Northeast Ohio
Regional Sewer District

2021 Cuyahoga River
Biological, Water Quality, and Habitat Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

March 2022

Table of Contents

List of Figures

List of Tables

Introduction

The Cuyahoga River is located in Northeast Ohio, flowing through the major cities of Akron and Cleveland before its final confluence with Lake Erie. In 2021, the Northeast Ohio Regional Sewer District (NEORSD) and the Ohio Environmental Protection Agency (EPA) 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 NEORSD's Southerly Wastewater Treatment Center (SWWTC) on the lower Cuyahoga River and identify any spatial and temporal water quality trends. Data from this study may also be used to perform regulatory tasks by the Ohio EPA. During the 2021 sampling season, four stream locations were evaluated between river mile (RM) 13.15 and RM 8.60 by the NEORSD, while the Ohio EPA sampled five stream locations between RM 24.10 and 9.70. Water chemistry data was used at two additional sites in accordance with the Ohio EPA National Pollution Discharge Elimination System (NPDES) permit on the Cuyahoga River.

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. The 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 SWWTC 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 EPA 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.

Past monitoring 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 2020 according to the Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2020a). Despite this, historically, some sites have displayed full attainment of their respective biological criteria. Currently, there are four parameters included in the approved TMDL for the Cuyahoga River within NEORSD's service area: dissolved oxygen (DO), total phosphorus (TP), nitrate-nitrite (NO_3-NO_2), and in-stream habitat. The major causes of impairment listed in the 2003 TMDL report were classified as organic enrichment, toxicity, low dissolved oxygen, nutrient enrichment, and flow alteration (Ohio EPA, 2003).

Sampling was conducted by the Ohio EPA and 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 *2021 Cuyahoga River Environmental Monitoring*. All sampling and environmental assessments occurred between June 15, 2021, and September 30, 2021 (through October 15 for fish sampling assessments), as outlined 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.

Table 1 lists the sampling locations details and the types of surveys conducted. Figure 1 is a study area map, noting each sampling location evaluated during the 2021 study. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD WQIS Division.

Table 1. Cuyahoga River Sampling Locations					
Location description	Station ID	River Mile	Drainage Area	Latitude/ Longitude	Sampling Type
*At Jaite; Highland Road	F01S13	24.10	555 mi^2	41.2888, -81.5650	F, M
*Near Old Carriage Trail	300510	22.40	559 mi^2	41.2968, -81.5710	M
*US Station Road (free flowing)	304227	20.80	583 mi^2	41.3207, -81.5875	M
*At Hillside Road	F01S11	15.61	698 mi^2	41.3789, -81.6147	F, M
Ust. Rockside Road and confluence with Mill Creek	502020	13.15	703 mi^2	41.3929, -81.6295	F, M, C
**Ust. Southerly WWTC @ chlorine access bridge	--	10.95	743 mi^2	41.4180, -81.6480	C
Ust. Southerly WWTC effluent discharge	F01A25	10.75	743 mi^2	41.4196, -81.6547	F, M, C
Downstream of Southerly WWTC effluent discharge	F99Q02	10.10	744 mi^2	41.4242, -81.6638	M, C
**Dst. Southerly WWTC @ Southerly Interceptor bridge access bridge	F01S09	9.78	744 mi^2	41.4272, -81.6662	C
*Dst. Southerly WWTC at Conrail RR	F01S10	9.70	744 mi^2	41.4269, -81.6658	F, M, C
Downstream of Southerly WWTC effluent discharge	200025	8.60	745 mi^2	41.4381, -81.6680	F, M, C

F = Fish community biology (includes habitat assessment)
M = Macroinvertebrate community biology
C = Water column chemistry
*Data was collected by the Ohio EPA at these sites
**Water chemistry is collected 2x/month as part of Southerly WWTC NPDES permit

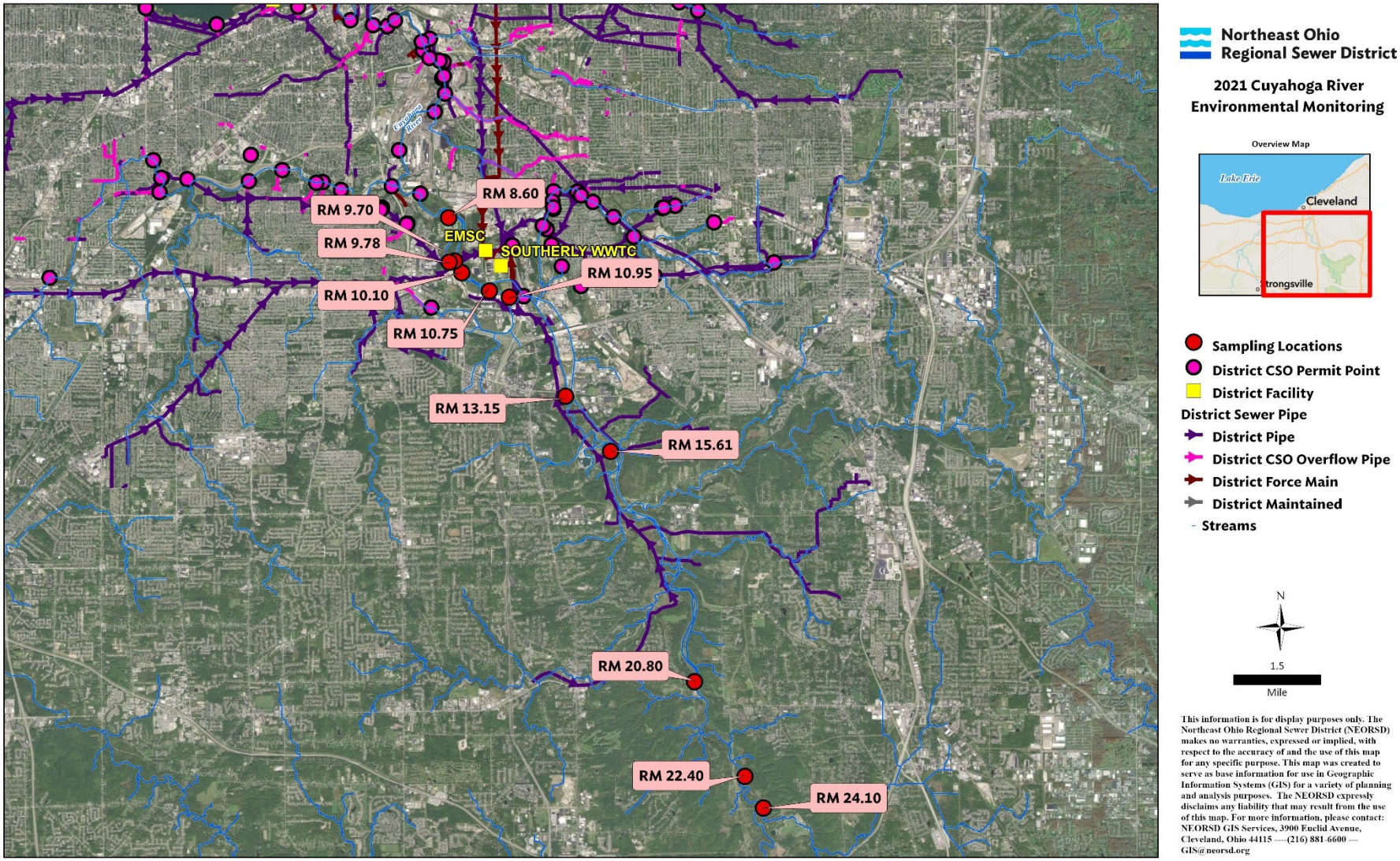


Figure 1. Cuyahoga River Sampling Locations

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).

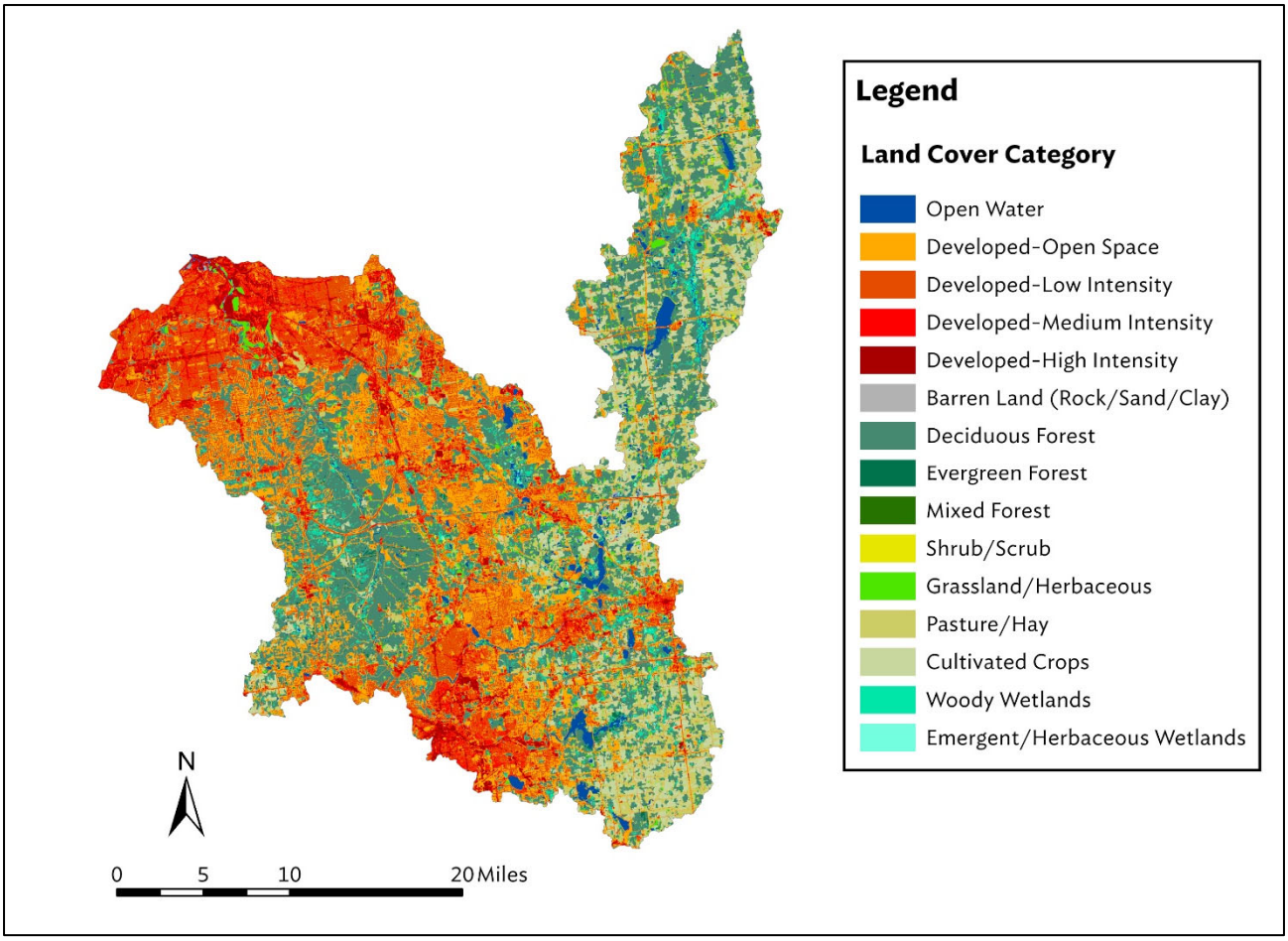
Table 2. Beneficial Use Designations for the Cuyahoga River

Water Body Segment	Beneficial Use Designation												
	Aquatic Life Use (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 changes 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 ArcMap 10.3 and the intersect tool was used to combine the watershed with the 2016 National Land Cover Database (Homer et.al, 2016). The resulting Figure 2 represents the different types of land cover that drain to the Cuyahoga River. An analysis of the drainage specific to each of the sites monitored in 2021 was also conducted. Similar land cover types were combined, and the percentages of each land cover type were then calculated for the four sites downstream of 13.15 (Figure 2).



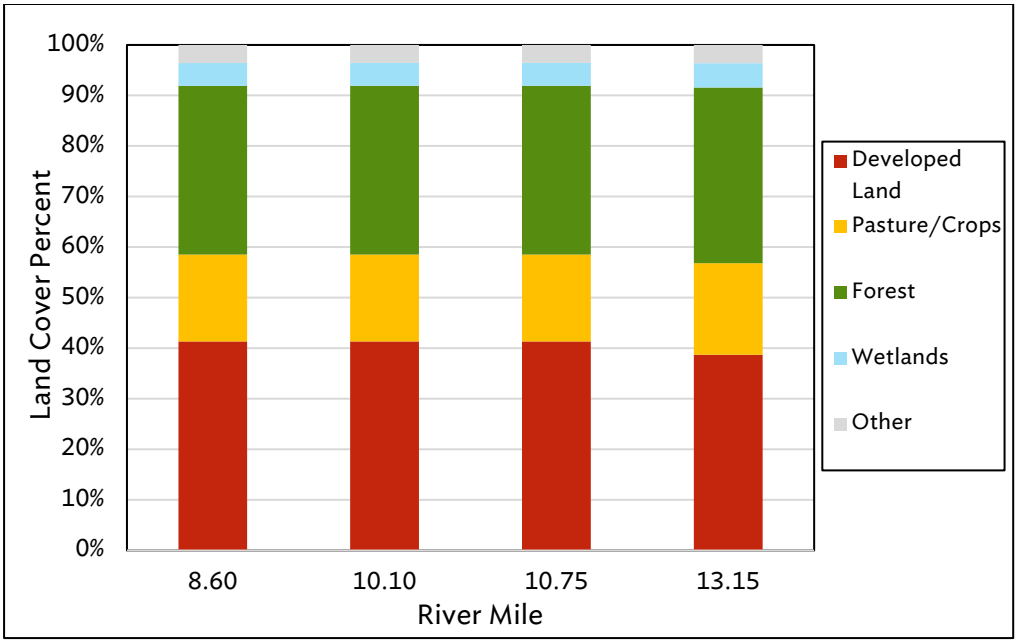


Figure 2. Cuyahoga River Watershed Land Cover Map and percentage land use at each site

Both Cleveland and Akron lie within the Cuyahoga River watershed, contributing significantly to overall developed lands. Other than the two major municipalities, the Cuyahoga River watershed is quite rural, with about sixty percent of the watershed classified as either forested, pastured, or wetlands. The majority of 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 25 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 2021, 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 land when compared to all other sites. Highly developed land consists of a vast landscape of impervious surfaces which quickly removes rainfall and increases 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, 1993). 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 20 and August 17, 2021, at the locations assessed by the NEORSD 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 either a Yellow Springs Instrument (YSI) 600XL or EXO1 sonde. Duplicate samples and field blanks were each collected at randomly selected sites, at a frequency not less than 5% of the total samples collected. Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and duplicate sample (Formula 1).

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

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

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

Formula 2: 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 Cuyahoga River flow data (USGS 04208000) are shown below in Figure 3.

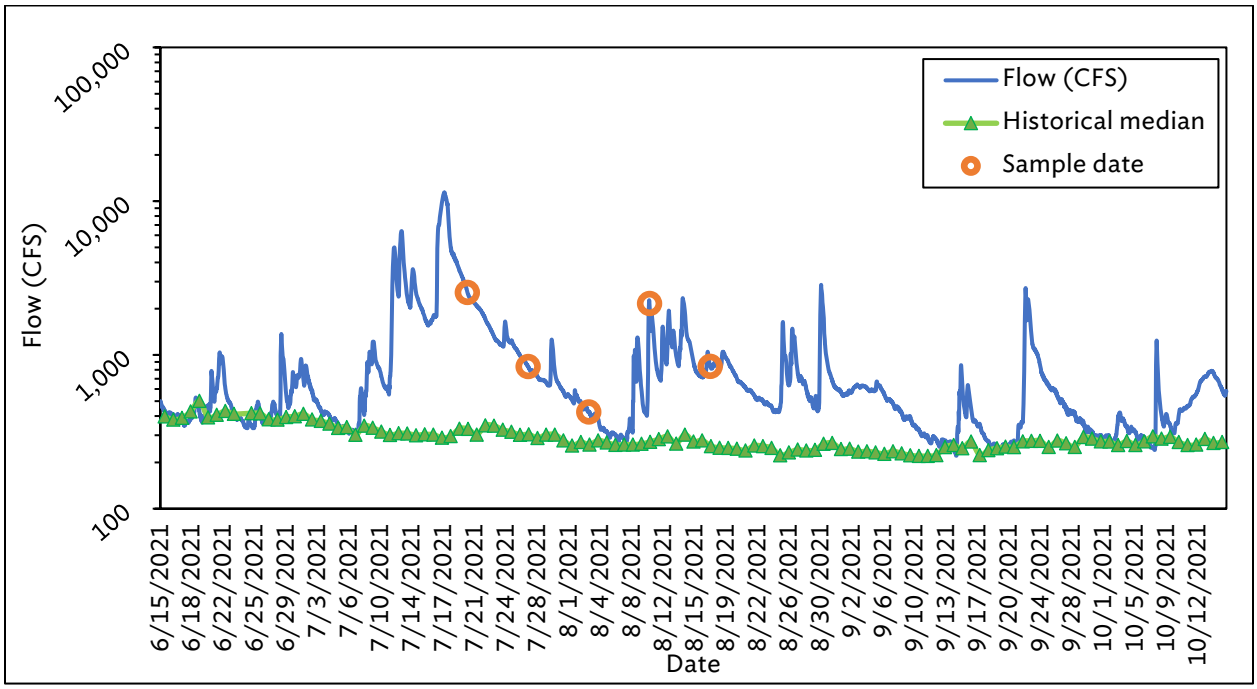


Figure 3. 2021 Cuyahoga River USGS gage 0420800 Flow Data

Results and Discussion

Quality Assurance / Quality Control

Over the course of five sampling events in 2021, two field blanks and two duplicate samples were collected as part of this study. Of the two field duplicate samples collected, three instances occurred 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 10.10	7/20/2021	COD	46.7%	105.1%
RM 13.15	7/27/2021	Alkalinity	44.6%	87.8%
		Ammonia	61.6%	90%

Parameters that showed possible contamination in the field blanks are listed in Table 4. It is unclear how the field blanks became contaminated, but may be due to inappropriate sample collection, handling, and/or contaminated blank water. The results were qualified appropriately as either rejected, estimated, or trend qualifiers.

Table 4. Parameters Affected by Possible Blank Contamination
Zinc, total
Nitrate-nitrite, total
Phosphorus, total
BOD, total

The final QA/QC check was for paired parameters, or those parameters in which one is a subset of the other. There was one instance in which the data for the paired parameters needed to be qualified because the daughter parameter value was greater than the parent value. On July 27, 2021, at RM 10.75, both the results for total solids and total dissolved solids data were rejected.

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 taken during any ninety-day period. The second component is a ninety-day geometric mean criterion of 126 MPN/100mL (Ohio EPA, 2020b). 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.

The four sample locations listed in Table 1 were sampled for *E. coli* five times (Table 5). 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. The data from this was also used to assess the recreational criteria attainment and is listed in Table 6. When duplicate samples were collected at a sample location, the results were reported as an average.

Both recreational criteria were exceeded at all six sample locations. Nine of the seventeen sampling dates were collected during or after a wet-weather event, as defined in Table 5. 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 5. 2021 *E. coli* Densities (MPN/100mL)

Date	RM 13.15	RM 10.75	RM 10.10	RM 8.60
7/20/2021	411	276	479	488
7/27/2021	138	111	155	172
8/3/2021	119	96	109	111
8/10/2021*	13,590	15,520	14,660	13,000
8/17/2021	365	435	387	291
90-day Geomean	507	457	540	512

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.

Table 6. 2021 *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
5/5/2021*	348	189	147	165
5/17/2021	55	264	78	242
6/2/2021	194	338	199	292
6/15/2021	166	398	185	357
7/6/2021	141	430	91	373
7/15/2021*	517	517	517	472
8/2/2021	1414	517	770	472
8/16/2021*	488	423	461	428
9/1/2021*	308	408	291	421
9/16/2021*	613	449	816	476
10/4/2021*	285	384	255	363
10/18/2021*	517	517	517	517
Seasonal geomean	298		264	
Seasonal geomean (dry weather days)	197		172	
% samples > STV	38%		38%	

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

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 *E. coli* densities in the Cuyahoga River. Both datasets from Tables 5 and 6 were used jointly and separated by either upstream or downstream of the Southerly WWTC effluent. No significant difference ($p<0.05$) was observed over the 17 sampling days.

Figure 5 below displays the impact of wet weather on increased *E. coli* densities in the Cuyahoga River watershed. Nonpoint source critical conditions typically occur during high flows, when rainfall runoff contributes the bulk of the pollutant load, while point source critical conditions occur during low flows when wastewater treatment plant (WWTP) effluent dominates base flows (USEPA, 2007). Source contributions in the Cuyahoga River seem to have both point and nonpoint sources, as *E. coli* densities were highest during wet-weather, yet 27% of 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 and Miltner, 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) over the previous two years.

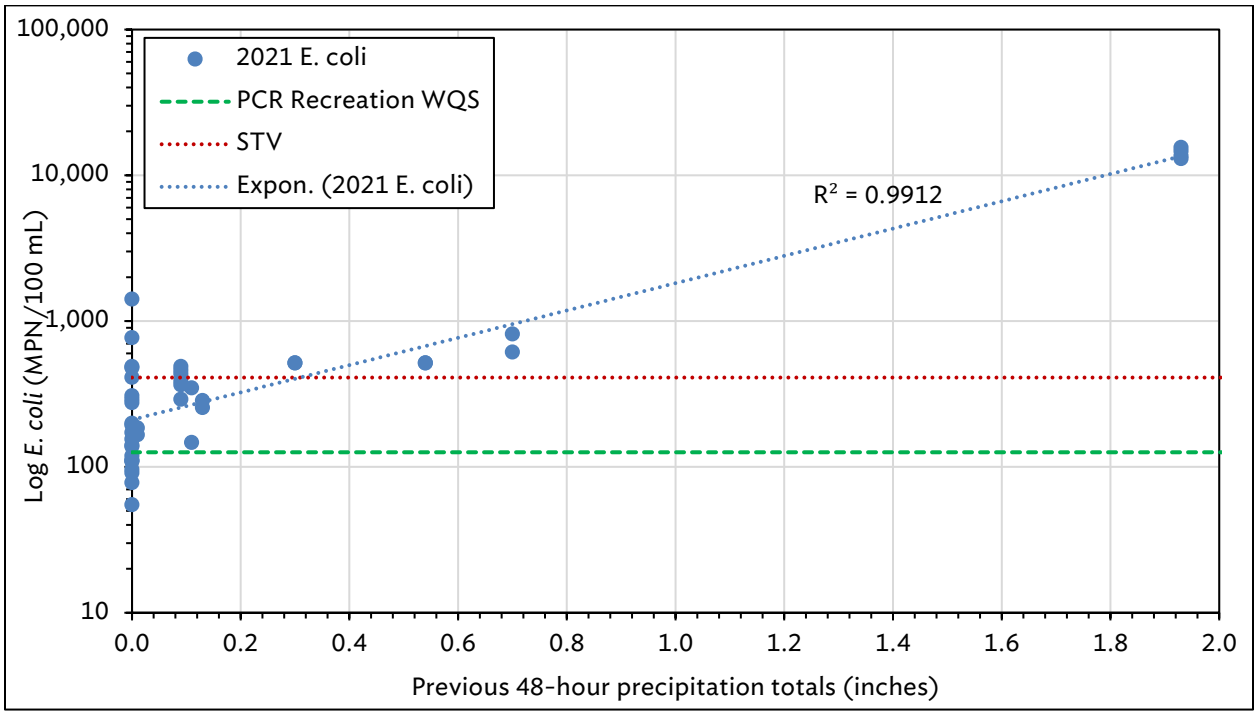


Figure 4. Previous 48-hour rainfall & *E. coli* values

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 $3 billion of investments that will reduce the amount of wastewater pollution entering Lake Erie. The overall goal of this consent decree, also known as *Project Clean Lake*, is to capture

98% of all CSOs for treatment. Figure 4 below outlines progress of this consent decree as of October 2021. Major current and future milestones of this project benefitting the Cuyahoga River include the Westerly Storage Tunnel (tunnel completed 2021, pump station to be completed by mid-2023), Shoreline Storage Tunnel (estimated completion 2025), Southerly Tunnel (estimated completion: 2027), Big Creek tunnel (estimated completion 2033). A total of fifty-four green infrastructure projects have also been awarded by the NEORSD through 2021 in combined sewer areas in the greater Cleveland area to effectively manage surface water runoff and reduce excess stormwater volumes contributing to CSOs.

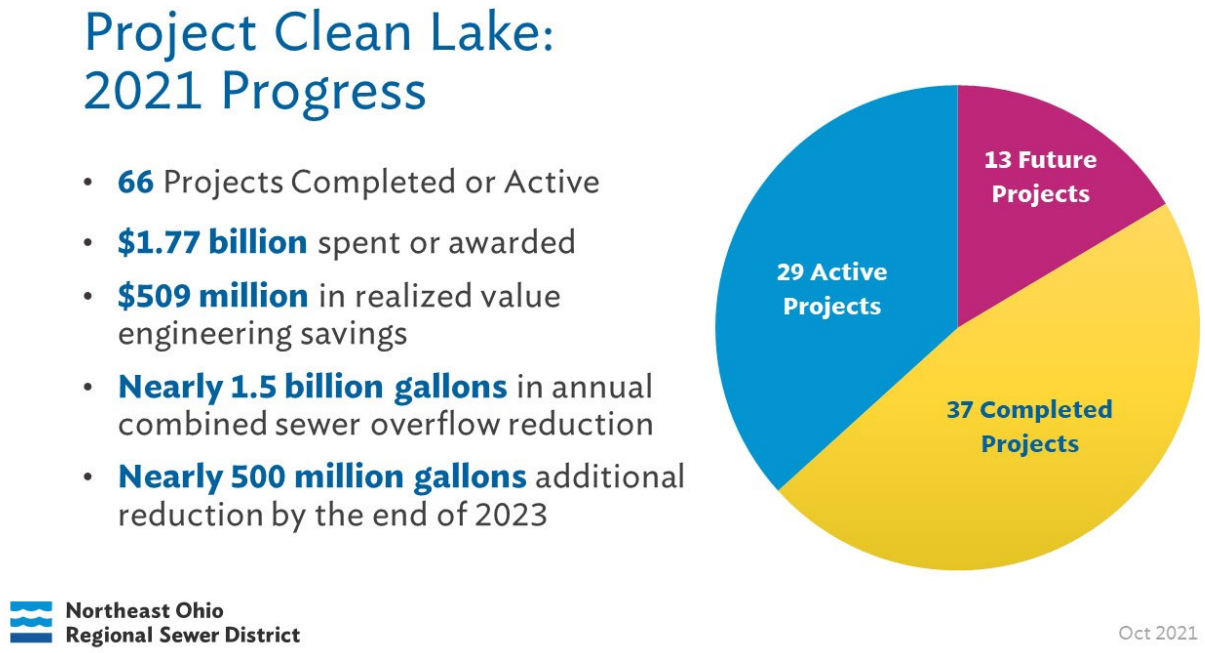


Figure 5. Project Clean Lake: 2021 Progress

The NEORSD owns and maintains thirty-five CSOs tributary to the Cuyahoga River. Nearly all 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 2021 sampling location. 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.

Numerous approved 9-element nonpoint source implantation strategies (NPS-IS) have been developed for sub-watersheds throughout the Cuyahoga River watershed. Causes for the impairment of the recreational criteria include urban runoff, CSOs, and permitted NPDES point sources (Chagrin River Watershed Partners 2020; Ohio EPA 2003; West Creek Conservancy, 2021). Many projects developed from these NPS-IS are focused on habitat restoration, floodplain restoration, septic to sanitary sewer conversions, and stormwater management. Numerous areas of clustered home sewage treatment systems have been converted to sanitary sewer systems in the City of Seven Hills over the past 10 years, eliminating these as sources of bacterial pollution.

However, numerous unsewered areas remain in the upstream, more rural areas of the Cuyahoga River watershed and may be contributing to the total *E. coli* load in the river.

Water Column Chemistry Results and Discussion

Mercury was analyzed 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 with results below the detection limit 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. All four sample locations had one result that was above the mercury detection limit, and therefore exceeding both the wildlife and aquatic life OMZA criteria.

Table 7. 2021 Mercury Concentrations (ug/L)

Date/location	13.15	10.75	10.10	8.60
7/20/2021	<0.022	<0.022	0.0275J	0.023J
7/27/2021	<0.0199	<0.0199	<0.0199	<0.0199
8/3/2021	<0.0199	<0.0199	<0.0199	<0.0199
8/10/2021	0.0315J	0.026J	<0.0199	<0.022
8/17/2021	<0.0199	<0.0199	<0.0199	<0.0199

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

The NEORSD currently holds a NPDES mercury variance through the Ohio EPA for all three WWTPs. The NEORSD Mercury Pollutant Minimization Program (PMP) aims to reduce mercury at the source, prior to entering the WWTPs. Efforts of the mercury PMP include monitoring mercury sources from industrial discharges, dental offices, and studying atmospheric deposition mercury concentrations as part of the National Mercury Deposition Network (MDN). Precipitation samples are collected for the MDN weekly from a rooftop near downtown Cleveland. Concentrations of mercury in precipitation typically averages 5-25 ng/L (NEORSD, 2019). Since beginning the mercury PMP in 2005, WWTP effluent mercury concentrations have declined to concentrations near the water quality-based effluent limit (WQBEL; Figure 6). In addition, mercury removal efficiencies at the Southerly WWTC have improved and consistently exceed 98% (Figure 7).

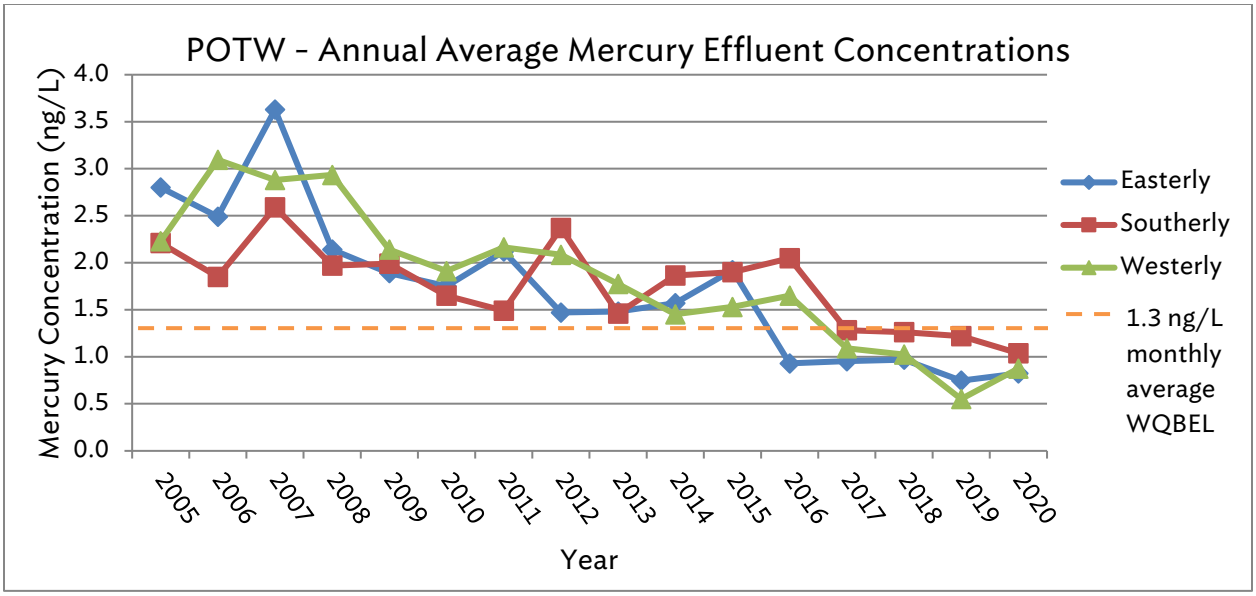


Figure 6. 2005-2020 Annual Average Effluent Mercury Concentrations

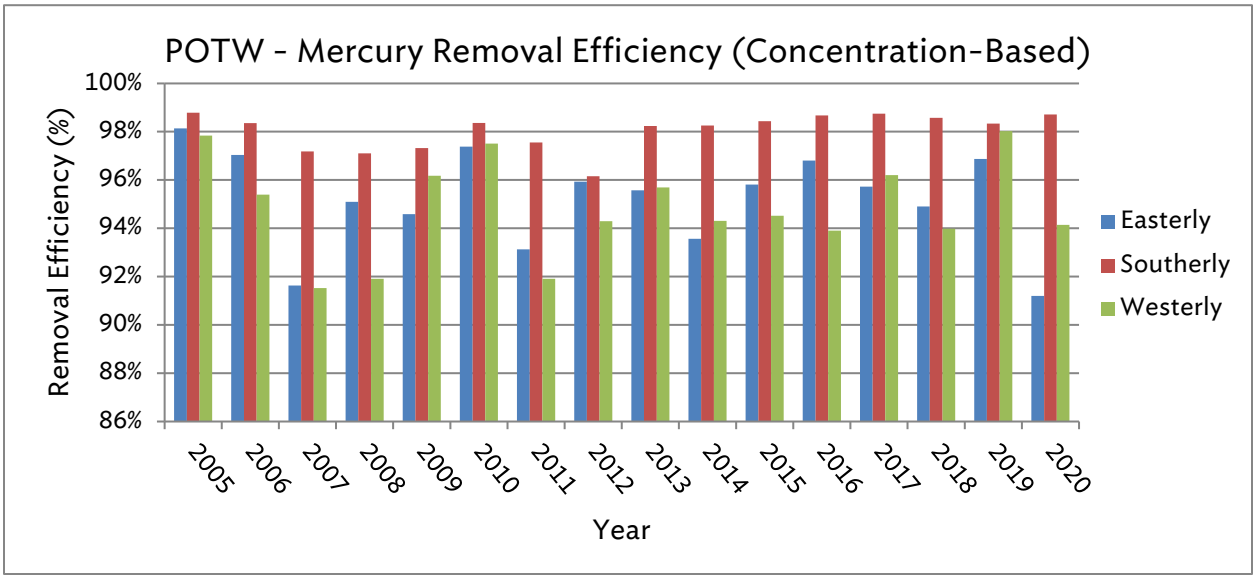


Figure 7. 2005-2020 Annual Concentration-Based Removal Efficiency

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 to a cleaner 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, 2018). 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.

Copper and lead are two other parameters that exceeded OMZA and OMZM (maximum) criteria (Table 8). These copper exceedances demonstrate periods of acute toxicity following significant rainfall events. The August 10 sampling was taken after 48-hour rain totals approached two inches; by far the most significant rain event that water chemistry sampling was taken afterwards in 2021. These wet-weather events in highly urbanized areas often contain elevated levels of toxic metals in stormwater runoff and may negatively impact aquatic life (Fulkerson et al., 2007).

Table 8. Metal Aquatic Life Use Exceedances

Location	Start date	End date	Parameter	Result (ug/l)	Criterion (ug/l)	Type of exceedance
RM 13.15	8/10/2021	--	Copper	26.35	22.05	WWH OMZM
	8/10/2021	9/8/2021	Copper	15.03	14.09	WWH OMZA
RM 10.10	8/10/2021	--	Copper	25.4	24.36	WWH OMZM

Iron concentrations exceeded the Agricultural Water Supply (AWS) OMZA WQS at all four locations assessed by the NEORSD for at least one 30-day period. Concentrations of iron were lower and met the WQS during baseline flows and with little to no recent precipitation. The August 10 sampling date taken during high flows, as mentioned earlier, resulted in extremely elevated iron concentrations in the Cuyahoga River, averaging 15,763 ug/L across the four sampling locations. These elevated iron concentrations of more than 10x baseline flow concentrations are attributed to urban runoff, erosion, and natural sources of iron in Ohio soils.

In 2018, the Ohio EPA released an Early Stakeholder Outreach regarding Nutrient Water Quality Standards for Ohio's Large Rivers ($\geq$500 mi^2 drainage area). The proposed eutrophication standard, shown in Table 9, 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 TP at 0.130 mg/L as a management target for presently over-enriched waters (Miltner, 2017). 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 higher concentration of suspended solids; all of which display gross levels of enrichment and suggest a high likelihood of biological enrichment (Miltner, 2017). As of the date this report was published, these large river nutrient water quality standards have not been finalized. 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 75th 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 9. 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 six NEORSD sample locations in 2021 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". Forty-seven percent of the sampling dates were taken during or after wet-weather events (see Tables 5 and 6 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 10). Five of the six sample locations also exceeded the proposed TP target of 0.130 mg/L. All six sampling locations exceeded the nitrate-nitrite TMDL target concentration as well. The four dates 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 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 three major tributaries and Lake Erie near Cleveland. Sestonic chlorophyll data from the previous five years support this hypothesis as concentrations in the Cuyahoga River have averaged 11.04 ug/L at RM 10.95 (upstream of SWWTC effluent) and 7.45 ug/L at RM 0.20 over the previous five years, well below the 30 mg/L WQS seasonal average.

Table 10. 2021 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	1.29	1.69	0.0531	0.177*	72.2	4.3*
RM 10.95 (SUS)	12	0.94	2.55	0.0979	0.128	21.6	2.1
RM 10.75	5	1.21	1.85	0.0619	0.167*	74.4	4.3*
RM 10.10	5	1.28	2.47	0.0646	0.192	83.9	4.1*
RM 9.78 (SDS)	12	0.89	3.54	0.0972	0.158	15.0	1.6
RM 8.60	5	1.28*	2.49	0.0618	0.172	65.7	3.8*

Over enriched – acute condition
Enriched – chronic condition
Exceeds Nitrate-nitrite TMDL target criterion
*N<5 samples due to QA/QC rejected data

Instantaneous DO measurements are collected on the Cuyahoga River every 30 minutes by a YSI EXO1 data sonde at USGS gage #04208000 in Independence, OH (RM 13.08). Compiled with field data sonde 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, 2017). During the summer months, algae tend to grow best during low-flow conditions and maximum light penetration. The summer months from May through October were unique in 2021, as rainfall data at the NEORSD Independence gage measured 5.62 inches greater than average, corresponding to flows consistently exceeding median values (Figure 3). Continuously elevated stream flows with high 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 sonde from the summer months of May through October to analyze and compare daily DO swings to the proposed large river nutrient WQS. The maximum daily DO swing in 2021 was measured on August 7 at 5.60 mg/L and below the 6.50 mg/L threshold, indicating acceptable conditions. However, Figure 8 displays DO daily swings approaching the 6.50 mg/L daily swing threshold between August 6-8 before a significant rain event caused high flows and algal biomass to flow downstream.

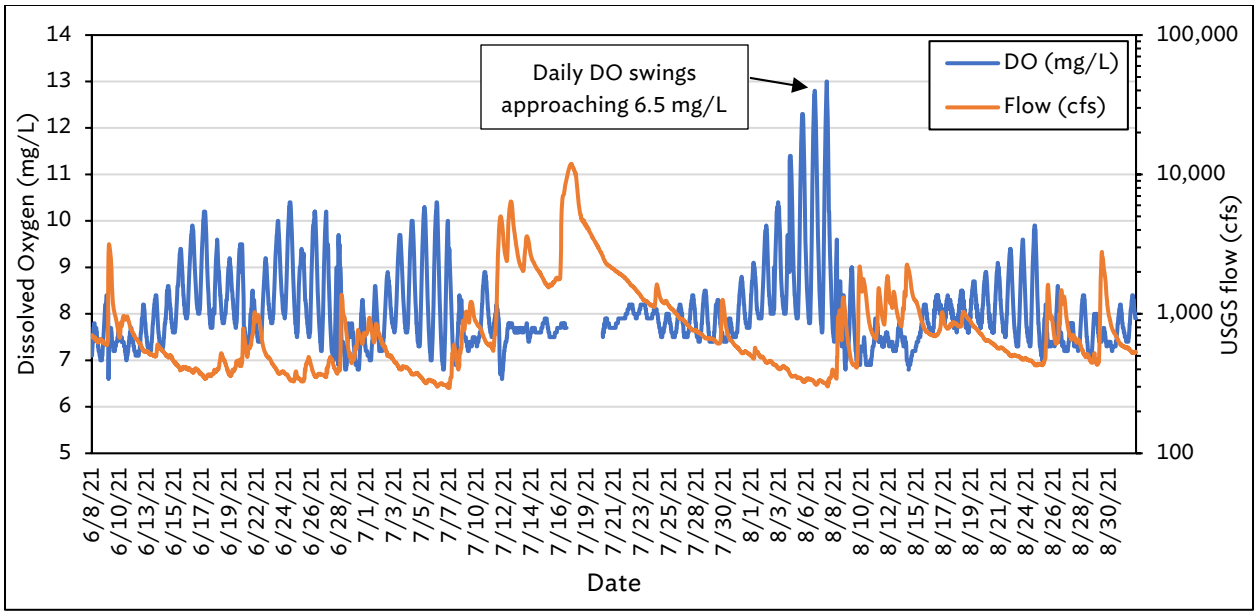


Figure 8. Effects of river flow on DO concentrations.

As mentioned earlier, the proposed large river WQS is based on sampling performed during baseline summer conditions. Similar results to those observed in Table 10 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 also likely a significant contributor.

The NEORSD 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. There is currently no limit for TKN, but concentrations are reported. Nutrient data was retrieved and analyzed from the SWWTC treated effluent to reflect the discharge during summer months (Table 11).

Table 11. NEORSD Southerly WWTC Effluent Nutrient Concentrations May 1-Oct 31, 2021

Parameter	N	Mean	Min	Max
TKN (mg/l)	26	1.01	0.67	1.58
NO3-NO2 (mg/l)	131	10.17	3.41	15.00
TP (mg/l)	184	0.39	0.12	0.92

The effects of the SWWTC on the Cuyahoga River nutrient concentrations are evident. TP concentrations have historically increased downstream of the SWWTC effluent to levels exceeding the seasonal average target criterion of 0.130 mg/l (Figure 9). TKN concentrations in the Cuyahoga River are less affected by the SWWTC effluent and concentrations upstream of the SWWTC effluent are consistently elevated, surpassing the *over enriched – acute condition* indicator threshold. Numerous other major and minor wastewater dischargers 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.

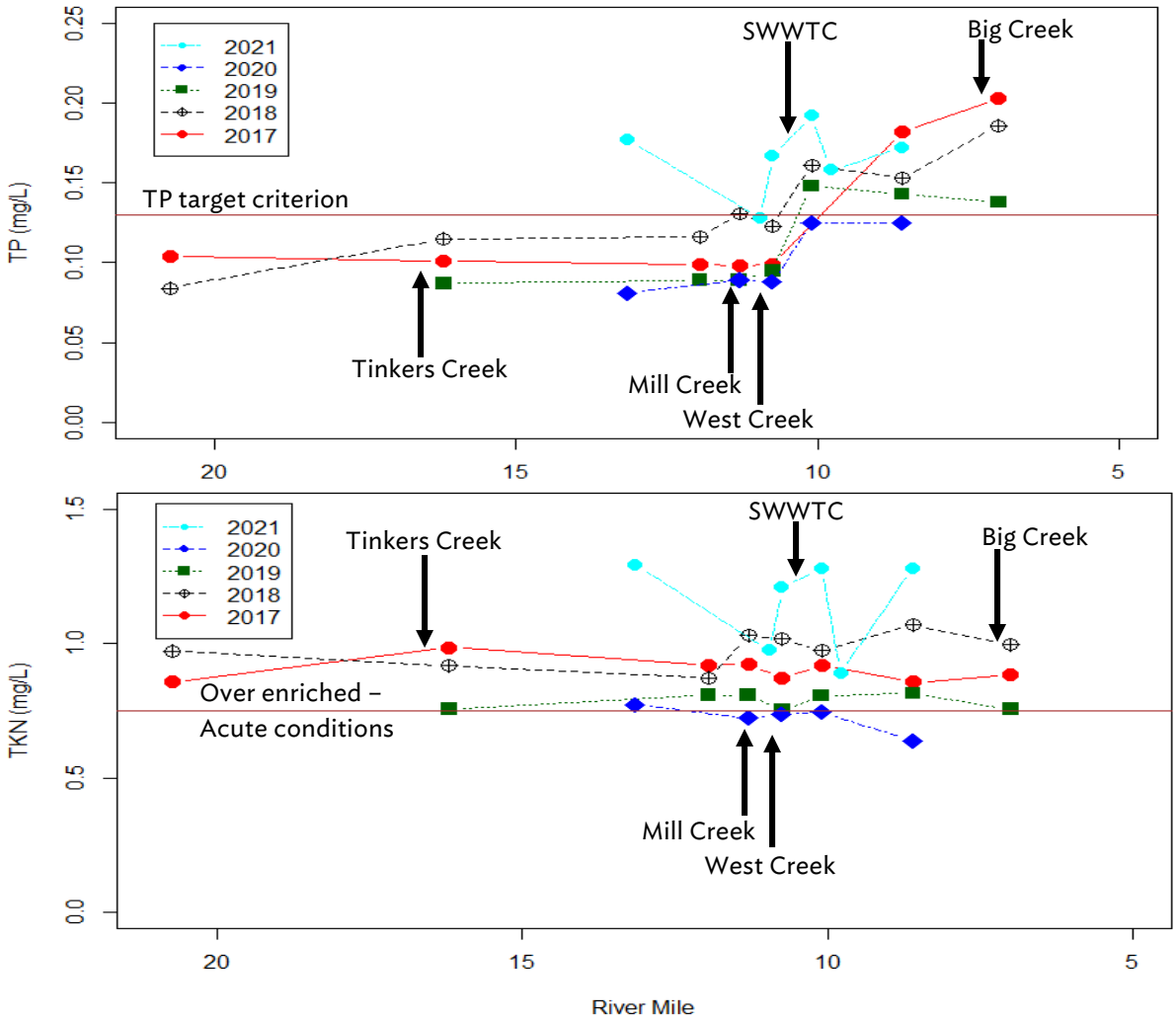


Figure 9. Longitudinal geomean concentrations of total phosphorus and TKN on the Cuyahoga River 2017-2021.

The 2020 Ohio EPA Nutrient Mass Balance Study details nutrient sources on major Ohio tributaries on a five-year average from 2015-2019. Figure 10 below displays source percentages for TP and total nitrogen (TN) loading within the Cuyahoga River watershed (Ohio EPA, 2020c). As one of the most urbanized watersheds in Ohio, the Cuyahoga River contained the highest NPDES permitted source contribution of all rivers included in this study.

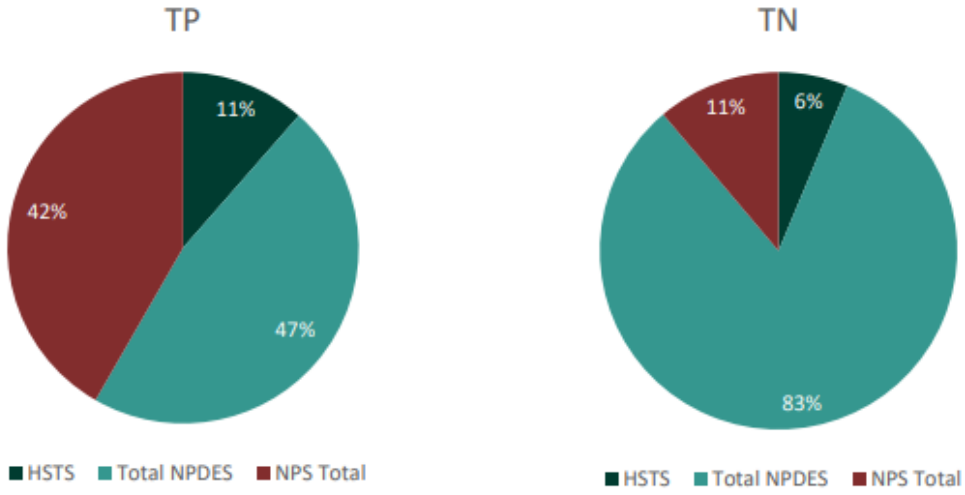


Figure 10. Proportion TP and TN from different sources for the Cuyahoga River watershed, average of 5-years (water years 2015-2019).

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site from RM 24.10 to RM 8.60 using the Qualitative Habitat Evaluation Index (QHEI). NEORSD conducted the assessments at RMs 13.15, 10.75, and 8.60, while Ohio EPA conducted the assessments at the remaining sites. 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 (Ohio EPA, 1989). The QHEI has a maximum score of 100, and a score greater than 60 on streams with >20 mi^2 drainage suggests that sufficient habitat exists to support a fish community attaining the warmwater habitat criterion (Ohio EPA, 2006). Scores greater than 75 frequently demonstrate habitat conditions that 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.

Individual components of the QHEI can also be used to evaluate whether a site is capable of meeting its 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). The habitat restoration targets identified in the lower Cuyahoga River TMDL are now outdated and the Ohio EPA uses a different

approach in assessing habitat restoration targets. Tables 12 and 13 list the Ohio EPA's new habitat targets for addressing overall in-stream habitat and sedimentation (Ohio EPA, personal communication).

Table 12. Ohio EPA Habitat TMDL Targets

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

Table 13. Ohio EPA Sediment TMDL targets

QHEI category	WWH	EWH
Substrate	≥13	≥15
Channel	≥14	≥15
Riparian	≥5	≥5
Sediment TMDL	≥32	≥35

Results and Discussion

Excellent instream habitat was recorded at all six Cuyahoga River locations except for RM 9.70. QHEI scores ranged between 80.00 and 70.00 with a mean score of $\bar{x}$ = 76.00 (Table 15). All scores exceeded the Ohio EPA's target score of 60, which suggests that sufficient habitat exists to support a warmwater fish community. Figure 11 displays the QHEI scores in respect to RM and overall habitat targets. The Cuyahoga River lies entirely within the Erie/Ontario Drift and Lake plains, within the glaciated portion of northeast Ohio. The lower 13 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 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).

For the habitat assessments completed by the NEORSD, the RM 13.15, 10.75, and 8.60 sites all displayed predominately sand and gravel substrates, glacial till substrate origin, and moderate siltation and embedded substrates. Moderate to sparse instream cover consisted of deep pools, woody debris, boulders, and shallows. Substrate stability was scored as moderate, due to the high percentage of sand substrates mixed with gravel.

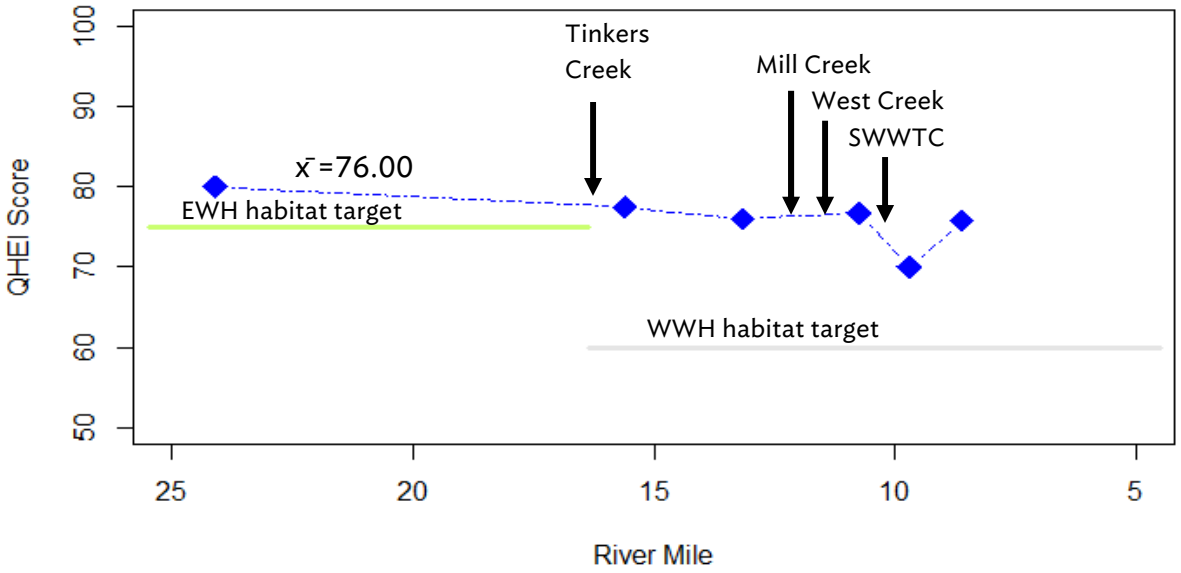


Figure 11. Longitudinal fish habitat QHEI scores Cuyahoga River mainstem 2021.

Table 14 uses the WWH and MWH attributes calculated in Table 15 below. Based on communication with Ohio EPA staff, Table 14 below compares the new TMDL and sediment targets for Cuyahoga River sites assessed by the Ohio EPA and NEORSD in 2021. WWH attributes outnumbered MWH attributes at all sites except for RM 15.61. From conversations with Ohio EPA staff, this is likely attributed to the dam removal and its associated sediment load migrating downstream. Mentions of unstable sediment and increased erosion rates from years past contributed to the increased MWH attributes observed at this location. The RM 24.30 sample location is likely still recovering from its past impoundment due to the Station Road dam, as it failed to meet the EWH habitat TMDL score and scored poorly in the substrate metric. RM 13.15 scored poorly in the riparian metric due to flood plain quality and failed to meet the sediment TMDL target score. RM 9.70, assessed by the Ohio EPA, did not meet any of the three sediment TMDL targets, and failed to meet the overall sediment TMDL score.

Table 14. 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	Riparian	Sediment TMDL score
24.30*	80.00	0	**3**	**2**	**13.0**	17.0	8.50	38.50
15.40	77.50	1	**5**	**2**	13.0	14.0	10.00	37.00
13.15	76.00	0	4	3	15.0	15.0	**4.50**	**34.50**
10.75	76.75	0	3	3	14.5	16.0	5.25	35.75
9.70	70.00	0	0	3	**12.5**	**12.5**	**4.00**	**29.00**
8.60	75.75	1	1	3	16.5	16.5	6.75	39.75

* EWH proposed site
Bold = metric not meeting TMDL targets

Sedimentation and its correlating negative effects on in-stream substrate seem to be the most significant negative factor to fish habitat in the lower Cuyahoga River. These problems may have many root causes. The removal of the Station Road Dam, 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 border 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.

Table 15. 2021 Cuyahoga River QHEI Scores and Physical Attributes

			WWH Attributes											**MWH Attributes**																	
														High Influence						Moderate Influence													
River Mile	**QHEI Score**	**Habitat 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 Substrates (Boat)	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**
24.10	80.00	*Excellent*	X	X		X	X	X	X		X		**7**						**0**		X								X	X		**3**
15.61	77.50	*Excellent*	X	X		X	X	X	X		X		**6**				X		**1**		X			X	X				X	X		**5**
13.15	76.00	*Excellent*	X	X		X	X	X	X	X	X		**8**						**0**		X			X					X	X		**4**
10.75	76.75	*Excellent*	X	X		X	X	X	X		X		**7**						**0**		X								X	X		**3**
9.70	70.00	*Good*	X	X		X	X	X	X		X		**7**						**0**	X	X			X					X	X		**5**
8.60	75.75	*Excellent*	X	X		X	X	X	X		X		**7**				X		**1**		X								X	X		**3**

Fish Community Biology Assessment

Methods

One quantitative electrofishing assessment was conducted at each site in 2021. 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 16. 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 16. Sampling Dates and River Flows

Date	Sites sampled (RMs)	Daily Mean Flow (CFS)
9/13/2021	8.60, 10.75	304
9/14/2021	13.15	292
9/30/2021	9.70*	335
10/6/2021	15.60*	313
10/7/2021	24.10*	436
*Ohio EPA assessment		

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 17). 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 17. 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) 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 IBI scoring criterion in the EOLP ecoregion is shown in Table 18 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 18. 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	≥9.6
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Results and Discussion

The Ohio EPA and the NEORSD collected 1691 individual fish, representing 44 unique species from the six sampling sites in 2021. The 2021 IBI and MIwb scores from each assessment location are listed below in Table 19. All six sites scored within attainment for the MIwb component, ranging from *Good* to *Very Good* (MIwb $\bar{x}$ = 8.9). Four of the six locations met applicable IBI ALU criterion, with RMs 10.75 and 8.60 being the two sample locations in non-attainment. However, IBI scores averaged $\bar{x}$ = 37.3 across these six assessment locations, which is within NSD of the WWH attainment.

Table 19. 2021 Cuyahoga River IBI and MIwb Results						
Stream RM	Native species	Relative number (minus tolerants)	Relative weights (kg)	Predominant species (%)	IBI	MIwb
Cuyahoga River (19-001-000) - WWH Existing/EWH Recommended						
24.10*	26	422	204.44	White sucker (31.8%) Smallmouth bass (11.4%) N. hog sucker (9.0%)	38^{NS} (Marg. *Good*)	8.5 (*Good*)
Cuyahoga River (19-001-000) - WWH Existing						
15.61*	22	542	77.20	Round goby (18.5%) Sand shiner (13.7%) Smallmouth bass (12.9%)	42 (*Good*)	9.4 (*Very Good*)
13.15	23	1152	31.88	Spotfin shiner (41.1%) Common shiner (15.7%) Sand shiner (11.6%)	40 (*Good*)	8.7 (*Good*)
10.75	22	190	37.06	Smallmouth bass (19.3%) Spotfin shiner (13.5%) White sucker (10.9%)	34 (*Fair*)	8.7 (*Good*)
9.70*	21	404	28.93	Spotfin shiner (31.1%) Sand shiner (13.7%) Bluntnose minnow (9.9%)	38^{NS} (*Marg. Good*)	8.9 (*Good*)
8.60	21	526	42.41	Gizzard shad (50.0%) Sand shiner (9.5%) Common shiner (6.2%)	32 (*Fair*)	8.9 (*Good*)
Bold = meets WWH criterion [IBI ≥40; MIwb ≥8.7] ^{NS} = non-significant departure from WWH criterion [IBI ≥36; MIwb ≥8.2] *Ohio EPA assessment						

The three most abundant species collected from the Cuyahoga River in 2021 were spotfin shiner (22.4%), gizzard shad (13.2%) and sand shiner (9.8%). The presence of the Eastern gizzard shad as the second most abundant fish may have affected the score calculations at some of the sites monitored in 2021. In some instances, it may be appropriate to exclude this species from sample results. As the summer progresses into fall, gizzard shad seasonally migrate into the Cuyahoga River from Lake Erie. This influx may skew IBI results 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 downstream of RM 16.00 may explain some of the yearly variations in IBI scores.

The fifth most common fish collected was the round goby (6.6%), an invasive benthic species thought to be introduced into the upper Great Lakes in the early 1990s and forming an established population by 1995. The round goby outcompetes, or alternatively eats, native darter, sculpin, and madtom species (Rice and Zimmerman, 2019). Round goby populations outnumbered the sum of the five darter species collected (4.0%) in the Cuyahoga River in 2021. The only darter that has shown any sort of co-existence with the round goby is the logperch (Rice and Zimmerman, 2019), which was collected in the Cuyahoga River in 2021, but was low in abundance. Ten round gobies were collected by the Ohio EPA in 2021 upstream of the former Station Road Dam at RM 20.70, which was thought to be a physical barrier for round goby migration upstream. These round gobies may be the first specimens ever collected upstream of the former Station Road Dam, as none were collected from the upstream dam pool during both 2017 assessments.

Three pollution-intolerant species were collected in 2021: rosyface shiner, mimic shiner, and stonecat madtom. The two locations where mimic shiners were collected were RM 9.70 and 8.60, downstream of the SWWTC discharge. This species has likely migrated upstream from the abundant populations along the Lake Erie shorelines, although a more stable population has been observed in the river in recent years. One state threatened species, bigmouth shiner, was also collected at RM 8.60. This species is typically only found in a select few tributaries to the Rocky River East Branch in drainage areas less than 75 mi^2. One source location of the bigmouth shiner is from Big Creek (Cuyahoga River tributary at RM 7.20), where they have been collected intermittently.

Fish community metric scores in 2021 saw a slight increase when compared to the previous year (Table 20) while the MIwb scores remained in the *Good-Very Good* range (Table 21). RM 13.15 and 10.10/9.70 saw an increase in IBI scores from *Fair* to *Good* and *Marginally Good* and are now in full attainment for fish community WQS criteria. IBI score increases at RM 13.15 are attributed to the increase in sucker species (+1), increase in insectivorous fish (+52.9%), an increase in relative number of fish (+574), and a decrease in overall DELT anomalies (-2.05%) from the previous year average. The RM 10.10/9.70 location saw a decrease in omnivorous fish (-33.3%) and an increase in insectivorous fish (+41.9%) increasing the IBI score 3 points from the previous year.

Table 20. Cuyahoga River Historic IBI Scores (1990-2021)

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	-	-	-	-	-	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	-	**42**	**40**	-	-	34	*38*	32	-

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

Table 21. Cuyahoga River Historic MIwb Scores (1990-2021)

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**	**8.9**	--

Bold = meets WWH criterion [≥8.7]
Italics = non-significant departure from WWH criterion [≥8.2]
***Meets Exceptional WWH Criterion**

Two metrics that consistently scored poorly again in 2021 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 the survey years and may correlate to negative influences from the urbanized watershed. Mercury and copper toxicity, bacteriological contamination, nutrient enrichment, siltation, and embeddedness are chemical and physical parameters that continuously affect the Cuyahoga River fish community. Mercury and copper concentrations were evident in toxic concentrations in multiple sampling dates and may locally extirpate intolerant fish species. The

low abundances of these intolerant fish are likely migrating from nearby higher quality tributaries that act as a refuge during times of toxic chemicals. 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.

Longitudinal trends for fish community biology performance on the Cuyahoga River are displayed below in Figure 12. The section of river between RM 24.17 to 16.36 is proposed to be upgraded from a WWH to an EWH ALU designation. This ALU upgrade was based on the removal of the Station Road Dam at RM 20.70 in 2020, which impeded fish migration upstream and restored a free-flowing stream. Biological indices immediately downstream of the former dam exhibited *Exceptional* scores for all three biological metrics in 2017 and 2018. The only fish community scores obtained upstream of the former dam were at RM 24.10 and did not meet the new EWH criteria for either fish community metric.

An interesting project led by the US Fish & Wildlife Service (USFWS) worth mentioning is the possible reintroduction of lake sturgeon (*Acipenser fulvescens*) into the Cuyahoga River. A fish that was once plentiful in Lake Erie and used the Cuyahoga River as a spawning tributary is now listed as endangered by the Ohio Division of Natural Resources (OSU, 2019). As water quality continues to improve in major Lake Erie tributaries, the plan is to repopulate lake sturgeon to their native ranges. This project gained popularity in the Maumee River, where introductions began in 2018 after a habitat suitability study confirmed spawning habitat was plentiful. The Cuyahoga River lake sturgeon introduction is now in the habitat suitability study phase, with efforts being led by the U.S. Fish and Wildlife Service.

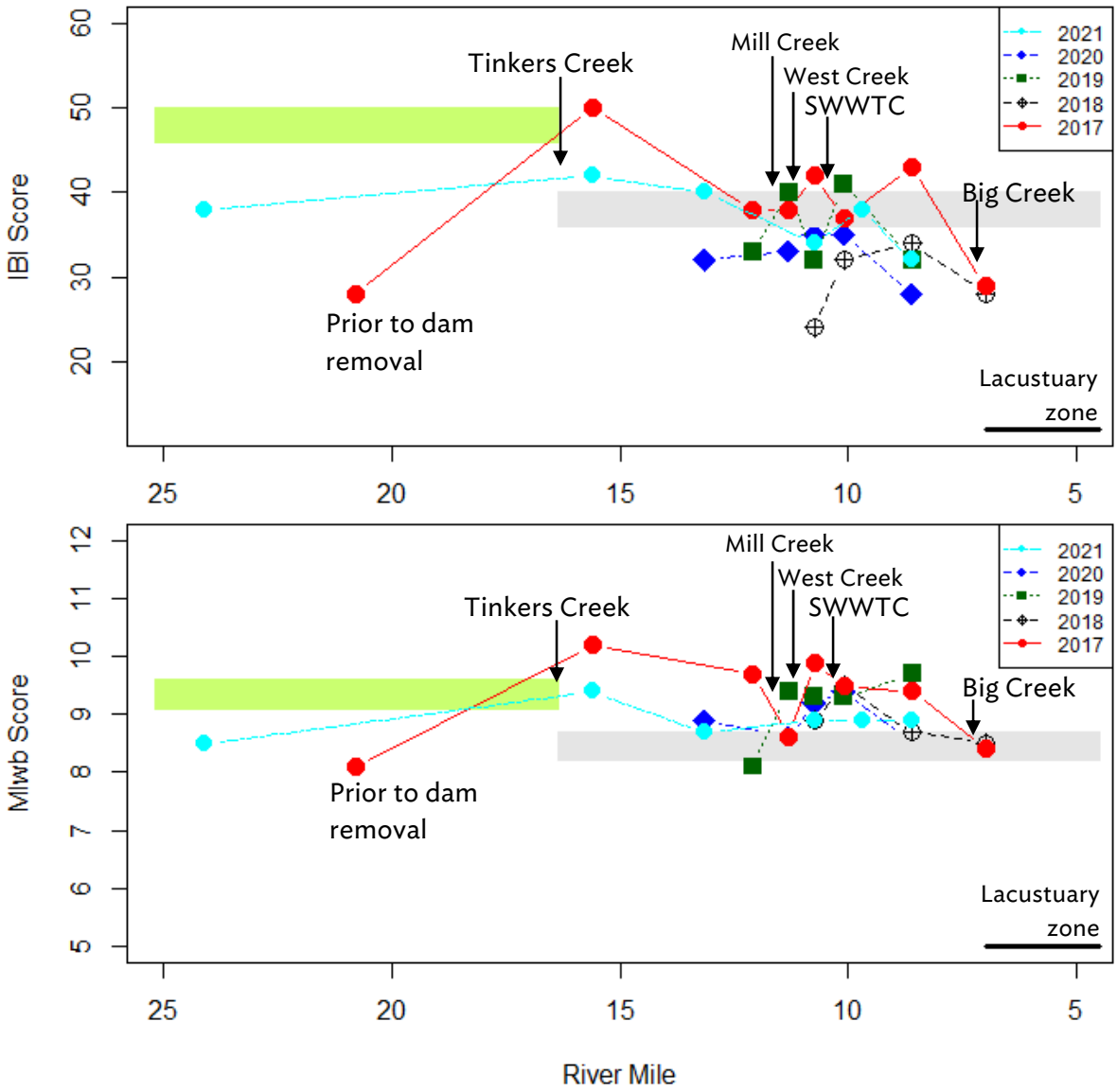


Figure 12. Longitudinal fish community biology scores Cuyahoga River mainstem 2017-2021. Gray box represents range of WWH attainment and NSD; light green box represents range of EWH attainment and NSD.

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 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 taxa 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 22), 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 ICI criterion in the EOLP ecoregion is shown below in Table 23 and a site is within non-significant departure if the score falls within 4 ICI units of the biocriterion.

Table 22. 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 23. 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

For the 2021 sampling season, all nine sampling sites met applicable ALU biocriterion (Table 24 and Figure 13). Temporal data displayed in Table 25 shows scores consistent with the previous year. Although a significant decline in ICI score was recorded at RM 8.60 compared to the previous year, this location still achieved a *Good* overall score. The stream reach designated as EWH averaged an ICI score of $\bar{x}$ =46.7 (*Exceptional*) when narrative ratings were converted to

numerical scores (Ohio EPA, 2017). The stream reach designated WWH averaged an ICI score of $\bar{x}$ =43.7 (*Very Good*). Table 24 shows a more detailed description of the Cuyahoga River macrobenthos community. Most sites displayed a moderate to high taxa diversity with an abundance of EPT and sensitive taxa. Sensitive taxa outnumbered tolerant taxa at all sample locations and the predominant organisms on the natural substrates were mostly members of the EPT group.

Table 24. 2021 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/EWH Recommended							
24.10*	1,278 / M	69 / 75	20 / 16	0.8% / 25.2%	Baetid mayflies, midges, Turbellaria, limpet snails	48	*Exceptional*
22.40*	- / M	74 / -	26 / 24	11 / 24 (#Ql. Taxa)	Midges, baetid mayflies, hydropsychid caddisflies, heptageniid mayflies	E	*Exceptional***
20.80*	- / M	68 / -	23 / 21	9 / 21 (#Ql. Taxa)	Baetid mayflies, hydropsychid caddisflies, *Chimarra* caddisflies, heptageniid mayflies	E	*Exceptional***
Cuyahoga River (19-001-000) - WWH Existing							
15.61*	1639 / M-H	67 / 71	22 / 19	0.0% / 35.9%	Midges, baetid mayflies, hydropsychid caddisflies	48	*Exceptional*
13.15	- / L	58 / -	19 / 18	9 / 18 (#Ql. Taxa)	Baetid mayflies, hydropsychid caddisflies, midges	E	*Exceptional***
10.75	976 / M-L	58/ 66	17 / 16	8.9% / 18.6%	Baetid mayflies, hydropsychid caddisflies, midges, scuds	44	*Very Good*
10.10	1,268 / M	49 / 60	16 / 9	4.1% / 41.2%	Baetid mayflies, hydropsychid caddisflies, isopods, amphipods	44	*Very Good*
9.70*	716 / M	55 / 65	19 / 14	5.0% / 19.0%	Midges, Turbellaria, baetid mayflies	40	*Very Good*
8.60	928/M	39 / 49	15 / 10	18.6% / 26.3%	Baetid mayflies, hydropsychid caddisflies, midges, leptocerid caddisflies, amphipods	36	*Good*

Qt. Quantitative sample collected on Hester-Dendy artificial substrates
Ql. Qualitative sample collected from natural stream substrates
Qualitative sample relative density: L=Low, M=Moderate, H=High
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List (2019) as *Moderately Intolerant or Intolerant*
*Ohio EPA assessment sites
**Narrative evaluation based on results from qualitative sampling only

Table 25. Cuyahoga River Historic ICI Scores (2006-2021)									
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
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***	**48***	**E***	--	--	**44**	**44**	**36**	--

Bold indicates attainment of WWH criterion of 34
Italics indicates non-significant departure (≤4 ICI units) from criterion
***Meets Exceptional WWH Criterion**

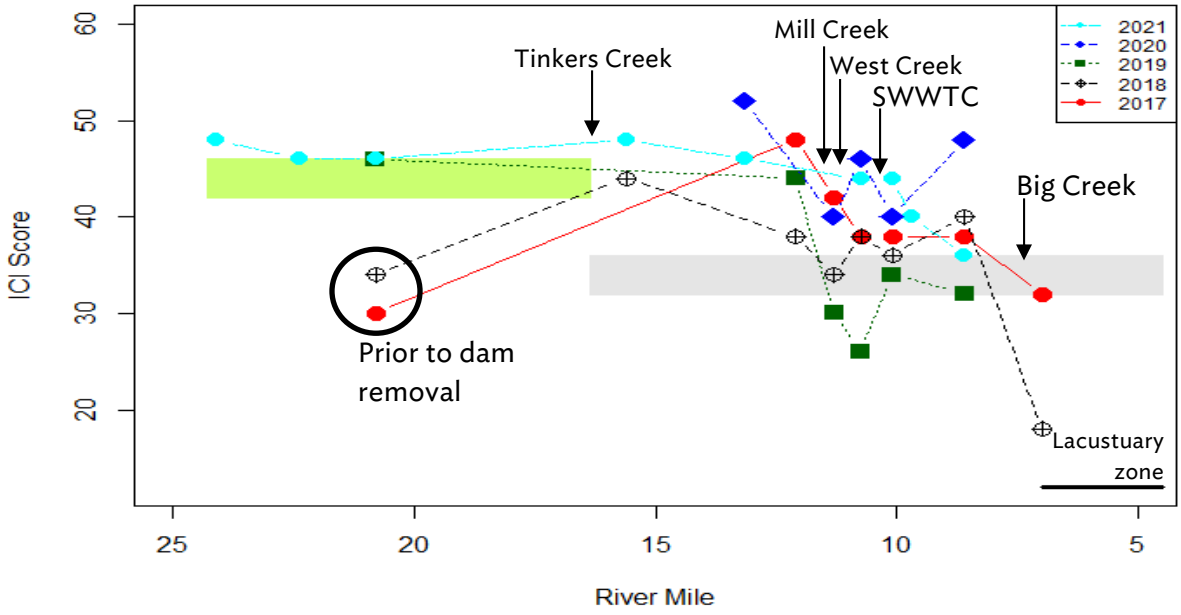


Figure 13. Longitudinal macroinvertebrate community biology scores Cuyahoga River mainstem 2017-2021. Gray box represents range of WWH attainment and NSD; light green box represents range of EWH attainment and NSD.

The HD at the RM 13.15 location was washed out following a heavy rain event. A narrative rating was given for this site based on the qualitative sample, comparing the results to expectations developed by the NEORSD for total taxa, EPT taxa, and sensitive taxa. These expectations reflect level 3 credible data and data collected by the Ohio EPA and NEORSD from the EOLP ecoregion from the ten-year period of 2005-2014, where qualitative data was compared to the ICI score generated for each site. Table 26 provides the expectation threshold limits for the small rivers category.

Table 26. NEORSD Recommended Expectation Threshold Limits for Narrative Rating Assignments in the EOLP

Drainage Category	Designation	Qualitative Total Taxa	Qualitative EPT Taxa	Qualitative Sensitive Taxa
Small River (200-1,000 miles^2)	EWH	44	16	10
	WWH	36	11	7
	Fair	29	9	5

The Cuyahoga River RM 13.15 was assigned a narrative rating of *Exceptional* in 2021. A total of 58 qual taxa were collected including 19 EPT taxa, 18 sensitive taxa, and one intolerant baetidae (*Acentrella turbida*). The predominant organism on the natural substrates were baetid mayflies, hydropsychid caddisflies, and midges. With a drainage area of 703 square miles, this site exceeded the EWH expectations for all three categories listed in Table 26. In 2020, RM 13.15 had an ICI score of 52 (*Exceptional*). The qualitative sample in 2020 contained fewer qualitative taxa (37), qualitative EPT taxa (15), and qualitative sensitive taxa (13) compared to the sample collected in 2021. This provides further support for the narrative rating assignment of *Exceptional* in 2021.

The Station Road Dam on the Cuyahoga River at RM 20.70 was removed in 2020, re-establishing a free-flowing section of Cuyahoga River that was previously a 3-4 mile dam pool. Immediate positive changes to the macroinvertebrate community have been noted since the dam removal. Pre-dam removal monitoring from 2017-2018 at RM 20.80-24.10 averaged 43 qual taxa, 12 EPT taxa, and 11 sensitive taxa from the qualitative assessments. The first assessments of the free-flowing section upstream of RM 20.70 in 2021 were performed by the Ohio EPA and nearly doubled all pre-dam removal qualitative assessment metrics. The three sites within the former dam pool averaged 70 qual taxa, 23 EPT taxa, and 20 sensitive taxa. All three sites within the former dam pool achieved an *Exceptional* narrative rating in 2021. Table 27 below displays the improvements to the three main qualitative sampling macroinvertebrate metrics before (2017) and after (2021) the dam was removed.

Table 27. Macroinvertebrate Improvements Post-Dam Removal (2020)						
RM	Qual taxa		Qual EPT		Qual sens. taxa	
	2017	2021	2017	2021	2017	2021
24.10	40	69	14	20	12	16
22.40	53	74	15	26	18	24
20.80	36	68	7	23	4	21

Figure 14 below shows the macroinvertebrate community compositions collected on the HD. The abundance of mayfly and caddisfly taxa from RM 24.10-10.10 demonstrate the well-balanced benthic community and reflect the *Very Good* and *Exceptional* ICI scores. The abundance of EPT taxa limits proportions of the more tolerant "other dipterans and non-insect" taxa throughout this reach. The Ohio EPA HD at RM 9.70 and the NEORSD HD were both set in a riffle reach near RM 10.00 and were pulled within a two-week period in mid-September. Although ICI scores were similar, community composition from both HDs showed differences. The Ohio EPA HD contained a lower proportion of EPT family taxa and Tribe Tanytarsini midges, and a higher proportion of "other dipterans and non-insects" than the NEORSD HD. A decrease in percent caddisflies, mayflies, and tribe tanytarsini midges and an increase in percent "other organisms" downstream of RM 10.10 and 9.70 may be due to changes in habitat and substrate embeddedness, increase in urban land use, changes in gradient and sub-ecoregion transition, and the discharge from the NEORSD SWWTC.

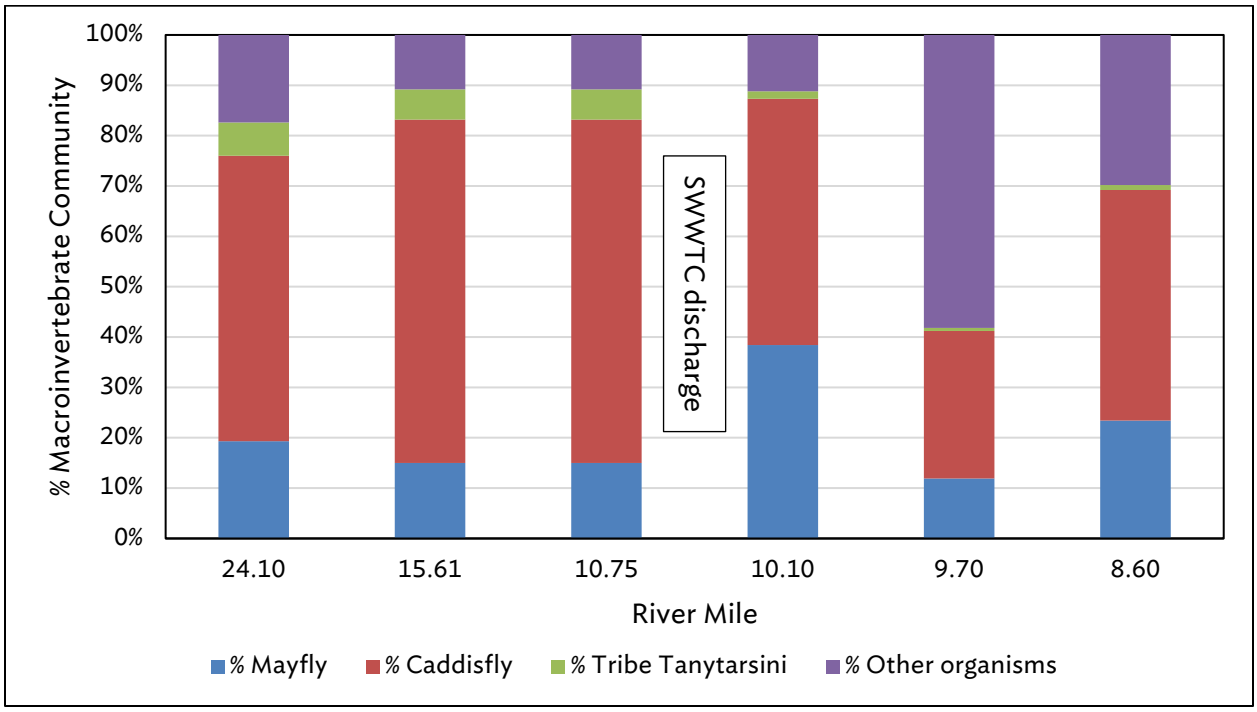


Figure 14. 2021 Cuyahoga River Macroinvertebrate Community Composition

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 15 below displays longitudinal trends on the Cuyahoga River from the previous two major study years of 2017 and 2021. Expectations for EWH and WWH are based on Table 26. Macroinvertebrate scores in 2021 improved for all three metrics at all sample locations. These increases in metric scores are attributable to multiple factors. The removal of the Station Road Dam had an immediate positive impact on the benthic community at sample locations upstream of RM 20.70. Sedimentation from the old dam pool was observed in the downstream reaches by both the Ohio EPA and NEORSD field staff but did not seem to negatively affect the overall macroinvertebrate community. Metric scores declined slightly from upstream to downstream and 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 that reach.

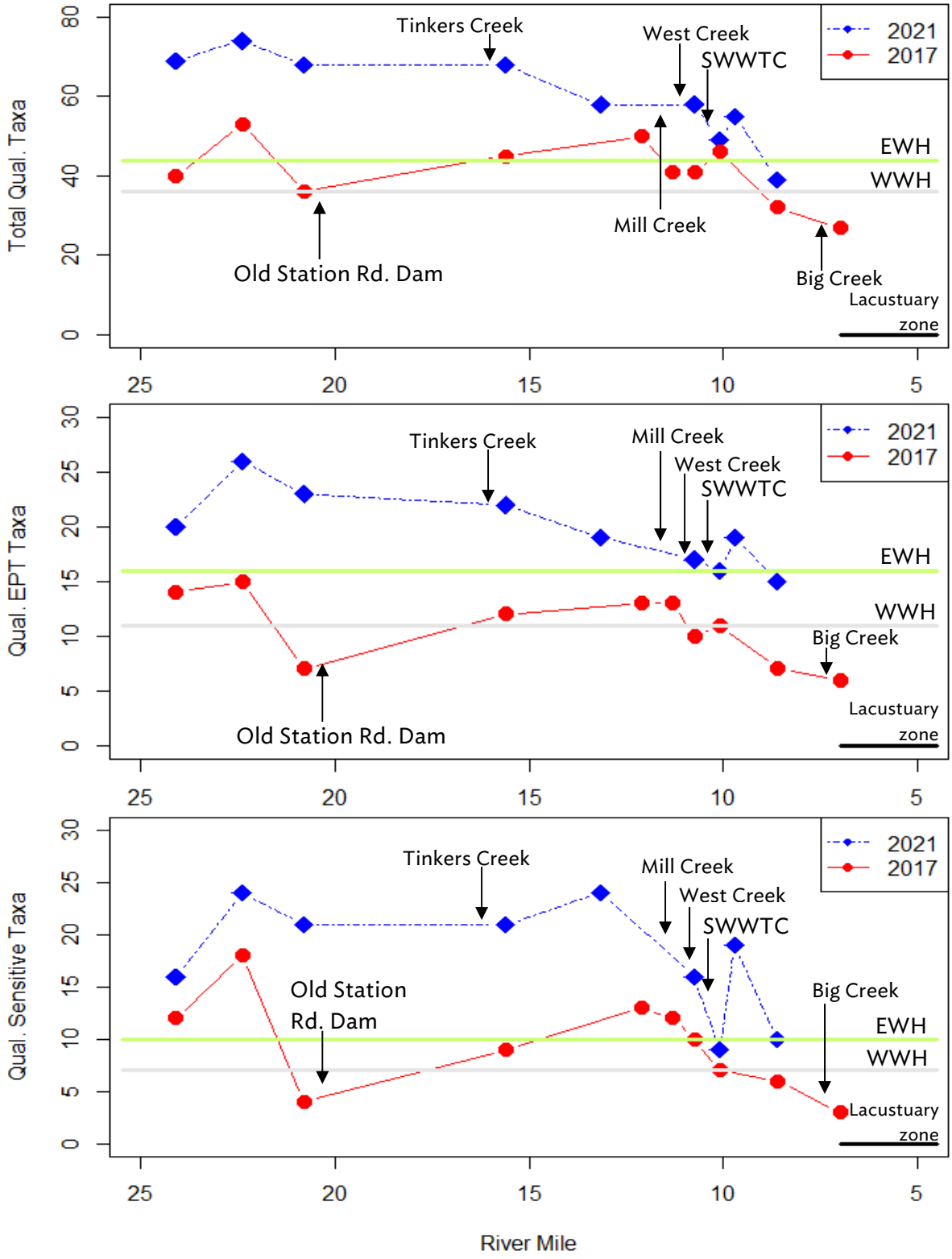


Figure 15. Longitudinal trends for qual. taxa, qual. EPT taxa, and qual. sensitive taxa richness scores in the Cuyahoga River mainstem 2017 and 2021. Gray line represents WWH expectation; light green line represents EWH expectation for the EOLP ecoregion.

Evaluation of the Cuyahoga AOC Beneficial Use Impairments (BUIs)

The evaluation of the following four BUIs are based on Ohio EPA WQS criteria, or habitat goals set for QHEI scores. In order for a BUI to be removed, a score within NSD of the designated ALU must be achieved. Rather than assessing attainment based on a site-by-site case, the Cuyahoga River AOC removal criteria is based on average scores within each 12-digit hydrologic unit code (HUC-12), or by the Large River Assessment Unit (LRAU) for the Cuyahoga River mainstem. Sites from 2021 are located within three different HUC-12s listed in Table 28. The LRAU is used for overall BUI removal analysis on the Cuyahoga River mainstem.

Table 28. Assessment of the Cuyahoga AOC BUI Removal Criteria

HUC-12: 04110002-	Description of HUC	BUI # 3: fish populations		BUI #4: Fish tumors	BUI #6: Benthos	BUI #14a: Fish habitat
		IBI score	MIwb score	% DELTs	ICI score	QHEI score
Criteria	WWH	≥36	≥8.2	≤3.0%	≥30	≥60
	EWH	≥46	≥8.9	≤3.0%	≥42	≥75
05 05* (n=3; 1 fish, 3 bug sites)	Cuyahoga River RM 24.16-16.36; EWH	38.0	8.5	0.45%	46.7	80.00
06 02 (n=2)	Cuyahoga River RM 16.36-11.40; WWH	41.0	9.1	1.01%	47.0	76.75
06 04 (n=4; 3 fish, 4 bugs)	Cuyahoga River RM 11.40-7.20; WWH	34.7	8.8	0.28%	41.0	74.17
LRAU	Cuyahoga River LRAU	37.3	8.9	0.55%	44.7	76.00
*EWH proposed site						
	Meets BUI delisting criteria					
	Does not meet BUI delisting criteria					

Sites throughout the lower 25 miles of the Cuyahoga River continue to demonstrate *Good* to *Excellent* in-stream habitat, meeting the BUI #14a goal at all three HUC-12s and the overall LRAU. Degradation of Benthos has also consistently met the WWH and BUI #6 removal criterion throughout all three HUC-12s and the LRAU. The RM 20.80 site within the former Station Road Dam pool had an immediate recovery from a *Marginally Good* benthic community in 2017 to an *Exceptional* community in 2021. BUI #3 is broken down into two sub-metrics. The MIwb scores at two of the three HUC-12 watersheds met BUI removal and WWH criteria. Fish community metrics in the 05 05 HUC-12 watershed did not meet either BUI #3 removal criteria due to an ALU redesignation to EWH. The 05 05 HUC-12 scores in 2021 did meet WWH removal criteria and could satisfy BUI #3 removal at this time if scored as a WWH watershed. The 06 04 HUC-12 watershed did not meet the IBI average component of the removal criteria but did meet the MIwb component. Based on the single LRAU, 2021 all five biological and habitat metrics meet the AOC BUI targets when averaged.

Incredible progress has been made on aquatic life recovery in the 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. Numerous watershed management action plans are in place throughout the Cuyahoga AOC focused on restoring the biological and habitat components. Once these projects are completed, these biological and habitat scores will be reviewed by the Cuyahoga River AOC committee for potential BUI removal.

Conclusions

The 2021 water quality assessment resulted in 66.7% of sites in full attainment and 33.3% in partial attainment (Table 29). All Cuyahoga River sites met the overall score target for the QHEI, although some substrate metrics did not meet sub-specific TMDL target criteria. The macroinvertebrate community has continued to demonstrate *Good* to *Exceptional* communities throughout the lower 25 miles of Cuyahoga River upstream of the ship channel. Sites that failed to meet the ALU biocriteria were RM 24.16 for both fish metrics, and RMs 10.75 and 8.60 for the IBI component only.

Table 29. 2021 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/EWH Recommended								
24.10	555	PARTIAL	38	8.5	48[E]	80.00		
22.40	559	(FULL)	--	--	E	--		
20.80	583	(FULL)	--	--	E	--		
Cuyahoga River (19-001-000) - WWH Existing								
15.61	698	FULL	42	9.4	48[E]	77.50		
13.15	703	FULL	40	8.7	E	76.00		
10.75	743	PARTIAL	34	8.7	44	76.75	Sedimentation Nutrient enrichment Toxic metals	Urban runoff NPDES permitted facilities Atmospheric deposition/ urbanization
10.10	744	(FULL)	--	--	44	--		
9.70	744	FULL	38[NS]	8.9	40	70.00		
8.60	745	PARTIAL	32	8.9	36	75.75	Sedimentation Nutrient enrichment Toxic metals	Urban runoff NPDES permitted facilities Atmospheric deposition/ urbanization

*Significant departure from biocriterion (> 4ICI; > 4IBI; > 0.5 MIwb units). Underlined scores are in the *Poor* or *Very Poor* narrative range
[E] *Exceptional* narrative range
[NS] Non-significant departure of WWH
Attainment status in ( ) are not based on a full biological assessment

Both the recreational *E. coli* WQS were exceeded at all six sample locations (Tables 5 and 6), which is common in urbanized watersheds due to improper sanitary connections, failing household sewage treatment systems, and urban stormwater runoff. Effluent from Southerly WWTC did not appear to significantly contribute to these exceedances. Toxic concentrations of mercury and copper were observed as exceedances of the OMZA and OMZM (Tables 7 and 8) and are likely caused by urban runoff. These periodic toxic concentrations 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 on biological performance, as geometric mean concentrations exceeded the proposed large river nutrient WQS at all but one sample location (Table 10). Nutrient enrichment promotes excess algal growth which was observed in the daily DO swings approaching the large river WQS threshold (Figure 8). 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 macroinvertebrate communities have recovered to full attainment throughout the lower 25 miles upstream of the lacustuary zone, with many stream reaches exhibiting *Exceptional* communities. The fish communities in the Cuyahoga River continue to meet WWH attainment in the reach within the National Park. The Cuyahoga River downstream of the National Park has exhibited *Fair* to *Good* fish community scores, that may be due multiple sources 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 throughout the system.

The NEORSD has recently completed sanitary sewer evaluation studies for the Mill Creek Interceptor, Southwest Interceptor, and Cuyahoga Valley Interceptor collection systems. These studies identified water quality problem areas related to sanitary sewer overflows, common trench sewers, surcharged sewers, illicit discharges, and areas of clustered septic systems. Reports from these studies are delivered to local municipalities and projects are then prioritized. The local municipalities can apply for funding assistance through the NEORSD Member Community Infrastructure Program (MCIP) or Community Cost Share Program (CCS), where funds are generally matched. Since 2017, funds provided through the MCIP and CCS have surpassed $22 million for projects throughout the NEORSD service area. In combined sewer areas, the NEORSD offers a Green Infrastructure program that offers competitive annual grants to member communities, governmental agencies, or local businesses. The NEORSD Regional Stormwater Management Program has invested over $74 million in past and current projects within the Cuyahoga River watershed to address bank erosion and stabilization, floodplain expansion, habitat restoration, and stormwater management.

Local partners participating in NPS-IS development and implementation, along with the continued efforts of the NEORSD Stormwater Management Program and Member Community Infrastructure Program 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.

Acknowledgments

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

Bert Remley (Third Rock Consulting, LLC)
Daniel Neelon
Hannah Boesinger
Kevin Fitzgibbons
Joseph Schiel
Mark Matteson
Marty Sneen (EA Engineering, Science, and Technology, Inc)
Eric Soehnlen
Justin Telep, Author
Seth Hothem
John W. Rhoades
Ron Maichle
Michael Meaney
Veronica Riedel

Analytical Services Division – Completed analysis for all water chemistry sampling

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