



Biological and Water Quality Study of the Lake Erie Central Basin Tributaries

Lorain, Cuyahoga, Lake, and Ashtabula Counties, Ohio



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Table of Contents

Executive Summary.....1

Recommendations 13

 Beneficial Uses..... 13

 Improvements to Water Quality 15

Introduction 16

Study Area Description..... 21

Results and Discussion..... 25

 Macroinvertebrate Community..... 25

 Cuyahoga County 31

 Lake County 34

 Ashtabula County..... 34

 Fish Community 42

 Stream Physical Habitat..... 56

 NPDES Permitted Facilities 65

 Water Chemistry..... 71

 Grab Results..... 71

 Water Quality Sonde Results 75

 Weight of Evidence Nutrient Evaluation 78

 Sediment Chemistry 83

 Organic Sediment Results 87

 Recreation Use..... 91

Acknowledgements 96

References..... 97

List of Tables

Table 1. Aquatic life use attainment status for sampling locations in the Lake Erie Central Basin Tributaries study area, 2015.....	3
Table 2. Lake Erie Central Basin Tributaries study area streams that are unlisted or assigned unverified aquatic life uses in Ohio Water Quality Standards. The streams are recommended for warmwater habitat, exceptional warmwater habitat, or coldwater habitat aquatic life uses. The coldwater habitat recommended sites are based on biological sampling alone.....	13
Table 3. Existing and recommended beneficial use designations for water bodies within the Central Basin Lake Erie Tributaries study area.	14
Table 4. Lake Erie Central Basin tributaries sampling stations, 2015 (listed by stream name and stream code).	18
Table 5. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Lake Erie Central Basin Tributaries study area, June to September 2015.....	26
Table 6. Uncommonly collected sensitive macroinvertebrate taxa locations in Lorain, Cuyahoga, and Lake counties in the Lake Erie Central Basin Tributaries study area, June to September 2015.....	30
Table 7. Uncommonly collected sensitive macroinvertebrate taxa and all freshwater mussel locations in Ashtabula County in the Lake Erie Central Basin Tributaries study area, June to September 2015. State listed species: E=Endangered, SC= Species of Concern.	30
Table 8. Summary of fish community data based on wading, pulsed D.C. electrofishing samples collected in the Lake Erie study area, 2015 (no boat sampling occurred).	43
Table 9. Qualitative Habitat Evaluation Index (QHEI) matrix with warmwater habitat (WWH) and modified warmwater habitat (MWH) attribute totals and ratios for the Lake Erie study area, 2015.....	58
Table 10. Facilities regulated by an Individual NPDES permit in the study area.	65
Table 11. Concentrations of monitored chemicals in effluent discharged from six facilities in the Lake Erie tributaries study area.	69
Table 12. Exceedances of Ohio Water Quality Standards criteria (OAC3745-1) for chemical/physical parameters measured in the Ohio Tributaries to the Lake Erie Central Basin Tributaries study area, 2015. Bacteria exceedances are presented in the Recreation Use Section.	74
Table 13. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring.	77
Table 14. Nutrient sampling results in the Lake Erie Central Basin Tributaries, summer (June 15 – October 15) 2015.....	82
Table 15. Chemical parameters collected by Ohio EPA from surficial sediments in 2015.....	84
Table 16. Sediment organic chemicals measured above screening levels in samples collected by Ohio EPA from surficial sediments in the Lake Erie Tributaries study area, 2015.....	89
Table 17. Statewide numerical criteria for the protection of recreation uses. These criteria apply inside and outside the mixing zone at all times during the recreation season.	92
Table 18. A summary of E. coli data for locations sampled in the Lake Erie Tributaries watershed (June 15 th , 2015 – Sept. 16 th , 2015).....	93

List of Figures

Figure 1. Attainment status of the Lake Erie Central Basin Tributaries study area. 42% of the sites sampled in the study area met their designated aquatic life use biocriteria.	1
Figure 2. Attainment status of the Lake Erie Central Basin Tributaries study area by land development percentages.	1
Figure 3. Aquatic life use attainment status of Lake Erie Central Basin Tributaries in Lorain County, 2015. Labels refer to station codes referenced in Table 1.	9
Figure 4. Aquatic life use Attainment status of the Lake Erie Central Basin Tributaries in Cuyahoga County, 2015. Labels refer to station codes referenced in Table 1.	10
Figure 5. Aquatic life use attainment status of Lake Erie Central Basin Tributaries in Lake and western Ashtabula counties, 2015. Labels refer to station codes referenced in Table 1.	11
Figure 6. Aquatic life use attainment status of Lake Erie Central Basin Tributaries in eastern Ashtabula County, 2015. Labels refer to station codes referenced in Table 1.	12
Figure 7. Locations of the Lake Erie Central Basin Tributaries within the geopolitical boundaries of Ohio.	16
Figure 8. Land use in the Lake Erie Central Basin Tributaries study area, 2015.	22
Figure 9. Land uses in the Pennsylvania portion of the Conneaut Creek watershed (USGS Stream Stats, NLCD 2016). Land uses within a 200m buffer of Conneaut Creek are highlighted. Please refer to Figure 8 for a land use key.	24
Figure 10. Doan Brook, RM 2.27, upstream view. Throughout this reach, Doan Brook is a concrete lined and channelized with a series of dams. Like all the streams sampled in Cuyahoga County, legacy sediment contamination, CSOs, habitat alteration, and urban runoff severely impact the macroinvertebrate community in this watershed.	32
Figure 11. Location of CSOs within the NEORS D survey area.	33
Figure 12. Tributary to Conneaut Creek at RM 17.1 at State Road, upstream view. This stream had an exceptional and coldwater macroinvertebrate community.	34
Figure 13. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Beaver Creek, 2015.	36
Figure 14. Longitudinal trend of the number of sensitive taxa in the qualitative sample and number of EPT taxa (EPT) in the qualitative sample in Doan Brook, 2015.	37
Figure 15. Longitudinal trend of the number of sensitive taxa in the qualitative sample and number of EPT taxa (EPT) in the qualitative sample in Euclid Creek, 2015.	38
Figure 16. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Arcola Creek, 2015.	39
Figure 17. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Cowles Creek, 2015.	40
Figure 18. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Conneaut Creek, 2015.	41
Figure 19. Longitudinal performance of the Index of Biotic Integrity (IBI) in Beaver Creek, 1992-2015.	48
Figure 20. Longitudinal performance of the Index of Biotic Integrity (IBI) in Arcola Creek, 1995-2015.	50
Figure 21. Longitudinal performance of the Index of Biotic Integrity (IBI) in Cowles Creek, 1981-2015.	52
Figure 22. Longitudinal performance of the Index of Biotic Integrity (IBI, upper plot) and of the Modified Index of well-being (MIwb, lower plot) in Conneaut Creek, 1989-2015.	54

Figure 23. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in Beaver Creek, 1992-2015	61
Figure 24. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in Arcola Creek, 1995-2015.	63
Figure 25. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in in Cowles Creek, 1981-2015 (upper plot) Conneaut Creek, 1989-2015 (lower plot).....	64
Figure 26. Madison WWTP outfall 001 data, 2000-2018	68
Figure 27. Daily average flow conditions in Euclid Creek at the USGS gage at Cleveland OH in 2015 (USGS, 2018)	72
Figure 28. Daily average flow conditions in Conneaut Creek at the USGS gage at Conneaut OH in 2015 (USGS, 2018)	72
Figure 29. Graph of average daily streamflow (USGS 04213000 – Conneaut Creek at Conneaut OH) relative to the median streamflow and normal daily air temperature (NOAA – GHCND:USC 00336389) for the sampling season.....	76
Figure 30. Longitudinal representation of diel DO, benthic/ sestonic chlorophyll-a, total phosphorus, and DIN used to evaluate the impact of nutrients on the Lake Erie Tributaries. Relevant benchmarks for chlorophyll-a and nutrient concentrations (Dodds 2006, Miltner 2010, Ohio EPA 2014) are presented within their respective plots. Boxes on DO plots are shaded if the diel range exceeds the benchmarks of 6.5 mg/L (Miltner, 2010).	80
Figure 31. Longitudinal representation of diel DO, benthic/ sestonic chlorophyll-a, total phosphorus, and DIN used to evaluate the impact of nutrients on the Lake Erie Tributaries. Relevant benchmarks for chlorophyll-a and nutrient concentrations (Dodds 2006, Miltner 2010, Ohio EPA 2014) are presented within their respective plots. Boxes on DO plots are shaded if the diel range exceeds the benchmarks of 6.5 mg/L (Miltner, 2010).	81
Figure 32. Sediment sampling locations for the Lake Erie Central Basin Tributaries study area, 2015.	83

Executive Summary

Rivers and streams in Ohio support a variety of uses such as recreation, water supply, and aquatic life. As part of the biological and water quality survey process, Ohio EPA evaluates streams to determine appropriate use designations and if current uses are meeting the goals of the Federal Clean Water Act. In 2015, chemical, physical, and biological sampling was conducted on 38 streams totaling 74 sites throughout the Lake Erie Central Basin Tributaries in northeast Ohio. Of the 74 sites, 57 sites included chemical sampling while 66 sites were assessed for biological attainment. As a result of previous biological surveys, six streams are listed in the Ohio Water Quality Standards (WQS) with the Warmwater Habitat (WWH) aquatic life use (ALU) designation, and one stream is listed with the Exceptional Warmwater Habitat (EWH) ALU. The WWH use was confirmed based on the 2015 survey results for eight streams, with previously unverified ALU designations. Additionally, the WWH use is recommended for 13 streams throughout the surveyed area. Higher quality recommendations, such as EWH was determined for one stream. Coldwater Habitat (CWH) were determined for seven streams, based on biological evaluations alone (Table 1).

Of the 66 sites assessed for ALUs, 28 sites (42.4%) were fully meeting their assigned or recommended ALU, nine sites (13.6%) were in partial attainment, and 29 sites (43.9%) were in non-attainment (Figure 1). Urban runoff/storm sewers and combined sewage overflows (CSOs), in addition to natural habitat and flow conditions, contributed to most of the ALU impairment. In addition to other sources, contaminated sediments account for (7.7%) of nonattainment. Figure 3 through Figure 6 show the locations and attainment statuses of the individual sites.

Of the 66 sites assessed, 23 were assessed for the first time. Small streams associated with municipal areas comprised a large part of the study area. In this survey, 80% of the streams sampled were considered headwater streams (< 20 square mile drainage area) and had only 30% full attainment evaluations. Compare this with 92% full attainment for streams over 20 square miles. Land use and impervious area have been shown to influence biological integrity. Figure 2 shows attainment status by land development percentages. Once developed land percentages exceed 30, full attainment of biological criteria was not achieved. Of the study area sites, 22% were in the Greater Cleveland area. Doan Brook, Euclid Creek, and Ninemile Creek are heavily urbanized and influenced by combined sewer overflows (these accounted for over half of the non-attaining sites). A long-term plan is currently being implemented to address the combined sewer overflows.

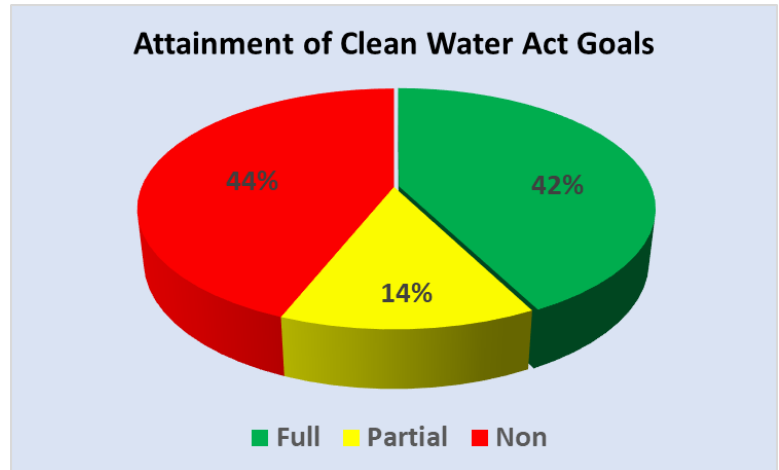
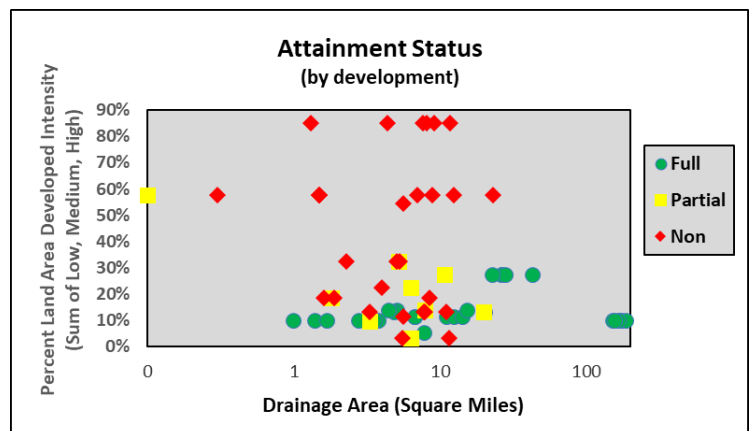


Figure 1. Attainment status of the Lake Erie Central Basin Tributaries study area. 42% of the sites sampled in the study area met their designated aquatic life use biocriteria.



Macroinvertebrate communities were assessed at 67 sites throughout the study area. The macroinvertebrate community quality was evaluated as exceptional at 12 sites; very good at three sites; good at 17 sites; marginally good at five sites; fair at nine sites, low fair at seven sites; poor at 11 sites and very poor at three sites. Within the sites evaluated, seven streams are recommended to be designated as coldwater habitat (CWH), due in part to the macroinvertebrate communities found. All five of these sites are within the Conneaut Creek watershed. Additionally, a new state record for a caddisfly, *Brachycentrus nigrosoma*, was collected in the watershed and listed as Endangered as a result of this survey.

Fish communities cumulatively comprised by 60 species were assessed at 63 sites in 2015 and four sites in 2016. Sixteen sites that supported poor fish assemblages occurred within heavily urbanized areas in Lorain and Cuyahoga counties. A novel native silver lamprey ammocoete was collected in Arcola Creek. Invasive, parasitic sea lamprey were not observed in Arcola, Cowles and Wheeler Creeks. Six Conneaut Creek locations achieved exceptional fish index scores. An increased abundance of pollution tolerant creek chubs with a decrease of pollution intolerant river chubs was noted based on data from 1989 to present. River chubs are a known non-target species effected by lampricide application. Since 1986, Conneaut Creek has been treated to eradicate sea lampreys at least nine times. Ohio EPA evaluated Turkey Creek for the first time in 2015. The presence of a mottled sculpin and absence of invasive round goby was a pleasant surprise.

Water quality samples were collected from 57 sites in the study area. Single sample dissolved oxygen (DO) levels were found below the minimum water quality standards at 10 sites a total of 17 times during the sampling season. Single sample exceedances for Iron occurred at three locations a total of five times in Cowles, Indian, and Arcola creeks. There was a one-time exceedance of selenium at an unnamed tributary to Euclid Creek at Anderson Road. Detections of organic contaminants occurred in three streams during the survey. Arcola Creek had detections of dieldrin, lindane, and endrin at three separate locations in 2015. Dieldrin, an organochlorine pesticide persistent in soils and sediments, exceeded the criteria for the protection of human health. Red Mill and Church creeks had detections of BHC-delta, an isomer formed from the degradation of the pesticide lindane, during additional sampling conducted in 2016.

Sediment samples were collected at 24 locations throughout the survey locations. No ALU impairments were found; however, heavily urbanized areas had certain heavy metals such as As, Pb, Ni, and Zn values above Sediment Reference Values (SRVs) and Threshold Effect Concentrations (TEC). None of these heavy metal analytes fell above the Probable Effect Concentrations (PEC), therefore the risk of toxicity to aquatic organisms is low. Organic sediment results exceeded the PEC for both PAHs and PCBs in several streams, indicating probable ecotoxic effects.

Evaluation of *E. coli* bacteria results revealed that 49 of the 51 locations did not attain the applicable geometric mean recreation use criterion, indicating non-attainment at these locations. The only sites that met Ohio's water quality standards were East Branch Euclid Creek near the mouth (RM 0.2) and an unnamed tributary to Arcola Creek (RM 4.32) at RM 0.1. Most of the study area lies within heavily urbanized areas and major sources of bacteria can be attributed to combined sewage overflows, separate sewage overflows, wastewater treatment plant effluents, and failing household sewage treatment systems (HSTS). Non-attainment in more rural areas, like Conneaut and Turkey creeks, can be attributed to wildlife and agricultural runoff, as well as failing HSTS.

Table 1. Aquatic life use attainment status for sampling locations in the Lake Erie Central Basin Tributaries study area, 2015.

The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. Stream habitat, as measured by the Qualitative Habitat Evaluation Index (QHEI), reflects the ability to support a biological community. The Lake Erie Central Basin Tributaries study area is located within the Erie Ontario Lake Plain (EOLP) ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. NA=not applicable

Station	Location	Assess. Unit (04)	RM ^a	DA ^b	IBI	MIwb ^c	ICI ^d	QHEI	Attainment ^e	Causes	Sources
Brownhelm Creek (20-100-000) Verified WWH											
303268	adj. Baumhart Rd.	110001 07 03	0.90 ^H	5.2	32*	-	MG ^{NS}	50.5	PARTIAL	Natural causes (flow or habitat)	Natural sources
Quarry Creek (20-101-000) Verified WWH											
303271	via FirstEnergy's access Rd.	110001 07 03	0.25 ^H	5.1	30*	-	<u>P</u> *	34.5	NON	Direct habitat alteration, sedimentation/siltation	Habitat modification (other than hydromodification)
Beaver Creek (20-003-000) WWH Existing											
303263	Quarry Rd.	110001 07 01	13.75 ^H	6.3	30*	-	G	54.5	PARTIAL	Low flow alterations	Hydromodification (quarries), crop production with subsurface drainage, agriculture
Y01S26	Russia Rd.	110001 07 01	11.02 ^H	11.5	30*	-	F*	51.0	NON	Natural causes (flow or habitat)	Natural sources
Y01S25	Middle Ridge Rd.	110001 07 02	6.95 ^W	23.0	34 ^{NS}	7.9	46	52.0	FULL		
303265	ust. Amherst WWTP	110001 07 02	4.00 ^W	26.7	46	8.7	G	67.5	FULL		
303264	dst. Amherst WWTP	110001 07 02	3.80 ^W	26.7	42	8.4	36	62.0	FULL		
Y01S23	Cooper Forest Park Rd.	110001 07 02	2.90 ^W	28.0	42	9.0	36	56.5	FULL		
Y01S22	Longbrook Rd. (Yorktown Rd.)	110001 07 02	1.75 ^W	43.0	40	9.7	44	68.5	FULL		
Willow Creek (Beaver RM 2.0) (20-005-000) Recommended WWH											
303267	SR 58	110001 07 02	1.25 ^H	10.7	36 ^{NS}	-	F*	52.5	PARTIAL	Pollutants in urban storm water, other flow regime alterations	Urban runoff/storm sewers
Squires Squamm Ditch (Beaver RM 9.41) (20-003-002) Recommended WWH											
303266	Annis Rd.	110001 07 01	1.30 ^H	5.5	36 ^{NS}	-	<u>P</u> *	50.0	NON	Natural causes (flow or habitat)	Natural sources (wetland)
Martin Run (20-004-000) Verified WWH											

Station	Location	Assess. Unit (04)	RM ^a	DA ^b	IBI	MIwb ^c	ICI ^d	QHEI	Attainment ^e	Causes	Sources
303269	at Tower Rd.	110001 07 03	2.35 ^H	2.3	<u>26*</u>	-	LF*	67.0	NON	Direct habitat alteration, other flow regime alterations	Urban runoff/storm sewers
303270	at Meister Rd.	110001 07 03	0.90 ^H	5.3	<u>24*</u>	-	LF*	57.5	NON	Direct habitat alteration, other flow regime alterations	Channelization, urban runoff/storm sewers
Doan Brook (19-039-000) WWH Existing											
F01G52	dst. Lee Rd.	110003 05 04	6.64 ^H	1.3	<u>26*</u>	-	VP*	62.0	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alterations	Combined sewer overflows, urban runoff/storm sewers, channelization
301696	Coventry Rd.	110003 05 04	5.50 ^H	4.4	<u>22*</u>	-	VP*	58.0	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alterations	Combined sewer overflows, urban runoff/storm sewers, channelization
200137	Wade Park	110003 05 04	2.70 ^H	7.7	<u>20*</u>	-	P*	73.0	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alteration	Combined sewer overflows, urban runoff/storm sewers, channelization
303287	adj. MLK Jr. Dr.	110003 05 04	2.27 ^H	8.1	<u>24*</u>	-	P*	60.1	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alteration	Combined sewer overflows, urban runoff/storm sewers, channelization
301428	St. Clair Ave.	110003 05 04	0.75 ^H	9.1	<u>12*</u>	-	P*	44.0	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alteration	Combined sewer overflows, urban runoff/storm sewers, channelization
Ninemile Creek (19-040-001) Verified WWH											
301432	Lake Shore Blvd.	110003 05 04	0.34 ^H	11.8	<u>12*</u>	-	P*	66.0	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alteration	Combined sewer overflows, urban runoff/storm sewers
Euclid Creek (19-041-000) WWH Existing											
303284	ust. project area; ust. Cedar Rd.	110003 05 03	9.20 ^H	1.3	-	-	LF*	-	NA	-	-
303285	within project area; dst. Cedar Rd. at Acacia Reservation	110003 05 03	8.90 ^H	1.5	<u>24*</u>	-	P*	69.5	NON	Pollutants in urban storm water, direct habitat alteration, other flow regime alteration	Urban runoff/storm sewers, channelization
303286	dst. project area at Acacia Reservation	110003 05 03	8.70 ^H	1.5	<u>20*</u>	-	P*	53.5	NON	Pollutants in urban storm water, other flow regime alterations	Urban runoff/storm sewers
F01G48	Euclid Park Blvd.	110003 05 03	3.30 ^H	8.8	<u>24*</u>	-	F*	66.0	NON	Pollutants in urban storm water, other flow regime alterations	Urban runoff/storm sewers

Station	Location	Assess. Unit (04)	RM ^a	DA ^b	IBI	MIwb ^c	ICI ^d	QHEI	Attainment ^e	Causes	Sources
F01A47	ust. Lake Shore Blvd.	110003 05 03	0.66 ^W	23.0	<u>26</u> *	7.2*	44	62.0	NON	Pollutants in urban storm water, other flow regime alterations	Urban runoff/storm sewers
Trib. to Euclid Creek (8.1) (19-041-004) Recommended WWH											
303299	via drive off Golfway Ln.	110003 05 03	0.50 ^H	0.2	36 ^{NS}	-	LF*	62.0	PARTIAL	Unknown	Unknown
303298	in Mayfield Sand Ridge Golf Club	110003 05 03	0.15 ^H	0.3	28*	-	<u>VP</u> *	54.8	NON	Unknown	Unknown
East Branch Euclid Creek (19-041-001) WWH Existing											
303283	at SR 175/US 6	110003 05 03	2.75 ^H	7.0	30*	-	F*	53.5	NON	Pollutants in urban storm water, other flow regime alterations	Urban runoff/storm sewers
301678	near mouth; ust. old dam	110003 05 03	0.20 ^H	12.5	32*	-	F*	68.0	NON	Pollutants in urban storm water, other flow regime alterations	Urban runoff/storm sewers
Marsh Creek (03-026-000) Verified WWH											
303281	Hendricks Rd.	110003 05 01	1.50 ^H	5.6	<u>26</u> *	-	LF*	61.5	NON	Sedimentation/siltation	Urban runoff/storm sewers
Red Mill Creek (07-024-000) Recommended WWH											
303280	US 20	110003 02 04	1.70 ^H	6.3	36 ^{NS}	-	LF*	71.0	PARTIAL	Priority organics	Unknown
Church Creek (07-022-000) Recommended WWH											
303279	McMackin Rd.	110003 02 04	0.65 ^H	4.0	<u>22</u> *	-	<u>P</u> *	47.0	NON	Priority organics	Contaminated sediments ^f
Arcola Creek (07-011-000) WWH Existing											
A01K18	Middle Ridge Rd.	110003 02 03	7.40 ^H	7.8	34*	-	F*	56.0	NON	Sedimentation/siltation, priority organics (pesticides)	Contaminated sediments ^f , agriculture
A01W22	dst. Madison WWTP	110003 02 03	7.05 ^H	7.9	30*	-	<u>P</u> *	49.0	NON	Direct habitat alteration, organic enrichment, priority organics (pesticides)	Unrestricted cattle access, channelization, contaminated sediments ^f
A01W24	US 20 at Madison Industrial Park	110003 02 03	5.10 ^H	11.1	<u>26</u> *	-	38	44.0	NON	Direct habitat alteration, flow alteration, priority organics (pesticides)	Channelization, impoundment, contaminated sediments ^f
A01W25	Cunningham Rd.	110003 02 03	2.02 ^H	19.8	30*	-	38	59.5	PARTIAL	Natural causes (flow or habitat), priority organics (pesticides)	Natural sources, contaminated sediments ^f

Station	Location	Assess. Unit (04)	RM ^a	DA ^b	IBI	MIwb ^c	ICI ^d	QHEI	Attainment ^e	Causes	Sources
A01K17	dst. Lake Rd. (Cashen Rd.)	110003 02 03	0.70 ^W	20.3	42	7.5 ^{NS}	38	52.0	FULL		
Trib. to Arcola (4.32) (07-011-003) Recommended WWH											
303278	adj. US 20	110003 02 03	0.10 ^H	4.9	38 ^{NS}	-	G	61.0	FULL		
Trib. to Arcola (0.22) (07-011-002) Recommended WWH											
303277	County Line Rd.	110003 02 03	0.20 ^H	3.3	28*	-	LF*	48.0	NON	Natural causes (flow or habitat)	Natural sources
Wheeler Creek (07-006-000) Verified WWH											
303276	Center Rd.	110003 02 02	2.75 ^H	6.8	46	-	G	70.0	FULL		
Cowles Creek (07-007-000) WWH Existing											
502700	Barnum Rd.	110003 02 02	7.24 ^H	6.8	42	-	G	73.5	FULL		
502710	North Ave.	110003 02 02	4.83 ^H	11.2	38 ^{NS}	-	44	51.5	FULL		
502720	Maple Ave.	110003 02 02	3.56 ^H	12.5	40	-	36	73.5	FULL		
A01P17	SR 534	110003 02 02	0.90 ^H	14.2	42	-	46	73.0	FULL		
Trib. to Cowles (0.2) (07-007-001) Recommended WWH											
303274	access from Geneva-on-the-Lake Municipal Golf Course	110003 02 02	0.90 ^H	5.6	32*	-	F*	55.5	NON	Sedimentation/siltation, other flow alteration	Channelization, flow regime modification (golf course)
Indian Creek (07-008-000) Verified WWH											
303272	Ninevah Rd.	110003 02 01	3.65 ^H	5.12	48	-	G	62.0	FULL		
303107	Myers Rd.	110003 02 01	0.65 ^H	15.3	36 ^{NS}	-	E	55.5	FULL		
Trib. to Indian (3.53) (07-008-001) Recommended WWH											
303275	Ninevah Rd.	110003 02 01	0.15 ^H	4.5	46	-	G	71.0	FULL		
Red Brook (07-009-000) Verified WWH											
303273	Wade Rd.	110003 02 01	2.30 ^H	7.9	34*	-	G	57.0	PARTIAL	Natural causes (flow or habitat)	Natural sources
Whitman Creek (07-012-000) Recommended WWH											
303297	Middle Rd.	120101 07 03	1.20 ^H	1.6	32*	-	F*	57.0	NON	Direct habitat alteration	Channelization

Station	Location	Assess. Unit (04)	RM ^a	DA ^b	IBI	MIwb ^c	ICI ^d	QHEI	Attainment ^e	Causes	Sources
A01P15	SR 531	120101 07 03	0.06 ^H	8.5	26*	-	MG ^{NS}	58.5	NON	Natural causes (flow or habitat)	Natural sources
Trib. to Lake Erie (1124.54) (07-025-000) Recommended WWH											
303296	SR 531	120101 07 03	0.30 ^H	1.8	28*	-	MG ^{NS}	62.0	PARTIAL	Unknown	Unknown
Trib. to Lake Erie (1117.00) (07-026-000) Recommended WWH											
303295	SR 531 (Lake Rd.)	120101 07 03	0.20 ^H	1.9	28*	-	F*	47.0	NON	Unknown	Unknown
Conneaut Creek (07-100-000) EWH Existing											
502900	Furnace Rd.	120101 06 05	23.24 ^W	151.0	53	10.1	56	100.0	FULL		
A01P09	State Rd. (Turnpike Rd.)	120101 06 05	17.20 ^W	158.0	47 ^{NS}	9.4	54	91.0	FULL		
502890	Ridge Rd.	120101 06 05	13.20 ^W	169.0	52	9.2 ^{NS}	56	77.5	FULL		
303288	Big D Campground	120101 06 05	12.27 ^W	171.0	51	9.1 ^{NS}	54	82.0	FULL		
502870	Keefus Rd.	120101 06 05	6.80 ^W	175.0	55	9.7	E	96.3	FULL		
A01P07	Main St.	120101 06 05	2.56 ^W	187.0	51	9.9	E	94.5	FULL		
Trib. to Conneaut (17.1) (07-100-003) Recommended EWH/CWH											
303397	dst. State Rd.	120101 06 05	0.15 ^H	3.6	46	-	E	87.0	FULL		
Trib. to Conneaut (14.82) (07-100-007) Recommended CWH											
303291	Fox Rd.	120101 06 05	0.85 ^H	1.0	32	-	E	78.5	FULL		
Trib. to Conneaut (13.61) (07-100-006) Recommended CWH											
303290	Mill Rd. (Kingsbury Rd.)	120101 06 05	0.20 ^H	1.4	32	-	MG ^{NS}	61.5	FULL		
Trib. to Conneaut (7.39) (07-100-005) Recommended CWH											
303293	adj. Creek Rd.	120101 06 05	0.10 ^H	1.7	32	-	G	66.8	FULL		
Trib. to Conneaut (4.67) (07-100-004) Recommended WWH											
303292	Daniels Ave.	120101 06 05	0.70 ^H	2.8	38 ^{NS}	-	MG ^{NS}	59.0	FULL		
Smokey Run (07-100-001) Recommended CWH											

Station	Location	Assess. Unit (04)	RM ^a	DA ^b	IBI	MIwb ^c	ICI ^d	QHEI	Attainment ^e	Causes	Sources
A01P05	Welton Rd.	120101 06 05	0.20 ^H	6.0	48	-	G	64.0	FULL		
Trib. to Smokey Run (0.31) (07-100-008) Recommended WWH											
303294	Dorman Rd.	120101 06 05	0.55 ^H	3.3	30*	-	G	72.0	PARTIAL	Unknown	Unknown
Turkey Creek (07-200-000) Recommended EWH											
A01P03	State Line Rd.	120101 07 02	1.20 ^H	7.8	46 ^{NS}	-	E	70.0	FULL		

Biological Criteria - EOLP		
Index – Site Type	EWH	WWH
IBI ^H	50	40
IBI ^W	50	38
IBI ^B	48	40
MIwb ^W	9.4	7.9
MIwb ^B	9.6	8.7
ICI	46	34

a River mile- H - headwater site. W - wading site, B - boat site.

b Drainage area (mi²)

c MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi².

d A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional.

e Attainment status is given for the existing or if a change is proposed then the proposed use designations. Attainment status was not assigned to isolated stream segments that were samples with only qualitative macroinvertebrate methods.

f See Tables 15 and 16 for list of contaminants

NS Nonsignificant departure from biocriteria (≤ 4 IBI or ICI units, or ≤ 0.5 MIwb units).

* Indicates significant departure from applicable biocriteria (> 4 IBI or ICI units, or > 0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

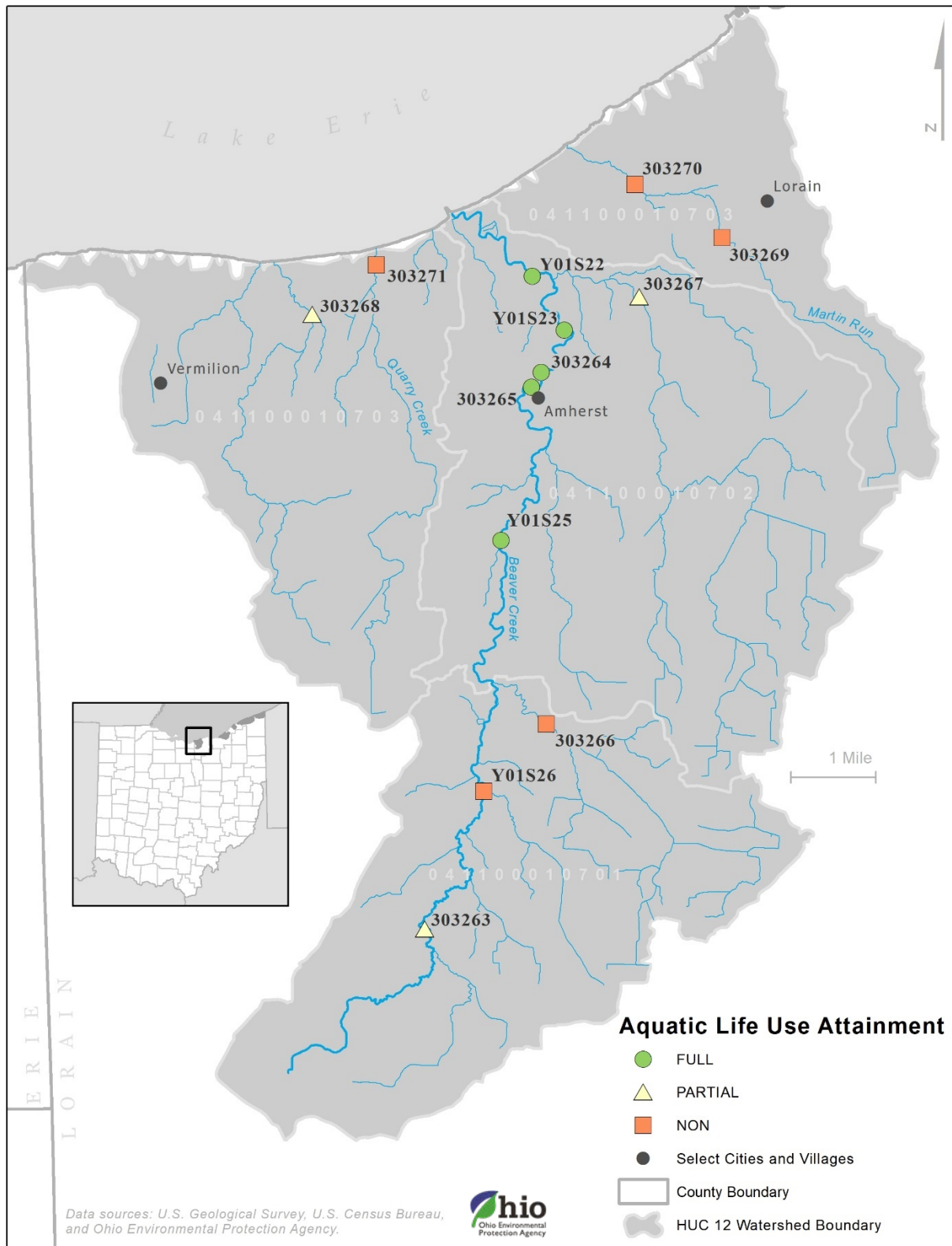


Figure 3. Aquatic life use attainment status of Lake Erie Central Basin Tributaries in Lorain County, 2015. Labels refer to station codes referenced in Table 1.

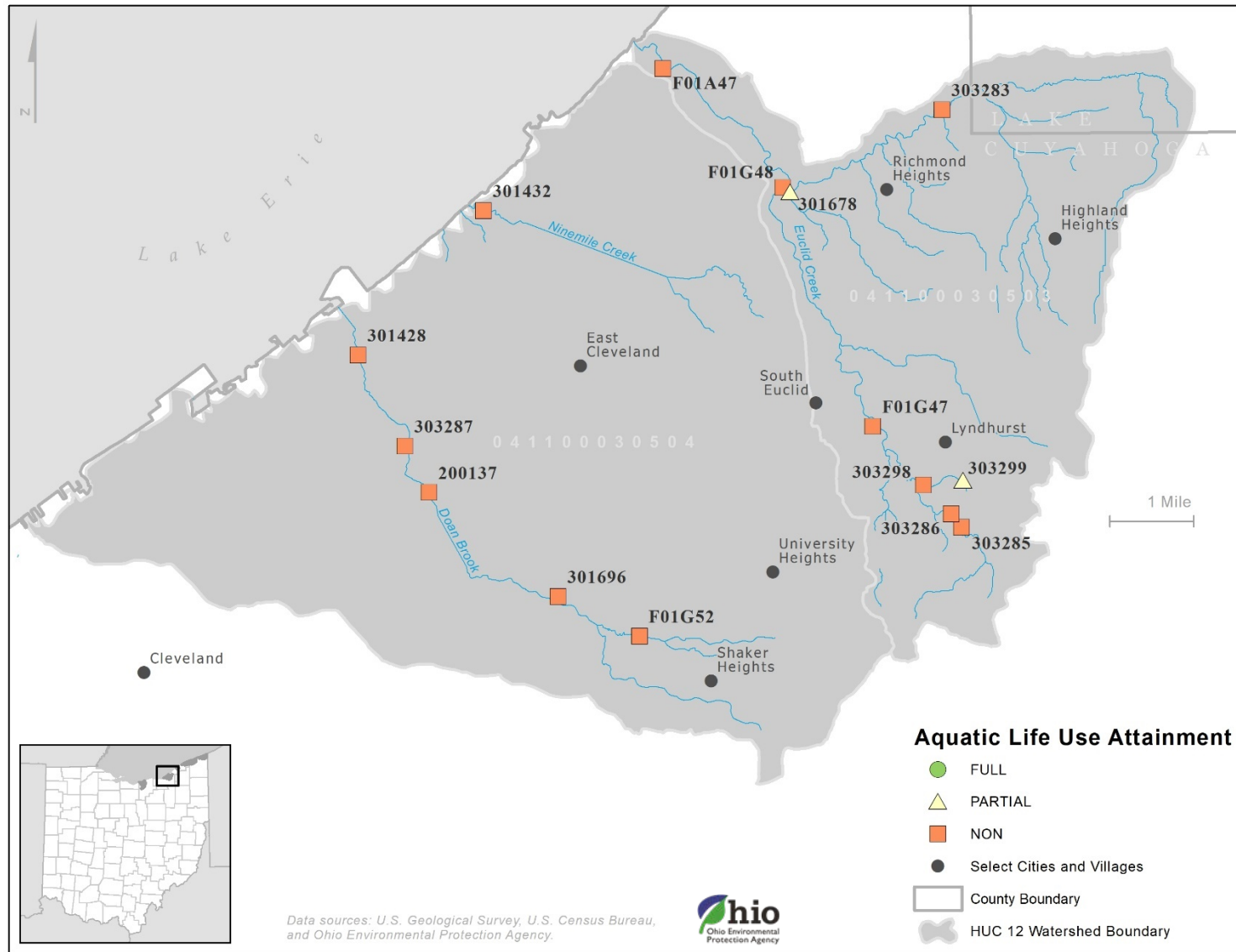


Figure 4. Aquatic life use Attainment status of the Lake Erie Central Basin Tributaries in Cuyahoga County, 2015. Labels refer to station codes referenced in Table 1.

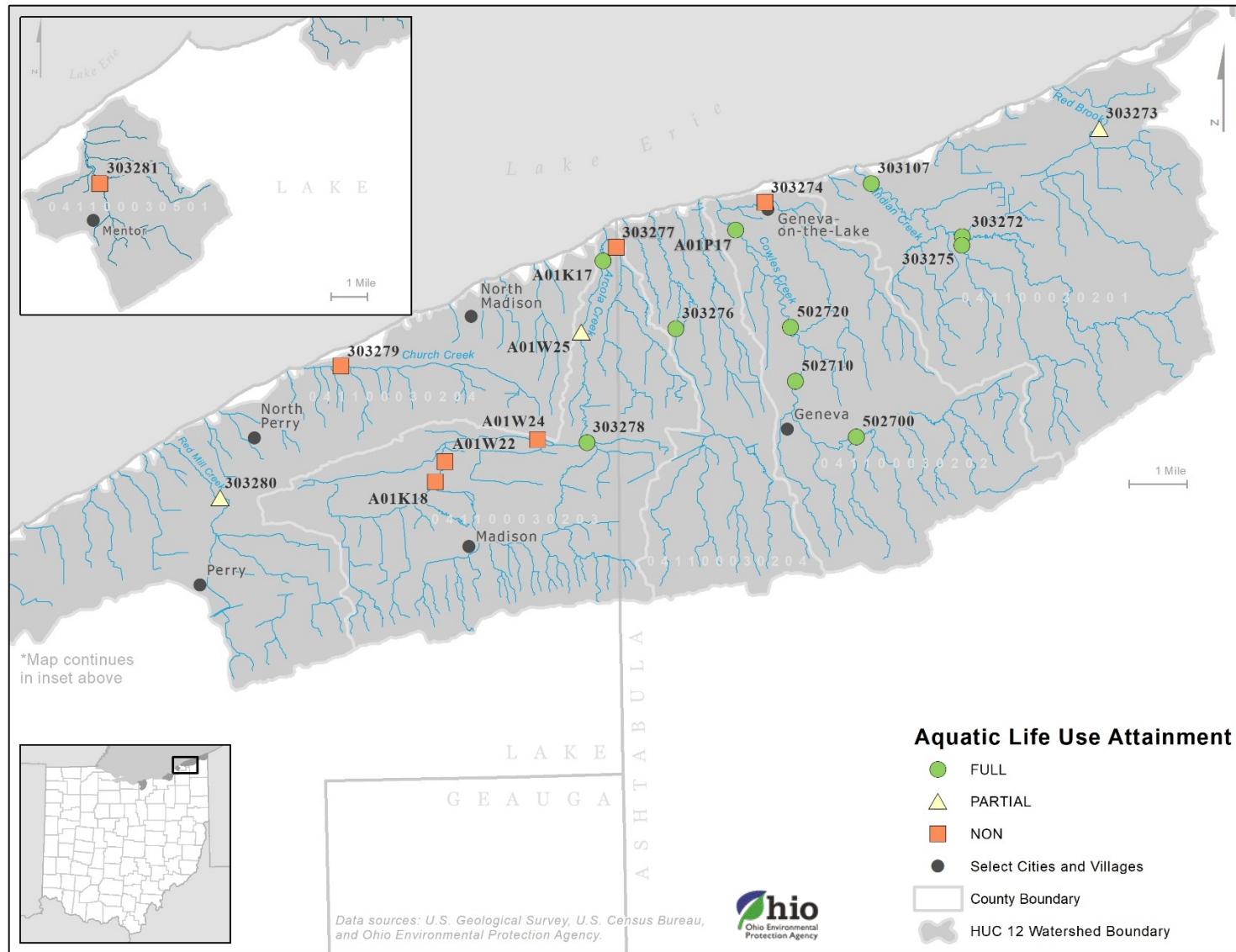


Figure 5. Aquatic life use attainment status of Lake Erie Central Basin Tributaries in Lake and western Ashtabula counties, 2015. Labels refer to station codes referenced in Table 1.

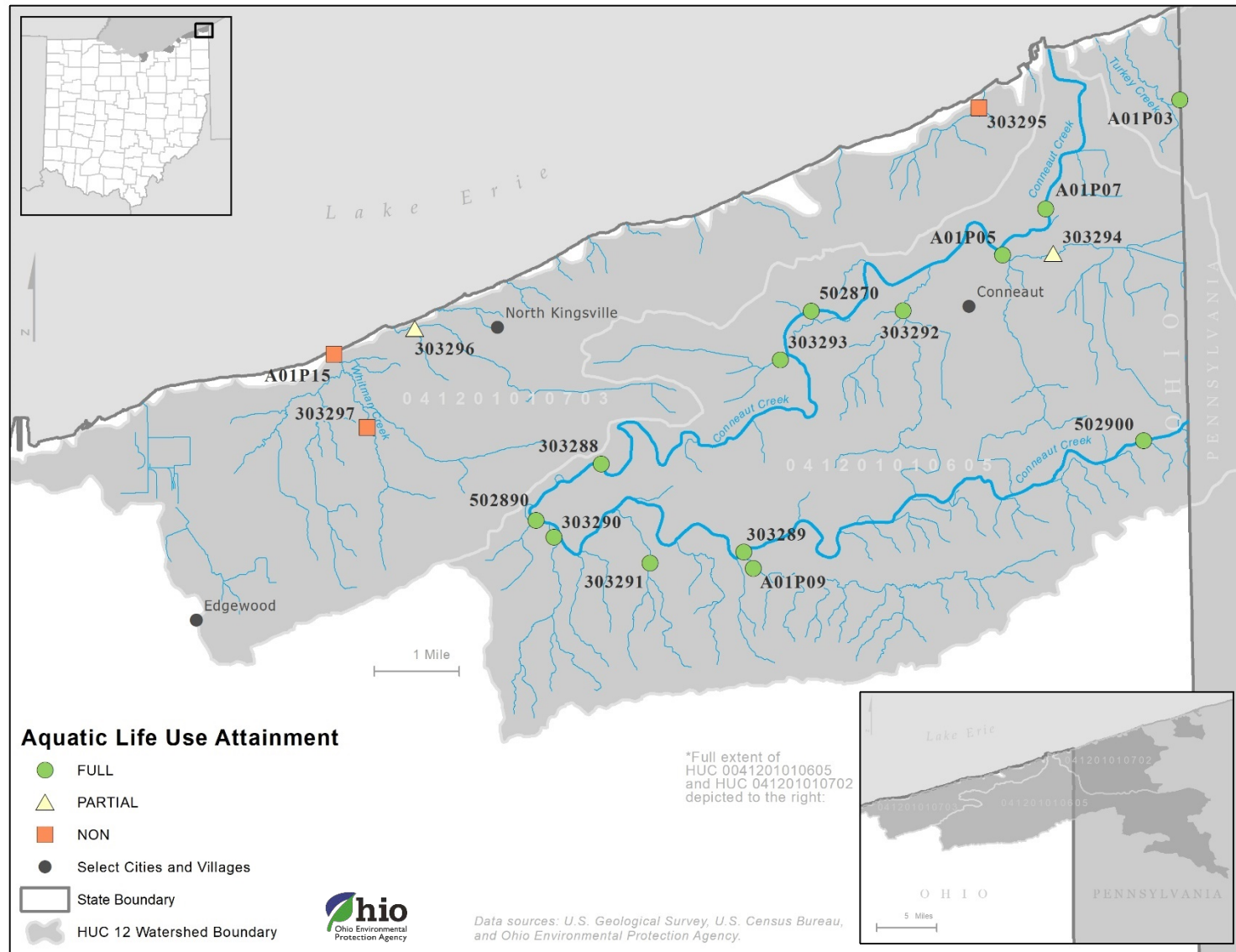


Figure 6. Aquatic life use attainment status of Lake Erie Central Basin Tributaries in eastern Ashtabula County, 2015. Labels refer to station codes referenced in Table 1.

Recommendations

Beneficial Uses

ALU designations have been verified or otherwise affirmed for seven of the named streams in the Lake Erie Central Basin Tributary study area. The streams currently listed in the Ohio Water Quality Standards (WQS) are assigned either the WWH or EWH ALU. The remaining waterbodies are classified as either unverified (identified on the WQS but have not been subjected to a use attainability analysis) or not listed (absent from the WQS).

Table 2 lists the recommended changes for ALUs based on the 2015 survey. The presence of sensitive and exceptional coldwater macroinvertebrate taxa within the tributaries of Conneaut Creek validate the recommendation of the CWH ALU being assigned to Whitman Creek and the Conneaut Creek tributaries. All streams in the 2015 survey currently designated for primary contact recreation (PCR), industrial water supply (IWS), and agricultural water supply (AWS) should retain the use. Additionally, assigning PCR, IWS, and AWS to unverified and unlisted streams from this survey is appropriate.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (e.g. National Pollution Discharge Elimination System (NPDES) permits, Director's Orders, or the WQS), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d) reports).

Table 2. Lake Erie Central Basin Tributaries study area streams that are unlisted or assigned unverified aquatic life uses in Ohio Water Quality Standards. The streams are recommended for warmwater habitat, exceptional warmwater habitat, or coldwater habitat aquatic life uses. The coldwater habitat recommended sites are based on biological sampling alone.

Unlisted Ohio WQS streams recommended for WWH aquatic life use
Willow Creek (Beaver Creek RM 2.0)
Squires Squamm Ditch (Beaver Creek RM 9.41)
Tributary to Euclid Creek (RM 8.1)
Red Mill Creek
Church Creek
Tributary to Arcola Creek (RM 4.32)
Tributary to Arcola Creek (RM 0.22)
Tributary to Cowles Creek (RM 0.2)
Tributary to Indian Creek (RM 3.53)
Tributary to Lake Erie (1124.54)
Tributary to Lake Erie (1117.0)
Tributary to Conneaut (RM 4.67)
Tributary to Smokey Run (RM 0.31)
Unverified Ohio WQS streams recommended for WWH aquatic life use
Brownhelm Creek
Quarry Creek
Martin Run
Ninemile Creek
Marsh Creek
Wheeler Creek
Indian Creek
Red Brook
Unlisted Ohio WQS streams recommended for EWH aquatic life use
Turkey Creek

Unlisted Ohio WQS streams recommended for CWH aquatic life use (based on biological sampling)
Whitman Creek
Tributary to Conneaut Creek (RM 17.1)
Tributary to Conneaut Creek (RM 14.82)
Tributary to Conneaut Creek (RM 13.61)
Tributary to Conneaut Creek (RM 7.39)
Smokey Run

Table 3. Existing and recommended beneficial use designations for water bodies within the Central Basin Lake Erie Tributaries study area.

Water Body Segment	Use Designations												Comments	
	Aquatic Life Habitat						Water Supply			Recreation				
	S R W	W W H	E W H	M W H	S S H	C W H	L R W	P W S	A W S	I W S	B W	P C R		S C R
Black River Basin (OAC 3745-1-27)														
Brownhelm creek		*/+							*/+	*/+		*/+		
Quarry creek		*/+							*/+	*/+		*/+		
Beaver creek		+							+	+		+		
Willow creek (Beaver creek RM 2.0)		▲							▲	▲		▲		
Squires Squamm ditch (Beaver creek RM 9.41)		▲							▲	▲		▲		
Martin run		*/+							*/+	*/+		*/+		
Cuyahoga River Basin (OAC 3745-1-26)														
Doan brook		+							+	+		+		
Shaker Lakes national environmental education landmark	*	+							+	+		+		
Ninemile creek		*/+							*/+	*/+		*/+		
Euclid creek - Anderson road (RM 5.6) to U.S. rte. 20 (RM 2.4)	*	+							+	+		+		
- all other segments		+							+	+		+		
Unnamed tributary (Euclid creek RM 8.1)		▲							▲	▲		▲		
East branch (Euclid creek RM 3.2)		+							+	+		+		
Unnamed tributary (East branch RM 1.55)							+		+	+			+	Channel modification
Chagrin River Basin (OAC 3745-1-10)														
Marsh creek		*/+							*/+	*/+		*/+		
Mentor creek and Mentor marsh	*	*							*	*		*		
Black brook		*							*	*		*		
Heisley creek		*							*	*		*		
McKinley creek		*							*	*		*		
Big creek		*							*	*		*		

Water Body Segment	Use Designations												Comments	
	Aquatic Life Habitat						Water Supply			Recreation				
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR		SCR
Ashtabula River Basin (OAC 3745-1-14)		▲							▲	▲			▲	
Red Mill creek		▲							▲	▲			▲	
Church creek		+			o				+	+			+	
Arcola creek - U.S. rte. 20 (RM 4.3) to the mouth - all other segments		+							+	+			+	
Unnamed tributary (Arcola creek RM 0.22)		▲							▲	▲			▲	
Unnamed tributary (Arcola creek RM 4.32)		▲							▲	▲			▲	
Wheeler creek - estuary zone		*			o				*	*			*	
- all other segments		*/+							*/+	*/+			*/+	
Cowles creek - estuary zone (RM 0.8 - 0.0)		+			+				+	+			+	
- all other segments		+							+	+			+	
Unnamed tributary (Cowles creek RM 0.2)		▲							▲	▲			▲	
Indian creek		*/+							*/+	*/+			*/+	
Unnamed tributary (Indian creek RM 3.53)		▲							▲	▲			▲	
Red brook		*/+							*/+	*/+			*/+	
Whitman creek		▲							▲	▲			▲	
Unnamed tributary at Lake Erie mile 1124.54		▲							▲	▲			▲	
Unnamed tributary at Lake Erie mile 1117.0		▲							▲	▲			▲	
Conneaut creek			+		o				+	+			+	
Smokey run (Conneaut creek RM 3.5)					o	▲			▲	▲			▲	
Unnamed tributary (Smokey Run RM 0.31)		▲							▲	▲			▲	
Unnamed tributary (Conneaut Creek RM 4.67)		▲							▲	▲			▲	
Unnamed tributary (Conneaut creek RM 7.39)						▲			▲	▲			▲	
Unnamed tributary (Conneaut creek RM 13.61)						▲			▲	▲			▲	
Unnamed tributary (Conneaut creek RM 14.82)						▲			▲	▲			▲	
Unnamed tributary (Conneaut creek RM 17.1)			▲		▲				▲	▲			▲	
Turkey creek			▲		o				*/+	*/+			*/+	

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.

Improvements to Water Quality

The heavily urbanized streams (Martin Run, Doan Brook, Ninemile Creek, Euclid Creek, and Marsh Creek) within this survey would benefit from improved storm water management throughout their watersheds. While development in these watersheds has slowed due to lack of space, care should be taken to reduce and slow down overland runoff and filter out pollutants before reaching their receiving streams. Recommended measures include, but are not limited to, increasing riparian vegetative buffers along riparian zones and implementing ‘green’ storm water infrastructure throughout the basins.

The Northeast Ohio Regional Sewer District (NEORS) has entered a Consent Decree with the Federal government and Ohio EPA to address the amount of raw sewage entering waterways via CSOs. Over 98% of the CSOs will be captured and treated when the project is complete in 2036. Additionally, significant investments in green infrastructure will aid in decreasing storm water runoff. The surveyed watersheds in Cuyahoga county, specifically Doan Brook and Euclid Creek, will directly benefit from these projects.

Areas in Lake County, and especially in the Arcola Creek watershed, are impacted by fertilizers and pesticides in irrigation runoff. Riparian buffers and other sediment control mechanisms should be heavily maintained in these areas, as well as a decrease in the amount of exposed soil that is susceptible to runoff in heavy rainfalls. During cold weather months, covered hoop houses are erected throughout the Arcola Creek watershed to prevent plant damage to nursery inventory, leading in an increase in the overall imperviousness of the watershed. Implementing storm water controls, as mentioned above, would aid in decreasing this seasonal storm water runoff, uniquely observed in this watershed. Additionally, water withdrawals in Cowles and Arcola creeks caused very low flow conditions in 1995. This was not observed in the 2015 study, however, a robust water withdrawal plan in times of drought would benefit overall stream health and nursery businesses.

Areas in the more rural and agricultural sections of the survey (eastern Lake county and Ashtabula county) would benefit from restricting access of cattle and other livestock in the streams. Livestock intrusion can destabilize streambanks which increases erosion and leads to higher rates of sedimentation in streams. Excess sediments have negative impacts on overall water quality and stream biology. Non-attainment at Arcola Creek (RM 7.05) was partially attributed to unrestricted cattle access in the stream and was observable throughout the summer field season. Other agricultural practices, specifically plant nursery production within the Arcola Creek watershed, inhibit stream quality with pesticide nutrient laden sediments entering the stream. Sedimentation and siltation are also prevalent causes of impairment throughout the urbanized portion of the survey area. Urban runoff can increase sedimentation in watersheds, as was documented in Marsh Creek. Efforts should be made to reduce storm water runoff contributing to this source of impairment.

Introduction

As part of the total maximum daily load (TMDL) process and in support of the basin approach for NPDES permitting, Ohio EPA conducted an intensive ambient assessment of the Lake Erie Central Basin Tributaries during the 2015 field sampling season. The study area is composed of 13 hydrologic unit code 12 (HUC-12) watershed assessment units and includes Brownhelm Creek, Quarry Creek, Beaver Creek, Martin Run, Doan Brook, Ninemile Creek, Euclid Creek, Marsh Creek, Red Mill Creek, Church Creek, Arcola Creek, Wheeler Creek, Cowles Creek, Indian Creek, Red Brook, Whiteman Creek, Conneaut Creek, and Turkey Creek.

A total of 66 sampling sites were allocated to provide for the biological assessment of the 38 named streams. Ambient biology, macrohabitat quality, water column chemistry, and bacteriological data were collected concurrently from the sampling sites (Table 4). Diel water quality (DO, pH, conductivity, and temperature), sediment chemistry (metals, organics, and particle size), nutrients, continuous temperature, and fish tissue were also collected at selected sampling locations. All of the biological, chemical, and bacteriological results can be downloaded from Ohio EPA's GIS interactive maps webpage at epa.ohio.gov/gis.

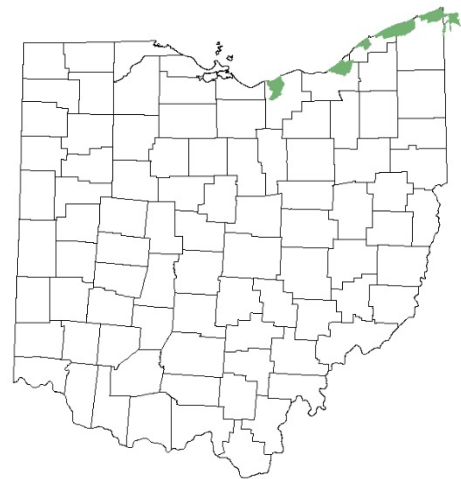


Figure 7. Locations of the Lake Erie Central Basin Tributaries within the geopolitical boundaries of Ohio.

The following specific sampling objectives were defined for the study:

- 1) Systematically sample and assess the principal drainage network of the selected Lake Erie Central Basin Tributaries in support of both the TMDL process and NPDES permits;
- 2) Gather ambient environmental information (biological, chemical, and physical) from undesignated water bodies to recommend an appropriate suite of Beneficial Uses (e.g. aquatic life, recreational, water supply);
- 3) Verify the appropriateness of existing unverified beneficial use designations, and recommend appropriate uses to undesignated waters;
- 4) Establish and evaluate baseline ambient biological conditions at selected reference stations to evaluate the effectiveness of past, ongoing, and future pollution abatement efforts;
- 5) Document any changes in the biological, chemical, and physical conditions of the study areas where historical information exists, thus expanding the Ohio EPA database for statewide trend analysis (e.g. 305[b]);
- 6) Collect fish samples for the Ohio Sport Fish Tissue Monitoring Program (used to assess chemical contaminant levels in fish) from four locations on Conneaut Creek at river miles (RM) 23.24, 12.27, 6.69, and 2.56;
- 7) Evaluate pre-construction conditions for planned 319 and GLRI funded projects on Doan Brook, Euclid Creek, and an unnamed tributary to Euclid Creek (at RM 8.1). Post-construction sampling for previously funded 319 projects will occur on East Branch Euclid Creek and Doan Brook; and
- 8) Evaluate eight sites for coldwater habitat (CWH) potential. Biological sampling to occur at all sites.

Table 4. Lake Erie Central Basin tributaries sampling stations, 2015 (listed by stream name and stream code).

Station	Stream / Location	RM	DA	Sample Type	HUC12	Latitude	Longitude
20-100-000 (stream code)							
303268	Brownhelm Creek / Baumhart Rd	0.90	5.2	B, C, D, F, Mq, Sd	041100010703	41.4197	-82.2829
20-101-000							
303271	Quarry Creek / US 6	0.25	5.1	B, C, D, F, Mq, Sd	041100010703	41.4281	-82.2684
20-003-000							
303263	Beaver Creek / Quarry Rd	13.75	6.3	B, C, F, Mq, Sd	041100010701	41.3148	-82.2578
Y01S26	Beaver Creek / Russia Rd	11.02	11.5	B, C, D, F, Mq, N	041100010701	41.3383	-82.2444
Y01S25	Beaver Creek / Middle Ridge Rd	6.95	23.0	C, D, F2, MQ, N	041100010702	41.3811	-82.2403
303265	Beaver Creek / UPST Amherst WWTP	4.00	26.7	B, C, D, F2, MQ, N	041100010701	41.4072	-82.2333
303264	Beaver Creek/ DST Amherst WWTP	3.80	26.7	B, C, D, F2, MQ, N	041100010701	41.4097	-82.2311
Y01S23	Beaver Creek / Cooper Foster Park Rd	2.90	28.0	C, D, F2, MQ, N	041100010702	41.4169	-82.2258
Y01S22	Beaver Creek / Longbrook Rd	1.75	43.0	B, C, D, F, Mq, Sd, Sn	041100010702	41.4261	-82.2331
20-005-000							
303267	Willow Creek (Beaver RM 2.0) / SR 58	1.25	10.7	B, C, F, Mq, Sd	041100010702	41.4225	-82.2088
20-003-002							
303266	Squires Squamm Ditch / Annis Rd	1.30	5.47	B, C, F, Mq	041100010701	41.3497	-82.2302
20-004-000							
303269	Martin Run / Towers Rd	2.35	2.34	B, C, F, Mq	041100010703	41.4326	-82.1900
303270	Martin Run / Meister Rd	0.90	5.3	B, C, D, F, Mq	041100010703	41.4417	-82.2097
19-039-000							
F01G52	Doan Brook / Lee Rd	6.64	1.3	B, C, F, Mq, Sd	041100030504	41.4840	-81.5656
301696	Doan Brook / Coventry Rd	5.50	4.4	F, Mq,	041100030504	41.4910	-81.5842
200137	Doan Brook / Wade Park	2.70	7.7	B, C, F, Mq, Sd	041100030504	41.5092	-81.6136
303287	Doan Brook / adjacent MLK Jr Dr	2.27	8.12	F, Mq,	041100030504	41.5172	-81.6190
301428	Doan Brook / St. Clair Ave	0.75	9.1	B, C, D, F, Mq, N, Sd	041100030504	41.5330	-81.6296
19-039-001							
301429	S. Br. Doan Brook / Attleboro Rd	1.31	3.4	B, C, Sd	041100030504	41.4751	-81.5976
19-040-001							
301432	Ninemile Creek / Lakeshore Blvd	0.34	11.8	B, C, D, F, Mq, Sd	041100030504	41.5577	-81.6004
19-041-000							
303284	Euclid Creek / Cedar Rd	9.20	1.3	F, Mq,	041100030503	41.5005	-81.4877
303285	Euclid Creek / Acacia Reservation	8.90	1.5	F, Mq,	041100030503	41.5022	-81.4914
303286	Euclid Creek	8.70	1.5	F, Mq,	041100030503	41.5045	-81.4937
F01G47	Euclid Creek / Mayfield Rd	7.10	3.4	B, C, Sd	041100030503	41.5198	-81.5115
F01G48	Euclid Creek / Euclid Park Blvd	3.30	8.8	C, D, F, Mq, N, Sd	041100030503	41.5612	-81.5316
F01A47	Euclid Creek / Lakeshore Blvd	0.66	23.0	B, C, D, F2, MQ, N, Sd, Sn	041100030503	41.5819	-81.5589
19-041-001							

Station	Stream / Location	RM	DA	Sample Type	HUC12	Latitude	Longitude
301678	East Branch Euclid Creek / near mouth	0.20	12.5	B, C, D, F, Mq, N, Sd	041100030503	41.5604	-81.5299
303283	East Branch Euclid Creek / US 6	2.75	7.0	B, C, F, Mq, Sd	041100030503	41.5743	-81.4948
19-041-003							
302508	Trib. to Euclid Creek (5.49) / Richmond Rd	1.35	1.2	B, C, Sd	041100030503	41.5320	-81.4970
19-041-004							
303298	Trib. to Euclid Creek (8.1)	0.15	0.3	F, Mq,	041100030503	41.5096	-81.5000
303299	Trib. to Euclid Creek (8.1)	0.50	0.2	F, Mq,	041100030503	41.5103	-81.4909
03-026-000							
303281	Marsh Creek / Hendricks Rd	1.50	5.6	C, D, F, Mq	041100030501	41.7049	-81.3322
303282	Marsh Creek / SR 283	0.20	14.2	B, C, F, Mq, Sd	041100030501	41.7200	-81.3390
07-024-000							
303280	Red Mill Creek / US 20	1.70	6.3	B, C, D, F, Mq	041100030204	41.7854	-81.1358
07-022-000							
303279	Church Creek / McMackin Rd	0.65	4.0	B, C, F, Mq, Sd	041100030204	41.8179	-81.0948
07-011-000							
A01K18	Arcola Creek / Middle Ridge Rd	7.40	7.8	B, C, D, F2, MQ, N, Sd	041100030203	41.7886	-81.0639
A01W22	Arcola Creek / DST Madison WWTP	7.05	7.9	B, C, D, F2, MQ, N	041100030203	41.7936	-81.0606
A01W24	Arcola Creek / US 20	5.10	11.1	C, F2, MQ	041100030203	41.7988	-81.0296
A01W25	Arcola Creek / Cunningham Rd	2.02	19.8	B, C, D, F2, MQ, N, Sd, Sn	041100030203	41.8254	-81.0143
A01K17	Arcola Creek / Lake Rd	0.70	20.3	C, D, F2, MQ, N, Sd	041100030203	41.8431	-81.0067
07-011-002							
303277	Trib. to Arcola (0.22) / County Line Rd	0.20	3.3	B, C, CT, F, Mq	041100030203	41.8465	-81.0022
07-011-003							
303278	Trib. to Arcola (4.32) / adj. US 20	0.10	4.9	C, F, Mq	041100030203	41.7978	-81.0130
07-006-000							
303276	Wheeler Creek / Center Rd	2.75	6.8	B, C, F, Mq, Sd	41100030202	41.8259	-80.9828
07-007-000							
502700	Cowles Creek / Barnum Rd	7.24	6.8	B, C, D, F2, MQ, Sd	041100030202	41.7981	-80.9231
502710	Cowles Creek / North Ave	4.83	11.2	B, C, D, F2, MQ, N	041100030202	41.8122	-80.9431
502720	Cowles Creek / Maple Ave	3.56	12.5	B, C, D, F2, MQ, N	041100030202	41.8258	-80.9444
A01P17	Cowles Creek / SR 534	0.90	14.2	B, C, F2, MQ, Sd, Sn	041100030202	41.8503	-80.9622
07-007-001							
303274	Trib. to Cowles (0.2) / GOTL Golf Course	0.90	5.6	C, F, Mq	041100030201	41.8571	-80.9523
07-008-000							
303272	Indian Creek / Ninevah Rd	3.65	5.12	B, C, D, F, Mq	041100030201	41.8477	-80.8865
303108	Indian Creek / North Bend Rd	1.65	14.2	Sn	041100030201	41.8543	-80.9068
303107	Indian Creek / Meyers Rd	0.65	15.3	B, C, D, F, Mq, Sd	041100030201	41.8613	-80.9166
07-008-001							

Station	Stream / Location	RM	DA	Sample Type	HUC12	Latitude	Longitude
303275	Trib. to Indian (3.53) / Ninevah Rd	0.15	4.5	C, F, Mq	041100030201	41.8455	-80.8867
07-009-000							
303273	Red Brook / Wade Rd	2.30	7.9	B, C, D, F, Mq, Sd	041100030201	41.8740	-80.8400
07-012-000							
303297	Whitman Creek / Middle Rd	1.20	1.6	F, Mq, CT	041201010703	41.9089	-80.7058
A01P15	Whitman Creek / SR 531	0.06	8.5	B, C, F, Mq, Sd	041201010703	41.9214	-80.7130
07-012-001							
A01P14	Trib. to Whitman Creek (0.32) / LaBounty Rd	1.24	1.7	C, Sd	041201010703	41.9118	-80.7254
07-025-000							
303296	Trib. to Lake Erie (1124.54) / SR 531	0.30	1.8	F, Mq, CT	041201010703	41.9255	-80.6945
07-026-000							
303295	Trib. to Lake Erie (1117.00) / SR 531	0.20	1.9	F, Mq	041201010703	41.9610	-80.5652
07-100-000							
502900	Conneaut Creek / Furnace Rd	23.24	151.0	B, C, FT, F2, MQ, Sd	041201010605	41.9039	-80.5294
A01P09	Conneaut Creek / State Rd	17.20	158.0	C, F2, MQ	041201010605	41.8864	-80.6208
502890	Conneaut Creek / Ridge Rd	13.20	169.0	B, C, D, F2, MQ	041201010605	41.8925	-80.6679
303288	Conneaut Creek / Big D Campground	12.27	171.0	C, FT, F2, MQ	041201010605	41.9019	-80.6528
502870	Conneaut Creek / Keefus Rd	6.69	175.0	B, C, D, F2, FT, MQ, N, Sd, Sn	041201010605	41.9271	-80.6043
A01P07	Conneaut Creek / Main St	2.56	187.0	B, C, FT, F2, MQ	041201010605	41.9436	-80.5505
07-100-001							
A01P05	Smokey Run / Welton Rd	0.20	6.0	B, C, CT, D, F, Mq	041201010605	41.9359	-80.5605
07-100-008							
303294	Trib. to Smokey (0.31) / Dorman Rd	0.55	3.3	F, Mq, CT	041201010605	41.9360	-80.5490
07-100-003							
303289	Trib. to Conneaut (17.1) / State Rd	0.300	3.6	C, CT, F, Mq	041201010605	41.8836	-80.6187
07-100-006							
303290	Trib. to Conneaut (13.61) / Mill Rd	0.20	1.4	F, Mq	041201010605	41.8896	-80.6639
07-100-007							
303291	Trib. to Conneaut (14.82) / Fox Rd	0.85	1.0	F, Mq, CT	041201010605	41.8849	-80.6422
07-100-004							
303292	Trib. to Conneaut (4.67) / Daniels Rd	0.70	2.8	F, Mq, CT	041201010605	41.9268	-80.5834
07-100-005							
303293	Trib. to Conneaut (7.39) / adj. Creek Rd	0.10	1.7	F, Mq, CT	041201010605	41.9189	-80.6116
07-200-000							
A01P03	Turkey Creek / State Line Rd	1.37	7.8	C, F, Mq	041201010702	41.9616	-80.5195

B- bacteria sampling (5 rounds)

D- DataSonde continuous monitors

F2- two pass fish sampling

C- water chemistry sampling (5 rounds)

FT- fish tissue sampling

N- nutrient sampling

CT- HOBO w temperature sampling

F- single pass fish sampling

Mq- macroinvertebrate qualitative sampling only

MQ- macroinvertebrate quantitative sampling

Sd- sediment sample

Sn- sentinel site

Study Area Description

The 2015 Lake Erie Central Basin tributaries study area covered thirteen 12-digit HUCs and four counties (Lorain, Cuyahoga, Lake, and Ashtabula). Sampled waterbodies included Brownhelm Creek, Quarry Creek, Beaver Creek (Squire Squamm Ditch, Willow Creek), Martin Run, Doan Brook, Ninemile Creek, Euclid Creek, Marsh Creek, Red Mill Creek, Church Creek, Arcola Creek, Wheeler Creek, Cowles Creek, Indian Creek, Red Brook, Whitman Creek, Conneaut Creek (Smokey Run), and Turkey Creek.

Lorain County – (Brownhelm Creek, Quarry Creek, Beaver Creek, Martin Run)

Lorain County is generally characterized by flat, low relief topography with areas that are predisposed to the formation of flooded zones and low-lying wetlands. Clayey soils and shale bedrock also play a role in the movement of water in these tributaries. Land use in the study area for this county is primarily agriculture in the headwaters and mostly urban/developed in the eastern portions downstream toward Lake Erie (Figure 8). The urban and industrial development in the study area contribute to the flashy nature of the streams and impacts from storm water are noticeable in many areas.

Brownhelm Creek has a watershed area of 5.64 mi² and drains acreage in Brownhelm Township. The watershed flows through mainly agricultural and wooded areas along its descent into Lake Erie. Quarry Creek drains 5.24 mi² directly east of Brownhelm Creek. Both creeks straddle an old Ford Assembly Plant that now houses various other industries, with a large area of impervious surfaces in the lower portions of both creeks.

Beaver Creek is a direct tributary to Lake Erie, located in Lorain County. The mainstem of the stream is 12.2 miles long with a drainage area of 43.92 mi². Beaver Creek lies within the northernmost reach of the Eastern Corn Belt Plains (ECBP) ecoregion. The area within the watershed is characterized by low rolling hills with occasional shale and sandstone outcroppings adjacent to the main channel. The headwaters of Beaver Creek lie within a low density residential and rural agricultural area, with increasing residential development. The lower portion of Beaver Creek is more urbanized and influenced by the city of Amherst. The city of Amherst WWTP discharges to the stream at RM 3.85. This downstream portion of the creek is effluent dominated in low flow conditions.

Martin Run has been highly modified in certain sections of the watershed has a history of intense flooding due to channel modifications and reduced upstream storage. Several 90-degree bends exist in in the watershed. Martin Run drains a 6.13 mi² area and has an average fall of 26 feet per mile. The underlying bedrock is sandstone and black shale. Following the 2015 survey of this area, the city of Lorain applied for and received approval for a Nationwide Permit from the US Army Corp of Engineers to improve drainage in lower portion of the watershed. Improvements include removing silt and sediments from the creek bottom and improving banks and meander areas with stream bank protections.

Cuyahoga County – (Doan Brook, Ninemile Creek, Euclid Creek)

Cuyahoga County lies within the Erie Ontario Lake Plain and borders Lake Erie to the north. Soils are composed primarily of glacial till and are characterized as poorly drained, clayey material. The lower portions of watersheds that empty into Lake Erie are state and federally designated Coastal Zone Management Area as established by the Ohio Coastal Management Program administered by Ohio Department of Natural Resources. This program outlines managements objectives to sustain and protect the coastal zone of Lake Erie. Land use is almost exclusively urban/developed in the study area for this county (Figure 8).

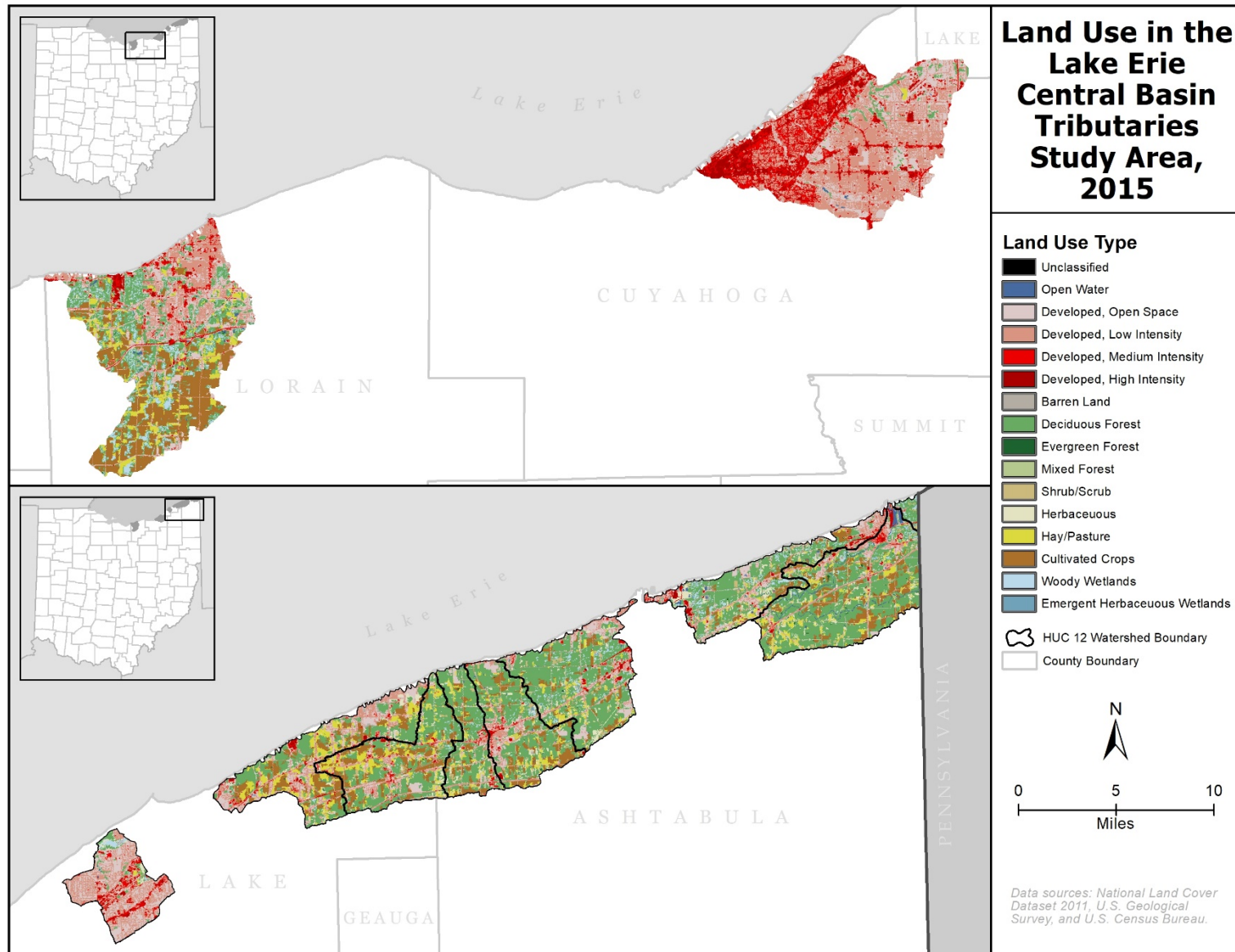


Figure 8. Land use in the Lake Erie Central Basin Tributaries study area, 2015.

Doan Brook watershed drains an area of 11.7 mi² and is located in the eastern part of Cleveland. The original drainage area was approximately 9.7 mi², but it expanded with the addition of storm sewer systems in the area. It is one of six tributaries between the Cuyahoga and Chagrin rivers that drain directly into Lake Erie. Three main branches make up the watershed that flows through Shaker Heights, Cleveland Heights, and Cleveland. Numerous man-made lakes are located on its tributaries, including Horseshoe Lake, Green Lake, Marshall Lake, Lower Shaker Lake, Wade Park Lagoon, and Rockefeller Park Lagoon. Doan Brook flows through the Cleveland Cultural Gardens, one of the more notable landmarks in the area. The watershed has one of the densest human populations compared to other watersheds within the Lake Erie Basin, and thus has impactful urban storm water issues. Approximately 1.3 river miles flow underground, through University Circle and Cleveland Lakefront Nature Preserve.

Ninemile Creek flows into Lake Erie through the city of Bratenahl, east of Cleveland. The watershed drains an area of 7.8 mi² flowing through Bratenahl, Cleveland, Cleveland Heights, East Cleveland, Shaker Heights, South Euclid, and University Heights. More than 90% of the watershed has been developed and the majority of the mainstem is culverted.

Euclid Creek lies between Cuyahoga and Lake counties and covers eleven separate municipalities. The watershed drains 24 mi² and has over 43 miles of stream segments. Seventy-five percent of the watershed is covered by impervious surfaces.

Lake County – (Marsh Creek, Red Mill Creek, Church Creek, Arcola Creek)

Lake County lies entirely within the Erie Ontario Lake Plain ecoregion of Ohio. Certain soil types prevalent in the area have sandy textures and are highly favorable for nursery production. Most of soils have severe limitations for development because of seasonal wetness. Land use in this county is urban/developed in the west closer to Cleveland, and gradually becomes a mix of agriculture and forest (Figure 8).

Marsh Creek lies within the Erie Ontario Lake Plain ecoregion and drains 28.3 mi² of land. Much of the creek has been modified and is developed. Marsh Creek drains to Mentor Marsh, an 868-acre wooded wetland/swamp complex. The marsh is the largest in northeast Ohio but has deteriorated in quality due to salt contamination dating back to the 1950s.

Red Mill Creek drains an area of 7.24 mi² and covers portions of Perry Township, Perry Village, North Perry Village and Madison Township. The primary land uses are agricultural and residential, with nursery operations common throughout the watershed. In winter months, many nurseries use plastic hoop house to cover nursery beds, causing a seasonal increase in imperviousness, that negatively affects the watershed. Church Creek drains an area 5 mi² through North Perry Village and Madison Township. The watershed is primarily forested and residential with coverage of 9.45% impervious surface (USGS Stream Stats).

Arcola Creek watershed drains an area of 23.5 mi² in both Lake and Ashtabula counties, before flowing into Lake Erie. The outlet of Arcola Creek into Lake Erie is a protected, low gradient estuary (one of two remaining natural estuaries on the south shore of Lake Erie). The watershed had significant amounts of bog iron and supported an iron industry in the mid-1800s, resulting in modifications to the creek. Nursery and farming industries are prevalent in the watershed today.

Ashtabula County – (Wheeler Creek, Cowles Creek, Indian Creek, Red Brook, Whitman Creek, Conneaut Creek, Turkey Creek)

Ashtabula County is within the Erie Ontario Lake Plain ecoregion, in the northeastern corner of Ohio. It is the largest county by area in Ohio and is sparsely populated compared to other counties along Lake Erie, due to limited ground water supplies with urbanized areas found closer to the lake. Watersheds in this county are primarily wooded and agricultural in the upper basins (Figure 8). The topography is characterized by ground and end moraines with glacial clays, sands and gravels overlaying bedrock shale.

The Wheeler Creek watershed has a drainage area of 8.28 mi² along the western edge of Ashtabula County. The lower portion and mouth of the creek flow through Geneva State Park, before entering Lake Erie. The watershed is mainly forested with a low impervious surface coverage of 4.22%.

Cowles Creek drains 20.6 mi² of land in Ashtabula County and covers areas in Geneva, Harpersfield, Saybrook, and Austinburg townships. The watershed drains most of the city of Geneva and receives wastewater from Geneva WWTP at RM 4.73. The mouth of Cowles Creek is also within Geneva State Park.

Indian Creek and Red Brook drain areas of 15.5 mi² and 9.5 mi², respectively. Indian Creek flows through Saybrook and Geneva townships before emptying into Lake Erie just within the Geneva-on-the-Lake city boundaries. This watershed has a very low impervious surface area coverage of 2.45%. Red Brook lies entirely within Saybrook Township and flows through Harbor Golf Club in its lower reaches.

The Conneaut Creek basin drains an area of 37.7 mi² in Ohio and originates south of Conneautville in Crawford County, Pennsylvania. The mainstem is 56.8 river miles in length, with 23.83 miles in the state of Ohio. With the majority of Conneaut Creek in Pennsylvania, interstate land uses bear a significant influence on the biological quality of Conneaut Creek within Ohio (Figure 9). Land uses in the Pennsylvania portion of the Conneaut Creek watershed consist primarily of forest (49%), agriculture (31%), and wetlands (13%). Within a 200m buffer of the Conneaut Creek mainstem, primary land uses are 44% forest, 25% wetlands, and 21% agriculture. This nearly 70% majority forest and wetlands along Conneaut Creek in Pennsylvania likely contributes to the positive habitat attributes (e.g. low siltation/sedimentation) currently and historically observed near the Ohio/PA border.

Conneaut Creek became one of Ohio's State Wild and Scenic Rivers in October 2005 and is only one of three watersheds with this high-quality designation. The designation provides state protection to a 21-mile stretch of the creek, beginning from the state line to the former Penn Central railroad in the city of Conneaut. A Superfund site, located at RM 12.4, was identified and investigated by USEPA from 1982 to 1989 and approximately 93,000 yds³ of hazardous material were found. This site was owned by the Olin Corporation and is known as Big D Campground in Kingsville, Ohio. The site consists of a 1.2-acre landfill created from a former sand and gravel quarry and filled with hazardous materials from 1964 to 1976. Ground water contamination from volatile organic compounds, barium, chromium, and lead was remediated from 1992 to 1994.

Turkey Creek is a 9.04 mi² watershed that is located primarily in western Pennsylvania, with 1.23 mi² within Ohio borders. The creek lies directly east of Conneaut Creek, and flows entirely within protected wildlife preserve borders in its Ohio portion.

The findings of this evaluation may factor into regulatory actions taken but the Ohio EPA (e.g. NPDES permits, Director's Orders, or the Ohio Water Quality Standards [OAC 3745-1] and may be eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

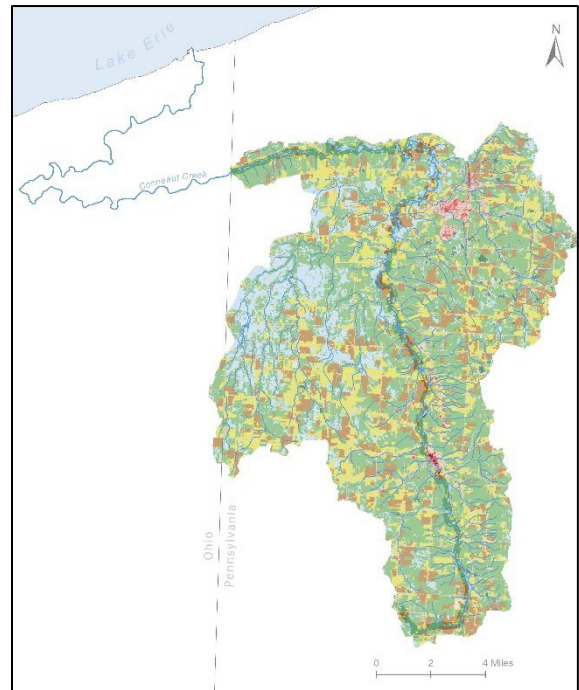


Figure 9. Land uses in the Pennsylvania portion of the Conneaut Creek watershed (USGS Stream Stats, NLCD 2016). Land uses within a 200m buffer of Conneaut Creek are highlighted. Please refer to Figure 8 for a land use key.

Results and Discussion

Macroinvertebrate Community

Macroinvertebrate communities were evaluated at 67 stations in the Lake Erie Central Basin Tributaries study area (Table 5, Appendices B and C). The community assemblages were evaluated as exceptional at 12 stations, very good at three, good at 17, marginally good at five, fair at nine, low fair at nine, poor at nine, and very poor at three stations.

Five streams are recommended to be designated as coldwater habitat (CWH). The station with the highest total Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa richness (EPT) was Conneaut Creek at South Ridge Road (RM 13.58) with 47 taxa. These insect orders are generally considered representative of high resource quality. Forty-six intolerant or uncommonly collected sensitive taxa were collected during this survey (Table 6 and Table 7), including a state-listed midge (*Rheopelopia acra*, Endangered), a state-listed caddisfly (*Chimarra socia*, Endangered), and a state-listed freshwater mussel *Ptychobranhus fasciolaris* (kidneyshell, Species of Concern). In addition, the first reported Ohio record of the caddisfly *Brachycentrus nigrosoma* (state-listed Endangered) was collected from Conneaut Creek at RM 2.7.



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Lorain County

Squires Squamm Ditch, Beaver Creek, Willow Creek, Brownhelm Creek, Quarry Creek, and Martin Run were evaluated in Lorain County, Ohio. The southern portion of the survey area within this county is mostly agriculture while the northern portion is predominantly urban development. Beaver Creek, the stream with the largest drainage area of the six, was sampled at seven sites. All sites met or exceeded the WWH biocriterion except for the site at Russia Road (RM 11.02) due to its natural wetland-like channel, aquatic vegetation, and low gradient conditions. The sampling location on Squires Squamm Ditch at Annis Road (RM 1.3) was also impaired because of natural wetland-like conditions. These two sites were only a couple miles from each other and are in an area with limited topographic relief. The non-achievement of the macroinvertebrate biocriterion of Brownhelm Creek was predominantly due to the sampling location being influenced by the lacustrine effect of Lake Erie. Willow Creek, Quarry Creek, and Martin Run flow through heavily developed areas and have macroinvertebrate communities that reflect the habitat alteration and urban runoff from the hardened watersheds. Throughout the county, even at sites that were meeting the ALU biocriterion, facultative macroinvertebrate taxa were the predominant organisms on the natural substrates, which may reflect elevated nutrient concentrations.

Table 5. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Lake Erie Central Basin Tributaries study area, June to September 2015.

Station	Stream RM	Dr. Ar. (mi ²)	QI. Taxa	EPT QI./Total	Sensitive Taxa QI./Total	Density QI./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	Narrative ICI	Evaluation
Lorain County										
Brownhelm Creek (20-100-000)										
303268	0.9	5.2	41	9	4	M	3	Hydropsychid caddisflies (F), midges (MT-F)	-	M. Good
Quarry Creek (20-101-000)										
303271	0.25	5.1	19	2	1	L	0	Sowbugs (T)	-	Poor
Beaver Creek (20-003-000)										
303263	13.75	6.3	55	12	6	M	0	Hydropsychid caddisflies (F), baetid mayflies (F), and heptageniid mayflies (F)	-	Good
Y01S26	11.02	11.5	40	8	4	M	0	Snails (MI-F), heptageniid mayflies (F), baetid mayflies (MI-F), and fingernail clams (F)	-	Fair
Y01S25	6.95	23	57	16/17	9/15	909	0	Baetid mayflies (F), blackflies (F), and midges (F)	46	
303265	4	26.7	45	12	7	H-M	0	Midges (F), baetid mayflies (F), hydropsychid caddisflies (F), and <i>Caenis</i> mayflies (F)	-	Good
303264	3.8	26.7	38	8/9	1/4	2535	0	Midges (F), baetid mayflies (F), and hydropsychid caddisflies (F)	36	
Y01S23	2.9	28	40	11/12	4/5	1108	0	Midges (F), baetid mayflies (F), and hydropsychid caddisflies (MI-F)	36	
Y01S22	1.75	43.0	38	10/11	3/8	2025	0	Midges (F), baetid mayflies (F), and hydropsychid caddisflies (MI-F)	44	
Squires Squamm Ditch (20-003-002)										
303266	1.3	5.47	32	3	0	M	0	Midges (T) and <i>Caenis</i> mayflies (F)	-	Poor
Willow Creek (Beaver RM 2.0) (20-005-000)										
303267	1.25	10.7	40	6	1	M-L	1	Hydropsychid caddisflies (F), riffle beetles (F), baetid mayflies (F), and midges (F-VT)	-	Fair
Martin Run (20-004-000)										
303269	2.35	2.34	21	3	1	L	0	Hydropsychid caddisflies (F), blackflies (F), and aquatic worms (T)	-	Low Fair
303270	0.9	5.3	36	4	0	L	0	Hydropsychid caddisflies (F), flatworms (F), midges (T-F), and aquatic worms (T)	-	Low Fair
Cuyahoga County										
Doan Brk (19-039-000)										
F01G52	6.64	1.3	12	0	0	L	0	Flatworms (F) and aquatic worms (T)	-	V. Poor
301696	5.5	4.4	12	0	0	L	0	Flatworms (F)	-	V. Poor
200137	2.7	7.7	23	3	1	M	0	Blackflies (F) and midges (T)	-	Poor
303287	2.27	8.12	29	2	0	H-M	0	Blackflies (F), midges (F-T), and baetid mayflies (F)	-	Poor
301428	0.75	9.1	26	2	0	M	0	Blackflies (F), midges (F-T), and baetid mayflies (F)	-	Poor
Ninemile Creek (19-040-001)										
301432	0.34	11.8	26	3	0	M	0	Blackflies (F)	-	Poor
Euclid Creek (19-041-000)										
303284	9.2	1.3	11	4	0	L	0	Blackflies (F), baetid mayflies (F), midges (T-MT) and aquatic worms (T)	-	Low Fair
303285	8.9	1.5	18	3	0	L	0	Blackflies (F), baetid mayflies (F), midges (T-MT) and aquatic worms (T)	-	Low Fair

Station	Stream RM	Dr. Ar. (mi ²)	QI. Taxa	EPT QI./Total	Sensitive Taxa QI./Total	Density QI./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI	Narrative Evaluation
303286	8.7	1.5	18	3	0	L	1	Blackflies (F), baetid mayflies (F), midges (T-MT) and aquatic worms (T)	-	Low Fair
F01G48	3.3	8.8	31	5	3	M	0	Hydropsychid caddisflies (F), baetid mayflies (F), and midges (MI-T)	-	Fair
F01A47	0.66	23.0	44	9/11	5/7	M/1262	1	Midges (F), baetid mayflies (F), and blackflies (F)	44	
Trib. to Euclid Creek (8.1) (19-041-004)										
303299	0.5	0.1	22	4	1	L	3	Midges (F-T) and blackflies (F)	-	Low Fair
303298	0.15	0.3	19	1	0	M	0	Blackflies (F) and flatworms (F)	-	V. Poor
East Branch Euclid Creek (19-041-001)										
303283	2.75	7.0	42	7	3	M-H	0	Midges (MI-F), blackflies (F), hydropsychid caddisflies (F), flatworms (F), and aquatic isopods (T)	-	Fair
301678	0.2	12.5	37	7	4	M	0	Midges (F), blackflies (F), hydropsychid caddisflies (F), and baetids (F)	-	Fair
Lake County										
Marsh Creek (03-026-000)										
303281	1.5	5.6	25	4	0	L	0	Hydropsychid caddisflies (F) and midges (F)	-	Low Fair
301157	0.2	14.1	17	2	0	L	0	Water mites (F) and midges (T)	-	Poor
Red Mill Creek (07-024-000)										
303280	1.7 ('15)	6.3	28	4	0	L	1	Hydropsychid caddisflies (F), blackflies (F), and midges (MT)	-	Low Fair
	1.7 ('16)	6.3	34	4	2	M	2	Midges (F)	-	Low Fair
Church Creek (07-022-000)										
303279	0.65	4.0	27	4	1	M	0	Amphipods (F) and flatworms (F)	-	Poor
Arcola Creek (07-011-000)										
A01K18	7.4	7.8	35	6	2	M	0	Hydropsychid caddisflies (F), baetid mayflies (F), and midges (F)	-	Fair
A01W22	7.05	7.9	20	4	0	M-H	0	Midges (MT-T)	-	Poor
A01W24	5.1	11.1	42	4/5	1/2	2284	0	Midges (F), hydropsychid caddisflies (F), baetids (F), and flatworms (T-F)	38	
A01W25	2.02	19.8	38	5/5	1/1	518	0	Hydropsychid caddisflies (F), flatworms (F), baetid mayflies (F), and midges (T-F)	38	
A01K17	0.7	20.3	51	6/8	6/7	243	0	Hydropsychid caddisflies (F), flatworms (F), baetid mayflies (F), and midges (T-F)	38	
Trib. to Arcola (4.32) (07-011-003)										
303278	0.1	4.94	52	13	10	M	4	Hydropsychid caddisflies (F), baetid mayflies (F), and midges (F)	-	Good
Trib. to Arcola (0.22) (07-011-002)										
303277	0.2	3.3	27	3	0	L	0	Aquatic isopods (T) and midges (T)	-	Low Fair
Ashtabula County										
Wheeler Creek (07-006-000)										
303276	2.75	6.77	62	15	10	M	3	Midges (F), hydropsychid caddisflies (F), and baetid mayflies (F)	-	Good
Cowles Creek (07-007-000)										
502700	7.24	6.8	54	16	13	M	0	Midges (F) and hydropsychid caddisflies (F)	-	Good
502710	4.83	11.2	59	15/16	13/15	420	1	Baetid mayflies (F), midges (F), hydropsychid caddisflies (F)	44	

Station	Stream RM	Dr. Ar. (mi ²)	QI. Taxa	EPT QI./Total	Sensitive Taxa QI./Total	Density QI./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	Narrative ICI	Evaluation
502720	3.56	12.5	38	4/5	1/1	581	1	Hydropsychid caddisflies (F), baetid mayflies (F), flatworms (F), and midges (F)	36	
A01P17	0.9	14.2	44	9/9	3/7	382	1	Midges (MI-F), baetid mayflies (F), hydropsychid and caddisflies (F)	46	
Trib. to Cowles (0.2) (07-007-001)										
303274	0.9	5.6	36	5	3	M-L	0	Hydropsychid caddisflies (F), midges (T-F), and aquatic worms (T)	-	Fair
Indian Creek (07-008-000)										
303272	3.65	5.12	55	14	13	L	0	Baetid mayflies (F), <i>Chimarra</i> caddisflies (MI), and blackflies (F)	-	Good
303107	0.65	15.3	64	20	14	M	0	Baetid mayflies (MI-F), <i>Hydroptila</i> caddisflies (F), and midges (F)	-	Exceptional
Trib. to Indian (3.53) (07-008-001)										
303275	0.15	4.5	43	14	11	M	2	Baetid mayflies (F), <i>Chimarra</i> caddisflies (F), midges (F), and hydropsychid caddisflies (F)	-	Good
Red Brook (07-009-000)										
303273	2.3	7.9	41	14	12	M	0	Hydropsychid caddisflies (MI-F), baetid mayflies (F), and riffle beetles (F)	-	Good
Whitman Creek (07-012-000)										
303275	1.2	1.6	25	4	5	M-L	1	Baetid mayflies (F), blackflies (F), and hydropsychid caddisflies (F)	-	Fair
303273	0.06	8.5	45	9	12	M-L	4	Midges (T-MI), hydropsychid caddisflies (F-MI), and baetid mayflies (F)	-	M. Good
Trib. to Lake Erie (1124.54) (07-025-000)										
303296	0.3	1.8	38	7	5	M-L	3	Amphipods (F), midges (F), hydropsychid caddisflies (F), and baetid mayflies (F)	-	M. Good
Trib. to Lake Erie (1117.00) (07-026-000)										
303295	0.2	1.9	40	5	2	M-L	3	Aquatic isopods (T), hydropsychid caddisflies (F), and <i>Hydroptila</i> caddisflies (F)	-	Fair
Conneaut Creek (07-100-000)										
303275	23.31	151.0	105	45/46	46/54	503	0	Baetid mayflies (I-F), hydropsychid caddisflies (MI-F), heptageniid mayflies (MI), and perlid stoneflies (MI-I)	56	
303273	17.12	158.0	105	42/44	42/50	549	0	Baetid mayflies (MI-F), hydropsychid caddisflies (MI-F), heptageniid mayflies (MI), perlid stoneflies (MI-I), and <i>Chimarra</i> caddisflies (MI)	54	
303297	13.58	169.0	116	45/47	48/52	403	0	Midges (F), hydropsychid caddisflies (MI-F), and heptageniid mayflies (F-MI)	56	
A01P15	12.05	171.0	121	45/45	51/53	1952	0	Midges (MI-F), baetid mayflies (I-F), hydropsychid caddisflies (MI-F), and heptageniid mayflies (F-MI)	54	
Conneaut Creek (07-100-000) <i>continued</i>										
303296	6.8	175.0	98	42	46	M	0	Midges (MI-F), perlid stoneflies (MI), baetid mayflies (I-F), hydropsychid caddisflies (MI-F), and heptageniid mayflies (F-MI)	-	Exceptional
303275	2.7	187.0	104	43	45	H	0	Hydropsychid caddisflies (F-MI), baetid mayflies (I-F), <i>Chimarra</i> caddisflies (I-MI), and <i>Isonychia</i> mayflies (MI)	-	Exceptional
Trib. to Conneaut (17.1) (07-100-003)										
303397	0.3	3.6	45	23	22	M-L	8	<i>Chimarra</i> caddisflies (MI), blackflies (F), heptageniid mayflies (MI-F)	-	CW/Exceptional
Trib. to Conneaut (14.82) (07-100-007)										
303291	0.85	1.0	44	20	19	M	2	Hydropsychid caddisflies (F-MI), perlid stoneflies (F), heptageniid mayflies (MI-F), and leptophlebiid mayflies (F)	-	Exceptional
Trib. to Conneaut (13.61) (07-100-006)										

Station	Stream RM	Dr. Ar. (mi ²)	QI. Taxa	EPT QI./Total	Sensitive Taxa QI./Total	Density QI./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI	Narrative Evaluation
303290	0.2	1.35	26	9	3	L	5	Midges (F) and <i>Neophylax</i> caddisflies (MI)	-	M. Good/CW
Trib. to Conneaut (7.39) (07-100-005)										
303293	0.1	1.7	41	11	16	H	12	Hydropsychid caddisflies (F), blackflies (F), and baetid mayflies (MI)	-	CW/Good
Trib. to Conneaut (4.67) (07-100-004)										
303292	0.7	2.8	39	9	6	M-L	2	Hydropsychid caddisflies (F), midges (F), and baetid mayflies (F)	-	M. Good
Smokey Run (07-100-001)										
A01P05	0.2	6.0	44	13	13	M-L	5	Baetid mayflies (MI-F), blackflies (F), midges (MI-F), and hydropsychid caddisflies (F-MI)	-	Good/CW
Trib. to Smokey (0.31) (07-100-008)										
303294	0.55	3.3	43	9	7	M	3	Baetid mayflies (F), midges (F), and hydropsychid caddisflies (F)	-	Good
Turkey Creek (07-200-000)										
A01P03	1.2	8.2	59	20	15	M-L	2	Midges (F), hydropsychid caddisflies (F), and heptageniid mayflies (F)	-	Exceptional

RM: River Mile.

Dr. Ar.: Drainage Area.

QI.: Qualitative sample collected from the natural substrates.

Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).

Qt.: Quantitative sample collected on Hester-Dendy artificial substrates; density is expressed in organisms per square foot.

Qualitative sample relative density: L=Low, M=Moderate, H=High.

CW: Coldwater.

Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant

Table 6. Uncommonly collected sensitive macroinvertebrate taxa locations in Lorain, Cuyahoga, and Lake counties in the Lake Erie Central Basin Tributaries study area, June to September 2015.

Taxa	Collection Location by River Mile
Mayflies	
<i>Acentrella turbida</i>	Euclid Cr. 0.66
Caddisflies	
<i>Trianodes melaca</i>	Trib. to Arcola Cr. (4.32) 0.1
Diptera	
<i>Dicranota</i> sp.	Trib. to Arcola Cr. (4.32) 0.1
<i>Eukiefferiella brehmi</i> group	Trib. to Euclid Cr. 0.5
<i>Parakiefferiella n. sp. 5</i>	Trib. to Arcola Cr. (4.32) 0.1
<i>Xylotopus par</i>	Quarry Cr. 0.25

Table 7. Uncommonly collected sensitive macroinvertebrate taxa and all freshwater mussel locations in Ashtabula County in the Lake Erie Central Basin Tributaries study area, June to September 2015. State listed species: E=Endangered, SC= Species of Concern.

Taxa	Collection Location by River Mile
Mayflies	
<i>Acentrella turbida</i>	Conneaut Cr. 23.3, 13.6, 12.05, 6.8, 2.7
<i>Plauditus dubius</i>	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 2.7
<i>Plauditus virilis</i>	Conneaut Cr. 6.8
<i>Baetis tricaudatus</i>	Smokey Run 0.2, Trib. to Conneaut Cr. (17.1) 0.15, Trib. to Conneaut Cr. (13.61) 0.2, Trib. to Conneaut Cr. (7.39) 0.1
<i>Choroerpes basalis</i>	Turkey Cr. 1.20; Trib. to Conneaut Cr. (17.1) 0.15
<i>Habrophlebiodes</i> sp.	Trib. to Conneaut Cr. (17.1) 0.15
<i>Teloganopsis deficiens</i>	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7
<i>Sparbarus lacustris</i>	Conneaut Cr. 13.6, 12.05
<i>Baetisca</i> sp.	Conneaut Cr. 6.8
<i>Ephemera blanda</i>	Trib. to Conneaut Cr. (14.82) 0.85
<i>Ephemera varia</i>	Trib. to Conneaut Cr. (14.82) 0.85
Stoneflies	
<i>Acroneuria internata</i>	Conneaut Cr. 23.3, 13.6, 12.05
<i>Acroneuria lycorias</i>	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7
<i>Agneta flavescens</i>	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7
<i>Neoperla</i> sp.	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7
Caddisflies	
<i>Chimarra socia</i> - E	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7
<i>Psychomyia flavida</i>	Indian Cr. 3.65, 0.65; Red Brook 2.3; Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7, Whitman Cr. 0.2
<i>Hydropsyche valanis</i>	Conneaut Cr. 13.6, 12.05, 6.8, 2.7
<i>Macrostemum zebratum</i>	Conneaut Cr. 13.6, 12.05
<i>Glossosoma</i> sp.	Trib. to Conneaut Cr. (17.1) 0.15, Trib. to Conneaut Cr. (7.39) 0.1
<i>Leucotrichia pictipes</i>	Conneaut Cr. 2.7
<i>Brachycentrus nigrosoma</i> - E	Conneaut Cr. 2.7
<i>Lepidostoma</i> sp.	Trib. to Conneaut Cr. (7.39) 0.1
<i>Ceraclea ancylus</i>	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8, 2.7
<i>Nectopsyche exquisite</i>	Cowles Cr. 7.24
<i>Oecetis avara</i>	Conneaut Cr. 23.3, 17.15, 13.6, 12.05, 6.8
<i>Trianodes ignitus</i>	Conneaut Cr. 17.15
<i>Trianodes melaca</i>	Cowles Cr. 7.24
Beetles	
<i>Microcylloepus pusillus</i>	Conneaut Cr. 13.6
<i>Optioservus ampliatus</i>	Conneaut Cr. 12.05, Trib. to Lake Erie (1124.54) 0.3
<i>Optioservus trivittatus</i>	Conneaut Cr. 23.3, 17.15, 13.6, 2.7
<i>Anchytarsus bicolor</i>	Trib. to Conneaut Cr. (7.39) 0.1

Taxa	Collection Location by River Mile
Diptera	
<i>Dicranota</i> sp.	Smokey Run 0.2, Trib. to Smokey Run (0.31) 0.55, Trib. to Conneaut Cr. (17.1) 0.15, Trib. to Conneaut Cr. (7.39) 0.1, Whitman Cr. 0.2
<i>Limnophila</i> sp.	Trib. to Conneaut Cr. (7.39) 0.1
<i>Pseudolimnophila</i> sp.	Trib. to Conneaut Cr. (7.39) 0.1
<i>Rheopelopia acra-</i> E	Conneaut Cr. 17.15, 12.05
<i>Corynonuera</i> sp. 12	Cowles Cr. 0.9
<i>Lopescladius</i> sp.	Conneaut Cr. 6.8
<i>Nanocladius (Plecopteracoluthus) downesi</i>	Conneaut Cr. 6.8
<i>Xylotopus</i> par	Trib. to Cowles Cr. (0.2) 0.9
<i>Polypedilum</i> n. sp. 1	Trib. to Conneaut Cr. (17.1) 0.15
<i>Cladotanytarsus vanderwulpi</i> group sp. 4	Red Brook 2.3
<i>Cladotanytarsus vanderwulpi</i> group sp. 5	Conneaut Cr. 17.15
Freshwater Mussels	
<i>Ptychobranchnus fasciolaris</i> - SC	Conneaut Cr. 23.3

Cuyahoga County

Euclid Creek, two unnamed tributaries to Euclid Creek, Doan Brook, and Ninemile Creek were sampled in Cuyahoga County as part of the 2015 sampling effort. These streams exhibited impairment typical of urban streams, including hydromodification, historic sediment contamination, habitat alteration, nonpoint source pollutants from storm water runoff, and CSOs (Figure 11). In addition to the known CSO locations as shown in Figure 11, there were also numerous documented improper connections and bacteriological contaminated storm sewers in the cities of Cleveland and Euclid, which could have an impact on the water quality in the streams sampled in Cuyahoga County (NEORS D 2015).

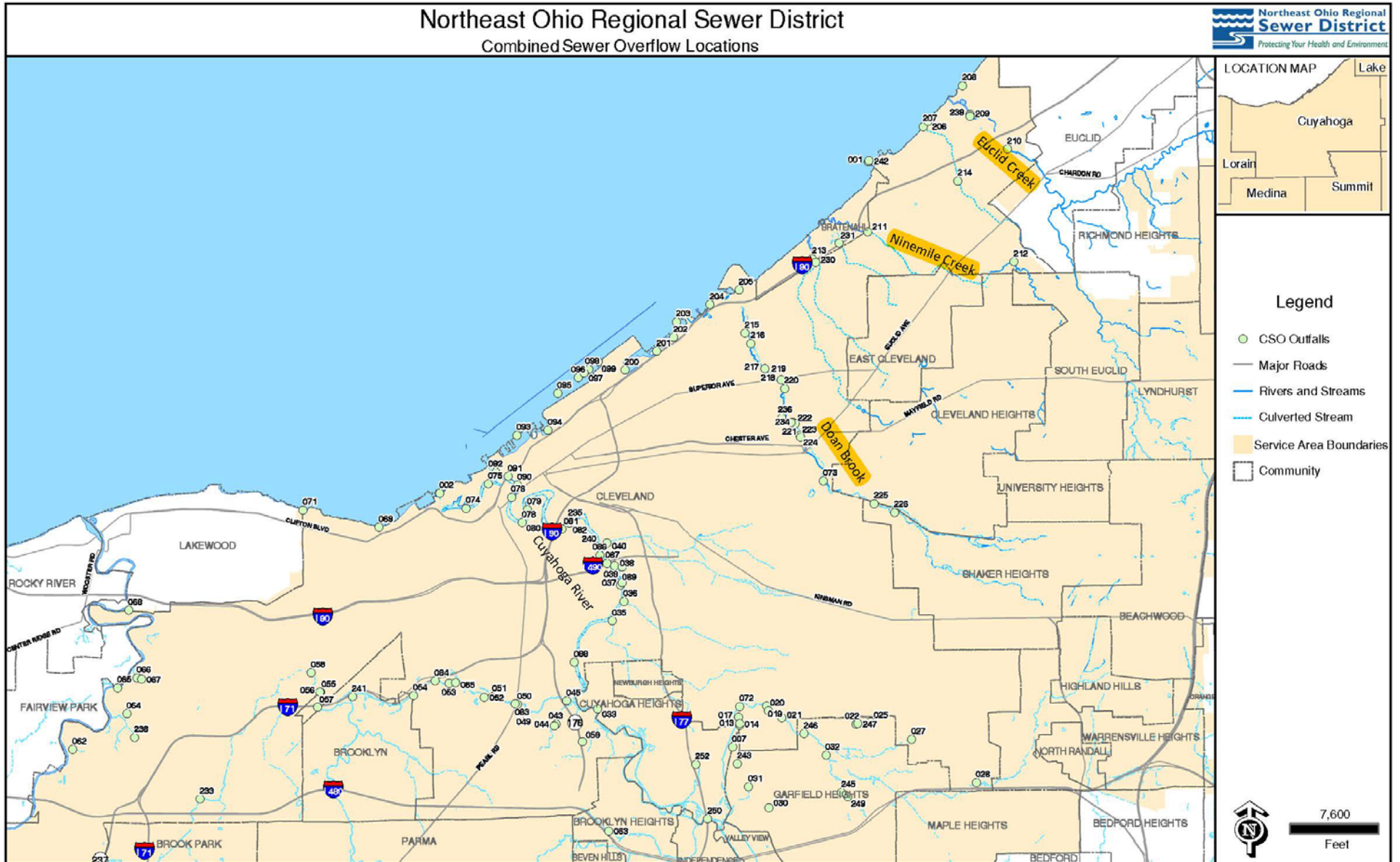
The macroinvertebrate communities at four of the five locations in Euclid Creek did not meet the WWH biocriterion, which were mostly attributable to the urban impacts mentioned in the preceding paragraph. Although the most downstream sampling station on Euclid Creek had a very good ICI score (44), the macroinvertebrate community was predominated by facultative organisms. This site can have a lacustrine influence from Lake Erie; however, the location sampled in 2015 was free-flowing and had requisite flow and depth for Hester-Dendy sampler deployment.

Two sites were evaluated on East Branch Euclid Creek, one in a former dam pool which is now free-flowing, and one two miles upstream from the old dam. In December 2010, an Ohio EPA Section 319 grant funded the removal of the dam and abutments and initiated the restoration of natural stream habitat conditions of approximately 700 linear feet of East Branch Euclid Creek. Although habitat has improved from a QHEI of 30 (poor) in 2008 to a 68 (good) in 2015, fair macroinvertebrate communities were associated with continued negative influences from the urbanized watershed. A dam removal project was proposed for a pond on the unnamed tributary to Euclid Creek at river mile 8.1, and the project was going to be funded through the Ohio EPA Section 319 grant program. To fulfill the grant requirements, the unnamed tributary was evaluated at one site upstream from impounded reach and at one site downstream from dam. The site upstream from the dam had a low fair macroinvertebrate community that was dominated by facultative and tolerant midges and blackflies. The site downstream from the dam was dominated by blackflies and flatworms and only one EPT taxon was collected. This site was evaluated as very poor.

Doan Brook and Ninemile Creek had only poor and very poor macroinvertebrate communities at all the locations sampled in 2015. Doan Brook had the highest concentration of CSOs of any of the streams sampled in the survey, a series of dams, and much of the stream is culverted or has a concrete lined channel (Figure 10). Evidence of elevated nutrient water quality parameters (Table 14) was evident in the relatively high densities of facultative taxa within the riffle/run habitats at these sites; however, nutrients were not cited as the primary cause for nonattainment at these sites (Table 1).



Figure 10. Doan Brook, RM 2.27, upstream view. Throughout this reach, Doan Brook is a concrete lined and channelized with a series of dams. Like all the streams sampled in Cuyahoga County, legacy sediment contamination, CSOs, habitat alteration, and urban runoff severely impact the macroinvertebrate community in this watershed.



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Figure 11. Location of CSOs within the NEORS D survey area.

Lake County

Marsh Creek, Arcola Creek, two unnamed tributaries to Arcola Creek, Church Creek, and Red Mill Creek were sampled in Lake County as part of the Lake Erie Central Basin Tributaries survey in 2015. Most of the streams within the county shared similar sources of water quality impacts from surrounding land use and contaminated sediment resuspension. Marsh Creek flows through Mentor and the surrounding suburbs before entering Mentor Marsh. The creek exhibited areas of natural wetland-like conditions, which can be a natural cause of impairment; however, this stream was not attaining due to sedimentation and siltation from urban runoff. Red Mill Creek is located between Marsh Creek and Church Creek and drains into Lake Erie west of the Perry Nuclear Power Plant. Despite a good habitat conditions, the qualitative macroinvertebrate sample was evaluated as low fair in both 2015 and 2016. Facultative hydropsychids, blackflies, and moderately tolerant and facultative midges were predominant in the riffles. This may reflect the elevated nitrate-nitrite values that were collected from the site; however, the macroinvertebrate community appeared to be negatively impacted by another unknown source. Church Creek had a poor macroinvertebrate community that was likely due to the resuspension of PCB contaminated sediments.

The streams within the Arcola Creek watershed exhibited impairment from the largest land use in the watershed - agriculture, which is mostly plant nursery production (Lake SWCD 2009). The entire length of Arcola Creek did not meet WWH expectations for macroinvertebrate communities; however, the three most downstream sampling locations had attaining ICI scores. Pesticides were found either in the water column and/or in sediment at all the sampling locations, which could be a reason for macroinvertebrate underperformance. Although nutrient parameters sampled at Arcola Creek at RM 7.05 were slightly elevated, the site had extremely high densities of the tolerant red midge *Chironomus C. riparius* group, which reflected enriched conditions likely sourced from unrestricted cattle access. Macroinvertebrate communities with high densities of facultative hydropsychid caddisflies, usually an indication of nutrient enrichment, were observed at RMs 5.0 and 2.02; however, nutrient parameters were within the statewide nutrient targets. A tributary to Arcola Creek at RM 0.22 did not meet ecoregional expectations due to natural wetland conditions. Another tributary at RM 4.32, which contained a relatively intact wooded floodplain, was the only stream exhibiting some attributes of a coldwater stream Lake County. Central mudminnows (*Umbra limi*), a coldwater fish, and four coldwater macroinvertebrates were collected at the site; however, due to the limited number of coldwater taxa collected, the WWH use designation will remain assigned to the stream.

Ashtabula County

Ashtabula County had the most sampling locations of the four counties that were sampled for the Lake Erie Central Basin Tributaries Survey (28 sites on 18 streams) and the highest percentage of attaining sites (approximately 89%) and the only county with streams that truly exemplify exceptional and coldwater habitat streams. Forty-four uncommonly collected sensitive taxa were collected in Ashtabula County and 27 of those were collected from the Conneaut Creek mainstem (Table 7).

The streams that did not achieve their ALU biocriterion - an unnamed tributary to Cowles Creek at RM 0.2, the upstream site on Whitman Creek, and an unnamed tributary to Lake Erie at RM 1117.00 - were all impacted by anthropogenic channel modification. The tributary to Cowles Creek at RM 0.2 had limited aquatic macroinvertebrate habitat due to channelization and sedimentation from

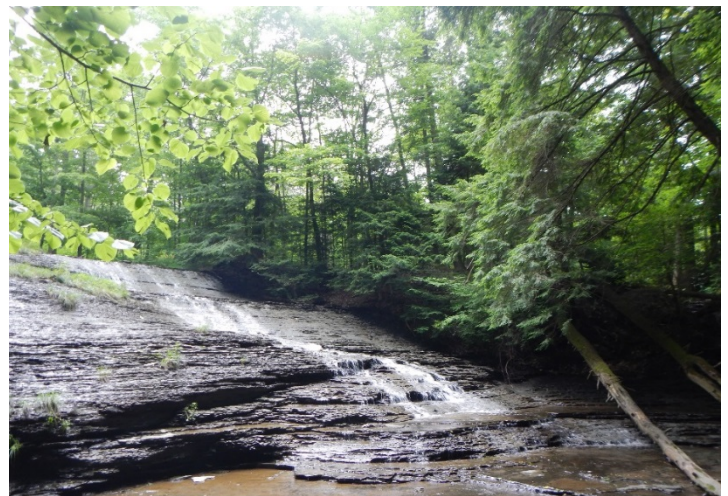


Figure 12. Tributary to Conneaut Creek at RM 17.1 at State Road, upstream view. This stream had an exceptional and coldwater macroinvertebrate community

the golf course upstream from the sampling location. The macroinvertebrate community seemed to be similarly impacted by channelization and sedimentation from a golf course upstream from the sampling location in the unnamed tributary to Lake Erie at RM 1117.00. The highest nitrate-nitrite values in the Lake Erie Central Basin Tributaries Survey were collected from Cowles Creek at RM 3.56 (Table 14). Although the site at RM 3.56 met WWH with an ICI score of 36, the diversity of qualitative EPT and sensitive taxa dropped significantly from the upstream site. The high densities of facultative hydropsychid caddisflies on both the natural and artificial substrates reflected the elevated nutrients at the site. The downstream site on Cowles Creek at RM 0.9 also had high nitrate-nitrite values and moderate densities of facultative hydropsychids and midges, but the diversity of EPT and sensitive taxa appeared to rebound from the site upstream (Table 6).

Conneaut Creek had some of the highest EPT and sensitive taxa quantities in the entire state. This is likely due to a combination of its northeastern location within the state, a relatively intact and wide riparian corridor in Pennsylvania, minimal direct anthropogenic alterations upstream from the shipping channel, and contribution of many high quality/coldwater tributaries. The plant community in Ashtabula County is unique in Ohio due to the Northern Allegheny Mountain influence (Cooperrider et. al. 2001), which may also contribute to significant aquatic macroinvertebrate diversity in the basin. Five of the six direct tributaries to Conneaut Creek are recommended to be designated as CWH or a dual use of CWH and EWH (Figure 12). A new state record for a caddisfly, *Brachycentrus nigrosoma*, was collected at RM 2.1 and was subsequently listed as Endangered.

Trends

The 2015 survey was the first time that many of the Lake Erie Central Basin Tributaries were systematically sampled. Three sites were sampled on Beaver Creek in 1997 (Figure 13). The two sites upstream from the Amherst WWTP at RMs 4.9 and 7.1 scored ICI values in the very good and exceptional range, respectively. The downstream site at RM 2.8 did not achieve the WWH biocriterion with an ICI value of 14 (fair). The 1997 TSD cited the Amherst WWTP as having an adverse impact on the macroinvertebrate community in Beaver Creek (Ohio EPA 1998). Although the 2015 ICI score has improved since 1997, the qualitative EPT and sensitive taxa showed that there is still some impairment at the site just downstream from the WWTP. Throughout most of the sampled stretch of Beaver Creek, the qualitative EPT and sensitive taxa numbers were below expected numbers for a WWH stream. Only three of the seven sites, RMs 13.75, 6.95, and 4.0, had qualitative EPT numbers that were at or above expected numbers.

Ohio EPA first sampled Doan Brook and Euclid Creek in 2000 (Figure 14 and Figure 15). The streams in this county have had many grant-funded restoration projects within their watersheds; however, little improvement has been observed in the macroinvertebrate communities. These streams failed to attain the WWH expectation for qualitative EPT and sensitive taxa and there has been little to no improvement in the macroinvertebrate community since they were first sampled. The most downstream site on Euclid Creek attained WWH with an ICI score of 44; however, the qualitative EPT and sensitive taxa were below what is expected for WWH stream.

All the 2015 sampling locations on Arcola and Cowles Creek were previously sampled in 1995 (Figure 16 and Figure 17). Despite meeting the WWH biocriterion at all sampling locations in Arcola Creek in 2015, qualitative sensitive and EPT numbers were similar to those from 1995, indicating only marginal recovery from the habitat modifications, enrichment, and surrounding land use practices implicated in the 1995 study (Ohio EPA 1996). Water withdrawals from local nurseries for irrigation were noted as causing lower than normal flows in late summer in both Cowles and Arcola creeks. This was not observed in the 2015 survey. The two most upstream sampling locations on Cowles Creek in 2015 showed improvement from the 1995 samples, as both qualitative EPT and sensitive taxa increased to above expectations for a WWH stream. The three sites quantitatively sampled on Cowles Creek in 2015 had improved ICI scores, but the qualitative EPT and sensitive taxa diversities were similar to the 1995 samples.

Only the mainstem of Conneaut Creek was sampled previously by Ohio EPA. The three stations in 1995 and five stations in 2006 showed exceptional macroinvertebrate communities similar to the 2015 survey (Figure 18).

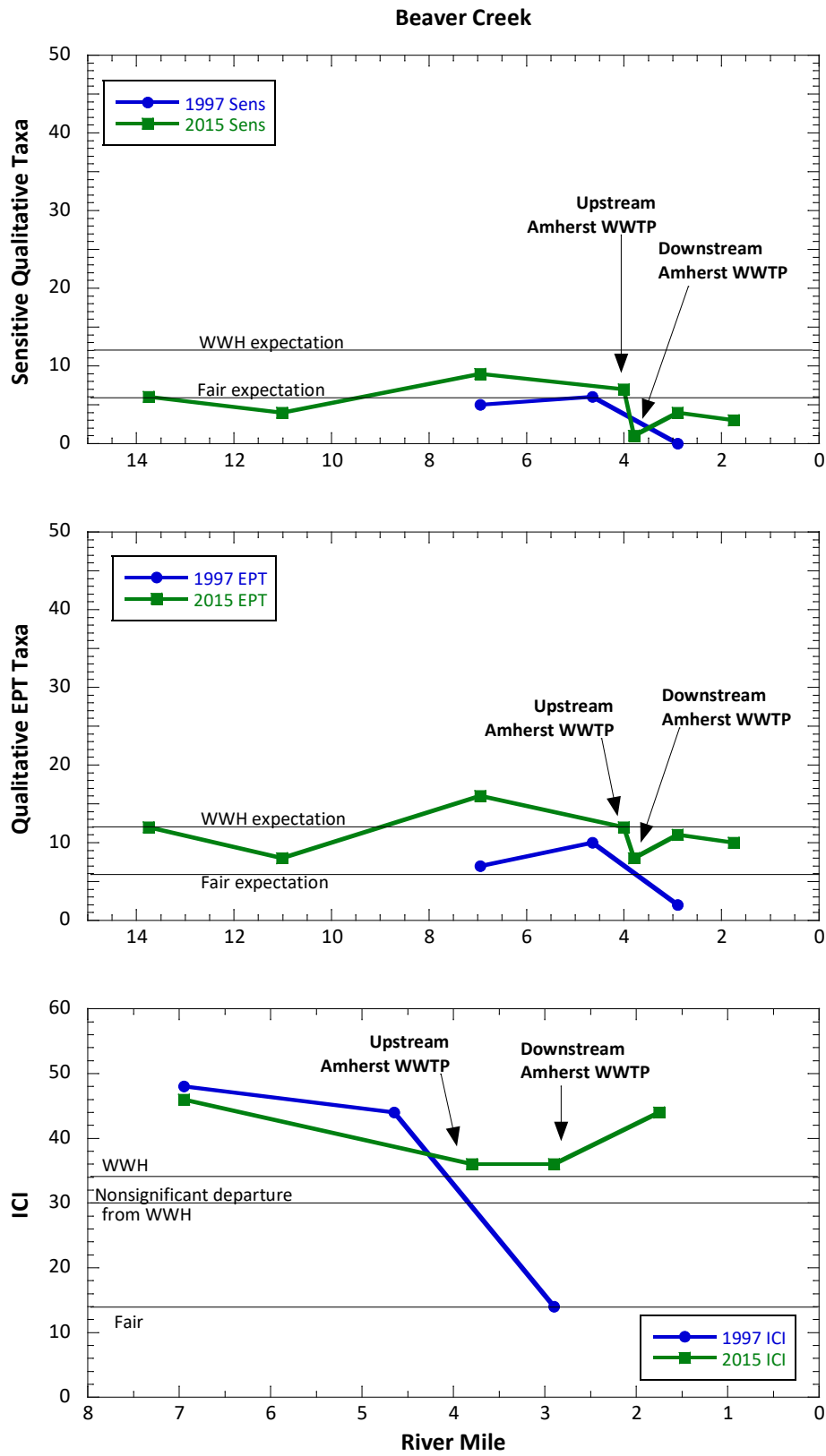


Figure 13. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Beaver Creek, 2015.

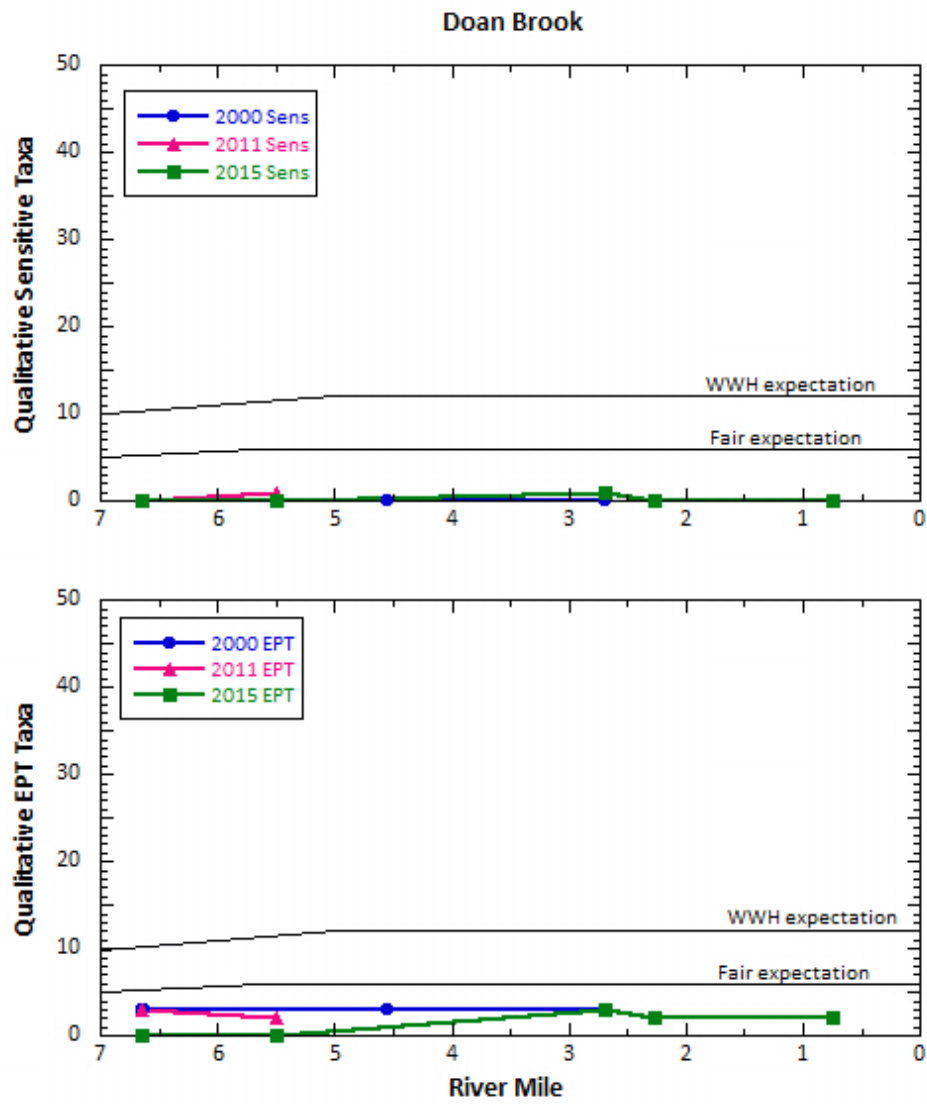


Figure 14. Longitudinal trend of the number of sensitive taxa in the qualitative sample and number of EPT taxa (EPT) in the qualitative sample in Doan Brook, 2015.

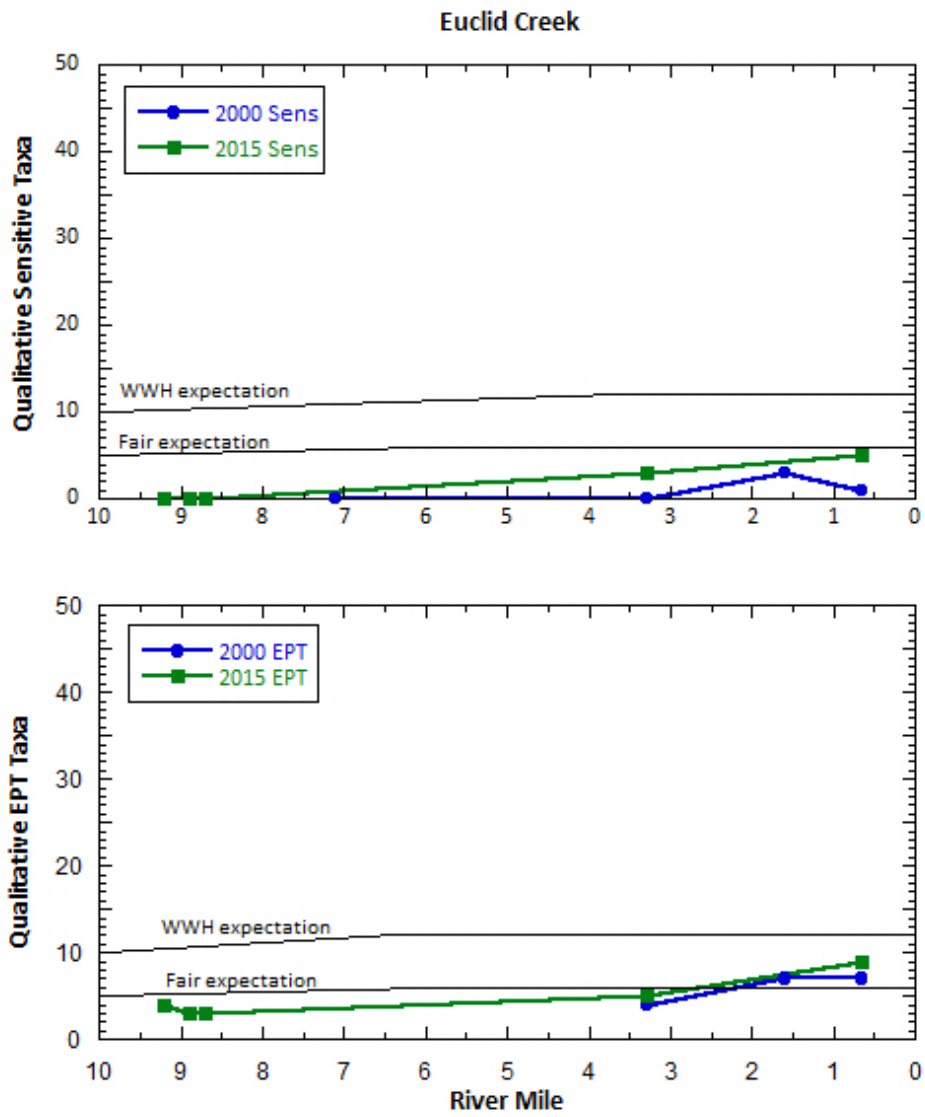


Figure 15. Longitudinal trend of the number of sensitive taxa in the qualitative sample and number of EPT taxa (EPT) in the qualitative sample in Euclid Creek, 2015.

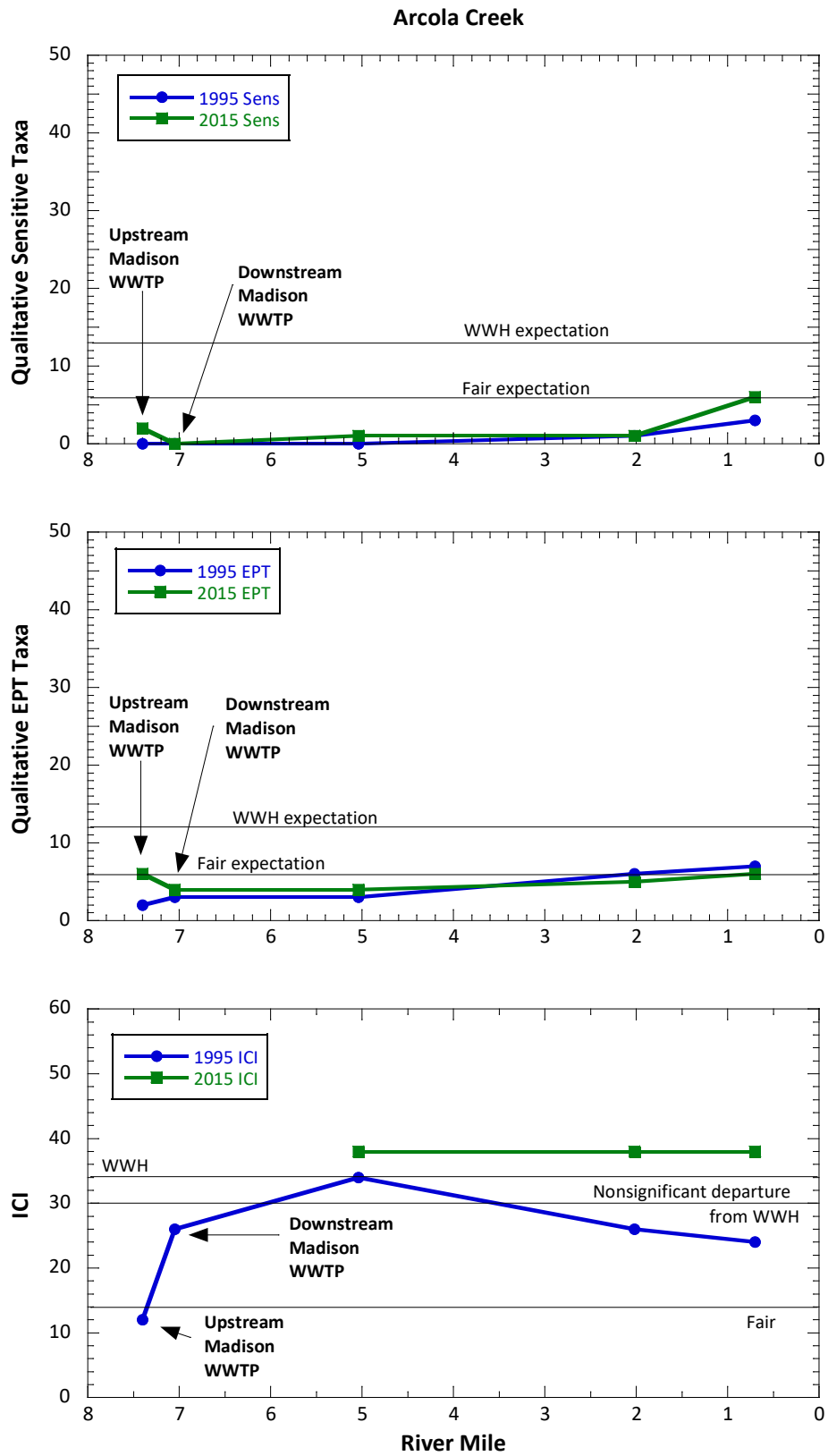


Figure 16. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Arcola Creek, 2015.

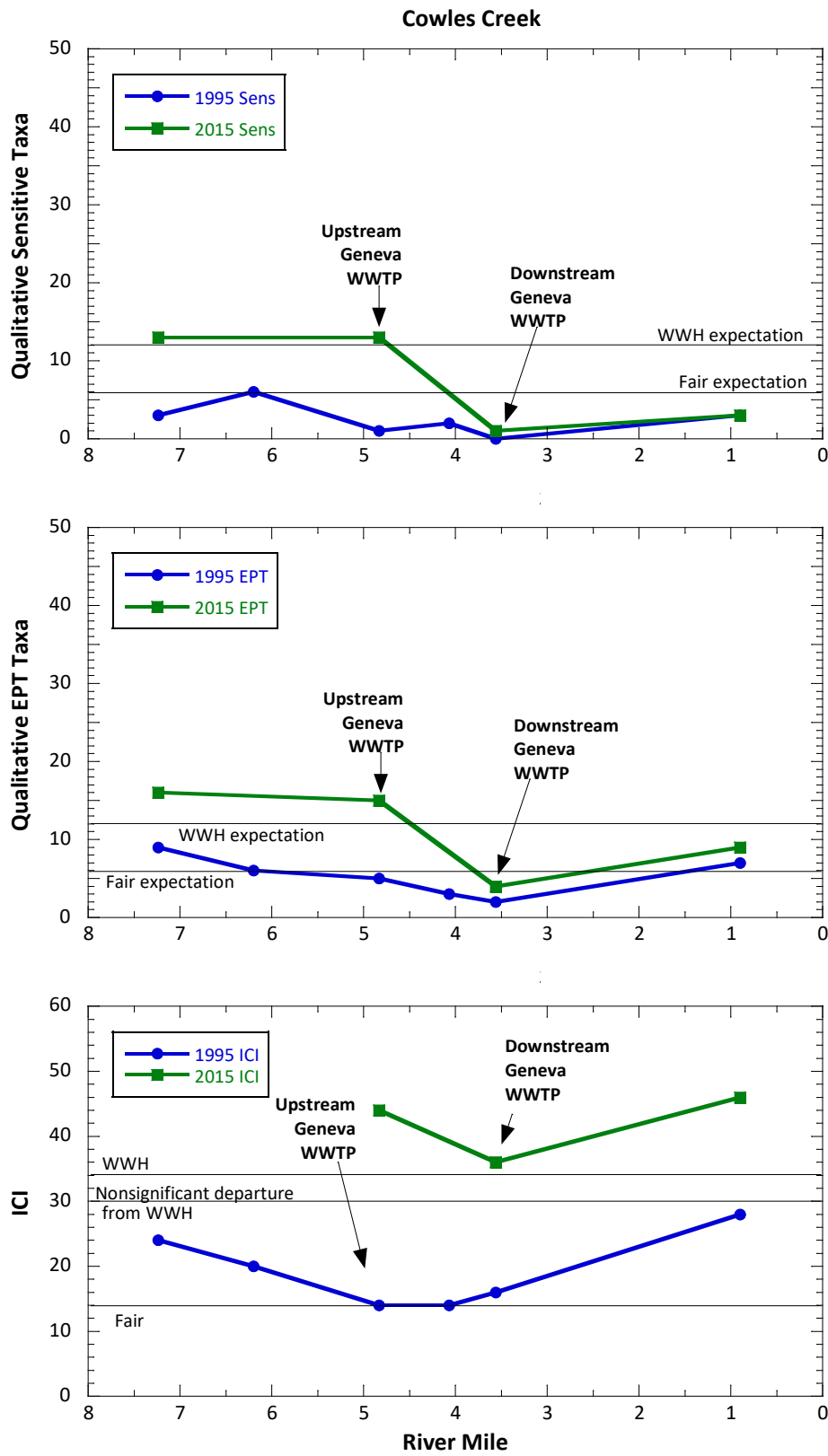


Figure 17. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Cowles Creek, 2015.

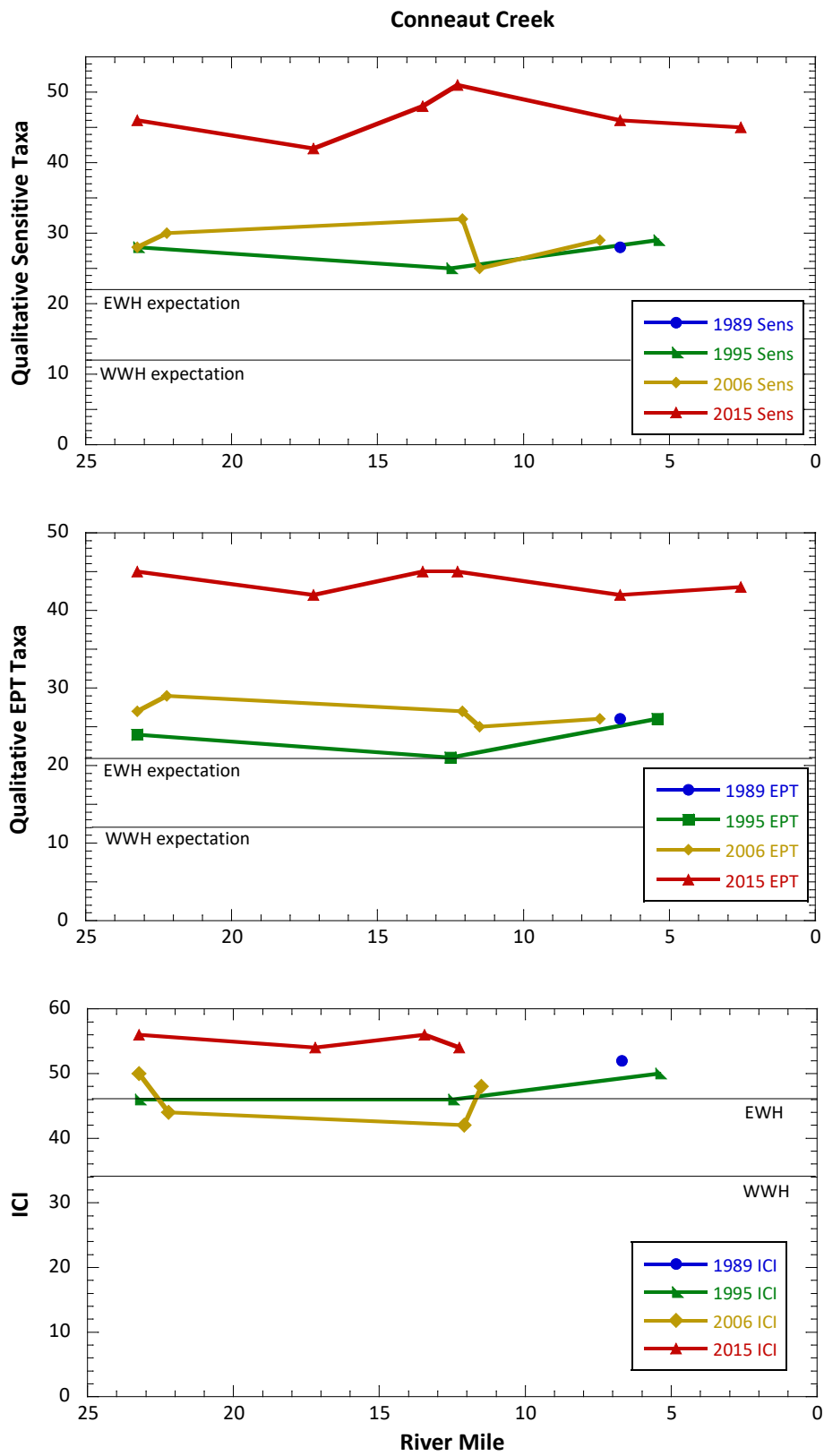


Figure 18. Longitudinal trend of the number of sensitive taxa in the qualitative sample, number of EPT taxa (EPT) in the qualitative sample, and the Invertebrate Community Index (ICI) in Conneaut Creek, 2015.

Fish Community

Summaries of the Central Basin Lake Erie tributaries fish communities in Lorain, Cuyahoga, Lake and Ashtabula counties are presented below. Ohio EPA collected 56,040 fish among 60 fish species in study area streams between Amherst and the Ohio Pennsylvania border at 63 sites in 2015 and four sites in 2016. Total species collected per location, relative number and relative number excluding pollution tolerant species, relative weight, predominant species, QHEI, MIwb, and IBI scores are listed in Table 8.

The 2015 survey was the first time many smaller Lake Erie Central Basin Tributaries were systematically sampled for fish by Ohio EPA. Watersheds with historical data include Beaver Creek (last sampled by Ohio EPA in 1997), Doan Brook and Euclid Creek (last sampled by Ohio EPA in 2000), Arcola and Cowles Creeks (last sampled by Ohio EPA in 1995), and Conneaut Creek (last sampled by Ohio EPA in 2007). Otherwise, 19 samples were obtained from 16 different smaller study area streams (three of these were assessed at two locations). Fair fish community performance (IBI \bar{x} =32) was documented at these sites in 2015.

Lorain County

Brownhelm and Quarry creeks were the most western streams in the 2015 survey. Both streams, at slightly more than five square miles drainage, were affected by degraded habitat qualities. Silty stream substrates and little noticeable current inhibited aquatic communities in both streams. Brownhelm Creek's fish assemblage was bolstered by the sample site's proximity to Lake Erie. About half of the 20 fish species in the fair scoring assessment represented the downstream refugia rather than serving as a reflection of upstream heritage. Unfortunately, access for fish sampling upstream wasn't possible. Quarry Creek, with ten fish species, registered a fair IBI score. The culvert under a railroad grade acted as a flow through dam in periods of extreme flow. Ample woody debris and significant fines were dispersed in the stream channel and across the adjacent flood way. Again, better fish sampling access could not be arranged to avoid the periodically inundated reach.

Beaver Creek drains 45 mi² upstream and through Amherst where seven mainstem fish communities averaged marginally good index scores (IBI \bar{x} =38, MIwb \bar{x} =8.7). Beaver Creek was previously assessed by Ohio EPA in 1992 and 1997 (Figure 19). Considerable water quality improvement has occurred in the lower reach of Beaver Creek since prior surveys. In 1992 and 1997, episodic releases from the Amherst WWTP exerted toxic influences on the downstream biological community. Sewage bypasses and instream residual chlorine were variously associated with downstream poor performance. Although a slight decline attributed to the facility was observed in 2015, all fish indices scores at sites bracketing the WWTP and downstream were in the good to very good range (IBI \bar{x} =43, MIwb \bar{x} =9.0, n=4). In 2015, 18 to 22 fish species were obtained at these four sample sites. In relative terms, each sample was comprised by 3,659 to 6,164 fish and entire catches weighed 15.2 kg to 23.7 kg. Previously, 8 to 15 fish species comprising catches numbering 203 to 1302 and weighing 1.3 kg to 10.6 kg were obtained among five sample locations in this lower reach beginning just upstream from the Amherst WWTP. Upgrades and process improvements completed at the WWTP have resulted in distinct fish assemblage improvements.

These improvements have not been realized upstream from the facility. Fish indices at RM 7.0 were fair-poor (IBI =32, MIwb =4.6) in 1992, marginally good-fair (IBI =35, MIwb =6.4) in 1997, and marginally good-good (IBI =34, MIwb =7.9) in 2015. Over the same period, habitat conditions at the site have declined from good in 1992 and 1997 (QHEI=71.5, 60.5, respectively) to fair in 2015 (QHEI=52.0). And, fair habitat quality was common at other upper reach locations in 2015 (QHEI \bar{x} =52.5, n=3). Likewise, fish community performance was fair at two upstream 2015 sample sites. The inability of Beaver Creek to demonstrate upper reach water quality improvement commensurate to that documented in the lower reach was attributed to habitat shortcomings. Beaver Creek exhibited limited water flow and generally shallow water depths throughout the upper reach. The stream appeared to be recovering from historical channel modification and attendant consequences of flashy flows.

Martin Run drains 5.3 mi² of area between Beaver Creek and the Black River, west from the City of Lorain. Like urban streams to the east, Martin Run rapidly conveys storm water from neighborhood developments. Martin Run's flashy stream hydrograph limits its aquatic community health. Poor fish index scores were recorded at two sample sites.

Table 8. Summary of fish community data based on wading, pulsed D.C. electrofishing samples collected in the Lake Erie study area, 2015 (no boat sampling occurred).

Total including non-native species is cumulative where multiple samples were obtained. Relative number or weight (kg) is normalized to 300-meter sampling distances for all sites. Weights are not recorded, and the Modified Index of well-being is not applicable at headwater locations. All sites were in the Erie Ontario Lake Plain (EOLP) ecoregion. Biocriteria follow Table 1. Other descriptions follow.

Stream	mi ²	Total Species	Relative Number /less tolerants	Relative Weights	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
<i>Lorain County</i>								
Brownhelm Creek								
0.9	5.2	20	1708/ 790	-	50.5	-	32*	Fair
creek chub (35%), central stoneroller (29%), white sucker (13%), round goby (11%)								
Quarry Creek								
0.3	5.1	10	2307/ 672	-	34.5	-	30*	Fair
creek chub (59%), central stoneroller (28%), white sucker (9%), bluntnose minnow (2%)								
Beaver Creek								
13.8	6.3	8	606/ 158	-	54.5	-	30*	Fair
creek chub (46%), green sunfish (16%), white sucker (13%), central stoneroller (11%)								
11.0	11.6	11	1461/ 621	-	51.0	-	30*	Fair
creek chub (50%), rainbow darter (22%), central stoneroller (14%), Johnny darter (4%)								
7.0	23.0	13	4478/ 3794	15.2	52.0	7.9	34 ^{ns}	Good-M Good
central stoneroller (65%), rainbow darter (14%), creek chub (12%), silverjaw minnow (3%)								
4.0	26.7	22	3933/ 3393	23.7	67.5	8.7	46	Good-V Good
central stoneroller (44%), rainbow darter (32%), creek chub (8%), striped shiner (7%)								
3.8	26.7	18	3659/ 3233	15.2	62.0	8.4	42	Good
central stoneroller (49%), rainbow darter (31%), white sucker (7%), striped shiner (4%)								
2.9	28.0	21	6164/ 5036	19.6	56.5	9.0	42	V Good-Good
central stoneroller (50%), rainbow darter (21%), creek chub (11%), white sucker (7%)								
1.8	43.2	21	3744/ 3227	22.4	68.5	9.7	40	Except.-Good
central stoneroller (32%), rainbow darter (21%), mimic shiner (13%), striped shiner (8%)								
Willow Creek								
1.3	10.7	11	4059/ 3561	-	52.5	-	36 ^{ns}	M Good
central stoneroller (76%), rainbow darter (10%), white sucker (7%), creek chub & green sf. (3%)								
Squires Squamm Ditch								
1.3	5.5	13	1462/ 122	-	50.0	-	36 ^{ns}	M Good
mudminnow (31%), creek chub (30%), green sunfish (20%), white sucker (9%)								
Martin Run								
2.4	2.3	7	580/ 118	-	67.0	-	26*	Poor
creek chub (63%), white sucker (16%), bluegill sunfish (10%), central stoneroller (9%)								
0.9	5.3	7	2302/ 870	-	57.5	-	24*	Poor
creek chub (35%), white sucker & central stoneroller (23%), round goby (11%)								

Stream RM	mi ²	Total Species	Relative Number /less tolerants	Relative Weights	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
Cuyahoga County								
Doan Brook								
6.6	1.3	4	825/ 100	-	62.0	-	<u>26</u> *	Poor
creek chub (69%), central stoneroller (12%), blacknose dace (10%), green sunfish (8%)								
5.5	4.4	5	478/ 35	-	58.0	-	<u>22</u> *	Poor
creek chub (80%), central stoneroller (7%), blacknose dace (6%), green sunfish (5%)								
3.1	7.7	4	50/ 0	-	73.0	-	<u>20</u> *	Poor
creek chub (88%), common carp, yellow bullhead & green sunfish (4%)								
0.8	9.1	1	2/ 0	-	44.0	-	<u>12</u> *	Poor
blacknose dace (100%)								
Doan Brook sampled in 2016								
2.3	8.1	4	111/ 5	-	73.8	-	<u>24</u> *	Poor
green sunfish (57%), creek chub (33%), white sucker (6%), central stoneroller (4%)								
Ninemile Creek								
0.3	11.8	2	5/ 0	-	66.0	-	<u>12</u> *	Poor
creek chub & white sucker (50%)								
Euclid Creek								
8.7	1.5	1	290/ 0	-	53.5	-	<u>20</u> *	Poor
creek chub (100%)								
8.5	1.5	1	50/ 0	-	53.0	-	<u>20</u> *	Poor
creek chub (100%)								
3.3	8.8	3	258/ 78	-	66.0	-	<u>24</u> *	Poor
blacknose dace (44%), central stoneroller (30%), creek chub (26%)								
0.7	23.0	17	2745/ 642	22.2	62.0	7.2	<u>26</u> *	Fair-Poor
white sucker (38%), creek chub (26%), central stoneroller (21%), blacknose dace (11%)								
Euclid Creek sampled in 2016								
8.9	1.5	4	3102/ 8	-	69.5	-	<u>24</u> *	Poor
creek chub (98%), fathead minnow, blacknose dace & bluegill sunfish (1%)								
East Branch Euclid Creek								
2.8	7.0	7	1860/ 990	-	53.5	-	30*	Fair
central stoneroller (53%), bluntnose minnow (15%), white sucker (12%) creek chub (11%)								
0.2	12.5	5	2988/ 1450	-	68.0	-	32*	Fair
central stoneroller (49%), blacknose dace (26%), creek chub (20%), white sucker (5%)								
Euclid Creek Tributary @ RM 8.1 sampled in 2016								
0.5	0.1	2	412/ 412	-	62.0	-	36 ^{ns}	M Good
bluegill sunfish (75%), largemouth bass (25%)								
0.2	0.3	4	1186/ 436	-	54.8	-	28*	Fair
creek chub (63%), bluegill sunfish (32%), pumpkinseed sunfish (5%)								
Lake County								
Marsh Creek								
1.5	5.6	12	664/ 220	-	61.5	-	<u>26</u> *	Poor
creek chub (37%), central stoneroller (21%), white sucker (19%)								
Red Mill Creek								
1.7	6.3	9	1260/ 824	-	71.0	-	36 ^{ns}	M Good

Stream RM	mi ²	Total Species	Relative Number /less tolerants	Relative Weights	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
central stoneroller (46%), creek chub (13%), blacknose dace (11%)								
Church Creek								
0.7	4.0	9	526/ 38	-	47.0	-	22*	Poor
white sucker (56%), creek chub (23%), green sunfish (9%)								
Arcola Creek								
7.4	7.8	13	1022/ 428	-	56.0	-	34*	Fair
creek chub (36%), central stoneroller (9%), white sucker (6%)								
7.0	7.9	13	1470/ 194	-	49.0	-	30*	Fair
white sucker (67%), creek chub (15%), Johnny darter (7%)								
5.0	11.1	12	650/ 275	-	44.0	-	26*	Poor
white sucker (37%), Johnny darter (30%), creek chub & central mudminnow (8%)								
2.0	19.8	14	1193/ 590	-	59.5	-	30*	Fair
white sucker (28%), central stoneroller (18%), rainbow darter (17%), Johnny darter (12%)								
0.7	20.3	22	1820/ 1002	3.8	52.0	7.5	42	M Good-Good
white sucker (20%), rainbow darter (30%), Johnny darter (12%)								
Arcola Creek Tributary at RM 0.22								
0.2	3.3	8	532/ 238	-	48.0	-	28*	Fair
Johnny darter (31%), central mudminnow & white sucker (23%), largemouth bass (12%)								
Arcola Creek Tributary at RM 4.32								
0.1	4.9	14	498/ 304	-	61.0	-	38 ^{ns}	M Good
rainbow darter (25%), Johnny darter (20%), creek chub (19%)								
Ashtabula County								
Wheeler Creek								
2.8	6.8	16	1172/ 638	-	70.0	-	46	V Good
creek chub (25%), rainbow darter (24%), blacknose dace (11%)								
Cowles Creek								
7.2	6.8	16	1156/ 626	-	73.5	-	42	Good
creek chub (31%), American brook lamprey (14%), central stoneroller (10%)								
4.8	11.2	15	934/ 576	-	51.5	-	38 ^{ns}	M Good
central stoneroller (47%), creek chub (18%), white sucker (15%)								
3.6	12.5	19	1498/ 634	-	73.5	-	40	Good
creek chub (30%), central stoneroller (24%), white sucker (10%)								
0.9	14.2	21	868/ 530	-	73.0	-	42	Good
central stoneroller (42%), creek chub (27%), common shiner (5%)								
Cowles Creek Tributary at RM 0.2								
0.9	5.6	17	962/ 368	-	55.5	-	32*	Fair
white sucker (22%), creek chub (19%), round goby (15%), Johnny darter (10%)								
Indian Creek								
3.7	5.1	14	1330/ 622	-	62.0	-	48	V Good
central mudminnow (26%), common shiner (17%), creek chub (13%)								
0.7	15.3	16	1312/ 876	-	55.5	-	36 ^{ns}	M Good
central mudminnow (34%), creek chub (20%), rainbow darter (8%)								
Indian Creek Tributary at RM 3.53								
0.2	4.5	17	1485/ 455	-	71.0	-	46	V Good

Stream RM	mi ²	Total Species	Relative Number /less tolerants	Relative Weights	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
central mudminnow (34%), creek chub (20%), rainbow darter (8%)								
Red Brook								
0.4	9.4	15	782/ 420	-	57.0	-	34*	Fair
Johnny darter (42%), creek chub (18%), blacknose dace (16%)								
Whitman Creek								
1.2	1.6	6	407/ 167	-	57.0	-	32*	Fair
creek chub (38%), Johnny darter (36%), white sucker (17%)								
0.1	8.5	16	760/ 126	-	58.5	-	26*	Poor
creek chub (39%), blacknose dace (31%), white sucker (11%)								
Lake Erie Tributary @ RM 1124.54								
0.3	1.8	3	795/ 125	-	62.0	-	28*	Fair
creek chub (60%), blacknose dace (24%), fantail darter (16%)								
Lake Erie Tributary @ RM 1117.00								
0.2	1.9	7	1278/ 63	-	47.0	-	28*	Fair
creek chub (70%), blacknose dace (18%), white sucker (7%)								
Conneaut Creek								
23.2	151	14	2444/ 62	75.8	100	10.1	53	Exceptional
creek chub (27%), central stoneroller, green sunfish & white sucker (12%)								
17.2	158	24	1523/ 293	19.3	91.0	9.4	47	Except.-V Good
fantail darter (17%), creek chub (12%), bluntnose minnow (8%)								
13.2	169	19	1335/ 958	49.0	77.5	9.2	52	V Good-Except.
striped shiner (21%), bluntnose minnow, fantail darter & logperch (11%)								
12.3	171	25	969/ 667	44.8	82.0	9.1	51	V Good-Except.
bluntnose minnow (42%), spotfin shiner (22%), bluegill sunfish (11%)								
6.8	175	21	1097/ 128	57.7	96.3	9.7	55	Exceptional
green sunfish (21%), spotfin shiner (19%), bluegill sunfish (10%)								
2.6	187	24	1465/ 383	44.4	94.5	9.9	51	Exceptional
bluntnose minnow (35%), gizzard shad (10%), spotfin shiner (9%)								
Conneaut Creek Tributary @ RM 17.1								
0.3	3.6	6	632/ 10	-	73.0	-	28*	Fair
creek chub (73%), blacknose dace (13%), white sucker (6%)								
0.2	3.6	16	404/ 184	-	87.0	-	46	V Good
creek chub (31%), white sucker (19%), Johnny darter (15%), fantail darter (10%)								
Conneaut Creek Tributary @ RM 14.82								
0.9	1.0	3	740/ 20	-	78.5	-	32*	Fair
blacknose dace (57%), creek chub (40%), redbside dace (3%)								
Conneaut Creek Tributary @ RM 13.61								
0.2	1.4	6	265/ 108	-	61.5	-	32*	Fair
creek chub (57%), rainbow trout (39%), white sucker (2%)								
Conneaut Creek Tributary @ RM 7.39								
0.7	1.7	1	464/ 464	-	66.8	-	32*	Fair
rainbow trout (100%)								
Conneaut Creek Tributary @ RM 4.67								
0.7	2.8	9	1474/ 866	-	59.0	-	38 ^{ns}	M Good

Stream RM	mi ²	Total Species	Relative Number /less tolerants	Relative Weights	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
central stoneroller (35%), Johnny darter (21%), creek chub & blacknose dace (13%)								
Smokey Run								
0.2	3.8	17	650/ 430	-	64.0	-	48	V Good
Rainbow trout (29%), central stoneroller (21%), creek chub & white sucker (14%)								
Smokey Run Tributary @ RM 0.31								
0.6	3.3	8	1023/ 135	-	72.0	-	30*	Fair
creek chub (49%), blacknose dace (23%), Johnny darter (11%), white sucker (7%)								
Turkey Creek								
1.4	7.8	18	616/ 436	-	70.0	-	46	V Good
rainbow darter (32%), Johnny darter (20%), creek chub (12%), bluntnose minnow (8%)								

RM: River mile.

mi²: Drainage area in square miles.

Relative Number less pollution tolerant fish is an IBI metric. MIwb calculations exclude these fish deemed tolerant by Ohio EPA: central mudminnow, white sucker, common carp, goldfish, golden shiner, blacknose dace, creek chub, bluntnose minnow, fathead minnow, green sunfish, yellow bullhead, brown bullhead, and eastern banded killifish.

QHEI: Qualitative Habitat Evaluation Index.

MIwb: Modified Index of well being.

IBI: Index of Biotic Integrity.

Cuyahoga County

Doan Brook (9.8 mi²) was inhabited by poor fish arrays at four 2015 sites and at one 2016 site (IBI \bar{x} =21). Doan Brook is a high gradient, urban storm water conveyance. Its upper reaches are checked by impoundments. Its middle course is hidden within a near mile long culvert. Its lower reach is constricted within vertical walled banks before it flows underground again, through twin 14 foot box culverts nearly three quarters of a mile long, to eventually join Lake Erie. Lingering enrichment in the aftermath of CSOs produced sewage fungus growth in most pooled areas. With numerous natural waterfalls and engineered gradient controls, Doan Brook has tremendous erosive capacity. The stream exhibits this trait by transporting an excessive amount of bedload it appears to have plucked from any unarmored surface along its course. Between rains, little flow leaves the various catchments and Doan Brook lacks water.

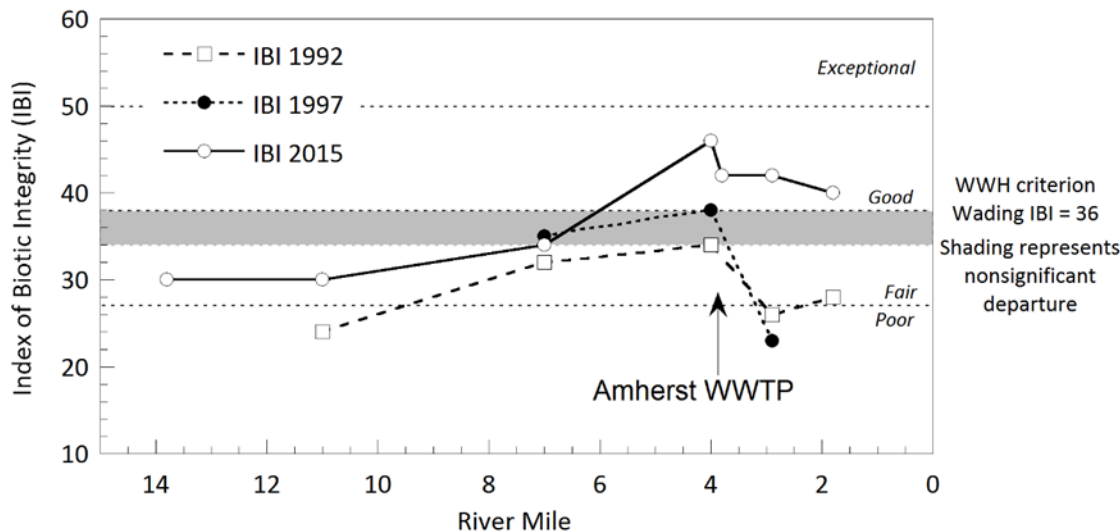


Figure 19. Longitudinal performance of the Index of Biotic Integrity (IBI) in Beaver Creek, 1992-2015.

Since 2000, Ohio EPA and the Northeast Ohio Regional Sewer District (NEORS) have completed 28 fish samples in Doan Brook between Horseshoe Lake and the box culvert. Six samples were conducted in the South Branch upstream from Green Lake. Results from these 34 samples have typically been poor. Index of Biotic Integrity values have ranged from 12 to 32. Only six samples achieved the lowest fair criterion. All South Branch scores were poor. Pollution tolerant creek chubs, blacknose dace, stoneroller minnows and green sunfish prevailed. Upstream refugia allow these hardy fish to repopulate downstream reaches following sporadic storm water toxicity.

Ninemile Creek drains 11.8 mi² of area between Doan Brook and Euclid Creek. Like Doan Brook and Euclid Creek, Ninemile Creek has been used for urban storm water management with most of its course buried in a culvert. The stream emerges from the culvert at the CSX railroad, flows a quarter mile in the open, then passes under eight lanes of I-90 into another culvert. Ninemile Creek then flows less than a half mile before finally meeting the backwater of Lake Erie at Lakeshore Blvd. Creek chub and white suckers were present in the open stream reach which achieved a poor IBI score. Sewage fungus and trash typical of CSOs were observed here. Between 2010 and 2014, NEORS assessed the Ninemile Creek fish community with 14 samples at a location near Lake Erie and at two headwater sites upstream from the culverted reach, all results were poor.

Poor fish assemblages were present at four Euclid Creek (23.3 mi²) sites in 2015 (IBI \bar{x} =23) and again at one 2016 location (IBI=24). Two different tributaries were sampled at two sites in 2015 and 2016. Fair IBI scores were observed at these sites (IBI \bar{x} =31.5). Euclid Creek sampling noted the extreme stress exerted by extraordinary flash flows and from random instances of toxic discharge or storm runoff. Sites in the most upstream part of the sub-basin were selected to assess the effect of future restoration projects. An abnormal amount of water at RM 8.5 in 2015 was traced to a ruptured drinking water distribution pipe. The accidental discharge entered Euclid Creek at RM 8.75. Only creek chubs were present at RM 8.7 and 8.5, yielding poor index scores. A year later, fathead minnows, blacknose dace, and bluegill sunfish were amongst the creek chubs at RM 8.9. Despite the presence of additional species, the assemblage still scored poorly. Fish assessment at RM 9.2 was prevented by numerous culverts and a storm water basin which interfered with establishing an appropriate sampling zone.

Marginally good fish performance in a tributary to Euclid Creek at RM 8.1 was the only achievement of a fish biocriterion in the sub-basin. Sampling in anticipation of the planned removal of an impoundment, the upstream achieving assemblage of fish was limited to bluegill sunfish and largemouth bass. This representation

of water quality at a site with about one hundred acres of drainage area is misleading. Fair results downstream from the impoundment were also skewed by bluegill and pumpkinseed sunfish. These pond inhabitants only confirmed the presence of the soon to be drained catchment. Similarly, a single goldfish was collected downstream. Otherwise, creek chubs at the downstream site were consistent with the fractional drainage area that may be dry in the future.

Removal of a dam in December 2010 on the East Branch near its confluence with Euclid Creek provided opportunity for upstream fish passage. Unfortunately, no new fish species have been recorded in the East Branch subsequent to the restoration project. Five pollution tolerant species, present in the former impoundment in 2015, earned a fair IBI score. Since 2000, ten fish samples in the vicinity of the dam (3 downstream, 2 upstream prior to removal and 1 downstream, 4 upstream afterwards) have all consistently returned fair IBI scores (28-34). Three additional samples at RM 2.8 in 2013, 2014, and 2015 obtained the same results.

During storms, the Euclid Creek sub-basin becomes a torrential, boulder crushing rapids that scours every surface in its course. Enhanced by significant impervious surfaces, efficient storm drains, and steep gradients, high flows in Euclid Creek are inhospitable to aquatic life. Only three fish species were collected at RM 3.3, just upstream from the East Branch confluence.

At RM 0.7, Euclid Creek is constrained within a U.S. Army Corps of Engineers flood control project. This lower gradient reach near Lake Erie is where the ground up rock that's been conveyed downstream is deposited as excessive bedload. The NEORSD removed 7400 cubic yards of this "shoaling" to aid storm water management in the winter of 2017 (Etling 2017). The reach begins at a grade control "spillway" structure situated immediately downstream from the CSX railroad tracks. The disparity in fish species abundance upstream compared to that downstream verifies the spillway prevents fish passage. Ohio EPA noted 17 fish species at RM 0.7 in 2015. Between 2000 and 2016, 20 fish assessments were completed by multiple investigators at RM 0.7. Cumulatively, 40 fish species were documented downstream from the spillway during the 17-year effort. For comparison, 36 fish samples upstream from the spillway in Euclid Creek or its tributaries since 1989 have recorded 17 fish species including a logperch darter, black bullhead, and redear sunfish in the former East Branch impoundment. Not including pond escapees and singular bait bucket type specimens yields a list of nine species that are endemic to the upstream sub-basin.

The paucity of fish species upstream from the spillway are likely attributed to historical pollution and barriers to fish migration. Aside from the one logperch darter obtained in the East Branch in 2008, no other darters have been recorded in the Euclid Creek sub-basin upstream from the spillway. Logperch are the only darter species that have been collected downstream and they were individually uncommon. Redhorse suckers have not been recorded upstream and only rarely downstream. Silverjaw minnows, sand shiners, and striped shiners exhibit the same pattern. More fish species likely once inhabited the entire Euclid Creek watershed, particularly in the upstream reaches. Subjected to unknown water quality perturbations, these fish were eliminated as the area was developed. Natural waterfalls, mill dams, drop culverts, and grade control structures have prevented fish from returning to former habitat. Area development has also modified Euclid Creek making the stream inhospitable for some native fish species. Contemporary efforts to slow runoff, reconnect flood plains, and to remove fish migration barriers in the Euclid Creek basin have occurred and more are planned. As these projects improve watershed conditions, some purposeful fish stocking may be needed to reintroduce species to isolated stream reaches.

Lake County

Mentor Marsh, a National Natural Landmark and a state nature preserve, lies in an abandoned channel of the Grand River, west from its present Lake Erie confluence. Marsh Creek (5.6 mi²) flows into the Marsh at its southwest perimeter. Reliance on Marsh Creek as a storm water conveyance was apparent considering its routinely scoured stream banks along with silty, sandy, pea gravel bedload. Those conditions were offset by

numerous types of cover and deep riffles, yielding a good habitat score (QHEI=61.5). However, those aspects were insufficient to support darters and only four native minnow species were collected. Ten of the twelve fish species comprising three fourths of the assemblage were tolerant or partially tolerant of pollution. The presence of nearby wetlands was reflected by several associated fish species. Recognizing these qualities, the lack of diversity was attributed to variable storm water effects and an excessive sediment load.

The Village of North Perry owns the Lake Erie waterfront Townline Park which encompasses the lower reach of Church Creek. This small stream (4.0 mi²) drains a beach ridge north from Arcola Creek. Dirty, sandy stream substrates offered no interstitial voids causing Church Creek to lack darters. Only three minnow species were present and all fish were tolerant or partially tolerant of pollution. Although the sand substrates seemed unstable and overall habitat conditions were fair (QHEI=47.0), the predominance of tolerant fish suggested additional factors may have limited the poor fish assemblage (IBI=22).

Arcola Creek (21 mi²) was home to fair fish communities at five mainstem sample locations (IBI \bar{x} =32, Figure 18) and at two tributary sites (IBI \bar{x} =33). Amongst Lake Erie tributaries, Arcola Creek is distinguished for the lack of development at its mouth. The natural wetland surrounding Arcola Creek at its confluence with Lake Erie provides a glimpse of what Euclid Creek and other small streams were like before flood control and storm water management was deemed necessary. Nevertheless, Arcola Creek was also modified upstream and habitat degradation taxes water quality throughout the watershed.

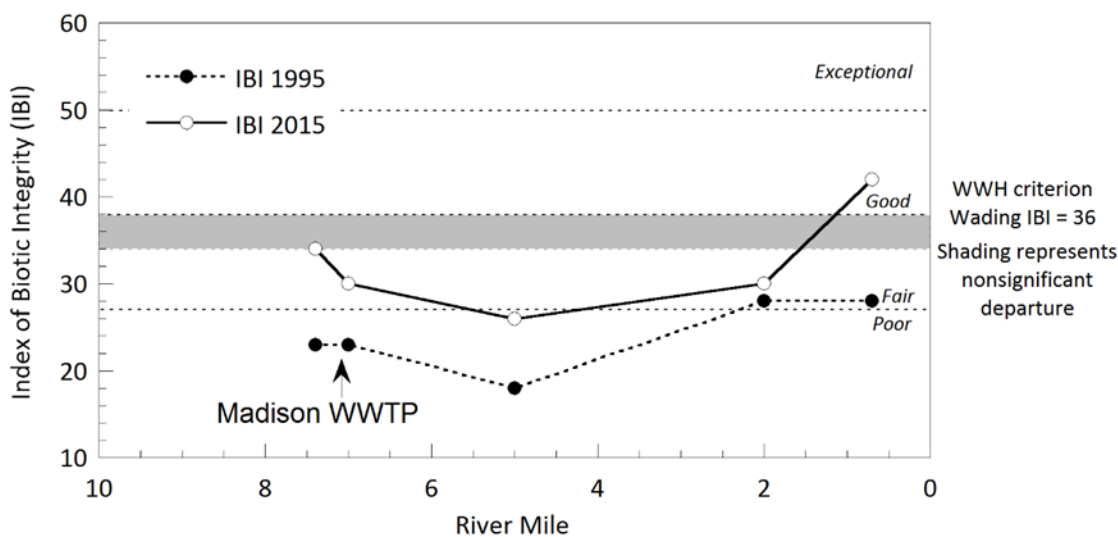


Figure 20. Longitudinal performance of the Index of Biotic Integrity (IBI) in Arcola Creek, 1995-2015

The most upstream Arcola Creek sample sites bracketed the Madison WWTP. In both 1995 and 2015, decreased stoneroller minnow abundance was offset by increased white sucker abundance downstream from the facility (Figure F2 lower plot). This shift reflects changing substrate conditions. Although Arcola Creek was embedded upstream from the Madison WWTP, the silty gravel stream bed transitioned, becoming more embedded in sandy gravel, and then entirely sand at the next two downstream locations. In 2015, white sucker abundance downstream from the facility dominated proportional metrics causing the IBI scores to fall from fair to poor. Bedrock at the farthest downstream sample sites supported increasing stoneroller minnow numbers while white suckers remained predominant. Rainbow and Johnny darters were most abundant at these locations. The proportional increases of these insectivores helped the IBI scores to climb from fair to good. Numerous juvenile largemouth bass at the most downstream site further affected the proportional metrics. Categorized as carnivores, these dubious predators positively skewed the corresponding metric value.

The small size of these and all other fish at the most downstream site generated a moderately good MIwb score.

The generally fair Arcola Creek fish community performance was consistent with generally fair habitat qualities (QHEI \bar{x} =52.1, n=5). Silty embedded substrates in the upper reach were exacerbated by cattle wading in the stream immediately downstream from the Madison WWTP. Channelization has disconnected the stream from adjacent floodplains and trapped sediment in an incised waterway in the middle reach. The overwide, bedrock based, lower reach was too shallow to support larger bodied, pool oriented fish species. The influence of the WWTP and other possible sources of enrichment were confused within this matrix of habitat limitations. Even so, the preponderance of omnivorous, pollution tolerant fish and near absence of intolerant species (two stonecat madtoms were at the most downstream site) were indicative of excessive silt loading.

Collection of a silver lamprey ammocoete (or possible identical northern brook lamprey ammocoete) in Arcola Creek at RM 2.0 was a unique record. Ohio EPA obtained northern brook lamprey ammocoetes in the Ashtabula River in 2011. This non-parasitic ecotype was also recorded in the Grand River. Because both nearby streams present barriers to migration from Lake Erie, it's reasonable to assume any ammocoetes must complete their life cycle within those stream basins and are thus the "brook" form of the species. Lacking a permanent barrier from Lake Erie, the Arcola Creek ammocoete was tentatively identified as the native, parasitic ecotype silver lamprey (Mandrak, Docker and Heath 2004).

Lampreys are evolutionarily ancient and surprisingly well adapted. Some, like the silver lamprey and northern brook lamprey exist as "pairs." They are considered the parasitic and non-parasitic descendants of a common parasitic ancestor. These genetically similar ecotypes are hypothesized to be the same species (Ren et al. 2014; Docker, Mandrak and Heath 2012). As native Ohio fish, they differ from the exotic sea lamprey which lacks a non-parasitic analog. Sea lamprey predation on Great Lakes fish has been studied earnestly since the 1950's. Meanwhile, attention toward other lampreys languished. Advances in genetic sequencing have recently led to new discoveries about lamprey phylogeny.

Ashtabula County

Good communities resided in Cowles Creek (20.5 mi²) at four mainstem (IBI \bar{x} =41, Figure 19) sites while a fair assemblage was noted at one tributary site (IBI=32). American brook lamprey ammocoetes were collected at all Cowles and Wheeler Creek survey sites. These native Ohio fish are one of four "satellite" species paired with the parasitic "stem" arctic lamprey. Despite apparent morphological differences exhibited by American brook lamprey with its stem and other satellites, there is little to no genetic variation between them (White 2014; Li 2014). Altogether, 144 ammocoetes obtained in the 2015 survey were carefully considered to ensure accurate identification. The absence of sea lamprey ammocoetes was unexpected. These results should influence any discussion of lampricide treatment for Arcola, Cowles and Wheeler Creeks.

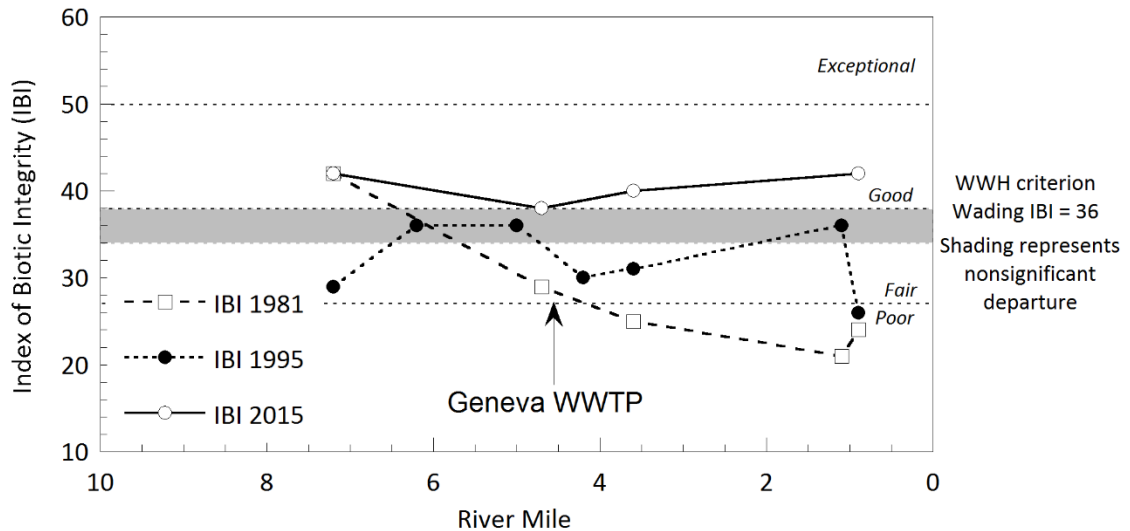


Figure 21. Longitudinal performance of the Index of Biotic Integrity (IBI) in Cowles Creek, 1981-2015

The Cowles Creek fish community has improved since 1981 and 1995 in response to upgrades at the Geneva WWTP (Figure F3). In previous surveys, declining IBI scores coincided with a dearth of darters downstream from the facility. This absence implied effluent had a toxic effect on aquatic life. In 2015, downstream darter abundance reflected site habitat conditions and no apparent effect was discerned due to the Geneva WWTP operation. Earlier surveys typically reported 11 species at each site. In 2015, 15 to 21 fish species were recorded (25 cumulatively) including American brook lamprey and a half dozen small rainbow trout.

Red Brook, draining 9.4 mi² on the west side of Ashtabula, is aptly named. Tannins stained the water and algal covered bedrock surfaces with a reddish hue. Habitat quality at the fish assessment site, in a golf course upstream from Lake Erie backwater, was fair (QHEI=57.0) consisting generally of shallow pool depths. A large 20-inch smallmouth bass, apparently stranded from Lake Erie, occupied the deepest pool in the sampled reach. Minnows were noticeably less abundant here. Moderate IBI metric scores were on par with marginal shale riffle habitat and less functional cover.

Whitman Creek was assessed at two sites in 2015 where fair and poor fish communities were documented. In 1995, poor and marginally good fish assemblages were present at the same respective locations. Johnny darters were proportionally numerous in 2015 (n=58) whereas only three were obtained in 1995. This shift and the exchange of mottled sculpin for round goby accounted for better upstream and declining downstream score differences. The impetus for the 1995 sampling was to discern possible effects from a landfill and hazardous waste injection facility on LaBounty Rd. Whitman Creek is especially dendritic. The downstream sample site captures potential influences from a branch draining the waste operation and from another branch draining the North Kingsville community. Neither survey identified any apparent impact from the waste facility. In 2015, the North Kingsville branch demonstrated storm water effects with a heavier sand bedload while the western branch appeared opaque with reddish precipitates, likely due to iron. Habitat conditions were deemed influential to fish community performance in both surveys. A single rainbow trout was present in both studies at the downstream site. Whitman Creek is noteworthy as one of two Ohio streams that contained endemic brook trout. A restoration project in the Chagrin River basin is striving to preserve native brook trout in that watershed. No brook trout have been recorded in Whitman Creek since the 1800's.

Two un-named tributaries to Lake Erie, each draining nearly 2mi², were sampled between Whitman and Conneaut Creeks. The Lake Erie Tributary at RM 1117.00 was assessed in Conneaut Township Park. Fair habitat quality (QHEI=47.0) due to abundant fine, unstable pea gravel probably restricted some fish, but the

collection of only one fantail darter suggested other factors may have been limiting. The likelihood that the Tributary could become completely dry in some years was plausible. The Lake Erie Tributary at RM 1124.54 had good habitat (QHEI=62.0), but only three species were present. Fantail darters were numerous (50), while the absence of four additional species collected from the Conneaut Park Tributary was perplexing. The Lake Erie Tributary at RM 1124.54, adjacent to Whitman Creek, had strong flow. Upstream land use included a cemetery, campground, golf course, rural residences and wooded property. Further consideration may discover factors underlying the fair fish performance recorded for both streams.

Conneaut Creek, which originates in Pennsylvania, was the largest study area stream (189 mi², 37 mi² in OH, 152 mi² in PA). Exceptional fish assemblages were typical at six mainstem Conneaut Creek locations (IBI \bar{x} =52, MIwb \bar{x} =9.6, Figure 22). In addition, marginally good performance was common at eight Conneaut Creek tributary sites (IBI \bar{x} =36). Ohio EPA previously evaluated Conneaut Creek fish communities at one site in 1989, two sites in 1995, three sites in 1999 and at five sites in 2007. Except for a very good 1989 MIwb score (8.5), all other results achieved fish index scores consistent with the EWH use designation. This reliable performance was attributed to outstanding habitat conditions at all Conneaut Creek locations (QHEI \bar{x} =90.2).

Conneaut Creek is well known for its steelhead (rainbow trout) fishery which attracts the fishing public from great distances. Both, Pennsylvania and Ohio routinely stock fingerling trout in Conneaut Creek. These fish become adults in Lake Erie and then return to Conneaut Creek in a spawning migration. In late June and early July 2015, Ohio EPA noted 38 small rainbow trout in Conneaut Creek mostly distributed at downstream locations. These fish were absent in August samples.

Conneaut Creek is also known to attract non-native spawning sea lampreys. Attempting to eradicate this undesirable species, the US Fish and Wildlife Service regularly treats Conneaut Creek with lampricide. Prior to the 2015 Ohio EPA study, lampricide was applied in Pennsylvania in and out of normal sequence dosage. The typical application had been delayed as Pennsylvania reviewed concerns regarding non-target lethality to river chubs, considered rare in that state.

Cursory consideration of Ohio EPA data supports that concern. It appears the pollution tolerant creek chub is replacing the intolerant river chub in recent fish collections. An average of 42 river chubs and no creek chubs were present in three 1989 samples. An average of seven river chubs were collected from four locations in 1995, while no creek chubs were present. A single creek chub was collected at one 1999 site, while 69 river chubs were documented at two other sample locations. An average of 21 river chub were present in seven 2007 samples, one of which included a single creek chub. In 2015, river chub were present in 11 of 12 samples averaging 5 in abundance. Creek chubs were present in eight of the 12 samples, averaging 19 in each collection.

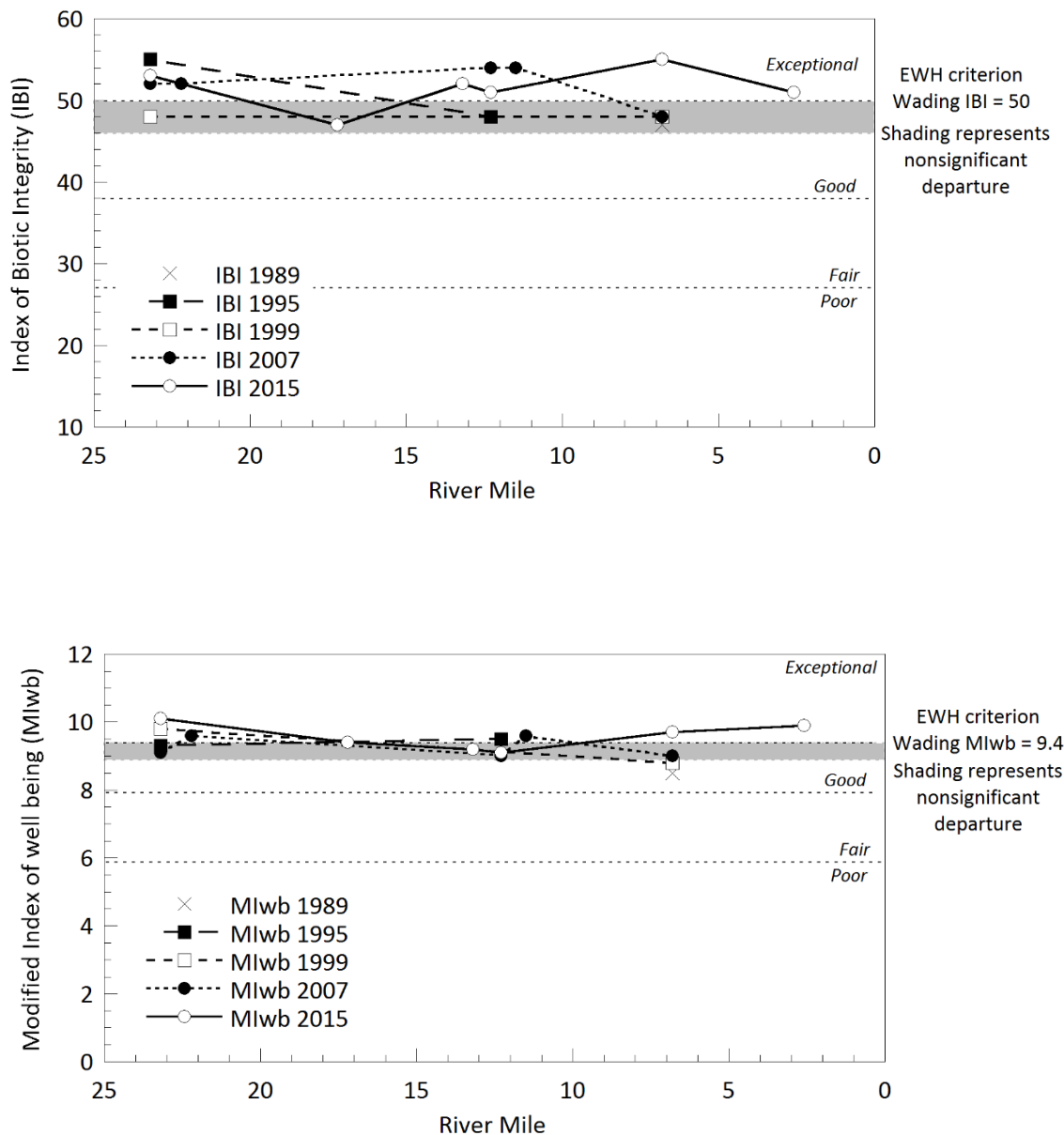


Figure 22. Longitudinal performance of the Index of Biotic Integrity (IBI, upper plot) and of the Modified Index of well-being (MIwb, lower plot) in Conneaut Creek, 1989-2015.

The new presence of creek chubs in recent Ohio EPA Conneaut Creek samples has also coincided with a modest decline in bigeye chub abundance. The pollution intolerant bigeye chub was numerically predominant in 1995 catches ($\bar{x}=98$, $n=4$). This abundance was regarded as a reflection of improved conditions from 1989 ($\bar{x}=11$, $n=3$). An average of 44 bigeye chubs were collected in each 1999 and 2007 sample ($n=3$ and $n=7$, respectively). Bigeye chubs numbered 35 on average in 11 of the 12 samples in 2015.

The intention to analyze tissue for Ohio’s fish consumption advisory program was thwarted by the lack of “keeper size” smallmouth bass, rock bass or other game fish in Conneaut Creek in 2015. Aside from two larger and a few eight-inch adults, the other 340 smallmouth bass noted in Conneaut Creek were juveniles or recent, young of year fish. Rockbass, although reasonably abundant (203 total), were also generally small or moderate in size. Prior Ohio EPA collections were similarly depauperate. Considering the outstanding habitat, the dearth

of adult game fish in Conneaut Creek was perceived to be a consequence of external influences. A similar lack of game fish was observed in the adjacent Ashtabula River in 2011. Because the lower reaches of both streams annually attract considerable steelhead fishing interest, one plausible explanation for the relative absence of other game fish may be due to recreational harvest.

Despite these population deficiencies, the overall Conneaut Creek fish assemblage was typically robust. Pollution intolerant black redhorse, rosyface and mimic shiners, and stonecat madtoms were present at every 2015 site. Large relative numbers with good species richness were noted at each sample location. Collection of a mudminnow, grass pickerel and longnose gar were considered indicative of the upstream connectivity with lower gradient reaches in Pennsylvania. Conneaut Creek lacks fish migration barriers. Sustaining fish movement is conducive to the exceptional aquatic integrity documented in Conneaut Creek in 2015.

Redside dace were documented in two Conneaut Creek Tributaries (at RM 17.1 and RM 14.82) in 2015. These pollution intolerant fish have been displaced from many formerly inhabited streams. Land use change leading to excess sediment and sunlight is often the reason for degrading the small streams where redside dace reside. The presence of redside dace in these Conneaut Creek Tributaries suggested good water quality conditions were extant despite fair fish biological index scores.

Natural barriers to fish movement also affected both streams. Only three fish species were present in the tributary at RM 14.82. Six species were present at an upstream location in the tributary at RM 17.1. These sample sites were situated above natural cascades created where streams downcutting through morainal deposits meet the more erosion resistant lake escarpment shale. The tributary at RM 17.1 was additionally sampled downstream from a cascade where 16 fish species were present. The disparity between fair fish community performance at both sites upstream from cascades and very good performance at the site below was accepted as a factor of the limitations imposed by isolated stream reaches.

The tributary to Conneaut Creek at RM 7.39 seemed to demonstrate a similar barrier influence. Immediate to its confluence with Conneaut Creek, this stream flows down a steep bolder strewn cascade nearly two stories high. Only rainbow trout were present, likely offspring from a forgotten stocking effort. A fair IBI score reflected the lack of diversity but was deemed consistent with the small drainage area and inaccessibility from downstream.

The tributary to Conneaut Creek at RM 13.61 was sampled upstream from Kingsbury Rd. This stream reach was underlain by lake escarpment shale and surrounded by a mature second growth wood lot. Rapid storm runoff from this previously deforested land once challenged the tributary's stream banks to resist erosion. A century later, the tributary remains wider than needed to now convey storm flow from a reforested catchment. A consequence of the recovering overwide channel is the generally shallow conditions are unsuitable for many expected fish species.

Similar attributes were apparent in the tributary to Conneaut Creek at RM 4.67. Presently, the upstream watershed is well forested. The likelihood that it was less wooded previously was evident by the over wide and especially shallow stream condition. This tributary did offer a few slightly deeper pools which supported more fish species than were present in the tributary to Conneaut Creek at RM 13.61.

The long expanses of flat shale noticed in tributary reaches flowing over the same bedrock that underlies Conneaut Creek were not as completely exposed in Smokey Run or in a tributary to it. More than two miles of the tributary to Smokey Run at RM 0.31 flows adjacent to a railroad grade. Erosional storm flows appeared to be adequately conveyed by the tributary, perhaps in part, because its course along the railroad is moderated by culvert passages. Aggressive flow conditions in the Smokey Run sub-basin were further buffered by the amount of undeveloped land (more wetland) and more forested property in comparison with other sampled Conneaut Creek tributaries.

Accordingly, Smokey Run near its Conneaut Creek confluence offered an array of substrates amongst a series of small step pools and also included a particularly large, deep bedrock-based pool, armored with rip rap on one bank, next to Welton Road. These pools supported various sized rainbow trout, one 10-inch brown trout and 15 native fish species. This very good assemblage was in contrast with a fair community upstream in the Smokey Run tributary. Only eight fish species were present, most of which (87%) were tolerant of pollution, at the tributary sample site. Unlike other Conneaut tributary sites upstream from escarpment created cascades, the Smokey Run tributary was not perceived to be isolated (whether stream conveyance under the railroad grade precludes fish passage is uncertain). An abandoned “junk yard” dump bordered the Smokey Run tributary sample location and a domestic sewage lift station was noticed near the Dorman Road bridge. An episodic event of unknown origin was reported to occur annually in October which stained the stream brown and generated abundant foam. These and other speculative causes for the lack of fish in the Smokey Run tributary merit further investigation.

Turkey Creek was the most eastern stream bookending the 2015 survey. A native mottled sculpin was collected in this small (7.8mi²) remote Lake Erie tributary. Without a downstream physical barrier between the Lake, the absence of invasive round goby was even more remarkable. Mottled and other sculpins were previously abundant along Lake Erie shores. Ohio EPA recorded mottled sculpin in Whitman Creek and the Ashtabula River mouth in 1995. Mottled sculpin were present around the Lake Erie islands in the early 2000's. Ohio EPA first collected round goby from Lake Erie in the 1990's. In 1998, round goby were present the Ashtabula River and Conneaut Creek mouths. In 2006, the exotic competitor was noted upstream in Toledo's Swan Creek and soon thereafter in many other Ohio streams, including Euclid and Ninemile creeks during 2010. Essentially, it appears round goby have displaced mottled sculpin in nearly all former Lake Erie and lower tributary reach locations. Round goby were present in ten 2015 survey sub-basins at 14 locations. A total of 690 round goby were collected. Turkey Creek was sampled downstream from an abandoned railroad grade. The base of the culvert, which conveys Turkey Creek under the former railroad, is high, creating a downstream plunge pool. As such, the culvert may act as a barrier and the mottled sculpin could have been separated from a more established upstream population. Nevertheless, the absence of round goby among 18 species comprising a very good scoring fish community was notable.

Stream Physical Habitat

Stream habitat conditions were assessed at 63 Lake Erie basin fish sampling sites in 2015 and at 4 sites in 2016 (Table 9). Based on the functional ability to support fish, each site's substrate, instream cover, and channel characteristics were graded and composited using the Qualitative Habitat Evaluation Index (QHEI, Rankin 1989). Generally, *good* QHEI scores above 60 are typical of habitat conditions associated with WWH aquatic communities. *Poor* QHEI scores less than 45 are consistent with MWH ALU. And, *very good* QHEI values above 75 are correlated with achievement of the EWH ALU. QHEI scores are most meaningful when considered in aggregate groups. For instance, an average of several QHEI's from a river reach or the trend among many small streams in close proximity is more informative than relying on any single location QHEI score. It's unlikely for any site with particularly good or poor habitat to exert the same extreme influences on its resident aquatic community. Instead, aquatic assemblages at unique habitat locations tend to reflect the wider ambient condition.

The 2015 survey was the first time Ohio EPA assessed habitat qualities in many smaller Lake Erie Central Basin Tributaries. Watersheds with historical data include Beaver Creek (last sampled by Ohio EPA in 1997), Doan Brook and Euclid Creek (last sampled by Ohio EPA in 2000), Arcola and Cowles Creeks (last sampled by Ohio EPA in 1995), and Conneaut Creek (last sampled by Ohio EPA in 2007). Aside from these, the habitat qualities in 16 smaller streams were evaluated at 19 locations (three streams were assessed at two locations). Five Lake Erie tributaries, west from the Black River, averaged fair habitat scores (QHEI \bar{x} =52.4). These mid-size streams (\bar{x} =5.7 mi²) were silty and embedded. Slow currents further diminished habitat functions. Seven larger (\bar{x} =6.7 mi²) Lake Erie tributaries between the Grand and Ashtabula Rivers presented generally good habitat attributes

(QHEI \bar{x} =61.9). Better pools and more distinct riffle run sequences were typical features at the sampled sites. Five Lake Erie tributaries, east from the Ashtabula River, averaged fair habitat scores (QHEI \bar{x} =58.8). Small drainage areas (\bar{x} =4.3 mi²), inconsistent flow regimes, and indistinctly defined riffles were common traits among these streams.

Lorain County

Beaver Creek, at the western end of the study area, exhibited fair habitat at seven sites (QHEI \bar{x} =58.9, Figure 23). A small wetland influenced tributary to Beaver Creek also exhibited fair habitat quality (QHEI =50.0). Beaver Creek habitat was previously evaluated by Ohio EPA in 1992 and 1997 (Figure 19, upper plot). Including the 2015 work, 15 habitat evaluations completed in Beaver Creek have all stipulated sparse or sparse to moderate amounts of cover were present at all sites. Better stream flow in 1992 resulted in good habitat scores (QHEI \bar{x} =68.7, n=5) as eddies and fast current were observed. Low flow and sediment laden runoff from housing construction rendered riffles functionless in 1997 (QHEI \bar{x} =57.2, n=3). Similarly, in 2015, little function was attributed to upper reach riffles and low flow was considered an overall deficit (QHEI \bar{x} =58.9, n=7).

Substrates transition in upper Beaver Creek from cobbles and gravels interspersed with fines, to silty gravels perched between patches of exposed bedrock. The middle reach features large boulders on top of bedrock. This shallow overwide reach is aggressively eroding stream banks despite efforts to stabilize them. Downstream, long areas of exposed bedrock are separated by spotty cobbles and silty gravel that becomes almost entirely sandy gravel as the stream approaches the Lake Erie backwater. And, the amount of bedload Beaver Creek is tasked to move is excessive.

Cuyahoga County

Doan Brook was the largest studied stream between Euclid and Beaver Creeks. Doan Brook drains an urban area. Historically, it has often been overwhelmed by rapid, erosive pulses of storm water. Those influences are moderated by the stream's course through city parks helping Doan Brook to sustain fair to good habitat at four 2015 sites (QHEI \bar{x} =59.3) and one 2016 location (QHEI =73.8), respectively.

Table 9. Qualitative Habitat Evaluation Index (QHEI) matrix with warmwater habitat (WWH) and modified warmwater habitat (MWH) attribute totals and ratios for the Lake Erie study area, 2015.

Key QHEI types	WWH Attributes									MWH Attributes									Total Moderate Influence MWH Attributes (MWH High Influence+1)/ (WWH+1) Ratio (MWH Mod. Influence+1)/ (WWH+1) Ratio														
	RM	QHEI	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	Maximum Depth > 40 cm	Low Normal Riffle Embeddedness	Total WWH Attributes	High Influence	Moderate Influence	Total High Influence MWH Attributes																		
												Channelized or No Recovery	Silt Muck Substrates	No Sinuosity	Sparse No Cover	Maximum Depth < 40 cm (Wade, HW)	Total High Influence MWH Attributes	Recovering Channel	Heavy/ Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/ Moderate Overall Embeddedness	High/ Moderate Riffle Embeddedness	No Riffle	Total Moderate Influence MWH Attributes	(MWH High Influence+1)/ (WWH+1) Ratio	(MWH Mod. Influence+1)/ (WWH+1) Ratio	
Brownhelm Creek																																	
	0.9	50.5									2	◇					1	○	○		○	○				○	○	○			7	1.00	2.67
Quarry Creek																																	
	0.3	34.5									1	◇	◇	◇			3	○	○		○	○				○	○	○			8	2.50	5.00
Beaver Creek																																	
	13.8	54.5	□	□		□					4		◇				1		○		○				○	○	○	○			6	0.40	1.40
	11.0	51.0	□	□							2		◇	◇			2	○	○		○	○				○	○	○	○		7	1.33	2.67
	7.0	52.0	□			□	□				4		◇				1		○		○				○	○	○	○		6	0.40	1.40	
	4.0	67.5	□	□		□	□	□			6						0		○						○	○	○	○		4	0.14	0.71	
	3.8	62.0	□	□		□	□	□			6			◇			1		○			○			○	○	○	○		5	0.29	0.86	
	2.9	56.5	□			□					3			◇			1		○			○			○	○	○	○		6	0.50	1.75	
	1.8	68.5	□	□		□	□	□			6						0		○						○	○	○	○		4	0.14	0.86	
Willow Creek																																	
	1.3	52.5	□			□					2			◇	◇		2		○			○			○	○	○			5	1.00	2.00	
Squires Squamm Ditch																																	
	1.3	50.0				□	□				3						0	○	○		○				○	○	○	○		6	0.50	1.75	
Martin Run																																	
	2.4	67.0	□	□		□	□	□			6						0		○						○	○	○			4	0.14	0.71	
	0.9	57.5	□	□		□	□				5						0		○		○	○			○	○	○	○		2	0.17	1.33	
Doan Brook																																	
	6.6	62.0	□	□		□	□				5						0		○		○				○	○	○	○		5	0.17	1.00	
	5.5	58.0	□	□		□	□		□	□	6			◇			1		○		○	○			○	○	○	○		7	0.29	1.41	
	3.1	73.0		□		□	□	□			6						0	○	○							○	○			4	0.29	0.71	
	0.8	44.0	□								2	◇	◇	◇			3		○		○		○	○	○	○	○	○		7	1.33	2.67	
Doan Brook evaluated in 2016																																	
	2.3	73.8	□	□		□	□	□			6						0	○			○	○			○	○				5	0.29	0.86	
Nine Mile Creek																																	
	0.3	66.0	□	□		□	□	□			6						0		○		○				○	○	○			5	0.14	0.86	
Euclid Creek																																	
	8.7	53.5	□	□		□	□	□		□	□	8			◇		1				○			○	○	○				4	0.22	0.56	
	8.5	53.0	□	□			□		□	□	5			◇			1				○	○		○	○	○				5	0.33	1.00	
	3.3	66.0	□	□	□		□	□	□	□	9			◇			1				○			○		○				2	0.20	0.30	
Key QHEI types	WWH Attributes									MWH Attributes																							
												High Influence	Moderate Influence																				

RM	QHEI	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	Maximum Depth > 40 cm	Low Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt Muck Substrates	No Sinuosity	Sparse No Cover	Maximum Depth < 40 cm (Wade, HW)	Total High Influence MWH Attributes	Recovering Channel	Heavy/ Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/ Moderate Overall Embeddedness	High/ Moderate Riffle Embeddedness	No Riffle	Total Moderate Influence MWH Attributes	(MWH High Influence+1)/ (WWH+1) Ratio	(MWH Mod. Influence+1)/ (WWH+1) Ratio
Smokey Run Tributary at RM 0.31																																
0.6	72.0	□	□	□	□	□	□	□			7						0	○								○	○			3	0.13	0.50
Turkey Creek																																
0.5	70.0	□	□	□	□	□	□	□			8						0				○		○							2	0.11	0.33

Since 2000, Ohio EPA and NEORS D have completed 26 habitat assessments in Doan Brook from RM 6.6 (QHEI \bar{x} =61.4, n=9), between Horseshoe and Shaker Lakes, to RM 0.8 (QHEI \bar{x} =57.6, n=8), upstream from Lake Erie backwater. Sites at RM 5.5 downstream from Shaker Lake, RM 3.1 in Wade Park and RM 2.3 in Rockefeller Park, were each sampled two or three times in different years (QHEIs \bar{x} =61.0, 70.5 and 58.6, respectively). In 2000, a very good QHEI score (75.0) was recorded at RM 1.3. Generally, good habitat conditions have been determined for the entire reach (QHEI \bar{x} =61.4, n=26). Likewise, the average of each sites QHEI with (QHEI \bar{x} =64.0) or without (QHEI \bar{x} =61.8) the single 2000 score has been good. In 2015, QHEIs were completed at four fish sampling sites (QHEI \bar{x} =59.3) and at two restoration project sites near the Rockefeller Lagoon (RM 2.4, QHEI=55.5; RM 2.3, QHEI=46.5; QHEI \bar{x} =56.5, n=6). A year later, the restoration project reach appeared more functional (QHEI=73.8).

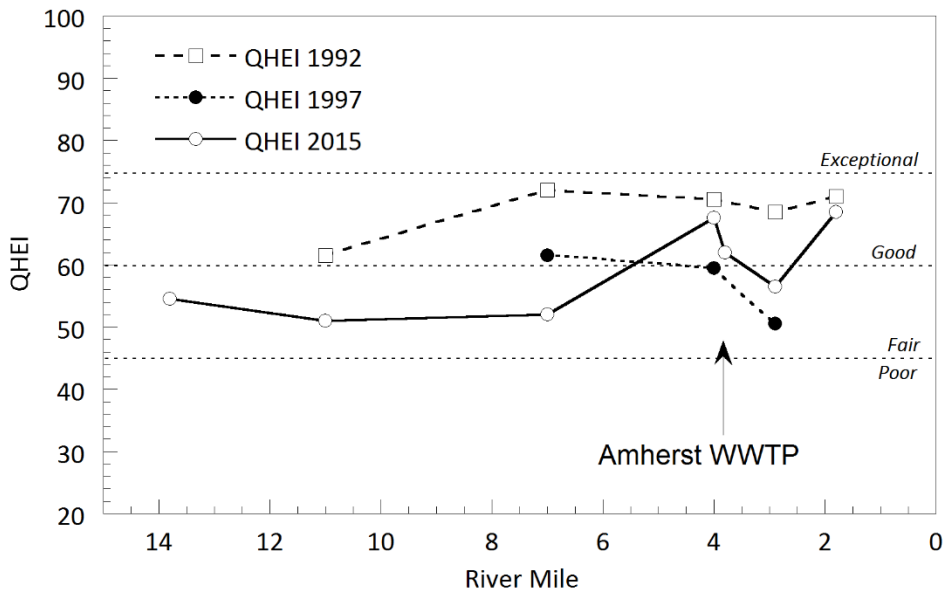


Figure 23. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in Beaver Creek, 1992-2015

Doan Brook is the featured element linking a series of historically and culturally important parks through several Cleveland area neighborhoods. More than a picturesque park amenity, Doan Brook is also the principal storm water conveyance for a basin that rapidly sheds rainwater. As discussed in the Doan Brook Watershed Action Plan, rooftops, roads and parking lots cover 20% of the basin (2013, pages 53-55). These impervious surfaces are a significant hindrance to water quality. Development has altered hydrology and increased flooding. Attempting to manage flood flows, retaining walls were built along Doan Brook beginning in the 1880s. The inadequacy of this infrastructure is apparent where the stream routinely destabilizes or buries the historic walls through excessive erosion and bedload deposition.

Cleveland's Euclid Creek was central to the southern Lake Erie shore study area. Fair habitat assessments at four locations (QHEI \bar{x} =58.6) were affected by the streams urban influenced, erratic flow conditions. Two sites on a tributary sampled in 2015 and two sites on a different tributary sampled in 2016 revealed similar scores (QHEI \bar{x} =59.6).

From 1989 to 2000, Ohio EPA evaluated Euclid Creek habitat at five locations between RM 7.1 and RM 0.7 on eight occasions, returning a good average QHEI score (62.4). From 2007 to 2016, Ohio EPA and the NEORS D evaluated Euclid Creek habitat at the same locations on 32 occasions, again returning a good average QHEI score (65.9). Similarly, from 1988 to 2000 and from 2008 to 2015, Ohio EPA and NEORS D evaluated East Branch of Euclid Creek habitat conditions at five sites. Good East Branch habitat qualities (QHEI \bar{x} =63.6, n=5) present in the 1990s persisted through the most recent studied period (QHEI \bar{x} =60.9, n=12). Overall, good habitat conditions in the Euclid Creek sub-basin have been reasonably constant over the past 30 years.

Lake County

Arcola and Cowles Creeks were the largest study area streams between Euclid and Conneaut Creeks. Arcola Creek presented generally fair stream habitat at five sites (QHEI \bar{x} =52.1, Figure 24). Similar values were noted at two tributary locations (QHEI \bar{x} =54.5).

Habitat conditions in Arcola Creek were degraded by cattle habitually wading downstream from the Madison WWTP. Results of a study comprehensive to Ohio incorporating 30 years of relevant data, found fencing to prevent livestock stream access was an effective agricultural conservation practice aimed at improving water quality (Miltner 2015). Cows in Arcola Creek within the Madison WWTP outfall plume led to increased stream bank erosion and extensively silt smothered substrates in 2015. Limiting livestock stream access would improve habitat and water quality at this, and other downstream Arcola Creek sites.

Alfalfa hay was observed growing at this location in 1995. Slightly more cover from root wads and woody debris in 2015 accounted for an increased QHEI score from poor to fair since the previous assessment. The prevalence of heavy to moderately silty embedded conditions in Arcola Creek in 2015 resulted in all five sampled sites scoring in the fair QHEI range. Good QHEI scores at the most downstream locations in 1995 reflected less silty conditions.

Ashtabula County

Appreciably better habitat conditions were documented in Cowles Creek at four locations (QHEI \bar{x} =67.9).

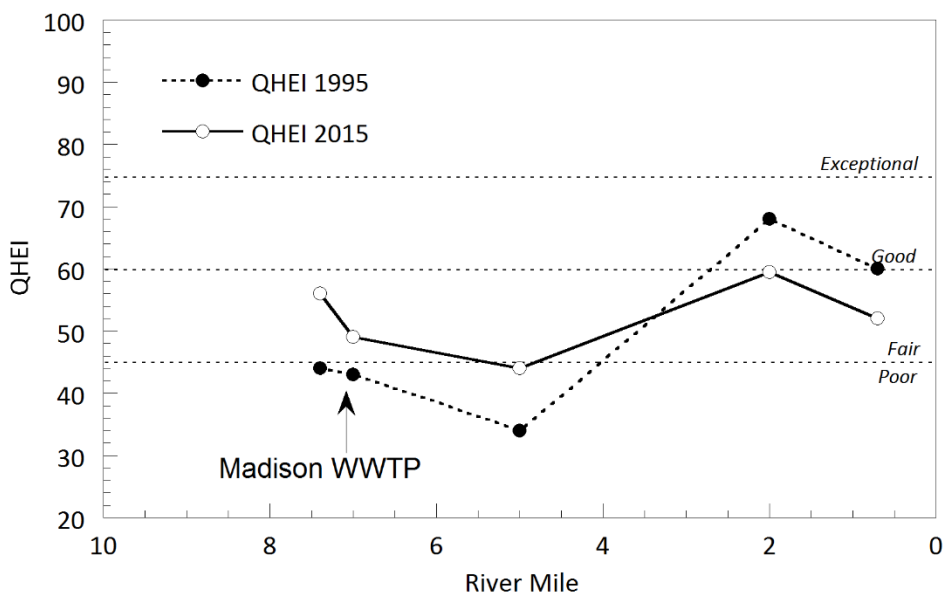


Figure 24. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in Arcola Creek, 1995-2015.

These good attributes were not as evident at one Cowles Creek tributary site (QHEI =55.5).

Cowles Creek habitat was evaluated in 1981, 1995 and 2015 (Figure 25, upper plot). Good 1981 attributes (QHEI \bar{x} =68.8, n=5) declined in 1995 (QHEI \bar{x} =59.6, n=7), but were improved again in 2015 (QHEI \bar{x} =67.9, n=4). The reach of Cowles Creek through Geneva is channelized and severely incised. The overwide stream is challenged to convey bedload through the area. Fines have become trapped, limiting substrate interstitial voids and inducing low flow conditions to become interstitial. Bedrock at downstream sites was conducive to better definition between pools, riffles and runs. Lower reach sites in 1995 were affected by road construction at RM 1.1 and by Lake Erie backwater influences at RM 0.3.

Aquatic habitat conditions in Conneaut Creek, on the eastern end of the study area, are among Ohio's best. Extraordinary QHEI scores were recorded at six 2015 sample sites (QHEI \bar{x} =90.2) including a perfect 100 at a location on the Pennsylvania State line (Figure 25, lower plot). Good habitat qualities were observed at eight tributary sites in the Conneaut Creek watershed (QHEI \bar{x} =69.3).

Ohio EPA previously evaluated Conneaut Creek habitat quality at one site in 1989, two sites in 1995, three sites in 1999 and at five sites in 2007. Except for fair to good QHEI scores in 1989 and 2007 at RM 6.8, respectively, all other scores have been exceptional (Figure 25). The presence of silt, albeit in normal amounts, distinguished downstream sites from the silt free most upstream locations, where a perfect QHEI score (100) was recorded in 2015. Substrate conditions at RM 6.8 have improved over the past quarter century. In 1989, a heavily eroded stream bank and another place where a bulldozer had recently modified the stream edge were sources of excessive sedimentation represented in the fair QHEI value. In 1995, Conneaut Creek was a popular destination for all terrain vehicle (ATV) use. Recreational ATV stream access was partly responsible for sedimentation concerns. The good 2007 QHEI score was influenced by bedrock presence through the sampled reach. Sampling in 2015 occurred downstream from the bedrock dominated area. Boulders and cobble were abundant downstream. Extensive amounts of nearly every assessed type of cover were responsible for the high function imparted in combination with variable flow velocities at the 2015 sample site. So, fewer overt sedimentation sources and careful sample zone selection explain the habitat score increase in Conneaut Creek at RM 6.8.

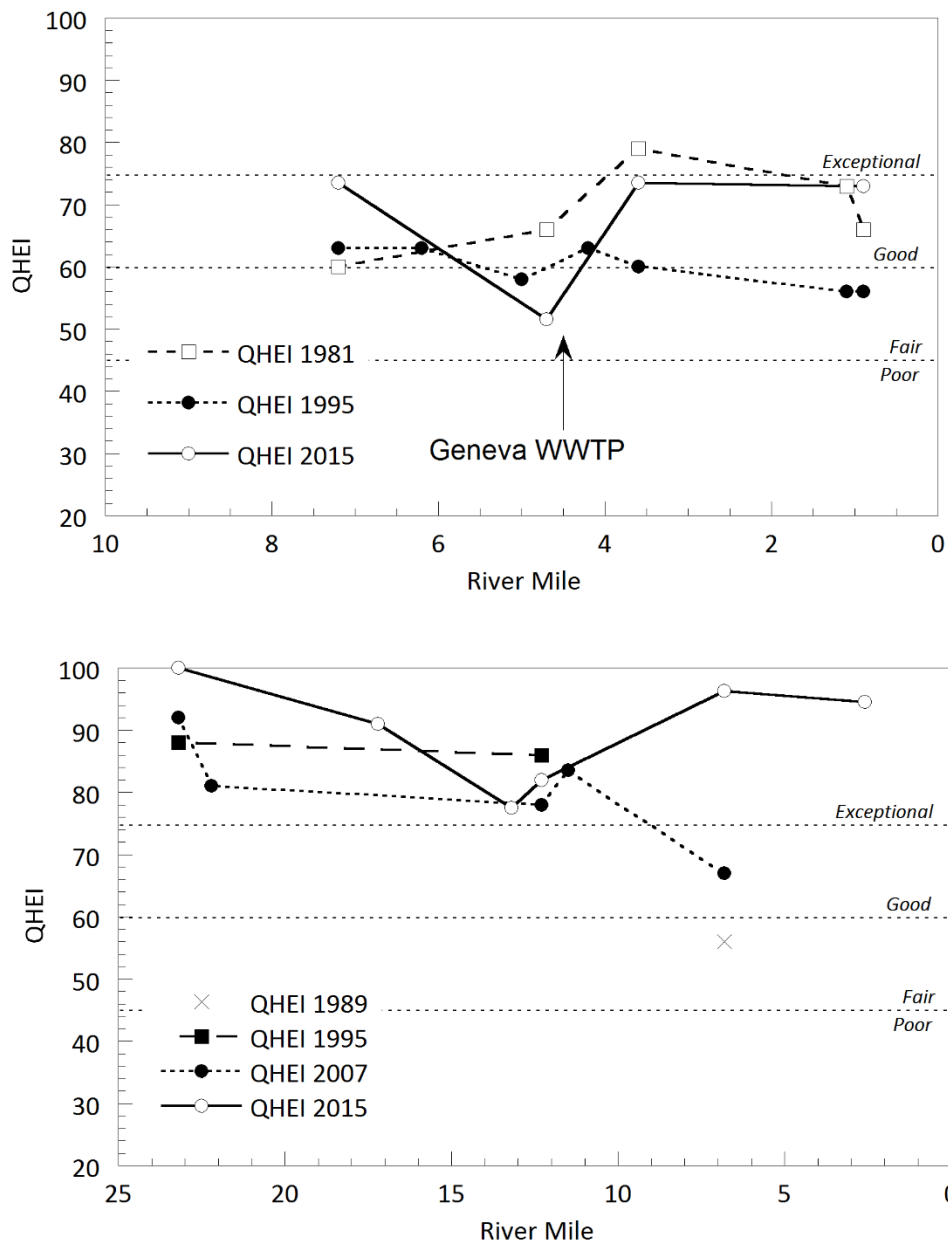


Figure 25. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in in Cowles Creek, 1981-2015 (upper plot) Conneaut Creek, 1989-2015 (lower plot).

Conneaut Creek tributaries were notable for adequate interstitial voids and less silt compared to streams in other study area sub-basins. Sparse (to moderate) amounts of cover represented in Table Q1 at some tributary sites were typically due to a bedrock base in an over wide stream channel providing a shallow depth of water that few fish species could inhabit. The over wide channels are products of a past era when timber was harvested and more land was farmed. Those barren conditions facilitated bursts of runoff with more erosive capacity than the previously forested land had permitted. Since bedrock was more erosion resistant, stream banks bore the brunt of the erosive action. Now reforested, the shallow overwide channels will constrict as vegetation knits the stream bank together and stable, but deeper flows will act in concert with other habitat attributes to support more aquatic diversity.

Historically, all small Conneaut Creek tributaries were habitat for a variety of fish, each adapted to unique niches. Drainage divides were fuzzy as wetland links provided a myriad of cross basin watered connections. Drainage management and related land use changes frequently exerted deleterious consequences on nearby stream life. Many Conneaut Creek tributaries have cascade type waterfalls often located close to the mainstem confluence. Some cascades were several meters tall and all were potential barriers to upstream fish migration. Thus, the contemporary presence of acceptable upstream habitat may by itself be an inadequate basis to infer fish community expectations. Or, the absence of expected fish species could prompt efforts to achieve biointegrity through darter or minnow fish stocking.

NPDES Permitted Facilities

Forty-five National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into the Lake Erie tributaries assessed in 2015, they are listed in Table 10.

Table 10. Facilities regulated by an Individual NPDES permit in the study area.

Facility Name	Ohio EPA Permit Number	Flow (GPD)	Receiving Stream
84 Video-News Stand Inc	3PR00610*AD	2500	Unnamed tributary (UT) to Conneaut Creek
A & B Tavern	3PR00571*AD	1750	UT to Beaver Creek
Amherst WPC	3PD00001*LD	3500000	Beaver Creek
Ashcraft WWTP	3PG00150*FD	80000	UT to Whitman Creek
Broadfield Care Center	3PR00131*ED	25000	UT to Arcola Creek
Collinwood BioEnergy, LLC	3IN00371*BD	Storm Only	Ninemile Creek
Conneaut Church of GOD	3PR00396*BD	2500	UT to Conneaut Creek
Conneaut WWTP	3PD00002*ND	3000000	Conneaut Creek (RM 0.3)
Creekside Tavern & Grill LLC	3PR00543*AD	1140	Cowles Creek
Cresthaven Homes WWTP	3PG00051*HD	80000	Martin Run (RM 5.9)
Deans Family Restaurant	3PR00237*DD	3025	UT to Arcola Creek
Dun Rovin MHP	3PV00043*DD	7000	UT to Lake Erie
East 185 Marathon	3IG00061*DD	10000	Euclid Creek
East of Chicago Pizza	3PR00615*AD	3000	Beaver Creek
General Electric Tungsten Products Plant	3II00132*FD	Storm Only	Euclid Creek and Lake Erie
Geneva Landfill	3II00192*ED	Storm Only	UT to Cowles Creek
Geneva Motel	3PR00549*AD	1500	UT to Cowles Creek
Geneva Trailer Park	3PV00117*CD	10000	UT to Cowles Creek
Geneva WWTP	3PD00014*RD	2000000	Cowles Creek
Holly Ridge Apts	3PR00376*CD	12000	Arcola Creek
International Paper	3IA00012*CD	3500	UT to Arcola Creek
Kay's Place Restaurant	3PR00621*AD	3500	Hubbard Run
Living Opportunities Inc DBA Lakeland Nursing Home	3PR00374*CD	2500	UT to Arcola Creek
Madison Health Care Inc	3PR00080*FD	16000	UT to Arcola Creek
Madison WWTP	3PB00030*ND	500000	Arcola Creek
Meadowood Allotment WWTP	3PG00075*GD	40000	UT to Indian Creek
MHP of Westwood Ltd	3PV00026*GD	92000	Tributary to Beaver Creek
Nelson Stud Welding Inc	3IS00040*HD	3200	Beaver Cr. (via UT to Battenhouse Ditch)

Facility Name	Ohio EPA Permit Number	Flow (GPD)	Receiving Stream
New Avenues to Independence Perry Home	3PR00218*DD	1501	UT to Lake Erie
New Russia Twp Hall & Service Complex	3PR00554*AD	1500	Herrick Ditch (Beaver Cr. @ RM 11.07)
North Kingsville Shopping Center WWTP	3PR00254*DD	3000	UT to Lake Erie
North Ridge Lanes	3PR00285*CD	6210	UT to Lake Erie
Nottingham Water Treatment Plant	3IV00080*FD	5000	Euclid Creek
Perry MHP	3PV00072*ED	30000	UT to Lake Erie
Reserve Environmental Services, Inc.	3IN00145*GD	Storm, 565 (tribs), 60000 (L. Erie)	Whitman Creek and Lake Erie
Rochling Glastic Composites	3IN00204*DD	Storm Only	Euclid Creek
Rustic Cove MHP	3PV00082*DD	20000	UT to Cowles Creek
Sahara MHP	3PV00046*ED	60000	UT to Arcola Creek (RM 6.72)
Sands Trailer Park WWTP	3PV00114*AD	16250	UT to Lake Erie
Stewart Lodge Nursing Home	3PR00332*CD	5580	UT of Arcola Creek
The Pittsburgh & Conneaut Dock Company	3IN00000*ID	1000000	Conneaut Cr. & Turkey Cr
The Pub	3PR00201*DD	1400	UT to Arcola Creek
Wiley's Lounge	3PR00617*AD	3000	UT to Quarry Creek
Willow Lake Campground	3PR00548*AD	10000	UT to Cowles Creek

Within the study area, additional information is presented below on six dischargers. There are currently four facilities classified as major dischargers by Ohio EPA: Amherst WPCCC, Conneaut WWTP, Geneva WWTP, and Reserve Environmental Services. Two additional facilities are included which are the Madison WWTP and The Pittsburgh & Conneaut Dock Company, inclusive of all permitted facilities discharging greater than 0.1 million gallons per day (MGD). Effluent data for selected parameters is presented in Table 11.

Amherst Water Pollution Control Center (WPCCC) (3PD00001) discharging to Beaver Creek

Amherst WPCCC was constructed in 1927 with the most current upgrade completed in 2004. It serves the city of Amherst and a portion of Amherst Township with a total population of 12,288 served. The design flow is 3.5 MGD with a peak hydraulic capacity of 10.5 MGD. Currently, the wet stream processes consist of bar screen, grit removal, scum removal, oxidation ditch, combined biological nitrification and biological oxygen demand, secondary clarification, tertiary filtration, alum addition, and ultra-violet disinfection. Solid stream processes are aerobic digestion, gravity thickening, dewatering by gravity belt thickening, and polymer addition. Sludge disposal is by land application at agronomic rates in accordance with an approved sludge management plan.

Amherst WPCCC is 100% separate sanitary sewer system with no combined sewer systems in place. The estimated current average inflow and infiltration flow rate for the sewerage system is 1.085 MGD. The City is currently implementing projects to minimize the inflow and infiltration rates. These projects mainly consist of relining or replacing sewer lines and manholes; the construction is expected to last until 2016.

The wastewater treatment facility has four bypass locations: influent screening, influent grit removal, oxidation ditch, and tertiary filtration.

Conneaut Wastewater Treatment Plant (WWTP) (3PD00002) discharging to Conneaut Creek

The Conneaut WWTP was constructed in 1957; the last major modification was in 2011. The WWTP, with an average daily design flow of 3.0 MGD and a peak hydraulic capacity of 9.0 MGD serves a population of approximately 12,785. The biological treatment system utilizes the following wet-stream processes: coarse bar screening, influent flow monitoring (Parshall flume), grit removal, comminution, off-line flow equalization (EQ), primary settling, conventional activated sludge aeration, final clarification, phosphorus removal (using sodium aluminate), chlorination, and de-chlorination. The treatment facility includes two internal bypasses: station 3PD00002602 which is an overflow from the EQ basin to the final outfall chamber (secondary bypass); and station 3PD00002603 which bypasses the primary settling tanks (primary bypass) to the secondary treatment process. Co-settled primary sludge and waste activated sludge (WAS) from the primary clarifiers are processed sequentially through the following operations: primary and secondary anaerobic digestion and sludge holding. Under normal operation, the digested sludge is agronomically land applied, in liquid form, as a Class B biosolids (i.e. station 3PD00002581). Under unusual circumstances, the Conneaut WWTP may contract for portable dewatering of the sludge prior to land application and/or hauling to an authorized solid waste landfill (i.e. station 3PD00002586). The quantity of sludge hauled for the past 5 years, based on Discharge Monitoring Report (DMR) data, is listed in Table 1.

The city of Conneaut's collection system is comprised entirely of separate sanitary sewers. The WWTP has a pretreatment program which was initially approved by Ohio EPA on December 31, 1987. Based on the NPDES application, local industries contribute approximately 0.0414 MGD to the flow received at the Conneaut WWTP. Categorical industrial users discharge an average of 0.0029 MGD to the Conneaut sewer system, while non-categorical significant industrial users contribute approximately 0.013 MGD.

Geneva WWTP (3PD00014) discharging to Cowles Creek

The original wastewater treatment works in Geneva was constructed in 1903 and consisted of a grit chamber, septic tank, pump station, dosing tank, and six intermittent sand filters. An Imhoff tank and four additional filters, which remain in use, were installed in 1922. Biological treatment in the form of rock-media trickling filters were constructed in 1938. The plant was expanded to a capacity of 1.0 MGD to provide second-stage nitrification and chlorination/dechlorination in 1988. Rapid sand filters were added to the plant in 1990 and a second nitrification tower was constructed in 1995. These modifications allowed the permitted design flow to increase to 2.0 MGD. The plant currently serves the city of Geneva and outlying parts of the unincorporated areas of Geneva and Harpersfield townships in Ashtabula County. The total population within the service area is approximately 6,715. The collection system is comprised of 100 percent separate sanitary sewers. The tertiary treatment facility is rated for an average daily design flow of 2.0 MGD, with a peak hydraulic capacity of 5.0 MGD. The existing wet-stream treatment processes and/or equipment include: pre-aeration, grit removal, coarse screening, comminution, influent pump station, primary clarification, rock-media trickling filters, phosphorus removal (alum addition), secondary clarification, nitrification towers, tertiary sand filtration, chlorination, and dechlorination.

When influent flows exceed the hydraulic capacity of the plant headworks, the excess flow overflows a fixed weir and is bypassed via monitoring station 3PD00014602. In addition to the headworks bypass, the plant is equipped with manually-operated "emergency" bypasses at the following locations: after the primary clarifiers (station 3PD00014603), after the secondary clarifiers (new station 3PD00014604), after the nitrification towers (new station 3PD00014605), and at the raw pump manifold (new station 3PD00014606). All internal plant bypasses, including stations 3PD00014602 and 3PD00014603, recombine with the fully-treated effluent prior to the composite sampler at outfall 3PD00014001.

Waste sludge from the treatment process is anaerobically digested for pathogen and vector control. The digested sludge is dewatered using a belt filter press. Depending on final sludge quality, available options for reuse and/or disposal of the dewatered sludge include distribution and marketing (Exceptional Quality Sludge), land application at agronomic rates (Class A or Class B Sludge) or hauling to a landfill.

The city of Geneva implements an Ohio EPA-approved industrial pretreatment program. Based on information in the NPDES renewal application, there is one (1) categorical and zero (0) non-categorical significant industrial users presently discharging to the Geneva WWTP. The total industrial flow is approximately 0.003 MGD.

Madison WWTP (3PB00030) discharging to Arcola Creek

The village of Madison WWTP discharges to Arcola Creek at approximately river mile 7.25 and has a permitted design flow of 0.5 MGD. The plant was initially constructed in 1928 with the most recent modification done in 1994. The plant uses an influent bar screen followed by comminution and oxidation ditches. Secondary clarification and ultraviolet disinfection follow the oxidation ditch. Sludge is placed in an aerated sludge lagoon and mechanically dewatered prior to disposal in a sanitary waste landfill.

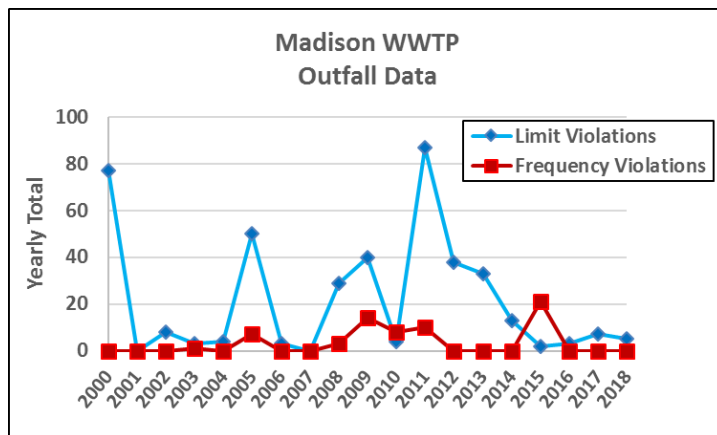


Figure 26. Madison WWTP outfall 001 data, 2000-2018

Point sources are listed as a source of nonattainment in this survey for Arcola Creek. The Madison WWTP has historically had compliance issues with its NPDES permit. Figure 26 shows permit limit and frequency violations by year. Ohio EPA has been working with the facility to address compliance issues which have greatly declined since 2013. Arcola Creek has shown improvements in macroinvertebrate communities, but the downstream site is still impaired (Poor narrative rating) in 2015. Fish communities are improved from 1995 results but still not consistently meeting biocriteria. Habitat scores from the upstream site (RM 7.4) through RM 2.0 were below 60, a target for WWH attainment.

The current NPDES permit for Madison has final outfall limits for: summer ammonia at 1.0 mg/l (monthly average) and 1.5 mg/l (weekly average), winter ammonia at 5.8 mg/l (monthly average) and 8.7 mg/l (weekly average), total suspended solids (TSS) at 16 mg/l (monthly average) and 24 mg/l (weekly average), and CBOD5 at 13 mg/l (monthly average) and 19.5 mg/l (weekly average). BADCT limits for winter ammonia are 3.0 mg/l (monthly average) and 4.5 mg/l (weekly average), for TSS are 12 mg/l (monthly average) and 18 mg/l (weekly average), and for CBOD5 are 10 mg/l (monthly average) and 15 mg/l (weekly average). Adequacy of exiting permit limits for the Madison WWTP will be evaluated as part of Ohio EPA’s TMDL process.

Pittsburgh & Conneaut Dock Company (3IN00000) discharging to Conneaut Creek and Turkey Creek

The Pittsburgh and Conneaut Docks Facility is bounded by Lake Erie to the north, the mouth of Turkey Foot Creek to the northeast, Thompson Road to the east, the Pennsylvania State Game Area to the southeast, CSXT Railroad to the south, and to the west by Ford Avenue, the city of Conneaut WWTP, and the Conneaut Yacht Club. Conneaut Creek flows through the approximate center of the facility and discharges to Lake Erie in Conneaut Harbor. The mouth of Turkey Foot Creek discharges into Lake Erie at the Northeast corner of the Facility.

A storm water collection and treatment system at the facility treats storm water runoff from the storage areas and docks. The treated effluent discharges to Conneaut Creek under an individual industrial storm water NPDES Permit. Storm water management includes water from building footer drains, runoff from paved areas of the facility, and various material stockpiles. Storm water is collected and discharged to ditches around the perimeter of the facility and is conveyed through one of nine alarm-equipped pump stations throughout the facility through additional ditches and collected in a siltation pond. Storm water is collected in a 30-million-gallon equalization basin. Influent flow and pH are monitored. Wastewater treatment includes neutralization with sodium hydroxide, polymer to aid in settling, and potassium to aid in iron removal. Components include a

500-gallon polymer tank, a 6,500-gallon caustic tank, with a 13,000-gallon mix tank for caustic, potassium, and polymer. Wastewater flows into a 274,000-gallon clarifier with skimmer. Sludge is removed from the clarifier weekly to a sludge pond. The pH is monitored at the clarifier discharge. Final discharge is to Conneaut Creek via outfall 001. A second outfall, outfall 002, discharged uncontaminated storm water runoff to Lake Erie.

The facility has been in operation since the late 1800s. It has been used for rail-to-ship transfer and storage of coal, iron ore, aggregate, and other miscellaneous materials.

Reserve Environmental Services (3IN00145) discharging to Whitman Creek via an unnamed tributary

Reserve Environmental Services (RES) is located in Ashtabula Township, Ohio, in Ashtabula County. Five of the six facility outfalls (001, 003, 004, 005 and 007) discharge to an unnamed tributary that flows to Whitman Creek and, subsequently, to Lake Erie. Outfall 006 discharges to Lake Erie via a diffuser. Two internal stations (603 and 604) monitor flows discharged through outfalls 003 and 006, respectively. Two other stations (901 and 902) monitor the areas surrounding the outfall 006.

RES provides wastewater treatment service to industries. Hazardous and nonhazardous liquid wastes are treated through a tank system. Nonhazardous solid wastes generated from the on-site wastewater treatment process are disposed of on-site in a Subtitle D landfill. The wastewater generated is discharged to Lake Erie through outfall 006. A diffuser is assisting in meeting acute and chronic limits at this outfall. The storm water that falls on the facility is treated before it is discharged. The facility obtains its water from the city of Ashtabula. The sanitary wastewater is treated on-site and discharged to Whitman Creek via an unnamed tributary. This wastewater from the outfall 006 now falls under 40 CFR Part 437 - The Centralized Waste Treatment Point Source Category, Subpart A- Metals Treatment and Recovery (guideline promulgated in December 22, 2000). An internal outfall 604 has been created to comply with the BPT and BAT guideline (437.11 and 437.13 respectively) limits for this outfall. The water quality-based effluent limits will remain at 006. This study did not assess the Lake Erie Discharge.

RES has had numerous compliance issues with several Ohio EPA regulatory programs. Consent Orders were entered October 14, 1993, a Consent Order modification February 7, 1995 and a Consent Order Modification October 28, 2009. During the period January 2010 through December 2010, there were 341 effluent limit violations at the facility identified through screening. Of those violations, 236 (69.2%) were associated with the Lake Erie discharge. Of the remaining, there were 34 at outfall 001, 64 at outfall 003, five at outfall 004, and two at outfall 603. The Ohio Attorney General's Office is currently negotiating another Consent Order with RES to address and resolve ongoing compliance issues. Our records indicate that the facility stopped receiving additional waste for treatment in the spring of 2014.

Table 11. Concentrations of monitored chemicals in effluent discharged from six facilities in the Lake Erie tributaries study area.

Discharger/ Parameter	50 th Percentile	95 th Percentile	Permit Limit Monthly (Weekly) Avg.	Permit Limit Maximum
Amherst WPCC (3PD00001) – 2010 to 2015 data				
Outfall 001 to Beaver Creek				
Dissolved Oxygen (mg/l)	9.1	10.9	6.0 minimum	-
Total Suspended Solids (mg/l)	1	3	12	18
Phosphorus (mg/l)	0.49	0.76	1.0	1.5
Nitrogen, Ammonia Summer (mg/l)	0.06	0.26	1.7	2.55
Nitrogen, Ammonia Winter (mg/l) winter	0.0	0.2	6.5	9.75
Nitrite Plus Nitrate, Total (mg/l)	9.86	15.14	-	-
<i>E. coli</i> (#/100 ml), Summer (2011-15)	5.2	96	161	362
Mercury, Total (Low Level) (ng/l)	0.62	1.86	1.3	1092
CBOD 5 day (mg/l)	0	2.7	10	15

Discharger/ Parameter	50 th Percentile	95 th Percentile	Permit Limit Monthly (Weekly) Avg.	Permit Limit Maximum
Flow Rate (MGD)	1.95	4.55	3.5 design flow	-
Total Dissolved Solids (mg/l)	650	959.8	-	-
Conneaut WWTP (3PD00002) – 2010 to 2015 data				
Outfall 001 to Conneaut Creek				
Dissolved Oxygen (mg/l)	5.9	7.71	-	-
Total Suspended Solids (mg/l)	5	16	20	30
Phosphorus (mg/l)	0.49	0.96	1	1.5
Nitrogen, Ammonia Summer (mg/l)	0.25	7.34	-	-
Nitrogen, Ammonia Winter (mg/l) winter	0.12	9.64	-	-
Nitrite Plus Nitrate, Total (mg/l)	11.4	21.65	-	-
<i>E. coli</i> (#/100 ml), Summer	16	347.9	126	284
Mercury, Total (Low Level) (ng/l)	2.7	6.32	3.4	1700
CBOD 5 day (mg/l)	3.84	8	15	20
Flow Rate (MGD)	2.33	4.64	3.0 design flow	-
Total Dissolved Solids	395	504.75	-	-
Geneva WWTP (3PD00014) – 2010 to 2015 data				
Outfall 001 to Cowles Creek				
Dissolved Oxygen (mg/l)	9.4	11.2	5.0 minimum	-
Total Suspended Solids (mg/l)	5	12	20	30
Phosphorus (mg/l)	0.53	0.86	1	1.5
Nitrogen, Ammonia Summer (mg/l)	0.07	2.64	1.4	2.1
Nitrogen, Ammonia Winter (mg/l) winter	0.27	5.35	5.1	7.7
Nitrite Plus Nitrate, Total (mg/l)	12.05	18.3	-	-
<i>E. coli</i> (#/100 ml), Summer (2013-15)	5	600	126	284
Mercury, Total (Low Level) (ng/l)	3.8	12.19	8.2	1100
CBOD 5 day (mg/l) Summer	3.1	6.57	15	23
CBOD 5 day (mg/l) Winter	3.5	6.1	20	30
Flow Rate (MGD)	0.99	2.21	2.0 design flow	-
Total Dissolved Solids	638	756.4	-	-
Madison WWTP (3PB00030) – 2010 to 2015 data				
Outfall 001 to Arcola Creek				
Dissolved Oxygen (mg/l)	8.77	11.61	6.0 minimum	-
Total Suspended Solids (mg/l)	6	24	16	24
Phosphorus (mg/l)	0.38	0.84	0.73	1.1
Nitrogen, Ammonia Summer (mg/l)	0.8	5.2	1.7	2.6
Nitrogen, Ammonia Winter (mg/l) winter	1.23	6.44	5.8	8.7
Nitrite Plus Nitrate, Total (mg/l)	2.7	7.1	-	-
<i>E. coli</i> (#/100 ml), Summer (2012-15)	70	794.75	126	284
Mercury, Total (Low Level) (ng/l)	3.5	9.75	7.7	1700
CBOD 5 day (mg/l)	3.9	10	13	19.5
Flow Rate (MGD)	0.41	0.88	0.5 design flow	-
Total Dissolved Solids	597.5	809.4	-	-
Pittsburgh & Conneaut Dock Company (3IN00000) – 2010 to 2015				
Outfall 001 to Conneaut Creek				
Total Suspended Solids (mg/l)	3.6	14	15	20
Iron (µg/L)	154	511.4	-	1000
Manganese (µg/L)	128	303.75	-	1000
Phosphorus (mg/l)	0	0	-	-
pH Minimum (S.U.)	8.4	8.6	-	-

Discharger/ Parameter	50 th Percentile	95 th Percentile	Permit Limit Monthly (Weekly) Avg.	Permit Limit Maximum
pH Maximum (S.U.)	8.5	8.7	-	-
Flow (MGD)	0.83	0.94	1.0 design flow	-
Reserve Environmental Services, Inc. (3IN00145) – 2010 to 2015				
Outfall 001 to Whitman Creek via UT				
Flow (GPD)	2457.5	8464.1	3000 design flow	-
Nitrogen, Ammonia (mg/l)	6.37	6.78	-	-
Barium (µg/L)	160	433.7	220	2000
Nickel (µg/L)	0	39.95	69	620
Lead (µg/L)	0	19.51	9.9	190
Copper (µg/L)	0	28.75	12	19
Tetrachloroethylene (µg/L)	0	0	-	10
Trichloroethylene (µg/L)	0	0	-	10
Mercury, Total (Low Level) (ng/l)	0	4.45	1.3	1700
Outfall 004 to Whitman Creek via UT				
Flow Rate (GPD)	2853	38561	-	-
Specific Conductance at 25 Degrees C (Umho/cm) 2012-2015	7140	16582	-	-
Total Suspended Solids (mg/l)	11	27.1	30	45
Outfall 005 to Whitman Creek via UT				
Flow Rate (GPD) 2013-2015	1902	13965	-	-
Specific Conductance at 25 Degrees C (Umho/cm) 2013-2015	6030	11732	-	-
Total Suspended Solids (mg/l) 2013-2015	9	24.25	30	45

Water Chemistry

Grab Results

Surface water chemistry samples were collected from the Lake Erie Central Basin Tributaries from May through December 2015 at 57 locations (Table 4). Stations were established in free-flowing sections of the streams and were primarily collected from bridge crossings. Surface water was collected directly into appropriate containers, preserved, and delivered to Ohio EPA's Division of Environmental Services laboratory. Methods for collection and preservation of samples can be found in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA, 2015). Interactive maps of surface water chemical data, downloadable to Excel files, are available at the following link: epa.ohio.gov/dsw/gis/index.aspx.

The United States Geological Survey (USGS) gage data from Euclid and Conneaut creeks was used to show flow trends during the survey (Figure 27 and Figure 28). Dates when water samples and bacteria samples were collected in the study area are noted on the graph. Flow conditions during the field season were above normal for the beginning of the survey, with major and intense rain events in June. Flow conditions during the end of the season fell to below average flows throughout the survey areas. Water samples collected captured a variety of flow conditions in the study area during the field season. Bacteria samples were collected during the recreation use season (May 1- October 31) and were typically collected during lower flows.

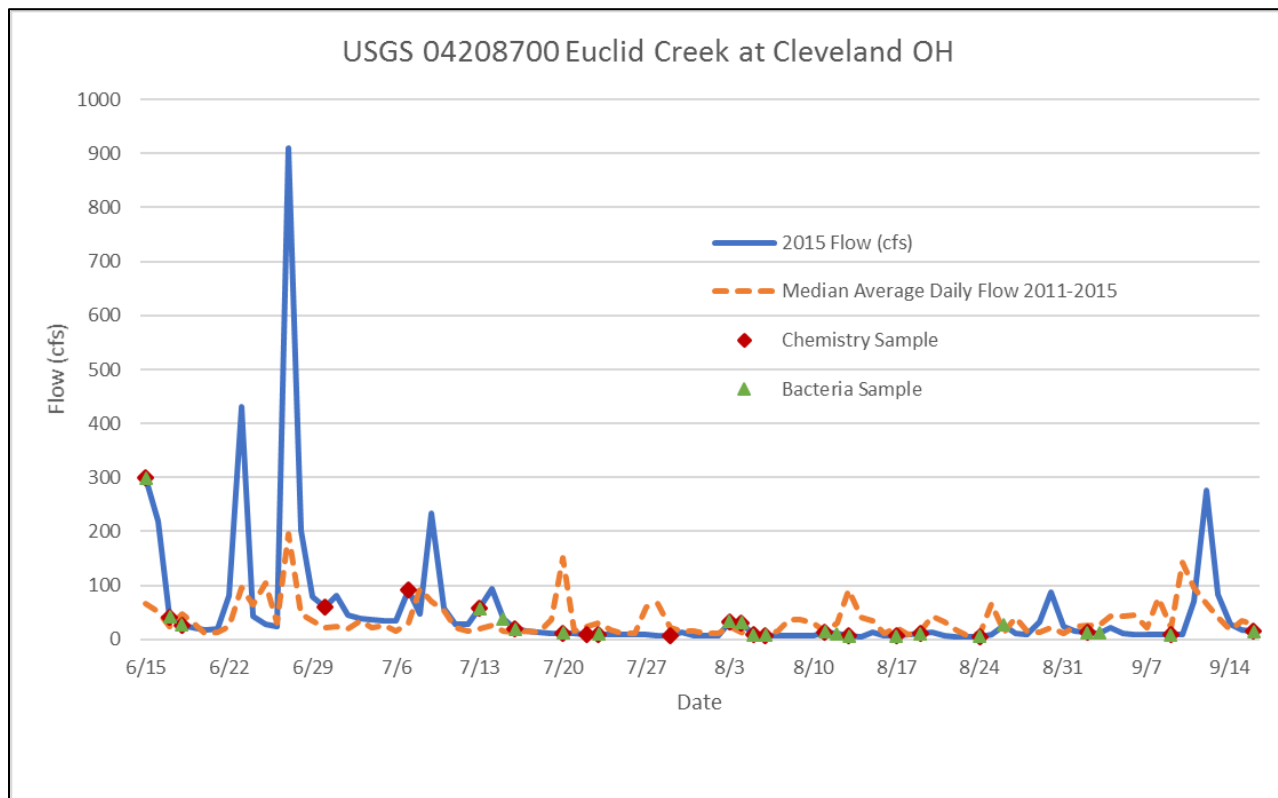


Figure 27. Daily average flow conditions in Euclid Creek at the USGS gage at Cleveland OH in 2015 (USGS, 2018)

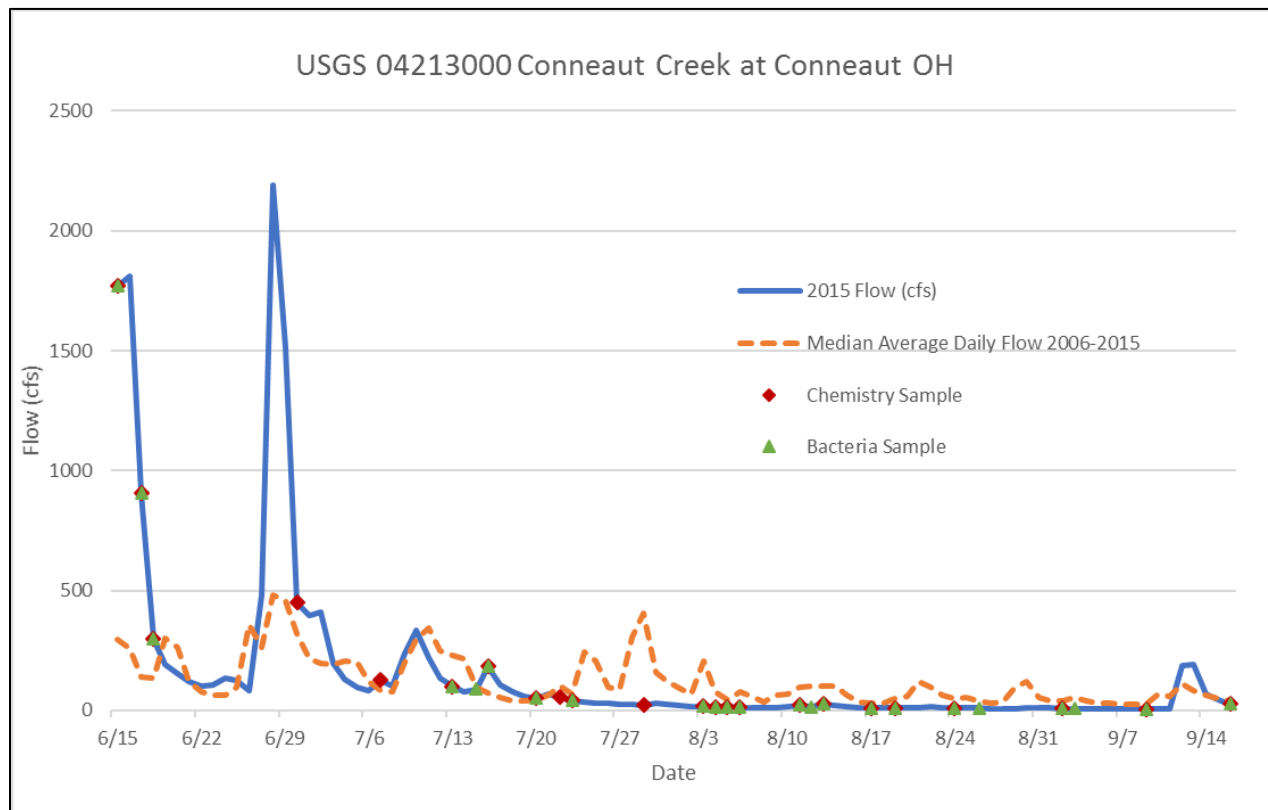


Figure 28. Daily average flow conditions in Conneaut Creek at the USGS gage at Conneaut OH in 2015 (USGS, 2018)

Surface water samples were analyzed for metals, nutrients, bacteria, pH, temperature, conductivity, DO, percent DO saturation, and suspended and dissolved solids (Appendix G). Exceedances of the Ohio WQS criteria are reported in Table 12. Bacteriological samples were collected from forty-two locations and are presented in the Recreation Use section of this document. Grab water samples were collected from the fifty-seven locations a minimum of five times from mid-June through mid-September 2015. All samples within the same HUC were collected on the same day to allow for longitudinal comparison of data, upstream and downstream from point sources, under similar stream flow conditions.

There were various DO exceedances throughout the different watersheds in the survey, due in part to the low-gradient and low flow nature of some of the watersheds, as well as the dry weather conditions in the later portion of the survey. Water quality exceedances observed with the data sondes are reported in Table 13.

Metals were measured at all locations sampled, with seventeen parameters tested. Iron exceedances were observed at three of 57 locations. The three exceedances of the statewide water quality criteria occurred at the lower portions of Arcola, Cowles, and Indian creeks. These exceedances corresponded to high flow events in the watersheds. Fluxes of aluminum and TSS followed in these high flow events, indicating influences of storm water and sediment inputs into the watersheds. The only other exceedance was a one-time water grab of selenium ($5.4 \mu\text{g/L}$) at the tributary to Euclid Creek near Anderson Rd.

Organic parameters were measured at five stations in Arcola Creek during the survey. Past surveys have documented dieldrin, endrin, and heptachlor epoxide in the water chemistry samples from Arcola Creek (Ohio EPA, 1996). The likely source of these chemicals was runoff from the nursery industry prevalent throughout the watershed. The organochlorine pesticide, dieldrin, was banned for agricultural use in 1970. However, it is persistent in soils and sediment. Dieldrin was detected during the September sampling event in Arcola Creek at RM 2.02 at a concentration of $0.0034 \mu\text{g/L}$, exceeding the water quality criteria for the protection of human health ($0.000065 \mu\text{g/L}$). There were detected concentrations for lindane and endrin in Arcola Creek at RMs 7.05 and 5.04, respectively, however neither pesticide exceeded any of the water quality standards.

Two rounds of organic sampling on Red Mill Creek and Church Creek occurred in the summer of 2016, to follow up with results from the 2015 survey. The first sampling event on April 21, 2016 yielded a detected result of BHC-delta in Red Mill Creek ($0.0022 \mu\text{g/L}$), but just above the reporting limit of $0.002 \mu\text{g/L}$. A second sampling event on May 31st, 2016 yielded detection of BHC-delta at both Red Mill Creek and Church Creek ($0.0052 \mu\text{g/L}$ and $0.002 \mu\text{g/L}$, respectively). BHC-delta is one of the isomers formed from the degradation of lindane, a persistent organochlorine insecticide.

Table 12. Exceedances of Ohio Water Quality Standards criteria (OAC3745-1) for chemical/physical parameters measured in the Ohio Tributaries to the Lake Erie Central Basin Tributaries study area, 2015. Bacteria exceedances are presented in the Recreation Use Section.

12 Digit HUC		Parameter (value – µg/L unless noted)
Stream (UD) RM	Location	
<i>41100010701</i>		
<i>Beaver Creek (WWH, AWS, IWS); RM 11 WWH</i>		
13.8	Quarry Rd	DO (3.49 mg/L)
11	Russia Rd	DO (3.38 mg/L)
<i>041100010702</i>		
<i>Willow Creek (WWH, AWS, IWS)</i>		
1.25	SR 58	DO (2.95 mg/L)
<i>041100010703</i>		
<i>Martin Run (WWH, AWS, IWS)</i>		
0.9	Meister Rd	DO (2.08 mg/L)
2.35	Towers Rd	DO (3.06 mg/L)
<i>041100010503</i>		
<i>Unnamed Tributary to Euclid Creek (WWH)</i>		
1.35	Anderson Rd	Selenium (5.4)
<i>041100010504</i>		
<i>South Branch Doan Brook (undesignated WWH apply)</i>		
1.31	Attleboro Rd	DO (3.84 mg/L)
<i>41100030203</i>		
<i>Arcola Creek (WWH)</i>		
2.02	Cunningham Rd	Iron (6950) ^c
<i>Unnamed Tributaries to Arcola Creek (undesignated WWH apply)</i>		
0.2	County Line Rd	DO (3.01, 2.04, 1.43, 2.84 mg/L)
0.1	Adjacent US 20	DO (3.93, 1.7, 1.05, 1.71, 2.07 mg/L), SPC (3044,3190)
<i>41100030202</i>		
<i>Cowles Creek (WWH, AWS, IWS)</i>		
4.83	North Avenue	DO (2.33 mg/L)
0.9	SR 534	Iron (7550, 8970) ^c
<i>41100030201</i>		
<i>Indian Creek (WWH, AWS, IWS)</i>		
1.65	North Bend Rd	Iron (5100, 7220) ^c
0.65	Myers Rd	Iron (6740) ^c
<i>41201010606</i>		
<i>Unnamed Tributary to Whitman Creek</i>		
1.24	LaBounty Rd	DO (3.81 mg/L)

^a Exceedance of the aquatic life Outside Mixing Zone Maximum water quality criterion (for D.O., below minimum).

^b Exceedance of the aquatic life Outside Mixing Zone Average water quality criterion (for D.O., below 24 hour average).

^c Exceedance of the statewide water quality criteria for the protection of agricultural uses.

Water Quality Sonde Results

Multi-parameter water quality sondes were deployed to monitor temperature, DO, pH and specific conductance (conductivity) at hourly intervals. Temperature, DO and pH are influenced by diel (24-hour) patterns. These diel fluctuations are greatest during stream critical conditions that include stable, low streamflow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in streamflow. Grab readings differ because they only represent one point on the diel cycle. While they are effective at characterizing water quality parameters that change based on hydrologic regime or season, they can miss or not fully characterize parameters that exhibit diel patterns. Diel patterns in temperature reflect air temperature, solar radiation, base flow (ground water), discharge, and shading. In general, diel fluctuations in temperature increase as base flow, discharge, and shading decrease. The inverse is also true.

DO responds in a similar diel pattern to temperature, as it is affected by similar factors. In addition, DO trends are directly dependent on temperature. At high temperatures, the solubility of oxygen in water decreases resulting in an inverse relationship. Without the influence of other environmental conditions, this would cause the two parameters to follow opposite trends. However, the DO produced by photosynthesis is, in most instances, enough to overwhelm the inverse relationship causing the trends to follow similar trajectories. Increasing diel fluctuation relates to an increase in productivity, resulting in DO reaching super saturation during the day with subsequent depletion by respiration at night. The result is a diel trend that typically reaches a maximum in the early evening and a minimum preceding sunrise. In some cases, DO does not exhibit strong diel trends in low flow, warm conditions. Either primary productivity is limited or decomposition of organic matter in the stream is controlling the DO concentrations. Diel monitoring helps to identify DO trends that are more influenced by primary productivity or decomposition.

Stream pH is generally controlled by the local geology that determines the natural alkalinity and acidity of the system. However, diel patterns in pH result as a function of primary productivity. Carbon dioxide, which dissolves in water to form carbonic acid, lower pH at night, then is consumed during photosynthesis, raising the pH of the stream. The result is a maximum pH value observed at a similar time to the maximum DO.

Critical conditions for temperature and DO are times when flows are low, temperatures are high, and daylight is long. These are the times that streams are most sensitive to organic and nutrient enrichment. To capture these conditions, sondes are typically deployed during low flow conditions from June to September. Two deployments occurred in the Lake Erie Central Basin Tributaries watersheds. The first was from July 21-23, 2015; 29 sites were sampled during this survey. A second deployment took place at 30 sites from August 26-28, 2015. Twenty-nine sites were sampled with water quality sondes to represent the general watershed area as well as target areas of concern (i.e. point sources). Summary plots of all data collected are included in Appendix K of this document. Figure 29 shows these dates relative to the air temperature and streamflow. Flows were slightly above normal at the first survey and below normal in the second survey, representing summer, low flow condition. The average air temperatures were around normal during much of the summer.

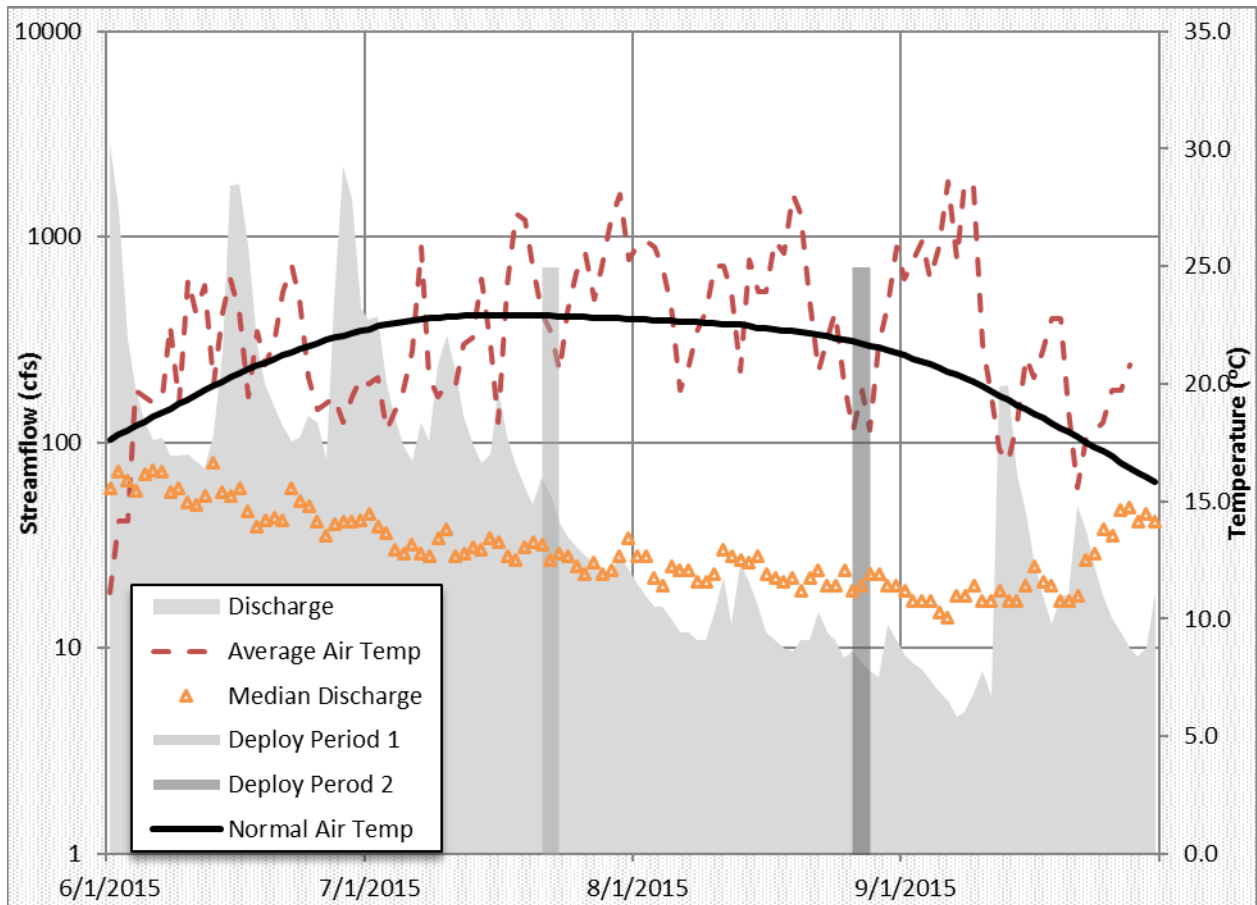


Figure 29. Graph of average daily streamflow (USGS 04213000 – Conneaut Creek at Conneaut OH) relative to the median streamflow and normal daily air temperature (NOAA – GHCND:USC 00336389) for the sampling season.

The data collected during the sonde deployments are sufficient to evaluate exceedances of the standards for the protection of aquatic life for: maximum daily temperature, minimum DO, 24-hour average DO, pH, and specific conductivity. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. The 24-hour average for DO is calculated as a rolling 24-hour average of the hourly data. An exceedance of the water quality criteria does not represent stream impairment; rather, if biological impairment is present the exceedances help develop a body of evidence that identifies the conditions that are stressing aquatic life. A summary of the exceedances is presented in Table 12.

Table 13. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring.

The first deployment was 7/21-23/2015 and 44-51 hours of data were collected at 29 sites. The second was 8/26-28/2015 resulting in 42-51 hours of data collection at 30 sites. Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average dissolved oxygen (DO) criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria. The duration is presented first followed by the magnitude in parenthesis on the table.

RM	Location	Parameter (DO in mg/L, Temp in °C, pH in SU & Specific Conductance in µS/cm)	
		7/21/15 – 7/23/15	8/26/15 – 8/28/15
<i>Brownhelm Creek (20-100-000)</i>		<i>EOLP – Warmwater Habitat</i>	
0.9	Adjacent Baumhart Road	None	None
<i>Quarry Creek (20-101-000)</i>		<i>EOLP – Warmwater Habitat</i>	
0.25	First Energy's access road	None	None
<i>Beaver Creek (20-003-000)</i>		<i>EOLP – Warmwater Habitat</i>	
11	Russia Road	None	None
6.95	Middle Ridge Rd	None	None
4	Upstream (UST) Amherst WWTP site	None	None
3.8	Downstream (DST) of Amherst WWTP site	None	None
2.9	At Cooper Forest Park Rd	None	None
1.75	At Longbrook Rd.	None	None
<i>Martin Run (20-004-000)</i>		<i>EOLP – Warmwater Habitat</i>	
0.9	Meister Rd.	None	None
<i>Doan Brook (19-039-000)</i>		<i>EOLP – Warmwater Habitat</i>	
0.75	St. Clair Ave.	None	None
<i>Ninemile Creek (19-040-001)</i>		<i>EOLP – Warmwater Habitat</i>	
0.34	At Cleveland @ Lake Shore Blvd	None	None
<i>Euclid Creek (19-041-000)</i>		<i>EOLP – Warmwater Habitat</i>	
3.3	Euclid Park Blvd	None	None
0.66	UST Lake Shore Blvd	None	None
<i>E. Br. Euclid Creek Cr (19-041-001)</i>		<i>EOLP – Warmwater Habitat</i>	
0.2	UST old dam	None	None
<i>Marsh Creek (03-026-000)</i>		<i>EOLP – Warmwater Habitat</i>	
1.5	Hendricks RD.	None	None
<i>Red Mill Creek (07-024-000)</i>		<i>EOLP – Warmwater Habitat</i>	
1.7	US 20	None	None
<i>Arcola Creek (07-011-000)</i>		<i>EOLP – Warmwater Habitat</i>	
7.4	At Madison @ Middle Ridge Rd.	None	None
7.05	DST Madison WWTP	None	None
2.02	NE of N. Madison @ Cunningham Rd	None	None
0.7	DNST. Lake Rd	None	None
<i>Cowles Creek (07-007-000)</i>		<i>EOLP – Warmwater Habitat</i>	
7.24	At Barnum Rd	None	None
4.83	At North Ave.	None	None
3.56	At Maple Ave.	None	None
0.9	At SR. 534	Not Deployed	None
<i>Indian Creek (07-008-000)</i>		<i>EOLP – Warmwater Habitat</i>	
3.65	At Ninevah Rd	None	None

RM	Location	Parameter (DO in mg/L, Temp in °C, pH in SU & Specific Conductance in µS/cm)	
		7/21/15 – 7/23/15	8/26/15 – 8/28/15
2.17	At North Bend Rd.	None	None
<i>Red Brook (07-009-000)</i>		<i>EOLP – Warmwater Habitat</i>	
2.3	At Wade Ave.	pH (9.1)	None
<i>Conneaut Creek (07-100-000)</i>		<i>EOLP – Exceptional Warmwater Habitat</i>	
13.2	DST of Kingsville trib. At Ridge rd.	None	None
6.69	At Keefus Rd	None	None
<i>Smokey Run (07-100-001)</i>		<i>EOLP – Coldwater Habitat</i>	
0.2	S. of Conneaut @ Welton Rd	None	None

Notes: EOLP: Erie-Ontario Lake Plain ecoregion

^a Applicable minimum DO criterion - WWH: 4 mg/l, EWH: 5 mg/l, CWH: 6mg/l

^b Applicable minimum 24-hour average DO criterion - WWH: 5 mg/l, EWH: 6 mg/l, CWH: 7 mg/l

^c The General Lake Erie basin daily maximum temperature criteria apply; See OAC 3745-1-35, Table 35-11(G).

^d The criteria for pH is 6.5-9.0 S.U.

^e The criteria for specific conductivity is 2400 µS/cm.

None of the 29 sites on the first deployment period (7/21/2015 to 7/23/2015), and 30 sites on the second deployment period (8/26/2015 to 8/28/2015) had any D.O., temperature, and specific conductivity exceedances. There was just one minor pH exceedance, which only occurred on the first survey in Red Brook (pH=9.1).

While not exceedances of water quality criteria, the following sites exhibited strong diel fluctuations in DO (>6.5 mg/L): Beaver Creek N. of Amherst @ Cooper Forest Park Rd (RM 2.9) had a maximum 8.2 mg/L range on the first deployment, Beaver Creek at Russia Rd (RM 11.0) had 8.3 mg/L range on second deployment, Beaver Creek S. of Amherst @ Middle Ridge Rd (RM 6.95) had 6.7 mg/L range on the second deployment, Martin Run at Meister Rd (RM 0.9) had a 6.53 mg/L range on the first deployment, and Arcola Creek downstream of Lake (Cashen Rd) (RM 0.7) had 6.6 mg/L range on the first deployment (Figure 30 and Figure 31).

Weight of Evidence Nutrient Evaluation

Nutrients were measured at each sampling location, and included ammonia, nitrate-nitrite, total Kjeldahl nitrogen (TKN), and total phosphorus (TP). In addition to nutrient monitoring, measurements were taken at a subset of locations to represent the algal biomass and associated DO production and consumption. The purpose of the nutrient monitoring summarized in this report is to consider the effects of nutrients on the biological conditions in the surveyed streams.

Chlorophyll- α samples were taken at select sites to aid in assessing stream health. Chlorophyll- α concentrations from benthic algae (attached to bottom substrates) are measured as a proxy for algal community biomass in wadable streams and small rivers, while chlorophyll concentrations measured from sestonic algae (suspended in the water column) serve as a proxy for algal abundance in large rivers. While many factors influence whether sestonic or benthic algae drive production and respiration, such as width-depth ration, time of travel, and longitudinal gradient, sestonic algae typically dominate streams defined as large rivers and benthic algae typically dominate small streams. Miltner (2010) identified benthic chlorophyll levels less than 90 mg/m² can be considered least disturbed and atypical for Ohio, while levels between 90-183 mg/m² are typical for Ohio Streams with modest amount of wastewater loadings or agricultural influences. Ranges from 183-320 mg/m² characterize areas that drain agricultural landscapes or effluent dominated streams and levels greater than 320 mg/m² indicate over enrichment or nuisance conditions. Sestonic chlorophyll, as described by Dodds (2006), between the levels of 40-100 µg/L, identify eutrophic conditions while concentrations greater than 100 µg/L indicate hyper-eutrophic conditions.

Nutrient reduction strategies have been a focus of Ohio and other states as cultural eutrophication begins becomes more problematic (USEPA 2015, Ohio EPA 2014a, Miltner 2010, and Markus 2003). Wide diel DO ranges associated with eutrophication are caused by excessive photosynthesis during daylight hours and respiration at night. Recent investigation by Ohio EPA identified a diel DO range of 6.5 mg/L as a threshold generally protective of biological and stream quality, and concentrations greater than 6.5 mg/L are indicative of eutrophication in Ohio streams (Ohio EPA, 2014).

Total phosphorus and dissolved inorganic nitrogen (DIN) usually represent the largest portion of phosphorus and nitrogen in Ohio streams. Ohio EPA assigns a risk category, based on Miltner (2010), using the geometric means of samples collected in the index period June 15-October 15. Table 14 compares the geomeans for all sites sampled in the study area with benchmarks based on reference conditions in Ohio streams. (Ohio EPA, 1999). Most locations sampled in 2015 were places in the low-risk category, five sites were placed in the moderate-risk category, and four sites are categorized as high-risk. The high-risk category sites fall in two watersheds, Beaver Creek and Cowles Creek. For each stream, the high-risk sites are immediately downstream of WWTP discharges; Amherst WWTP and Geneva WWTP in Beaver and Cowles creeks, respectively.

DO ranges, chlorophyll concentrations from both benthic and sestonic algae, and the total phosphorus and DIN discussed above, are presented in Figure 30 and Figure 31 below. Sestonic algae concentrations were consistently in the low range throughout the survey. Benthic chlorophyll- α data followed similar patterns, however, had levels in the moderate-high range at five sites. The moderate-high ranges were found in Beaver Creek, Doan Brook, East Branch Euclid Creek, and Arcola Creek, with the second highest range again found just below the Amherst WWTP on Beaver Creek. The highest benthic chlorophyll site (682 mg/m²), found in Arcola Creek, is located adjacent to Lake County WWTP but does not receive any discharge. This site also had diel DO values just above the threshold of 6.5 mg/L (6.63 mg/L) and may be influenced by lake back-flow.

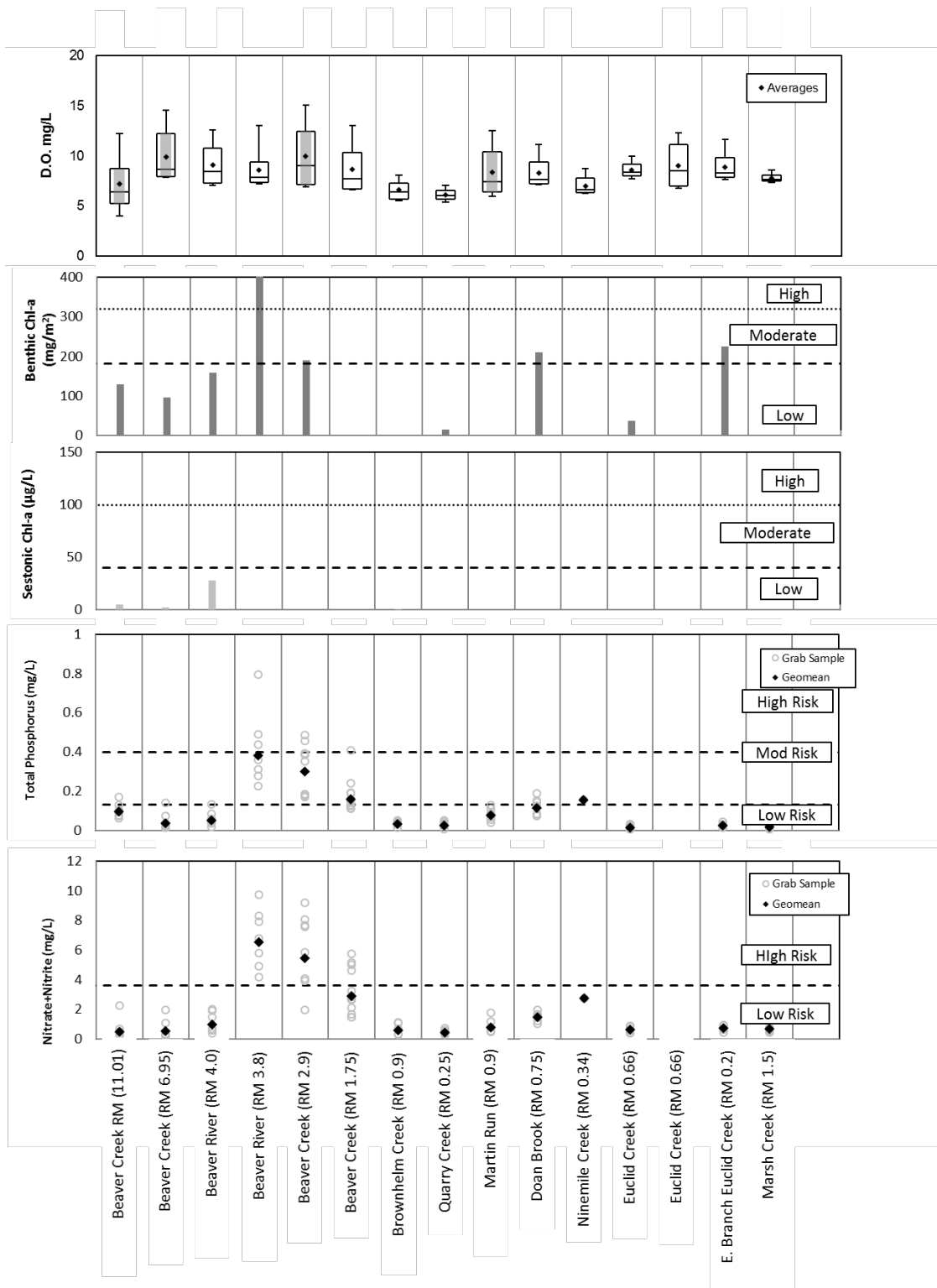


Figure 30. Longitudinal representation of diel DO, benthic/sestonic chlorophyll-a, total phosphorus, and DIN used to evaluate the impact of nutrients on the Lake Erie Tributaries. Relevant benchmarks for chlorophyll-a and nutrient concentrations (Dodds 2006, Miltner 2010, Ohio EPA 2014) are presented within their respective plots. Boxes on DO plots are shaded if the diel range exceeds the benchmarks of 6.5 mg/L (Miltner, 2010).

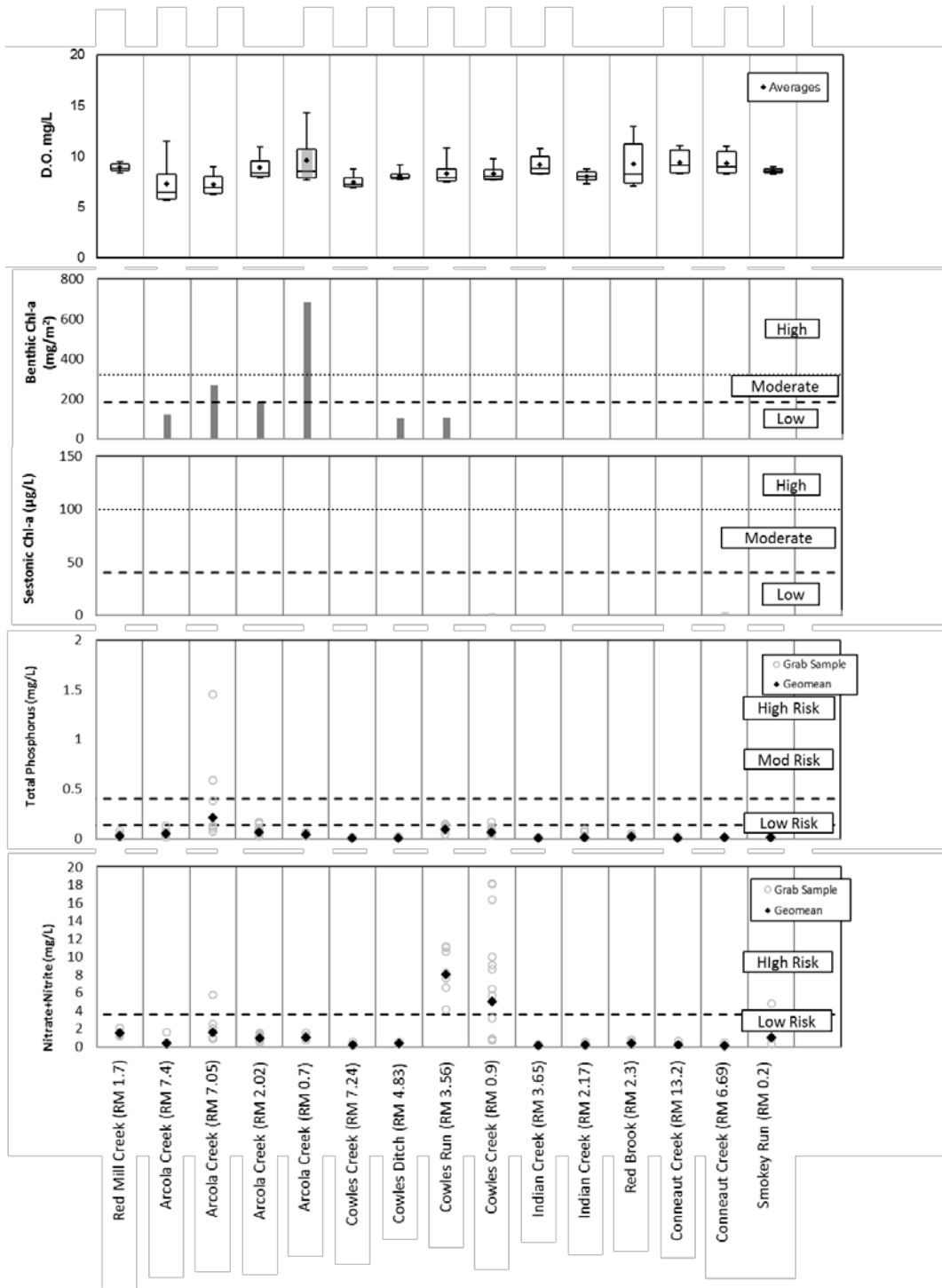


Figure 31. Longitudinal representation of diel DO, benthic/sestonic chlorophyll-a, total phosphorus, and DIN used to evaluate the impact of nutrients on the Lake Erie Tributaries. Relevant benchmarks for chlorophyll-a and nutrient concentrations (Dodds 2006, Miltner 2010, Ohio EPA 2014) are presented within their respective plots. Boxes on DO plots are shaded if the diel range exceeds the benchmarks of 6.5 mg/L (Miltner, 2010).

Table 14. Nutrient sampling results in the Lake Erie Central Basin Tributaries, summer (June 15 – October 15) 2015.

The seasonal geometric mean for each site was used to assign risk categories, based on Milner, 2010. Please note that the risk categories do not directly translate to Cause/Source determinations for aquatic life use impairment, rather this data serves as one of the many lines of evidence in the Cause/Source determination process.

Risk categories from Milner (2010).

H – Total Phosphorus ≥ 0.4 or DIN ≥ 3.6

M – Total phosphorus < 0.4 and ≥ 0.131 and DIN < 3.6

L – Total Phosphorus < 0.131 and DIN < 3.6

Station Name	Station	12 Digit HUC	River Mile	Phosphorus		DIN		Risk Category
				Samples (#)	Geometric Mean	Samples (#)	Geometric Mean	
Arcola Creek at Madison @ Ridge Rd.	A01K18	04110003 02 03	7.4	8	0.049	7	0.395	M
Arcola Creek dst. Madison WWTP	A01W22	04110003 02 03	7.05	8	0.214	7	1.587	L
Arcola Creek E of North Madison @ M.H. Supply Co.	A01W24	04110003 02 03	5.04	3	0.066	3	0.663	L
Arcola Creek NE of North Madison @ Cunningham Rd.	A01W25	04110003 02 03	2.02	16	0.054	14	0.914	L
Arcola Creek near mouth, dst. Cashen Rd.	A01K17	04110003 02 03	0.7	8	0.039	7	1.050	L
Beaver Creek dst Amherst WWTP	303264	04110001 07 02	3.8	7	0.382	7	6.547	H
Beaver Creek upst Amherst WWTP	303265	04110001 07 02	4	7	0.051	6	0.957	L
Beaver Creek @ Quarry Rd	303263	04110001 07 01	13.75	5	0.080	5	0.406	L
Beaver Creek dst. Amherst @ Longbrook Rd.	Y01S22	04110001 07 02	1.75	14	0.154	14	3.114	L
Beaver Creek N of Amherst @ Cooper Forest Park Rd.	Y01S23	04110001 07 02	2.9	7	0.294	7	5.199	H
Beaver Creek S of Amherst @ Middle Ridge Rd.	Y01S25	04110001 07 02	6.95	6	0.037	5	0.517	L
Beaver Creek SW of South Amherst @ Russia Rd.	Y01S26	04110001 07 01	11.02	7	0.096	6	0.490	L
Brownhelm Creek adj. Baumhart Rd	303268	04110001 07 03	0.9	6	0.034	5	0.598	L
Church Creek @ McMackin Rd.	303279	04110003 02 04	0.65	5	0.016	5	0.417	L
Conneaut Creek @ Big D Campground	303288	04120101 06 05	12.27	5	0.007	5	0.654	L
Conneaut Creek at Conneaut @ Keefus Rd.	502870	04120101 06 05	6.69	6	0.009	5	0.308	L
Conneaut Creek at Conneaut @ Main St.	A01P07	04120101 06 05	2.56	5	0.007	5	0.203	L
Conneaut Creek near Kingsville @ S. Ridge Rd.	502890	04120101 06 05	13.46	7	0.007	6	0.225	L
Conneaut Creek near OH/PA border @ Furnace Rd.	502900	04120101 06 05	23.24	5	0.010	5	0.395	L
Conneaut Creek SE of Conneaut @ State Rd. (Co. Rd. 354)	A01P09	04120101 06 05	17.2	5	0.008	5	0.256	L
Cowles Creek at Geneva @ North Ave.	502710	04110003 02 02	4.83	7	0.007	6	0.424	L
Cowles Creek dst. Geneva @ Maple Ave.	502720	04110003 02 02	3.56	7	0.096	7	8.082	M
Cowles Creek upst. Geneva @ Barnum Rd.	502700	04110003 02 02	7.24	6	0.007	6	0.216	L
Cowles Creek upst. Geneva-on-the-Lake @ St. Rt. 534	A01P17	04110003 02 02	0.9	15	0.061	14	4.626	M
Doan Brook at Cleveland @ St. Clair Ave.	301428	04110003 05 04	0.75	7	0.114	6	1.470	L
Doan Brook at Cleveland @ Wade Park	200137	04110003 05 04	3.1	5	0.143	5	2.051	L
Doan Brook at Shaker Heights, dst. Lee Rd.	F01G52	04110003 05 04	6.64	5	0.030	5	1.226	L
E. Br. Euclid Creek at Richmond Heights @ Richmond Rd.	303283	04110003 05 03	2.75	5	0.046	5	0.701	L
E. Br. Euclid Creek near mouth, upst. old dam (Free-Flowing)	301678	04110003 05 03	0.2	6	0.024	5	0.735	L
Euclid Creek @ Euclid Park Blvd.	F01G48	04110003 05 03	3.3	7	0.015	6	0.633	L
Euclid Creek @ Lake Shore Blvd.	F01A47	04110003 05 03	0.66	3	0.026	3	0.281	L
Euclid Creek dst. Mayfield Golf Course @ Mayfield Rd.	F01G47	04110003 05 03	7.1	5	0.009	5	0.663	L
Indian Creek E of Geneva-on-the-Lake @ Myers Rd.	303107	04110003 02 01	0.65	7	0.009	7	0.173	L
Indian Creek E of Geneva-on-the-Lake @ North Bend Rd.	303108	04110003 02 01	2.17	15	0.013	13	0.239	L
Indian Creek @ Ninevah Rd	303272	04110003 02 01	3.65	7	0.006	6	0.149	L
Marsh Creek @ Hendricks Rd	303281	04110003 05 01	1.5	7	0.018	6	0.697	L
Marsh Creek @ SR 283	303282	04110003 05 01	0.2	4	0.020	4	0.629	L
Martin Run @ Meister Rd	303270	04110001 07 03	0.9	7	0.076	6	0.759	L
Martin Run @ Tower Blvd	303269	04110001 07 03	2.35	5	0.128	5	0.942	L
Ninemile Creek at Cleveland @ Lake Shore Blvd.	301432	04110003 05 04	0.34	2	0.172	2	2.554	L
Quarry Creek @ First Energy Plant	303271	04110001 07 03	0.25	7	0.026	6	0.451	L
Red Brook @ Wade Rd	303273	04110003 02 01	2.3	7	0.021	6	0.370	L
Red Mill Creek @ U.S. Rt. 20	303280	04110003 02 04	1.7	7	0.028	7	1.495	L
S. Br. Doan Brook at Shaker Heights @ Attleboro Rd.	301429	04110003 05 04	1.31	5	0.081	5	1.039	L
Smokey Run S of Conneaut @ Welton Rd.	A01P05	04120101 06 05		6	0.009	5	1.047	L
Squires Squamm Ditch @ Annis Rd	303266	04110001 07 01	1.3	5	0.080	5	0.801	L
Tributary to Arcola Creek (RM 0.22) @ County Line Rd.	303277	04110003 02 03	0.2	5	0.030	5	0.899	L
Tributary to Arcola Creek (RM 4.32) adj. U.S. Rt. 20	303278	04110003 02 03	0.1	5	0.134	5	0.924	L
Tributary to Conneaut Creek (RM 17.1) @ State Rd	303289	04120101 06 05	0.3	5	0.006	5	0.550	L
Tributary to Cowles Creek (RM 0.2) @ Golf Course	303274	04110003 02 02	0.9	5	0.020	5	0.339	L
Tributary to Euclid Creek (5.49) NEAR EUCLID @ ANDERSON RD.	F01P50	04110003 05 03	0.2	4	0.078	4	1.014	L
Tributary to Indian Creek (RM 3.5) @ Ninevah Rd	303275	04110003 02 01	0.15	5	0.008	5	0.523	L
Tributary to Whitman Cr (0.32) E of Ashtabula@LaBounty Rd.	A01P14	04120101 06 06	1.14	5	0.009	5	0.724	L
Turkey Creek E of Conneaut @ State Line Rd.	A01P03	04120101 04 09	1.37	5	0.011	5	0.508	L
Wheeler Creek @ Center Rd	303276	04110003 02 02	2.75	5	0.008	5	0.442	L
Whitman Creek @ W of Kingsville-on-the-Lake @ SR 531	A01P15	04120101 06 06	0.06	5	0.012	5	0.715	L
Willow Creek @ St. Rt. 58	303267	04110001 07 02	1.25	5	0.054	5	0.928	L

Sediment Chemistry

Surficial sediment samples were collected at twenty-four locations in the Lake Erie Central Basin Tributaries study area (Figure 32). Sampling locations were co-located with water chemistry and biological sampling sites. Samples were collected following the *Sediment Sampling Guide and Methodologies, 3rd Edition* with a focus on obtaining a representative sample composed of >30% silt and clay particles (Ohio EPA, 2012). Individual samples were collected by focusing on depositional areas of fine grain material, mostly silts and clays. Compared to sands and gravels, the finer particles such as silts and clays typically contain higher contamination levels. Sampling locations with predominant silt and clay particles were found for all sampling locations, except for the mouth of Arcola Creek and Red Brook, both in Lake county.

Samples from the study were analyzed for total organic carbon (TOC), semi-volatile organic constituents (base neutral acid extractables (BNAs) and polycyclic aromatic hydrocarbons (PAHs)), polychlorinated biphenyls (PCBs), and various metals. Specific chemical parameter results are listed in Table 15 and Appendices I and J. Sediment data were evaluated using Tier I procedures for aquatic life according to the Guidance on Evaluating Sediment Contaminant Results (Ohio EPA, 2010). ALU impairment was not observed at any of the sediment sampling locations, therefore a Tier II assessment was not warranted.

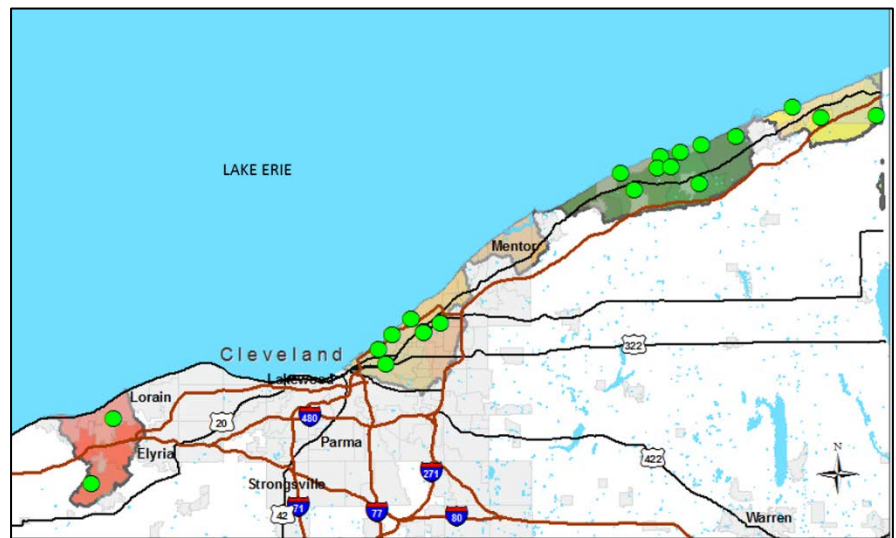


Figure 32. Sediment sampling locations for the Lake Erie Central Basin Tributaries study area, 2015.

Three levels of ecological sediment quality guidelines (SQGs) were applied to the sediment samples. Specific guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et.al.* 2000) were utilized to assess the sediment. These guidelines define two levels of ecotoxic effects on sediment dwelling organisms. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed and is comparable to background conditions. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be frequently observed. *Ohio Specific Sediment Reference Values* (SRVs) were developed for sediment metals using the same set of statewide ecoregion-based reference sites for ALU biocriteria (Ohio EPA 2003) and were also utilized to assess the samples.

Table 15. Chemical parameters collected by Ohio EPA from surficial sediments in 2015.

Contamination levels were determined for parameters using Ohio Sediment Reference Values (SRVs) and consensus-based sediment quality guidelines (MacDonald, et al. 2000). Shaded numbers indicate values above the following: SRVs (1) (yellow), Probable Effect Concentration – PEC (2) (red), Threshold Effect Concentration – TEC (3) (blue). Gray indicates that more than one threshold value has been exceeded. Stream sites are presented with corresponding river miles in parentheses. † Indicates USEPA priority pollutant (Appendix A, 40 CFR Part 423).

HUC 10					0411000107		0411000305					
Parameter	units	SRV ¹	PEC ²	TEC ³	Beaver Creek (13.7)	Willow Creek (1.25)	East Branch Euclid (2.75)	East Branch Euclid (0.2)	Euclid Creek (7.1)	Euclid Creek (3.3)	Doan Brook (6.64)	Doan Brook (2.7)
% solids	--	--	--	--	56.2	76.2	50	66.3	51.5	69.2	69.7	64.2
Aluminum	mg/kg	53000	--	--	6060	4730	5360	8000	5730	9980	6690	5340
Ammonia	mg/kg	--	--	--	78	32	75	34	73	11	38	73
Arsenic [†]	mg/kg	25.1	33	9.79	4.44	18.2	4.94	17.6	11.1	14.9	11.3	9.49
Barium	mg/kg	360	--	--	54.5	49.7	43.7	40.6	41.4	33.4	27.9	37
Cadmium [†]	mg/kg	0.8	5	0.99	0.588	1.88 ^{1,3}	0.722	0.599	0.464	0.468	0.398	0.482
Calcium	mg/kg	27000	--	--	4610	6940	6150	4090	10200	1860	3370	13300
Chromium [†]	mg/kg	53	111	43.4	12.8	11.7	10.7	12.6	13.6	13.5	11.6	14.9
Copper [†]	mg/kg	33	--	32	110 ^{1,3}	26.2	15.6	16.1	20.1	18.3	17.8	40.3 ^{1,3}
Iron	mg/kg	51000	--	--	25600	23300	12800	26600	25400	31200	22000	17200
Lead [†]	mg/kg	47	128	23	40.2	47.5 ^{1,3}	16.8	18	23.1	22.8	17	61.8 ^{1,3}
Magnesium	mg/kg	9900	--	--	2350	2800	2510	2850	3410	3160	2800	5300
Manganese	mg/kg	3000	--	--	268	493	683	404	434	284	321	343
Nickel [†]	mg/kg	61	49	23	18.3	33.3	13.2	20.3	16.4	27.6	17.3	14.5
Phosphorus	mg/kg	--	--	--	608	454	478	334	430	354	407	450
Potassium	mg/kg	14000	--	--	810	560	745	1490	665	1660	1190	525
Selenium [†]	mg/kg	2.6	--	--	0.81	1.84	0.745	0.51	0.665	0.46	0.54	0.525
Sodium	mg/kg	--	--	--	2020	1395	1860	1275	1660	1155	1350	1315
Strontium	mg/kg	250	--	--	12	8.5	11	17	23	7	8	22
Zinc [†]	mg/kg	170	459	121	122	164	119	105	109	109	78.9	129

Table 15 continued. Chemical parameters collected by Ohio EPA from surficial sediments in 2015.

HUC 10					0411000302							
Parameter	units	SRV ¹	PEC ²	TEC ³	Church Creek (0.65)	Arcola Creek (7.4)	Arcola Creek (2.02)	Arcola Creek (0.7)	Wheeler Creek (2.75)	Cowles Creek (7.24)	Cowles Creek (0.9)	Indian Creek (0.65)
% solids		--	--	--	63.9	70.1	60	67.1	75.3	77.4	54.1	57.1
Aluminum	mg/kg	53000	--	--	5630	6390	4840	2770	4760	5370	9110	5830
Ammonia	mg/kg	--	--	--	47	32	100	59	10	10	55	57
Arsenic [†]	mg/kg	25.1	33	9.79	14.1	5.81	8.05	3.52	4.49	6.73	10	7.06
Barium	mg/kg	360	--	--	55.3	123	64	35.4	32.6	37.4	63.7	55.8
Cadmium [†]	mg/kg	0.8	5	0.99	0.354	0.425	0.314	0.189	0.245	0.311	0.865	0.319
Calcium	mg/kg	27000	--	--	5570	5670	4520	5190	2950	5280	2930	4140
Chromium [†]	mg/kg	53	111	43.4	7.5	11	6.97	4.19	6.84	7.08	26.6	8.04
Copper [†]	mg/kg	33	--	32	10.8	11.7	10.7	8.27	8.01	9.45	29.7	10.3
Iron	mg/kg	51000	--	--	19500	13000	15900	8120	11900	15000	23300	16500
Lead [†]	mg/kg	47	128	23	8.76	11.4	10.4	6.24	8.81	9.08	41.1	14.2
Magnesium	mg/kg	9900	--	--	3430	2270	2180	1410	2120	3320	3580	2400
Manganese	mg/kg	3000	--	--	562	375	644	359	300	373	308	902
Nickel [†]	mg/kg	61	49	23	12.8	12.9	10.2	6.54	10.3	12.4	40.7	12.2
Phosphorus	mg/kg	--	--	--	914	422	659	307	272	290	847	433
Potassium	mg/kg	14000	--	--	595	444.5	640	580	525	505	720	720
Selenium [†]	mg/kg	2.6	--	--	0.595	0.445	0.64	0.58	0.525	0.505	0.72	0.72
Sodium	mg/kg	--	--	--	1485	1110	1600	1450	1315	1265	1805	1800
Strontium	mg/kg	250	--	--	9	91	9.5	8.5	8	7.5	11	11
Zinc [†]	mg/kg	170	459	121	59.8	58	64	37.1	44.5	62.2	145	59.3

Table 15 continued. Chemical parameters collected by Ohio EPA from surficial sediments in 2015.

HUC 10					0411000302	0412010106		
Parameter	units	SRV ¹	PEC ²	TEC ³	Red Brook (2.3)	Whitman Creek (0.06)	Conneaut Creek (23.24)	Conneaut Cr (12.27)
% solids		--	--	--	66	75.8	53	69.3
Aluminum	mg/kg	53000	--	--	7000	4860	7090	5630
Ammonia	mg/kg	--	--	--	35	42	100	55
Arsenic [†]	mg/kg	25.1	33	9.79	7.85	7.34	5.32	6.79
Barium	mg/kg	360	--	--	44.9	39	52.6	36.2
Cadmium [†]	mg/kg	0.8	5	0.99	0.34	0.222	0.261	0.183
Calcium	mg/kg	27000	--	--	5660	3170	1770	1140
Chromium [†]	mg/kg	53	111	43.4	9.7	6.91	8.22	7.35
Copper [†]	mg/kg	33	--	32	11.4	9.84	8.76	8
Iron	mg/kg	51000	--	--	21500	15200	14800	16100
Lead [†]	mg/kg	47	128	23	12.2	9.35	9.78	7.89
Magnesium	mg/kg	9900	--	--	4170	2650	2680	2420
Manganese	mg/kg	3000	--	--	718	375	424	264
Nickel [†]	mg/kg	61	49	23	15.7	11.2	12.5	11.1
Phosphorus	mg/kg	--	--	--	508	374	543	326
Potassium	mg/kg	14000	--	--	475.5	493	665	525
Selenium [†]	mg/kg	2.6	--	--	0.475	0.29	0.29	0.21
Sodium	mg/kg	--	--	--	1190	1230	1660	1320
Strontium	mg/kg	250	--	--	7	8	7	6
Zinc [†]	mg/kg	170	459	121	94.5	54.5	58.3	54

Certain metals exceeded one or more of the SQGs described above. Several heavy metals in the analysis exceeded the SRV and/or the TEC values. The most common metals detected above the SRV or TEC thresholds were arsenic, lead, nickel, and zinc. Beaver Creek, Willow Creek, Euclid Creek, and Doan Brook watersheds are all in highly urban and/or industrialized areas, therefore higher metal concentrations in the sediments are to be expected. Potential sources include urban runoff, CSOs, illicit discharges, or legacy pollutant contamination from past activities in the watersheds. Elevated levels above the TEC for certain metals in Cowles Creek may be due to discharge from the Geneva WWTP upstream (see NPDES Permitted Facilities). None of these analytes, in any of the watersheds, exceeded their respective PEC concentrations, therefore the risk of metal toxicity to aquatic organisms appears to be low.

Organic Sediment Results

Organic pollutant compounds detected in the sediments from the study area are below in Table 16.

Values above the PEC for many organic chemicals were observed throughout the study. As stated above, PEC threshold limits indicate levels above which harmful effects are likely to be frequently observed. The main contaminants detected in the samples were PAH compounds, however there were high concentrations of PCBs and pesticides documented in sediments within certain watersheds of the study. Some parameters have no SQGs, but their detected results are still reported in Table 15.

Exceedances of PEC values were also observed throughout the watersheds in this study area for PAHs and PCBs. The detected values are presented for individual PAHs and PCBs, and totals were calculated to represent the accumulative effects of these contaminants. PAHs represent a large class of suspected carcinogens that are freely discharged into the environment and are often closely related to local and regional sources in urban areas. These compounds, as documented by USGS, are found in high concentrations in storm water runoff, especially from coal-tar-based sealants. Additionally, combustion engines release various PAHs and are ubiquitous in urban areas, as well as near roadsides. Other fuel-based activities that utilize petrochemicals, like coal and motor oil, contribute to PAHs found in the sediment. East Branch of Euclid Creek (RM 2.75), Euclid Creek mainstem (RM 7.10), Doan Brook (RM 2.70), and Ninemile Creek all had total PAH values above the PEC guideline value for total PAHs. As discussed above, the PEC values are where ecotoxic effects are likely observed. The contaminated sediments found in these streams are ongoing issues caused by storm water runoff from the heavily urbanized watersheds. All other sampling locations had total PAH values above the TEC values, except Arcola Creek (RM 2.02) and Wheeler Creek (RM 2.75), where PAHs were not detected. Most PAHs are not documented as being bioaccumulative, except Benzo(g,h,i)perylene.

PCBs were widely used from 1929 until banned in 1979 in numerous industrial products and applications. PCBs are also well documented as chemical compounds that bioaccumulate in the food chain. Total PCB values calculated from detected PCB Aroclors in sediments collected at five sampling locations were below the PEC value but above the TEC value, except for Cowles Creek. The total PCB value reported for Cowles Creek was the only result over the PEC guideline value. The source is currently unknown. However, PCBs are slow degrading chemical compounds that, depending on the environment, are persistent enough to be transferred from air, water, and soil for years. This characteristic of PCBs makes determining a source difficult, unless a local source is well known, or an extensive investigation is conducted.

Pesticides, such as dichlorodiphenyltrichloethane (DDT), banned from use within the United States in 1972, were found in various watersheds of the survey. DDT presence remains in the environment due to its slow degradation rate. Degradation by-products of DDT, DDD and DDE, also remain prevalent in soils and sediments. These three parameters were found in Euclid Creek mainstem (RM 3.30 & 7.10), a tributary to Euclid Creek at Anderson Rd, Doan Brook mainstem (RM 0.20 & 6.64), South Branch of Doan Brook, Ninemile Creek, and Wheeler Creek. All detected results from these sampling locations were over the TEC values. However, only at the Ninemile Creek and Doan Brook (RM 2.70) sampling locations, DDT, DDE, and DDD were

all above the PEC guideline values. In Doan Brook (RM 0.75), DDD values were above the PEC, but the DDE values only exceeded the TEC guideline value.

The most likely sources of the organic pollutants found in the stream sediments are erosion of historically contaminated soils from the industrial areas near Cleveland (Doan Brook, Euclid Creek, Ninemile Creek) and Lorain/Elyria (Willow and Beaver creeks). Organic pollutants found in the more rural locations of the study area can be attributed to agricultural activities and the high volume of nursery industries (Arcola, Cowles, Church, and Wheeler creeks). Arcola Creek has had documented issues of dieldrin in the water column in the past and in this survey, however, sediment contamination of dieldrin was not observed. Urban runoff plays a significant role in polyaromatic hydrocarbon (PAH), pesticides, and polychlorinated biphenyl (PCB) contaminant loadings in the sediments. The NEORS is continuing to eliminate CSOs in the Cleveland area. Once the CSOs are contained and no longer release untreated waters to our surface water systems, the chemical quality of stream sediment will improve.

Table 16. Sediment organic chemicals measured above screening levels in samples collected by Ohio EPA from surficial sediments in the Lake Erie Tributaries study area, 2015.

Shaded numbers indicate values above the following: Threshold Effect Concentration - TEC (blue), Probable Effect Concentration – PEC (red). Blank cells indicate values below detection limits. Stream sites are presented with corresponding river miles in parentheses. † Indicates USEPA priority pollutant (Appendix A, 40 CFR Part 423).

Parameter	Units	PEC	TEC	East Br. Euclid (2.75)	East Br. Euclid (0.20)	Euclid Cr (7.10)	Euclid Cr (3.30)	Trib. Euclid Cr (0.20)	Doan Brook (6.64)	Doan Brook (2.70)	Doan Brook (0.75)	S. Br. Doan Brook (1.31)	Ninemile (0.34)
Anthracene [†]	mg/kg	0.845	0.0572			0.85				0.97			1.22
Benzo[a]anthracene [†]	mg/kg	1.05	0.108	2.44		3.04		0.59	0.64	4.44	1.01	1.1	4.69
Benzo[a]pyrene [†]	mg/kg	1.45	0.15	3.65	1.08	3.33		0.65	0.8	4.77	1.16	1.31	5.03
Benzo(b)fluoranthene [†]	mg/kg	--	--	4.65	1.35	3.82	0.7	0.68	1.18	6	1.51	1.45	6.47
Benzo[g,h,i]perylene [†]	mg/kg	--	--	3.72	1.11	2.8		0.58	0.8	3.85	0.95	1.15	3.21
Benzo[k]fluoranthene [†]	mg/kg	--	--	3.37	0.95	3.05		0.64	0.63	3.59	0.83	1.15	3.51
Chrysene [†]	mg/kg	1.29	0.166	3.88	1.1	3.93	0.63	0.77	0.95	5.54	1.29	1.42	5.69
Dibenz[a,h]anthracene [†]	mg/kg	--	0.033			0.89				1.51			1.15
Fluoranthene [†]	mg/kg	2.23	0.423	6.83	2.09	7.19	1.12	1.71	1.85	12	2.79	3.35	11.9
Fluorene [†]	mg/kg	0.536	0.0774										0.71
Indeno[1,2,3-cd]pyrene [†]	mg/kg	--	--	3.92	1.16	3.05		0.62	0.81	4.13	1.05	1.2	3.53
Phenanthrene [†]	mg/kg	1.17	0.204	2.54		4.39		0.71	0.69	6.01	1.17	1.43	6.82
Pyrene [†]	mg/kg	1.52	0.195	5.29	1.65	5.76	0.92	1.27	1.41	9.05	2.17	2.5	8.65
Total PAHs	mg/kg	22.8	1.61	40.29	10.49	42.1	3.37	8.22	9.76	61.86	13.93	16.06	62.58
DDD [†]	ug/kg	28	4.88			17.9	8.7	32.3	108	80	30.9	73.6	32
DDE [†]	ug/kg	31.3	3.16			24.2	8	8.9	90.3	55.3	21.3	41.5	35.7
DDT [†]	ug/kg	62.9	4.16			36.3	12	6.6	57.2	72.2		42.4	79.3
Dieldrin [†]	ug/kg	61.8	1.9										7.4
Methoxychlor	ug/kg	--	--				17.5		87.5			19.4	
PCB-Aroclor 1254 [†]	ug/kg	--	--					93.9			570		
PCB-Aroclor 1260 [†]	ug/kg	--	--										607
Total PCB	ug/kg	676	59.8					93.9			570		607
Total Organic Carbon	%	--	--	4.5	2.9	2.9	1.1		1.8	2.7		1.3	

Table 16 continued. Sediment organic chemicals measured above screening levels in samples collected by Ohio EPA from surficial sediments in the Lake Erie Tributaries study area, 2015.

Parameter	Units	PEC	TEC	Willow Cr (1.25)	Church Cr. (0.65)	Arcola Cr (7.4)	Arcola Cr (2.02).	Wheeler Cr (2.75)	Cowles Cr (0.9)
Anthracene [†]	mg/kg	0.845	0.0572						
Benzo[a]anthracene [†]	mg/kg	1.05	0.108		0.83				
Benzo[a]pyrene [†]	mg/kg	1.45	0.15	0.52	0.65				
Benzo(b)fluoranthene [†]	mg/kg	--	--	0.66	0.63				
Benzo[g,h,i]perylene [†]	mg/kg	--	--	0.55					
Benzo[k]fluoranthene [†]	mg/kg	--	--		0.63				
Chrysene [†]	mg/kg	1.29	0.166	0.69	0.84				
Dibenz[a,h]anthracene [†]	mg/kg	--	0.033						
Fluoranthene [†]	mg/kg	2.23	0.423	1.23	2.78	1.21			0.87
Fluorene [†]	mg/kg	0.536	0.0774						
Indeno[1,2,3-cd]pyrene [†]	mg/kg	--	--	0.52					
Phenanthrene [†]	mg/kg	1.17	0.204		1.6				
Pyrene [†]	mg/kg	1.52	0.195	0.95	1.96	0.94			
Total PAHs	mg/kg	22.8	1.61	5.12	9.92	2.15			0.87
DDD [†]	ug/kg	28	4.88			6.3		10.1	
DDE [†]	ug/kg	31.3	3.16			12.7	12.1	51.6	
DDT [†]	ug/kg	62.9	4.16				7.1	78.5	
Dieldrin [†]	ug/kg	61.8	1.9						
Methoxychlor	ug/kg	--	--						
PCB-Aroclor 1254	ug/kg	--	--		34.8				618
PCB-Aroclor 1260	ug/kg	--	--	26.4					163
Total PCB	ug/kg	676	59.8	26.4	34.8				781
Total Organic Carbon	%	--	--	1.7	1.6	1.2	1.4	0.8	2.1

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column. New revisions to the recreation use rules in Ohio became effective on January 4, 2016. However, as sampling to assess the recreation use for the Lake Erie Central Basin Tributaries study area occurred when the previous rules were in effect, the assessment of data was based on the prior rules (Table 17).

Escherichia coli (*E. coli*) bacteria are microorganisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but there is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more practicable. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. Fecal indicator bacteria by themselves, including *E. coli*, are usually not pathogenic. However, some strains of *E. coli* can be pathogenic; capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

The streams of the Lake Erie Central Basin evaluated in this survey are designated as Primary Contact Recreation (PCR) use in OAC Rule 3745-1-24. Water bodies with a designated recreational use of PCR “are waters that, during the recreation season, are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking and SCUBA diving” [OAC 3745-1-07(B)(4)(b)]. There are three classes of PCR used to reflect differences in the potential frequency and intensity of use. Streams designated PCR Class A typically have identified public access points and support primary contact recreation. Streams designated PCR Class B support, or potentially support, occasional primary contact recreation activities. The Conneaut Creek mainstem is designated Class A PCR waters, from RM 23.24 to the mouth. All other streams assessed during this survey are designated Class B PCR waters. The *E. coli* criteria that apply to PCR Class A and B streams include a geometric mean of 126 and 161 cfu/100 ml, and a maximum value of 298 and 523 cfu/100 ml, respectively. The geometric mean is based on two or more samples and is used as the basis for determining attainment status when more than one sample is collected.

Summarized bacteria results are listed in Table 18, and the complete dataset is reported in Appendix K.

Fifty-one locations in the survey were sampled for *E. coli* two to nine times, from June 15th – September 16th, 2015. Evaluation of *E. coli* results revealed that 49 of the 51 locations did not attain the applicable geometric mean criterion, and thus were in non-attainment of the recreation use. The only sites that met Ohio’s water quality standards were East Branch Euclid Creek near the mouth (RM 0.2) and an unnamed tributary to Arcola Creek (RM 4.32) at RM 0.1.

The causes of non-attainment within the Lake Erie Central Basin are the result of point and nonpoint polluters and may include CSOs, separate sewer overflows (SSOs), urban runoff, wastewater treatment plant (WWTP) discharges, HSTS, and agricultural runoff. Significant bacteria loading from failing HSTS, urban discharge, and CSOs are the probable causes for the extremely elevated maximum values (i.e. 28,000 cfu/ml). Bacterial contamination in most streams was present during both wet and dry weather events, indicating both nonpoint

and point source influence. Some of the potential sources of bacteria are listed in Table 18 and are not necessarily confirmed as a source of impairment nor are they exclusive of other sources. The full attainment status achieved at RM 0.2 of the East Branch Euclid Creek can be attributed to elimination of HSTS and SSOs within the area in the past two decades.

Urban runoff impacts can be reduced by utilizing proper storm water controls, installing rain gardens in heavily paved areas, and household pet waste management. Currently, NEORSD is constructing large underground tunnel projects in Euclid Creek and Doan Brook watersheds that will store combined sewer and storm water, as detailed in the recent Consent Decree nicknamed 'Project Clean Lake.' The Euclid Creek tunnel project will be in service by the summer of 2018 and Doan Brook underground storage tunnel is estimated to be finished by 2021. After these projects are completed, the release from CSOs will be drastically reduced to once or twice a year resulting in significant improvements to water quality. Other areas listed in non-attainment of the recreation use standard for failing HSTS may need individual system improvements to reduce the discharge of bacteria. Agricultural areas with elevated levels of bacteria could be improved by the installation of vegetated buffers along the stream as well as incorporating livestock exclusion fencing.

Table 17. Statewide numerical criteria for the protection of recreation uses. These criteria apply inside and outside the mixing zone at all times during the recreation season.

E. coli (colony counts per 100 ml)		
Recreation Use	Seasonal Geometric Mean	Single Sample Maximum ¹
Bathing water	126	235 ²
Class A primary contact recreation	126	298
Class B primary contact recreation	161	523
Class C primary contact recreation	206	940
Secondary contact recreation	1030	1030

- 1 Except as noted in footnote 2, these criteria shall not be exceeded in more than 10% of the samples taken during any 30-day period.
- 2 This criterion shall be used for the issuance of beach and bathing water advisories. Note: in 2016, the water quality standards for recreational use was changed. The evaluation of recreational attainment for this survey is based on the rule that was in effect at the time of sampling.

Table 18. A summary of E. coli data for locations sampled in the Lake Erie Tributaries watershed (June 15th, 2015 – Sept. 16th, 2015).

Recreation use attainment is based on comparing the geometric mean to the Contact Recreation criterion (OAC 3745-1-07, Table 7-13). All values are expressed in colony forming units (cfu) per 100 ml of water. Red colored italicized bold values exceed the applicable geometric mean criterion or single sample maximum. Grey shaded cells indicate the location does not meet recreational use criteria.

HUC 10 / 12	Location	River Mile	Recreation Use*	# of Samples	Geometric Mean	Max Value	Recreational Use Attainment	Potential Source(s) of Bacteria
0411000107								
01	Beaver Creek @ Quarry Rd	13.75	B	5	413	2,600	NON	Agricultural runoff, HSTS
01	Beaver Creek @ Russia Rd	11	B	5	659	1,200	NON	Agricultural runoff, HSTS
01	Squires Squamm Ditch @ Annis Rd	1.3	B	5	587	9,700	NON	Agricultural runoff, HSTS
02	Beaver Creek UPST Amherst WWTP	4.0	B	5	358	880	NON	Urban runoff
02	Beaver Creek DST Amherst WWTP	3.8	B	5	326	490	NON	WWTP
02	Beaver Creek @ Cooper Forest Park Rd	2.9	B	4	505	970	NON	Urban runoff, HSTS
02	Beaver Creek @ Longbrook Rd	1.8	B	5	509	804	NON	Urban runoff, HSTS
02	Willow Creek @ SR 58	1.3	B	5	3,134	12,000	NON	Urban runoff, HSTS
03	Brownhelm Creek ADJ Baumhart Rd	0.9	B	5	526	1,100	NON	Agricultural runoff, HSTS
03	Martin Run @ Towers Rd	2.4	B	5	2,142	3,100	NON	Urban runoff
03	Martin Run @ Meister Rd	0.9	B	5	3,461	10,000	NON	Urban runoff
03	Quarry Creek near US 6	0.3	B	5	740	2,600	NON	HSTS, urban runoff
0411000302								
01	Indian Creek @ Ninevah Rd	3.7	B	7	356	960	NON	Agricultural runoff, HSTS
01	Indian Creek @ North Bend Rd	2.2	B	5	509	3,700	NON	HSTS
01	Indian Creek @ Myers Rd	0.7	B	7	223	450	NON	HSTS
01	Red Brook @ Wade Rd	2.3	B	7	943	8,700	NON	HSTS
01	Trib. to Indian Creek (RM 3.5) @ Ninevah Rd	0.15	B	4	318	440	NON	HSTS
02	Cowles Creek @ Barnum Rd	7.2	B	7	166	320	NON	HSTS
02	Cowles Creek @ North Ave	4.8	B	7	808	6,000	NON	Urban runoff
02	Cowles Creek @ Maple Ave	3.6	B	7	520	1,400	NON	WWTP
02	Cowles Creek @ SR 534	0.9	B	9	824	3,400	NON	HSTS
02	Wheeler Creek @ Center Rd	2.8	B	7	616	1,200	NON	HSTS

HUC 10 / 12	Location	River Mile	Recreation Use*	# of Samples	Geometric Mean	Max Value	Recreational Use Attainment	Potential Source(s) of Bacteria
02	Trib. to Cowles Creek (RM 0.2) @ Golf Course	0.9	B	4	770	1,900	NON	Runoff, HSTS
03	Arcola Creek @ Middle Ridge Rd	7.4	B	5	1,613	2,900	NON	Agricultural runoff, HSTS
03	Arcola Creek DST Madison WWTP	7.1	B	5	2,306	28,000	NON	WWTP
03	Arcola Creek @ M.H. Supply Co.	5.0	B	2	758	1,400	NON	HSTS
03	Arcola Creek @ Cunningham Rd	2.0	B	6	440	1,450	NON	HSTS
03	Arcola Creek near mouth	0.7	B	3	321	510	NON	HSTS
03	Trib. to Arcola Creek (RM 4.32) adj. US Rt. 20	0.1	B	2	88	250	FULL	
03	Trib. to Arcola Creek (RM 0.2) @ County Line Rd	0.2	B	5	137	900	NON	Agricultural runoff
04	Church Creek @ McMackin Rd	0.7	B	5	396	770	NON	HSTS
04	Red Mill Creek @ US 20	1.7	B	5	442	830	NON	HSTS, Agricultural Runoff
0411000305								
01	Marsh Creek @ Hendricks Rd	1.5	B	2	240	304	NON	Urban runoff
01	Marsh Creek @ SR 283	0.2	B	4	1,039	2,100	NON	Urban runoff
03	Euclid Creek @ Mayfield Rd	7.1	B	5	882	3,700	NON	
03	Euclid Creek @ Euclid Park Blvd	3.3	B	5	165	2,600	NON	
03	Euclid Creek @ Lake Shore Blvd	0.7	B	8	729	2,300	NON	
03	E. Branch Euclid Creek @ SR175/US 6	2.8	B	5	505	1,100	NON	
03	E. Branch Euclid Creek, near mouth	0.2	B	5	95	280	FULL	
03	Trib. to Euclid Creek (RM 5.49) @ Richmond Rd	0.2	B	4	730	12,000	NON	
04	Doan Brook DST Lee Rd	6.6	B	5	216	520	NON	
04	Doan Brook @ Wade Park	3.1	B	5	1,661	8,700	NON	
04	Doan Brook @ St. Clair Ave	0.8	B	5	1,887	16,000	NON	
04	Ninemile Creek @ Lake shore Blvd	0.3	B	5	2,989	24,000	NON	
04	S. Br. Doan Brook @ Attleboro Rd	1.3	B	5	1,594	9,900	NON	
0412010106								
05	Conneaut Creek @ Furnace Rd	23.0	B	5	164	280	NON	HSTS, Agricultural Runoff
05	Conneaut Creek @ Ridge Rd	13.0	A	5	243	2,100	NON	HSTS, Agricultural Runoff

HUC 10 / 12	Location	River Mile	Recreation Use*	# of Samples	Geometric Mean	Max Value	Recreational Use Attainment	Potential Source(s) of Bacteria
05	Conneaut Creek @ Keefus Rd	6.7	A	5	191	390	NON	HSTS, Agricultural Runoff
05	Conneaut Creek @ Main St	2.6	A	5	245	1,600	NON	HSTS, Agricultural Runoff
05	Smokey Run @ Welton Rd	0.2	B	4	173	760	NON	HSTS, Agricultural Runoff
0412010107								
03	Whitman Creek @ SR 531	0.1	B	3	209	880	NON	HSTS, Agricultural Runoff

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