Northeast Ohio
Regional Sewer District

2023 Stream Restoration Projects

Biological, Water Quality, and Habitat Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

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Introduction

In 2023, the Northeast Ohio Regional Sewer District (NEORSD) performed biological and water quality assessments at three sites to determine the effectiveness of recently completed, or planned restoration projects focused on improving water quality, habitat, and fish and macroinvertebrate communities. The Stickney Creek sampling location was used to assess water quality trends four years after stream restoration was completed. Sampling at the Baldwin Creek location assessed baseline water quality conditions prior to a low-head dam removal and habitat improvements. The Mill Creek sampling location was used to assess baseline conditions prior to the planned stream restoration project. All water quality surveys were conducted by the Environmental Assessment group of the NEORSD Water Quality and Industrial Surveillance (WQIS) Division.

Two stream restoration projects have been completed on Stickney Creek between river miles (RMs) 0.60 and 1.45. The *Stickney Creek Stream Relocation and Utility Repair Project* located upstream of Ridge Road (RM 1.10) was completed on November 8, 2019. This project restored more than 1,000 feet of urban stream channel where bank erosion exposed and threatened the integrity of a NEORSD sanitary sewer. Additionally, the restoration expanded existing floodplain storage, slowed stream velocities, and created more in-stream habitat. Dogwood stakes were planted along the stream banks in March of 2022 for additional streambank stabilization and to improve riparian vegetation. This project was funded by the NEORSD Regional Stormwater Management Program, with a total cost of $2,491,233.

A second project, *Stickney Creek Stream Stabilization and Floodplain Restoration Project at Ohio Veterans Memorial Park,* located just downstream of RM 1.10 was completed in 2021. This project generated more than 1,500 linear feet of natural stream system, including six acres of associated floodplain. The restoration design features included boulder toe, toe wood and buried soil riprap protection, and soil lifts with live branch layerings (Biohabitats, 2020). This project was funded by Ohio Environmental Protection Agency (EPA) Nonpoint Source Program 319 funds ($300,000) and a NEORSD Regional Stormwater Management Program matching grant ($461,000). Although the Stickney Creek sampling location for this study plan is within the upstream restoration reach, this project contributes to overall Stickney Creek habitat improvements and is worth noting.

One low-head dam remains on Baldwin Creek, located downstream of South Eastland Road at RM 1.00 located in the cities of Berea and Middleburg Heights. The Cleveland Metroparks have been approved for $706,731 in funding from an Ohio EPA, 2023 Water Pollution Control Loan to remove this dam. The NEORSD contributed $325,000 to support the acquisition of the property and demolition of structures. Three dams on Baldwin Creek were removed in 2012, downstream of the dam to be removed during this project. Biological index scores in these stream reaches improved shortly after dam removal, and the lower one mile of Baldwin Creek was in full attainment of the Aquatic Life Use (ALU) Water Quality Standard (WQS) in 2014, 2019, and 2020. The low-head dam downstream of South Eastland Road is the last major impediment isolating the Baldwin Creek headwaters from the Rocky River East Branch. This project will address the removal of the

low-head dam, creation of in-stream riffles, connection of the active floodplain along +/- 510 linear feet of the stream, removal of the existing residential structure and impervious surfaces within the floodplain, treatment for invasive plants as well as native plantings in the riparian area.

The Mill Creek stream restoration project will restore approximately 1,844 linear feet of stream channel that is currently experiencing eroding banks upstream of Northfield Road (RM 10.13) in Highland Hills. This project will raise the streambed elevation approximately 1.5 feet, redirect the stream channel away from eroding banks, install grade control riffles, and stabilize eroding streambanks using stone. Three floodplain benches will be created in abandoned stream sections, restoring approximately 1.75 acres of existing floodplain (Ohio EPA, 2023a). This project will be led by the West Creek Conservancy, with a total project estimate of $355,016. Funding will be provided by an Ohio EPA Nonpoint Source Program 319 fund, along with NEORSD Regional Stormwater Management Program matching funds.

Sampling was conducted by NEORSD Level 3 Qualified Data Collectors (QDCs) certified by the Ohio EPA in Fish Community Biology, Benthic Macroinvertebrate Biology, Chemical Water Quality, and Stream Habitat Assessments as explained in the NEORSD study plan *2023 Stream Restoration Projects Environmental Monitoring*. All sampling and environmental assessments occurred between June 15, 2023, and September 30, 2023 (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* (2023b) and compared to the Ohio Water Quality Standards for their designated use to determine attainment (Ohio EPA, 2023c). 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 RM, latitude/longitude, description, and surveys conducted. A digital photo catalog of the sampling locations is available upon request by contacting the WQIS Division.

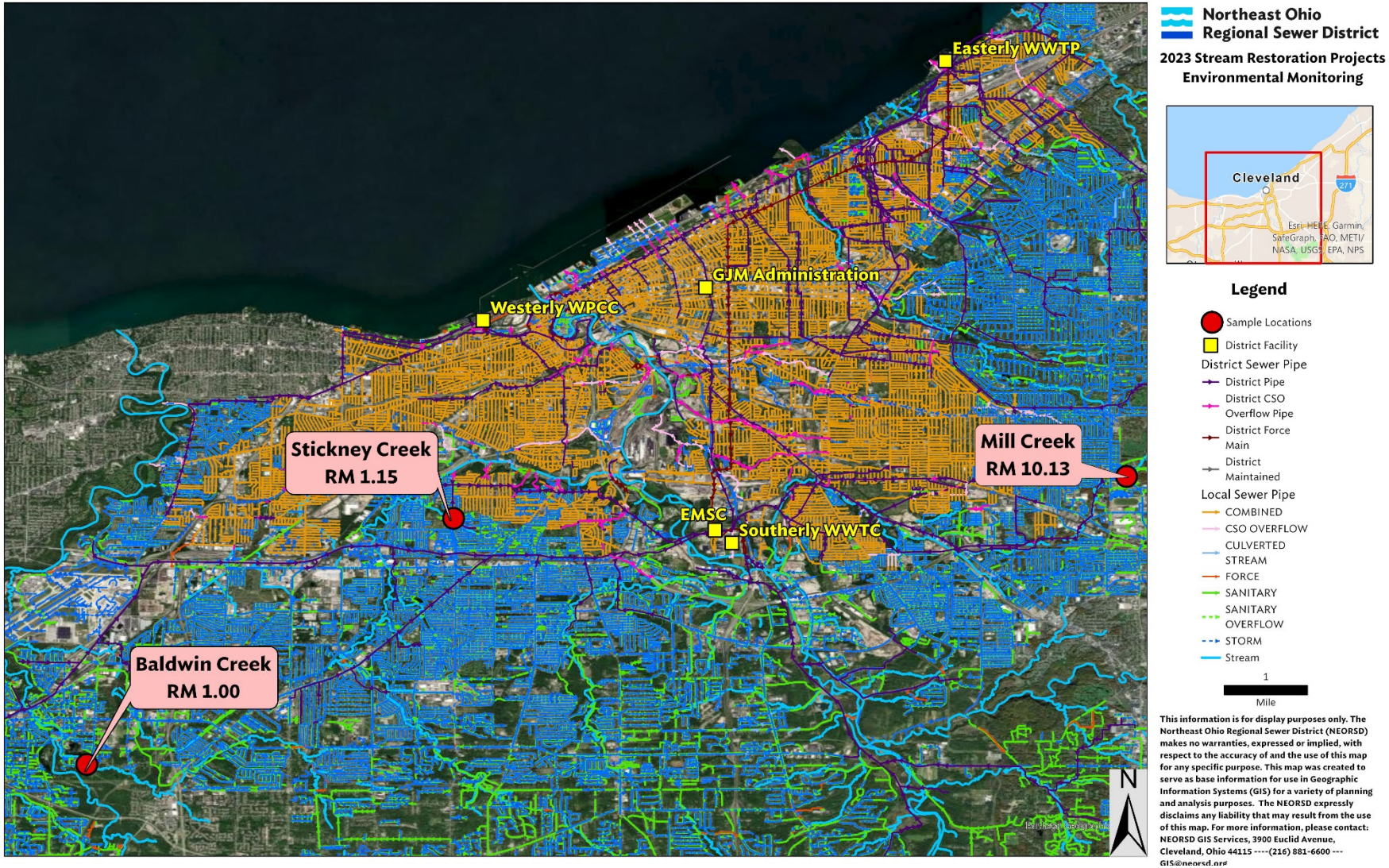

Figure 1. 2023 Stream Restoration Project Sampling Locations

Table 1. 2023 Stream Restoration Projects Sampling Locations									
Waterbody	Lat	Long	River Mile	Drainage Area	Station ID	Location Information	USGS HUC 12	Project Name	Purpose
Baldwin Creek	41.3586	-81.8462	1.00	9.60 mi^2	T01W59	Baldwin Creek downstream of South Eastland Road	041100010202 Baldwin Creek-East Branch Rocky River	Baldwin Creek low-head dam removal	Evaluate water chemistry, habitat, fish & macroinvertebrates pre-dam removal
Mill Creek	41.4460	-81.5312	10.13	2.60 mi^2	F01P08	Upstream of Northfield Road	041100020601 Mill Creek	Mill Creek restoration at University Hospital	Evaluate water chemistry, habitat, fish & macroinvertebrates pre-construction
Stickney Creek	41.4334	-81.7351	1.15	3.17 mi^2	303948	Upstream of Ridge Road	041100020603 Big Creek	Stickney Creek Restoration	Evaluate water chemistry, habitat, fish & macroinvertebrates post-construction

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 2023 Restoration Projects are listed below in Table 2 (Ohio EPA, 2023c).

Table 2. Beneficial Use Designations for 2023 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
Baldwin Creek at RM 0.48		+						+	+	+		+	
All other sections		+							+	+		+	
Mill Creek		+							+	+		+	
Stickney 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 28, 2023, and July 26, 2023, 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* (2023b). 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 of 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, 2023c).

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 flow data from Baldwin Creek (Figure 2) and Mill Creek (Figure 3) are shown below. There is no flow data available for Stickney Creek, but flow is assumed to be proportional to the figures below.

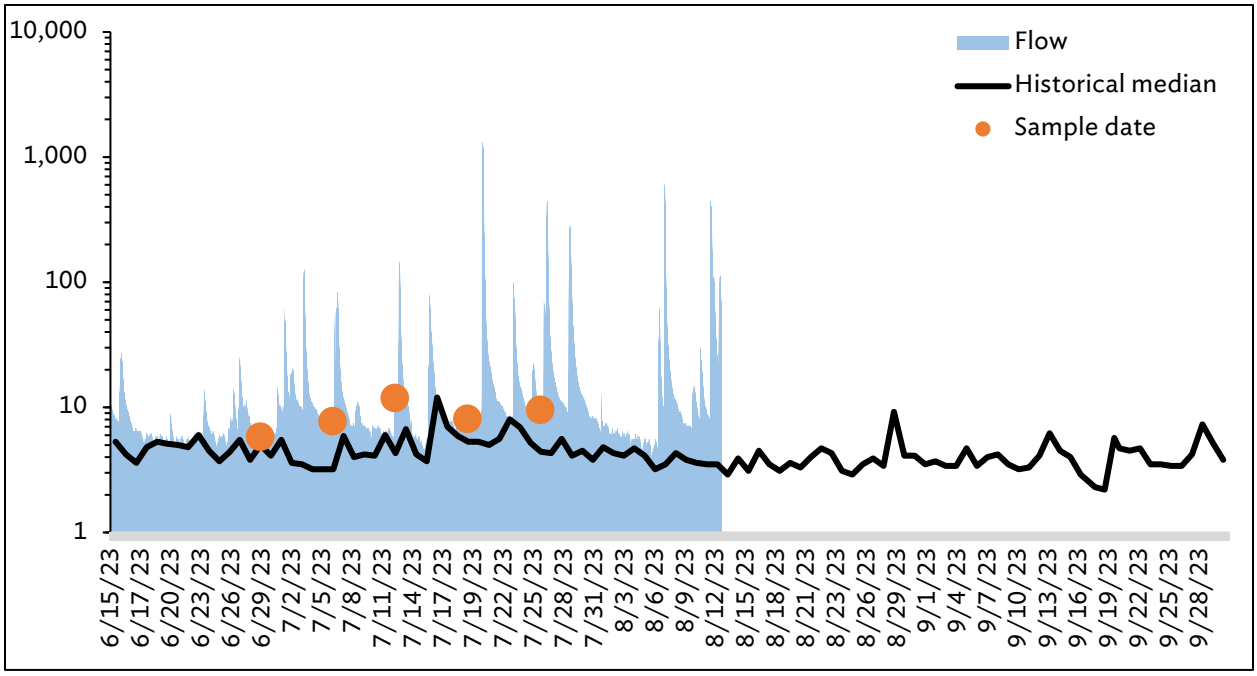

Figure 2. USGS Baldwin Creek 04201495 flow data and sampling dates.

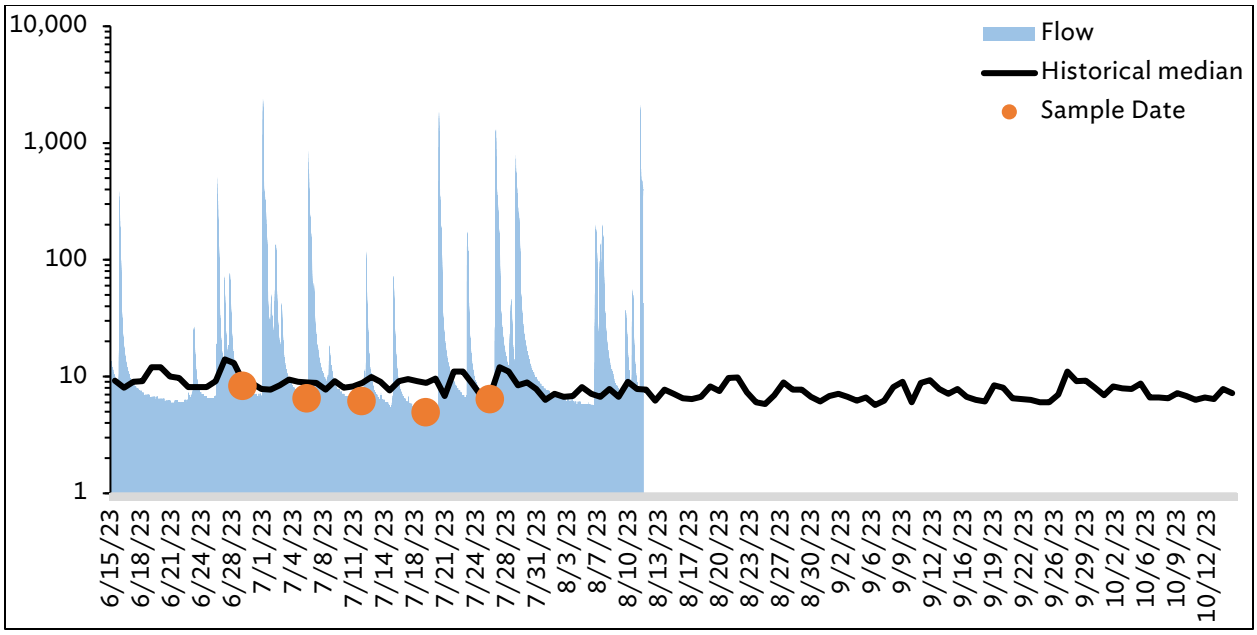

Figure 3. Mill Creek USGS 04208460 flow data and sampling dates.

Results and Discussion

Quality Assurance / Quality Control

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 Stickney Creek RM 1.15 on July 12, 2023. The chemical parameter total strontium was rejected based on RPD values outside of the acceptable RPD range for this sample (Table 3).

Table 3. Replicate Sample with RPDs Greater than Acceptable

Site Location	Date	Parameter	Acceptable RPD	Actual RPD
Stickney Creek	7/12/2023	Strontium, Total	12.5	15.5

The field blank sample was collected on July 06, 2023, at Baldwin Creek RM 1.00. Results from the field blank 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. No paired parameters needed to be qualified based on approved results.

Recreational Use Results and Discussion

Attainment of the primary contact recreation (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, 2023c). 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.

Of the fifteen total samples, eighty percent of the samples taken exceeded the STV of 410 colony counts/100mL, resulting in PCR impairment at all sampling sites in 2023. Additionally, all three streams exceeded the 90-day geometric mean criterion of 126 colony counts/100mL (Table 4). Two of the five sampling dates were following a wet-weather event, which may lead to elevated *E. coli* densities due to urban runoff and potential sanitary sewer overflows. *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. The NEORSD has identified numerous active improper sanitary connections in the City of Parma tributary to Stickney Creek that have yet to be remediated. This is likely the primary cause of the elevated *E. coli* results in Stickney Creek.

Table 4. 2023 *E. coli* Densities (MPN/100mL)

Date	Baldwin Creek RM 1.00	Mill Creek RM 10.13	Stickney Creek RM 1.15
6/28/2023*	1,164	1,230	7,945
7/6/2023*	857	273	5,199
7/12/2023	1,300	365	1,472
7/19/2023	579	435	1,203
7/26/2023	816	210	1,986
90-day Geomean	907	407	2,707

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.

Since one of the primary objectives of the Stickney Creek stream restoration project was to eliminate erosion causing sanitary contamination from a local sanitary sewer, more recent post construction (2021-2023) results were compared to pre-restoration bacteria results. Figure 4 below displays a boxplot of *E. coli* densities throughout the four assessment years. The pre-restoration boxplot contained the highest maximum and upper quartile results, although the values were not significantly different than recent years. Background *E. coli* densities in Stickney Creek from illicit discharges are likely masking a more substantial decrease in bacteria.

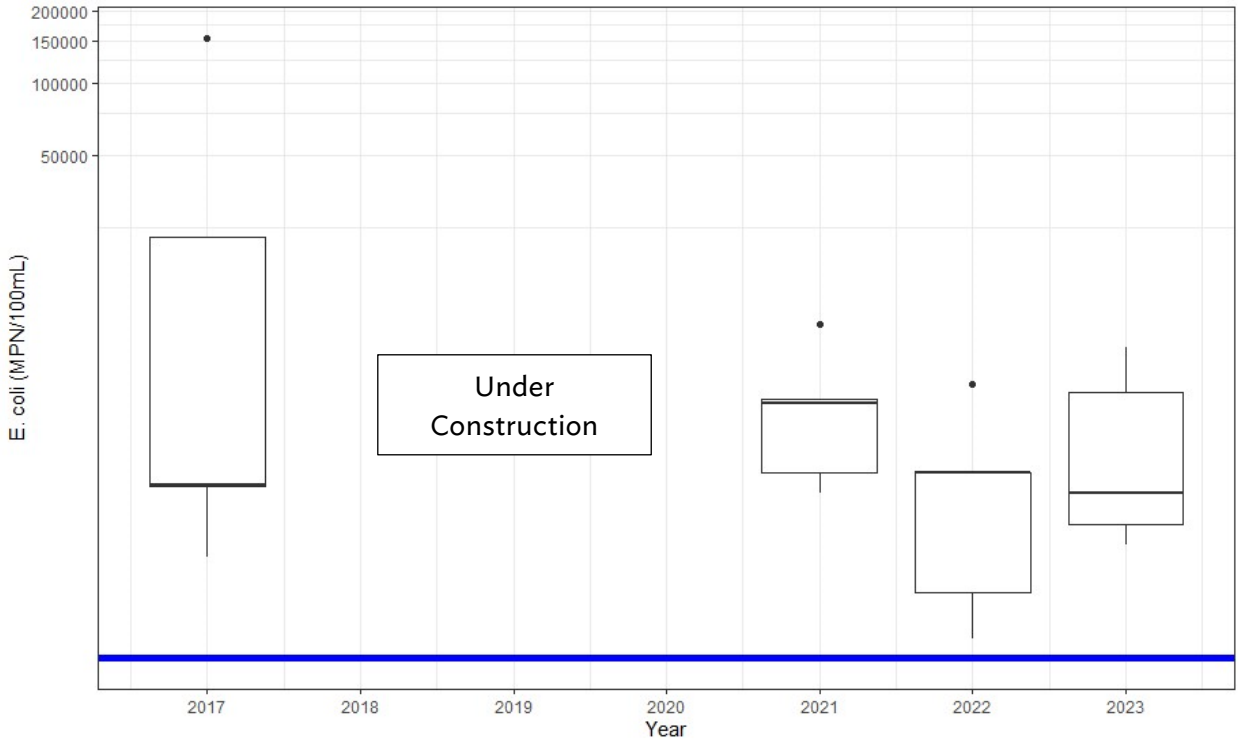

Figure 4. Box Plot for Stickney Creek *E. coli* densities from all four assessment years. The blue line represents the *E. coli* STV WQS value of 410 MPN/100mL.

Water Column Chemistry Results and Discussion

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 detected in all three streams above the detection limit on the same day, July 26, 2023. All three sample results were estimated results between 0.027-0.029 ug/L, resulting in exceedance of the Human Health Nondrinking and Protection of Wildlife OMZAs.

One sampling event on Mill Creek exceeded the Aquatic Life Outside Mixing Zone Maximum (OMZM) for zinc. While the results of the four other samples from Mill Creek were either below or near the detection limit of 5.5 ug/L, the July 26, 2023, result was 102 ug/L, exceeding the hardness-based calculated OMZM criteria of 100.4 ug/L. Mill Creek also had the highest specific conductivity values, averaging 1,467 uhoms/cm over the five sampling events. Elevated conductivity values correlate well with increasing chloride anion concentrations, which have been well documented in Mill Creek above the US EPA chronic chloride criterion value of 230 mg/L (Ohio EPA 2023e, USEPA 1988).

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 (Ohio EPA, 2015). 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 (DIN; ammonia + nitrate-nitrite). NEORSD did not assess DO swings or benthic chlorophyll *a* in 2023; however, nutrient concentrations were assessed. Figure 5 shows the risk categories from the SNAP table 2. The Ohio EPA also uses causal associations to determine the risk association between nutrients (TP and DIN) and biological performance. Table 5 lists the annual 2023 geomeans and the narrative risk categories based on Miltner (2010).

		← 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 5. Table 2 of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015)

Table 5. Nutrient Analysis (Geometric Means)						
Waterbody	River Mile	DIN (mg/L)	NO_3-NO_2 (mg/L)	DRP (mg/L)	TP (mg/L)	Risk Category[R]
Baldwin Creek	1.00	6.41	6.20	0.06	0.15	High
Mill Creek	10.13	0.23*	0.19*	0.014	0.04*	Low
Stickney Creek	1.15	1.12	1.08	0.23	0.25	Mod

* Geomean calculations based on four sample results instead of five

[R] Risk Categories based on Miltner (2010)

Risk Category	**Total Phosphorus**	**DIN**
Low	<0.131	<3.6
Medium	≥0.131 and <0.4	<3.6
High	≥0.4	≥3.6

Baldwin Creek received a SNAP narrative rating of an enriched condition with generally high risk to beneficial uses and fell into the high-risk category based on Ohio EPA, 2015b. The nutrient concentrations from Baldwin Creek also resulted in a moderate-high risk using the causal association risk values (Figure 6). The DIN concentrations are the most elevated; however, TP concentrations also fell into the moderate risk narrative.

The North Royalton Wastewater Treatment Plant (WWTP) B discharges effluent to Baldwin Creek at RM 7.30 and the Strongsville C WWTP at RM 2.90. The average design flow Baldwin Creek receives from the two WWTPs is 2.8 million gallons per day (MGD), or 4.31 cubic feet per second. The more oxidized nitrogen form of nitrate-nitrite (NO_3-NO_2) discharging from these WWTPs is elevating the total DIN concentrations observed in Baldwin Creek. Neither plant has a National Pollution Discharge Elimination system (NPDES) permit limit for NO_3-NO_2 since the objective is to oxidize raw ammonia to NO_3-NO_2 via nitrification. The North Royalton WWTP B discharges NO_3-NO_2 at a much higher concentration, averaging 15.59 mg/L from the 2023 summer months of April through October, compared to the Strongsville C WWTP, which averages 0.59 mg/L (USEPA, ECHO). Elevated NO_3-NO_2 concentrations have not shown a correlation to diel DO swings compared to elevated TP (Ohio EPA, 1999) and are not as detrimental to aquatic life until concentrations exceed 3 mg/L. Median NO_3-NO_2 concentrations on Baldwin Creek were 7.26 mg/L, suggesting a potential stress to aquatic life.

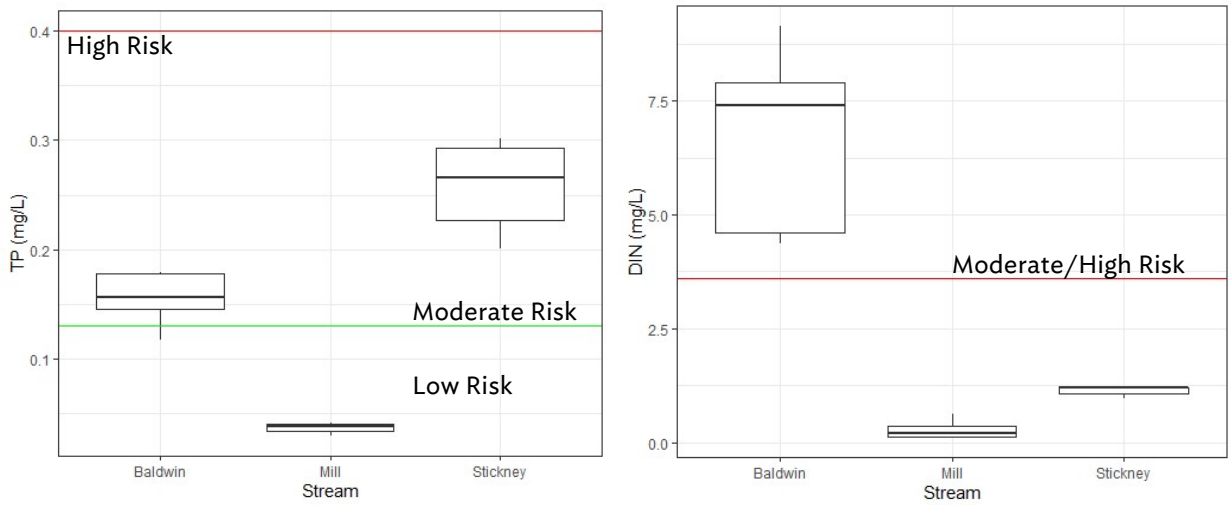

Figure 6. TP and DIN concentrations and Risk Categories for the streams assessed in 2023. Risk categories are based on Miltner (2010).

Mill Creek contained low nutrient concentrations, typical of background levels and a low-risk category for both the SNAP and causal association risks. This small headwater stream drains only 2.8 square miles of highly urban (89.5%) land cover and does not receive any WWTP effluent. The majority of the Mill Creek main channel for 2 miles upstream flows through the recently restored Highland Park Golf Course. This restoration project removed a highly channelized section of Mill Creek while restoring natural stream meandering and floodplain access and may have led to lower nutrient concentrations by allowing natural processes and nutrient uptake through this stretch.

Nutrient concentrations in Stickney Creek were typical of enriched conditions and a moderate risk based on the TP geomean. Known illicit sanitary conditions upstream of this sample location remain unresolved by the local municipality. The upstream watershed is 98.8% developed, densely urbanized, and the stream is predominately culverted. Stormwater runoff from highly urbanized watersheds is commonly associated with higher concentrations of bacteria, nutrients, and solids (Bannerman et al., 1993; Geldreich et al., 1968). These concentrations are exasperated during wet-weather events in urban watersheds (Mallin et al., 2008). Elevated nutrients, particularly TP, can also result in wide diel DO swings due to increased algal growth via respiration and photosynthesis (Ohio EPA, 1999). Although a long-term data sonde deployment was not used to measure diel DO swings, grab DO saturation values are good indicators of over-enrichment when saturation exceeds 120% (Ohio EPA, 2023d). The grab sample on July 26, 2023, was recorded at 120%, and one sample in 2022 was recorded at 136%, further suggesting nutrient enrichment in Stickney Creek. Sanitary sewage contamination from illicit connections and the highly urban landscape of the upstream watershed are likely the primary sources of nutrients. The continued growth of a wooded riparian zone can effectively reduce nutrient concentrations locally (Rankin et al., 1999); however, the overall land use of the upstream watershed will remain the same.

Nutrients are evident in raw wastewater as organic nitrogen and phosphorus. The restoration project on Stickney Creek removed a major source of sanitary sewage from a leaking sewer. Even though this source has been removed, major nutrient values were not significantly reduced. An analysis of variance was used to determine significant differences in means of nutrient parameters, followed by a t-test to determine which years contained different mean values. Ammonia and DIN concentrations were significantly higher ($p<0.05$) in 2021 (Figure 7) than all other years. Overall, there are no trends in nutrient reduction since project completion.

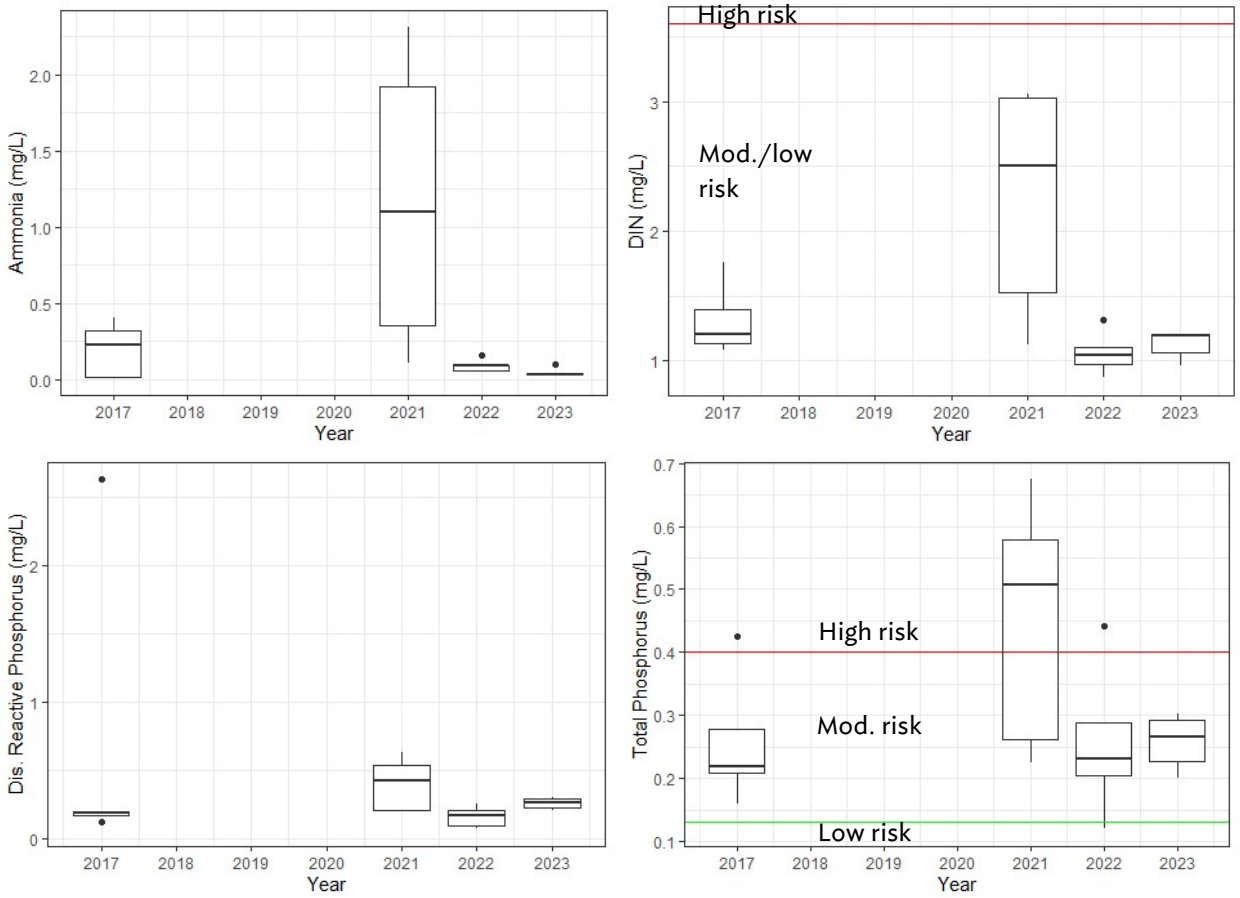

Figure 7. Stickney Creek annual nutrient concentrations boxplot. The stream restoration construction was in 2018-2019. The red lines represent the lower bound for the high-risk narrative rating and the green line represents the upper bound for the low-risk narrative rating (Miltner, 2010).

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site in 2023 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

Baldwin Creek, Mill Creek, and Stickney Creek all met the Ohio EPA Warmwater QHEI target score of 55 for headwater streams. Individual stream habitat metrics are discussed in the sections below.

Baldwin Creek RM 1.00

Baldwin Creek at RM 1.00 was assessed before the low-head dam is removed and other stream restoration efforts are completed. The QHEI assessment at Baldwin Creek RM 1.00 received a score of 62.50 (*Good*). The most prominent types of substrate present consisted of gravel and sand with a moderate silt narrative. This section is currently recovering from channelization, with low overall sinuosity, simply due to being impounded (Figure 8). A moderate amount of instream cover consisted of undercut banks, deep pools, overhanging vegetation, rootwads and rootmats, woody debris, and shallows in slow water. No riffle or run habitat was documented in the sampling reach. Deep pools were present due to the dam structure, allowing solids to settle and moderately embed the underlying

Figure 8. Baldwin Creek dam pool.

substrates.

Mill Creek RM 10.13

Mill Creek at RM 10.13 was assessed prior to a major stream restoration project. The QHEI assessment at Mill Creek RM 10.13 scored a 72.75 (*Excellent*). The most prominent types of substrate present consisted of cobble and gravel with a normal silt narrative. Moderate sinuosity, with shallow riffles and deeper pools resulted in fair to good development. A moderate amount of instream included undercut banks, rootmats and rootwads, deeper pools, and woody debris.

Figure 9. Erosion and lack of riparian buffer on Mill Creek.

Erosion in this area is exasperated by the lack of riparian wooded vegetation on river right. A mowed grassy area is nearly exposed with the last row of immature trees hanging over the stream channel (Figure 9). These eroding banks are proposed to be protected with a rock toe. The stream channel downstream of the sharp, eroding bends are planned to be widened with a floodplain bench in the immediate downstream sections.

Stickney Creek RM 1.15

The QHEI assessment at Stickney Creek RM 1.15 scored a 57.00 (*Good*), meeting the Ohio EPA WWH headwater stream target of 55. Prior to the restoration project, the QHEI score was 59.75 and has not fully recovered to pre-restoration habitat quality. The amount of instream cover present was the major QHEI scoring difference, scoring four points higher during the pre-restoration assessment.

The most prominent types of substrate present consisted of cobble and gravel with a normal silt narrative. Although this stream has been restored to improve sinuosity, and riffle, run, and pool sequences, it still received a recovering channel morphology score due to the anthropogenic influences. The stream is not necessarily channelized, rather it is moderately to highly sinuous, and contains artificially placed limestone boulders to stabilize the low-flow stream channel. Uniquely placed logs perpendicular to the flow are anchored into the banks creating a thalweg for run development. The development of the riffle/run/pool complexes was fair, mostly

due to the lack of pool depth. A sparse to moderate amount of instream cover included an increased abundance of overhanging vegetation (Figure 10), newly forming aquatic macrophytes, and shallows in slow water compared to previous habitat assessments. The lack of wooded riparian vegetation lowered the score and is typical of newly restored stream sections. As the riparian zone matures, woody vegetation should grow and offer shade and riparian protection.

Figure 10. In-stream overhanging vegetation in Stickney Creek.

Figure 11 below shows Stickney Creek before (left) and after (right) restoration. In 2023, the riparian area is beginning to establish wooded growth, tall grasses, and shrubs. A few small trees were planted in 2017 during the restoration and are growing, but still provide no shade for the stream. Although the riparian grass and shrub offer limited shade relief, they do provide important bank stabilization features for the stream. The 2023 picture also shows the floodplain access the river has on both sides of the stream. During high-flow conditions, the river will rise into the floodplain while the vegetation may allow for solids and nutrients to settle. Over time, the trees planted in the riparian area will offer some woody protection for Stickney Creek.

Figure 11. Stickney Creek RM 1.15 in 2017 (left) and in 2023 (right).

The sample location 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. The lack of a riparian buffer to provide shade over the stream channel, along with artificial limestone and excess nutrients are likely driving the benthic algae growth observed earlier in the summer months.

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 (Rankin et al., 1999).

Table 6 describes QHEI scores and physical attributes for each stream segment and determines the influence each parameter has on the QHEI score. Typically, as MWH/WWH ratios increase above 2:1, the potential for instream habitat to cause biological impairment increases. Baldwin Creek displayed the highest number of MWH attributes and the highest MWH:WWH attribute ratio at 2:1. Both Mill Creek and Stickney Creek scored well for WWH attributes compared to MWH attributes and the MWH:WWH ratios were both 0.40.

Table 6. 2023 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**	**(MWH-H.I.+1) / (WWH+1) Ratio**	**(MWH M.I.+1) / (WWH+1) Ratio**
Baldwin Creek	1.00	62.50	*Good*		X				X			X		**3**						**0**	X	X		X	X			X	X			**7**	0.3	2.0
Mill Creek	10.13	72.75	*Excellent*	X	X		X	X	X		X	X	X	**8**						**0**				X				X		X		**3**	0.1	0.4
Stickney Creek	1.15	57.00	*Good*		X			X	X		X	X	X	**6**				X		**1**	X			X				X				**3**	0.3	0.4

Fish Community Biology Assessment

Methods

Two quantitative electrofishing passes were conducted at each site in 2023. 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 7. 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, 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 7. USGS Flow Data for Electrofishing Surveys

Date	Sample Locations	Daily Mean Flow (CFS)
6/29/23	Stickney RM 1.15	6.58
8/22/23	Baldwin RM 1.00 Mill RM 10.13	4.73 6.57
9/15/23	Stickney RM 1.15	3.22
9/21/23	Baldwin RM 1.00	4.86
9/22/23	Mill RM 10.13	3.92

Baldwin Creek measured at USGS 04201495
Mill Creek measured at USGS 04208460
Stickney Creek measured at Big Creek E. Br. USGS 042085017

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 8). 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 8. IBI Metrics
Number of indigenous fish species
Number of darter species
Number of sunfish species
Number of sucker species
Number of intolerant species
Percent tolerant species
Percent omnivore species
Percent insectivore species
Percent of top carnivore species
Number of individuals (minus tolerants)
Percent of simple lithophilic spawners
Percent DELT anomalies

The 2023 Stream Restorations sites are located completely within the Erie-Ontario Lake Plains (EOLP) ecoregion and follows the EOLP IBI metric scoring. An IBI score of 40 in this ecoregion meets the WWH WQS and sites are within non-significant departure (NSD) if the score falls within 4 IBI units of the criterion (Table 9). 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 9. 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

The NEORSD collected 8,220 fish among 16 species while surveying these three sampling locations. Table 10 lists a summary of the fish community biological scores for all three sample locations.

Table 10. 2023 Fish Community Assessment Scores

Stream RM	Total no. of species	Predominate species (%)	Rel. no./ less tolerants	IBI Score		
				1st Pass	2nd Pass	Average
Baldwin Creek						
1.00	14	White sucker (55.0%) Creek chub (13.9%) Bluntnose minnow (9.4%)	1,017/130	22*	22*	22*
Mill Creek						
10.13	4	Blacknose dace (49.9%) Creek chub (49.9%) Golden shiner (0.1%)	1,482/0	20*	24*	22*
Stickney Creek						
1.15	6	Central stoneroller (81.5%) White sucker (5.9%) Bluntnose minnow (5.0%)	5,721/ 4,665	36ns	40	38ns

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

Baldwin Creek RM 1.00

Although Baldwin Creek contained by far the most diverse fish community with fourteen total species, consecutive IBI scores of 22 reflect the *Poor* fish community. In Ohio headwater streams, darter, headwater, and simple lithophilic spawning species are important components in the IBI scoring. Zero darter and one headwater species (blacknose dace) were collected. Only two simple lithophilic spawning species were collected, lowering the score for this metric. Pollution-tolerant fish predominated the fish community at 85% and 89% percent, and the highly tolerant white sucker comprised more than half of the total fish collected. One lone pollution-sensitive sand shiner was collected, demonstrating the inability of this section of stream to support a high-quality fish community. One notable fish that was collected was the bigmouth shiner (*Notropis dorsalis*), which is a state threatened species only found in a select few stream sections in the Rocky River and Cuyahoga River watersheds.

Stream habitat plays a major role in the fish community observed in this section of Baldwin Creek. The dam pool sampling zone consists of slow moving, deeper water which is suitable for many lentic and pool-dwelling species. The lack of any resemblance of riffle habitat contributed to the absence of darter and headwater species. This fish community reflects more of a lake or estuary community due to the physical habitat limitations. Suspended sediments drop out in the dam pool due to the lack of current velocity and inability to export sediments. Sediment accumulation depths upstream of the dam are approximately 6-8 feet and are nearly topped out with the crown of the dam. These sediments smother the substrates in fine sand, gravel, and silt

and do not offer the interstitial spaces between rocks for simple lithophilic spawning fish to successfully spawn.

The Cleveland Metroparks is leading the efforts to remove the low-head dam, remove accumulated sediments in the streambed, improve floodplain access, and restore the riparian zone. The biological improvements this project will have on the stream should be observed immediately. The downstream fish community biology scores have scored *exceptional* during the last three community assessments. Sixteen native fish species, including three darter species, were collected in 2020 by the NEORSD. Species that have commonly been collected since 2014 downstream of the dam, but are absent upstream, include the northern hogsucker, silverjaw minnow, johnny darter, and rainbow darter. With the removal of this dam as the last physical barrier in Baldwin Creek, these high-quality fish are likely to migrate back upstream and recolonize the newly restored section of stream.

Mill Creek RM 10.13

The fish community in Mill Creek at RM 10.13 is highly simplified and averaged an IBI score of 22 (*Poor*). Only four highly-tolerant fish species were collected, which is consistent with the 2022 NEORSD data at RMs 10.70 and 11.52. No darters, one simple lithophilic spawning species, and no sensitive species were collected. In-stream habitat scores suggest suitable habitat exists in Mill Creek to support a WWH fish assemblage. The urban watershed of Mill Creek poses its own stormwater quantity-related issues and is surely a leading cause to the erosion resulting in the need for this restoration project. Urban stormwater pollutants, as evident by the zinc outside mixing zone criterion exceedance and elevated conductivity values, are likely compounding stressors to local aquatic life.

Two fish barriers in Mill Creek prevent fish from recolonizing the upstream reaches. The natural Mill Creek falls at RM 2.80 and a stormwater retention basin at RM 7.60 eliminate any possible fish migration upstream. The stretch of Mill Creek downstream of RM 2.80 has mostly achieved WWH attainment for the fish community biology component as recently as 2016 when assessed by the NEORSD. Common fish species that have recolonized this section of lower Mill Creek include striped shiner, common shiner, spotfin shiner, sand shiner, as well as low abundances of johnny, greenside, and rainbow darters. Although these barriers prevent fish passage upstream, the Ohio EPA has noted that the urban watershed development remains a profound stressor to the aquatic communities and would likely preclude the fish assemblages from meeting the WWH criterion through the upper reaches of Mill Creek (Ohio EPA, 2023e).

Stickney Creek RM 1.15

Stickney Creek has been assessed for four separate years since 2017. Fish IBI scores have increased slightly from an average of 35 (*Fair*) in 2017 before the stream restoration project to an average of 39 (*Marginally Good*) in 2023 (Figure 10). The 2023 sampling year marks the second consecutive year that Stickney Creek has met NSD of the WWH criterion. The 2023 fish community

consisted of six total species, totaling 5,721 fish during the two electrofishing surveys. Five of the six species collected are listed as highly tolerant to pollution, with the sixth fish being the herbivorous central stoneroller minnow. Once again, no pollution-sensitive species were collected.

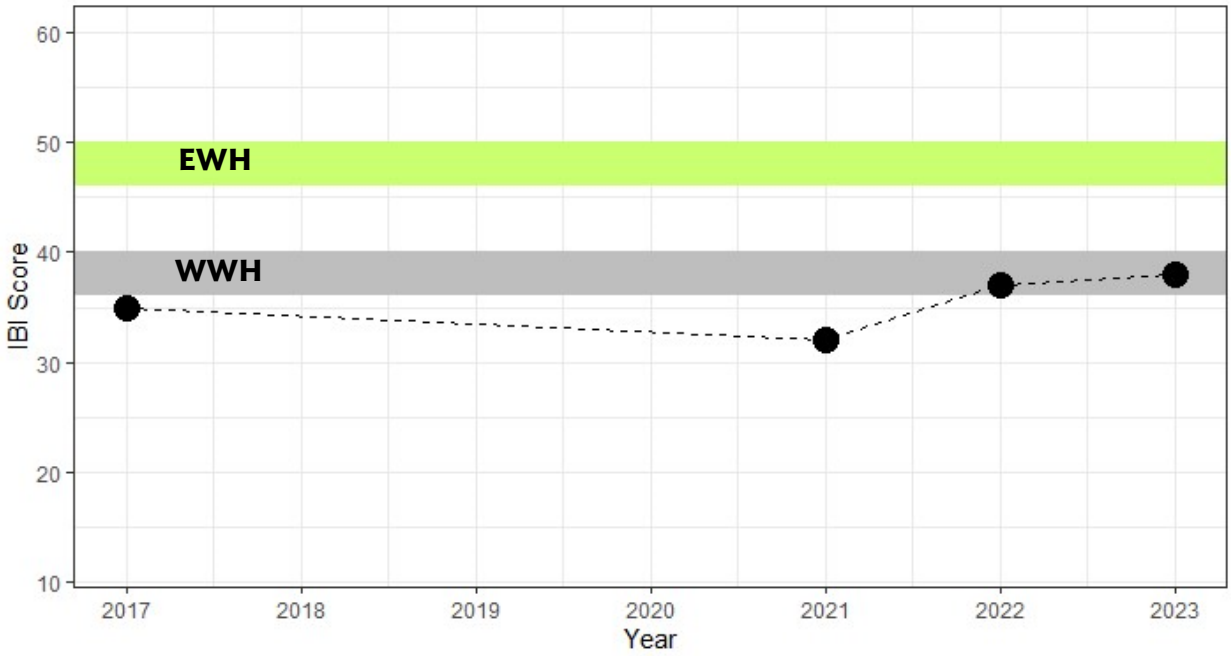

Figure 12. Stickney Creek IBI scores from 2017-2023. The gray box represents range of WWH attainment and NSD; the green box represents range of EWH attainment and NSD.

The sheer abundance of fish collected suggests a stream that is over-enriched with nutrients, which is supported by the nutrient data discussed earlier. The central stoneroller continues to be the most abundant fish (81.5% in 2023) since the stream restoration project has been completed. The combination of newly placed limestone, which benthic algae seems to thrive on, excess nutrients from illicit sewage connections and urban runoff, and the lack of a riparian shaded buffer are likely stimulating primary production in the form of benthic algae. The central stonerollers' primary forage is benthic algae when predation is absent (Power et al., 1985), which is the case in Stickney Creek. In 2017 before the stream restoration project was completed, the average number of central stonerollers collected during an electrofishing survey was 345 fish. Since project completion, the last three years have averaged 1,787 central stonerollers per survey. The increase in central stoneroller abundance has helped to increase the overall fish IBI score, as It decreases the proportion of tolerant fish and increases the relative number of fish. All other fish species have also seen a slight increase in overall abundance, but it is minimal compared to the increase in the central stoneroller abundance (Figure 13).

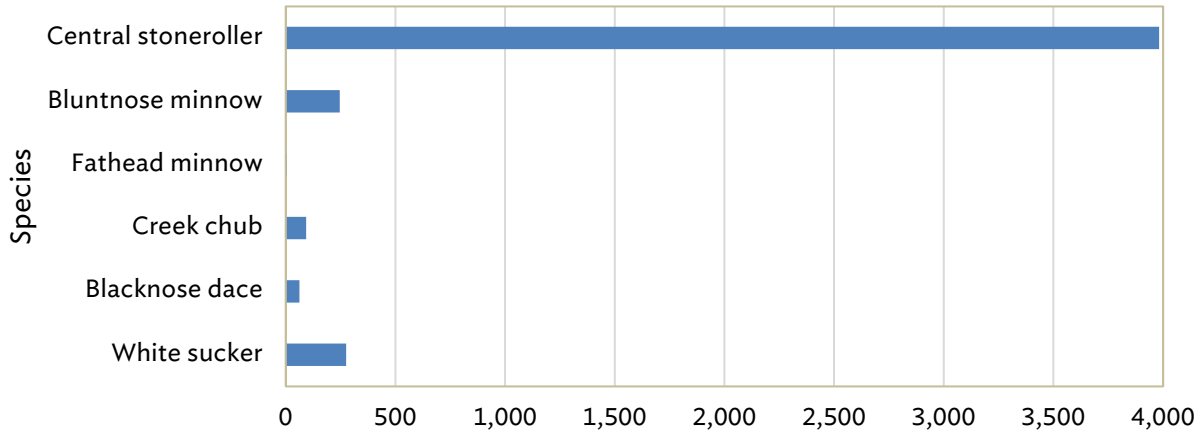

Figure 13. Change in fish species abundance between 2017 and 2023. This accounts for two electrofishing passes for both years.

There are no obvious fish passage barriers along Stickney Creek downstream of the sampling location. Stickney Creek flows into Big Creek, which has its own array of urban water quality issues. A fish passage barrier in the form of a high gradient rock cascade replaced a 30-foot drop structure on Big Creek at RM 2.90 (Figure 14), separating the headwaters of Big Creek and the entirety of Stickney Creek from fish colonization from the Cuyahoga River. The fish community in Stickney Creek is similar to Big Creek, both highly simplified and comprised of predominately highly tolerant fish capable of surviving the urban environment. Even with the ability of fish to recolonize Big and Stickney Creeks from the Cuyahoga River, the urban land use may limit the biological potential of both streams.

Figure 14. Big Creek 30-foot drop structure (left, 2018) and rock cascade (right, 2020) fish passage barriers.

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 minimum recommended 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 11), 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 12) and a site is within non-significant departure if the score falls within 4 ICI units of the criterion.

Table 11. 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 12. 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

Both a qualitative and quantitative macroinvertebrate assessment were performed on all three sites during 2023. Eighty-four unique taxa were identified, totaling 5,614 individuals colonizing the three artificial substrates. Table 13 lists a summary of the macroinvertebrate data collected from the artificial substrates (quantitative sampling) and natural substrates (qualitative sampling).

Table 13. Stream Restoration Projects Macroinvertebrate Results

Stream RM	Density Qt. (ft^2) /Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. On natural substrates	ICI	Narrative Evaluation
Baldwin Creek							
1.00	117 / L	45 / 52	4 / 1	18.26% / 0.0%	Isopods, amphipods	28*	*Fair*
Mill Creek							
10.13	372 / M-L	43 / 48	7 / 3	1.56% / 1.2%	Baetid mayflies, hydropsychid caddisflies, midges	40	*Good*
Stickney Creek							
1.15	634 / M-L	31 / 43	4 / 2	16.16% / 0.1%	Flatworms, hydropsychid caddisflies, baetid mayflies	30^{ns}	*Marg. 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.
*Significant departure from biocriterion (>4 ICI).
^{ns} non-significant departure from biocriterion (≤4 ICI).

Baldwin Creek RM 1.00

The Baldwin Creek macroinvertebrate community contained the highest total taxa count of the three stream restoration sites. However, the ICI score fell short of the WWH criterion with a score of 28 (*Fair*). The physical habitat limitations including no riffle or run, slow current velocity, and embedded substrates are reflected in the *Fair* macroinvertebrate community. Similar to the fish community, the dam pool habitat in Baldwin Creek was predominately inhabited by the lentic-type macroinvertebrates of isopods and amphipods. Less than eight percent of the artificial substrate was comprised of mayflies and caddisflies, with dipterans and other non-insects making up 67% (Figure 15). A total of four EPT taxa and one sensitive taxa were collected during the qualitative assessment, and zero sensitive taxa were identified on the artificial substrate. The 2023 *Fair* narrative rating is slightly lower than the most recent 2014 Ohio EPA assessment at RM 1.13 which scored *Marginally Good*.

The most recent 2014 Ohio EPA ICI scores from five other locations on Baldwin Creek have all met the WWH macroinvertebrate criterion. The removal of the dam and restoration of stream habitat features will most likely have an immediate positive impact on the macroinvertebrate

community in the restored dam pool. Post-restoration monitoring is planned within five years of project completion.

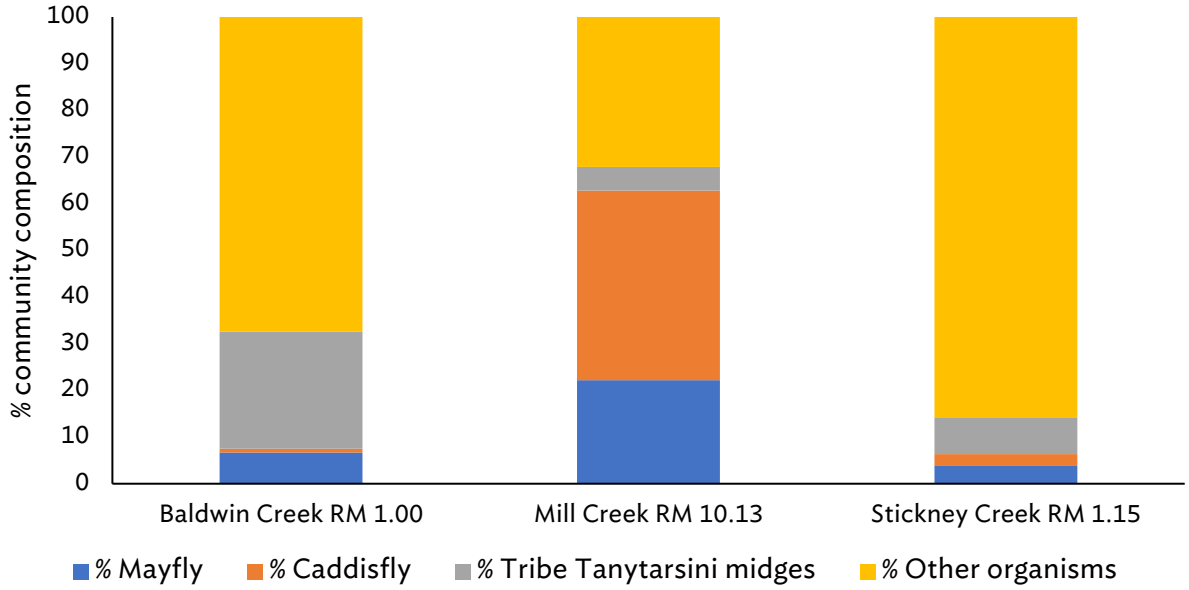

Figure 15. 2023 Macroinvertebrate Community Composition

Mill Creek RM 10.13

Mill Creek scored a narrative rating of *Good* with an ICI score of 40. The artificial substrate was colonized by 29 taxa, including two mayfly and five caddisfly taxa. The community was predominated by macroinvertebrates of intermediate pollution tolerances, with a low proportion of both tolerant organisms (2.7%), and sensitive organisms (1.2%). Caddisflies and mayflies were well represented on both the natural and artificial substrates, comprising over 62% of the community (Figure 16). The qualitative dip net sampling resulted in 43 total taxa which included seven EPT taxa and three sensitive taxa.

Major pollution abatement projects by the NEORSD have vastly improved the macroinvertebrate community in Mill Creek. The NEORSD Mill Creek combined sewer overflow (CSO) tunnel was completed in 2012 and is designed to store up to 72 million gallons of sewage and stormwater overflow. The design estimated the Mill Creek tunnel will reduce CSOs from entering Mill Creek by 97%. Macroinvertebrate community scores first sampled in 1984 by the Ohio EPA were *Very Poor* throughout Mill Creek. This CSO control tunnel, along with the generally improved water quality in the entire Cuyahoga River watershed, have resulted in significantly increased Mill Creek ICI scores since 1984, and scores have consistently met WWH attainment.

Stickney Creek RM 1.15

Stickney Creek showed a slight improvement in macroinvertebrate performance compared to previous years. The *Marginally Good* ICI score of 30 is the first time that this sample location has met the WWH designated use (Figure 15). Eight more qualitative taxa and twelve more total taxa

were collected than previous assessments. A total of four pollution-sensitive taxa were also collected, which was higher than in any other year and possibly indicates improving water quality since the stream restoration project has been completed. The low mayfly taxa richness and high proportion of dipterans and non-insects both performed poorly with ICI metric scores of zero. Other poorly performing metrics included the proportions of mayfly taxa and tribe tanytarsini midges, and qual EPT taxa richness.

The macroinvertebrate community composition based on percent identified from the artificial substrate is displayed in Figure 15. Nearly 86% of the community at Stickney Creek was composed of "other diptera and non-insects". Breaking down this 86% further, 60% were listed as non-tribe tanytarsini midges and 39% were a combination of flatworms and aquatic earthworms. The high proportion of these facultative or tolerant macroinvertebrates in Stickney Creek reflects the stress from urban land use.

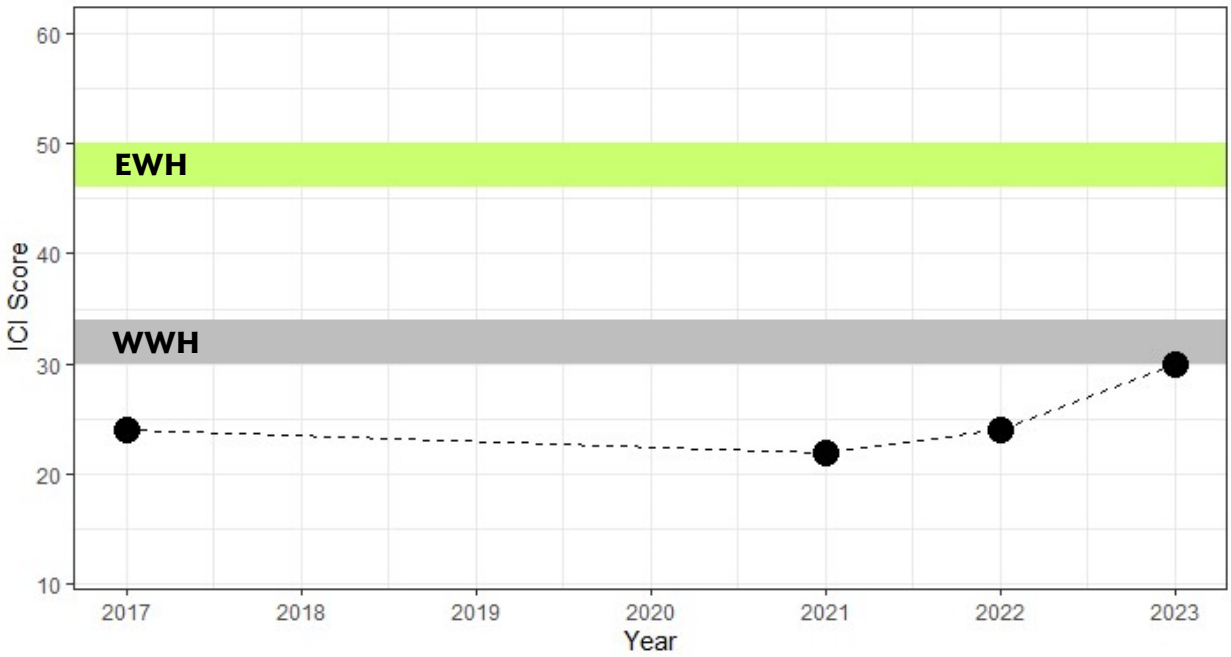

Figure 16. Stickney Creek ICI scores from 2017-2023. The gray box represents range of WWH attainment and NSD; the green box represents range of EWH attainment and NSD.

Conclusions

The post-restoration monitoring location at Stickney Creek was the only sampling site to achieve full WWH attainment (Table 14), albeit both biological metrics were within NSD of the criteria. The accumulative stream restoration efforts have increased both the fish and macroinvertebrate community index scores. The increase in overall macroinvertebrate taxa, EPT taxa, and sensitive taxa are all signs of improving water quality. One of the biggest stressors to the aquatic life in Stickney Creek is nutrient over-enrichment and its corresponding effects on dissolved oxygen and algae biomass. Of equal importance is the lack of an established riparian buffer to shade the streambed and reduce the effects of primary production. As the riparian vegetation continues to grow and provide shaded relief, the effects of primary production should be reduced. Lastly, the high intensity urban land use and the associated effects of stormwater quantity and quality limit the biological potential of this small, urban stream.

Table 14. ALU Attainment Status for 2023 Stream Restoration Projects

RM	DA (mi^2)	Attainment Status	IBI Score	ICI Score	QHEI Score	Cause(s)	Source(s)
Baldwin Creek (WWH Existing)							
1.00[H]	9.60	NON	22*	28*	62.50	Fish passage barrier Habitat and flow alterations	Impoundment Urban runoff
Mill Creek (WWH Existing)							
10.13[H]	2.60	NON	22*	40	72.75	Fish passage barrier Pollutants in urban stormwater	Hydromodifications Urban runoff
Stickney Creek (WWH Existing)							
1.15[H]	3.17	FULL	38[ns]	30[ns]	57.00		

*Significant departure from biocriterion (> 4IBI and ICI points). Underlined scores are in the *Poor* or *Very Poor* narrative range
[H] Headwater scoring criteria
[ns] non-significant departure from biocriterion (≤4 IBI and ICI points)

Both Baldwin Creek and Mill Creek did not meet the applicable ALU WWH criteria for various reasons. Baldwin Creek has a high proportion of moderate influence MWH attributes due to the dam pool and a fish passage barrier limiting the fish community upstream. The effects of the dam pool on in-stream habitat are reflected in the *Fair* fish and macroinvertebrate communities. Three other dams have been removed on Baldwin Creek downstream of the last remaining dam and have resulted in improved biological communities meeting the WWH designated use. The final dam removal and habitat modifications proposed for Baldwin Creek should have an immediate impact on both the fish and macroinvertebrate communities.

The Mill Creek stream restoration project site has baseline habitat capable of supporting a WWH fish assemblage. While the macroinvertebrate community met the WWH ALU, the fish community was extremely simplified and contained only four fish species over two sampling

events. With a major natural fish barrier at RM 2.80 and a simplified, highly tolerant fish community present upstream, fish IBI scores are not likely to increase and meet the WWH criterion without a fish translocation type project. However, the 90% urban land-use of Mill Creek poses major limitations to the fish community as evident in the zinc OMZM exceedance and elevated conductivity values. Stream restoration efforts aim to restore in-stream habitat and floodplain access through an 1,844 section of Mill Creek (Ohio EPA, 2023a). Stormwater quantity control is an essential component to consider in urban areas where floodplains have been developed, channelized, and are eroding at an accelerated rate.

Additional biological and water quality assessments will be performed on Stickney Creek to track improvements since stream restoration completion. Post-restoration assessments will be performed on both the Baldwin Creek and Mill Creek locations within five years of project completion.

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