



Northeast Ohio Regional Sewer District

2022 Euclid and Dugway Storage Tunnels Post-Construction Biological, Water Quality, and Habitat Study



**Water Quality and Industrial Surveillance
Environmental Assessment Group
May 2023**

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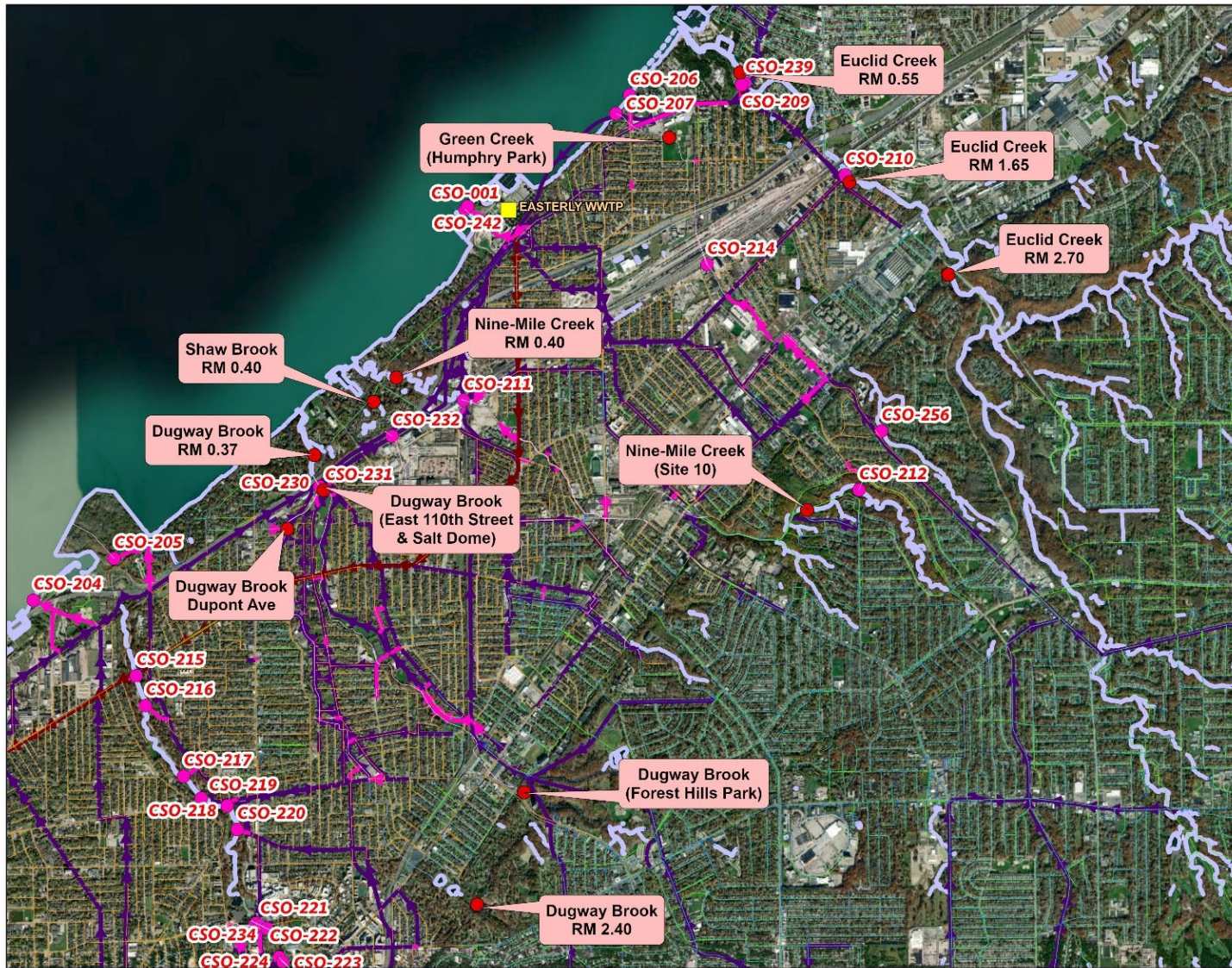
Introduction

In 2022, the Northeast Ohio Regional Sewer District (NEORS) conducted post-construction environmental monitoring of several streams tributary to Lake Erie, including Euclid Creek, Dugway Brook, Nine-Mile Creek, Shaw Brook, and Green Creek. Water quality improvement in each of these streams has been a long-term target of the NEORS "Project Clean Lake" infrastructure projects. The specific infrastructure projects that have anticipated impacts on these streams include the Euclid Creek Tunnel (ECT), the Dugway Storage Tunnel (DST), the Dugway East Interceptor Relief Sewer (DEIRS), the Dugway West Interceptor Relief Sewer (DWIRS), and the East 140th Street Relief and Consolidation Sewer, among other associated relief sewer and regulator upgrades. The goal is the improved conveyance of wastewater and stormwater during wet-weather events, reducing the occurrence of combined sewer overflow (CSO) discharges to Lake Erie via its tributary streams. As of 2022 most of these projects have been fully completed and are now receiving sanitary and stormwater flows.

All five streams that were sampled in 2022 are heavily urbanized, flowing through eastside suburbs of Cleveland before flowing beneath Interstate 90, through Cleveland or Bratenhal, and discharging into Lake Erie. In 2020, the Ohio Environmental Protection Agency (Ohio EPA) identified Euclid Creek as a Prioritized Impaired Water under section 303(d) of the Clean Water Act (Ohio EPA, 2020). The Ohio EPA recommended that Dugway Brook, Nine-Mile Creek, and Shaw Brook receive WWH aquatic life use designations (Table 2). Green Creek is only open at its headwaters bordering the City of Euclid and Cleveland and is culverted the rest of its length to Lake Erie. Because of this, it does not have a beneficial use designation, but was included in this study due to potential impact by these construction projects.

Sampling was conducted by NEORS Level 3 Qualified Data Collectors (QDCs) certified by the Ohio Environmental Protection Agency (EPA) in Fish Community Biology, Benthic Macroinvertebrate Biology, Chemical Water Quality, and Stream Habitat Assessments as explained in the NEORS study plan *2022 Euclid/Dugway Storage Tunnels Post-Construction Monitoring*. All sampling and environmental assessments occurred between June 15, 2022, and September 30, 2022 (through October 15 for fish sampling assessments), as required in the Ohio EPA *Biological Criteria for the Protection of Aquatic Life Volume III* (1987b). The results 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* (2021) and compared to the Ohio Water Quality Standards for their designated use 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 map of the sampling locations, and Table 1 indicates the sampling locations with respect to stream, river mile, latitude and longitude, and station identification where applicable. Table 2 indicates the Beneficial Use Designations with respect to stream. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's Water Quality and Industrial Surveillance (WQIS) Division.



Northeast Ohio Regional Sewer District

2022 Euclid/Dugway Storage Tunnel Post-Construction Monitoring

Overview Map

Legend

- Sample Locations
- Streams
- Local Sewer Pipe
- Combined Sewer
- CSO Overflow
- Culverted Stream
- Force Main
- Sanitary Sewer
- Sanitary Overflow
- Storm Sewer
- District Facility
- District CSO Permit Point
- District Sewer Pipe
- District Pipe
- District CSO Overflow Pipe
- District Force Main
- District Maintained

0.55
Mile

This information is for display purposes only. The Northeast Ohio Regional Sewer District (NEORS) makes no warranties, expressed or implied, with respect to the accuracy of and the use of this map for any specific purpose. This map was created to serve as base information for use in Geographic Information Systems (GIS) for a variety of planning and analysis purposes. The NEORS expressly disclaims any liability that may result from the use of this map. For more information, please contact: NEORS GIS Services, 3900 Euclid Avenue, Cleveland, Ohio 44115 —(216) 881-6600 — GIS@neorsd.org

Figure 1. Sampling Locations.

2022 Euclid and Dugway Tunnels Post-Construction Biological, Water Quality, and Habitat Study
 May 10, 2023

Table 1. Sampling Locations						
Location	River Mile	Drainage Area	Latitude	Longitude	Station ID	Sampling Conducted
Dugway Brook West Branch	2.40	2.6	41.5122	-81.5905	301431	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Dugway Brook West Branch	Culverted-Dupont Ave.	N/A	41.5446	-81.6118	N/A	Water Chemistry
Dugway Brook East Branch	Culverted-Forest Hills Park	N/A	41.5218	-81.5850	N/A	Water Chemistry
Dugway Brook East Branch	Culverted-E. 110 th St.	N/A	41.5479	-81.6076	N/A	Water Chemistry
Dugway Brook Main Branch	0.37	6.3	41.5509	-81.6086	301430	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	2.70	21.9	41.5658	-81.5358	200138	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	1.65	22.3	41.5738	-81.5470	504250	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Euclid Creek	0.55	23.1	41.5833	-81.5594	F01A47	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Green Creek	Humphrey Park Culvert	N/A	41.5778	-81.5676	N/A	Water Chemistry
Nine-Mile Creek	Site 10	0.7	41.5457	-81.5523	301435	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Nine-Mile Creek	0.40	3.1	41.5575	-81.5991	301432	Habitat, Fish, Macroinvertebrates, and Water Chemistry
Shaw Brook	0.40	0.04	41.5554	-81.6018	302509	Habitat, Fish, Macroinvertebrates, and Water Chemistry

Table 2. Applicable Beneficial Use Designations for Streams Assessed in 2022													
Stream	Beneficial Use Designation												
	Aquatic Life Habitat (ALU)							Water Supply			Recreation		
	S R W	W W H	E W H	M W H	S S H	C W H	L R W	P W S	A W S	I W S	B W	P C R	S C R
Dugway Brook		+							+	+		+	
Euclid Creek-Anderson Road (RM 5.6) to U.S. Rte. 20 (RM 2.4)	*	+							+	+		+	
-all other segments		+							+	+		+	
Nine-Mile Creek		*							*	*		*	
Shaw Brook		+							+	+		+	

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.
 *Designated use based on the 1978 water quality standards.
 +Designated use based on the results of a biological field assessment performed by the Ohio Environmental Protection Agency.

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted at each site five times between June 23 and November 3, 2022, and analyzed for all parameters. Five additional samples were collected at each site between August 30 and November 3, 2022, and analyzed for *Escherichia coli* (*E. coli*) and total phosphorous. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2021). Chemical water quality samples from each site were collected with a 4-liter disposable polyethylene cubitainer with a disposable polypropylene lid, three 473-mL plastic bottles and one 125-mL plastic bottle. The first 473-mL plastic bottle was field preserved with trace nitric acid, the second was field preserved with trace sulfuric acid and the third bottle received no preservative. The sample collected in the 125-mL plastic bottle (dissolved reactive phosphorus) was filtered using a 0.45- μm PVDF syringe filter. All water quality samples were collected as grab samples. Bacteriological samples were collected in 250 mL sterilized plastic bottles. At the time of sampling, measurements for dissolved oxygen, dissolved oxygen percent, pH, temperature, specific conductance, and conductivity were collected using a YSI EXO1 sonde. Replicate, duplicate, and field blank samples 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/replicate sample (Formula 1).

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

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

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

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

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

X = sample/detection limit ratio

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

Water chemistry analysis sheets for each site are available upon request from the NEORSD WQIS Division. Dates of water chemistry sampling compared to Euclid Creek flow data (USGS 04208700) are shown below in Figure 2.

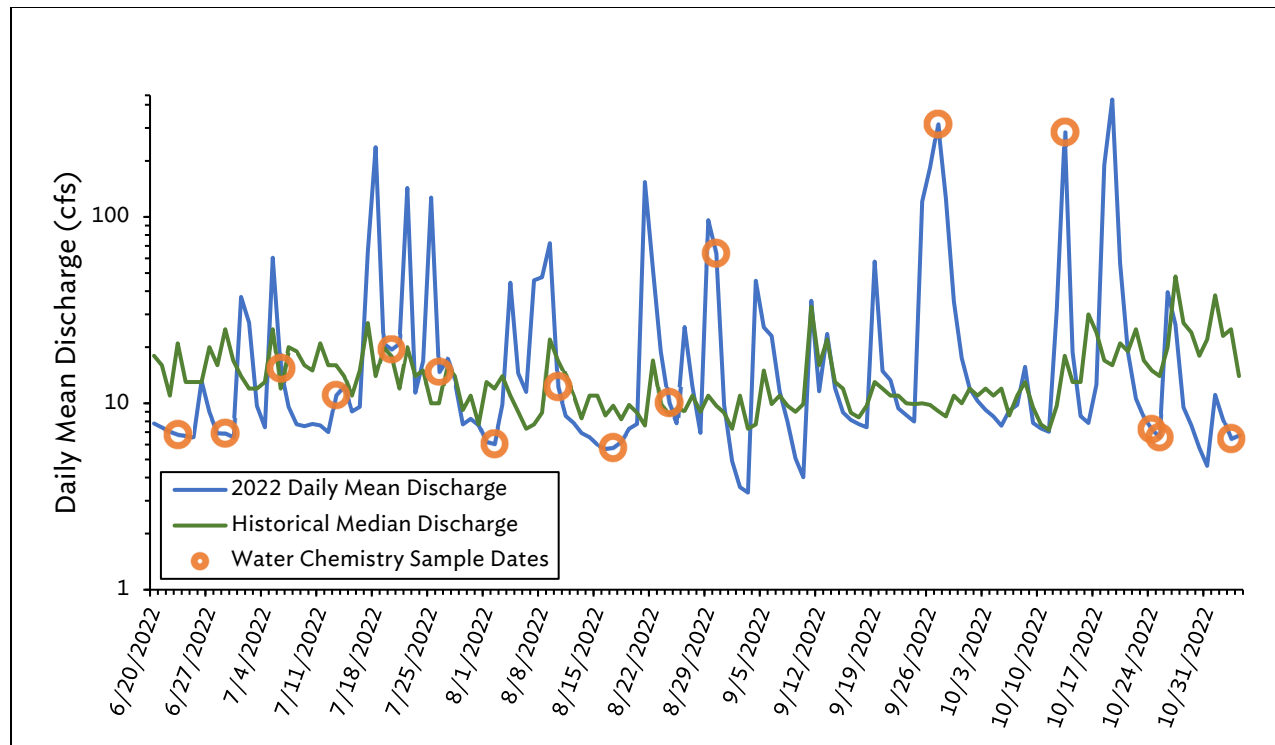


Figure 2. Daily mean discharge in cubic feet per second for Euclid Creek at USGS Station 04208700. Shown are the daily mean discharge records for June–November 2022 and the historical daily median. Orange circles indicate water chemistry sampling dates.

Results and Discussion

Data Validation QA/QC Checks

Over the course of the ten sampling events in 2022, four field blanks, three duplicate samples, and three replicate samples were collected as part of this study and analyzed for all parameters. One replicate and field blank each were collected during the additional *E. coli*/total phosphorus sampling events. Parameters that showed possible contamination in the field blank included biochemical oxygen demand (BOD) and alkalinity (Table 3). It is unclear how the field blanks became contaminated and may be due to inappropriate sample collection, handling, and/or contaminated blank water. The results listed for BOD and alkalinity were rejected because they were insufficiently different than the field blank results.

Table 3. Parameters with Field Blank Concentrations Showing Possible Contamination					
Stream	Location	Date	Parameter	Result/Blank Result	Qualifier
Dugway Brook	Dupont Ave Culvert	8/10/2022	BOD	1.04	Rejected
Dugway Brook	E. 110 th St. Culvert	8/10/2022	BOD	1.50	Rejected
Dugway Brook	RM 0.37	8/10/2022	Alkalinity	0.90	Rejected
			BOD	0.92	Rejected
Nine-Mile Creek	RM 0.40	8/10/2022	Alkalinity	1.68	Rejected
			BOD	1.58	Rejected
Shaw Brook	RM 0.40	8/10/2022	Alkalinity	1.00	Rejected
			BOD	1.17	Rejected

Of the duplicate/replicate samples collected, two instances occurred in replicate samples in which the acceptable RPD was exceeded (Table 4). 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 4. Rejected Replicate Samples with RPDs Greater than Acceptable					
Stream	Location	Date	Parameter	Acceptable RPD	Actual RPD
Shaw Brook	RM 0.40	8/2/2022	Lead	26.6	53.8
			Manganese	15.0	30.0
Dugway Brook	RM 2.40	8/17/2022	Ammonia	69.6	97.2
			Strontium	13.1	16.0
			TSS	50.6	100.0

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 sub-parameter value was greater than the parent value (Table 5). The results for dissolved reactive phosphorus and total phosphorus for Euclid Creek RM 2.70 on June 23, 2022, were rejected.

Table 5. Paired Parameters with Sub-Parameter Values Greater Than Parent Values					
Stream	Location	Date	Sub Parameter	Parent Parameter	Qualifier
Euclid Creek	RM 2.70	6/23/2022	Dissolved Reactive Phosphorus (mg/L)	Total Phosphorus (mg/L)	Rejected
			0.236	0.0841	

Field conductance was also compared to lab conductance for the Euclid Creek sites (RMs 2.70, 1.65, and 0.55) by utilizing a comparison of both the RPD and absolute difference following the Ohio EPA *Surface Water Field Sampling Manual-Data Management* (2021). No samples met both criteria (greater than 10% RPD results and greater than a 50 $\mu\text{mho/cm}$ absolute difference between field and lab results), therefore no qualification of field specific conductance was required.

Bacteriological Data

Open sections of Dugway Brook, Nine-Mile Creek, Euclid Creek, and Shaw Brook are designated as a warmwater habitat (WWH) and primary contact recreation according to the Ohio EPA Water Quality Standards (2021b). Exceedances of the recreational bacteriological criteria for primary contact recreation occurred at all four streams during the 2022 sampling season. The recreational criteria for *E. coli* consist of two components: a 90-day geometric mean and a statistical threshold value (STV) not to be exceeded in more than 10% of the samples collected during a 90-day period. For streams designated as primary contact recreation, these criteria are 126 colony counts/100mL or most-probable number (MPN)/100mL and 410 colony counts/100mL or MPN/100mL, respectively. These calculations are formulated when there are at least five samples collected within a rolling 90-day period.

Both primary contact recreation criteria were exceeded at all twelve sites for the 90-day periods that started beginning when the first sample was collected (Tables 6-8). Therefore, all sites (excluding culverted locations that are not compared to standards) were in non-attainment of both criteria in 2022. Out of all locations sampled during the study, the Dugway Brook East Branch East 110th Street Culvert reported the highest geometric mean value of 15,231 MPN/100 mL with 100 percent of the samples exceeding the STV criterion (Table 6). Table 9 provides a summary of the recreational use criteria exceedances for all sites assessed in 2022.

These exceedances may be due to significant wet-weather events¹ which occurred on seven of the ten sampling dates. Potential sources of bacteria inputs may include stormwater runoff, illicit discharges, CSOs, and failing household sewage treatment systems (HSTS).

¹ 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. 2022 Dugway Brook <i>E. coli</i> Densities (MPN/100mL)					
Date	RM 2.40	RM 0.37	Dugway Forest Hills Park**	Dugway E. 110 th Street**	Dugway Dupont Avenue**
7/26/2022*	866	26,130	866	32,820	1300
8/2/2022	435	3930	517	12,810	14,010
8/10/2022*	687	6700	1860	11,120	1254
8/17/2022	435	2420	1300	9590	1553
8/24/2022*	282,720	9678	343	14,060	1164
8/30/2022*	9995	11,870	3590	16,240	12,960
9/27/2022*	99,315	44,100	13,775	14,750	18,200
10/13/2022*	19,180	9678	21,420	19,180	8820
10/25/2022	98	2420	435	2420	3500
11/3/2022	113	1986	727	3050	1733
90-day Geomean (7/26-10/23)	5282	9750	2110	15,231	5571
	<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 10px; background-color: #f4a460; margin-right: 5px;"></div> Exceeds statistical threshold value of 410 MPN/100mL </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <div style="width: 20px; height: 10px; background-color: #ffff00; margin-right: 5px;"></div> Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL </div>				
*Wet-weather Event					
** <i>E. coli</i> densities at culverted locations were not compared to the primary contact recreation standards but are listed here for reference.					

Table 7. 2022 Euclid Creek <i>E. coli</i> Densities (MPN/100mL)			
Date	RM 2.70	RM 1.65	RM 0.55
6/23/2022	98	411	727
6/29/2022	249	548	411
7/6/2022*	1844	1379	1164
7/13/2022	261	302	308
7/20/2022	354	276	518
8/30/2022*	3360	4200	4260
9/27/2022*	7195	9873	6932
10/13/2022*	6932	9678	11,880
10/24/2022	86	111	172
11/3/2022	20	147	
90-day Geomean (6/23-9/20)	491	691	786
	<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 10px; background-color: #f4a460; margin-right: 5px;"></div> Exceeds statistical threshold value of 410 MPN/100mL </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <div style="width: 20px; height: 10px; background-color: #ffff00; margin-right: 5px;"></div> Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL </div> <div style="display: flex; align-items: center; margin-top: 5px;"> <div style="width: 20px; height: 10px; background-color: #d9e1f2; margin-right: 5px;"></div> No Sample Collected </div>		
*Wet-weather Event			

Table 8. 2022 Green Creek, Nine-Mile Creek, and Shaw Brook <i>E. coli</i> Densities (MPN/100mL)								
Date	Green Creek Humphrey Park**	Nine-Mile Creek Site 10	Nine-Mile Creek RM 0.40	Shaw Brook RM 0.40				
7/26/2022*	20,980	488	1733	1553				
8/2/2022	231	192	1120	1162				
8/10/2022*	18,720	308	1553	488				
8/17/2022	1046	105	411	1046				
8/24/2022*	6932	328	3390	293				
8/30/2022*	5450	10,810	10,140	7540				
9/27/2022*	7945	36,350	24,350	10,900				
10/13/2022*	7945	17,640	22,380	6932				
10/24/2022	1300	135	687	140				
11/3/2022	488	70	921	39				
90-day Geomean (7/26-10/23)	4670	1273	3513	1876				
<table border="0"> <tr> <td style="background-color: #f4a460; width: 20px; height: 15px;"></td> <td>Exceeds statistical threshold value of 410 MPN/100mL</td> </tr> <tr> <td style="background-color: #ffff00; width: 20px; height: 15px;"></td> <td>Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL</td> </tr> </table>						Exceeds statistical threshold value of 410 MPN/100mL		Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL
	Exceeds statistical threshold value of 410 MPN/100mL							
	Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL							
*Wet-weather Event								
** <i>E. coli</i> densities at culverted locations were not compared to the primary contact recreation standards but are listed here for reference.								

Table 9. 2022 Summary of Recreational Use Criteria Exceedances for All Sites				
Site	90-Day Geomean % Exceedance	STV % Exceedance	Max 90-Day Geomean Value (MPN/100 mL)	Seasonal Geomean*
Dugway Brook				
RM 2.40	89	89	13,946	3392
Forest Hills Culvert**	100	100	5044	1771
East 100 th St Culvert **	100	100	15,231	12,415
Dupont Ave Culvert**	100	100	9238	5290
RM 0.37	100	100	10,523	8351
Euclid Creek				
RM 2.70	89	89	2775	731
RM 1.65	89	89	3244	1016
RM 0.55	100	89	3672	1144

Table 9. 2022 Summary of Recreational Use Criteria Exceedances for All Sites				
Site	90-Day Geomean % Exceedance	STV % Exceedance	Max 90-Day Geomean Value (MPN/100 mL)	Seasonal Geomean*
Green Creek				
Humphrey Park Culvert**	100	100	4992	4052
Nine-Mile Creek				
Site 10	100	89	5531	992
RM 0.40	100	100	7849	2931
Shaw Brook				
RM 0.40	100	89	2989	1406
*Seasonal Geomean does not apply. Calculated for comparative purposes only.				
** <i>E. coli</i> densities at culverted locations were not compared to the primary contact recreation standards but are listed here for reference.				

Metals and Other Exceedance Data

Mercury was analyzed using EPA Method 245.1. Because the detection limit for this method is above the criteria for the Human Health and Protection of Wildlife OMZAs, it 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 streams. All the mercury results were below the MDL. It is expected, though, that the use of a low-level mercury analysis like EPA Method 1631E, instead of EPA Method 245.1, may have resulted in exceedances of the criteria throughout the sampling period. It is possible that mercury may be introduced into these streams from urban runoff, industrial wastewater discharge, and atmospheric deposition within the watershed.

Iron also exceeded the Agricultural OMZA (average) at Dugway Brook RM 2.40 for one 30-day period (Table 10). The source of this iron is uncertain as the sample was collected during a dry-weather event.

Table 10. 2022 Metal Exceedances						
Stream	Location	30-Day Start date	Parameter	Result (ug/l)	Criterion (ug/l)	Type of exceedance
Dugway Brook	RM 2.40	8/17/2022	Iron	5083.8	5000	Agriculture OMZA

Dissolved oxygen also exceeded the minimum required Aquatic Life OMZM criterion at Shaw Brook RM 0.40 for the August 2nd and November 3rd sampling events (2.67 mg/L and 2.4

mg/L, respectively). The minimum required criterion is 4 mg/L for the protection of aquatic life. Low dissolved oxygen can be due to low flow, higher water temperatures, and pollution or organic enrichment. Under normal flow conditions there is minimal flow in Shaw Brook north of Interstate 90. These flow regime modifications have likely significantly impacted dissolved oxygen levels and ecological function of the stream.

Nutrient Assessment Data

In 2015, the Ohio EPA Nutrients Technical Advisory Group released a proposed Stream Nutrient Assessment Procedure (SNAP) designed to determine the degree of impairment in a stream due to nutrient enrichment. SNAP assigns designations for quality of surface waters based on factors including dissolved oxygen (DO) swings, benthic chlorophyll α , total phosphorous, and dissolved inorganic nitrogen (Ohio EPA, 2015).


Maintenance of low levels of nutrients such as nitrogen and phosphorus in Euclid Creek, Dugway Brook, Nine-Mile Creek, Shaw Brook, and Green Creek will help limit loading to Lake Erie. An excess of nitrogen and phosphorus can lead to nutrient enrichment in the lake, fueling harmful algal blooms (HABs), which can contribute to hypoxic or anoxic (low or oxygen depleted) zones. Hypoxia degrades water quality, impacting biogeochemical cycling and can be fatal to aquatic life.

Some species of cyanobacteria responsible for HABs can produce toxins like microcystins. Microcystins are potent toxins that are harmful to human and animal health. Exposure can occur through ingestion, inhalation, or dermal contact. Acute effects include vomiting, headache, rashes, fever, diarrhea, and abdominal pain. Additional research is needed to determine long-term health effects and the fate of microcystins in the environment, but the toxin has high potential as a carcinogen.

Table 11 shows the 2022 nutrient concentrations for all sampling sites. The results of dissolved inorganic nitrogen (DIN) and total phosphorous (TP) were compared to Table 2 listed in the SNAP document (Figure 3; Ohio EPA, 2015). According to this section of SNAP, Green Creek, and Nine-Mile Creek Site 10 received an ecological risk narrative described as “levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges”. Sites on Dugway Brook West Branch (Dupont Ave Culvert and RM 2.40), Shaw Brook RM 0.40, and Nine-Mile Creek RM 0.40 received an ecological risk narrative described as “levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges”. Sites on Dugway Brook Main and East Branch (RM 0.37; Forest Hills and East 110th Street Culvert) received an ecological risk narrative described as “levels of typical enriched condition; low risk to beneficial use if allied responses are within normal ranges; increased risk with poor habitat”.

Table 11. 2022 Nutrient Analysis (Geometric Mean) for All Samples

Stream	Location	DIN (mg/L)	NO ₃ -NO ₂ (mg/L)	DRP (mg/L)	TP (mg/L)
Dugway Brook	RM 2.40	0.74*	0.63	0.21	0.27
	Forest Hills	1.14	1.09	0.15	0.16
	East 110 th	1.22	1.13	0.15	0.19
	Dupont Ave	0.97	0.85	0.10	0.21
	RM 0.37	1.31	1.06	0.09	0.17
Euclid Creek	RM 2.70	0.32	0.27	0.06*	0.09**
	RM 1.65	0.37	0.31	0.06	0.08
	RM 0.55	0.21*	0.13*	0.05	0.08**
Green Creek	Humphry Park Culvert	2.09	2.03	0.07	0.10
Nine-Mile Creek	Site 10	0.75	0.69	0.07	0.09
	RM 0.40	0.95	0.84	0.11	0.17
Shaw Brook	RM 0.40	0.65	0.47	0.09	0.15

 Data used in Table 2 of SNAP (Ohio EPA, 2015b)

Geometric means for DIN, NO₃-NO₂, and DRP (n=5, unless otherwise noted)

Geometric means for TP (n=10, unless otherwise noted)

* n=4 due to rejected data based on RPD being greater than acceptable or analysis not conducted for parameter

**n=9 due to rejected data based on RPD being greater than acceptable or analysis not conducted for parameter

Bold: Exceeds provisional WQTC.

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

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

Figure 3. Table two of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015b)

All Euclid Creek sites (RM 2.70, 1.65, and 0.55) received an ecological risk narrative “levels of modestly enriched condition in nitrogen limited systems; low risk to beneficial use if allied responses are within normal ranges”. This indicates that neither phosphorus nor nitrogen are a primary source of impairment, and no TP or DIN concentrations exceeded the provisional water quality target concentration levels (WQTC). However, the risk level is moderate based on the provisional WQTC and narrative ecological risk levels and has the potential increase with poor habitat.

The allied response indicator data for 24-hour DO swing was only measured at Euclid Creek RM 0.55. A YSI EXO 2 sonde installed and maintained by NEORS D near USGS gage #04208700 in Euclid, Ohio (RM 0.55) measured instantaneous DO measurements every 15 minutes. The 24-hour DO swings were determined by calculating the difference between the maximum and minimum daily concentrations of DO and compared to the threshold value established in the SNAP recommendation guidance (OEPA, 2015). A low to normal DO swing value is ≤ 6.5 mg/L and a wide DO swing is > 6.5 mg/L. In 2022, 24.8% of the 24-hour DO swings measured at Euclid Creek RM 0.55 exceeded 6.5 mg/L, indicating that the site is impaired, and that nutrient enrichment may be a material cause when also considering non-attainment of the biological criteria to be discussed later in the report (Figure 4).

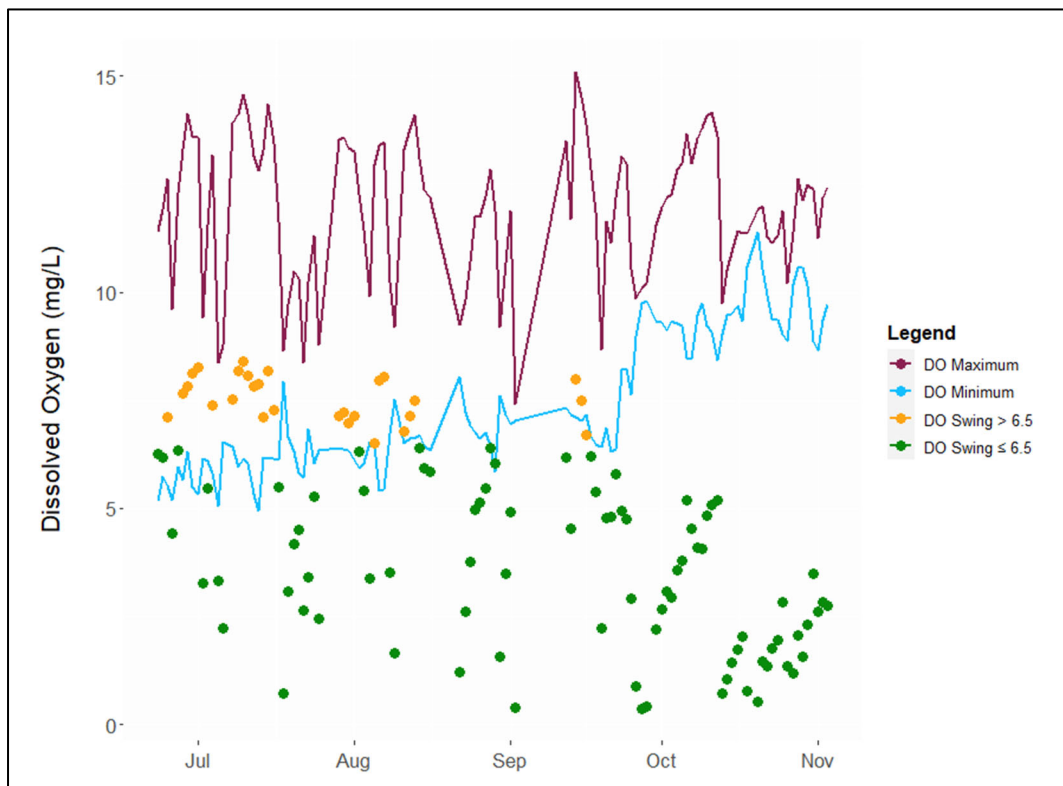


Figure 4. Daily Dissolved Oxygen Maximum and Minimum Concentrations for Euclid Creek RM 0.55 measured by an EXO 2 sonde plotted with 24-hour DO swing (difference between maximum and minimum daily concentration).

Benthic chlorophyll *a* was not assessed by NEORS in 2022, creating a potential limitation to the interpretation of risk presented using the provisional method.

Habitat Assessment

Methods

Instream habitat assessments were conducted at all in-stream sites using the Qualitative Habitat Evaluation Index (QHEI). The QHEI was developed by the Ohio EPA to assess aquatic habitat conditions that may influence the presence or absence of fish species by evaluating the physical attributes of a stream. The index is based on six metrics: stream substrate, instream cover, channel morphology, riparian zone and bank condition, pool and riffle quality, and stream gradient. The QHEI has a maximum score of 100, with slightly different narrative ranges for streams based on total drainage area (Table 12). For headwater streams, a score greater than 55 (and for larger streams a score greater than 60) suggests that sufficient habitat exists to support a fish community that attains the warmwater habitat criterion (Ohio EPA, 2006). Scores greater than 70 for headwaters (and 75 for larger streams) frequently demonstrate habitat conditions that can support exceptional warmwater fauna. 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 NEORS WQIS Division.

Table 12. Narrative Ranges Assigned to QHEI Scores		
Narrative Rating	QHEI Range	
	Headwaters (drainage ≤ 20 sq miles)	Larger Streams (drainage > 20 sq miles)
<i>Excellent</i>	≥70	≥75
<i>Good</i>	55-69	60-74
<i>Fair</i>	43-54	45-59
<i>Poor</i>	30-42	30-44
<i>Very Poor</i>	<30	<30

Results and Discussion

Of the sites assessed in 2022, Nine-Mile Creek RM 0.40, Dugway Brook RM 0.37, and Euclid Creek RMs 1.65 and 2.70 met the QHEI targets for their respective stream sizes and should be of high enough quality to support fish assemblages. (Figure 5).

Both sites on Dugway Brook received a narrative rating of *Fair*, while Shaw Brook, which is heavily urbanized and culverted throughout most of its length, resulted in a narrative rating of *Very Poor*. Euclid Creek RM 0.55 received a narrative rating of *Fair*. However, this site is highly dynamic and influence from Lake Erie regularly modifies the habitat. At the time of the habitat evaluation,

the riffle was not present, although a riffle intermittently forms at the site depending on Lake Erie water levels and stream flow.

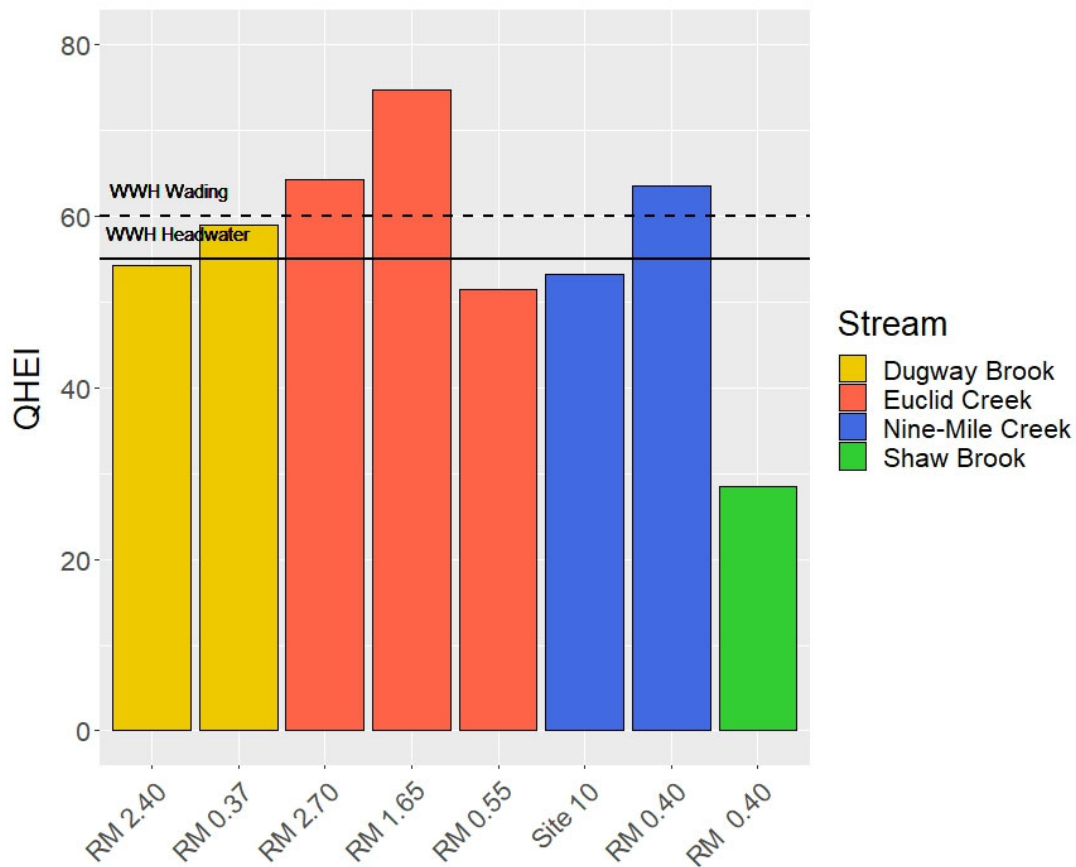


Figure 5. QHEI Scores for each site monitored in 2022.

Individual components of the QHEI can also be used to evaluate whether a site can meet its WWH designated use (Table 13). 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, 2006). All sites in 2022 had one or more high influence characteristics, and almost all had four or more moderate influence characteristics indicating that there was a greater prevalence of characteristics that have the potential to prevent a site from meeting WWH attainment.

Table 13. QHEI Scores and Physical Attributes

			MWH Attributes																																
			WWH Attributes											High Influence						Moderate Influence															
Sampling Location	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	(MWH H.I.+1) / (WWH+1) Ratio	(MWH M.I.+1) / (WWH+1) Ratio	
Dugway Brook RM 2.40	54.25	Fair	X	X		X		X	X				5			X	X	X	3		X			X					X	X		4	0.8	0.8	
Dugway Brook RM 0.37	52.50	Fair	X					X		X	X		5		X				1		X			X	X			X	X	X		6	0.3	1.4	
Euclid Creek RM 2.70	64.25	Good	X	X		X	X		X		X		6				X		1					X	X				X	X		4	0.3	0.7	
Euclid Creek RM 1.65	74.75	Good	X	X		X	X		X	X	X	X	8				X		1		X								X	X		3	0.2	0.4	
Euclid Creek RM 0.55	51.50	Fair	X	X							X		3				X		1		X			X	X		X	X		X		6	0.5	1.8	
Nine-Mile Creek Site 10	53.25	Fair	X	X		X			X				4				X	X	2					X	X	X			X	X		5	0.6	1.2	
Nine-Mile Creek RM 0.40	63.50	Good	X	X		X		X			X		5				X		1		X			X	X		X	X	X		6	0.3	1.2		
Shaw Brook RM 0.40	28.50	Very Poor	X	X			X				X		4		X		X		2		X			X		X		X	X		X		6	0.6	1.4

Fish Community Biology Assessment

Methods

Two to three quantitative electrofishing passes were conducted at each stream site in 2022. A list of the dates when the surveys were completed are shown in Table 14. Sampling was conducted using longline electrofishing techniques and consisted of shocking all habitat types within a sampling zone while slowly and steadily wading from upstream to downstream, and occasionally moving more swiftly. The sampling zone was 0.15 kilometers for the headwater sites and 0.20 kilometers for the wading sites and followed the Ohio EPA methods as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Fish collected during the surveys were identified and examined for the presence of anomalies, including DELTs (deformities, eroded fins, lesions, and tumors). Fish collected at streams with a drainage area greater than twenty square miles were weighed and counted, while sites with a drainage area less than twenty square miles were counted only. 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 14. Electrofishing Dates	
Date	Sites sampled
6/15/2022	Dugway Brook RM 2.40; Nine-Mile Creek Site 10
6/16/2022	Euclid Creek RMs 0.55, 1.65
6/29/2022	Euclid Creek RM 2.70
6/30/2022	Shaw Brook RM 0.40
7/11/2022	Nine-Mile Creek RM 0.40; Dugway Brook RM 0.37
8/10/2022	Euclid Creek RM 0.55
8/12/2022	Euclid Creek RMs 1.65, 2.70
9/14/2022	Dugway Brook RM 2.40; Shaw Brook RM 0.40
10/3/2022	Dugway Brook RM 0.37; Nine-Mile Creek Site 10, RM 0.40
10/12/2022	Euclid Creek RM 0.55

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 15). 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 15. IBI Metrics	
Wading sites	Headwater sites (<20 sq. miles)
Number of indigenous fish species	Number of indigenous fish species
Number of darter species	Number of darter species
Number of sunfish species	Number of headwater species
Number of sucker species	Number of minnow species
Number of intolerant species	Number of sensitive species
Percent tolerant species	Percent tolerant species
Percent omnivore species	Percent omnivore species
Percent insectivore species	Percent insectivore species
Percent of top carnivore species	Percent pioneering species
Number of individuals (minus tolerants)	Number of individuals (minus tolerants)
Percent of simple lithophilic spawners	Number of simple lithophilic species
Percent DELT anomalies	Percent DELT anomalies

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 (\bar{H}) (Formula 2 below) based on sample numbers, and the Shannon Diversity Index (\bar{H}) based on sample weights.

Formula 1:
$$MIwb = 0.5 \ln N + 0.5 \ln B + \bar{H}(No.) + \bar{H}(Wt.)$$

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

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

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

Formula 2:
$$\bar{H} = - \sum \left[\left(\frac{n_i}{N} \right) \log_e \left(\frac{n_i}{N} \right) \right]$$

n_i = Relative numbers or weight of species

N = Total number or weight of the sample

The streams evaluated are located completely within the Erie-Ontario Lake Plains (EOLP) ecoregion and follow the EOLP IBI metric scoring. The WWH IBI scoring criterion in the EOLP ecoregion is 40 for headwater sites and 38 for wading sites. A site is within nonsignificant departure if the score falls within 4 IBI units or 0.5 MIwb units of the criterion (Table 16). 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 NEORSW WQIS Division.

Table 16. Fish Community Biology Scores in the EOLP Ecoregion							
Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
Wading							
IBI Score	12-17	18-27	28-33	34-37	38-45	46-49	50-60
MIwb Score	0-4.4	4.5-5.8	5.9-7.3	7.4-7.8	7.9-8.8	8.9-9.3	≥9.4
Headwaters							
IBI Score	12-17	18-27	28-35	36-39	40-45	46-49	50-60
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Results and Discussion

The 2022 IBI and MIwb scores from each assessment location are listed below in Table 17. For both indices, no sites were found to be in attainment of the warmwater habitat criteria.

Euclid Creek

The two passes at Euclid Creek RM 2.70 resulted in an average score of 29 (*Fair*), indicating the site was not in attainment of the WWH criterion for the fish community. The second pass resulted in a greater number of total fish collected, as well as the notable presence of a single rainbow trout (*Oncorhynchus mykiss*). The presence of the bluegill sunfish (*Lepomis macrochirus*) collected during the second pass positively impacted the score. The lack of darter species, the low diversity of sucker species, and the high percentage of tolerant species, particularly the blacknose dace (*Rhinichthys atratulus*), lowered the score on both passes. The average MIwb score was 6.0 (*Fair*) with the primary difference between each pass being the greater number of native fish collected on the second pass. The site’s QHEI score indicated that the overall habitat met the WWH target with a score of 64.25 (*Good*), suggesting that the habitat was not limiting to the establishment of a healthy fish community. Water chemistry results indicated that the stream did have exceedances for *E. coli* during wet-weather events, indicating that there may still be urban runoff and illicit discharges impacting water quality upstream. Because this section of the stream is immediately downstream from a relatively urban area, there exists potential from the anthropogenic activity to affect fish populations. Additionally, the Euclid Creek spillway downstream of this site may be acting as a migration barrier, preventing upstream fish passage.

Table 17. 2022 Stream IBI and MIwb Results

Location	IBI (Narrative)				MIwb (Narrative)			
	1 st Pass	2 nd Pass	3 rd Pass	Average	1 st Pass	2 nd Pass	3 rd Pass	Average
Dugway Brook RM 2.40	16 (Very Poor)	16 (Very Poor)		16 (Very Poor)				
Dugway Brook RM 0.37	26 (Poor)	26 (Poor)		26 (Poor)				
Euclid Creek RM 2.70	26 (Poor)	32 (Fair)		29 (Fair)	5.7 (Poor)	6.2 (Fair)		6.0 (Fair)
Euclid Creek RM 1.65	24 (Very Poor)	26 (Poor)		25 (Poor)	3.2 (Very Poor)	5.7 (Poor)		4.5 (Poor)
Euclid Creek RM 0.55	30 (Fair)	30 (Fair)	20 (Poor)	27 (Poor)	5.7 (Poor)	6.8 (Fair)	4.2 (Very Poor)	5.6 (Poor)
Nine-Mile Creek Site 10	12 (Very Poor)	20 (Poor)		16 (Very Poor)				
Nine-Mile Creek RM 0.40	20 (Poor)	24 (Poor)		22 (Poor)				
Shaw Brook RM 0.40	12 (Very Poor)	12 (Very Poor)		12 (Very Poor)				
WWH criterion: Wading = IBI ≥38; MIwb ≥7.9 Headwaters = IBI >40								

Euclid Creek RM 1.65 received an IBI score of 24 on the first pass and 26 on the second pass, an average of 25 (*Poor*), which is not in attainment of the fish community WWH criterion. Limiting the site's IBI scores were a high percentage of tolerant species, the low diversity of sucker species on the first pass and absence of sucker species on the second, and the lack of darter and sunfish species. The absence of DELTs positively impacted the score on both passes. The MIwb score for the first pass was 3.2 (*Very Poor*), while the second pass was 5.7 (*Poor*). Approximately three times the number of fish were collected on the second pass, with significantly more central stoneroller minnows (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), and blacknose dace collected. This reduces the effect of the number of tolerant species collected, which would account for the difference in scores. Past monitoring of RM 1.65 indicates that this year's assessment, although not in attainment of WWH criterion, is consistent with *Poor* ratings of 23 and 24 in 2019 and 2020, respectively (Figure 6). Like RM 2.70, the QHEI score met the WWH target, with the site scoring 78.75, narratively *Good*, indicating habitat was not a limiting factor to the score. This portion of Euclid Creek runs through a heavily urbanized area and had dry-weather

exceedances of *E. coli*, indicating there may be illicit discharges to the stream impacting its water quality. This site is also upstream of the Euclid Creek spillway, which could be negatively impacting the fish community.

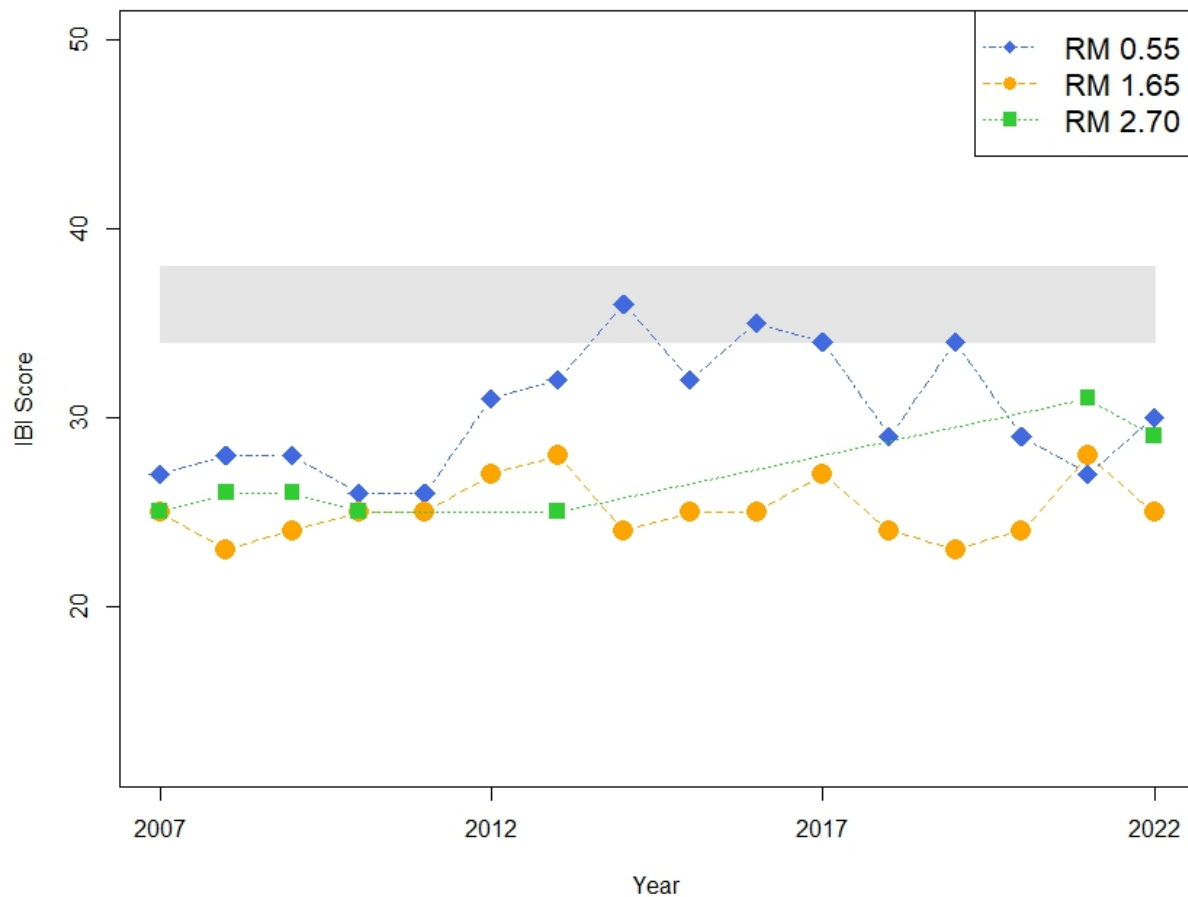


Figure 6. Historic IBI Scores for Euclid Creek Wading Sites. Gray box represents range of WWH attainment and NSD from wading criterion.

The three fishing passes at Euclid Creek RM 0.55 scored an average of 27 (*Poor*) and were not in attainment of WWH criterion. The average MIwb score was 5.6 (*Poor*) which is also not in attainment of the WWH criterion (Figure 7). The first pass had significantly fewer species but a higher percentage of insectivore species and greater number of sunfish species. Despite the higher fish species diversity found on the second pass, the overall number of fish collected was low, resulting in greater negative impacts to the score from the lower percentage of insectivore species (18.8%) and the absence of the green sunfish (*Lepomis cyanellus*). The presence of two sucker species, the central quillback carpsucker (*Carpionodes Cyprinus*) and the common white sucker (*Catostomus commersonii*), on the second pass positively impacted the score. Notably, the intolerant mimic shiner (*Notropis volucellus*) and the moderately intolerant smallmouth bass (*Micropterus dolomieu*) and northern logperch darter (*Percina caprodes*) were collected in the second pass. The third pass resulted in the highest total number of fish collected; however, species diversity was low, and the percentage of tolerant species was high (70.3%), which negatively

impacted the score. Seasonality of fish species assemblages and sample timing may have also impacted the score of the third pass. Similar results were observed in the MIwb scores, with the first pass having fewer total fish and lower species diversity resulting in a score of 5.7 (*Poor*). The second pass benefited from an increase in the number and weight of collected fish and resulted in a score of 6.8 (*Fair*), and the third pass was negatively impacted by the higher percentage of tolerant species excluded from the relative number and weight of fish calculated. This site is near the beginning of the lacustuary section of Euclid Creek, and frequently experiences influence from Lake Erie. During the habitat assessment period, there was no riffle present, and the flow of the stream was relatively slow as it approached the Lake, which can negatively impact the stream's ability to host a successful fish community. This changing physical state of the site may account for variations in score from year to year, and even annually based on seasonality.

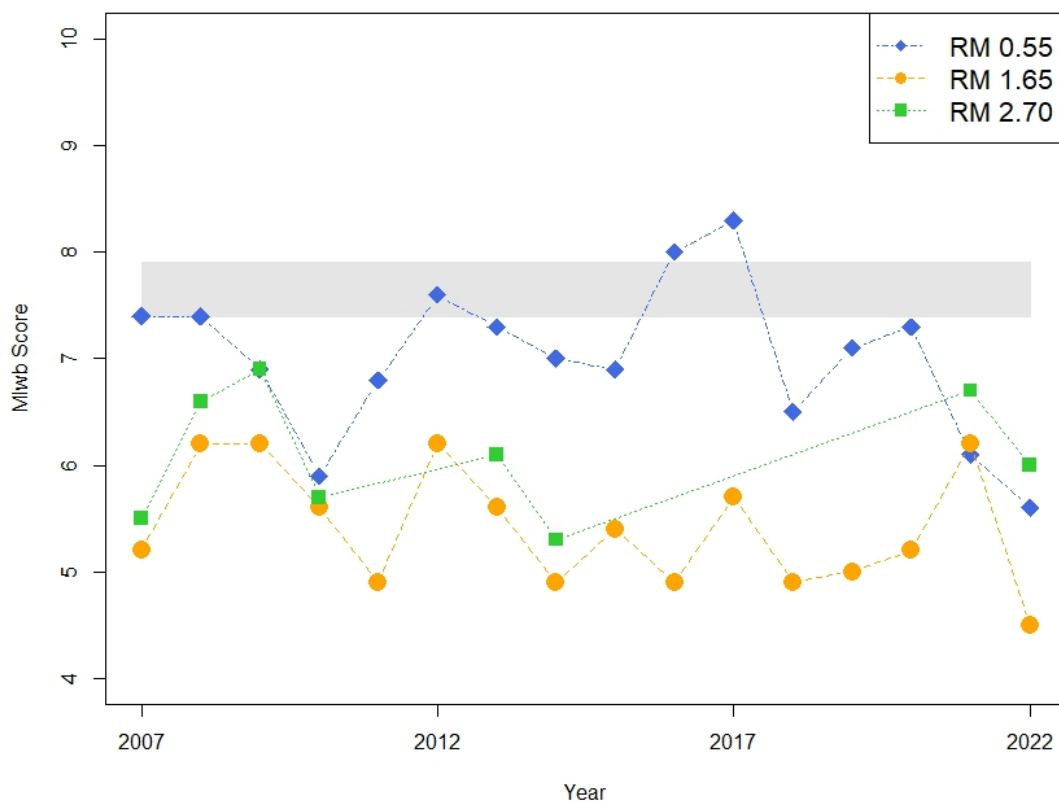


Figure 7. Historic MIwb Scores for Euclid Creek Wading Sites. Gray box represents range of WWH attainment and NSD from the wading criterion.

Dugway Brook

An IBI score of 16 was calculated at river mile 2.40, which resulted in a narrative rating of *Very Poor*. In both passes, only one species was collected, the northern fathead minnow (*Pimephales promelas*). This reach is relatively shallow and open, leaving no habitat for deeper

water species or species that require instream cover. Additionally, it is likely that the overall location of the reach negatively impacted the fish score by limiting recruitment of species. This stretch of Dugway Brook is a short open stretch downstream of the Lakeview Cemetery Dam and upstream of a culverted stretch of the stream. Thus, it faces fish migration barriers from both upstream and downstream. The QHEI score of 54.25 (*Fair*) also indicates that habitat conditions may be influencing the absence of fish species. This score was comparable to what has been calculated in past surveys (Figure 8).

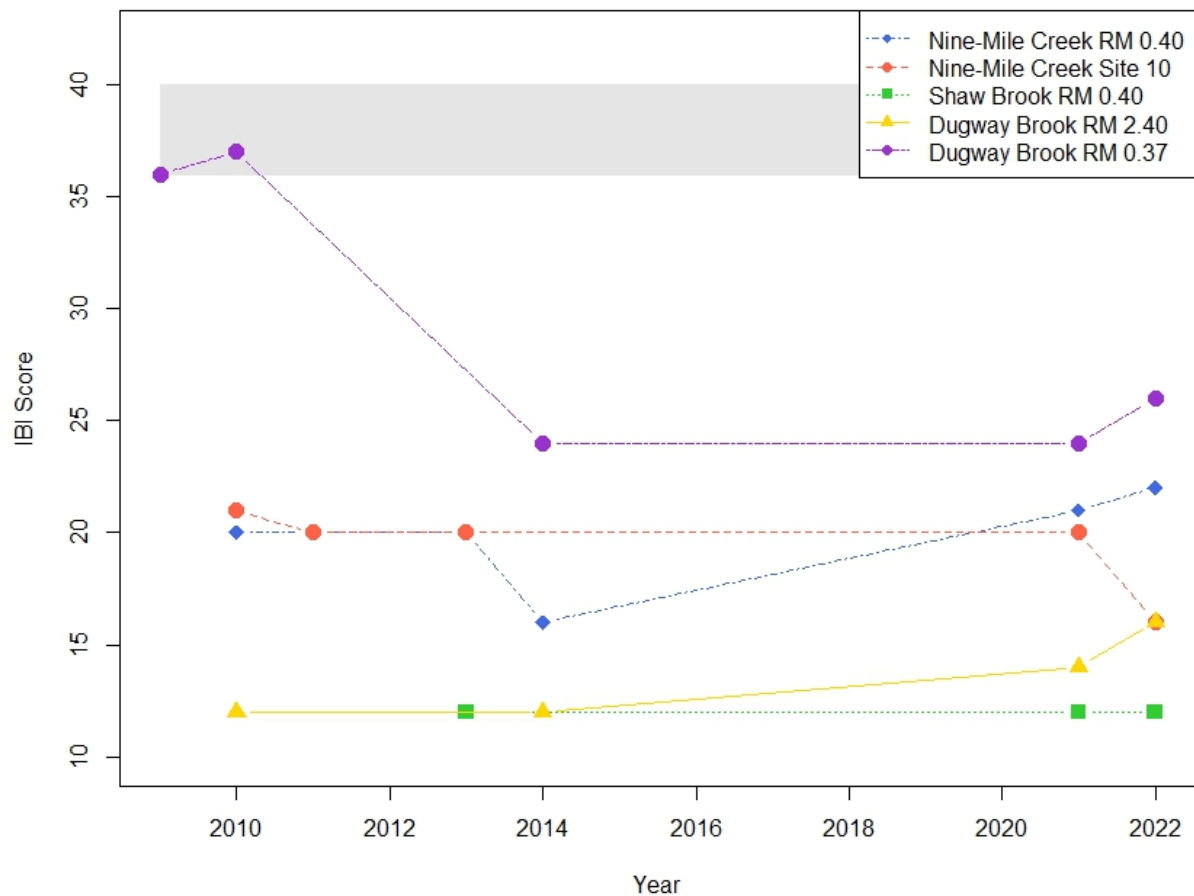


Figure 8. Historic IBI Scores of Headwater Sites sampled in 2022. Gray box represents range of WWH attainment and NSD from the (≤ 4 IBI units) wading criterion.

For both passes, the IBI score at RM 0.37 was calculated at 26 (*Poor*) and was not in attainment of the WWH criterion. There was one moderately intolerant species collected during the first assessment, the sand shiner (*Notropis stramineus*). The lower percentage of insectivores and higher percent pioneering species negatively impacted the score during the second survey. The presence of three additional minnow species; common emerald shiner (*Notropis atherinoides*), striped shiner (*Notropis chrysocephalus*), and spotfin shiner (*Cyprinella spiloptera*), balanced the differences between individual metric scores on the second survey. However, the low number of total fish collected during both surveys significantly impacted the IBI scores.

This reach is a relatively slow-moving section of Dugway Brook that is immediately downstream of a culverted section and a floatable control structure. These conditions lead to the deposition of silt and accumulation of muck along the reach. Due to the limited instream habitat conditions, including lack of riffle habitat and poor substrate quality, it is unlikely that the site can support a robust fish community. There were no darter or headwater species found with either pass, which negatively impacted the IBI score.

Nine-Mile Creek

There were two electrofishing sampling events conducted in 2022 at Nine-Mile Creek Site 10. The averaged IBI score was calculated at 16, which resulted in a narrative rating of *Very Poor*, which is not in attainment with the WWH designated use. The only fish species collected during both sampling events was the pollution-tolerant creek chub totaling 12 individuals during the first pass and 244 individuals during the second pass, respectively. For both sampling events, the lack of species diversity including the absence of key taxa such as darters and headwater species, no sensitive species, and no insectivorous species present negatively impacted the IBI score. No omnivorous species or DELTS were observed in either sample population which positively contributed to the IBI score.

The habitat assessment of Nine-Mile Creek Site 10 indicated that the stream reach would be suitable to support a quality fish community. Site 10 showed a decrease in the average IBI score compared to assessments that were completed in 2013 and 2021 (Figure 7). Site 10 is located between two culverted sections of Nine-Mile Creek, which are creating significant barriers to the migration of fish to the reach. Fish that can migrate to the area may find minimal refugia and conditions inhabitable to larger species during low flow or for smaller species, a lack of habitat cover from predation. Anthropogenic sources of pollution, the high percentage of impervious surface contributing to stormwater runoff, and CSO discharges may still be affecting the fish population negatively at Site 10 as well. While the Dugway Storage Tunnel and East 140th Relief and Consolidation Sewer projects have resulted in the reduction of bacteria and sediment loads and may decrease the number of water quality exceedances at Site 10, the large proportion of culverted sections along the entire stretch of Nine-Mile Creek will continue to remain a significant barrier to fish community establishment.

There were two electrofishing sampling events conducted in 2022 at RM 0.40 on Nine-Mile Creek. The average IBI score was calculated at 22, resulting in a narrative rating of *Poor*, which is not in attainment of the WWH designated use. The first electrofishing pass resulted in an IBI score of 20 and a narrative rating of *Poor* (Figure 8). Multiple factors contributed to low scores in several metrics, including the absence of key taxa such as darters and headwater species, no sensitive species, a high number of generalist omnivores, and no insectivorous species. Three species of fish were collected, totaling 108 individuals, and included creek chubs and white suckers, which are pollution tolerant, and yellow perch (*Perca flavescens*), which have an intermediate pollution tolerance. A lower proportion of pioneering taxa (27.8%) and no DELTS being observed in the sample population positively contributed to the IBI score.

The second electrofishing pass resulted in an IBI score of 24 and a narrative rating *Poor*. Taxa diversity increased and included the presence of six additional minnow species, a key taxa indicator. A total of eleven species of fish totaling 244 individuals were collected during this assessment. However, the number of fish collected were dominated primarily by pollution-tolerant species, including the white sucker and the creek chub. The invasive round goby (*Neogobius melanostomus*) was also present in the second pass, potentially competing with native fish for resources and negatively altering fish community composition. The presence of the pollution-sensitive sand shiner as well as the number of minnow species positively contributed to the IBI score.

Although the instream habitat assessment at RM 0.40 indicates that the stream reach is suitable to support a quality fish community, the current fish community falls short of supporting it. RM 0.40 has showed a slight improvement in the average IBI scores since 2014 (Figure 7). However, anthropogenic sources of pollution, the high percentage of impervious surface contributing to stormwater runoff, and CSO discharges may still be affecting the fish population negatively.

CSO-211 (East of Coit Rd.) is located approximately half a mile upstream of RM 0.40. The Dugway Storage Tunnel and East 140th Relief and Consolidation Sewer, which were completed in late 2020, have reduced the number of CSO discharges and annual discharge volume from this outfall. In 2014 through 2019, CSO-211 averaged 47 overflows per year with an average total volume of 71.5 million gallons per year. In 2021, the number of discharges was reduced to 15 (67.7% reduction) and the total volume was reduced to 6.1 million gallons (91.5% reduction). While CSO volumes have been greatly reduced, *E. coli* densities remained elevated at this site. This indicates that additional anthropogenic pollution sources including, but not limited to, local sanitary and storm sewer inflow and infiltration, remaining CSO discharges, and urban runoff, may still be contributing to impairment of the fish community at this site.

Shaw Brook

Two passes were conducted on Shaw Brook at RM 0.40. Each assessment resulted in zero fish collected in 2022, which defaults to a score of 12 with a narrative rating of *Very Poor* (Figure 8). Having no riffle and low flow, the instream habitat resulted in a score of 28.5 with a narrative rating of *Very Poor*, thus this site is unable to support any fish assemblage. Additionally, there is a culverted control point upstream, which significantly reduces dry-weather flow to the site, as well as a culvert immediately downstream of the site impacting recruitment of fish to the location. Even with the reduction in CSO events upstream of the site, in its current state, it is unlikely to support a healthy fish community in the future without significant restoration efforts.

Macroinvertebrate Community Biology Assessment

Methods

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers and/or with a qualitative assessment of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), also referred to as EPT taxa, inhabiting available habitats at the time of HD retrieval. Sampling was conducted at all locations listed in Table 18. 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 NEORSD WQIS Division.

Table 18. HD Locations and Installation Dates		
Site	HD Installation Date(s)	Qualitative Sample Date
Dugway Brook RM 2.40	7/20/22* 8/10/22*	9/22/22
Dugway Brook RM 0.37	No HD**	8/18/22
Euclid Creek RM 2.70	6/23/22* 7/20/22	9/23/22
Euclid Creek RM 1.65	6/23/22	8/12/22
Euclid Creek RM 0.55	6/23/22	8/12/22
Shaw Brook RM 0.40	No HD**	8/24/22
Nine-Mile Creek Site 10	No HD**	8/18/22
Nine-Mile Creek RM 0.40	7/20/22	9/01/22
*HD was not retrieved.		
**HD was not installed due to unsuitable stream conditions.		

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 34 (Table 20) and a site is within non-significant departure if the score falls within 4 ICI units of the criterion.

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
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

Table 21 shows the results for locations successfully sampled with HDs in 2022 and those sites that had a qualitative sample only. For the 2022 sampling season, two sites, Euclid Creek RMs 1.65 and 2.70, were in attainment of the WWH criterion. Nine-Mile Creek RM 0.40 was in non-significant departure of the WWH criterion. Temporal data displayed in Table 22 shows the historical scores for Euclid Creek monitoring locations. Figure 9 shows the historic ICI scores for Euclid Creek.

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Table 21. 2022 Macroinvertebrate Results							
Stream RM	Density Qt. (ft ²)/Ql.	Ql./ Total Taxa	Ql. EPT/ sensitive Taxa	Qt. % Tolerant/ Sensitive taxa	Predominant orgs. on natural substrates	ICI	Narrative Evaluation
Dugway Brook (19-131-000)							
2.40	---/L-M	27/---	4/1	---	Baetid mayflies, Simuliids	--	Fair
0.37	---/L-M	29/---	2/0	---	Turbellaria, chironomids	--	Poor
Euclid Creek (19-041-000)							
2.70	260/L-M	27/47	10/10	4.22/18.59	Baetid mayflies, Philopotamids, Hydropsychids	46	Very Good
1.65	288/L-M	31/45	10/9	9.46/14.88	Baetid mayflies, Hydropsychids, Turbellaria	40	Good
0.55	992/L	20/33	3/2	29.72/0.75	Chironomids, Turbellaria	22	Fair
Nine-Mile Creek (19-040-000)							
Site 10	---/L-M	23/---	5/4	---	Baetid mayflies, Philopotamids, Amphipods	--	Moderately Good
0.40	354/L-M	23/34	5/2	23.4/0.45	Baetid mayflies, Simuliids, Amphipods	32	Marginally Good
Shaw Brook (19-044-000)							
0.40	---/L	17/---	0/0	---	Turbellaria, Chironomids	--	Very Poor
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 <i>Moderately Intolerant</i> , no <i>Intolerant</i> taxa were collected.							

Table 22. 2007– 2022 Euclid Creek ICI Scores			
Year	RM 2.70	RM 1.65	RM 0.55
2007	36	26	22
2008	28	26	12
2009	36	38	24
2010	42	42	18
2011	---	36	24
2012	---	36	24
2013	42	Fair	34
2014	36	30	34
2015	---	36	18
2016	---	38	16
2017	---	40	16
2018	---	38	Fair
2019	---	46	18
2020	---	32	Low Fair
2021	42	44	22
2022	46	40	22
Bold indicates attainment of WWH biocriterion			
<i>Italics indicates non-significant departure of WWH biocriterion</i>			
HD not collected; qualitative assessment used to assign narrative rating			

Euclid Creek

Benthic macroinvertebrate sampling was conducted on Euclid Creek at RM 0.55 in 2022. The ICI score was calculated at 22 with a narrative rating of *Fair*, which is not in attainment of the WWH criterion. Several metrics negatively impacted this score. Primarily, there were only two mayfly species that colonized on the HD (*Baetis flavistriga* and *Baetis intercalaris*). These mayfly species made up a significantly low overall percentage (0.04%) of the community composition of organisms collected at the site (Figure 10). Additionally, caddisfly species were only present as a small percentage of the HD sample (0.10%), and none were collected in the qualitative assessment. Finally, a high number of dipteran and other taxa relative to EPT taxa also lowered the score. The lack of a riffle, as well as a slower current and higher embeddedness at this site, severely impacts the ability for EPT taxa to successfully colonize this reach. As previously discussed, with the site being near the lacustrine zone of Euclid Creek, it frequently experiences influence from Lake Erie, which further exacerbates the challenges with successful EPT colonization annually.

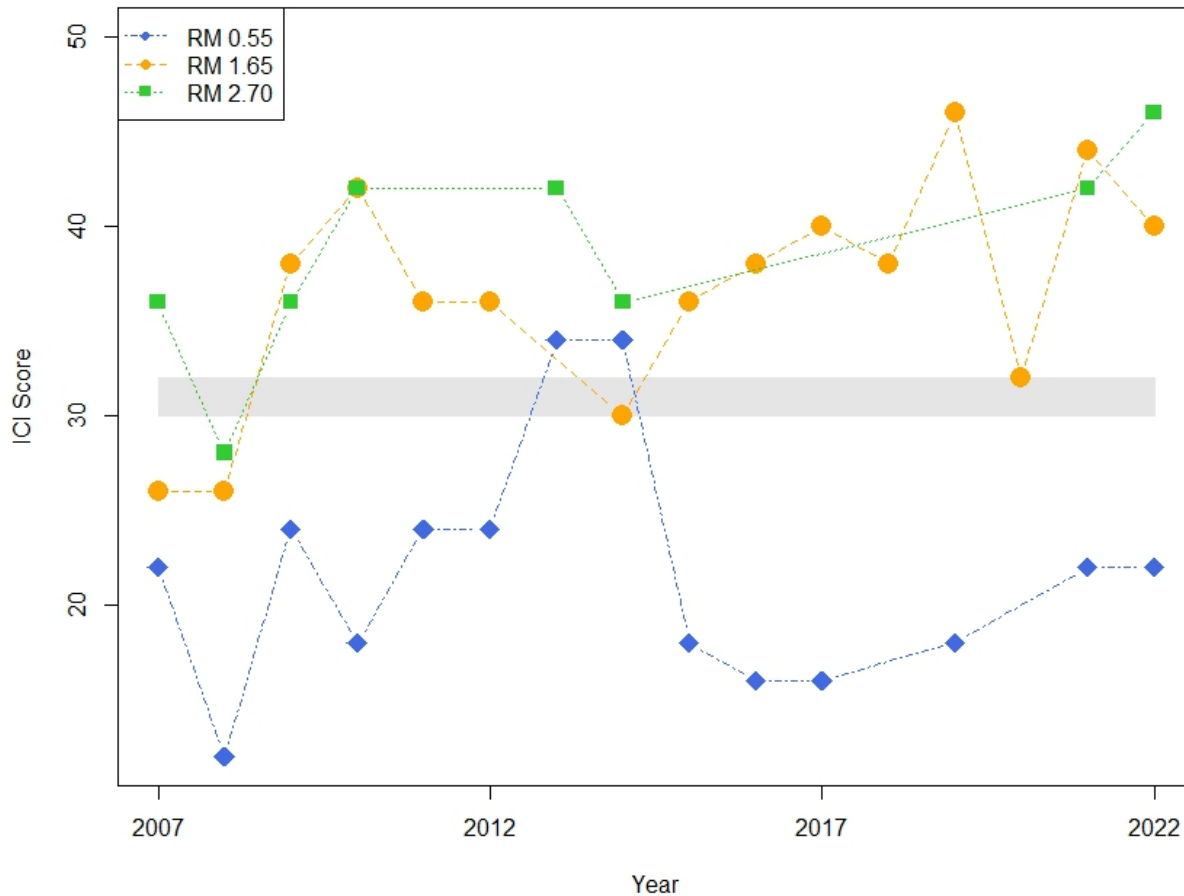


Figure 9. Historic ICI Scores for Euclid Creek. Gray box represents range of WWH attainment and NSD from the criterion.

The ICI score at RM 1.65 was calculated at 40 with a narrative rating of *Good*, which is in attainment of the WWH criterion. Although the same two species of mayfly colonized on the HD (*Baetis flavistriga* and *Baetis intercalaris*) as RM 0.55, they comprised a larger proportion of the collected organisms overall. Secondly, the number (seven) and percentage of caddisfly taxa (28.58%) was much higher than RM 0.55, which contributed to a higher ICI score. Lastly, lower relative percentages of dipteran and non-insect taxa also contributed to the higher ICI score. Tribe Tanytarsini comprised only 14.19% of the total taxa, indicating that there is likely pollution stress impacting successful colonization (Figure 10). The fast current and non-embedded riffle provided the ideal habitat for EPT taxa, which allows the habitat to support a robust benthic macroinvertebrate community.

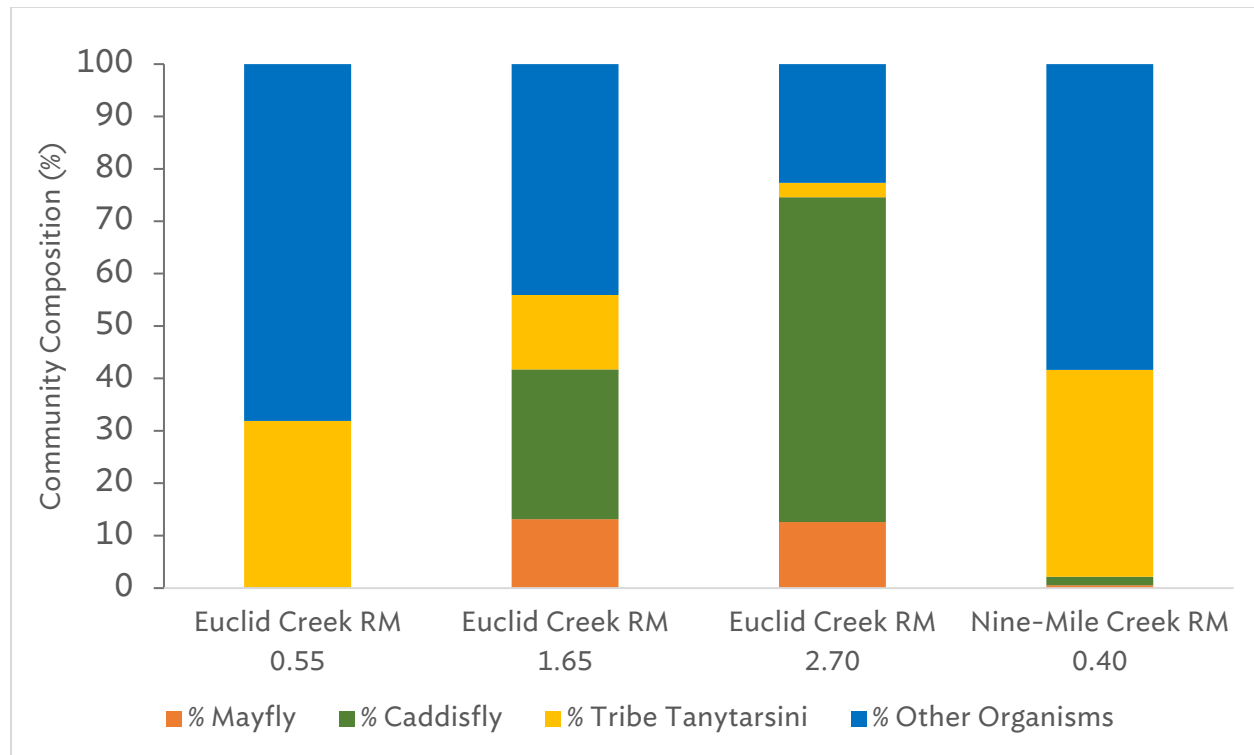


Figure 10. Macroinvertebrate Percent Community Composition.

The ICI score at RM 2.70 was calculated at 46 resulting in a narrative rating of *Very Good*, thus meeting attainment of the WWH. Like RM 1.65, a high number of caddisfly species (6) and a high percentage of caddisflies (61.98%) colonized on the HD contributed to the high score. Additionally, a low percentage of dipteran and non-insects (21.97%) as well as a low percentage of tolerant organisms (4.22%) contributed to the higher ICI score (Figure 9). Fast currents and low embeddedness at this reach provided ample good quality habitat for EPT species to colonize. Improvement in colonization of mayfly species and Tribe Tanytarsini midges would increase the score further.

Nine-Mile Creek

The ICI score at Nine-Mile Creek RM 0.40 was calculated at 32, resulting in a narrative rating of *Marginally Good*, which is in non-significant departure of the WWH criterion. The presence of one mayfly species (*Baetis flavistriga*) colonized on the HD which is indicated by the low overall percentage of mayflies (0.5%) collected at the site. Caddisfly diversity increased in 2022 (n=4) compared to only one caddisfly species collected the previous year; however, the percent caddisflies community composition (1.64%) was still low. The low percentage of these two EPT taxa metrics resulted in a relatively high percentage of other dipteran and non-insect taxa at the site (58.37%), further affecting the score. The relatively high percentage of Tribe Tanytarsini midges (39.48%), as well as a lower percentage of tolerant organisms (23.42%) contributed in a

positive manner to the ICI score. Although the instream habitat assessment resulted in a narrative rating of *Good*, the slow current and high embeddedness may be preventing these taxa in reaching their colonization potential. However, the ICI score improved significantly from the previous year of 24 to 32 in 2022. This increase in score may reflect improvements in water quality based on the reduction in number and volume of CSO overflows upstream of RM 0.40 with Project Clean Lake infrastructure investments.

Macroinvertebrate Narrative Rating Assignments

No HDs were installed at Nine-Mile Creek Site 10, Shaw Brook RM 0.40, and Dugway Brook RM 0.37 due to unsuitable stream conditions. The initial HD installed at Dugway Brook RM 2.40 was unable to be retrieved, and the second HD installed was buried. Therefore, narrative rating assessments were performed for these sites based on the results of the qualitative sample. The qualitative sample data was compared to expectations developed by NEORS in 2021 using threshold limit models. These models were developed using QDC Level 3 macroinvertebrate data provided by the Ohio EPA from the Erie Ontario Lake Plain ecoregion (EOLP) from the ten-year period between 2005 and 2014 (threshold limit model analysis available upon request). Table 23 provides the expectation threshold limits for qualitative total taxa, qualitative EPT taxa, and qualitative sensitive taxa metrics, grouped by drainage area category. Figures 11-13 provide distributions of these metrics grouped by ICI narrative rating category developed by NEORS in comparison with the expectation threshold limits provided in Table 24.

Table 23. NEORS Recommended Expectation Threshold Limits for Narrative Rating Assignments in the EOLP				
Drainage Category	Designation	Qualitative Total Taxa	Qualitative EPT Taxa	Qualitative Sensitive Taxa
Headwater (0-20 miles ²)	EWH	38	12	6
	WWH	27	7	2
	Fair	23	4	1
Wadable (20-200 miles ²)	EWH	51	18	12
	WWH	41	11	6
	Fair	33	8	2
Small River (200-1,000 miles ²)	EWH	44	16	10
	WWH	36	11	7
	Fair	29	9	5

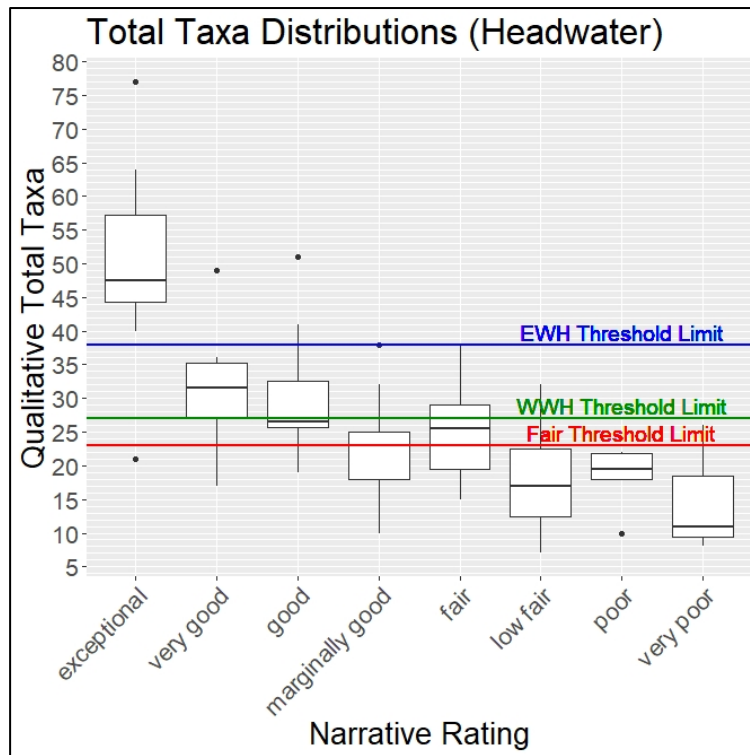


Figure 11. Distribution of the number of qualitative total taxa in EOLP headwater streams grouped by ICI score narrative rating category with expectation threshold limits.

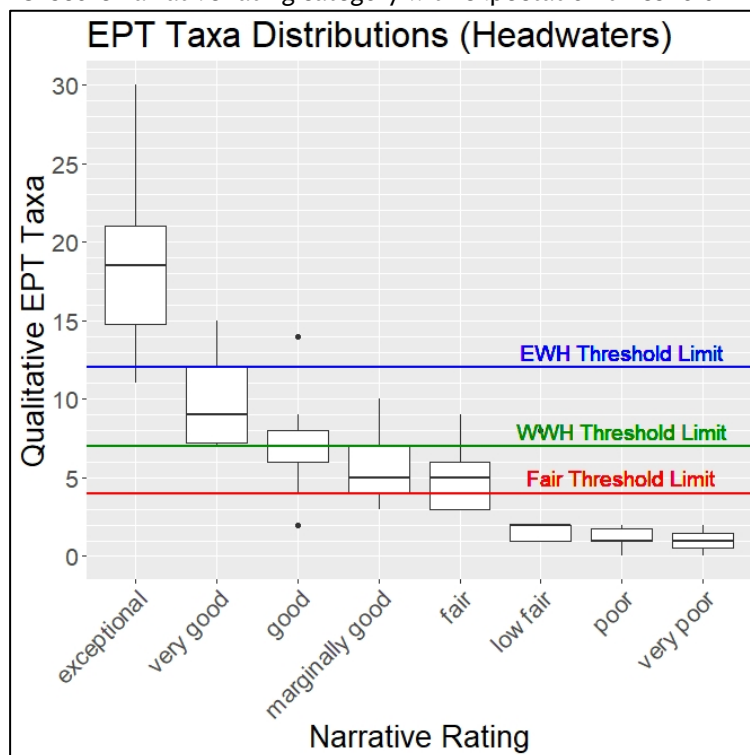


Figure 12. Distribution of the number of qualitative EPT taxa in EOLP headwater streams grouped by ICI score narrative rating category with expectation threshold limits.

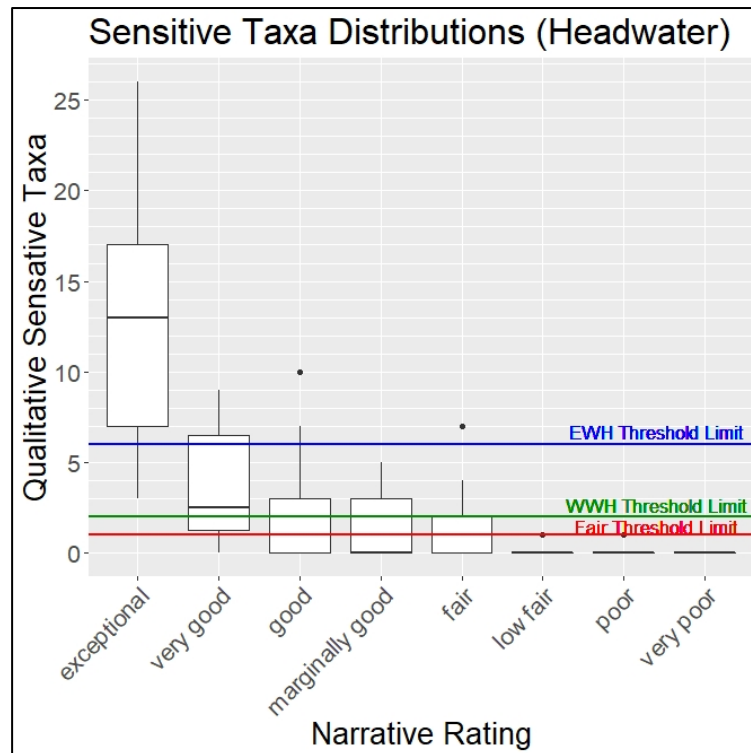


Figure 13. Distribution of the number of qualitative sensitive taxa in EOLP headwater streams grouped by ICI score narrative rating category with threshold limits.

Nine-Mile Creek Site 10 was assigned a narrative rating of *Moderately Good*. This site has a drainage area of only 0.7 square miles, placing it on the low end of the headwater drainage area category. A total of 23 taxa were collected in the qualitative sample meeting the *Fair* expectation for a headwater stream. Five EPT taxa were collected, which scores in between the WWH and *Fair* expectations for a headwater stream. The EPT taxa collected included one Baetidae mayfly, *Baetis flavistriga*, two Philopotamidae caddisflies, *Chimarra aterrima* and *Chimarra obscura*, one Polycentropodidae caddisfly, *Polycetropus sp.*, and one Hydropsychidae caddisfly, *Hydropsyche depravata group*. Four sensitive taxa were collected, which scores above the WWH habitat expectation. The site was assigned a field narrative rating of *Good* at the time of sample collection. Field observations indicated that the most predominant taxa were Baetidae. Nine-Mile Creek is also culverted and heavily urbanized throughout much of its reach. Taking into consideration the above listed data as well as the very low drainage area for this site, the site was assigned a narrative rating of *Moderately Good* in 2022.

Shaw Brook RM 0.40 was assigned a narrative rating of *Very Poor*. This site has a drainage area of 0.04 square miles, placing it on the low end of the headwater drainage area category. A total of 17 taxa were collected in the qualitative sample, which scores below the *Fair* expectation for a headwater stream. No EPT taxa were collected, which scores well below the *Fair* expectation. No sensitive taxa were collected, which also scores below the *Fair* expectation. Field observations indicated that the two most predominant groups were Turbellaria and Chironomidae. The site was assigned a field narrative rating of *Very Poor* at the time of sample collection. Taking into

consideration the above listed data and the culverted control point upstream which limits dry weather flow and significantly impacts water quality, the site was assigned a narrative rating of *Very Poor* in 2022.

Dugway Brook RM 2.40 was assigned a narrative rating of *Fair*. This site has a drainage area of 2.6 square miles and is classified as a headwater. A total of 27 taxa were collected meeting WWH expectations. Four EPT taxa were collected meeting *Fair* expectations. EPT taxa collected included *Baetis flavistriga*, *Chimarra obscura*, *Hydropsyche depravata group*, *Hydroptila sp.* One sensitive taxon was collected, meeting *Fair* expectations. The site was assigned a narrative rating of *Fair* during field sample collection. The most predominant groups sampled were Baetidae and Simuliidae. Considering the data, low drainage area, and large impoundment directly upstream, the site was assigned a narrative rating of *Fair* in 2022. One of potential causes for impairment at this sites is the large impoundment located just upstream.

Dugway Brook RM 0.37 was assigned a narrative rating of *Poor*. This site has a drainage area of 6.3 square miles, placing it in the headwater drainage area category. A total of 29 taxa were collected, which scores in between the *Fair* and WWH expectations. Two EPT taxa were collected, which scores below the *Fair* expectation. The EPT taxa collected included *Baetis flavistriga* and *Hydropsyche depravata group*. No sensitive taxa were collected at the site, which scores below the *Fair* expectation. Field observations indicated that the two most predominant groups were Turbellaria and Chironomidae. A large floatable control structure directly upstream of the site is also likely impacting flow and water quality at the site. The site was assigned a field narrative rating of *Poor* at the time of sample collection. Taking into consideration the above listed data, the site was assigned a narrative rating of *Poor* in 2022.

Conclusions

The results of NEORSD’s 2022 water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys indicate that despite Project Clean Lake infrastructure improvements, most of the direct tributaries to Lake Erie (Euclid Creek, Dugway Brook, Green Creek, Nine-Mile Creek, and Shaw Brook) are likely still impacted by a variety of anthropogenic driven habitat limitations and environmental stressors listed in Table 24.

Table 24. 2022 Survey Results								
RM	DA (mi ²)	Attainment Status	IBI Score	MIwb Score	ICI Score	QHEI Score	Cause(s)	Source(s)
Dugway Brook (WWH Existing)								
2.40 ^H	2.6	NON	<u>16*</u>	---	F	54.25	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development. Flow alterations.	Urbanization and urban runoff. Culverted stream reaches. Atmospheric deposition/urbanization.

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Table 24. 2022 Survey Results

RM	DA (mi ²)	Attainment Status	IBI Score	MIwb Score	ICI Score	QHEI Score	Cause(s)	Source(s)
0.37 ^H	6.3	NON	<u>26</u> *	---	<u>P</u>	59	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development. Flow alterations.	Urbanization and urban runoff. Culverted stream reaches. Atmospheric deposition/urbanization.
Euclid Creek (WWH Existing)								
2.70	21.9	PARTIAL	29*	6.0*	46	64.25	Sedimentation. Nutrient enrichment. Toxic metals. Physical barrier and enclosure.	Urbanization and urban runoff. Fish migration barrier. Atmospheric deposition/urbanization.
1.65	22.3	NON	<u>25</u> *	<u>4.5</u> *	40	74.75	Sedimentation. Nutrient enrichment. Toxic metals. Physical barrier and enclosure.	Urbanization and urban runoff. Fish migration barrier. Atmospheric deposition/urbanization.
0.55	23.1	NON	30*	6.3*	22*	51.5	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development.	Urbanization and urban runoff. Lacustrine influences. Atmospheric deposition/urbanization.
Nine-Mile Creek (WWH Existing)								
Site 10 ^H	0.7	NON	<u>16</u> *	---	MG*	53.25	Sedimentation. Nutrient enrichment. Toxic metals. Flow alterations.	Urbanization and urban runoff. Culverted stream reaches. Atmospheric deposition/urbanization.
0.40 ^H	3.1	NON	<u>22</u> *	---	32	63.5	Sedimentation. Nutrient enrichment. Toxic metals.	Urbanization and urban runoff. Atmospheric deposition/urbanization.
Shaw Brook (WWH Existing)								
0.40 ^H	0.04	NON	<u>12</u> *	---	<u>VP</u>	28.5	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development. Flow alterations.	Urbanization and urban runoff. Culverted stream reaches. Atmospheric deposition/urbanization.

*Significant departure from biocriterion (>4 ICI; >4 IBI; >0.5 MIwb units). Underlined scores are in the *Poor* or *Very Poor* narrative range.

^H Headwater scoring criteria

^F Fair narrative rating

^{MG} Marginally Good narrative rating

^P Poor narrative rating

^{VP} Very Poor narrative rating

Instream habitat at Dugway Brook RM 2.40 is degraded and limited likely due to the large impoundment and multiple culverted sections located both upstream and downstream. Poor habitat quality, a moderately embedded riffle, flow modifications, and the small drainage area are likely limiting factors contributing to the poor and fair biological index scores. The pollution-tolerant northern fathead minnow was the only fish species collected in both passes, and the total number of EPT taxa collected during the qualitative sample at this reach was low. Iron concentrations also exceeded water quality criteria for at least one of the 30-day periods of record, which is indicative of water quality impacts from urbanization.

Stream habitat at Dugway Brook RM 0.37 has been historically modified and influenced by multiple sources of impairment upstream of the reach including CSOs, illicit discharges, and a floatable control structure. Flow modifications including large, culverted sections, a significant amount of impervious surface, and the small drainage area likely have contributed to heavy siltation and poor water quality. For both passes, fish IBI scores were *Poor* and did not meet WWH habitat expectations. One moderately intolerant species, the sand shiner, was collected on the first pass, and three additional minnow species were collected on the second pass; however, the total number of overall fish collected was low. Macroinvertebrate assemblages were *Poor* and only two EPT taxa were collected, *Baetis flavistriga* and *Hydropsyche depravata* group.

Euclid Creek RM 2.70 was the only site assessed to be in partial attainment of the WWH status in 2023. Euclid Creek RM 2.70 met WWH expectations for both the habitat and macroinvertebrate community indices targets. This indicates that the habitat is of high enough quality for healthy fish assemblages and is likely not the limiting factor for establishment of a diverse fish community. The macroinvertebrate index score was *Very Good* and highly influenced by the high number of caddisfly species contributing to the score. Both IBI and MIwb indices scores were *Fair* and did not meet WWH expectations. The lack of darter species, low diversity of sucker species, and higher percentage of tolerant species impacted the scores for both passes. The Euclid Creek Spillway downstream of this site is likely preventing successful fish passage and migration upstream.

Euclid Creek RM 1.65 was in attainment of both the QHEI and ICI index targets and received the highest QHEI score of all study sites assessed in 2023. This indicates that the habitat is of high enough quality to support colonization of a diverse and healthy fish community. However, the IBI and MIwb scores were *Poor* and did not meet WWH expectations. The Euclid Creek Spillway downstream is likely influencing fish migration to RM 1.65 also. The macroinvertebrate ICI score was *Good* and the overall percentage of EPT taxa and Tribe Tanytarsini midges collected increased from 2021; however, the percentage of these two metrics was still low, and are likely an indicator of continued pollution stress impacting successful colonization of a diverse community of taxa.

Euclid Creek at RM 0.55 likely continues to not meet WWH expectations due to the lack of developed riffle habitat, and dynamic lacustrine influences due to the proximity of the mouth of Lake Erie. These factors, including moderate embeddedness and siltation, all contributed to the

Fair habitat quality index score and not meeting warmwater habitat expectations at this reach. For both the IBI and ICI indices, species abundance and richness were low at this reach and scores were *Fair*. Mlwb scores also did not meet WWH expectations. Timing of sample collection can also potentially influence seasonal variability in fish assemblages. While biological indices scores have improved at the reach compared to 2020 and 2021, the changing physical state may account for variations in score annually and within seasons.

Stream habitat at Nine-Mile Creek Site 10 is highly modified and influenced by multiple sources of impairment upstream including CSOs and high percent impervious surfaces, which influence substrate quality, riffle development, and overall embeddedness. These factors all contributed to the *Fair* QHEI score and did not meet WWH expectations. However, macroinvertebrate index scores were *Marginally Good*. Five EPT taxa and four sensitive taxa were collected, indicating that habitat was not a factor heavily influencing colonization of EPT taxa at this reach. The fish IBI scores were *Very Poor*, not meeting WWH expectations. The only species of fish collected during each pass was the pollution-tolerant creek chub, and total abundance was low. Site 10 is between two culverted sections of stream in a heavily urbanized watershed, which likely significantly limit successful fish colonization at the reach.

In-stream habitat at Nine-Mile Creek RM 0.40 achieved WWH expectations with a *Good* habitat index score. Channel development is good, and instream cover is moderate; however, overall embeddedness and siltation persists. This is likely a reflection of the high percentage of impervious surface and anthropogenic sources of pollution contributing to water quality issues at the reach. For both passes, fish scores were *Poor* and did not meet WWH expectations. The low diversity and abundance of species collected, which included the pollution-tolerant creek chub and white sucker, and the absence of key darter and headwater species highly influenced the scores. Macroinvertebrate index scores at Nine-Mile Creek RM 0.40 significantly improved in 2022, *Marginally Good* (32), compared to 2021, *Fair* (24). The diversity and richness of EPT taxa increased overall; however, the total number of EPT taxa was still low, leading to a large percentage of dipteran and other taxa comprising the total sample. This improvement may reflect a reduction in bacterial loads and a trend towards improvement in water quality due to reduced nutrient enrichment with reductions in CSO volume upstream of the reach.

Shaw Brook RM 0.40 is heavily urbanized and culverted throughout much of its length except for this small stretch. The primary source of streamflow is surface runoff due to the significant hydrologic modifications. Historically, water quality has been very poor and little to no dissolved oxygen is available to support successful colonization of a diverse fish community. The instream habitat is highly degraded and modified, and both biological indices scores were *Very Poor*. No fish were collected in either electrofishing pass, and no EPT taxa were collected, with Turbellaria and Chironomidae dominating the sample.

Exceedances of both bacteriological criteria for primary contact recreation occurred at all four streams with open sections during the 2022 recreation season. *E. coli* densities at the three culverted sites were not compared to the primary contact recreation standards but would have

also exceeded the criteria for all sampling events (Table 8). Samples collected outside of the recreation season (May 1st through October 31st) were excluded from the use attainment analysis. Potential sources of bacterial inputs may include stormwater runoff, illicit discharges, common trench sewer inflow and infiltration, failing household sewage treatment systems (HSTS), and CSOs.

Additionally, variations in-tunnel control measure implementations and differences in yearly weather patterns that can influence other environmental variables make it difficult to evaluate the impact of improvements with confidence. This created a limitation to this study. Continued monitoring in 2023 will focus on the collection of wet- and dry-weather water chemistry samples at Euclid Creek, Dugway Brook, Green Creek, Nine-Mile Creek, and Shaw Brook targeted during the recreation season. This data will be used to further evaluate the impact of the benefits of significant CSO volume and bacterial load reductions expected from NEORS's Project Clean Lake infrastructure improvements, specifically Euclid Creek Tunnel (ECT), the Dugway Storage Tunnel (DST), the Dugway East Interceptor Relief Sewer (DEIRS), the Dugway West Interceptor Relief Sewer (DWIRS), and the East 140th Street Relief and Consolidation Sewer, and other associated relief sewer and regulator upgrades. Data collected in 2023 will also reflect a period of full implementation of all control measures.

Acknowledgments

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

Brittany Dalton, Author
Eric Soehnlén, Co-Author
Laura Ferguson
Jeff Harrison
Kelsey Hickox (Amidon)
Seth Hothem
Jack King
Ron Maichle
Mark Matteson
Christina Miller
Denise Phillips
Wyatt Ramey
John Rhoades
Francisco Rivera
Shawn Robinson
Tyler Sagi
Justin Telep

Analytical Services Division – Completed analysis for all water chemistry sampling.

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