Northeast Ohio Regional Sewer District

2022 Cuyahoga River
Biological, Water Quality, and Habitat Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

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Introduction

The Cuyahoga River is located in Northeast Ohio, flowing through the cities of Akron and Cleveland before its final confluence with Lake Erie. The Northeast Ohio Regional Sewer District (NEORSD) service area spans the lower 25.3 miles of the Cuyahoga River. The NEORSD responsibilities include managing sewage conveyance and treatment through its major interceptor sewers and three wastewater treatment plants. The NEORSD Southerly Wastewater Treatment Center (WWTC) is a major discharger to the Cuyahoga River at RM 10.57, with a design flow of 175 million gallons per day (MGD) and a peak flow capacity of 400 MGD. The treatment process consists of preliminary screening, grit removal, primary settling, activated sludge process, secondary clarification, and chlorine disinfection from May-October.

The NEORSD also manages local stormwater runoff, flooding, and erosion issues through its Regional Stormwater Management Program. Communities bordering the Cuyahoga River that participate in both the wastewater and stormwater services include Brecksville, Sagamore Hills, Valley View, Independence, Brooklyn Heights, Cuyahoga Heights, and Cleveland. All cities listed here are issued an Ohio Environmental Protection Agency (EPA) National Pollution Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) or a stormwater general permit for all, or portions of their municipality. The NEORSD assists in numerous control measures listed in these MS4 permits, including the stormwater management and illicit discharge programs.

The lower 46.5 miles of the Cuyahoga River was designated as one of the 42 Great Lakes Areas of Concern (AOC) in 1985 by the International Joint Commission. This designation described the river as having severe anthropogenic environmental degradation, and not capable of supporting its beneficial use designations. Past monitoring has indicated impairment of the aquatic biota and recreational standards, particularly in the northernmost sections of river. The Ohio EPA has listed numerous sites on the Cuyahoga River as impaired in 2022 according to the Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2022a). Major causes of impairment to the river have been classified as organic enrichment, toxicity, low dissolved oxygen, nutrients, and flow alteration (Ohio EPA, 2003). There are currently four parameters included in the approved TMDL for the Cuyahoga River within NEORSD's service area: dissolved oxygen (DO), total phosphorus (TP), nitrate-nitrite (NO3-NO2), and in-stream habitat. Recent environmental monitoring by the NEORSD has indicated that some sites have displayed full attainment of their respective biological criteria.

In 2022, the NEORSD conducted water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community assessments on the lower Cuyahoga River. The objective of this study was to evaluate the potential water quality impacts of Southerly WWTC on the lower Cuyahoga River and identify any spatial and temporal water quality trends. During the 2022 sampling season, five stream locations were evaluated from river mile (RM) 13.15 downstream to RM 8.60 (Table 1 and Figure 1). Additional water chemistry data was collected at two additional sites (SUS and SDS, Table 1) in accordance with the Ohio EPA National Pollution Discharge Elimination System (NPDES) permit on the Cuyahoga River.

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 project study plan "*2022 Cuyahoga River Environmental Monitoring"* approved by Ohio EPA on May 11, 2022. All sampling and environmental assessments occurred between June 15 through 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), Modified Index of Well-Being (MIwb), 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* (2021a) and compared to the Ohio Water Quality Standards (WQS) for their designated use(s) to determine attainment (Ohio EPA, 2021b). An examination of the individual metrics that comprise the IBI, MIwb, 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 study area map illustrating each sample location evaluated during the 2022 study. Table 1 lists each sampling location with respect to RM, latitude/longitude, description, and the types of surveys conducted. Benthic macroinvertebrate and water chemistry collection sites are located near the midpoint of each electrofishing zone, indicated by the RM. GPS coordinates are recorded at the downstream end of each sampling zone. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's Water Quality and Industrial Surveillance (WQIS) Division.

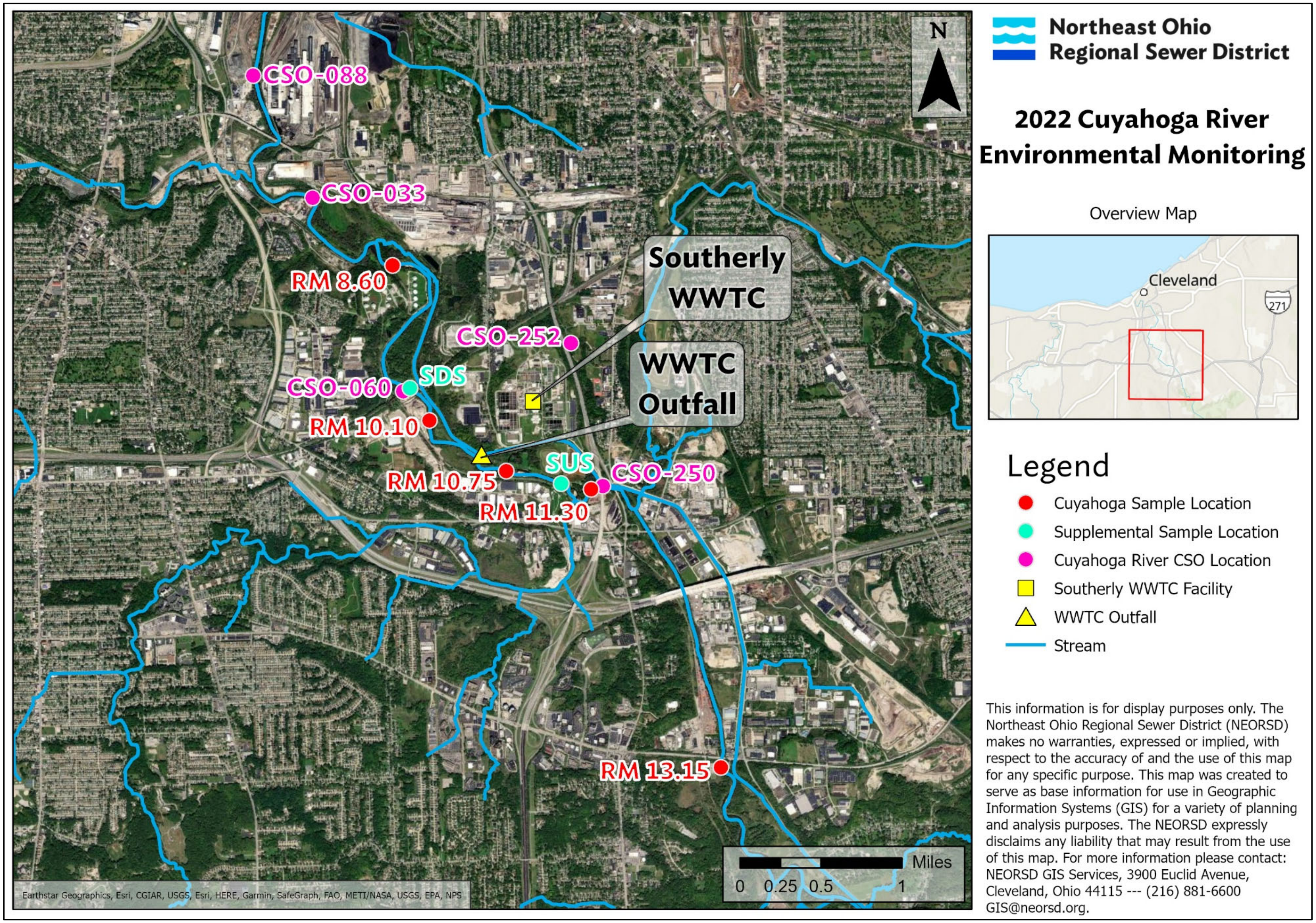


Figure 1. Cuyahoga River Sampling Locations

Table 1. Sampling Locations					
Location	Latitude	Longitude	River Mile	Station ID	Sampling Conducted
U.S. of Rockside Road and Confluence with Mill Creek	41.3929	-81.6295	13.15	502020	F, M, C
D.S. of Confluence with Mill Creek	41.4179	-81.6446	11.30	F01S10	F, M, C
*U.S. Southerly WWTC @ Chlorine Access Bridge	41.4180	-81.6480	10.95 (SUS)	––	C
U.S. Southerly WWTC Effluent Discharge	41.4196	-81.6547	10.75	F01A25	F, M, C
D.S. Southerly WWTC Effluent Discharge	41.4242	-81.6638	10.10	F99Q02	F, M, C
*D.S. Southerly WWTC @ Southerly Interceptor Bridge	41.4272	-81.6662	9.78 (SDS)	F01S09	C
D.S. Southerly WWTC Effluent Discharge	41.4381	-81.6680	8.60	200025	F, M, C
F = Fish community biology (includes habitat assessment) M = Macroinvertebrate community biology C = Water chemistry *Water chemistry is collected 2x/month as part of Southerly WWTC NPDES permit					

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 Cuyahoga River are listed below in Table 2 (Ohio EPA 2021b).

Table 2. Beneficial Use Designations for the Cuyahoga River

Water Body Segment	Beneficial Use Designation												
	Aquatic Life Habitat (ALU)							Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Cuyahoga River – Entirety of ship channel (RM 5.60) to the mouth (including the old river channel) *							+			+		+	
- Brandywine Creek to Tinkers Creek (RM 24.17 to RM 16.36) **			+		+				+	+		+	
- All other segments		+							+	+		+	
- Gorge area (RM 44.6) to the mouth (excluding old river channel) **					+								

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.

*During the months of June-January when a biological survey would be performed, the ALU designation is LRW.
**Proposed Beneficial Use Designation changed based on data collected between 2016-2018 (Ohio EPA, 2021b).

Watershed Land Use Analysis

A land cover analysis was performed on the Cuyahoga River watershed. The United States Geologic Survey StreamStats Program (U.S. Geological Survey, 2012) was used to obtain a watershed polygon representing the Cuyahoga River watershed. The corresponding watershed polygon was then imported into ArcGIS Pro 3.0 and the intersect tool was used to combine the watershed with the 2019 National Land Cover Database (Dewitz and U.S.G.S., 2021). Figure 2 illustrates the different land cover types that drain to the Cuyahoga River within the entire watershed. An analysis of the drainage types specific to each of the study sites monitored during 2022 was conducted. Similar land cover types were combined, and the percentages of each land cover type were then calculated for the five sites downstream of RM 13.15 (Figure 2).

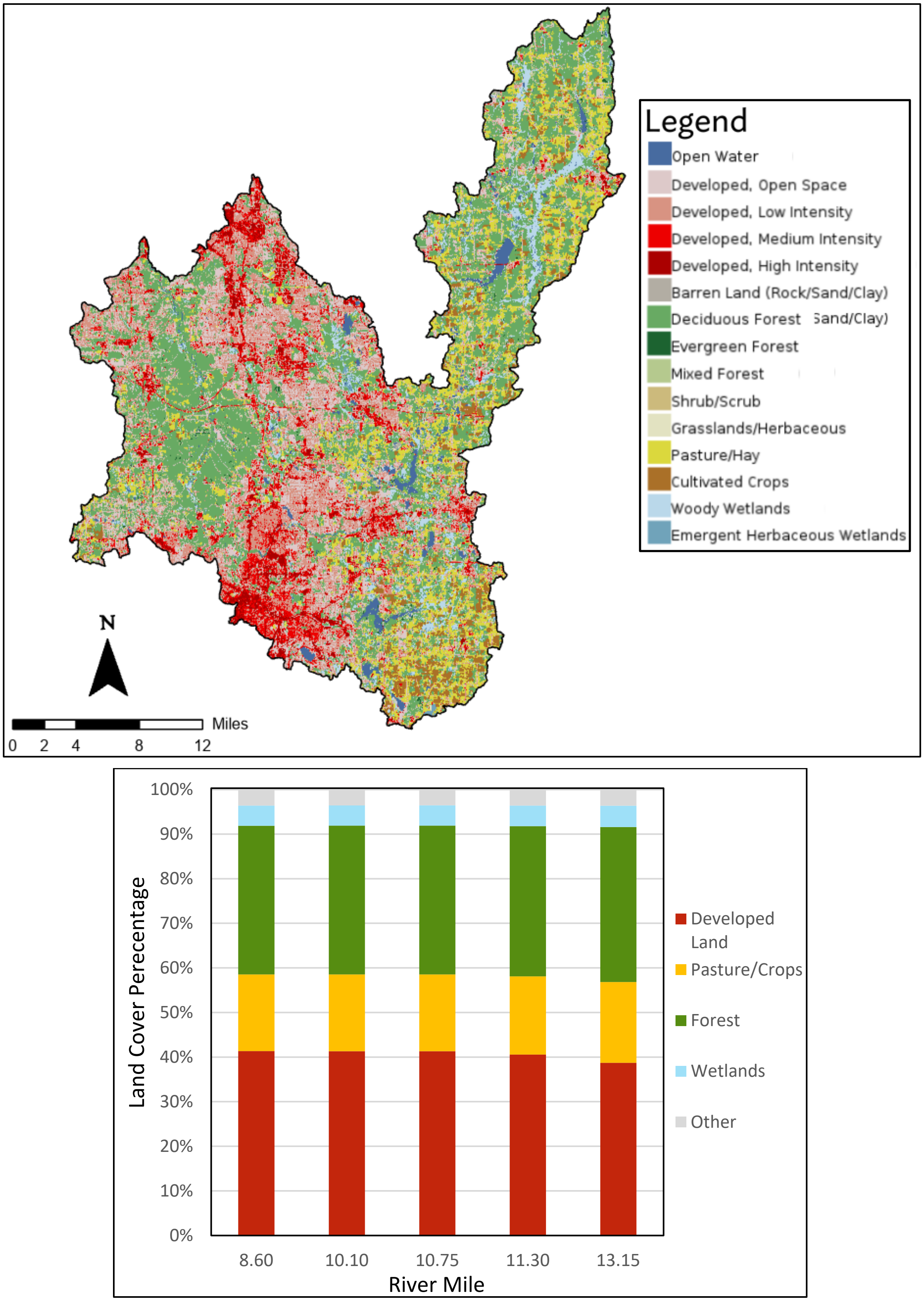


Figure 2. Cuyahoga River Watershed Land Cover Map and percentage land use at each site

Both Cleveland and Akron lie within the Cuyahoga River drainage basin, contributing significantly to the overall developed lands. Other than the two major cities, the Cuyahoga River watershed is quite rural, with about sixty percent of the watershed classified as either forested, pastured, or wetlands. The majority of the natural landcover is found northeast of Akron, where the river flows southwest through low gradient wetlands, pastures, and forested lands. The 33,000-acre Cuyahoga Valley National Park (CVNP) protects over 24 miles of Cuyahoga River mainstem from RM 37.25 to RM 13.00, acting as a natural stream buffer and conservation land. Among the sites assessed in 2022, approximately forty percent of the land draining to the lower Cuyahoga River is developed, with the most upstream site, RM 13.15, having only a slightly lower percentage of developed area when compared to all other sites.

The highly developed land consists of a vast landscape of impervious surfaces which quickly transports rainfall, increasing the stormwater runoff and peak flow rates in the river. This increased stormwater runoff leads to increased bank erosion and increased pollutants transferred to the stream across the urban landscape (USEPA, 1999). Pollutants associated with urban and industrial runoff include excess sediments, nutrients, pathogens, oxygen-demanding matter, heavy metals, and salts (Schueler, 1987). The highly developed and urban landscapes in the Cuyahoga River watershed may have a negative effect on the overall water quality and a degradation of aquatic biota.

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted five times between July 28 and August 23, 2022, at the locations 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* (2021a). 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. Duplicate/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 duplicate/replicate sample (Formula 1).

Formula 1: $$\mathbf{RPD} = \left| \frac{x-y}{\left[\frac{(x-y)}{2}\right]} \right| \times 100$$

x = is the concentration of the parameter in the primary sample

y = is the concentration of the parameter in the duplicate/replicate sample

The acceptable percent RPD is based on the ratio of the sample concentration and detection limit (Formula 2) (Ohio EPA, 2021a).

Formula 2: $$\mathbf{Acceptable\ \%\ RPD} = [(0.9465x^{-0.344}) \times 100] + 5$$

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 Cuyahoga River flow data (USGS 04208000) are shown below in Figure 3.

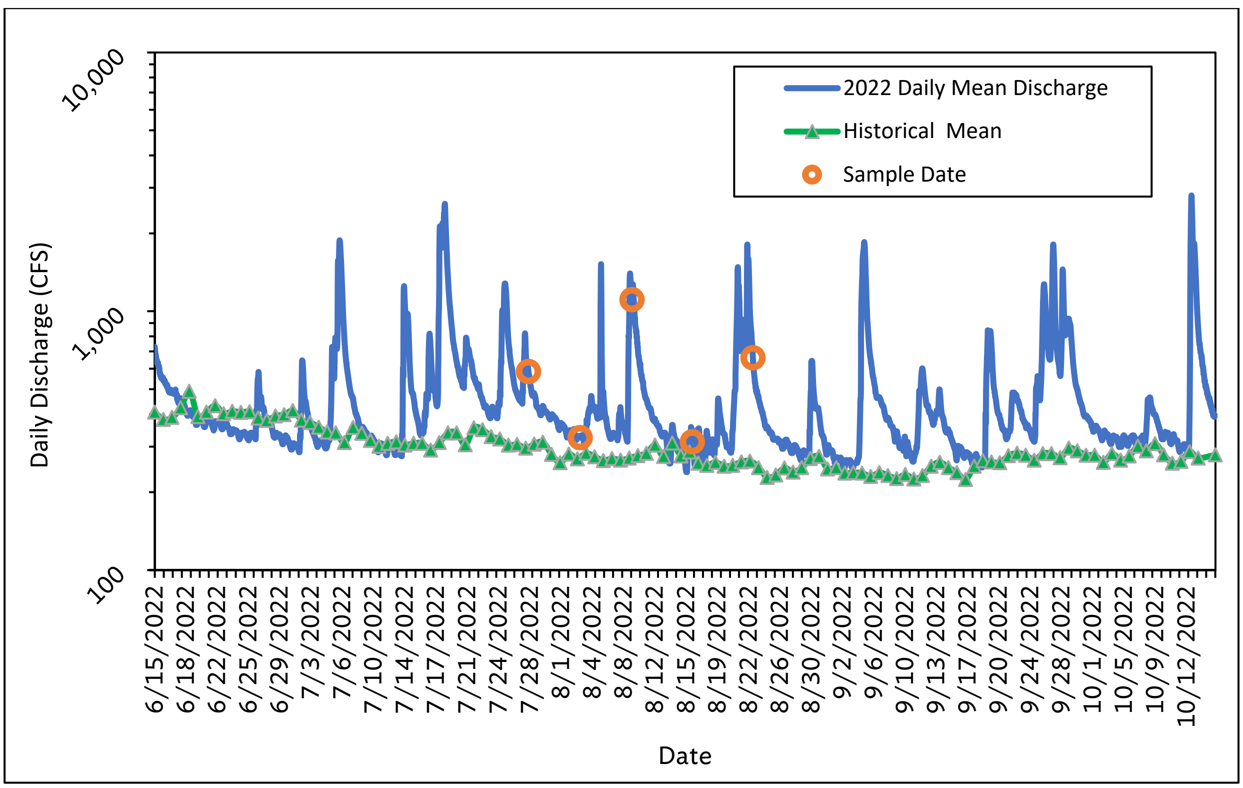


Figure 3. 2022 Cuyahoga River Flow Data at USGS Station 04208000. Shown are the daily mean discharge values for 2022 and the historical daily means; **Orange** circles indicate NEORSD water chemistry sampling dates.

Results and Discussion

Quality Assurance / Quality Control

Over the course of five sampling events completed in 2022, two field blanks, one duplicate sample, and one replicate sample were collected as part of this study. Of the two-field duplicate/replicate samples collected, nine instances occurred at RM 8.60 in which the acceptable RPD was exceeded (Table 3). These results were rejected based on Ohio EPA protocols. Potential reasons for this discrepancy include lack of precision and consistency in sample collection and/or analytical procedures, environmental heterogeneity, and/or improper handling of samples.

Table 3. Duplicate Samples with RPDs Greater than Acceptable

River Mile	Date	Parameter	Acceptable RPD	Actual RPD
RM 8.60	8/9/2022	Aluminum	32.6%	34.4%
		Barium	21.8%	33.0%
		Calcium	24.7%	28.0%
		Lead	33.1%	37.5%
		Magnesium	22.6%	27.1%
		Manganese	16.3%	32.7%
		Sodium	20.0%	24.5%
		Strontium	15.9%	26.6%
		Total Dissolved Solids	23.0%	24.0%

The field blank samples were collected on July 28 and August 3, 2022, at RM 13.15 and RM 10.75, respectively. Results from each sample indicated that no parameters were affected by possible field blank contamination.

Paired parameters, wherein one parameter is a subset of another, were evaluated in accordance with QA/QC protocols for all samples collected at each sampling site. There were no instances in which the data for the paired parameters needed to be qualified because the sub-parameter value was greater than the parent value.

Recreation Use Results and Discussion

Escherichia coli (*E. coli*) is a fecal indicator bacteria commonly found in the intestinal tract and feces of warm-blooded animals and is used to measure the presence of feces (USEPA, 2012). The primary contact recreation (PCR) criteria consist of two components. First is an *E. coli* criterion not to exceed a statistical threshold value (STV) of 410 colony counts or most probable number per 100 milliliters (410 MPN/100ml) in more than ten percent of the samples collected during any 90-day period. The second component is a 90-day geometric mean criterion of 126

MPN/100mL (Ohio EPA, 2022b). In accordance with the Ohio EPA procedure and practice to qualify *E. coli* exceedances for the Primary Recreation criteria, the geometric mean and STV are only calculated and compared when a minimum of five bacteriological samples have been collected within a rolling 90-day period.

The Cuyahoga River sites sampled in 2022 are designated as a warmwater habitat (WWH) and primary contact recreation according to the Ohio EPA Water Quality Standards (2020a). The five sample locations were sampled for *E. coli* five times (Table 4). The Southerly WWTC's NPDES permit requires sampling of the Cuyahoga River upstream (SUS; RM 10.95) and downstream (SDS; RM 9.78) of the effluent channel (Table 1 and Figure 1). The data from this sampling was also used to assess the recreational criteria attainment and is listed in Table 5. When duplicate samples were collected at a sample location, the *E. coli* results are reported as an average.

Exceedances of the recreational bacteriological criteria for primary contact recreation occurred at all five sites during the 2022 sampling season (Table 4). These exceedances may be due to sample collection during or following a wet-weather event, as defined in Table 4. Sampling dates collected during or after a wet-weather event are indicated on the following tables. During wet-weather storm events, stormwater runoff from urban areas collects pollutants, and excessive stormwater flows may overwhelm local and interceptor sewers causing combined sewer overflows (CSOs) and sanitary sewer overflows.

Table 4. 2022 *E. coli* Densities (MPN/100mL)

Date	RM 13.15	RM 11.30	RM10.75	RM 10.10	RM 8.60
7/28/2022*	222	430	471	504	857
8/3/2022	38	46	46	54	30
8/9/2022*	4,185	5,654	9,678	9,678	7,666
8/16/2022	308	326	166	131	142
8/23/2022*	689	1,844	1,045	1,146	2,452
90-day Geomean	375.8	582.8	515.4	524.1	585.2

(orange) Exceeds statistical threshold value of 410 MPN/100mL.
(yellow) 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.

Table 5. 2022 *E. coli* Densities (MPN/100mL) from NPDES permit sampling				
Date	SUS (RM 10.95)		SDS (RM 9.78)	
	Sample result	90-day geomean	Sample result	90-day geomean
5/2/2022*	411	460	579	165
5/16/2022*	1,733	351	1,120	242
6/1/2022	60	225	84	292
6/15/2022*	276	276	313	357
7/5/2022*	3,683	260	9,678	373
7/15/2022	219	139	308	472
8/1/2022	81	133	44	472
8/15/2022	119	147	147	428
9/1/2022	205	154	345	421
9/15/2022	194	140	232	476
10/3/2022	86	119	104	363
10/17/2022	166	166	162	517
Seasonal geomean	247		264	
Seasonal geomean (dry weather days)	128		148	
% samples > STV	25%		25%	

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

Figure 4 below displays the impact of wet weather on increased *E. coli* densities in the Cuyahoga River watershed. There is generally a positive correlation with wet weather and greater *E. coli* densities. Wet-weather determinations were used using NEORSD's rain gauge monitor located at Southerly WWTC. Non-point source conditions typically occur during elevated flows, when rainfall runoff contributes the bulk of the pollutant load, while point source conditions occur during low flows when wastewater treatment plant (WWTP) effluent dominates base flows (USEPA, 2007). Source contributions in the Cuyahoga River have both point and non-point sources, as *E. coli* densities were greatest during wet-weather, and no dry-weather days exceeded the 410 MPN/100mL STV WQS value. In addition to the loss of riparian and in-stream habitat, one of the greatest impacts on aquatic life in Ohio's urban watersheds are contributions of excessive nutrients, oxygen-demanding wastes, and toxic chemical pollutants via urban runoff (Yoder et al., 1999). Local sanitary sewer overflows may also be an issue as several of these have been documented in the Mill Creek Watershed (Cuyahoga River tributary at RM 11.40) during the previous years.

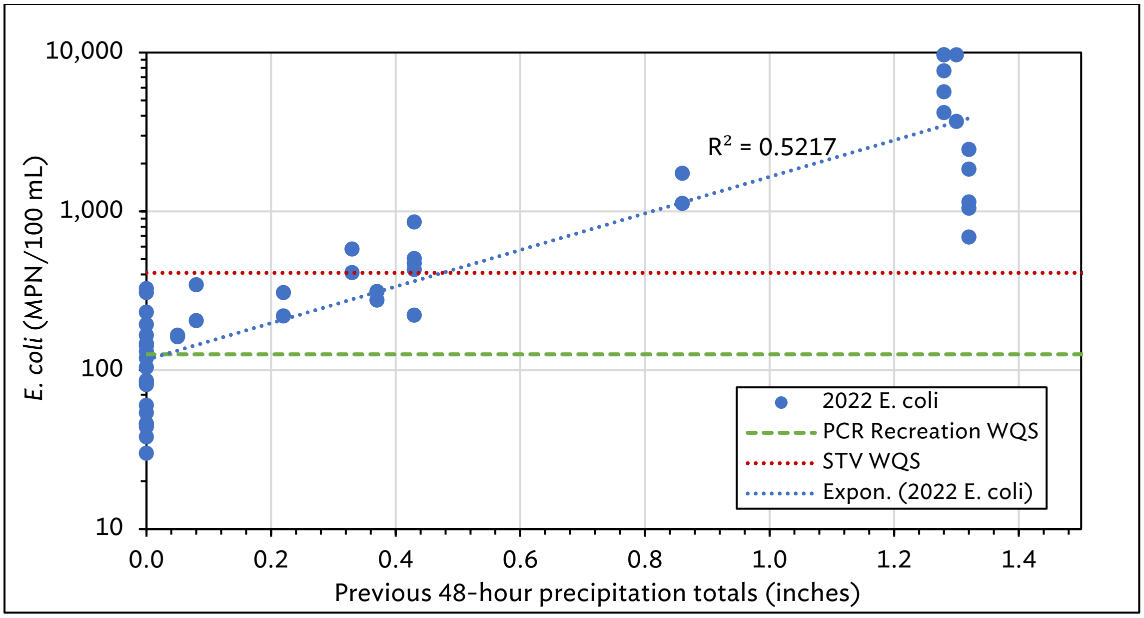


Figure 4. Previous 48-hour rainfall and *E. coli* values

The NEORSD Southerly WWTC discharges to the Cuyahoga River at RM 10.57. A two-tailed t-test was performed to determine if Southerly WWTC's effluent contributes significantly to the *E. coli* densities within the Cuyahoga River. Both datasets from Tables 8 and 9 were used jointly and separated by either upstream or downstream of the Southerly WWTC effluent. The calculated p-value was not less than the significance level, indicating that the difference between the mean *E. coli* densities from upstream to downstream is not statistically significant over the 17 sampling days.

The NEORSD entered a federal CSO long-term control plan (LTCP) consent decree with the United States EPA on June 30, 2011. This legally binding consent decree is a 25-year plan that outlines infrastructure investments that will reduce the amount of wastewater pollution entering Lake Erie. NEORSD currently owns and maintains twenty-three CSOs that discharge directly to the Cuyahoga River. Nearly all of the CSOs are considered controlled or in the process of being controlled through the CSO LTCP, meaning that they meet the US EPA's minimum control measures. Only two of these CSOs are located upstream of any 2022 sampling location (Figure 1). CSO-250 discharges to the Cuyahoga River at approximately RM 11.34 and CSO-060 at RM 9.68. Based on estimates of the volume of discharge during a typical year, it is not expected that these CSOs have a significant impact on the overall water quality within the river.

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 Non-drinking 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 river. None of the sample locations had any results that were above the mercury detection limit.

Mercury pollution is not uncommon in the Great Lakes region. Coal fired power plants have historically lined the southern shores of Lake Erie. It was not until 2011 that the US department of energy established national standards to control mercury emissions. Three major coal fired power plants in the greater Cleveland area ceased operations in 2015 (Cleveland.com, 2015), as the parent company switched energy sources from coal over to natural gas. A 2018 NEORSD fish tissue study found mercury contamination in fish across the Cleveland Lake Erie shoreline and from fish in the Cuyahoga River (NEORSD, 2020). However, contamination was lower than the US EPA Human Health water quality criterion for methylmercury and an apparent decline in median mercury concentrations was evident. Other sources of mercury to surface waters are from atmospheric deposition, impervious surface runoff (Fulkerson et al., 2007), and other NPDES permitted point sources within the watershed.

In 2018, the Ohio EPA released an Early Stakeholder Outreach regarding Nutrient Water Quality Standards for Ohio's Large Rivers (≥500 mi2 drainage area). The proposed eutrophication standard, shown in Table 6, will establish standards based on sestonic chlorophyll *a*, 5-day biochemical oxygen demand (BOD), 24-hour dissolved oxygen (DO) range, total Kjeldahl nitrogen (TKN), and use total suspended solids (TSS) for sites where chlorophyll *a* data are lacking (Ohio EPA, 2018).

The Ohio EPA is also proposing a seasonal average, summer base-flow target level of total phosphorous (TP) at 0.130 mg/L as a management target for presently over-enriched waters (Miltner, 2018). The TP target of 0.130 mg/L has been proposed to reduce chlorophyll *a* concentrations to less than 100 μg/L in large rivers. Chlorophyll *a* concentrations greater than 100 μg/L contribute to elevated BOD, large daily DO swings, and a greater concentration of suspended solids; all of which display gross levels of enrichment and suggest a high likelihood of biological enrichment (Miltner, 2018). In addition to these proposed nutrient WQS, nutrient target concentrations remain from the lower Cuyahoga River TMDL (Ohio EPA, 2003). This TMDL lists target criteria for TP at 0.12 mg/L and nitrate-nitrite at 1.42 mg/L. These concentrations were developed from statewide reference, or least impacted sites, as either the 75^{th} percentile (nitrate-nitrite) or concentrations typical of fish IBI scores achieving attainment (TP) (Ohio EPA, 1999). The proposed WQS seasonal phosphorus average will be used in lieu of the TMDL target criterion since it represents the most recent criteria.

Table 6. Ohio EPA Proposed Eutrophication Standards for Ohio's Large Rivers			
	Acceptable	Enriched or Over Enriched	Over Enriched
Indicator		Chronic Condition	Acute Condition
Sestonic Chlorophyll	< 30 μg/L as seasonal average	Magnitude 30 < 100μg/L seasonal average with biological impairment Frequency ≥ 30 μg/L < 100μg/L as seasonal average in two of three years	Magnitude ≥ 100μg/L anytime with biological impairment Frequency ≥ 100μg/L multiple observations at base flow
BOD5	< 2.5 mg/L as seasonal average	Magnitude ≥ 2.5mg/L < 6mg/L seasonal average with biological impairment Frequency ≥ 2.5mg/L < 6mg/L seasonal average in two of three years	Magnitude ≥ 6mg/L anytime with biological impairment and seasonal average chlorophyll ≥ 30μg/L Frequency ≥ 6mg/L two or more times during the base flow period
24-hour D.O. Range	< 6.5 mg/L	≥ 7mg/L - 9mg/L (default to chlorophyll, BOD5 and biological indicators)	Magnitude and Frequency ≥ 9.0mg/L anytime with biological impairment
TKN	N/A	N/A	≥ 0.75mg/L may substitute for BOD5
TSS		~ 20mg/L; general screening level of inspection of data sets lacking chlorophyll observations.	

Nutrient data was collected at all five NEORSD sample sites and two Southerly WWTC NPDES sample locations in 2022 during the summer months of May through October. TKN, dissolved reactive phosphorus (DRP), TP, TSS, and BOD were collected at each site during water chemistry sampling. The proposed eutrophication standards require sampling during "summer base-flow conditions". Of the total 17 sampling events in 2022, seven dates were completed during or after wet-weather events (see Tables 4 and 5 for wet-weather dates).

TKN seasonal geomean levels at all six sample locations exceeded the "enriched or over enriched chronic condition" criterion for the proposed eutrophication standards (Table 7). Three of the seven sample locations also exceeded the proposed TP target of 0.130 mg/L. All sampling locations exceeded the nitrate-nitrite TMDL target concentration. The two locations with BOD5 results greater than 2.5 did not meet the minimum of five samples needed to calculate a seasonal geomean due to QA/QC rejected data. However, both the SUS and SDS sites on the Cuyahoga River indicated acceptable BOD5 values over the recreational season.

The proposed large river WQS is based on sampling performed during baseline summer conditions. Similar results to those observed in Table 7 were observed when analyzing data only for dry-weather days. These dry-weather, baseline flow results display elevated nutrient concentrations throughout the lower 13 miles of the Cuyahoga River, indicating that point sources are likely a significant contributor.

Table 7. 2022 Nutrient Analysis (Geometric Means)

Sample Location	N	TKN (mg/L)	NO_3-NO_2 (mg/L)	DRP (mg/L)	TP (mg/L)	TSS (mg/L)	BOD (mg/L)
RM 13.15	5	0.79	3.47*	0.0502	0.098	18.9	2.0*
RM 11.30	5	0.87	3.30	0.0477	0.099	20.9	2.0*
RM 10.95 (SUS)	12	0.96	2.56	0.0409	0.078	14.9	1.8
RM 10.75	5	0.89	3.12	0.0464	0.096	18.4	2.0*
RM 10.10	5	0.96	4.32	0.1068	0.193	21.6	3.0*
RM 9.78 (SDS)	12	0.94	3.91	0.0734	0.135	9.3	1.5
RM 8.60	5	1.01	4.11	0.1024	0.183	21.4	3.2*

Over enriched – acute condition.
Enriched – chronic condition.
Exceeds Nitrate-nitrite TMDL target criterion.

*Number of sampling results <5 due to QA/QC rejected data

The TSS results greater than 20 mg/L are likely indicative of suspended sediments from elevated stream flows and not necessarily sestonic chlorophyll *a*. The NEORSD Lake Erie Nutrient study monitors trends of nutrients and chlorophyll concentrations in Lake Erie near Cleveland and in three of its major tributaries. Sestonic chlorophyll data from the previous five years support this hypothesis as concentrations in the Cuyahoga River have averaged 9.0 ug/L at RM 10.95 (upstream of SWWTC effluent) and 7.77 ug/L at RM 0.20 over the previous five years, well below the 30 mg/L WQS seasonal average.

The increased phosphorus levels downstream of RM 10.75 (Table 7) are possibly due to the discharge of treated wastewater from the Southerly WWTC at RM 10.57. Southerly WWTC is subject to the NPDES permit number 3PF00002*OD, as issued by the Ohio EPA. This permit limits TP effluent concentrations to 1.10 mg/L weekly and 0.70 mg/L monthly. Despite the NPDES permit limit being above the proposed total phosphorus target level of 0.130 mg/L, the phosphorus levels downstream of Southerly WWTC were not in acute condition at the time of sampling. There is currently no limit for TKN, but concentrations are reported. Nutrient data was retrieved and analyzed from the Southerly WWTC treated effluent to reflect the discharge during the summer months (Table 8).

Table 8. NEORSD Southerly WWTC Effluent Nutrient Concentrations May 1-Oct 31, 2022				
Parameter	N	Mean	Min	Max
TKN (mg/l)	26	1.15	0.73	1.66
NO3-NO2 (mg/l)	132	10.74	4.29	16.60
TP (mg/l)	184	0.42	0.14	3.40

The effects of the Southerly WWTC on the Cuyahoga River nutrient concentrations are evident. TP concentrations have historically increased downstream of the Southerly WWTC effluent to levels exceeding the seasonal average target criterion of 0.130 mg/l (Figure 5). TKN concentrations in the Cuyahoga River are less affected by the Southerly WWTC effluent and concentrations upstream of the Southerly WWTC effluent are consistently elevated (Table 7, Figure 6), surpassing the *over enriched – acute condition* indicator threshold (Table 6). Numerous other major and minor wastewater treatment plant discharges are also located within the Cuyahoga River watershed (ex: Akron, Bedford, Twinsburg, Aurora). All WWTPs within the Cuyahoga River watershed contribute to the overall wasteload allocation, and inevitably, the overall nutrient enrichment of the watershed.

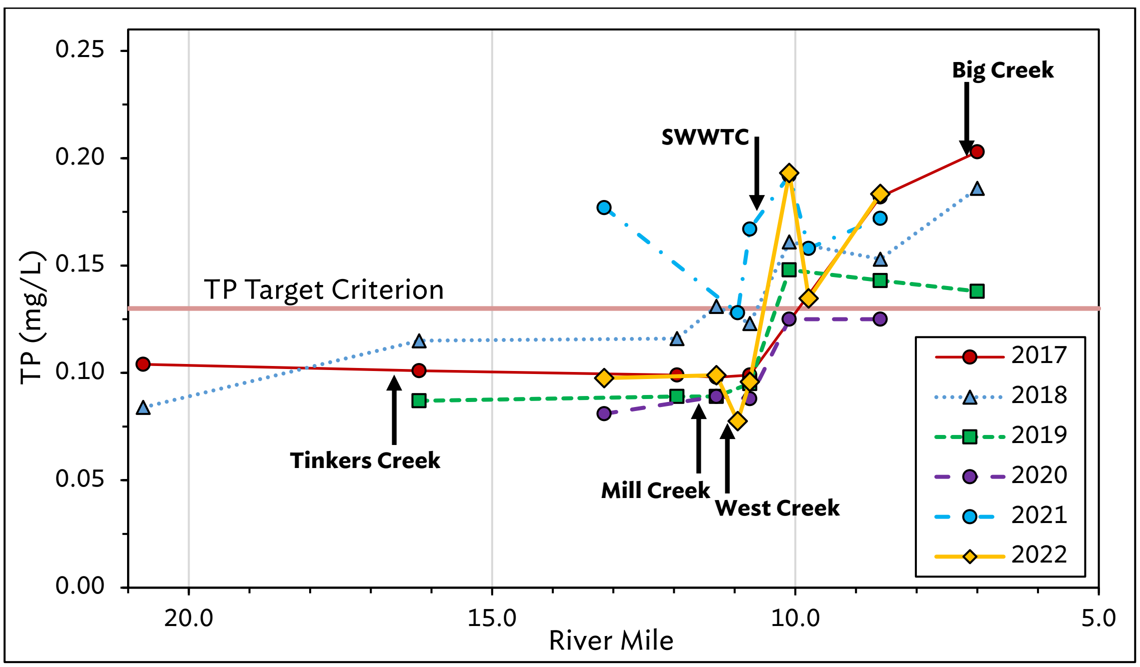


Figure 5. Longitudinal geomean concentrations of TP on the Cuyahoga River 2017-2022

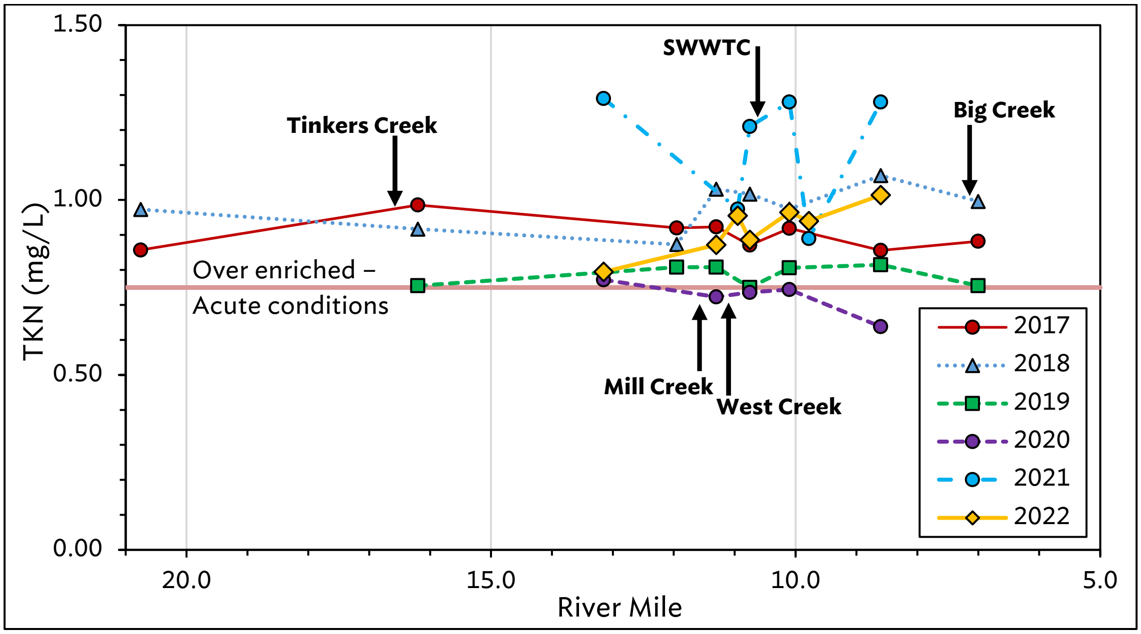


Figure 6. Longitudinal geomean Concentrations of TKN on the Cuyahoga River 2017-2022

Instantaneous DO measurements are collected on the Cuyahoga River every 30 minutes by a YSI EXO2 data sonde at USGS gage #04208000 in Independence, OH (RM 13.08). Compiled with NEORSD data sonde field observations, no WQS exceedances were observed for daily OMZ minimum DO concentrations. Daily range in DO swings increase with increasing chlorophyll concentrations through photosynthesis and respiration, demonstrating its usefulness as an indicator for measuring algal biomass (Miltner, 2018). During the summer months, algae tend to grow best during low-flow conditions and maximum light penetration. Rainfall data at the NEORSD Independence rain gage measured nearly four inches greater than the preceding 10-year average of 3.9 inches of rainfall during the months of June through October in 2022. This corresponded to river flows consistently exceeding the median values (Figure 3).

Continuously elevated stream flows with increased turbidity do not promote an extended algal growth period, even when nutrient concentrations are readily available. Data was pulled from the USGS RM 13.08 data sonde for the months of May through October to analyze and compare daily DO swings to the proposed large river nutrient WQS (Figure 7). The maximum 24-hour DO swing in 2022 was measured on July 11th at 5.1 mg/L; this is below the 6.50 mg/L proposed eutrophication threshold, shown in Table 6, indicating acceptable conditions.

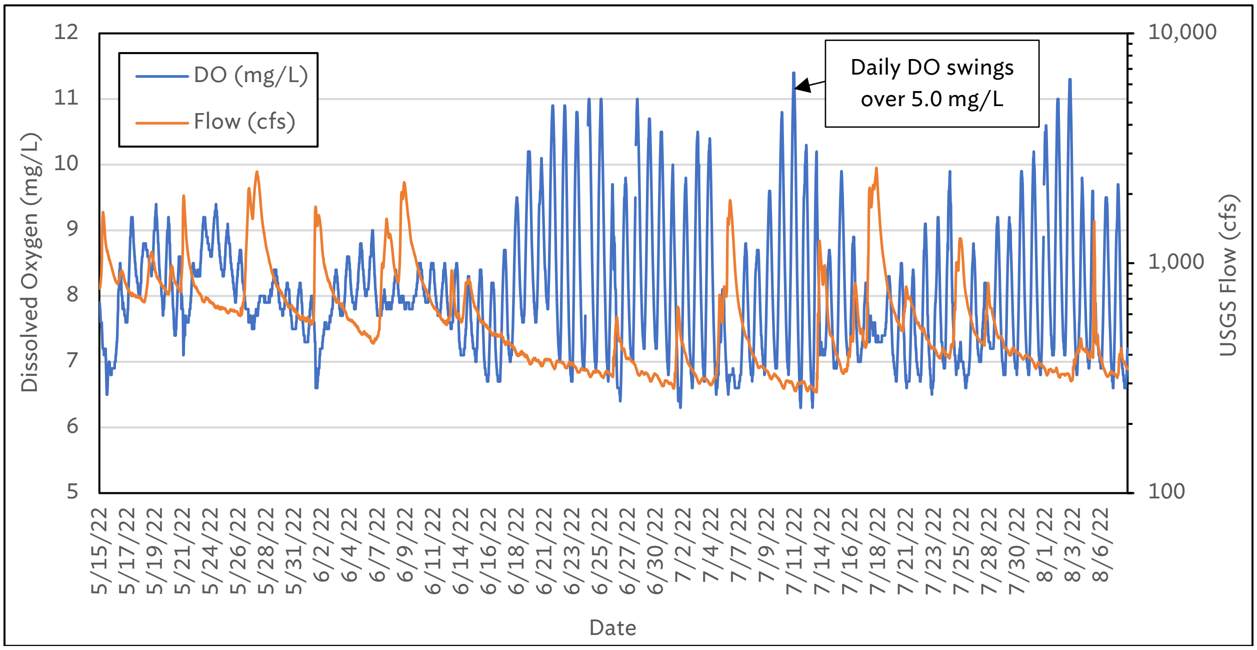


Figure 7. Effects of River Flow on DO Concentrations

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site from RM 13.15 to RM 8.60 in 2022 (Table 1) 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. Some of the habitat metrics used to determine a QHEI score include: type(s) and quality of substrates, amount and quality of in-stream cover, channel morphology, extent and quality of riparian vegetation, pool and riffle development and quality, and stream gradient (Ohio EPA, 1989). The QHEI can be used to assess and evaluate a stream's aquatic habitat and determine which of the six habitat components need to be improved to reach the QHEI target score.

The QHEI has a maximum score of 100, and a score greater than 60 on streams with >20 mi^2 drainage area 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 fish communities. 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.

Various attributes of stream habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional fish communities. Individual components of the QHEI can be used to evaluate whether a site is capable of meeting its warmwater habitat (WWH) designated use. 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).

Habitat is strongly correlated with the IBI biocriteria and the QHEI provides a target to evaluate how habitat impairments affect attainment of the aquatic use designations. The correlations with QHEI and habitat have worked well in the past in riverine systems, but there are occasions when the individual metric scores totaled 60 yet the habitat displayed impairments. The habitat TMDL target reflects the relationship of critical habitat parameters to aquatic community performance. The QHEI score also provides a numeric target for sedimentation and accounts for the distribution and texture of the sediment. It accounts for the overall quality of the substrate and sediment build-up in the embeddedness and silt metric. The habitat and sediment attributes can be utilized as a monitoring tool to measure progress towards the enhancement and protection of aquatic life in streams. Tables 9 and 10 list the Ohio EPA's target in-stream habitat and substrate characteristics (Ohio EPA, 1999).

Table 9. Ohio EPA Habitat TMDL Targets

QHEI Category	Target		Score
	WWH	EWH	
Overall QHEI Score	≥60	≥75	+1
High Influence MWH Attributes	≤1	0	+1
Total # of MWH Attributes	≤4	≤2	+1
		Habitat TMDL	+3

Table 10. Ohio EPA Sediment TMDL Targets

QHEI Category	WWH	EWH
Substrate Metric Score	≥13	≥15
Channel Metric Score	≥14	≥15
Substrate Embeddedness Score	≥3	4
Sediment TMDL	≥30	≥34

Results and Discussion

The Cuyahoga River lies entirely within the Erie/Ontario Drift and Lake plains ecoregion, within the glaciated portion of northeast Ohio. The lower 13 river miles fall within the Erie Lake Plains sub-ecoregion. This sub-ecoregion is a nearly level coastal strip of lacustrine deposits punctuated by beach ridges and swales (USEPA, 2012). The predominately sand and gravel substrates and moderate gradient typically encountered throughout the lower 13 river miles of the Cuyahoga reflect the general characteristics of this sub-ecoregion. Upstream of RM 13.00 is the lower section of the Erie Gorge sub-ecoregion, which is uniquely steep with rock exposures and high fluvial erosion rates. The RM 13.15 location is also located at the northern most, downstream end of the Cuyahoga Valley National Park (CVNP).

All sites evaluated in 2022 exceeded the Ohio EPA's target score of 60, which suggests that sufficient instream habitat exists to support a warmwater fish assemblage. QHEI scores ranged from 71.50 to 78.75 (Table 11), with a mean score of $\bar{x}$ = 74.50. This is down slightly from the reported 2020 mean score of $\bar{x}$ = 76.00, which was the last year in which all five of these sites were evaluated at the same time. RM 10.75 is the only site in 2022 with a QHEI score >75, which resulted in a narrative rating of *Excellent*. Figure 8 displays the QHEI scores with respect to RM and the overall habitat targets.

For the habitat assessments completed in 2022, all sites displayed the WWH characteristics of either having never been channelized or have recovered from channelization, extensive to moderate cover, fast current/eddies, and exhibited maximum depths > 40 cm as shown in Table 11. The moderate to sparse instream cover consisted of deep pools, woody debris, boulders, root wads, and shallows. Additionally, all sites displayed predominately sand and gravel substrates, glacial till substrate origin, and moderate to normal siltation.

All sites showed moderate to high sinuosity, with the exception of RMs 10.75 and 10.10. These sites were reported to have low sinuosity, but previous years indicated that these sites had moderate sinuosity. These differences were due to the subjective nature of QHEI assessments and not due to changes in the actual sinuosity of the sites. All sites in 2022 displayed moderate to extensive embedded substrates with the exception of RM 10.10 which displayed normal embeddedness. Substrate stability was calculated as moderate or high, due to the elevated percentage of sand substrates mixed with gravel; although RM 13.15 scored low for stability due to the river shifting from river left to river right over unstable substrate.

Table 11. 2022 Cuyahoga River QHEI Scores and Physical Attributes																																
													MWH Attributes																			
			WWH Attributes										High Influence						Moderate Influence													
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	Sand Substrate (Boat Sites)	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**
13.15	74.50	*Good*	X	X		X	X	X	X		X		**7**						**0**										X	X		**3**
11.30	74.00	*Good*	X	X		X	X	X	X		X		**6**						**0**	X	X			X					X	X		**6**
10.75	78.75	*Excellent*	X	X		X		X	X		X	X	**6**						**0**		X				X				X	X		**5**
10.10	71.50	*Good*	X	X				X	X	X	X	X	**7**				X		**1**		X			X	X							**4**
8.60	73.75	*Good*	X	X		X	X	X	X		X		**7**						**0**		X								X	X		**4**

WWH attributes outnumbered MWH attributes at all sites except for RM 11.30 (Table 11). There were slight variations in scores between 2022 and 2020, the last time that each of the field sites were surveyed (Figure 8). The narrative ratings for RM 13.15, 11.30, and 8.60 all declined from *Excellent* to *Good*. This is likely due to increases in silt loading covering the bottom substrates, generally causing moderate to extensive embeddedness. Additionally, mentions of unstable sediment and increased erosion rates in 2022 were noted for RM 13.15, this is possibly attributed to the Station Road Dam removal in 2020 and its associated sediment load migrating downstream.

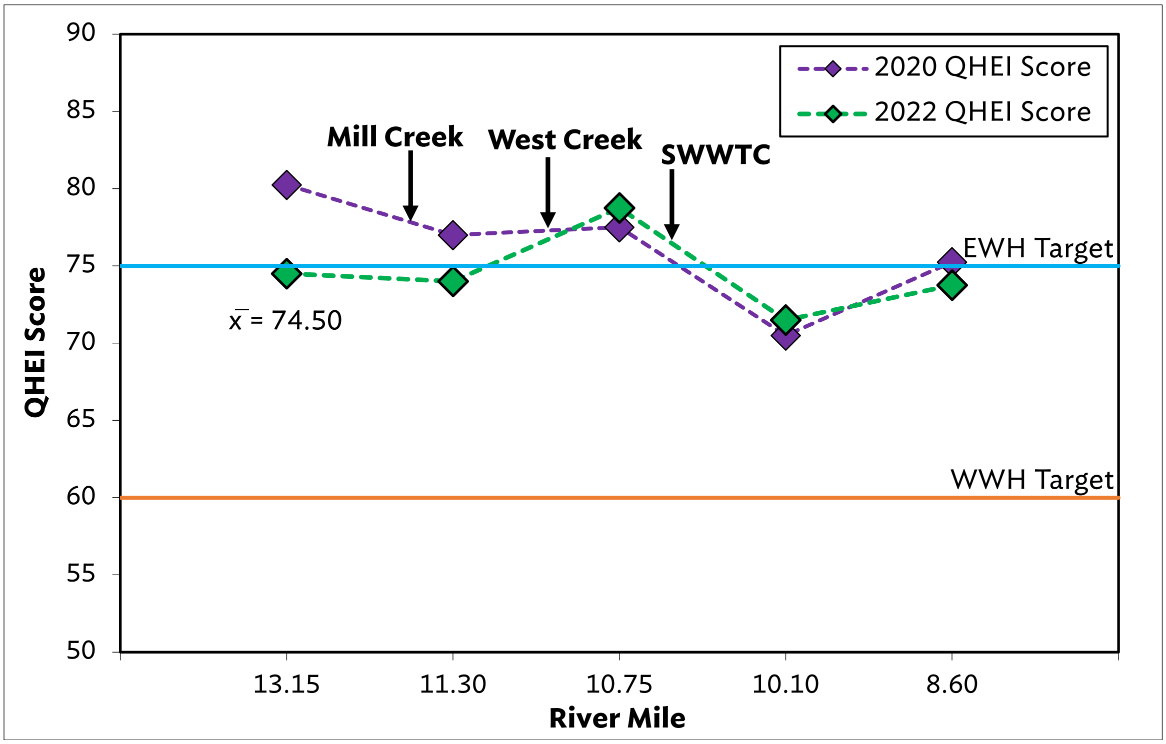


Figure 8. Longitudinal fish habitat QHEI scores Cuyahoga River mainstem 2022

In recent years, QHEI scores at all river miles have consistently met most WWH attributes. In 2022, there were only two high influence attributes across all sampled sites. Table 12 below uses the WWH and MWH attributes shown in Table 11, and it compares the 2022 field QHEI scoring to the habitat and sediment TMDL targets. All sites evaluated in 2022 failed to meet the overall sediment TMDL target score and were reported to have moderate to extensive embeddedness and moderate silt cover of the substrate. RM 10.10 was the only site to have normal silt quality.

Table 12. Cuyahoga River Habitat and Sediment TMDL Targets Scoring								
RM	Habitat TMDL Targets				Sediment TMDL Targets			
	QHEI Score	High Influence MWH #	# MWH Influences	Habitat TMDL score	Substrate	Channel	Embeddedness	Sediment TMDL score
13.15	74.50	0	3	3	14.5	15.0	**[2.00]**	**27.50**
11.30	74.00	0	**6**	**2**	13.5	14.0	**[2.00]**	**25.50**
10.75	78.75 E	0	**5**	**2**	14.5	15.0	**[1.00]**	**28.50**
10.10	71.50	1	4	3	15.5	14.0	**[0.50]**	**29.00**
8.60	73.75	0	4	3	13.5	16.5	**[3.50]**	**26.50**

E *Exceptional* narrative range
Bold = metric not meeting TMDL targets
[ ] = Bracket results indicate overall negative scores

Based on this information, all sites evaluated in 2022 are impacted by silt sedimentation, and its correlating negative effects on in-stream substrate seem to be the most significant limiting factor to the fish communities living within the lower Cuyahoga River. These problems may have many root causes. The removal of the Station Road Dam at RM 20.70, although important in restoring the stream biologically, seems to be having a temporary negative effect on sedimentation issues throughout the river downstream of the dam. This problem will likely remediate itself, but the river will take time to assimilate the excess sediment load. Urban and industrial land use borders the Cuyahoga River throughout most of the lower 13 miles once the river exits the CVNP, resulting in a loss of riparian habitat and flood plain access. Influences from other highly urbanized major tributaries throughout the lower Cuyahoga River (Tinkers Creek, Mill Creek, and West Creek) may also be a factor resulting in excess sedimentation through higher peak flows and increased erosion rates.

Fish Community Biology Assessment

Methods

Two quantitative electrofishing assessments were conducted at each site in 2022. A list of dates when the surveys were completed, along with approved flow measurements from the USGS gage station in Independence are shown in Table 13. Sampling was conducted using boat electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from upstream to downstream by slowly and steadily maneuvering the boat as close to shoreline and submerged habitat as possible. The sampling zone was 0.50 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 13. Sampling Dates and River Flows		
Date	Sites sampled (RMs)	Daily Mean Flow (CFS)
6/23/2022	13.50, 11.30	334
6/24/22	10.75, 10.10, 8.60	324
8/16/22	10.75, 10.10, 8.60	261
8/17/22	13.15, 11.30	254

The electrofishing results were compiled and utilized to evaluate fish community health through the application of two Ohio EPA indices. The first index, the Index of Biotic Integrity (IBI), incorporates twelve community metrics representing structural and functional attributes (Table 14). 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 14. IBI Metrics (Boat Sites)
Total Number of Indigenous Fish Species
Percent Round-bodied Suckers
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 in a Sample
Percent of Simple Lithophilic Spawners
Percent of Individuals with DELTs

The second fish index used by the Ohio EPA is the Modified Index of Well-being (MIwb). The MIwb (calculated using Formula 1 below) incorporates four fish community measures: numbers of individuals, biomass, the Shannon Diversity Index ($\overline{H}$) (Formula 2 below) based on sample numbers, and the Shannon Diversity Index ($\overline{H}$) based on sample weights.

Formula 1: $$MIwb = 0.5\ lnN + 0.5\ lnB + \overline{H}(No.) + \overline{H}(Wt.)$$

N = Relative numbers of all species excluding species designated as highly tolerant, hybrids, or exotics

B = Relative weights of all species excluding species designated as highly tolerant, hybrids, or exotics

$\overline{H}(No.)$ = Shannon Diversity Index based on numbers

$\overline{H}(Wt.)$ = Shannon Diversity Index based on weight

Formula 2:

$$\overline{H} = -\sum\left[\left(\frac{n_i}{N}\right)log_e\left(\frac{n_i}{N}\right)\right]$$

n_i = Relative numbers or weight of species

N = Total number or weight of the sample

The Cuyahoga River is located completely within the Erie-Ontario Lake Plains (EOLP) ecoregion and follows the EOLP fish community metrics scoring. The WWH IBI scoring criterion in the EOLP ecoregion is shown in Table 15, and a site is considered to be within non-significant departure if the score falls within 4 IBI units or 0.5 MIwb units of the criterion. 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 15. Fish Community Biology Scores for Boat Sites in the EOLP Ecoregion

Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
IBI Score	12-17	18-27	26-35	36-39	40-43	44-47	48-60
MIwb Score	0-4.9	5.0-6.3	6.4-8.1	8.2-8.6	8.7-9.0	9.1-9.5	$\geq$9.6
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Results and Discussion

The NEORSD collected 4,276 individual fish, representing 42 unique species from the five sampling sites in 2022, with two electrofishing passes completed at each site for a total of ten surveys. The 2022 IBI and MIwb scores from each assessment location are listed below in Table 16. All five sites, with the exception of RM 8.60, scored within attainment for the MIwb component, ranging from *Good* to *Exceptional* (MIwb $\overline{x}$ = 9.3). The MIwb for RM 8.60 was calculated to be within the non-significant departure (NSD) of WWH criterion. Four of the five locations were within NSD of the applicable IBI Aquatic Life Habitat (ALU) criterion, with RM 8.60 being the only sample location in non-attainment. However, IBI scores averaged $\bar{x}$ = 36 across the five assessment locations, which is within NSD of the WWH attainment.

Table 16. 2022 Cuyahoga River IBI and MIwb Results

Stream RM	Native species	Relative Number (N)	Relative weights (B)(kg)	Predominant species (%)	IBI Score	MIwb Score	Avg. Site IBI Score	Avg. Site MIwb Score
13.15 *1st Pass*	20	762	114.52	Spotfin shiner (36.0%) Sand shiner (23.2%) Central stoneroller (8.0%)	38	9.1	38 [NS] (*Marg. Good*)	**9.65** [E] (*Excep.*)
13.15 *2nd Pass*	23	2068	52.84	Common shiner (20.4%) Stoneroller (17.1%) Spotfin shiner (14.3%)	38	10.2		
11.30 *1st Pass*	19	572	151.1	Spotfin shiner (14.5%) White sucker (14.5%) Stoneroller (14.0%)	36	9.0	37 [NS] (*Marg. Good*)	**9.3** (*Very Good*)
11.30 *2nd Pass*	21	530	52.58	Spotfin shiner (15.4%) Common shiner (15.4%) Stoneroller (15.1%)	38	9.6		
10.75 *1st Pass*	24	316	91.15	Sand shiner (16.9%) White sucker (13.6%) Shorthead redhorse (9.9%)	36	9.4	36 [NS] (*Marg. Good*)	**9.45** (*Very Good*)
10.75 *2nd Pass*	24	390	39.06	Bluntnose minnow (22.4%) Shorthead redhorse (10.5%) Golden redhorse (9.2%)	36	9.5		
10.10 *1st Pass*	19	912	84.41	Spotfin shiner (37.9%) White sucker (19.7%) Sand shiner (16.3%)	36	9.1	36 [NS] (*Marg. Good*)	**9.7** [E] (*Excep.*)
10.10 *2nd Pass*	27	680	94.63	Spotfin shiner (17.9%) Bluntnose minnow (9.6%) Shorthead redhorse (9.1%)	36	10.3		
8.60 *1st Pass*	17	206	52.99	White sucker (24.7%) Emerald shiner (11.3%) Shorthead redhorse (10.0%)	36	9.0	33 * (*Fair*)	8.5 [NS] (*Marg. Good*)
8.60 *2nd Pass*	19	340	9.2	Sand shiner (39.1%) Stoneroller (19.8%) White sucker (10.6%)	30	8.0		

Bold = meets WWH criterion [IBI ≥ 40; MIwb ≥ 8.7]
[NS] = non-significant departure from WWH biocriterion [IBI ≥ 36; MIwb ≥ 8.2]
* Significant departure from the biocriterion (*>4 ICI units; >5 MIwb units*)
[E] = Exceptional WWH score

Comparing the fish community metric scores between 2022 and 2020, the last time that all the field sites were sampled, the scores increased across all locations (Table 17). Four of the five RMs surveyed showed an increase in the IBI scores from *Fair* to *Marginally Good,* which is considered to be within attainment of the WWH biocriterion. Additionally, the score at RM 10.75

increased from *Fair* to *Marginally Good* between the 2021 and 2022 surveys. The score at RM 8.60 remained consistent with previous years with a *Fair* IBI score. The QHEI scores for all sites in 2022 were greater than 60, indicating that the habitat is not a limiting factor in the fish community attaining the warmwater habitat criterion (Ohio EPA, 2006).

Table 17. Cuyahoga River Historic IBI Scores (1990-2022)

Year	RM 20.75	RM 16.20	RM 13.15	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00
Cuyahoga River (19-001-000) - WWH Existing									
1990	-	-	-	-	-	15	15	-	-
1991	-	-	-	-	-	17	16	-	18
1992	-	-	-	-	-	20	19	-	21
1997	-	-	-	-	-	25	17	-	18
1998	-	-	-	-	-	26	27	-	21
1999	-	-	-	-	-	31	31	-	24
2001	-	-	-	-	-	30	29	-	22
2003	-	-	-	-	-	34	28	-	23
2004	-	-	-	-	-	35	35	-	-
2006	-	-	-	-	-	*39*	*36*	-	31
2007	-	*39*	-	30	*38*	34	35	-	33
2008	-	**44**	-	34	*38*	*37*	*36*	-	34
2009	-	**45**	-	*38*	**44**	*36*	31	**40**	31
2010	-	**43**	-	*39*	*39*	33	*37*	**41**	31
2011	-	**47**	-	*39*	35	**44**	*36*	**40**	32
2012	-	-	-	*36*	35	*38*	34	*38*	29
2013	-	-	-	**41**	**42**	*36*	33	**41**	34
2014	-	-	-	**44**	**42**	*38*	**40**	34	32
2015	-	-	-	-	-	33	28	32	31
2016	-	-	-	*39*	34	*36*	32	**41**	33
2017	28	**50***	-	*38*	*38*	**42**	*37*	**43**	29
2018	-	-	-	-	-	24	32	34	28
2019	-	-	-	33	**40**	32	**41**	32	-
2020	-	-	32	-	33	35	35	28	-
2021	-	-	**40**	-	-	34	-	32	-
2022	-	-	*38*	-	*37*	*36*	*36*	33	-

Bold = meets WWH criterion (≥ 40)
Italics = non-significant departure from WWH criterion (≥ 36)
*Meets Exceptional WWH Criterion

Individual metrics in the IBI were examined further to determine specific components of the fish community that increased/decreased from the 2020 survey. The score increase at RM 13.15 is attributed to the increase in the relative number of insectivorous fish (+40.2%), a decrease in omnivorous fish (-53.4%), an increase in relative number of fish (+849), and a decrease in overall DELT anomalies (-66.7%) from the 2020 survey year, increasing the IBI score by 6 points. The RM 11.30 location saw an increase in insectivorous fish (+90.9%), an increase in top carnivorous species (+139.2%), and an increase in simple lithophilic species (161.4%) increasing the IBI score 4 points from 2020. The IBI scores at RMs 10.75 and 10.10 increased by one point between the survey years. Overall, the IBI scores were higher than scores for 2020. Table 17 shows the historic scores for sites sampled as part of the Cuyahoga River Environmental Monitoring, and Figure 9 shows the historical scores from the past six years at field sites monitored in 2022.

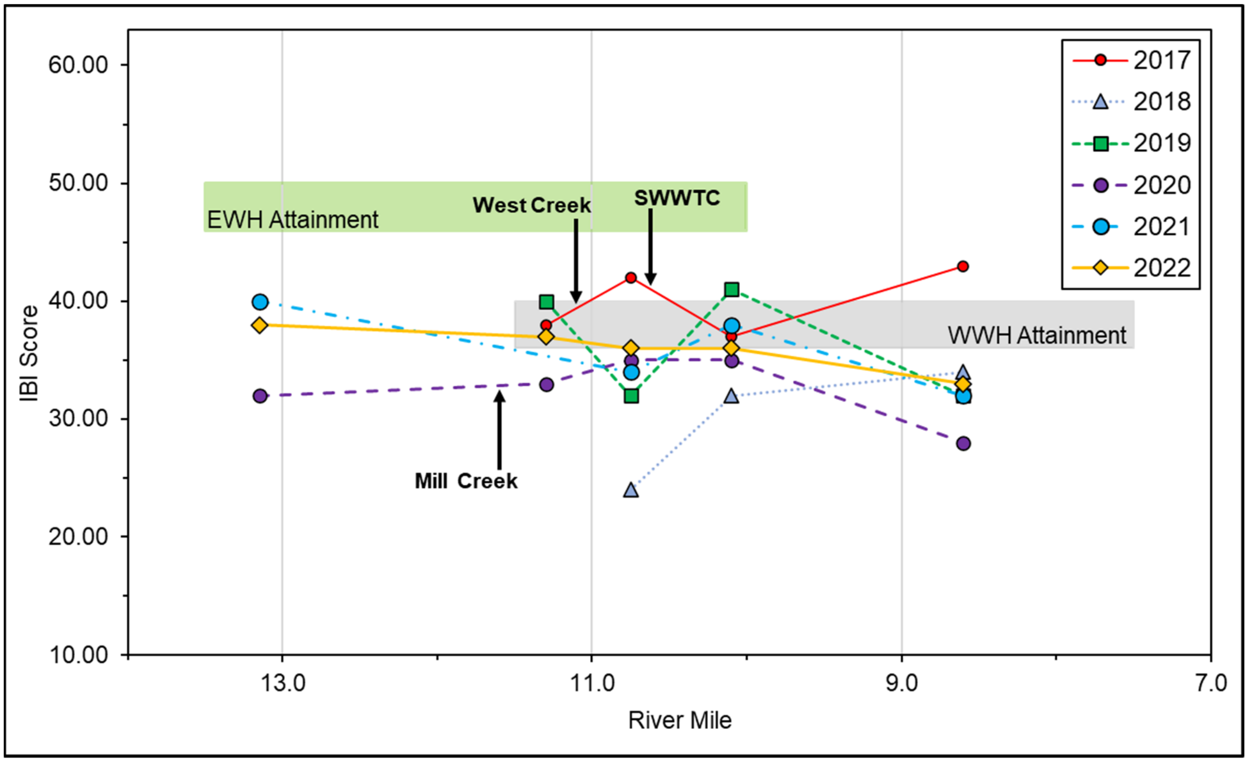


Figure 9. Longitudinal IBI scores at Cuyahoga River monitoring sites 2017-2022. Gray box represents range of WWH attainment and NSD (4 points); light green box represents range of EWH attainment and NSD.

The presence of the Eastern gizzard shad (*Dorosoma cepedianum*) as an abundant fish counted in historical surveys may have affected the IBI score calculations from previous years at some of the monitoring sites. The low relative number of the Eastern gizzard shad at sites monitored in 2022 may be due to the timing of the surveys which occurred during warmer water temperatures in June and August. As the summer progresses into fall, gizzard shad seasonally migrate into the Cuyahoga River from Lake Erie because of the river's warmer temperatures. This influx may have skewed IBI results in previous surveys because many gizzard shad that enter the river do not actually reside there and do not benefit the IBI score. Rather, they are seeking refuge due to their fatal response to cold temperature fluctuations. The presence of large schools of gizzard shad among the collected samples at lower RMs may explain some of the yearly variations in IBI scores.

The MIwb scored in the *Very Good-Exceptional* range (Table 18) for RMs 13.15, 11.30 and 10.10, which is an increase from the 2020 data. The MIwb scores at RM 10.75 and RM 8.60 remained consistent with the 2020 survey with scores of *Very Good* and *Marginally Good*, respectively. Except for RM 8.60, all sites surveyed in 2022 are in full attainment of the WWH criterion based on the MIwb scores. Table 18 shows the historical MIwb scores at various Cuyahoga River sites sampled over the last three decades, and longitudinal trends for the fish community MIwb scores at the sites monitored in 2022 are illustrated in Figure 10. The general score increases over the years indicates a positive trend towards attainment of the WWH criterion.

Table 18. Cuyahoga River Historic MIwb Scores (1990-2022)

Year	RM 20.75	RM 16.20	RM 13.15	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00
1990	-	-	-	-	-	4.5	4.6	-	-
1991	-	-	-	-	-	5.5	5.6	-	6.1
1992	-	-	-	-	-	5.6	6.6	-	5.8
1997	-	-	-	-	-	7.5	6.1	-	6.1
1998	-	-	-	-	-	7.8	7.6	-	5.5
1999	-	-	-	-	-	8.2	*8.6*	-	7.0
2001	-	-	-	-	-	7.4	*8.2*	-	6.1
2003	-	-	-	-	-	7.6	7.8	-	7.0
2004	-	-	-	-	-	8.0	*8.4*	-	-
2006	-	-	-	-	-	**8.8**	*8.5*	-	7.8
2007	-	*8.6*	-	*8.5*	*8.3*	**9.4**	**9.7**	-	*8.3*
2008	-	**9.9***	-	*8.2*	**9.1**	**8.9**	**9.4**	-	*8.5*
2009	-	**9.9***	-	**8.8**	**9.5**	**9.1**	**9.2**	**9.0**	*8.5*
2010	-	**9.5**	-	**9.0**	**9.7***	**9.7***	**9.5**	**9.2**	**8.8**
2011	-	**9.6***	-	**8.7**	**8.9**	**9.5**	**9.1**	**8.8**	*8.4*
2012	-	-	-	**9.2**	**9.5**	**9.6**	**10.1***	**9.6***	*8.6*
2013	-	-	-	8.3	**9.2**	**9.2**	**9.1**	**8.8**	*8.3*
2014	-	-	-	**9.1**	**9.3**	**9.0**	**9.5**	*8.2*	7.6
2015	-	-	-	-	-	**9.3**	**9.0**	*8.8*	7.8
2016	-	-	-	*8.6*	**9.5**	**9.7***	**9.2**	**9.1**	*8.2*
2017	8.1	**10.2***	-	**9.7***	*8.6*	**9.9***	**9.5**	**9.4**	*8.4*
2018	-	-	-	-	-	**8.9**	**9.5**	**8.7**	*8.5*
2019	-	-	-	8.1	**9.4**	**9.3**	**9.3**	**9.7***	-
2020	-	-	**8.9**	-	*8.6*	**9.2**	**9.4**	*8.5*	-
2021	-	**9.4**	**8.7**	-	-	**8.7**	**-**	**8.9**	-
2022	-	-	**9.7***	-	**9.3**	**9.5**	**9.7***	*8.5*	-

Table 18. Cuyahoga River Historic MIwb Scores (1990-2022)									
Year	RM 20.75	RM 16.20	RM 13.15	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00
Bold = meets WWH criterion (≥ 8.7) *Italics = non-significant departure from WWH criterion (≥ 8.2)* ***Meets Exceptional WWH Criterion**									

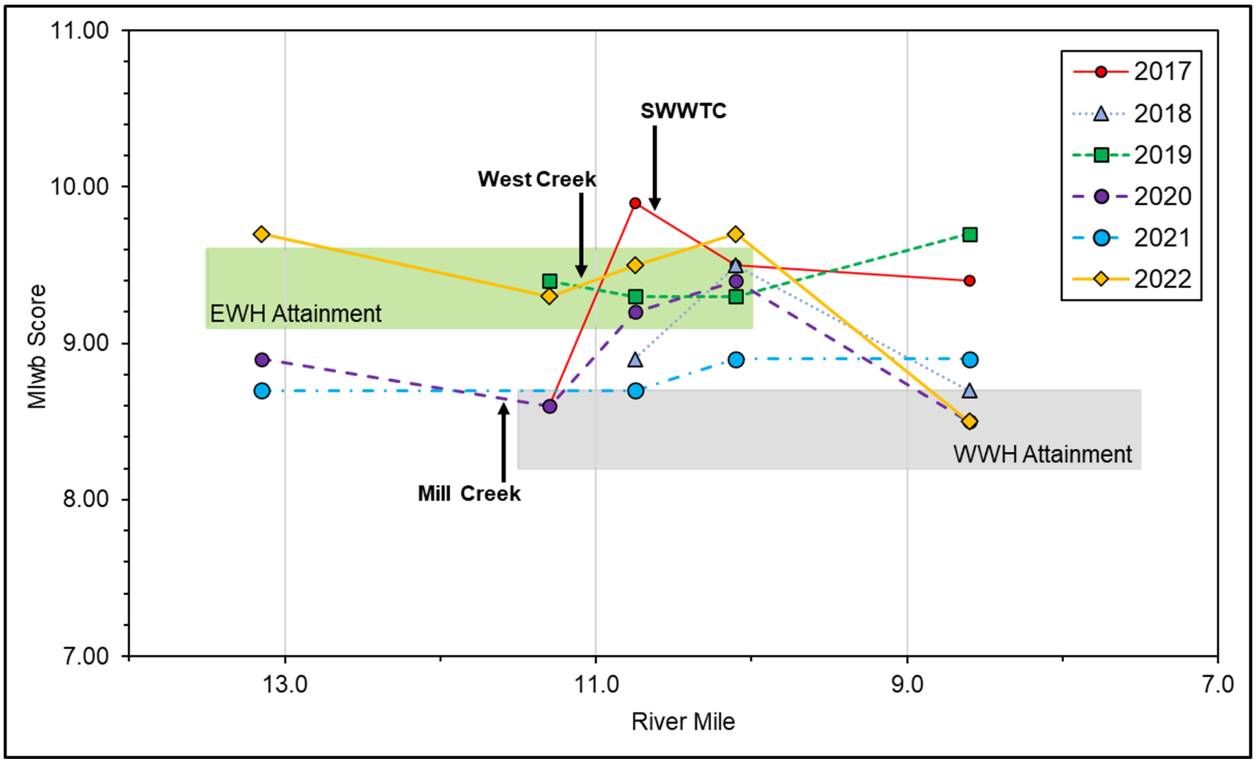


Figure 10. Longitudinal MIwb scores at Cuyahoga River monitoring sites 2017-2022. Gray box represents range of WWH attainment and NSD (0.5 points); light green box represents range of EWH attainment and NSD.

Two metrics that consistently scored poorly in 2022, and during previous survey years, were the number of intolerant species and the proportion of round-bodied sucker species. Intolerant species decline with decreasing water quality and are absent when a waterbody is degraded to the "fair" category (Karr et al., 1986). The generally low number of intolerant fish in the Cuyahoga River has been common throughout past survey years and may correlate to negative influences from the urbanized watershed. Bacteriological contamination, nutrient enrichment, siltation, and embeddedness are chemical and physical parameters that continuously affect the Cuyahoga River fish community.

Siltation and embeddedness are two metrics measured in the QHEI, focused on substrate quality. Round-bodied suckers, which as a family are more sensitive to chemical pollutants, also need clean and unembedded substrates to successfully spawn. With moderate to heavy siltation and embeddedness recorded throughout the lower 13 miles of the Cuyahoga River, simple lithophilic species like round-bodied suckers do not have the clean substrates needed for proper egg development.

Macroinvertebrate Community Biology Assessment

Methods

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers in conjunction with a qualitative (qual.) 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 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 19), 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 shown below in Table 20 and a site is considered to be within non-significant departure if the score falls within 4 ICI units of the biocriterion.

Table 19. 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

Table 19. ICI Metrics
Percent Tolerant Organisms (as defined)
Number of Qualitative EPT Taxa

Table 20. 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

The five sites on the Cuyahoga River were sampled quantitatively using HDs in conjunction with qualitative kick sampling in 2022. All five HDs were able to be recovered during the field sampling season. In the ELOP ecoregion, an ICI score of 30 or greater is needed to meet the WWH biocriterion. For the 2022 sampling season, all five sampling sites were in attainment of the applicable WWH biocriterion of 34. The stream reach monitored in 2022 averaged an ICI score of $\bar{x}$ = 38.8 (*Good*). Table 21 shows a more detailed description of the Cuyahoga River macroinvertebrate community. Most sites displayed a moderate taxa diversity with an abundance of EPT and sensitive taxa. The predominant organisms on the natural substrates were mostly members of the EPT group.

Table 21. 2022 Cuyahoga River Macroinvertebrate Results							
Stream RM	Density Qt. (ft^2) / Ql.	Ql. / Total Taxa	Ql. EPT / Sens. Taxa	Qt. % Tol. / % Sens. Taxa	Predominant Orgs. on Natural Substrate	ICI	Narrative Evaluation
Cuyahoga River (19-001-000) - WWH Existing							
13.15	829 / M-L	60 / 71	19 / 17	10.8% / 25.3%	Baetid mayflies, hydropsychid caddisflies, midges	42	*Very Good*
11.30	1,047 / M-L	54 / 58	15 / 15	7.7% / 22.1%	Baetid mayflies, hydropsychid caddisflies, midges, scuds	36	*Good*
10.75	1,929 / M-L	58 / 66	17 / 16	21.8% / 20.4%	Baetid mayflies, hydropsychid caddisflies, leptocerid caddisflies, isopods, midges	38	*Good*
10.10	934 / M	42 / 54	12 / 10	12.6% / 17.2%	Baetid mayflies, hydropsychid caddisflies, midges, isopods, amphipods	42	*Very Good*
8.60	1,244/ M	47 / 59	15 / 15	27.6% / 10.5%	Baetid mayflies, hydropsychid caddisflies,	36	*Good*

Table 21. 2022 Cuyahoga River Macroinvertebrate Results							
Stream RM	Density Qt. (ft^2) / Ql.	Ql. / Total Taxa	Ql. EPT / Sens. Taxa	Qt. % Tol. / % Sens. Taxa	Predominant Orgs. on Natural Substrate	ICI	Narrative Evaluation
Cuyahoga River (19-001-000) - WWH Existing							
					leptocerid caddisflies, amphipods, midges		
Qt. - Quantitative sample collected on Hester-Dendy artificial substrate. Ql. - Qualitative sample collected from natural stream substrate. 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 or Intolerant*							

Temporal data displayed in Table 22 indicate that 2022 scores are consistent with previous years. Figure 11 shows the historic ICI scores for the field sites monitored in 2022. Although a slight decrease in ICI scores was recorded at RM 13.15 and RM 10.75 compared to the previous year, these locations still achieved a *Very Good* and *Good* score, respectively. The qualitative sample at RM 13.15 in 2022 contained less qualitative taxa (58), qualitative EPT taxa (19), and qualitative sensitive taxa (15) compared to the survey conducted in 2021. This is reflected in the overall decrease in the score at the site from *Exceptional* to *Very Good* when compared to the previous year. The score at RM 10.75 decreased from *Very Good* in 2021 to a score of *Good* received in the 2022 survey. This was likely due to the greater percentage of organisms in the "other diptera and non-insects" metric, as well as an increase in the percentage of pollution-tolerant taxa. The ICI scores at the other three sites surveyed in 2022 were consistent with the previous year.

Table 22. Cuyahoga River Historic ICI Scores (2006-2022)									
Year	RM 20.75	RM 16.20	RM 13.15	RM 12.10	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00
2006	--	30	--	--	--	**38**	**34**	--	--
2007	--	**34**	--	**35**	**34**	*32*	**36**	--	**38**
2008	--	**40**	--	**40**	**40**	**40**	**40**	--	**38**
2009	--	**36**	--	**38**	**36**	**42**	**38**	**36**	**42**
2010	--	**36**	--	**40**	**40**	**36**	32	**44**	**34**
2011	--	**40**	--	**36**	**36**	*30*	--	--	26
2012	--	**40**	--	**44**	**38**	**40**	**34**	**40**	*30*
2013	--	**36**	--	**40**	**34**	**46***	**34**	**42**	**38**
2014	--	**44**	--	--	**48***	--	**34**	*30*	28

Table 22. Cuyahoga River Historic ICI Scores (2006-2022)

Year	RM 20.75	RM 16.20	RM 13.15	RM 12.10	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00
2015	--	**44**	--	**44**	**46***	**50***	**44**	**44**	24
2016	--	--	--	*30*	*32*	*32*	**38**	28	*32*
2017	*30*	**46**	--	**48***	**42**	**38**	**38**	**38**	*32*
2018	G	**44**	--	**38**	**34**	**38**	**36**	**40**	18
2019	--	VG	--	**44**	*30*	26	G	*32*	--
2020	--	--	**52***	--	**40**	**46***	**40**	**48***	--
2021	**--**	**--**	**E***	--	--	**44**	**44**	**36**	--
2022	--	--	**42**	--	**36**	**38**	**42**	**36**	--

Bold = meets WWH criterion (≥ 34)
Italics = non-significant departure from WWH criterion (≥ 30)
***Meets Exceptional WWH Criterion**

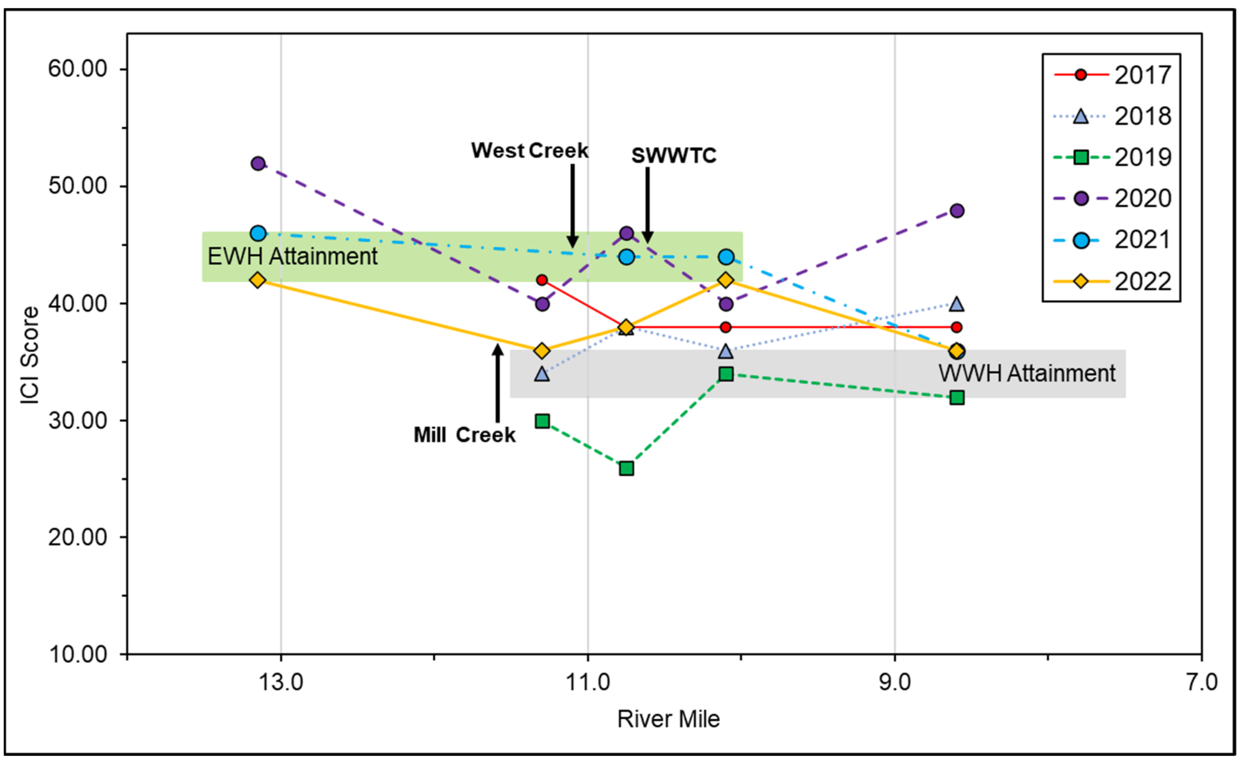


Figure 11. Longitudinal ICI scores at Cuyahoga River monitoring sites 2017-2022. Gray box represents range of WWH attainment and NSD (4 points); light green box represents range of EWH attainment and NSD.

Figure 12 below shows the breakdown in macroinvertebrate community compositions colonized on the HD at each site. The abundance of mayfly and caddisfly taxa in the upstream reaches of the study area, from RM 13.15-11.30, demonstrates the well-balanced benthic community and is reflected in the *Good* and *Very Good* ICI scores. The abundance of EPT taxa limits proportions of the more tolerant "other dipterans and non-insect" taxa throughout this reach.

The lower reaches from RM 10.75-10.10 contained a lower proportion of EPT family taxa and a higher proportion of "other dipterans and non-insects". These study locations also contained a higher percentage of pollution-tolerant taxa (Table 21). A decrease in the percent of caddisflies and mayflies, and an increase in percent "other organisms" downstream of RM 10.75 may be due to changes in habitat and substrate embeddedness, increase in urban land use, changes in gradient and sub-ecoregion transition, and the effluent from the NEORSD Southerly WWTC.

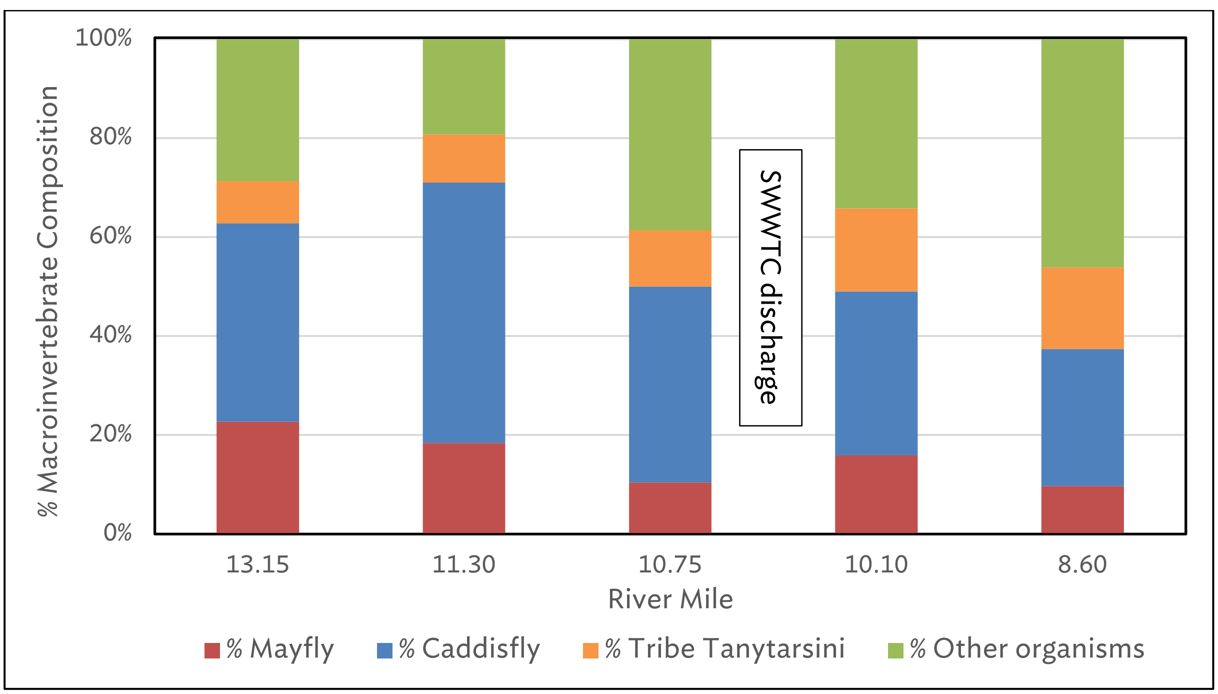
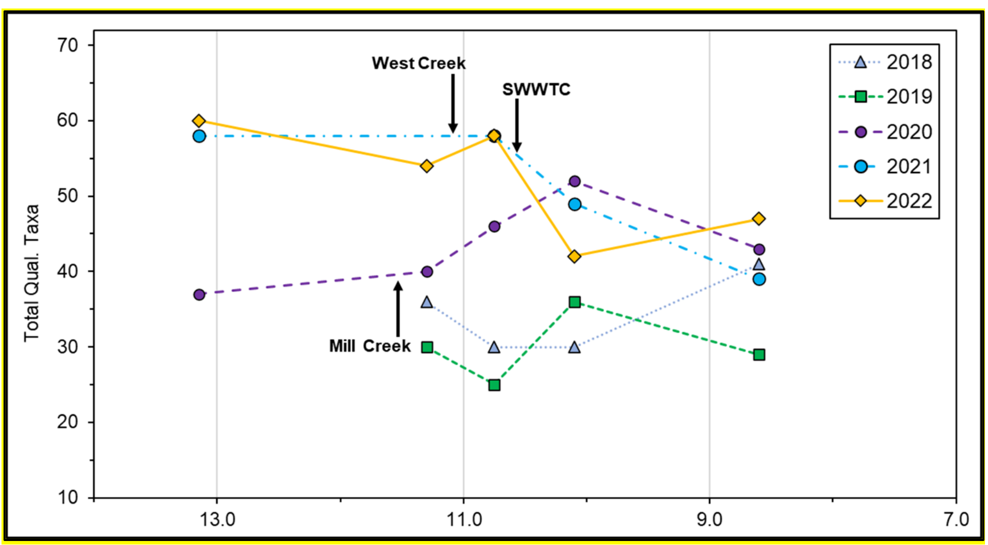


Figure 12. 2022 Cuyahoga River Macroinvertebrate Community Composition

Three metrics commonly used to assess the health of a stream are the number of qualitative taxa, number of qualitative EPT taxa, and number of qualitative sensitive taxa. Figure 13 below displays longitudinal trends on the Cuyahoga River for the last five years at the field sites monitored in 2022. Macroinvertebrate scores have generally improved over time for all three metrics at each sample location. The increase in scores over time indicates a positive trend towards the attainment of the WWH criterion.

Substrate embeddedness and increased siltation was observed at field sites by NEORSD field staff, but this did not seem to negatively affect the overall macroinvertebrate community. The increase in silt may be attributed to the removal of the Station Road Dam (RM 20.70) in 2020 and silt migration downstream from the former dam pool. Metric scores declined slightly from upstream to downstream and this is likely due to changes in land use and habitat. The upstream reaches are protected by the CVNP until approximately RM 13.00. Downstream of RM 13.00, the sub-ecoregion changes to a lower gradient Lake Erie Plains. High intensity development, impervious surfaces, and storm sewers may cause higher erosion rates and increase substrate embeddedness in the lower reaches.



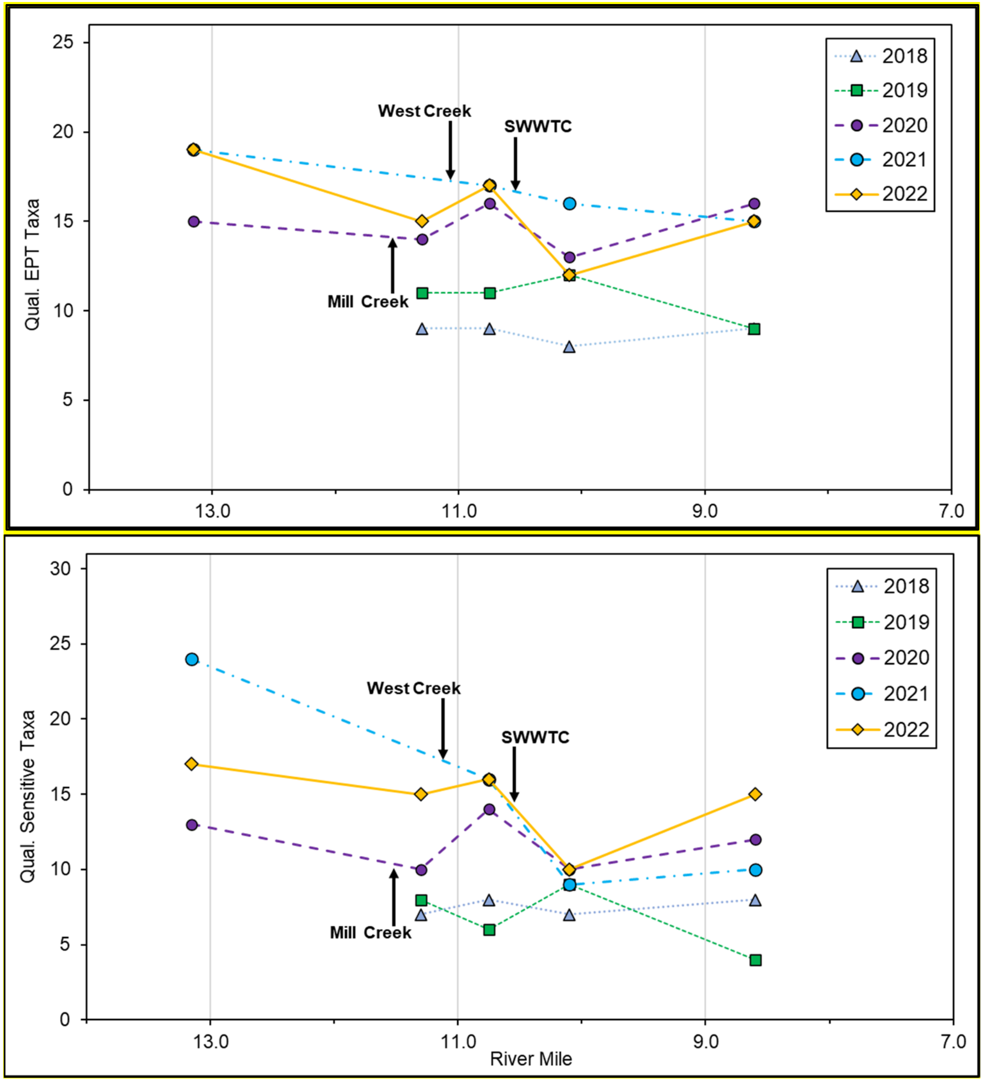


Figure 13. Longitudinal trends for Qual. Taxa, Qual. EPT Taxa, and Qual. Sensitive Taxa richness scores in the Cuyahoga River 2018-2022.

Conclusions

Incredible progress has been made on the aquatic life recovery in the lower Cuyahoga River. From a stream that was once devoid of aquatic life, most sections of the Cuyahoga River mainstem are meeting statewide biocriteria for the protection of aquatic life. The 2022 Cuyahoga River water quality assessment resulted in 80% of the filed sites in full attainment of the aquatic life criterion (Table 23). All Cuyahoga River sites met the WWH target for the QHEI, although some substrate metrics did not meet sub-specific TMDL target criteria. RM 8.60 failed to meet the ALU biocriterion for the IBI fish metric only, while the remaining four sites were within non-significant departure. All five sites were in attainment of the MIwb with two sites, RM 13.15 and RM 10.10, achieving an *Exceptional* narrative score. The macroinvertebrate community has continued to demonstrate *Good* to *Very Good* communities throughout the lower reaches of the Cuyahoga River that were monitored in 2022 upstream of the ship channel.

Table 23. 2022 Cuyahoga River Biological Survey Results

RM	DA (mi^2)	Attainment Status	IBI Score	MIwb Score	ICI Score	QHEI Score	Cause(s)	Source(s)
Cuyahoga River (19-001-000) - WWH Existing								
13.15	706	FULL	38 [NS]	9.7 [E]	42	74.50		
11.30	733	FULL	37 [NS]	9.3	36	74.00		
10.75	749	FULL	36 [NS]	9.5	38	78.75 [E]		
10.10	751	FULL	36 [NS]	9.7 [E]	42	71.50		
8.60	752	PARTIAL	33 *	8.5 [NS]	36	73.75	Pollutants in urban stormwater, Sedimentation, Toxic metals	Urban runoff/stormwater, Atmospheric deposition/ urbanization

[NS] Non-significant departure of WWH of biocriterion (≤ 4ICI; ≤ 4IBI; ≤ 0.5 MIwb units)
[E] *Exceptional* narrative range
* Significant departure from the biocriterion (>4 ICI; >4 IBI; >0.5 MIwb units).

As in years past, assessments in 2022 showed water quality impairments at all sites which may be preventing the establishment of a healthier biological community. Following significant wet-weather events, *E. coli* densities exceeded WQS at all five sample locations (Tables 4). This is common in urbanized watersheds due to improper sanitary connections, combined sewer overflows, failing household sewage treatment systems, and urban stormwater runoff. Effluent from Southerly WWTC did not appear to significantly contribute to these exceedances (Table 5), as the *E. coli* densities were also elevated upstream of the Southerly WWTC effluent discharge and did not increase downstream.

All mercury results in 2020 were below the method detection limit. Because the detection limit for EPA Method 245.1 is above the criteria for the Human Health Non-Drinking and Protection of Wildlife OMZAs, it cannot be determined if the sites were in attainment of those criteria. Periodic toxic concentrations of mercury due to urban runoff may be one of the causes for the low abundance of intolerant fish species in the Cuyahoga River mainstem. Nutrient enrichment may also potentially be a hinderance to biological performance, as geometric mean concentrations exceeded the proposed large river nutrient WQS (Table 7). Nutrient enrichment promotes excess algal growth which was observed in the daily DO swings approaching the large river WQS threshold (Figure 7). However, the site in which these swings were measured was in full attainment of the biocriteria, so any impacts from nutrients remain unclear.

Biological communities have continued to improve over time throughout the Cuyahoga River mainstem. The QHEI analyses of the five study sites indicate that each should be able to support a healthy fish community with the potential to meet the WWH biocriteria. The Cuyahoga

River, downstream of the National Park, has exhibited *Fair* to *Good* fish community scores that are impacted by multiple attributes as mentioned earlier. Sedimentation from urban runoff appears to be the main cause of impairment for the fish community component. Further biological monitoring will determine the positive effects from the former Station Road Dam removal once the sediment load has migrated through the system. The macroinvertebrate communities have recovered to full attainment throughout the lower 25 miles upstream of the shipping channel, with stream reaches exhibiting *Good* to *Very Good* communities. Overall, monitoring of the Cuyahoga River since the 1990s has shown improvements in water quality over time. Fewer water quality exceedances are being observed and overall biological assessments have shown increases in scores.

The local municipalities participating in the Member Community Infrastructure Program (MCIP) and continued efforts by NEORSD towards the CSO long-term control plan (LTCP), as part of *Project Clean Lake*, will improve water quality problem through the reduction in sanitary sewer overflows and surcharged sewers, elimination of common trench sewers, illicit discharges, and areas of clustered septic systems. The NEORSD Regional Stormwater Management Program will continue to invest in projects within the Cuyahoga River watershed to address bank erosion and stabilization, floodplain expansion, habitat restoration, and stormwater management. The NEORSD Stormwater Management Program and the MCIP projects are critical to effectively manage urban stormwater runoff and the associated negative effects on the Cuyahoga River. These efforts will help to manage stormwater runoff and peak flow rates, control erosion and excess sedimentation, and reduce the influx of toxic metals and nutrients. As projects are completed, continued biological, habitat, and water chemistry monitoring by the NEORSD will demonstrate the overall water quality improvements. Future watershed monitoring will be used to evaluate the implementation of these and other changes, as well as assess the related impacts on the quality of the river.

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