Northeast Ohio
Regional Sewer District

2023 Green Creek

Biological, Water Quality, and Habitat Study

Water Quality and Industrial Surveillance

Environmental Assessment Group

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Introduction

Continued efforts by the Northeast Ohio Regional Sewer District (NEORSD) towards the combined sewer overflow (CSO) long-term control plan (LTCP), as part of "*Project Clean Lake*", will improve water quality impacts through the reduction in sanitary sewer overflows and surcharged sewers, elimination of common trench sewers, illicit discharges, and areas of clustered septic systems. The storage tunnel systems are integral parts of the larger gray infrastructure capital improvements of "*Project Clean Lake*". The project also includes significant investments in large-scale green infrastructure projects that are aimed at reducing CSO events and increasing the storage capacity within the sanitary collection system.

Green Creek flows through the eastside suburbs of Cleveland before flowing beneath Interstate 90, through East Cleveland and discharging directly into Lake Erie. 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 specified beneficial use designation, but was included in the *2023 East Side Tributaries Environmental Monitoring* study due to potential impact by recent construction projects. The specific infrastructure projects that have anticipated impacts on Green Creek include the London Road Relief Sewer (LRRS), Euclid Creek Storage Tunnel (ECT) system, and the Lakeshore Boulevard Relief Sewer (LBRS) and associated regulator upgrades on the east side of the NEORSD service area. The primary goal of the collection system improvements was to improve the conveyance of wastewater and stormwater during wet-weather events and reduce the occurrence of CSO discharges to Lake Erie.

The Green Creek watershed is heavily urbanized, consisting of a vast landscape of impervious surfaces which quickly transports rainfall, increasing the stormwater runoff and peak flow rates within Green Creek. Increased stormwater runoff leads to higher bank erosion and increased pollutants transferred to a stream across the urban landscape (USEPA, 1999). Pollutants associated with urban and industrial runoff include excess sediments, nutrients, pathogens, oxygen-demanding matter, heavy metals, and salts (Schueler, 1987).

In 2023, NEORSD conducted water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community assessments on several direct tributary streams to Lake Erie, including Green Creek. The objective of this study was to evaluate the effectiveness of recently completed construction projects in improving water quality impacts on Green Creek by evaluating if a reduction of bacterial loading through CSO control has occurred and what impacts this has had on the water quality of the receiving waters. Green Creek is included in the NEORSD *2023 East Side Tributaries Environmental Monitoring* project, and this monitoring was completed to support the Ohio Environmental Protection Agency (Ohio EPA) National Pollution Discharge Elimination System (NPDES) Permit No. 3PA00002*JD. Surveys of Green Creek were conducted by the Environmental Assessment (EA) group of the NEORSD Water Quality and Industrial Surveillance (WQIS) Division.

Sampling was conducted by NEORSD Level 3 Qualified Data Collectors (QDCs) certified by the Ohio EPA in Fish Community Biology, Benthic Macroinvertebrate Biology, Chemical Water Quality, and Stream Habitat Assessments as explained in the NEORSD project study plan "*2023 East Side Tributaries Environmental Monitoring*" approved by Ohio EPA on April 28, 2023. All sampling and environmental assessments occurred between June 15 through September 30, 2023 (through October 15 for fish sampling assessments), as required in the Ohio EPA *Biological Criteria for the Protection of Aquatic Life Volume III* (1987b).

The majority of Green Creek is culverted; however, the headwaters of the creek exist as open sections of stream. Therefore, Green Creek was evaluated at RM 2.50 for chemical water quality, habitat, and biological criteria using the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI), Index of Biotic Integrity (IBI), and NEORSD Macroinvertebrate Threshold Model. An examination of the individual metrics that comprise the IBI and Macroinvertebrate Threshold Model was used in conjunction with the water chemistry data and QHEI scores to assess the health of the stream. The downstream site(s) monitored during this study are in a culverted section of the creek and is inaccessible for biological sampling and habitat evaluation. Therefore, only chemical water quality was evaluated at this location. The typical downstream monitoring site was at RM 0.01, but during wet-weather or during periods when water levels in Lake Erie made sampling at the outfall impractical, the downstream sample was collected from Humphrey Park (Table 1).

Table 1 lists each sampling location with respect to river mile, latitude/longitude, description, and the types of surveys conducted at each location. GPS coordinates are recorded at the downstream end of each sampling zone. Figure 1 shows a study area map illustrating each sample location evaluated during the 2023 study. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's WQIS Division.

Table 1. Sampling Locations

Location	Latitude	Longitude	River Mile	Station ID	Sampling Conducted
Culvert Outfall to Lake Erie	41.5799	-81.5737	0.01	--	C
Upper Valley Drive, South of Euclid Avenue (Site 7)	41.5578	-81.5470	2.50	302510	F, M*, C
Third Manhole Upstream of Confluence w/Lake Erie	41.5778	-81.5676	**Humphrey Park Culvert	––	C

F = Fish community biology (includes habitat assessment)
M = Macroinvertebrate community biology (* qualitative survey only)
C = Water chemistry
** Downstream sample location during wet-weather and elevated Lake Erie water levels

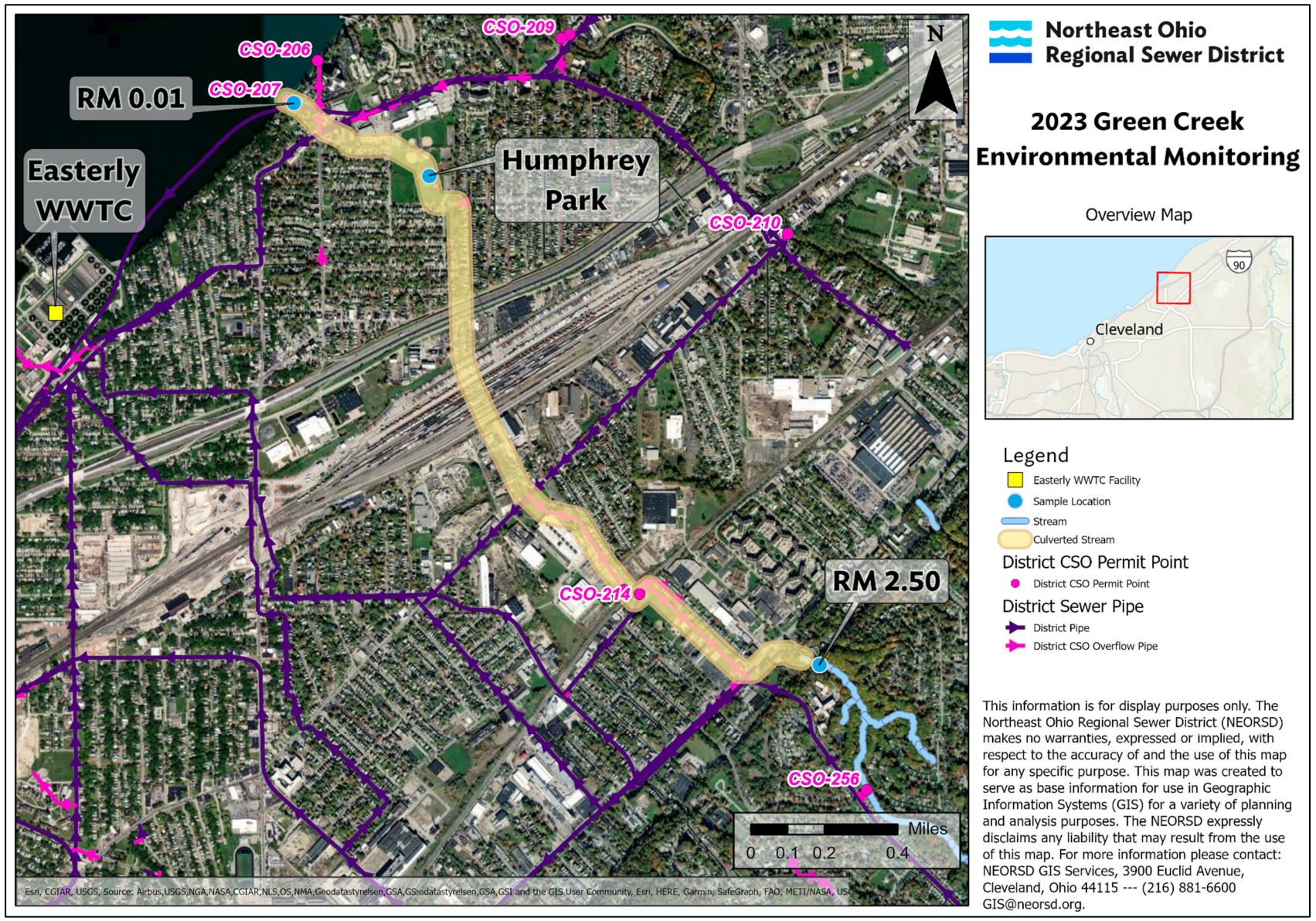

Figure 1. Green Creek Sampling Locations

Water chemistry data was validated per methods outlined by the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2023). The Ohio EPA assigns designated uses to establish minimum water quality requirements for surface waters. These requirements represent measurable criteria for assessing the chemical, physical, and biological integrity of Ohio's surface waters consistent with Clean Water Act requirements. Green Creek has not been assigned an aquatic life use (ALU) designation. As of November 29, 2022, the Ohio Administrative Code 3745-1-07 (Ohio EPA, 2022a) indicates that the chemical criteria for the protection of human health, aquatic life (warmwater), and wildlife apply to all surface waters of the state unless designated otherwise.

In 2023, bacteriological water quality criteria for primary contact recreation, as well as the Outside Mixing Zone Maximum (OMZM) and Outside Mixing Zone Average (OMZA) chemical water quality criteria identified for the warmwater habitat (WWH) use designation were applied to Green Creek. Primary contact recreational use criteria for *Escherichia coli* (*E. coli*) apply at RM 2.50, but do not apply to the culverted sections of the stream. The chemical water quality criteria for the WWH designation and the primary contact recreational use criteria for *E. coli* were applied to the culverted downstream site of Green Creek for comparative purposes only. The beneficial use designations for the 2023 Green Creek sampling are listed below in Table 2.

Table 2. Beneficial Use Designations for Green Creek

Water Body Segment	Beneficial Use Designation												
	Aquatic Life Habitat (ALU)							Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Green Creek RM 0.01		+							+	+		+	
Green Creek RM 2.50		+							+	+		+	

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water
PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

Water Chemistry and Bacteriological Sampling

Methods

Water chemistry and bacteriological sampling was conducted five times between June 21 and July 19, 2023, at the locations listed in Table 1. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows*

(2023). Chemical water quality samples from each site were collected with a 4-liter disposable polyethylene cubitainer with a disposable polypropylene lid, three 473-mL plastic bottles and one 125-mL plastic bottle. The first 473-mL plastic bottle was field preserved with trace nitric acid, the second was field preserved with trace sulfuric acid and the third bottle received no preservative. The sample collected in the 125-mL plastic bottle (dissolved reactive phosphorus) was filtered using a 0.45-µm PVDF syringe filter. All water quality samples were collected as grab samples. Bacteriological samples were collected in sterilized plastic bottles and preserved with sodium thiosulfate. At the time of sampling, measurements for dissolved oxygen, dissolved oxygen percent, pH, temperature, conductivity, and specific conductance were collected using a YSI EXO1 sonde. Replicate samples and field blanks were each collected at randomly selected sites from the *2023 East Side Tributaries Environmental Monitoring* study plan, at a frequency of not less than 5% of the total samples collected. Therefore, one field blank sample was collected at a randomly selected Green Creek site. Duplicate/replicate samples were not collected at Green Creek during the 2023 study, but they were collected at other sites as part of the *2023 East Side Tributaries Environmental Monitoring* project.

Water chemistry analysis sheets for each site are available upon request from the NEORSD WQIS Division. Dates of water chemistry sampling compared to rain gauge data from NEORSD's South Euclid precipitation gauge are shown below in Figure 2.

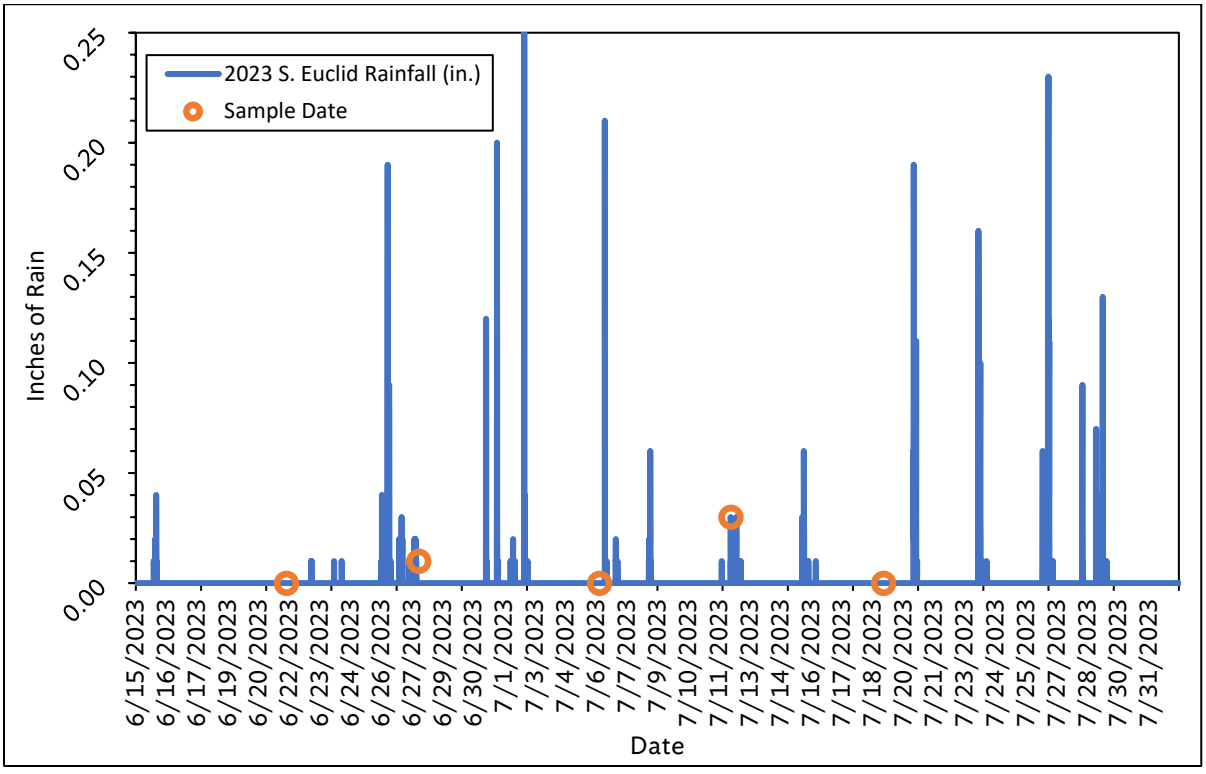

Figure 2. 2023 Rainfall Data at NEORSD's South Euclid Precipitation Gauge; **Orange** circles indicate NEORSD water chemistry sampling dates.

Results and Discussion

Quality Assurance / Quality Control

Green Creek is not assigned an ALU designation. However, the OMZM and OMZA water quality criteria identified for the WWH use designation apply to water bodies not assigned a specific ALU designation (Ohio Administrative Code 3745-1-07). Therefore, the WWH designation was applied to Green Creek. The water chemistry samples collected at each site were compared to the applicable Ohio Water Quality Standards for the designated use to determine attainment.

Over the course of the five sampling events in 2023, one field blank sample was collected and analyzed for all parameters. The field blank sample was collected at RM 2.50 on June 21, 2023. Due to possible contamination in the field blank sample, one parameter was rejected or estimated (Table 3). Ohio EPA's Credible Data program includes a data validation protocol for QA/QC samples. Data were qualified using the factor of three method to differentiate a detected compound from background "noise" present in the analytical system. Therefore, the sample analyte concentration must be at least three times the field blank concentration to be considered reliably present in the sample, otherwise the sample data is qualified as rejected ("R"). An ammonia sample from RM 0.01 was rejected and the ammonia sample from RM 2.50 received a "J" qualifier and is considered an estimate due to the result being lower than the Practical Quantitation Limit (PQL).

Table 3. Parameters with Field Blank Concentrations Showing Possible Contamination

Location	Date	Parameter	Result/ Blank Result	QA/QC Code
Green Creek RM 0.01	6/21/23	Ammonia	0.106/0.111	Rejected
Green Creek RM 2.50	6/21/23	Ammonia	0.0266/0.111	Estimated

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

Recreation Use Results and Discussion

E. coli is a fecal indicator bacterium commonly found in the intestinal tract and feces of warm-blooded animals and is used to measure the presence of feces (USEPA, 2012). The primary contact recreation (PCR) criteria consist of two components. First is an *E. coli* criterion not to exceed a statistical threshold value (STV) of 410 colony counts or most probable number per 100 milliliters (410 MPN/100ml) in more than ten percent of the samples collected during any 90-day period. The second component is a 90-day geometric mean criterion of 126 MPN/100mL (Ohio EPA, 2022b). In accordance with the Ohio EPA procedure and practice to qualify *E. coli* exceedances for the Primary Recreation criteria, the geometric mean and STV are only calculated and compared when a minimum of five bacteriological samples have been collected within a rolling 90-day period.

The primary contact recreation designation was applied to the Green Creek sites sampled in 2023 in accordance with Ohio Administrative Code 3745-1-07 (Ohio EPA, 2022a). The two sample locations were sampled for *E. coli* five times to assess the recreational criteria attainment. Exceedances of the recreational bacteriological criteria for primary contact recreation occurred at all sampling sites during the 2023 sampling season (Table 4). Additionally, the two locations exceeded the 90-day geometric mean criterion of 126 colony counts/100mL. These exceedances may be due to sample collection during or following a wet-weather event, as defined in Table 4. Two of the five sampling dates were taken during or following a wet-weather event, which may lead to elevated *E. coli* densities due to urban runoff and potential sanitary sewer overflows. *E. coli* exceedances may also have been a result of domestic and/or wild animal waste and improper sanitary sewage connections upstream of the sampling locations.

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

Date	RM 2.50	RM 0.01
6/21/2023	238	228
6/28/2023*	689	15,780
7/6/2023	774	205,300
7/12/2023*	6,970	29,090
7/19/2023	816	2,620
90-day Geomean	937	8,915

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

*Wet-weather Event: greater than 0.10 inches of rain, but less than 0.25 inches, samples collected that day, and the following day are considered wet-weather samples; greater than 0.25 inches, the samples collected that day and the following two days are considered wet-weather samples.

E. coli exceedances have historically been observed at Green Creek, exceeding the 410 MPN/100mL threshold. Figure 3 below displays median *E. coli* densities between the 2013 and 2023 assessment years. The boxplot for the downstream sites contained the highest maximum and upper quartile results, and results are similar between the two sampling years.

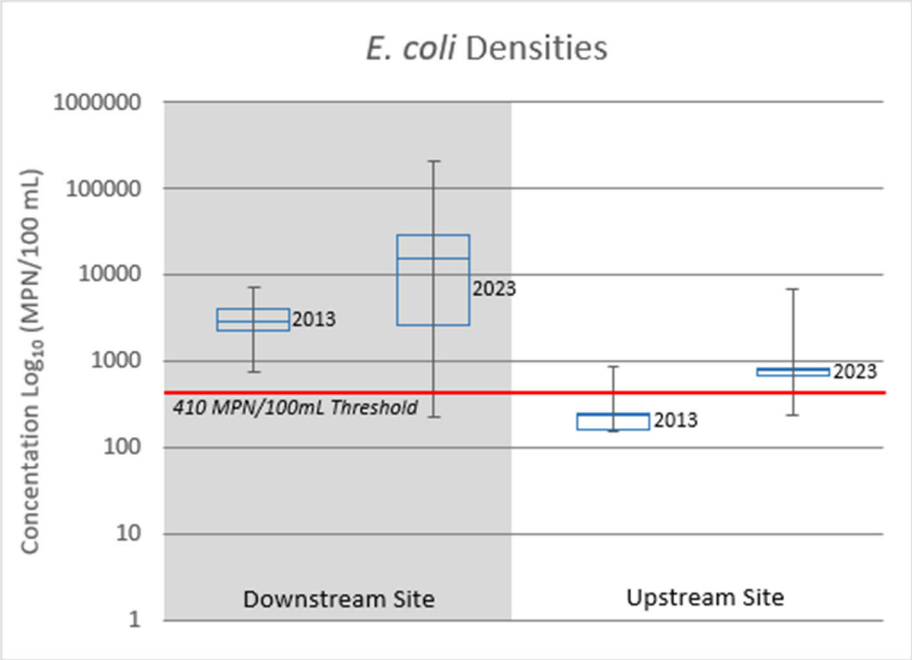

Figure 3. Historical *E. coli* Densities

The NEORSD entered a federal CSO LTCP consent decree with the United States EPA on June 30, 2011. This legally binding consent decree is a 25-year plan that outlines infrastructure investments that will reduce the amount of wastewater pollution entering Lake Erie. NEORSD currently possesses and maintains three CSOs that discharge directly to Green Creek, but only one is located upstream of RM 2.50 (Figure 1).

The LRRS project was completed in 2020 and is one of several projects included in the NEORSD's Consent Decree. The LRRS project provided surcharge relief for sewers tributary to the Ivanhoe-Holmes Branch Interceptor within the cities of Cleveland and East Cleveland to control CSOs to Nine-Mile Creek and Green Creek. Historically, three CSO locations along Green Creek activate about 30 times in a typical year, which results in the discharge of combined sewage into the creek. Following the completion of the LRRS project in 2020, all the CSOs to Green Creek are considered controlled through the CSO LTCP, meaning that they meet the US EPA's minimum control measures. As shown in Figure 4 below, the volume of combined sewage discharged into Green Creek was less than 0.15 million gallons in the years since the completion of the LRRS project. Overflow performance at regulators associated with permitted outfall CSO 214 are reported under CSO 207. NEORSD requested that CSO 214 be removed from the CSO permit as there is no discharge to a receiving water at this location; rather, all flows from CSO 214 discharge

to the environment at CSO 207. Therefore, model predicted flow volumes for CSO 214 and CSO 207 were combined in the figure below. Based on model estimates of the volume of discharge during a typical year, it is not expected that these CSOs have a significant impact on the overall water quality within Green Creek as CSO activation has been reduced to approximately once per year since 2020.

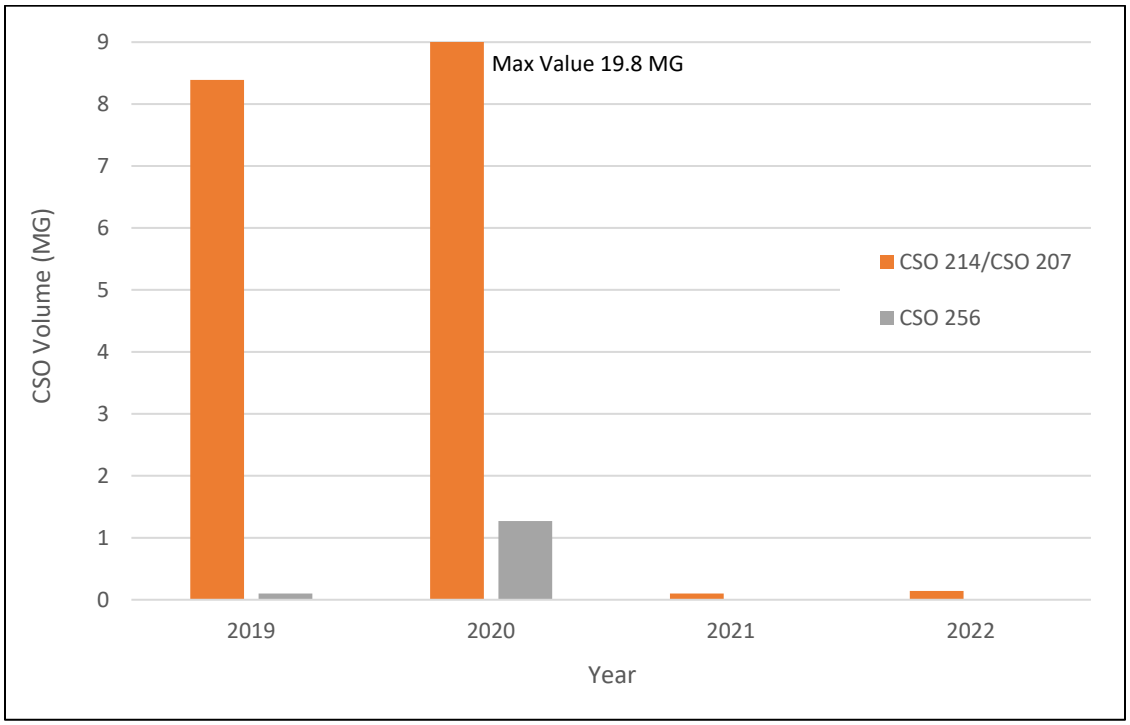

Figure 4. Overflow volumes (MG) for CSOs located along Green Creek 2019-2022

During the 2023 survey, there were no dry weather overflows reported at any of the three NEORSD-controlled CSOs along Green Creek. On July 6, 2023, there was a blockage in a local Cleveland Water Pollution Control sanitary sewer line that caused sanitary flow to enter Green Creek just upstream of RM 0.01. During field sampling, sanitary odors and debris were reported at the location, and the results show significantly higher *E. coli* results on that sampling date than the other dry weather sampling events as outlined in Table 4.

Water Column Chemistry Results and Discussion

Mercury pollution is not uncommon in the Great Lakes region. Coal fired power plants have historically lined the southern shores of Lake Erie. It was not until 2011 that the US Department of Energy established national standards to control mercury emissions. Three major coal fired power plants in the greater Cleveland area ceased operations in 2015 (Cleveland.com, 2015), as the parent company switched energy sources from coal over to natural gas. Other sources of mercury

to surface waters are from atmospheric deposition, impervious surface runoff (Fulkerson et al., 2007), and other NPDES permitted point sources within the watershed.

Mercury analysis for all the sampling events was done using EPA Method 245.1. Because the detection limit for this method is above the criteria for the Human Health Non-drinking and Protection of Wildlife Outside Mixing Zone Averages (OMZA), it generally cannot be determined if the sites were in attainment of those criteria. Instead, this type of mercury sampling was used as a screening tool to determine whether contamination was present above those levels typically found in the stream. On June 21, 2023, mercury was detected in both stream samples above the analytical method detection limit (MDL), but below the PQL; therefore the results are considered to be estimated (Table 5). Mercury was not detected above detection limits in any other samples collected.

Table 5. Mercury Samples Results Above Detection Limit

Location	Date	Parameter	Estimated Result	MDL	PQL
Green Creek RM 0.01	6/21/23	Total Mercury	0.022 µg/L	0.0199 µg/L	0.05 µg/L
Green Creek RM 2.50			0.024 µg/L	0.0199 µg/L	0.05 µg/L

For the protection of aquatic life, the minimum required dissolved oxygen (DO) criterion is 4 mg/L. Low DO levels can result from low-flow conditions, elevated water temperatures, and organic enrichment. Green Creek is almost completely culverted, with the exception of the headwaters, and under normal conditions the upstream reaches receive minimal flow. Even with low flow through Green Creek, no dissolved oxygen exceedances were observed in 2023 as all results were above the 4 mg/L threshold; a datasonde monitoring DO continuously would need to be utilized to better assess diel DO trends.

Stream Nutrient Assessment

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 DO swings, benthic chlorophyll *a*, total phosphorous, and dissolved inorganic nitrogen (Ohio EPA, 2015). Figure 5 shows the risk categories from the SNAP Table 2. NEORSD did not assess DO swings or benthic chlorophyll *a* in 2023; however, nutrients were assessed.

Nutrient data was collected at the Green Creek sample sites in 2023 during the summer months of May through October. Total Kjeldahl nitrogen (TKN), dissolved reactive phosphorus (DRP), total phosphorus (TP), total suspended solids (TSS), and biochemical oxygen demand (BOD) were collected at each site during water chemistry sampling. Of the total 10 sampling

events in 2023, two dates were completed during or after wet-weather events (see Table 4 for wet-weather dates). The Ohio EPA uses causal associations to determine the risk association between nutrients [TP and dissolved inorganic nitrogen (DIN)] and biological performance. Table 6 lists the annual geomeans for the Green Creek study and the narrative risk categories based on Miltner (2010).

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

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

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

Table 6. 2023 Nutrient Analysis (Geometric Means)

Sample Location	DIN * (mg/L)	NO_3-NO_2 (mg/L)	DRP (mg/L)	TP * (mg/L)	Risk Category [R]
RM 0.01	1.60	1.27	0.094	0.139	Medium
RM 2.50	0.44	0.40	0.043	0.061	Low

*Data used in Table 3 of SNAP (Ohio EPA, 2015)

[R] Risk Categories based on Miltner (2010)

Risk Category	Total Phosphorus	DIN
Low	<0.131	<1.10
Medium	≥0.131 and <0.4	≥1.10 and <3.6
High	≥0.4	≥3.6

The upstream location on Green Creek contained low nutrient concentrations, typical of background levels, and received a SNAP narrative rating of a low-risk category. This small headwater stream drains only 0.63 square miles of highly urban urbanized land cover. The majority of the upstream reaches of Green Creek flow through residential areas with minimal sanitary connections. This may have led to lower nutrient concentrations by allowing natural processes and nutrient uptake through this stretch.

In the 2013 study of Green Creek, the average concentrations of TP at RM 0.01 and RM 2.50 were 0.071 mg/L and 0.051 mg/L, respectively. At both sites, these nutrient levels were considered to be "concentrations typical of healthy streams in working landscapes". In 2023, the downstream section of Green Creek (RM 0.01) contained nutrient levels that were more typical of enriched conditions with a moderate-risk based on the TP geomean. Known CSO points and other possible illicit sanitary conditions upstream of this sample location remain unresolved by the local municipality. The lower section of Green Creek is developed with commercial/industrial facilities, densely urbanized, and the stream is predominately culverted. Stormwater runoff from highly urbanized watersheds is commonly associated with higher concentrations of bacteria, nutrients, and solids (Bannerman et al., 1993; Geldreich et al., 1968). These concentrations are exasperated during wet-weather events in urban watersheds (Mallin et al. 2008). Sanitary sewage contamination from illicit connections and the highly urban landscape of the culverted stream are likely the primary sources of nutrients.

Habitat Assessment

Methods

An instream habitat assessment was conducted at RM 2.50, the only site in this study that is an open channel, 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 (Ohio EPA, 1989). The QHEI can be used to assess and evaluate a stream's aquatic habitat and determine which of the habitat components need to be improved to reach the QHEI target score. The QHEI is completed at least once for a sampling site each year during the study. An exception to this would be when substantial changes to the macrohabitat have occurred between sampling passes.

The QHEI has a maximum score of 100, and a score greater than 55 for streams with less than 20 mi^2, which applies to the Green Creek site, suggests that sufficient habitat exists to support a fish community that attains the WWH criterion (Ohio EPA, 2006). Scores greater than 75 frequently demonstrate habitat conditions that have the ability to support exceptional warmwater fish communities. A more detailed description of the QHEI can be found in Ohio EPA's *Methods for*

Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI) (2006). QHEI field sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

Green Creek RM 2.50 was evaluated for physical habitat characteristics that are important in the support of fish communities. Between the two fish sampling passes (between August and September), a noticeable change in pool habitat occurred because the local municipality removed a logjam at the downstream end of the sampling zone; the QHEI scores are detailed in Table 7. The downstream portion of the creek is culverted, therefore no QHEI assessment was completed there.

During the August survey, the channel at RM 2.50 was impounded by a logjam, resulting in nearly 100 percent pool habitat, while silt and fine sands predominated the bottom substrates. The City of Euclid was notified of the stream logjam and removed the debris by the end of August. Following the return of free-flow conditions in September, most of the silt was washed away and gravel/cobble was the predominant substrate. It was noted in the second survey that sediment deposition was prevalent along the stream bank because the water level has dropped by over two feet. Figure 6 below shows Green Creek before (left) and after (right) woody debris removal.

Figure 6. Green Creek RM 2.50 in August 2023 (left) and September 2023 (right)

The QHEI assessment at RM 2.50 resulted in a mean score of $\bar{x}$ = 37 (*Poor*) which did not meet the Ohio EPA Warmwater QHEI target score of 55 for headwater streams, suggesting a lack of instream habitat to support a diverse warmwater fish assemblage. The reach displayed recovering from channelization simply due to the downstream section of the stream being channelized by timber walls that have failed and the stream eroding into the hillside (Figure 7). Erosion in this area is exasperated by the lack of riparian wooded vegetation and residential property on river right. The lack of sufficient instream cover and riffle areas reduced the overall

QHEI scores compared with larger free-flowing streams. Suitable riffle habitat was lacking in this stream stretch in 2023 simply because of the small drainage area and low flow through the stream system. In 2013, a QHEI score of 48 was calculated with a narrative rating of *Fair*. This higher QHEI score was due to increased instream cover and a greater riffle habitat.

Figure 7. Green Creek RM 2.50 in 2013 (left) and in 2023 (right)

Various attributes of stream habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional fish communities. Individual components of the QHEI can be used to evaluate whether a site is capable of meeting its WWH designated use. This is done by categorizing specific attributes as indicative of either a WWH or modified warmwater habitat (MWH) (Rankin, 1995). Attributes that are considered characteristic of MWH are further classified as being a moderate or high influence on fish communities. The presence of one high or four moderate influence characteristics has been found to result in lower IBI scores, with a greater prevalence of these characteristics usually preventing a site from meeting WWH attainment (Ohio EPA, 1999).

Table 7 describes the QHEI scores and physical attributes for each stream segment and determines the influence each parameter has on the QHEI score. As negative habitat attributes begin to outnumber positive stream habitat characteristics, there is higher potential for habitat quality to limit the biological performance at a site (Rankin, 1989). MWH attributes outnumbered WWH attributes at RM 2.50 and showed a high MWH/WWH ratio (Table 7). Typically, as the MWH/WWH ratio increases above 2:1, there is a higher likelihood that the lack of instream habitat leads to degraded biological performance and impairments.

Table 7. 2023 Green Creek QHEI Scores and Physical Attributes

			MWH Attributes																																
			WWH Attributes											High Influence						Moderate Influence																
Stream Site	**QHEI Score**	**Narrative Rating**	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max. Depth >40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or no Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW sites)	**Total High Influence Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total Moderate Influence Attributes**	**(MWH-H.I.+1) / (WWH+1) Ratio**	**(MWH M.I.+1) / (WWH+1) Ratio**
2.50 (8/10/23)	33	*Poor*		X							X		**2**	X	X		X		**3**	X	X		X	X	X		X	X		X	**8**	**1.3**	**3.0**
2.50 (9/25/23)	41	*Poor*		X					X	X			**3**				X	X	**2**	X	X		X	X				X		X	**6**	**0.8**	**1.8**
Average	37	*Poor*																																	

Fish Community Biology Assessment

Methods

Two quantitative electrofishing assessments were conducted at Green Creek RM 2.50 in 2023. Sampling was conducted using longline electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from downstream to upstream. The sampling zone was 0.15 kilometers for each site and followed the Ohio EPA methods as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Fish collected during the surveys were identified, weighed, and examined for the presence of anomalies, including DELTs (deformities, eroded fins, lesions, and tumors). All fish were then released to the waters from which they were collected, except for vouchers and those that could not be easily identified in the field.

The electrofishing results were compiled and utilized to evaluate fish community health. The Index of Biotic Integrity (IBI) incorporates twelve community metrics representing structural and functional attributes (Table 8). The structural attributes are based upon fish community aspects such as fish abundance and diversity. The functional attributes are based upon fish community aspects such as feeding strategies, environmental tolerances, and disease symptoms. These metrics are individually scored by comparing the data collected at the survey site with values expected at reference sites located in a similar geographical region. The maximum possible IBI score is 60 and the minimum possible score is 12. The summation of the 12 individual metrics scores provides a single-value IBI score, which corresponds to a narrative rating of *Exceptional, Good, Marginally Good, Fair, Poor* or *Very Poor*.

Table 8. IBI Metrics
Total Number of Native Fish Species
Number of Darter Species
Number of Headwater Species
Number of Minnow Species
Number of Intolerant Species
Percent Tolerant Species
Percent Omnivore Species
Percent Insectivore Species
Percent of Pioneering Species
Number of Individuals in a Sample
Number of Simple Lithophilic Spawners
Percent of Individuals with DELTs

Green Creek is located completely within the Erie-Ontario Lake Plains (EOLP) ecoregion and follows the EOLP fish community metric scoring. The WWH IBI scoring criterion in the EOLP ecoregion is 40 and sites are considered to be within non-significant departure if the score falls within 4 IBI units of the criterion (Table 9). Lists of the species diversity, abundance, pollution tolerances, and incidence of DELT anomalies for fish collected during the electrofishing passes at RM 2.50 are available upon request from the NEORSD WQIS Division.

Table 9. Fish Community Biology Scores for Headwater Sites in the EOLP Ecoregion

Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
IBI Score	12-17	18-27	28-35	36-39	40-45	46-49	50-60
Ohio EPA Status	Non-Attainment			NSD	Attainment		

NSD – Non-Significant Departure of WWH attainment

Results and Discussion

The NEORSD collected 397 total fish from Green Creek RM 2.50 with two electrofishing passes completed in 2023. The IBI scores from each assessment are listed below in Table 10. Only one species of fish (Creek Chub) was collected from Green Creek and IBI scores averaged $\bar{x}$ = 19 (*Poor*) across the two assessments, reflecting the poor fish community within the stream. In Ohio headwater streams, darter species, headwater species and simple lithophilic spawning species are important components in the IBI scoring; none of which were present in the 2023 survey. Comparing the fish community metric scores between 2023 and 2013, the last time that this site was surveyed, the scores remained the same with an IBI score of 20 from the 2013 survey, again with only Creek Chub present, which is considered highly pollution tolerant. The fish community within Green Creek is comprised of a single species that is highly tolerant to pollution, demonstrating the inability of this section of stream to support a healthy fish community.

Table 10. 2023 Green Creek Fish Community Assessment Scores

Stream RM	Total Number of Fish	Predominant Species (%)	% of DELTS	IBI Score	Average IBI Score
2.50 *1st Pass*	287	Creek Chub (100%)	0.70	18*	19* (Poor)
2.50 *2nd Pass*	110	Creek Chub (100%)	0.00	20*	

* Significant departure from the biocriterion *(>4 IBI units*)

Degraded water quality indicated by *E. coli* exceedances may be contributing to the lack of pollution-intolerant species. Additionally, Green Creek is extensively culverted from Lake Erie, to immediately downstream of the electrofishing zone at RM 2.50, decreasing the site accessibility to fish populations. Additionally, the culvert outfall opening at Lake Erie is typically higher than the water level of the lake which acts as a fish barrier between the lake and Green Creek.

Stream habitat plays a major role in the fish community observed in this section of stream. The lack of a riffle within the zone contributes to the low darter and headwater species abundance observed. The lack of current velocity within the stream to form a suitable riffle also deposits fine sand, silt, and shale along the substrate and does not offer adequate interstitial spaces between larger rocks for simple lithophilic spawning fish to successfully spawn. As noted in the physical habitat section, fine sediments were predominant bottom substrates within the fish sampling zone. Excessive fine-grained sediments have a major impact on the degradation of stream fish communities (Waters, 1995). The corresponding effects of the urbanized land surrounding Green Creek and influences from pollution are evident in the simplified fish community.

Macroinvertebrate Community Biology Assessment

Methods

Macroinvertebrates were sampled at Green Creek using a single qualitative (qual.) assessment of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), also referred to as EPT taxa, inhabiting available habitats at the time of sampling. The macroinvertebrate samples were sent to Third Rock Consultants, LLC for identification and enumeration. Specimens were identified to the lowest practical taxonomic level as defined by the Ohio EPA (1987b). Lists of the species collected during the quantitative and qualitative sampling at each site are available upon request from the NEORSD WQIS Division.

The macroinvertebrate sampling methods followed Ohio EPA protocols as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Sampling was only conducted at the open stream channel at RM 2.50. A Hester-Dendy (HD) sampler was not installed at Green Creek RM 2.50 due to unsuitable conditions for HD installation. The aquatic macroinvertebrate community at RM 2.50 was evaluated using 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 from the ten-year period between 2005 and 2014 (threshold limit model analysis available upon request). Table 13 provides the expectation threshold limits for qualitative total taxa, qualitative EPT taxa, and qualitative sensitive taxa metrics for headwater drainage areas. Figures 8 through 10 provide distributions of these metrics grouped by Invertebrate Community Index (ICI) narrative rating category developed by NEORSD in comparison with the expectation threshold limits from Table 13.

Table 11. 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

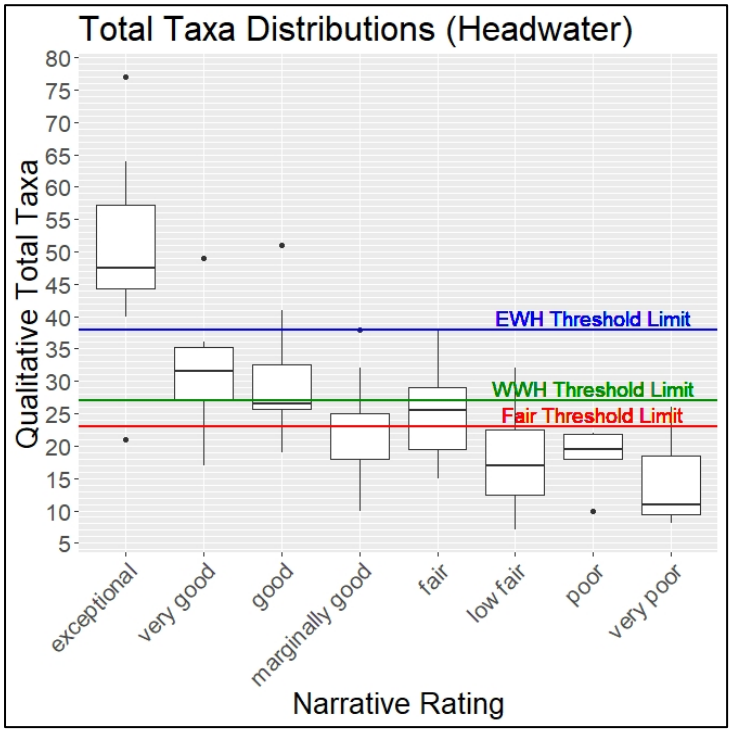

Figure 8. Distribution of the number of qualitative total taxa in EOLP headwater streams grouped by ICI score narrative rating category with expectation threshold limits developed by NEORSD.

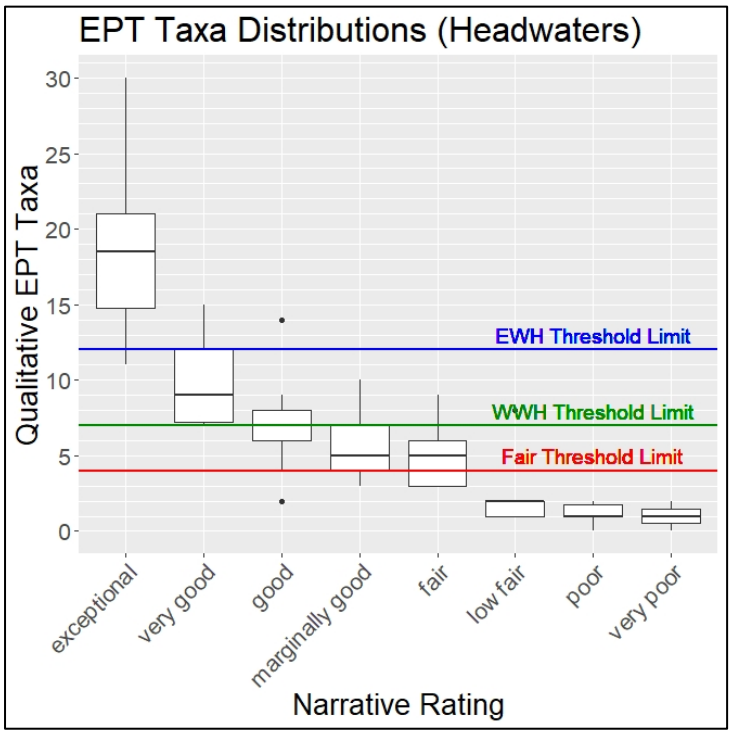

Figure 9. Distribution of the number of qualitative EPT taxa in EOLP headwater streams grouped by ICI score narrative rating category with expectation threshold limits developed by NEORSD.

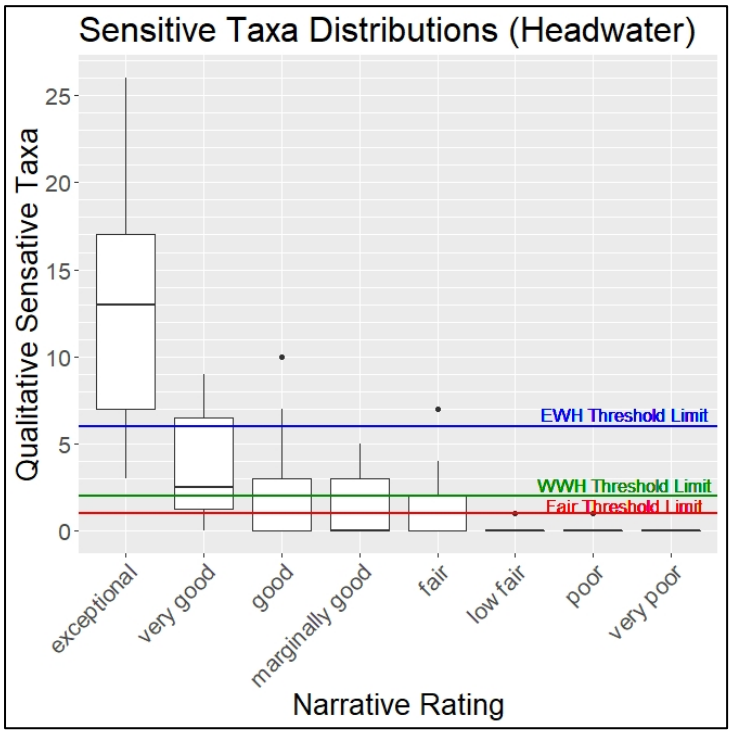

Figure 10. Distribution of the number of qualitative sensitive taxa in EOLP headwater streams grouped by ICI score narrative rating category with threshold limits developed by NEORSD

Results and Discussion

Green Creek RM 2.50 has a drainage area of 0.6 square miles placing it on the low end of the headwater drainage area category. A narrative rating assessment was performed for Green Creek RM 2.50 based on data from a qualitative sampling conducted on July 17, 2023, and by utilizing the best professional judgment of the leading field QDCs. Factors considered in the assignment of narrative ratings include but are not limited to: historical site data; total site drainage area; macroinvertebrate population composition in the qualitative sample with respect to the number of total taxa, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa, pollution-sensitive taxa, and pollution-tolerant taxa; and organism abundance within individual families or groups noted during sample collection. Based on the field assessment and NEORSD models, the benthic macroinvertebrate community at RM 2.50 was in non-attainment of the ICI WWH designated use criterion with a narrative rating of *Very Poor*.

A total of 15 taxa were collected in the 2023 qualitative sample which scores below the *Fair* expectation for a headwater stream. One EPT taxa, *Baetis flavistriga*, was collected which scores well below the *Fair* expectation for number of EPT taxa. No sensitive taxa were collected which also scores below the *Fair* expectation. Field observations from the qualitative kick sample conducted on July 14, 2023, indicated that the most predominant group sampled was Chironomidae. RM 2.50 was therefore assigned a field narrative rating of *Very Poor* at the time of sample collection.

Table 14 provides a summary of the 2023 Green Creek RM 2.50 macroinvertebrate data as well as a comparison to 2013 data. HD samplers have never been deployed at Green Creek due to the inability of the site to meet the required minimal current velocity of 0.3 feet per second over the HD. Both 2023 and 2013 sampling events consisted of a single round of qualitative kick sampling to assess the macroinvertebrate community. Four EPT taxa were collected in 2013 versus a single species in 2023. A total of eleven taxa were identified in the qualitative sample in 2013 compared to 15 taxa in 2023. Two coldwater taxa, *Zavrelimyia sp*. and *Parametriocnemus sp*., were collected at the site in 2023. The pollution tolerance of the identified taxa during both surveys ranged from moderately intolerant to tolerant with the majority of the taxa being categorized as facultative. Turbellaria has been the most predominant organism found in each survey and Green Creek was assigned a narrative rating of *Poor-Very Poor* in each of the last two surveys.

Table 12. Green Creek Macroinvertebrate Results

Stream RM	Survey Year	Density / Ql.	Ql. Total Taxa	Ql. EPT / Sens. Taxa	Predominant Orgs. on Natural Substrate	Narrative Evaluation
2.50	2013	L	11	4/1	Turbellaria, Chironomidae	*Poor*
	2023	L	15	1/0	Turbellaria, Chironomidae	*Very Poor*

Ql. - Qualitative sample collected from natural stream substrate.
Qualitative sample relative density: L=Low, M=Moderate, H=High
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List (2019) as *Moderately Intolerant or Intolerant* - Polycentropus sp. was collected in 2013

Substrate embeddedness and increased siltation was observed at the field site by NEORSD field staff in 2023, which could also have a negative effect on the overall macroinvertebrate community. Urban development, impervious surfaces, and storm sewers may cause higher erosion rates in the upstream reaches and increase substrate embeddedness throughout the survey site. Low stream gradient, stream channelization, sparse instream cover, poor marginal habitat, and potential sanitary sewage contamination indicated by elevated levels of *E. coli* may also contribute to the lack of a healthy macroinvertebrate community within Green Creek.

Conclusions

The Ohio Administrative Code 3745-1-07 (Ohio EPA, 2022a) indicates that the chemical criteria for the protection of human health, aquatic life (warmwater), and wildlife apply to all surface waters of the state unless designated otherwise. Therefore, the WWH aquatic life habitat use designation was applied to Green Creek for comparison purposes in this study. According to the Ohio EPA (2022b), WWH are capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater organisms having a species composition, diversity, and functional organization comparable to the twenty-fifth percentile of the identified reference sites within its respective ecoregion.

The results of NEORSD's 2023 Green Creek study, which included water chemistry sampling, habitat assessments, and fish/benthic macroinvertebrate community surveys, indicate limiting conditions exist within Green Creek. Green Creek was not found to be in attainment of the designated ALU criteria at RM 2.50 during the 2023 sampling season (Table 15).

Table 13. 2023 Green Creek Biological Survey Results

RM	DA (mi^2)	Attainment Status	IBI Score	ICI Score	QHEI Score	Cause(s)	Source(s)
2.50[H]	0.6	Non	19*	VP	37	Sedimentation, Low flow gradient, Pollutants in urban stormwater, and Poor habitat.	Urban runoff/stormwater, Atmospheric deposition, urbanization, and culverted stream reaches.

* Significant departure from the biocriterion (>4 ICI; >4 IBI; >0.5 MIwb units).
Underlined scores are in the *Poor* or *Very Poor* narrative range
[H] Headwater scoring criteria
[NS] Non-significant departure of WWH of biocriterion (≤ 4ICI; ≤ 4IBI; ≤ 0.5 MIwb units)

The results of water chemistry sampling, habitat assessments, and fish/benthic macroinvertebrate community surveys conducted by NEORSD indicate that the Green Creek watershed may be impacted by a variety of environmental stressors, as mentioned previously. As

in years past, assessments in 2023 showed water quality impairments within Green Creek which may be preventing the establishment of a healthier biological community. Water chemistry sampling found exceedances of the applicable water quality standards occurred for *E. coli* densities during four of the five sampling events. This is common in urbanized watersheds due to improper sanitary connections, combined sewer overflows, failing household sewage treatment systems, and urban stormwater runoff.

Most of the mercury results in 2023 were below the method detection limit. Because the detection limit for EPA Method 245.1 is above the criteria for the Human Health Non-Drinking and Protection of Wildlife OMZAs, it cannot be determined if the sites were in attainment of those criteria. Periodic toxic concentrations of mercury due to urban runoff may be one of the causes for the low abundance of fish species in Green Creek.

Biological communities have continued to be in the poor range over the last decade. With a QHEI score of 37, stream habitat in Green Creek was found to be in poor condition, which falls short of the target score of 55 to support a warmwater fish community. Green Creek has exhibited a *Poor* fish community score that is impacted by multiple attributes as mentioned earlier. Sedimentation from urban runoff and high *E. coli* appear to be the main causes of the impairments to the fish community component. The macroinvertebrate communities received a narrative rating of *Very Poor* during the 2023 study. The macroinvertebrate assemblage was comprised primarily of pollution-tolerant and moderately-tolerant species. Overall, historical monitoring of Green Creek has not shown improvements in water quality or aquatic biology over time.

The highly developed and urban landscape surrounding Green Creek may have a negative effect on the overall water quality and a degradation of aquatic biota. As previously mentioned, Green Creek is almost completely culverted, with the exception of the very upstream headwater reaches, and there is minimal baseline flow through Green Creek during non-wet weather events. The local municipalities participating in the Member Community Infrastructure Program (MCIP) and continued efforts by NEORSD towards the CSO LTCP, as part of *Project Clean Lake*, have reduced sanitary sewer overflows in Green Creek. Even with the reduction in CSO events upstream of the site, the site still is in an enriched condition with water quality impairments. In its current state, Green Creek unlikely can attain the WWH ALU without significant restoration efforts.

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