



Northeast Ohio Regional Sewer District

2021 Euclid and Dugway Storage Tunnels Post-Construction Biological, Water Quality, and Habitat Study



**Water Quality and Industrial Surveillance
Environmental Assessment Group
May 2022**

Table of Contents

List of Figures	ii
List of Tables	ii
Introduction	1
Water Chemistry and Bacteriological Sampling.....	4
Methods	4
Results and Discussion	5
Habitat Assessment	11
Methods	11
Results and Discussion	11
Fish Community Biology Assessment.....	14
Methods	14
Results and Discussion	16
Macroinvertebrate Community Biology Assessment	22
Methods	22
Results and Discussion	24
Conclusions.....	32
Acknowledgments.....	35
References.....	35

List of Figures

Figure 1. Sampling Locations	2
Figure 2. Table two of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015b)	9
Figure 3. QHEI Scores for each site monitored in 2021.....	12
Figure 4. Historic IBI Scores for Euclid Creek.....	18
Figure 5. Historic IBI Scores of Headwater Sites sampled in 2021	20
Figure 6. Historic ICI Scores for Euclid Creek.....	26
Figure 7. Macroinvertebrate Community Composition	27
Figure 8. Distribution of the number of qualitative total taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORSD.	29
Figure 9. Distribution of the number of qualitative EPT taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORSD.	30
Figure 10. Distribution of the number of qualitative sensitive taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair threshold limits developed by NEORSD.	31

List of Tables

Table 1. Sampling Locations	3
Table 2. Parameters with Field Blank Concentrations showing possible contamination	5
Table 3. Duplicate Samples with RPDs Greater than Acceptable.....	6
Table 4. Paired Parameters with sub-parameter values greater than parent values	6
Table 5. 2021 Stream E. coli Densities (MPN/100mL).....	7
Table 6. 2021 Nutrient Analysis (Geometric Means).....	9
Table 7. 2021 Metal Aquatic Life Use Exceedances	10
Table 8. Narrative ranges assigned to QHEI Scores	11
Table 9. QHEI Scores and Physical Attributes.....	13
Table 10. Electrofishing Dates	14
Table 11. IBI Metrics	15
Table 12. Fish Community Biology Scores in the EOLP Ecoregion	16
Table 13. 2021 Stream IBI and MIwb Results	16
Table 14. HD Locations and Installation Dates	23
Table 15. ICI Metrics	23
Table 16. Invertebrate Community Index (ICI) Range for EOLP Ecoregion	24
Table 17. 2021 Macroinvertebrate Results	24
Table 18. 2007– 2021 Euclid Creek ICI Scores	25
Table 19. NEORSD Recommended Expectation Threshold Limits for Narrative Rating Assignments in the EOLP.....	29
Table 20. 2021 Survey Results	32

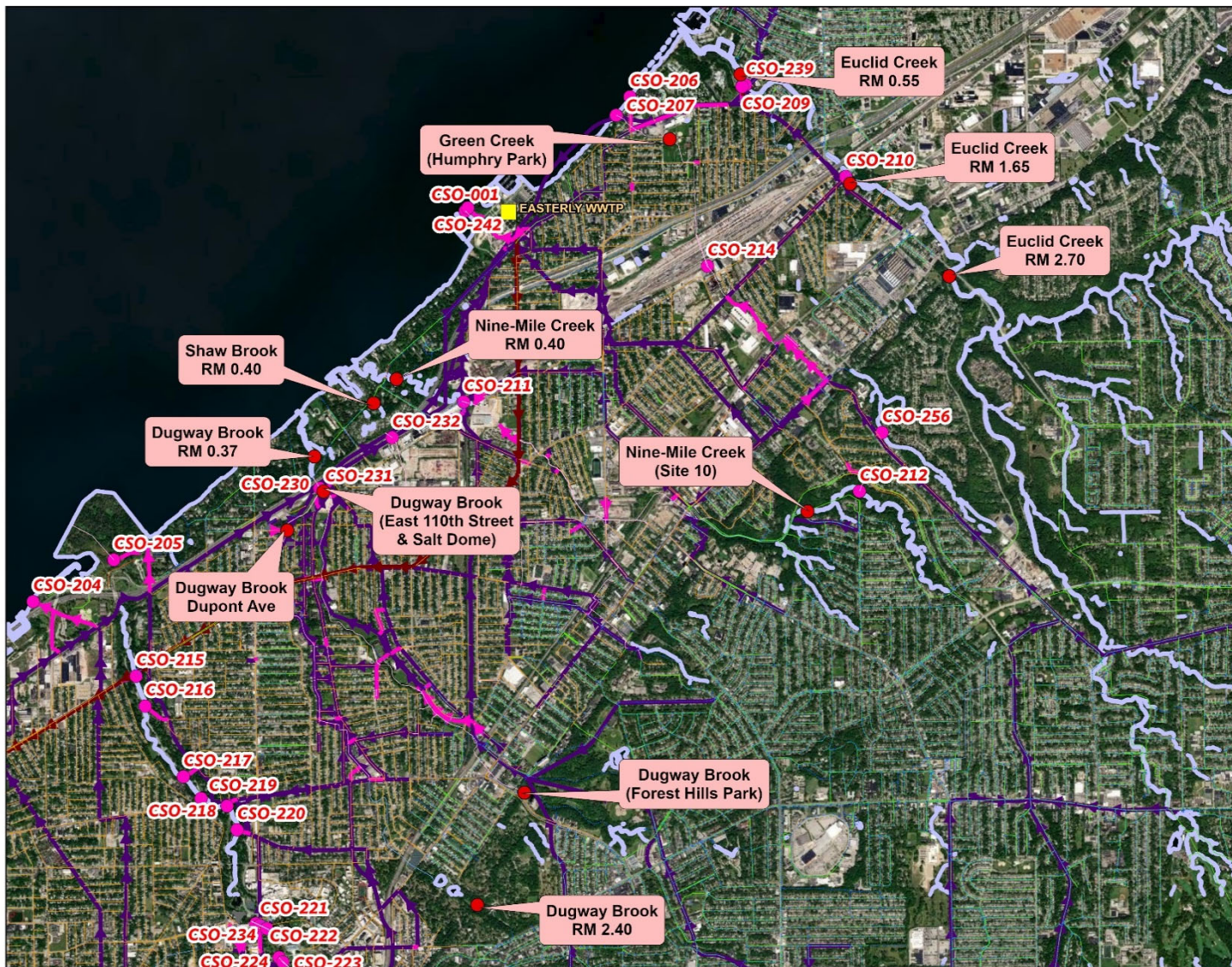
Introduction

In 2021, 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 improvements 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 included 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 CSO overflows to Lake Erie via its tributary streams. As of 2021 most of these projects have been fully completed and are now receiving sanitary and stormwater flows.

All five streams that were sampled in 2021 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, 2018a). The Ohio EPA recommended that Dugway Brook, Nine-Mile Creek, and Shaw Brook receive WWH aquatic life use designations. 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 as its conveyance should also be impacted 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 *2021 Euclid/Dugway Storage Tunnels Post-Construction Monitoring*. All sampling and environmental assessments occurred between June 15, 2021 and September 30, 2021 (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, 2020). 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. A digital photo catalog of the sampling locations is available upon request by contacting the NEORS's Water Quality and Industrial Surveillance (WQIS) Division.



Northeast Ohio Regional Sewer District

2021 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

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

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted at each site five times between July 21 and August 18, 2021. 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- μ m PVDF syringe filter. All water quality samples were collected as grab samples. Bacteriological samples were collected in sterilized plastic bottles. At the time of sampling, measurements for dissolved oxygen, dissolved oxygen percent, pH, temperature, specific conductance, and conductivity were collected using either a 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).

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

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, 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.

Mercury analysis for all the sampling events was done using EPA Method 245.1. Because the detection limit for this method is above the criteria for the Human Health Nondrinking and Protection of Wildlife Outside Mixing Zone Averages (OMZA), it generally cannot be determined if the streams sampled 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. Water chemistry analysis sheets for each site are available upon request from the NEORSW WQIS Division.

Results and Discussion

Over the course of five sampling events in 2021, two field blanks and two duplicate samples were collected as part of this study. Parameters that showed possible contamination in the field blank included biological oxygen demand (BOD), nitrate, and total nitrate and nitrite and are listed in Table 2. 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 for BOD were rejected, while the nitrate and total nitrate-nitrite were between five and ten times the field blank result and are thus estimated concentrations and still Level 3 data.

Table 2. Parameters with Field Blank Concentrations showing possible contamination					
Stream	Location	Date	Parameter	Result/Blank Result	Qualifier
Dugway Brook	RM 2.40	7/21/2021	Nitrate	7.7x	Estimated
			Nitrate/Nitrite Total	8.0x	Estimated
Dugway Brook	Forest Hills Culvert	7/21/2021	Nitrate	7.4x	Estimated
			Nitrate/Nitrite Total	7.6x	Estimated
Dugway Brook	E. 110 th St. Culvert	8/11/2021	BOD	1.7x	Rejected
Dugway Brook	RM 0.37	8/11/2021	BOD	1.5x	Rejected
Euclid Creek	RM 2.70	7/21/2021	Nitrate	5.5x	Estimated
			Nitrate/Nitrite Total	5.6x	Estimated
Euclid Creek	RM 0.55	8/11/2021	BOD	1.3x	Rejected
Green Creek	Humphry Park Culvert	8/11/2021	BOD	1.1x	Rejected
Nine-Mile Creek	Site 10	7/21/2021	Nitrate/Nitrite Total	2.1x	Rejected
			Nitrate	2.1x	Rejected
Nine-Mile Creek	RM 0.40	8/11/2021	BOD	1.1x	Rejected
Shaw Brook	RM 0.40	8/11/2021	BOD	1.6x	Rejected

Of the two duplicate samples collected, two instances occurred in which the acceptable RPD was exceeded (Table 3). 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					
Stream	Location	Date	Parameter	Acceptable RPD	Actual RPD
Euclid Creek	RM 1.65	7/28/2021	TKN	53.8	137.3
			TSS	52.2	55.4

The final QA/QC check was for paired parameters, or those parameters in which one is a subset of the other. There were several instances in which the data for the paired parameters needed to be qualified because the sub-parameter value was greater than the parent value (Table 4). Most of this data remained Level 3 with the sample result estimated, while the results for total solids and total suspended solids for Nine-Mile Creek Site 10 on August 12, 2021, were rejected (Table 4).

Table 4. Paired Parameters with sub-parameter values greater than parent values					
Stream	Location	Date	Sub Parameter	Parent Parameter	Qualifier
Dugway Brook	E. 110 th St Culvert	7/28/2021	Nitrate	Nitrate-Nitrite	Estimated
		8/18/2021	Total Dissolved Solids	Total Solids	Estimated
Dugway Brook	Forest Hills Culvert	8/4/2021	Nitrate	Nitrate-Nitrite	Estimated
Dugway Brook	RM 0.37	7/21/2021	Total Dissolved Solids	Total Solids	Estimated
Euclid Creek	RM 2.70	7/28/2021	Nitrate	Nitrate-Nitrite	Estimated
		8/12/2021	Total Suspended Solids	Total Solids	Estimated
		8/18/2021	Nitrate	Nitrate-Nitrite	Estimated
Euclid Creek	RM 1.65	8/18/2021	Nitrate	Nitrate-Nitrite	Estimated
		8/12/2021	Total Suspended Solids	Total Solids	Estimated
Euclid Creek	RM 0.55	8/4/2021	Nitrate	Nitrate-Nitrite	Estimated
Nine-Mile Creek	Site 10	7/21/2021	Nitrate	Nitrate-Nitrite	Estimated
		7/28/2021	Nitrate	Nitrate-Nitrite	Estimated
		7/28/2021	Dissolved Reactive Phosphorus	Total Phosphorus	Estimated
		8/12/2021	Total Suspended Solids	Total Solids	Rejected
		8/18/2021	Nitrate	Nitrate-Nitrite	Estimated
Nine-Mile Creek	RM 0.40	8/18/2021	Total Dissolved Solids	Total Solids	Rejected

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 (2021). Exceedances of the recreational bacteriological criteria for primary contact recreation occurred at all four streams during the 2021 sampling season. The recreational criteria for *Escherichia coli* (*E. coli*) consist of two components: a 90-day geometric mean and a value not to be exceeded in more than 10% of the samples collected during a 90-day period (statistical threshold value). 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 criteria were exceeded at all eleven sites for the 90-day periods beginning on July 21, 2021 (Table 5). These exceedances may be due to significant wet-weather events* which occurred on two of the five sampling dates. Potential sources of bacteria inputs may include stormwater runoff, illicit discharges, combined sewer overflows (CSOs), and failing household sewage treatment systems (HSTS).

Table 5. 2021 Stream *E. coli* Densities (MPN/100mL)

Site	Sample Date						90-Day Geomean
	7/21	7/28	8/4	8/11*	8/12*	8/18	
Dugway Brook West Branch RM 2.40	579	326	308		129,970	1300	1579
Dugway Brook East Branch Forest Hills**	613	18,600	1		61,310	816	894
Dugway Brook East Branch East 110 ^{th**}	5560	3360	5120	9330		23,820	7337
Dugway Brook Main Branch RM 0.37	6500	7430	6155	13,540		2920	6517
Euclid Creek RM 2.70	101	61	124		30,955	185	337
Euclid Creek RM 1.65	921	448	345		61,310	249	1168
Euclid Creek RM 0.55	770	461	326	2230		5880	1087
Green Creek**	727	579	2420	21,050		1553	2016
Nine-Mile Creek Site 10	299	135	308		86,640	219	749
Nine-Mile Creek RM 0.40	1553	748.5	1733	16,160		1553	2192
Shaw Brook	1120	649	770	2990		365	906

- Exceeds statistical threshold value of 410 MPN/100mL
- Exceeds geometric mean criterion for 90-day period of 126 MPN/100mL
- No Sample collected

*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.

***E. coli* densities at culverted locations were not compared to the primary contact recreation standards but are listed here for reference

Mercury was analyzed using EPA Method 245.1. Because the detection limit for EPA Method 245.1 is above the criteria for the Human Health Non-Drinking and Protection of Wildlife OMZAs, it cannot be determined if the sites were in attainment of those criteria. It is expected 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. All eleven sample locations had at least one result that was above the mercury detection limit, and therefore exceeding both the wildlife and aquatic life OMZA criteria.

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

Maintenance of low levels of nutrients such as nitrogen and phosphorus in Euclid Creek, Dugway Brook, Nine-Mile Creek, Shaw Brook, and Green Creek is imperative in limiting loading to Lake Erie. An excess of nitrogen and phosphorus can lead to nutrient enrichment in the lake, fueling harmful algal blooms (HABs) which contributes 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 hepatotoxins 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 6 shows the 2021 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 2). According to this section of SNAP, sites on Euclid Creek (RM 0.55, 1.65, and 2.70), Green Creek, and Nine-Mile Creek Site 10 received an ecological risk narrative level described as “levels typical of working landscapes; low risk to beneficial use if allied responses are within normal ranges”. Sites on Dugway Brook East, West, and Main Branches (Forest Hills, East 100th St., RM 0.37 and 2.40), Shaw Brook, and Nine-Mile Creek RM 0.40 received an ecological risk narrative level described as “levels typical of enriched condition; low risk to beneficial use if allied responses are within normal ranges” (Ohio EPA 2015). 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. Allied response indicators, 24-hour DO swing, and benthic chlorophyll, were not assessed

by NEORS in 2021, creating a limitation to the interpretation of risk presented using the provisional method.

Table 6. 2021 Nutrient Analysis (Geometric Means)

Stream	Location	DIN (mg/L)	NO ₃ -NO ₂ (mg/L)	DRP (mg/L)	TP (mg/L)
Dugway Brook	RM 2.40	0.793*	0.682	0.185	0.258*
	Forest Hills	0.838*	0.734	0.146	0.199*
	East 110 th	0.867*	0.832	0.139	0.196*
	RM 0.37	0.889*	0.837	0.079	0.177*
Euclid Creek	RM 2.70	0.227*	0.717	0.043	0.075*
	RM 1.65	0.205*	0.178	0.036	0.070*
	RM 0.55	0.098*	0.054	0.030	0.044*
Green Creek	Humphry Park Culvert	1.060*	1.013	0.063	0.101*
Nine-Mile Creek	Site 10	0.597*	0.492	0.061	0.084*
	RM 0.40	0.674*	0.645	0.111	0.138*
Shaw Brook	RM 0.40	0.767*	0.612	0.107	0.157*

* Data used in Table 2 of SNAP (Ohio EPA 2015)
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 2. Table two of the Stream Nutrient Assessment Procedure (Ohio EPA, 2015b)

Copper exceeded the Aquatic Life OMZM (maximum) criterion at Euclid Creek RM 1.65 (Table 7). Copper, lead, and zinc also exceeded the OMZA and OMZM criteria at Dugway Brook RM 2.40. These exceedances occurred for at least one 30-day period or sampling event at both locations. Copper and zinc exceeded the Aquatic Life OMZA criteria at Nine-Mile Creek and Dugway Brook Forest Hills for at least one sampling event.

These metal exceedances occurred in highest concentration at all sites post significant rainfall events representing periods of acute toxicity. The 48-hour rainfall on August 12th was 1.42 inches, and the highest 24-hour rainfall volume on record in 2021 (1.20 inches), occurred on August 10th. Runoff during peak flow in urban areas with a large percentage of impervious often contain elevated levels of heavy metals and other dissolved solids. The phenomenon is referred to as the first flush syndrome and can adversely impact human health and aquatic life (Joshi & Balasubramanian, 2010).

Table 7. 2021 Metal Aquatic Life Use Exceedances

Stream	Location	Start date	End date	Parameter	Result (ug/l)	Criterion (ug/l)	Type of exceedance
Euclid Creek	RM 1.65	8/12/2021	--	Copper	14.2	13.8	WWH OMZM
Nine-Mile Creek	Site 10	8/12/2021	--	Copper	9.7	6.6	WWH OMZM
				Zinc	69.2	60.1	
Dugway Brook	Forest Hills	8/12/2021	--	Copper	9.32	8.1	WWH OMZM
	RM 2.40	8/12/2021	--	Copper	21.6	10.9	WWH OMZM
		8/12/2021	9/10/2021		12.5	12.4	WWH OMZA
		7/28/2021	8/26/2021	Lead	14.8	13.3	WWH OMZM
		8/4/2021	9/2/2021		19.7	12.8	
		8/12/2021	9/10/2021		29.4	9.9	
		8/12/2021	--	Zinc	126	96.0	WWH OMZM

At Shaw Brook RM 0.40, total dissolved solids (TDS) exceeded both the Aquatic Life OMZA and the Human Health Drinking Water OMZA and OMZM (maximum) criteria for at least one 30-day period. Mean total dissolved solid exceedance concentrations were 1436 mg/L (SD=283.9). The Aquatic Life TDS criterion is 1500 mg/L, and the Human Health criterion is 500 mg/L. Dissolved oxygen was also below the minimum required Aquatic Life OMZA criterion for the July 28th sampling event; concentrations measured 3.6 mg/L and the criterion is 4 mg/L.

Elevated TDS concentrations are associated with human activities, urban land use, and increasing trends in chloride concentration in freshwater systems worldwide. Concentrations

above the drinking water criterion can lead to drinking water taste and odor issues that are difficult to treat and can negatively impact human health. The corrosivity potential is also increased with higher concentrations of TDS, impacting infrastructure and mobilization of heavy metals. Elevated TDS concentrations can also lead to aquatic life toxicity concerns and negatively impact stream ecosystem processes (Edward et al., 2020).

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 8). 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 NEORSD WQIS Division.

Table 8. 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 2021, Nine-Mile Creek RM 0.40 and Site 10 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 3).

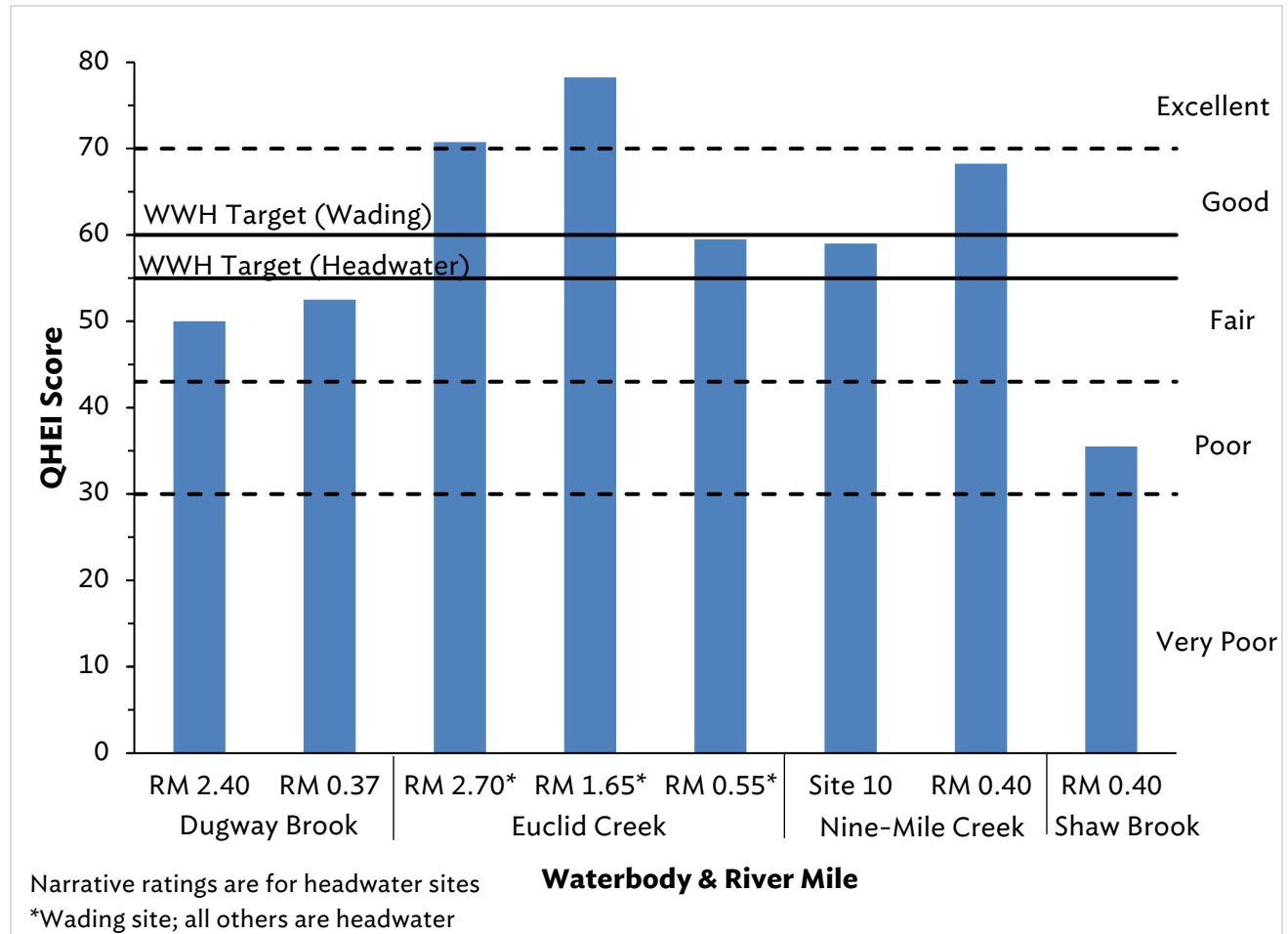


Figure 3. QHEI Scores for each site monitored in 2021.

Both sites on Dugway Brook were narratively *Fair*, while Shaw Brook, which is heavily urbanized and culverted throughout most of its length, was narratively *Poor*. RM 0.55 on Euclid Creek was narratively *Fair*; however, it was only half a point below the QHEI criteria for *Good*. 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.

Individual components of the QHEI can also be used to evaluate whether a site can meet its WWH designated use (Table 9). 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 only two sites that met these criteria in 2021 were the ones at Euclid Creek RMs 2.70 and 1.65.

Table 9. QHEI Scores and Physical Attributes																																		
WWH Attributes														MWH Attributes																				
Sampling Location	QHEI Score	Habitat Rating	WWH Attributes											High Influence						Moderate Influence														
			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	50.00	Fair	X	X									2			X	X	X	3					X					X	X		3	1.3	1.3
Dugway Brook RM 0.37	52.50	Fair	X					X			X		3		X				1		X			X	X			X	X		X	6	0.5	1.8
Euclid Creek RM 2.70	70.75	Good	X	X		X		X	X	X	X	X	8						0					X							1	0.1	0.2	
Euclid Creek RM 1.65	78.25	Excellent	X	X		X	X	X	X	X	X	X	9						0		X										1	0.1	0.2	
Euclid Creek RM 0.55	59.50	Fair	X	X				X			X		4						0		X		X	X			X	X		X	6	0.2	0.4	
Nine-Mile Creek Site 10	59.00	Good	X	X		X	X		X		X		6				X		1				X					X	X		3	0.3	0.6	
Nine-Mile Creek RM 0.40	68.25	Good	X	X		X	X	X			X	X	7						0		X		X	X			X	X	X		6	0.1	0.9	
Shaw Brook RM 0.40	34.50	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 quantitative electrofishing passes were conducted at each in stream site in 2021. A list of the dates when the surveys were completed is shown in Table 10. Sampling was conducted using longline electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from downstream to upstream by slowly and steadily walking through the stream. 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 10. Electrofishing Dates	
Date	Sites sampled
6/24/2021	Dugway Brook RM 0.37; Nine-Mile Creek RM 0.40; Shaw Brook RM 0.40;
6/25/2021	Euclid Creek RM 2.70
6/28/2021	Euclid Creek RM 0.55
7/2/2021	Euclid Creek RM 1.65
7/15/2021	Nine-Mile Creek Site 10; Dugway RM 2.40;
8/18/2021	Euclid Creek RM 2.70
8/20/2021	Nine-Mile Creek RM 0.40; Shaw Brook 0.40
8/26/2021	Euclid Creek RMs 0.55, 1.65
09/3/2021	Dugway Brook RM 2.40; Nine-Mile Creek Site 10
09/30/2021	Dugway Brook RM 0.37

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 11). 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 11. 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 follows 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 12). 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 12. 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 2021 IBI and MIwb scores from each assessment location are listed below in Table 13. For both indices, no sites were found to be in attainment of the warmwater habitat criteria.

Table 13. 2021 Stream IBI and MIwb Results						
Location	IBI (Narrative)			MIwb (Narrative)		
	1 st Pass	2 nd Pass	Average	1 st Pass	2 nd Pass	Average
Dugway Brook RM 2.40	14 (<i>Very Poor</i>)	14 (<i>Very Poor</i>)	14 (<i>Very Poor</i>)			
Dugway Brook RM 0.37	20 (<i>Poor</i>)	28 (<i>Fair</i>)	24 (<i>Poor</i>)			
Euclid Creek RM 2.70	30 (<i>Fair</i>)	32 (<i>Fair</i>)	31 (<i>Fair</i>)	6.0 (<i>Fair</i>)	7.3 (<i>Fair</i>)	6.5 (<i>Fair</i>)
Euclid Creek RM 1.65	28 (<i>Fair</i>)	28 (<i>Fair</i>)	28 (<i>Fair</i>)	5.5 (<i>Poor</i>)	6.8 (<i>Fair</i>)	6.1 (<i>Fair</i>)
Euclid Creek RM 0.55	24 (<i>Poor</i>)	30 (<i>Fair</i>)	27 (<i>Poor</i>)	5.6 (<i>Poor</i>)	6.6 (<i>Fair</i>)	6.1 (<i>Fair</i>)
Nine-Mile Creek Site 10	20 (<i>Poor</i>)	20 (<i>Poor</i>)	20 (<i>Poor</i>)			
Nine-Mile Creek RM 0.40	18 (<i>Poor</i>)	24 (<i>Poor</i>)	21 (<i>Poor</i>)			
Shaw Brook RM 0.40	12 (<i>Very Poor</i>)	12 (<i>Very Poor</i>)	12 (<i>Very Poor</i>)			
WWH criterion: Wading = IBI ≥38; MIwb ≥7.9 Headwaters = IBI >40						

Euclid Creek

The two fishing passes at RM 2.70 resulted in nearly identical species assemblages, except for the brown bullhead (*Ictalurus natalis*) being collected only on the first pass. Additionally, nearly twice the number of fish were collected on the second pass compared to the first. Overall, the site

received an average IBI score of 31, narratively *Fair*, indicating the site is not in attainment of WWH criteria for the fish community. The presence of two sunfish species - the bluegill sunfish (*Lepomis machrochirus*) and the pumpkinseed sunfish (*Lepomis gibbosus*) - positively impacted the score, while the lack of darter species, the low number of sucker species, and the high percentage of tolerant species lowered the score. The MIwb score was also similar across each pass, again with the primary difference between each pass being twice the number of fish collected on the second pass. The average MIwb score was 6.7 (narratively *Fair*). Negatively impacting the score were the number of tolerant species present throughout both passes, particularly the blacknose dace (*Rhinichthys atratulus*). The site's QHEI score indicated that the overall habitat was in attainment of the WWH target with a score of 70.75 (narratively *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 located downstream of this site may be acting as a migration barrier, preventing upstream fish passage.

RM 1.65 received an IBI score of 28 each pass, which is narratively *Fair* and not in attainment of the fish community WWH criterion. Limiting the site's IBI scores was a high percentage of tolerant species, the low number of sucker species, and the lack of darter species. Low percentages of DELTs and the presence of sunfish species did positively impact the score, however. The MIwb score for the first pass was 5.5 (narratively *Poor*), while the second pass was 6.8 (narratively *Fair*). Twice the number of fish were collected on the second pass, with significantly more central stoneroller minnows (*Campostoma anomalum*) 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 improved from the *Poor* ratings of 23 and 24 in 2019 and 2020, respectively (Figure 3). Like RM 2.70, the QHEI score met the WWH target, with the site scoring 78.25, narratively *Excellent*, 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 there.

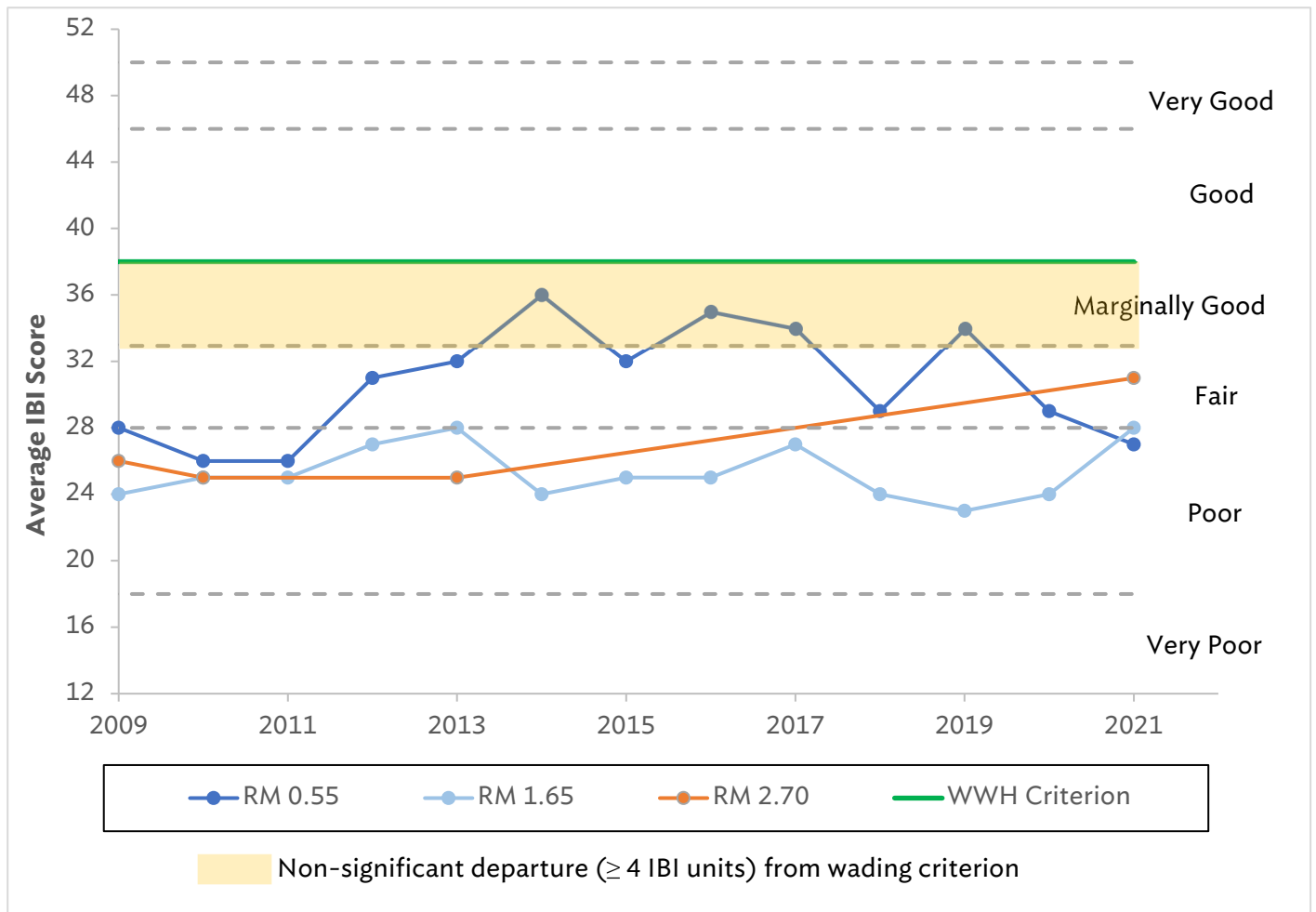


Figure 4. Historic IBI Scores for Euclid Creek

Over two fishing passes, RM 0.55 averaged a score of 27 (narratively *Poor*) with the first pass (24, *Poor*) scoring lower than the second pass (30, *Fair*), and thus was not in attainment of WWH criterion. The average MIwb score was 6.1 (*Fair*) which is also not in attainment of the WWH criterion. The first pass had fewer species and was impacted by the number of observed DELTs on the fish present. Despite a greater number of fish species found on the second pass, the overall number of fish at the site was low, resulting in greater negative impacts to the score from the percentage of tolerant species (60.5%) and percentage of omnivores (29.8%). The presence of several sunfish species including the bluegill sunfish, the pumpkinseed sunfish, the green sunfish (*Lepomis cyanellus*) and the rock bass (*Ambloplites rupestris*) did positively impact the score. Similar results were observed in the MIwb scores, with the first pass having fewer species resulting in a score of 5.6 (narratively *Poor*). The second pass benefited from an increase in the number and weight of collected fish and resulted in a score of 6.6 (*Fair*).

These are lower scores compared to assessments done in 2019 and 2020. This site is near the beginning of the lacustuary section of Euclid Creek, and frequently experiences influence from Lake Erie. During the 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 state of the site may account for variations in score from year to year, and even within years, as the range of the 2021 scores could have been influenced by the timing of the fish passes, which occurred several months apart.

Dugway Brook

River mile 2.40 received an IBI score of 14, which is narratively *Very Poor*. In both passes, it hosted only one species, the northern fathead minnow (*Pimephales promelas*). Its habitat score of *Fair* did indicate room for improvement. 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. This score was comparable to what has been found there historically (Figure 5).

Over two passes, RM 0.37 scored 20 (narratively *Poor*) and 28 (narratively *Fair*) averaging to a score of 24, which is narratively *Poor* and not in attainment of the WWH criterion. There was one moderately intolerant species present, the sand shiner (*Notropis stramineus*), as well as the notable presence of a single rainbow trout (*Oncorhynchus mykiss*). However, the low number of fish on the first pass significantly impacted the score. 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. Along with the lack of a riffle, the overall habitat condition negatively impacted the ability of the site to support a robust fish community. Likely due to the poor substrate, there were no darter species or headwater species, which negatively impacted the IBI score.

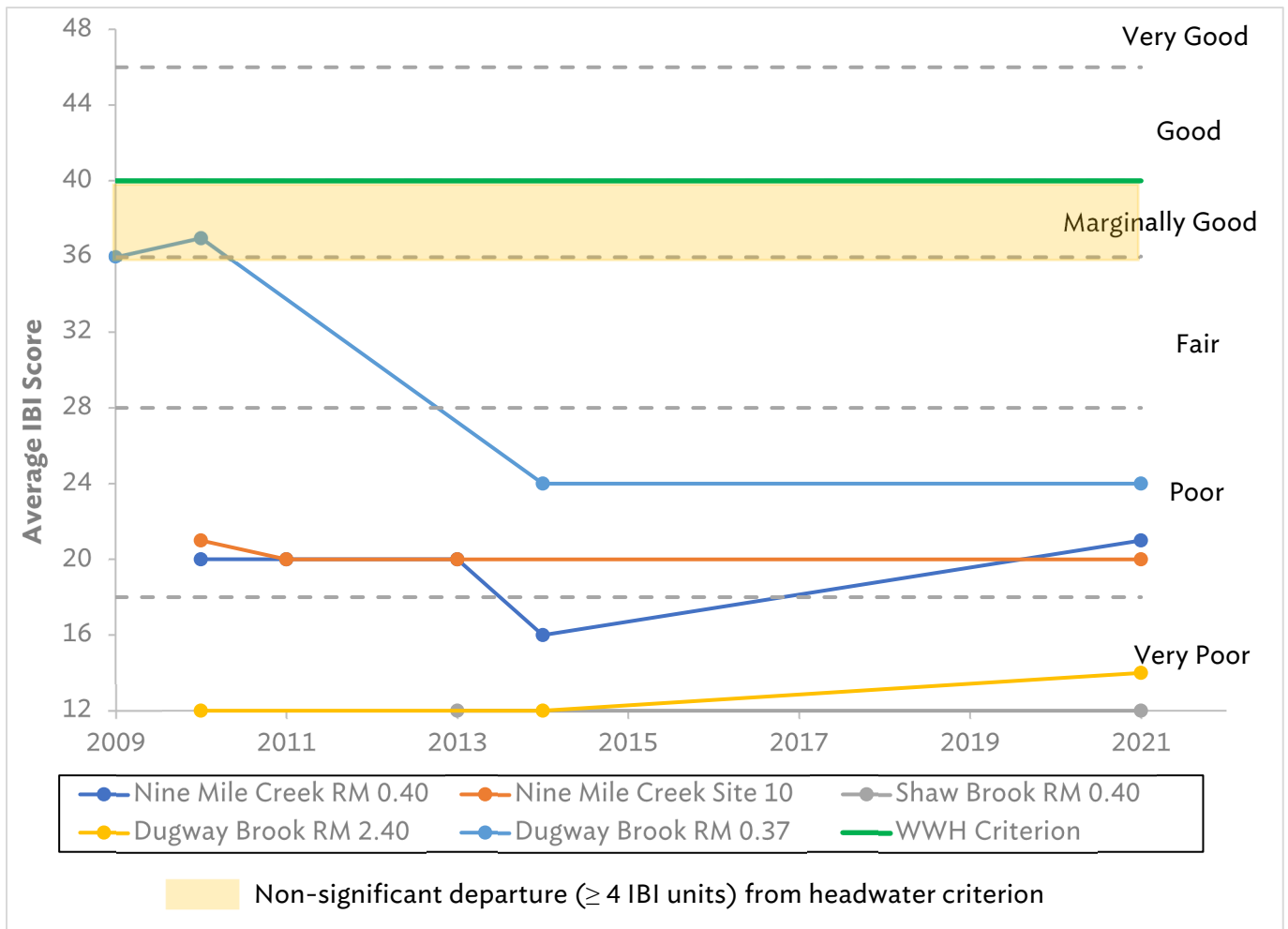


Figure 5. Historic IBI Scores of Headwater Sites sampled in 2021

Nine-Mile Creek

Results from two 2021 electrofishing sampling events in the stream segment at Nine-Mile Creek RM 0.40 averaged an IBI score of 21, which is narratively *Poor* and not in attainment of the IBI WWH designated use criterion.

The first electrofishing pass resulted in an IBI score of 18 and a narrative rating of *Poor*. Multiple factors contributed to RM 0.40 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 a low number of insectivorous species. Only seven species of fish totaling 513 individuals were collected during this sampling event and a majority were pollution tolerant. These species included the creek chub (*Semotilus atromaculatus*), white sucker (*Catostomus commersonii*), common carp (*Cyprinus Carpio*), and yellow bullhead (*Ameiurus natalis*). The three remaining fish species collected were the bluegill sunfish, central stoneroller minnow, and the round goby (*Neogobius melanostomus*). The common carp and the round goby are non-

native. Non-native or invasive species compete with native fish for resources, and negatively alter fish community composition. A lower proportion of pioneering taxa (47%), and no DELTS being observed in the sample population positively contributed to the IBI score but did not influence attainment of the criterion.

The second electrofishing pass resulted in an IBI score of 24 (*Poor*) and was also not in attainment of the IBI WWH criterion. Taxa diversity increased by 58% and included the presence of six minnow species, a key taxa indicator. A total of twelve species of fish totaling 467 individuals were collected during this sample. However, the number of fish collected during this pass were dominated by primarily pollution-tolerant species (94%), including the white sucker and the creek chub. The invasive round goby was also present in the second pass, potentially competing with native fish for resources and negatively altering fish community composition. The presence of pollution-sensitive species, the rosyface shiner (*Notropis rubellus*), sand shiner, and mimic shiner (*Notropis volucellus*), as well as the number of minnow species, positively contributed to the IBI score, but were not sufficient to influence attainment of the criterion.

The habitat assessment of Nine-Mile Creek RM 0.40 indicated that the stream reach would be suitable to support a quality fish community. However, the IBI score calculated in 2021 contradicts the QHEI score. The average IBI score has increased from the last survey conducted at RM 0.40 in 2014. However, anthropogenic sources of pollution, the high percentage of impervious surface contributing to stormwater runoff, and combined sewer outfall 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. Historically, CSO-211 averaged 77 overflows each year, but with the Dugway Storage Tunnel and East 140th Relief and Consolidation Sewer going online in 2020, the number and volume of overflows has been significantly decreased. While some improvements have been made, the negative impacts of bacteria and sediment deposition from additional sources may be influencing the high proportion of tolerant taxa.

Results from two 2021 electrofishing sampling events in the stream segment at Nine-Mile Creek Site 10 averaged an IBI score of 20, which is narratively *Poor* and not in attainment of the IBI WWH designated use criterion.

Both electrofishing passes resulted in an IBI score of 20 and a narrative rating of *Poor*. The only fish species collected during both sampling events was the pollution-tolerant creek chub totaling 54 individuals during the first pass and 81 individuals during the second pass. 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 but did not influence the attainment of the criterion.

The habitat assessment of Nine-Mile Creek Site 10 indicated that the stream reach would be suitable to support a quality fish community. However, the low IBI score in 2021 contradicts this QHEI score. Compared to the last survey conducted at Site 10 in 2013, the IBI score has remained the same and fish community composition was similar. 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 combined sewer outfall discharges may still be affecting the fish population negatively at Site 10 as well. While Project Clean Lake infrastructure improvements have resulted in the reduction of bacteria and sediment loads and may improve the historic 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.

Shaw Brook

Across two passes, no fish were collected at Shaw Brook in 2021. The site received the default low score of 12, *Very Poor*. Having no riffle and low flow, the site habitat received a score of 34, *Poor*, and 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 14. 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 14. HD Locations and Installation Dates		
Site	HD Installation Date	Qualitative Sample Date
Dugway Brook RM 2.40	7/21/21	9/1/21
Dugway Brook RM 0.37	No HD	9/1/21
Euclid Creek RM 2.70	7/21/21	9/1/21
Euclid Creek RM 1.65	7/21/21	9/2/21
Euclid Creek RM 0.55	7/21/21	9/1/21
Euclid Creek RM 1.65	7/21/21	9/2/21
Euclid Creek RM 2.70	7/21/21	9/1/21
Shaw Brook RM 0.40	No HD	9/2/21
Nine-Mile Creek Site 10	7/21/21*	9/1/21
Nine-Mile Creek RM 0.40	7/21/21	9/2/21
*HD was not retrieved.		

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

Table 15. ICI Metrics
Total Number of Taxa
Number of Mayfly taxa
Number of Caddisfly taxa
Number of Dipteran taxa
Percent Mayflies
Percent Caddisflies
Percent Tanytarsini Midges
Percent Other Diptera and Non-Insects
Percent Tolerant Organisms (as defined)
Number of Qualitative EPT Taxa

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

Results and Discussion

Table 17 shows the results for locations successfully sampled with HDs in 2021 and those sites that had a qualitative sample only. For the 2021 sampling season, two sites, Euclid Creek RMs 1.65 and 2.70, were in attainment of the WWH criterion. Temporal data displayed in Table 18 shows the historical scores for Euclid Creek monitoring locations. Figure 5 shows the historic ICI scores for Euclid Creek.

Table 17. 2021 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	575/L-M	16/22	1/0	10.64/0	Baetid mayflies, Turbellaria, chironomids	26	Fair
0.37	---/L	18/---	0/0	---	Turbellaria, chironomids	--	Very Poor
Euclid Creek (19-041-000)							
2.70	913/L-M	41/54	10/7	1.51/29.3	Baetid mayflies, Turbellaria, chironomids	42	Very Good
1.65	865/L	43/53	7/	1.32/	Philopotamid mayflies, Turbellaria, chironomids	44	Very Good
0.55	543/L	/36	2/	38.84/	Chironomids, Oligochaetes	22	Fair
Nine-Mile Creek (19-040-000)							
Site 10	---/L-M			---	Baetid mayflies, Turbellaria		Marginally Good
0.40	265/L-M	/28	1/	7.6/	Chironomids, baetid mayflies	24	Fair
Shaw Brook (19-044-000)							
0.40	---/L			---	Chironomids, Culicids	--	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 18. 2007– 2021 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
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		

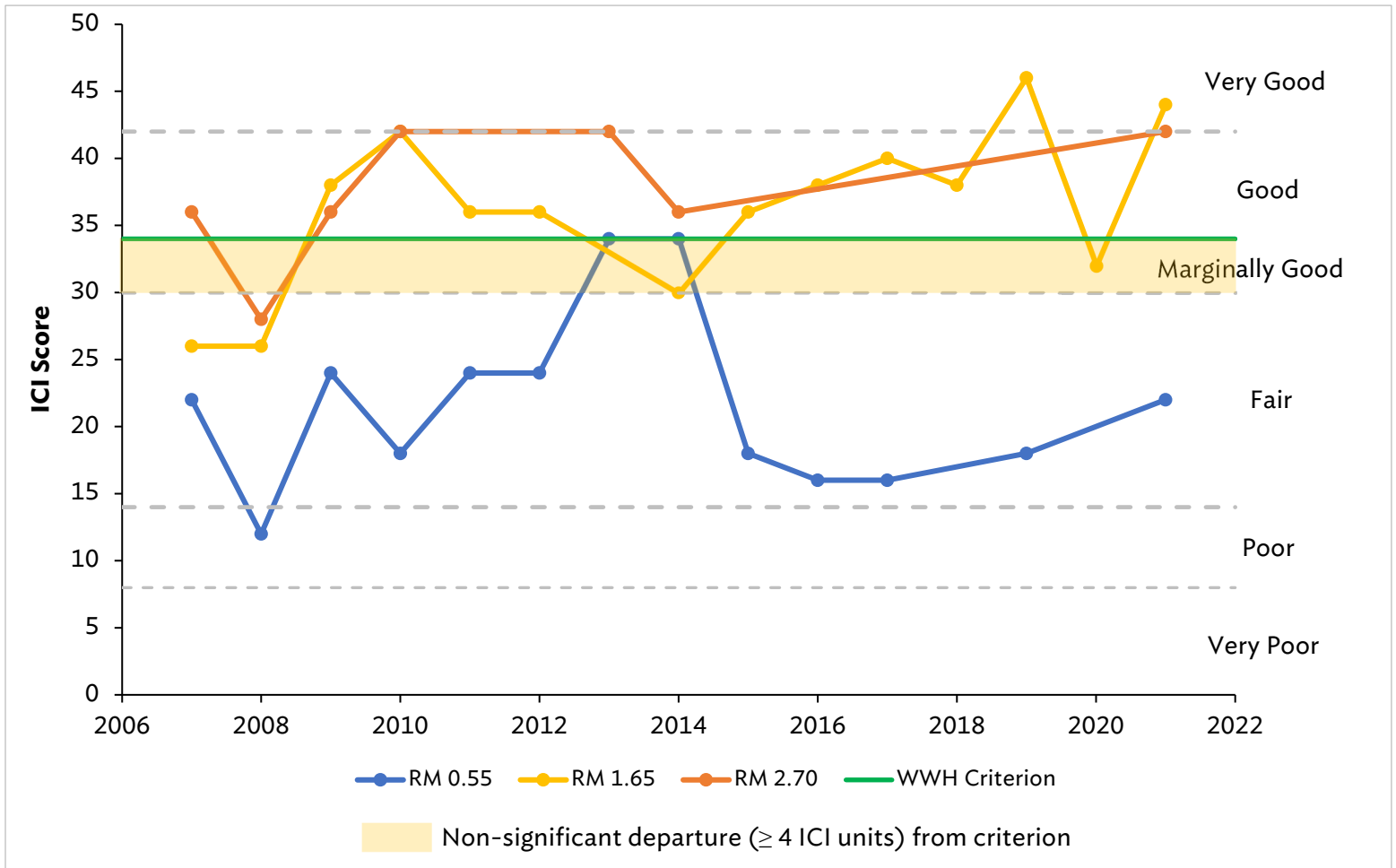


Figure 6. Historic ICI Scores for Euclid Creek

Euclid Creek

The qualitative and HD sampling conducted at Euclid Creek RM 0.55 received an ICI score of 22 (*Fair*), which is not in attainment of the WWH criterion. Several metrics negatively impacted this score. Primarily, there were only two mayfly species collected (*Stenonema femoratum* and *Caenis sp*), and they were a low overall percentage of the organisms collected at the site (Figure 6). Additionally, caddisfly species were only present as a small percentage on the HD sample, and none were collected in the qualitative assessment. Finally, a high number of dipteran 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.

RM 1.65 had a higher ICI score of 44 (*Very Good*) which is in attainment of the WWH criterion and an increase from the score in 2021 (32; *Marginally Good*). Although only two species of mayfly were collected (*Baetis flavistriga* and *Baetis intercalaris*), they made up a relatively large proportion of the collected organisms overall. Secondly, the number and percentage of caddisfly

taxa was much higher than RM 0.55, which positively affected the score. Lastly, lower relative percentages of dipteran and non-insect taxa also increased the score. Few midges from Tribe Tanytarsini were found, however, which is room for improvement for this reach. The fast currents over a non-embedded riffle provide the ideal habitat for EPT taxa, which allows the reach to support a robust macroinvertebrate community.

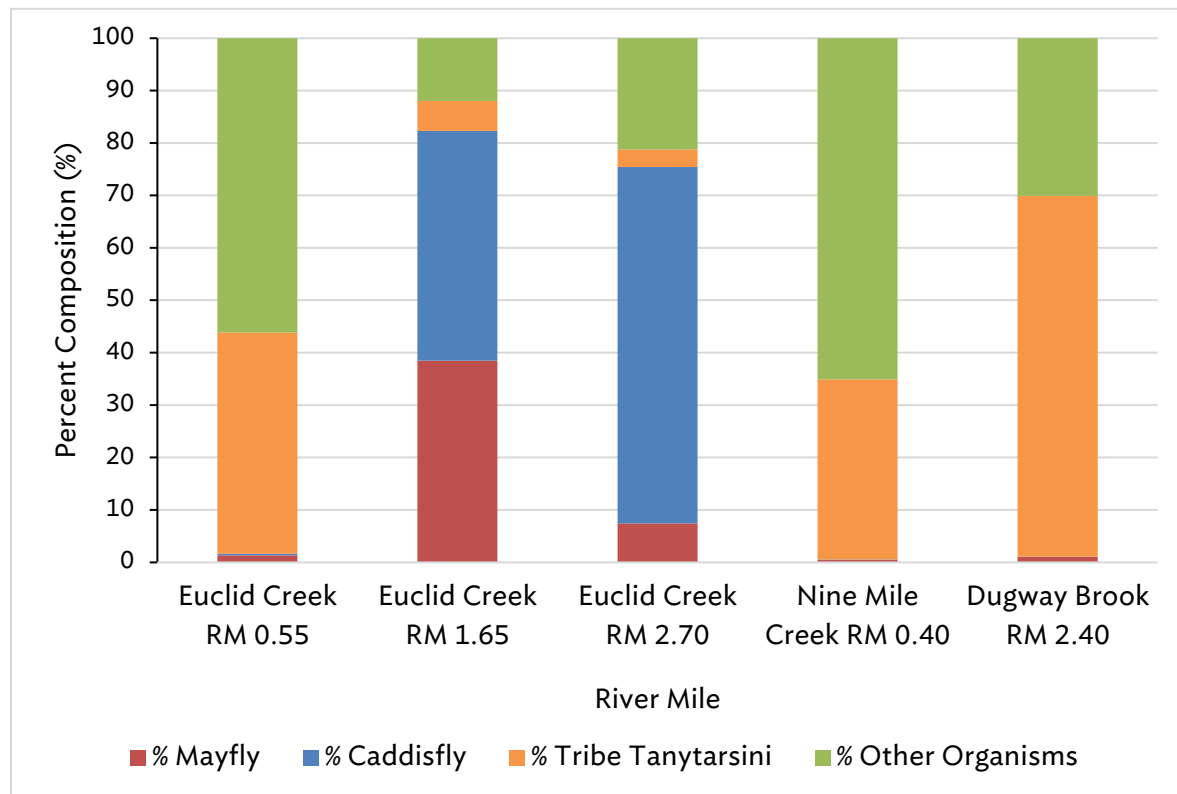


Figure 7. Macroinvertebrate Community Composition

RM 2.70 had an ICI score of 42 (*Very Good*) and is thus in attainment of the WWH criterion for macroinvertebrate communities. Like RM 1.65, a high number of caddisfly species and a high percentage of caddisflies in the HD contributed to the high score. Additionally, a low percentage of dipteran and non-insects as well as a low percentage of tolerant organisms positively impacted the score. Fast currents and low embeddedness at this reach provide ample good quality habitat for EPT species. Improvement in mayfly species and Tribe Tanytarsini midges would increase the score further.

Dugway Brook

Dugway Brook RM 2.40 received an ICI score of 26 (*Fair*) which is not in attainment of the WWH criterion. Impacting its score were the very low numbers of mayfly and caddisfly species present at the site. These each made up a low percentage of the collected organisms, which

ultimately impacts the score across four metrics. Only one EPT taxa was collected during the qualitative assessment (*Baetis flavistriga*), which also caused the site to receive the lowest score for that metric. However, the score was positively increased by the relatively high percentage of Tribe Tanytarsini midges at the site. The QHEI habitat assessment (*Fair*), identified a shallow flow, high embeddedness overall and within the riffle, as well as poor development. These factors could be impacting the stream's ability to host EPT taxa.

Nine-Mile Creek

Nine-Mile Creek RM 0.40 received an ICI score of 24 (*Fair*), which is not in attainment of the WWH criterion. Severely impacting the score was the presence of just one mayfly species (*Baetis flavistriga*) and one caddisfly species (*Cheumatopsyche*) at the site. These were present in very low percentages as well, impacting the metrics for both taxa groups. This absence resulted in a relatively high percentage of dipteran and non-insect taxa at the site, further decreasing the score. Positively impacting the score was a relatively high percentage of Tribe Tanytarsini midges, as well as a low percentage of tolerant organisms. Ultimately, the low number of EPT taxa is preventing this site from reaching attainment. While the habitat assessment resulted in a QHEI score of 68.25 (*Good*), the slow current and high embeddedness could be preventing the colonization of these taxa.

Macroinvertebrate Narrative Rating Assignments

The HD sampler at Nine-Mile Creek Site 10 was washed out following a heavy rain event. No HDs were installed at Shaw Brook RM 0.40 and Dugway Brook RM 0.37 due to unsuitable conditions for HD installation including slow current velocity. Therefore, narrative rating assessments were assigned for these sites based on the results of qualitative sampling. The qualitative sample data was compared to expectations developed by NEORSD in 2021 using threshold limit models. These models were developed using QDC Level 3 macroinvertebrate data provided by the Ohio EPA from the EOLP ecoregion from the ten-year period between 2005 and 2014 (threshold limit model analysis available upon request). Table 1 provides the expectation threshold limits for qualitative total taxa, qualitative EPT taxa, and qualitative sensitive taxa metrics, grouped by drainage area category. Figures 8-10 provide distributions of these metrics grouped by ICI narrative rating category in comparison with the expectation threshold limits provided in Table 19.

Table 19. NEORSD 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

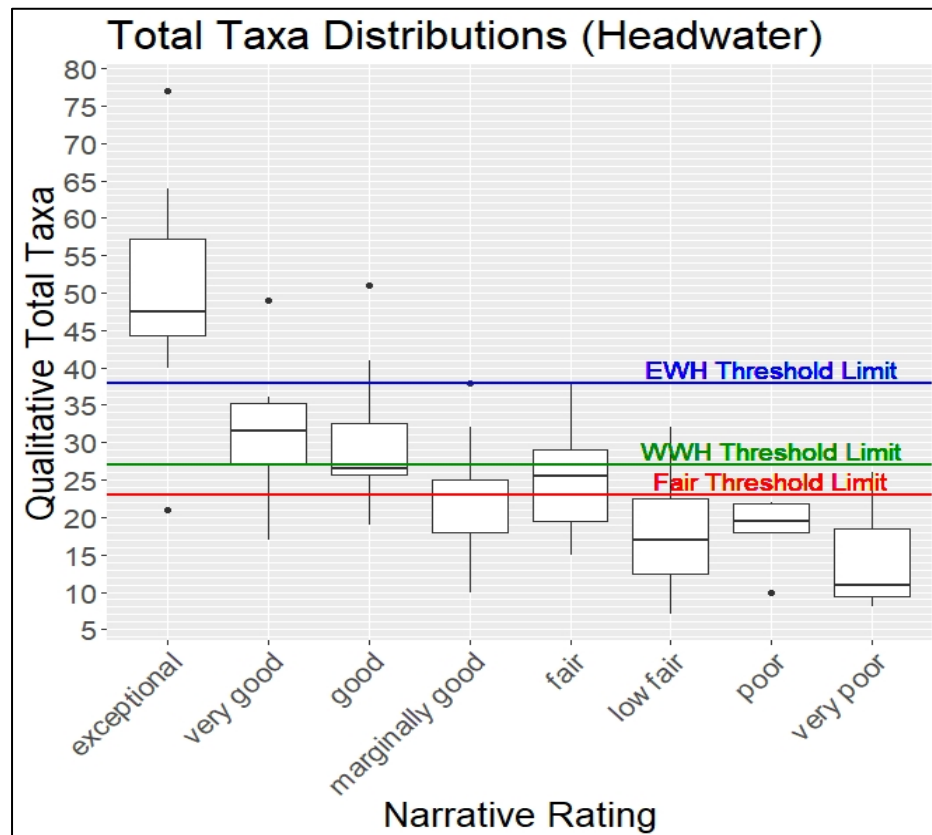


Figure 8. Distribution of the number of qualitative total taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORSD.

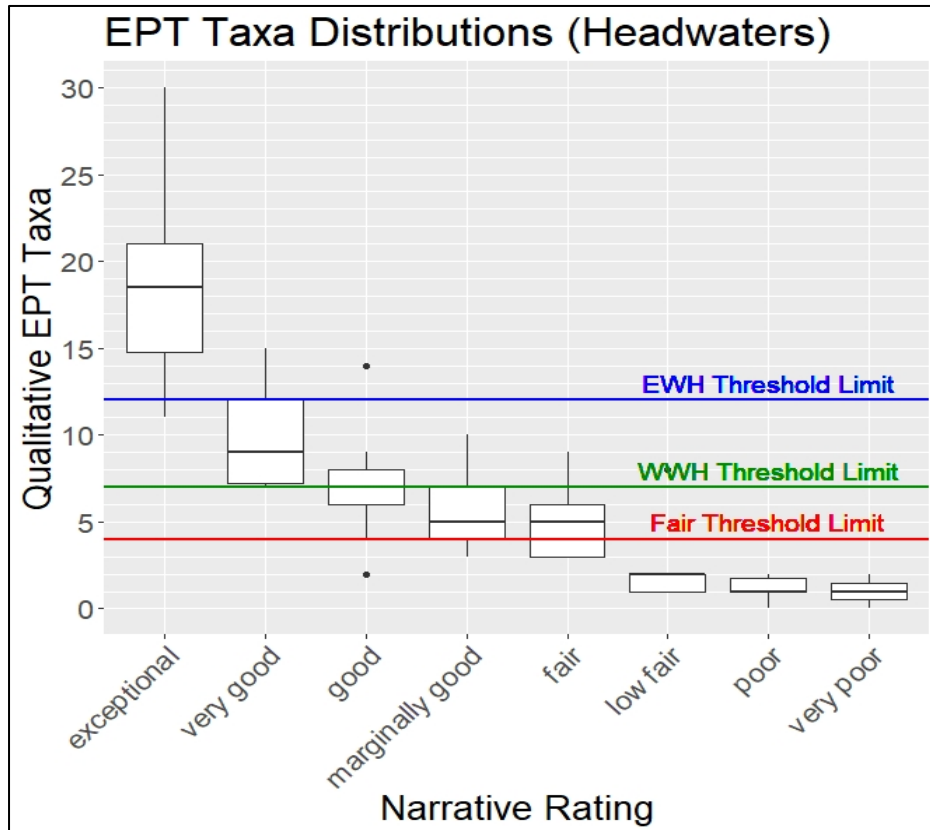


Figure 9. Distribution of the number of qualitative EPT taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair expectation threshold limits developed by NEORS.

Nine-Mile Creek Site 10 was assigned a narrative rating of *Marginally 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 22 taxa were collected in the qualitative sample, which scores just below the *Fair* expectation for a headwater stream. Six EPT taxa were collected, which scores just below the WWH expectation for a headwater stream. The EPT taxa collected included one Baetidae mayfly, *Baetis flavistriga*, one Philopotamidae caddisfly, *Chimarra aterrima*, one Polycentropodidae caddisfly, Polycetropus group, and three Hydropsychidae caddisflies, *Cheumatopsyche sp*, *Hydropsyche depravata* group, and *Hydropsyche simulans*. Three sensitive taxa were collected, which scores just above the WWH habitat expectation. The site was assigned a field narrative rating of *Marginally Good* at the time of sample collection. Field observations indicated that the two most predominant taxa were Baetidae and Turbellaria. 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 *Marginally Good* in 2021.

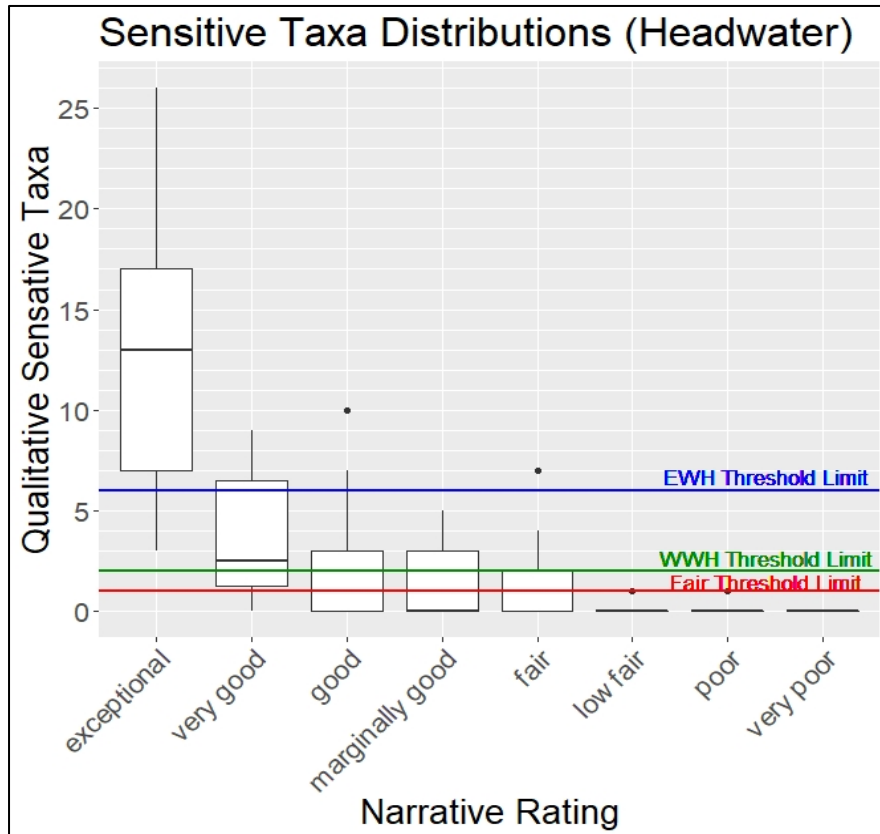


Figure 10. Distribution of the number of qualitative sensitive taxa in EOLP headwater streams grouped by ICI score narrative rating category with EWH, WWH, and Fair threshold limits developed by NEORS.

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 eleven taxa were collected in the qualitative sample, which scores well below the *Fair* expectation for a headwater stream. No EPT taxa were collected, which also scores well below the *Fair* expectation. One sensitive taxon was collected, the moderately intolerant Tipulidae, *Pseudolimiphila sp.* This meets the *Fair* expectation but falls below the WWH expectation for sensitive taxa. 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, the site was assigned a narrative rating of *Very Poor* in 2021.

Dugway Brook RM 0.37 was assigned a narrative rating of *Very Poor*. This site has a drainage area of 6.3 square miles placing it in the headwater drainage area category. A total of 18 taxa were collected, which included no EPT or sensitive taxa. This placed the macroinvertebrate community at this site below the *Fair* expectation for all three qualitative metrics. 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 the site was assigned a narrative rating of *Very Poor* in 2021.

Conclusions

The results of NEORSD’s 2021 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 (Table 20).

Table 20. 2021 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>14</u> *	---	26*	50	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development. Flow alterations.	Urbanization and urban runoff. Culverted stream reaches. Atmospheric deposition/urbanization.
0.37 ^H	6.3	NON	<u>24</u> *	---	VP	52.5	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	31*	6.5*	42	70.75	Sedimentation. Nutrient enrichment. Toxic metals. Physical barrier and enclosure.	Urbanization and urban runoff. Fish migration barrier. Atmospheric deposition/urbanization.
1.65	22.3	PARTIAL	28*	6.1*	42	78.25	Sedimentation. Nutrient enrichment. Toxic metals. Physical barrier and enclosure.	Urbanization and urban runoff. Fish migration barrier. Atmospheric deposition/urbanization.
0.55	23.1	NON	<u>27</u> *	6.1*	22*	59.5	Sedimentation. Nutrient enrichment. Toxic metals. Poor habitat development.	Urbanization and urban runoff. Lacustrine influences. Atmospheric deposition/urbanization.

2021 Euclid and Dugway Tunnels Post-Construction Biological, Water Quality, and Habitat Study
 May 26, 2022

Nine-Mile Creek (WWH Existing)								
Site 10 ^H	0.7	NON	<u>20</u> *	---	MG	59	Sedimentation. Nutrient enrichment. Toxic metals. Flow alterations.	Urbanization and urban runoff. Culverted stream reaches. Atmospheric deposition/urbanization.
0.40 ^H	3.1	NON	<u>21</u> *	---	24*	68.25	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> *	---	VP	34.5	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 <i>Poor</i> or <i>Very Poor</i> narrative range ^H Headwater scoring criteria ^{MG} Marginally Good narrative rating ^{VP} Very Poor narrative rating								

Euclid Creek RM 1.65 and 2.70 were in partial attainment of the WWH status. While Nine-Mile Creek RM 0.40, Site 10, and Euclid Creek RMs 1.65 and 2.70 met the QHEI targets for their respective stream sizes indicating that the habitat should be of high enough quality to support fish assemblages, no sites were assessed to be in attainment of the wastewater habitat criterion for both the IBI and MIwb indices due to low metric scoring overall (Table 20).

Euclid Creek at RM 1.65 and 2.70 did not reach full WWH attainment, despite having *Excellent* and *Good* habitat quality and supporting a good macroinvertebrate community indicated by the *Very Good* ICI narrative rating. This is likely due to the fish barrier at RM 1.50 which prevents migration to the upper reaches of the watershed, a significant potential driver of the non-attainment and the *Fair* IBI and MIwb narrative for RM 1.65 and 2.70.

The habitat quality at both Dugway Brook RM 2.40 and 0.37 resulted in a narrative rating of *Fair* and both sites were in non-attainment of the WWH status. River mile 0.37 received a *Poor* IBI narrative rating highly influenced by the low number of individuals collected likely due to poor substrate quality. Due to low velocity, no HD was installed, and a *Very Poor* ICI narrative was assigned based on the qualitative sample with no EPT taxa collected. River mile 2.40 received a *Very Poor* IBI narrative rating and only one species of fish was found, the northern fathead minnow. The *Fair* ICI narrative rating was driven by the low numbers of mayfly and caddisfly

species present at the site. Both RM 2.40 and 0.37 have highly embedded poorly developed riffles limiting recruitment of species. Dugway Brook is also a highly culverted, engineered, and urbanized stream.

Euclid Creek at RM 0.55 likely continues to not meet attainment standards due to the lack of riffle habitat, dynamic lacustrine influences, and timing of sample collection potentially influencing seasonal variability in fish assemblages. In both fish and macroinvertebrate community surveys, species abundance and richness were low. All these factors contribute to the WWH non-attainment status.

Nine-Mile Creek at Site 10 and RM 0.40 likely were unable to reach full WWH attainment despite *Good* habitat narrative ratings due to both sites receiving a *Poor* IBI narrative rating. Pollution-tolerant fish species dominated all sampling events at both sites. While taxa diversity increased between passes at RM 0.40 and pollution-sensitive species, the rosyface shiner, sand shiner, and mimic shiner, were present, that wasn't significant enough to influence attainment. Only one species of fish was collected at Site 10 in both passes, the pollution-tolerant creek chub.

Shaw Brook RM 0.40 is heavily urbanized and culverted directly upstream and downstream of the sample location and throughout most of the length. These factors likely influenced non-attainment of the WWH status by limiting fish recruitment to the site. The stream habitat assessment resulted in a narrative rating of *Poor*, and no fish were collected in either electrofishing pass resulting in the default IBI narrative of *Very Poor*. Due to low velocity, no HD was installed, and an ICI narrative rating of *Very Poor* was assigned based on the qualitative sample. No EPT taxa were collected, and Turbellaria and Chironomidae dominated the sample.

Exceedances of both bacteriological criteria for primary contact recreation occurred at all four streams with open sections during the 2021 sampling 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 if that had been done (Table 5). Potential sources of bacterial inputs may include stormwater runoff, illicit discharges, failing household sewage treatment systems (HSTS), and CSOs.

The lack of sufficient wet-weather data collected in 2021 makes it difficult to evaluate the impact of infrastructure improvements with confidence and was a limitation to this study. Continued monitoring 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.

This data will be used to further evaluate the impact of the benefits of significant combined sewer overflow 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.

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