as part of pre-restoration monitoring at Mill Creek RM 10.70 in 2011. The average IBI score was 20 with a narrative rating of *Poor*. Only three species were collected with a total of 646 fish were collected between the two passes. The three species collected included creek chub, western blacknose dace, and goldfish; however, goldfish were only collected in the second pass.

From the results of the habitat assessment, the QHEI score of 58.5 suggests that sufficient habitat exists to support a warmwater fauna. However, there may be other factors contributing to the poor IBI score. This section of Mill Creek is also located on a golf course; therefore, this section lacks a developed riparian zone and has been historically channelized.

Macroinvertebrate Community Biology Assessment

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 all locations listed in Table 1. The colonization period for HDs to be installed is six weeks.

The macroinvertebrate samples were sent to Third Rock Consultants, LLC 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 NEORSD WQIS Division.

The macroinvertebrate sampling methods followed Ohio EPA protocols as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). The overall aquatic macroinvertebrate community in the stream was evaluated using Ohio EPA's Invertebrate Community Index (ICI). The ICI consists of ten community metrics (Table 15), each with four scoring categories. Metrics 1-9 are based on the quantitative sample, while metric 10 is based on the qualitative EPT taxa collected. The sum of the individual metric scores results in the overall ICI score. This scoring evaluates the macroinvertebrate community against Ohio EPA's reference sites for each specific eco-region. The WWH ICI criterion in the EOLP ecoregion is 34 (Table 16) and a site is within non-significant departure if the score falls within 4 ICI units of the criterion.

Table 15. 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

Table 16. Invertebrate Community Index (ICI) Range for EOLP Ecoregion								
Ohio EPA Narrative	Very Poor	Poor	Low Fair	Fair	Marginally Good	Good	Very Good	Exceptional
ICI Score	0-6	8-12	14-20	22-28	30-32	34-40	42-44	46-60
Ohio EPA Status	Non-Attainment				NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment								

Results and Discussion

Stickney Creek RM 1.15

In 2022, an HD was installed at Stickney Creek RM 1.15, and a qualitative kick sample was conducted at the site when the HD was removed. Table 17 provides a summary of 2022 Stickney Creek RM 1.15 macroinvertebrate data. The benthic macroinvertebrate community at RM 1.15 was in non-attainment of the ICI WWH designated use criterion with a score of 24 (*Fair*).

Table 17. Stickney Creek Macroinvertebrate Results

Stream RM	Year	Density Qt. (ft^2) /Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. on natural substrates	ICI	Narrative Evaluation
Stickney Creek (19-005-002)								
1.15	2017	300/M-L	13/31	1 / 0	38 / 0	Baetidae, Amphipoda	24	*Fair*
	2021	957/M-L	19/30	1 / 0	49 / 0	Turbellaria, Baetidae	22	*Fair*
	2022	441/L	23/31	4/0	30/0	Turbellaria, Chironomidae	24	*Fair*

Qt. Quantitative sample collected on Hester-Dendy artificial substrates
Ql. Qualitative sample collected from natural stream substrates
Qualitative sample relative density: L=Low, M=Moderate, H=High
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List (2019) as *Moderately Intolerant*, no *Intolerant* taxa were collected

Figure 17 below shows the quantitative macroinvertebrate species composition at each site. Stickney Creek RM 1.15 had a total of 2,203 organisms collected on the HD, which included 22 taxa. A high percentage of diptera and non-insects (80.75%) and a low percentage of tanytarsini (12.66%), mayflies (3.72%), and caddisflies (2.86%) were collected from the HD.

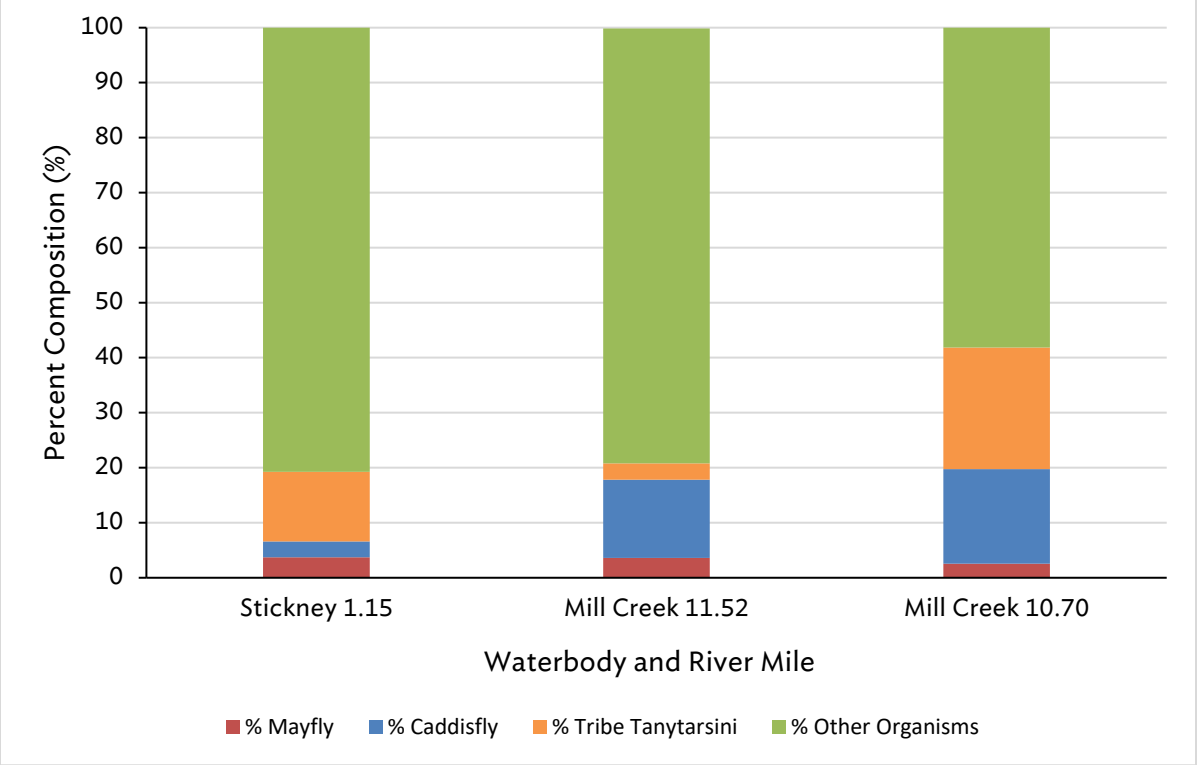

Figure 17. 2022 Macroinvertebrate Community Composition

Figure 18 shows temporal trends in ICI scores from past assessments. Post-construction ICI scores have scored similar to pre-construction scores. Additionally, Table 17 also provides historical ICI scores with additional data summaries for Stickney Creek RM 1.15. Compared to the previous records in 2017 and 2021, the Stickney Creek RM 1.15 ICI score remained the same with a narrative rating of *Fair*. The number of quantitative taxa decreased from 26 in 2017 to 22 in 2022. However, this site showed improvements in the number of qualitative taxa and qualitative EPT taxa, which suggests improvements in biodiversity and overall health of the macroinvertebrate community.

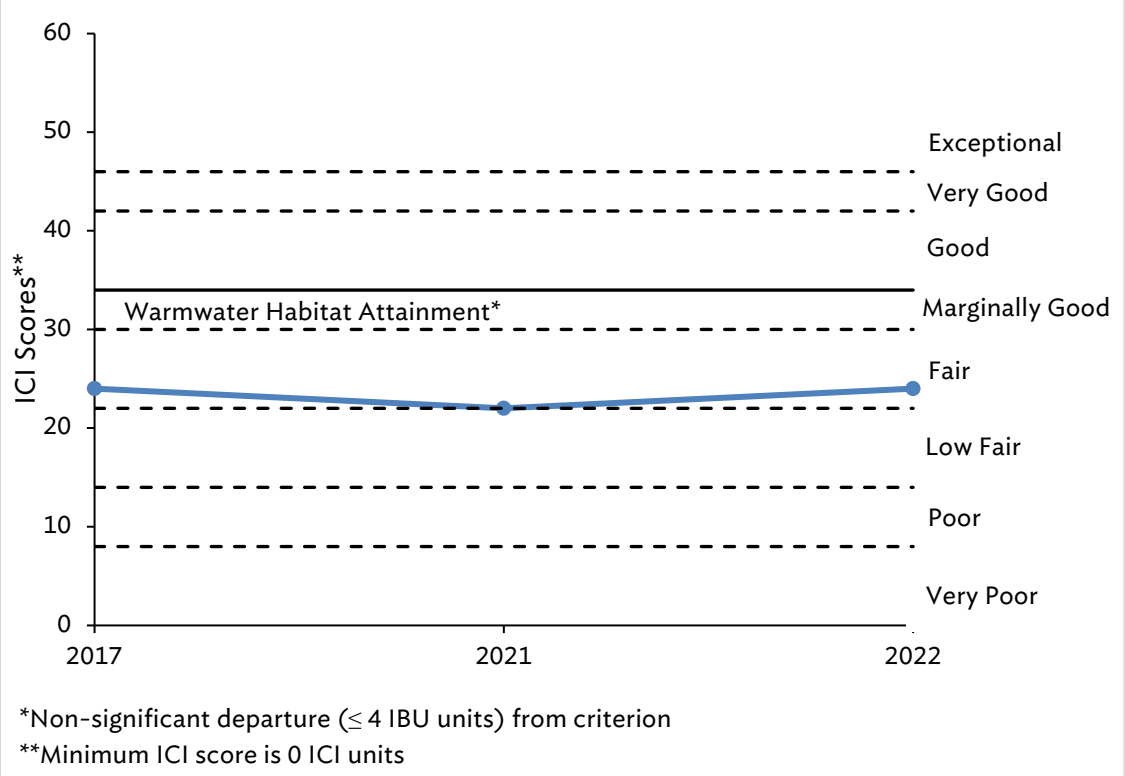

Figure 18. Historical Stickney Creek RM 1.15 ICI Scores

Mill Creek RM 11.52 and 10.70

In 2022, the HDs were installed at Mill Creek RM 11.52 and RM 10.70. Qualitative kick samples were conducted at the site when the HDs were removed. Table 18 provides a summary of 2022 Mill Creek RMs 11.52 and 10.70 macroinvertebrate data. The benthic macroinvertebrate communities at RM 11.52 and 10.70 were both in attainment of the WWH biological criterion with ICI scores of 32 (*Marginally Good*) and 36 (*Good*), respectively.

Figure 17 above shows the quantitative macroinvertebrate species composition at each site. Mill Creek RM 11.52 had a total of 1,112 organisms collected on the HD, which included 32 taxa. A high percentage of diptera and non-insects (79.5%) and a low percentage of caddisflies

(14.21%), mayflies (3.60%), tanytarsini (2.97%) were collected on the HD. The quantitative sample at Mill Creek RM 10.70 had a total of 1,606 organisms collected, which included 27 taxa. A high percentage of diptera and non-insects (57.47%) and a lower percentage of tanytarsini (22.10%), caddisflies (17.19%), and mayflies (2.55%) were collected on the HD.

Table 18. Mill Creek Macroinvertebrate Results

Stream RM	Year	Density Qt. (ft^2) /Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. on natural substrates	ICI	Narrative Evaluation
Mill Creek (19-006-000)								
11.52	2009	1029/ L	22/32	3/0	9/0	Turbellaria	28	*Fair*
	2011	664/ M-L	21/32	3/0	47/0	Chironomidae, Baetidae	22	*Fair*
	2017	1033/ H-M-L	23/34	1 / 0	20/0	Physidae, Hirudinea	24	*Fair*
	2022	222/M-L	30/42	4/0	12/0	Baetidae, Chironomidae	32	*Marginally Good*
10.70	2009	638/ L	10/27	0/0	4/0	Chironomidae, Turbellaria	30	*Marginally Good*
	2011	332/ M-L	26/35	6/0	21/0	Baetids, Chironomidae	24	*Fair*
	2017	471/ H-M-L	17/29	2/0	21/0	Simulidae, Turbellaria	24	*Fair*
	2022	321/M-L	35/39	4/0	16/0	Turbellaria, Chironomidae	36	*Good*

Qt. Quantitative sample collected on Hester-Dendy artificial substrates
Ql. Qualitative sample collected from natural stream substrates
Qualitative sample relative density: L=Low, M=Moderate, H=High
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List (2019) as *Moderately Intolerant*, no *Intolerant* taxa were collected

Figure 19 shows temporal trends in ICI scores from past assessments at both sites. ICI scores for each stream segment have surpassed pre-construction ICI scores. Additionally, Table 18 provides historical ICI scores with additional data summaries from Mill Creek RM 11.52 and 10.70. At Mill Creek RM 11.52 and 10.70, the macroinvertebrate communities scored similarly in 2011 and 2017 with a narrative rating of *Fair*; however, both sites showed improvements in their macroinvertebrate communities and increased their ICI score. The site at RM 11.52 received a score of 32 (*Marginally Good*), while the one at RM 10.70 increased to 36 (*Good*). Although RM 11.52 received a *Marginally Good* narrative score, some macroinvertebrates are particularly sensitive to elevated concentration of TDS and rapid variations can be stressful for certain populations (Miltner, 2021), which may be one reason why pollution-sensitive species were not found. Overall, though, these sites showed improvements in the number of qualitative EPT taxa, indicating continued improvements in biodiversity and health of the macroinvertebrate community.

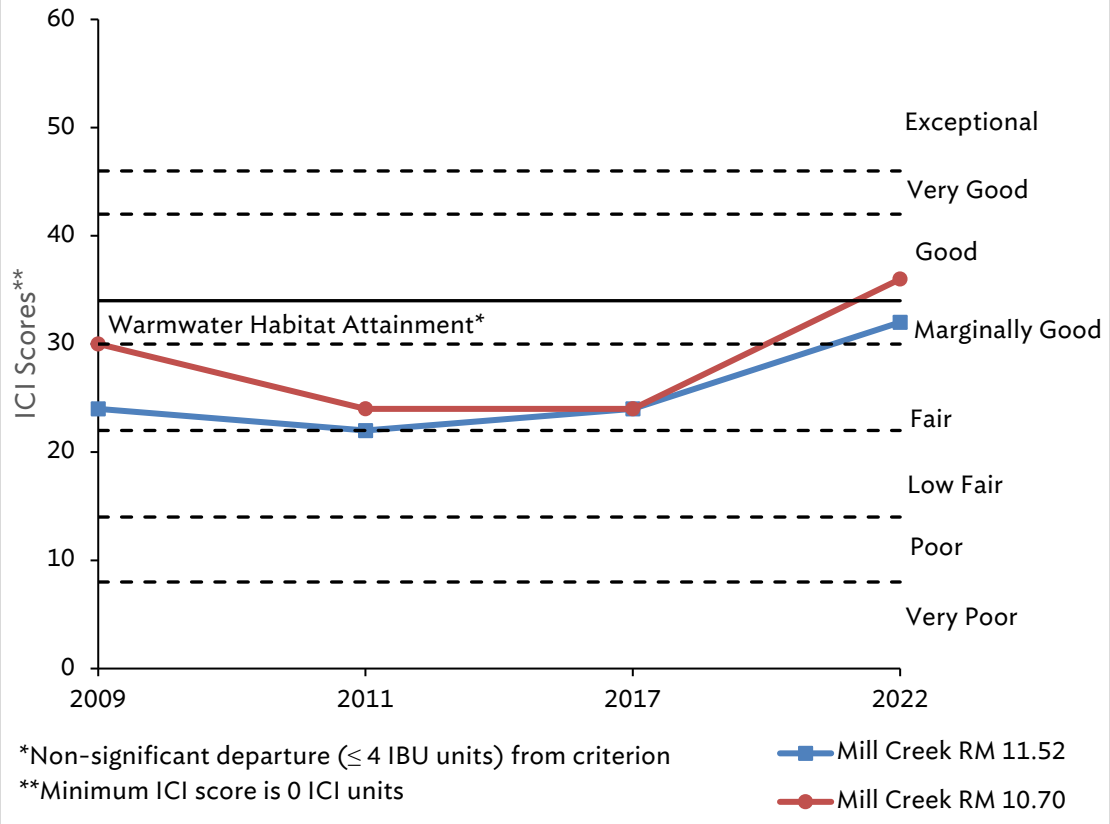

Figure 19. Historical Mill Creek ICI Scores

Conclusions

The stream segments at each site in this study are assigned an aquatic life habitat use designation defined as WWH. According to the Ohio EPA (2021), warmwater habitats are capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater organisms having a species composition, diversity, and functional organization comparable to the twenty-fifth percentile of the identified reference sites within its respective ecoregion. The results of NEORSD's 2022 Stream Restoration Projects water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys indicate limiting conditions at most sites despite the presence of generally functional habitat. Neither Mill Creek site assessed was found to be in full attainment; however, Stickney Creek RM 1.15 was found to be in partial attainment of the biological criteria for the first time since NEORSD has monitored the site (Table 19).

Table 19. 2022 Survey Results							
RM	DA (mi^2)	Attainment Status	IBI Score	ICI Score	QHEI Score	Cause(s)	Source(s)
Stickney Creek (WWH Existing)							
1.15[H]	3.2	PARTIAL	37[ns]	24*	54.5	Nutrient enrichment and Flow regime alterations	Lack of Developed Riparian Zone; Urbanization; and Urban runoff; Illicit discharges
Mill Creek (WWH Existing)							
11.52[H]	1.3	NON	<u>22</u>*	32[ns]	49.5	Flow regime alterations	Urbanization; Runoff from Golf Course; and Lack of established riparian zone
10.70[H]	1.8	NON	<u>21</u>*	36	58.5	Flow regime alterations	Urbanization; Runoff from Golf Course; and Lack of established riparian zone
*Significant departure from biocriterion (> 4ICI; > 4IBI; > 0.5 MIwb units). Underlined scores are in the *Poor* or *Very Poor* narrative range [H] Headwater scoring criteria [ns] non-significant departure from biocriterion (≤4ICI; ≤4IBI; ≤0.5 MIwb units)							

Stickney Creek RM 1.15

Stickney Creek did meet one of the necessary standards for the designated aquatic life use and obtained partial attainment status at RM 1.15 during the 2022 sampling season (Table 12). The results of water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys conducted by NEORSD indicate that the Stickney Creek watershed may be impacted by a variety of environmental stressors, as mentioned previously. From water chemistry sampling, it was found that exceedances of the applicable water quality standards occurred for *E. coli* densities during all sampling events. Stormwater runoff during wet-weather events and illicit discharges are likely responsible for the elevated *E. coli* densities found in Stickney Creek. Additionally, SNAP analysis concluded that Stickney Creek was in an enriched condition; however, nutrient concentrations have improved since the 2021 assessment.

With a QHEI score of 54.5, stream habitat in Stickney Creek was found to be in fair condition, which falls just short of the target score of 55 to support a warmwater fish community. However, it is believed that once the riparian zone is more established the habitat scores will improve. Although the habitat received a *Fair* narrative at RM 1.15, this narrative may not represent the entire Stickney Creek watershed as upstream reaches of the stream are nearly completely culverted and void of habitat.

The fish and macroinvertebrate communities received narrative ratings of *Marginally Good* and *Fair*, respectively, in 2022. Both assemblages were comprised of a high percentage of pollution-tolerant species. It should be noted that the recently removed John Nagy drop structure located downstream on Big Creek at RM 2.10 also acted as a fish barrier and eliminated connectivity of Stickney Creek to Big Creek and the Cuyahoga River. Monitoring at this site will continue to help document changes that result from elimination of illicit discharges and as the stream continues to recover from restoration activities.

Mill Creek RM 11.52 and 10.70

Mill Creek at RMs 11.52 and 10.70 did not meet the necessary standards for the designated aquatic life use and received non-attainment status at both RM 11.52 and 10.70 during the 2022 sampling season (Table 14). The results of water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys conducted by NEORSD indicate that the Mill Creek watershed may be impacted by a variety of environmental stressors, as mentioned previously. From water chemistry sampling, it was found that exceedances of the applicable water quality standards occurred for *E. coli* during all but one sampling event at RM 11.52 and 10.70. Additionally, Mill Creek RM 11.52 had exceedances on three sample dates for TDS. Stormwater runoff during wet-weather events and illicit discharges are likely responsible for the elevated *E. coli* densities and TDS found in Mill Creek.

Mill Creek at RM 11.52 had a QHEI score of 49.5, which was rated *Fair* and suggests that sufficient habitat does not exists to support a warmwater fish community. Mill Creek at RM 10.70 had a QHEI score of 58.5, which was rated *Good* and suggests that sufficient habitat exists to support a warmwater fish community. The fish communities received narrative ratings of *Poor* at both sites in 2022. The macroinvertebrate communities were *Marginally Good* and *Good* at RMs 11.52 and 10.70, respectively. Although the macroinvertebrate scores were considered to be in attainment, the *Poor* fish community scores resulted in the sites being in non-attainment of the biocriteria.

The 2011 Mill Creek assessment showed that fish species richness increased downstream of Mill Creek Falls. Due to the very small drainage area and the sites being upstream of the natural fish barrier, it is uncertain if the restoration will drastically improve fish community scores. However, five years post-construction, the IBI narrative rating has improved from *Very Poor,* which is the lowest possible narrative, to *Poor.* Additionally, macroinvertebrate community ICI scores have improved from a narrative rating of *Poor* to a narrative rating of *Good* five years post-construction. Although it is most likely these sites have stabilized post restoration, continued monitoring will be helpful to document any further improvements of the biological communities.

Acknowledgments

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

Shawn Robinson, author
Brittany Dalton
Jeff Harrison
Seth Hothem
Mark Matteson
Christina Miller
John W. Rhoades
Eric Soehnlen
Justin Telep
Analytical Services Division – Completed analysis for all water chemistry sampling
WQIS Interns- Jack King, Ian Lucic, Eric Mitchell, and Tyler Sagi

References

Mill Creek Watershed Partnership. (2022). *Highland Hill Golf Course 2015,* online at https://millcreekpartnership.org/project/highland-hills-golf-course-2015/

Miltner, R. (2021). *Assessing the Impacts of Chloride and Sulfate Ions on Macroinvertebrate Communities in Ohio Streams.* Water 2021, 13, 1815.

Ohio Environmental Protection Agency. (1999). *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams.* Columbus, OH: Division of Surface Water.

Ohio Environmental Protection Agency. (1987a). *Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters* (Updated January 1988; September 1989; November 2006; August 2008). Columbus, OH: Division of Water Quality Monitoring and Assessment.

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

Ohio Environmental Protection Agency. (1999). *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (MAS/1999-1-1). Columbus, OH: Division of Surface Water.

Ohio Environmental Protection Agency. (2003). Total Maximum Daily Loads for the Lower Cuyahoga River. Ohio EPA, Division of Surface Water. Water Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2006). *Methods for assessing habitat in flowing waters: using the Qualitative Habitat Evaluation Index (QHEI)*. (Ohio EPA Technical Bulletin EAS/2006-06-1). Columbus, OH: Division of Surface Water; Division of Ecological Assessment Section.

Ohio Environmental Protection Agency. (2021). *Surface Water Field Sampling Manual for water quality parameters and flows*. Columbus, Ohio: Division of Surface Water.

Ohio Environmental Protection Agency. (2022). *State of Ohio Water Quality Standards Ohio Administrative Code Chapter 3745-1* Columbus, OH: Division of Surface Water, Standards and Technical Support Section.

Rankin, E.T. (1995). Habitat indices in water resource quality assessments. In W.S. Davis and T. Simon (eds.). *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making* (pp. 181-208). Boca Raton, FL: Lewis Publishers.

U.S. Geological Survey (2012). *The StreamStats program for Ohio*, online at https://water.usgs.gov/osw/streamstats/ohio.html