



**Environmental
Protection
Agency**

Biological and Water Quality Study of Conotton Creek and Selected Tributaries

Tuscarawas, Carroll, and Harrison Counties, Ohio



Conotton Creek at RM 11.4, at CR 90, New Cumberland Road

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TMDL DEVELOPMENT | ●●○○○

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Acronyms

ALU	aquatic life use
AMD	acid mine drainage
BMP	best management practice
CCC	criterion continuous concentration
CEI	Compliance Evaluation Inspection of a permitted facility
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
CR	County Road
CSO	combined sewer overflow
CWA	Clean Water Act
DC	direct current
DELT	deformities, erosions, lesions, tumors
DMR	Discharge Monitoring Report, a regular account of parameter measurements provided by an entity
D.O.	dissolved oxygen
Dst.	downstream
ECBP	Eastern Corn Belt Plains Ecoregion
<i>E. coli</i>	<i>Escherichia coli</i>
EPT	ephemeroptera, plecoptera, trichoptera; macroinvertebrate genera counted for ICI metric score
EWH	exceptional warmwater habitat
FAMSL	Feet Above Mean Sea Level
FWPCA	Federal Water Pollution Control Act (amendments of 1972)
GIS	geographic information system
GPD	gallons per day, sometimes as MGD for million gallons per day of flow
GPS	global positioning system
HABs	harmful algal blooms
HHEI	Headwater Habitat Evaluation Index
HSTS	Home Sewage Treatment System (often a septic tank and leech field, but alternatives are also common)
HUC	hydrologic unit code
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
I/I	inflow and infiltration (of stormwater into a closed sanitary wastewater treatment system)
IPS	integrated prioritization system
LRAU	large river assessment unit
LRW	limited resource water
MBI	Mean Baseflow Index, a ratio of groundwater sourced baseflow to streamflow
mi²	miles squared; watershed drainage is expressed in square miles of area (1 mi ² =640 acres)
MGD	million gallons per day
MIwb	Modified Index of well-being
MWCD	Muskingum Watershed Conservancy District
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
ns	nonsignificant departure from biocriterion (≤ 4 IBI or ICI units; ≤ 0.5 MIwb units).
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
OHIO EPA	Ohio Environmental Protection Agency
OMZA	outside mixing zone average
OMZM	outside mixing zone maximum (or minimum, for dissolved oxygen, or both, for pH)
O&M	operation and maintenance manual pertinent to a wastewater treatment and collection system
ORC	Ohio Revised Code
P_{95%}	95 th percentile. The subscript number denotes a percentage in rank from a range of values.
PAH	polycyclic aromatic hydrocarbon

PCB	polychlorinated biphenyl
PCR	primary contact recreation
PEC	probable effects concentration
PEMSO	Planning and Engineering Data Management System for Ohio
pH	“power of hydrogen,” a logarithmic approximation of a water-based solution’s acidic or basic qualities.
Q₂	second quartile, 50 th percentile, median value. The middle number from a range of values.
QHEI	Qualitative Habitat Evaluation Index
RM	river mile
RMI	river mile index
ROV	Resolution of Violation letter
SC	specific conductance, conductivity
SCR	secondary contact recreation
s.u.	standard unit, a pH inference as used in Ohio WQS, OAC Chapter 3745-1.
SR	State Route
SRV	sediment reference value
SSO	sanitary sewer overflow
TALU	tiered aquatic life use
TDS	total dissolved solids
TEC	threshold effect concentration
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TR	Township Road
TSS	total suspended solids
UAA	use attainability analysis
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
Ust.	upstream
VOC	volatile organic compound
WAU	watershed assessment unit
WQS	water quality standard
WWH	warmwater habitat
WAP	Western Allegheny Plateau Ecoregion
WWTP	wastewater treatment plant
\bar{x}	Mean (average value)

Executive Summary

In the summer of 2016, Ohio EPA evaluated biological and water quality conditions in the Conotton Creek watershed (Figure 2, page 9). This study was completed in 2024. This study fully accounts for the 2016 data consistent with similar Ohio EPA biological and water quality reports.

Within the scheme set forth to administer the federal Clean Water Act (CWA), aquatic life, recreation, and water supply uses are assigned to a stream. Criteria are stipulated to maintain these “beneficial” uses. Consequently, environmental protection is inherently a determination of use attainment status and an assessment of any conditions that preclude the full benefit of a use (Table 1). In 2016, full aquatic life use attainment occurred at 31 sites (64%) in the Conotton Creek basin. Partial aquatic life use attainment occurred at nine sites (19%), while non-attainment was recorded at eight locations (17%, Figure 1). Full recreation use attainment, determined at eight sites (17%), was contrasted with non-attainment at 39 locations (83%, Figure 3). Agricultural and industrial water supply uses were fully achieved at all 47 locations (100%).

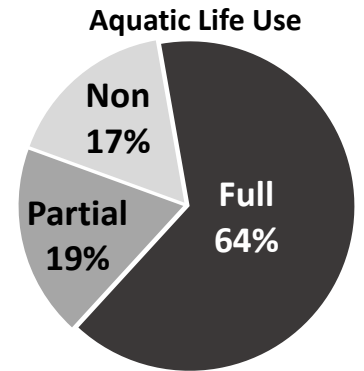


Figure 1 – Aquatic life use attainment status in the Conotton Creek study area, 2016

Because resource extraction industries have routinely abandoned wells and mines across the Conotton Creek landscape leaving polluted water and spoil piles, the latest episode of the attendant economic boom and bust cycle might have been expected to add to the legacy of exploitation. In 2016, five years after Ohio’s first horizontal Utica/Point Pleasant shale oil and gas site was developed, nearly all possible new well sites in the Conotton Creek basin were established and the first phases of the Utica East Ohio Gathering and Williams Harrison Hub Fractionation Facility with adjacent railroad yard were operational. Pipelines and other petroleum processing infrastructure were under construction throughout the 2016 summer sampling period. However, no contemporary conditions were associated with aquatic life use impairment. Instead, impacts from former coal mines continued to degrade water quality as shown by fair biological community performance and related water chemistry stressors in five different streams. Similarly, markers of historic well waste brine were evident, but no indication of discharge (“fracking fluid”) from a new well was documented.

Draining 286 mi² at the Tuscarawas confluence, flood flows in the lower reach of Conotton Creek are routinely checked by Dover Dam. The two largest tributaries to Conotton Creek are impounded by Atwood and Leesville lakes. In effect, the mismatch between overall basin size and upper reach uncontrolled stream flow conditions has been especially favorable to lower reach sediment deposition. Both lakes discharge hypolimnetic water prone to anoxia. Subsequent redox reactions liberate toxins in reaches downstream from both lakes. Collectively, aquatic life use impairment in four separate streams was attributed to flood control hydromodification.

Stream modification to improve drainage e.g., channelization and denuding riparian vegetation, alters water quality. The effects can linger for decades. Sites on four Conotton Creek basin streams revealed these tributaries had debilitated habit characteristics. Marginal fish assemblages in these streams were challenged by altered flow hydrology, unnatural morphology, and continuing encroachment in the riparian zone. Cold Spring Run drains much of the Carrollton hilltop community. Devoid of trees, Cold Spring Run was not cold, but extreme chloride concentrations suggested winter road conditions were icy.

The Carrollton wastewater treatment plant (WWTP) was a source of excessive nutrient loading and dissolved copper concentrations over Ohio's Water Quality Standard (WQS) criterion. Impaired aquatic communities at sites immediate to the facility and farther downstream were predominated by pollution tolerant species. Although nutrient amounts were most compelling, other WWTP effluent constituents combined with runoff from Carrollton contributed to sediment contamination and chronic chloride stress in downstream reaches.

Considering the fraction of Conotton Creek basin sites where aquatic life use was impaired (36%), impacts from abandoned mine land accounted for 13% (six sites), flood control hydromodification limited 10% (five sites), stream habitat alteration affected eight percent (four sites), and municipal WWTP effluent degraded four percent (two sites). Unlike other Ohio stream basins where changes in agricultural practices and natural attenuation have cooccurred with appreciable water resource improvements, directed efforts will be required to correct the Conotton Creek basin water quality deficiencies.

Many acid mine drainage (AMD) abatement projects have been completed in the Huff Run watershed. And yet, Huff Run remains impaired. Recognizing abandoned mine issues were extant in four other streams where no AMD abatement has occurred, suggests those impairments will be difficult to resolve.

The U.S. Army Corps of Engineers (USACE) modified the Tappan Lake outlet structure, improving discharge water quality in 2015. Similar retrofits at Atwood and Leesville lakes are planned but have not been installed. It's unclear what operationally could be done at Dover Dam or at either lake to address other hydromodification related impairments.

Habitat enhancement efforts in four study area streams are needed to restore important water quality functions. Because drainage interests generally disregard those functions, finding traction for habitat improvement projects can be slippery to start. Additionally, reduction in the amount of salt spread in Carrollton is warranted. Alternative means to address slippery winter road conditions are encouraged.

Lastly, the U.S. EPA with cooperation from the Ohio EPA in 1973 determined the Carrollton WWTP delivered one fourth of the annual phosphorus load to Atwood Lake, an amount several times higher than appropriate (U.S. EPA 1975). Since then, improvements were made at the Carrollton treatment facility, both agencies advanced nutrient evaluation proficiency, and emerging threats from harmful algal blooms (HABs) and pathogens have become apparent. Now, evidence indicates that Carrollton WWTP upgrades are necessary again.

Escherichia coli (*E. coli*) sample results determine recreational use attainment. Four percent of the sites within the basin were in full recreational use attainment (*Figure 2*); however, the two locations where where full recreational use was achieved were downstream from Atwood and Leesville Lakes where anoxia and toxicity likely precluded *E. coli* presence. Interpretation of *E. coli* results is rife with caveats. For instance, the highest *E. coli* values for about half of the study sites were consequent to a mid-summer storm. Recreating in storm induced flood flows is tacitly dangerous regardless of pathogen exposure.

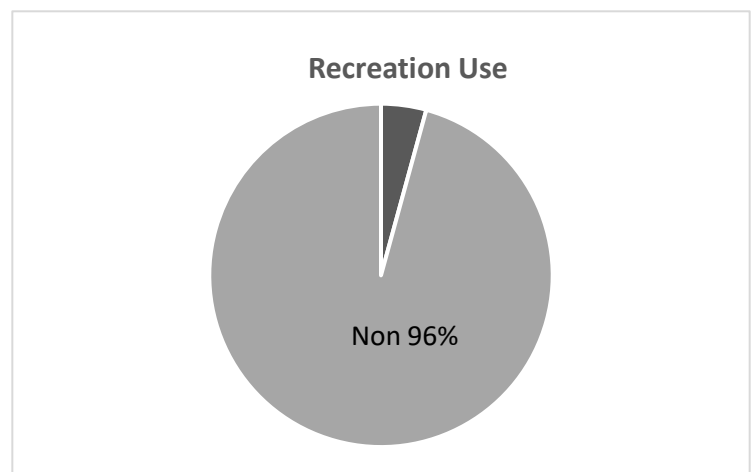


Figure 2 – Recreation use attainment status in the Conotton Creek study area, 2016.

Although the storm influenced *E. coli* values specifically resulted in non-attainment of the recommended recreational use for many sites, those results were important for understanding where and when pathogenic exposure risk was greatest. And despite the caveats, it was reasonable to assert *E. coli* were too abundant in the Conotton Creek basin. Across the study area, high *E. coli* concentrations were associated with runoff from livestock pastures, failing home sewage treatment systems (HSTS), municipal stormwater contaminated by illicit sanitary connections along with yard and pet waste, and from poorly operated WWTPs including unacceptable sanitary sewer overflows (SSOs). Keeping waste from these sources out of area streams will benefit everyone.

Leesville Lake is widely regarded for outstanding fishing and outdoor recreational opportunities. Exceptional biological communities inhabiting Leesville Lake feeder streams affirmed the fact that good water quality has been integral to the area's success. Arising from a ridge known as the Flushing Escarpment along the basin's eastern boundary, McGuire, North Fork McGuire, and Long Creeks with Bear Hole Run continuously spill spring fed groundwater into the lake. Home to many cold-water reliant species, these well forested small streams are among Ohio's most valuable natural assets.

Conotton Creek

Ohio EPA evaluated Conotton Creek watershed streams in 2016. Colored streams and sample sites show biological results.

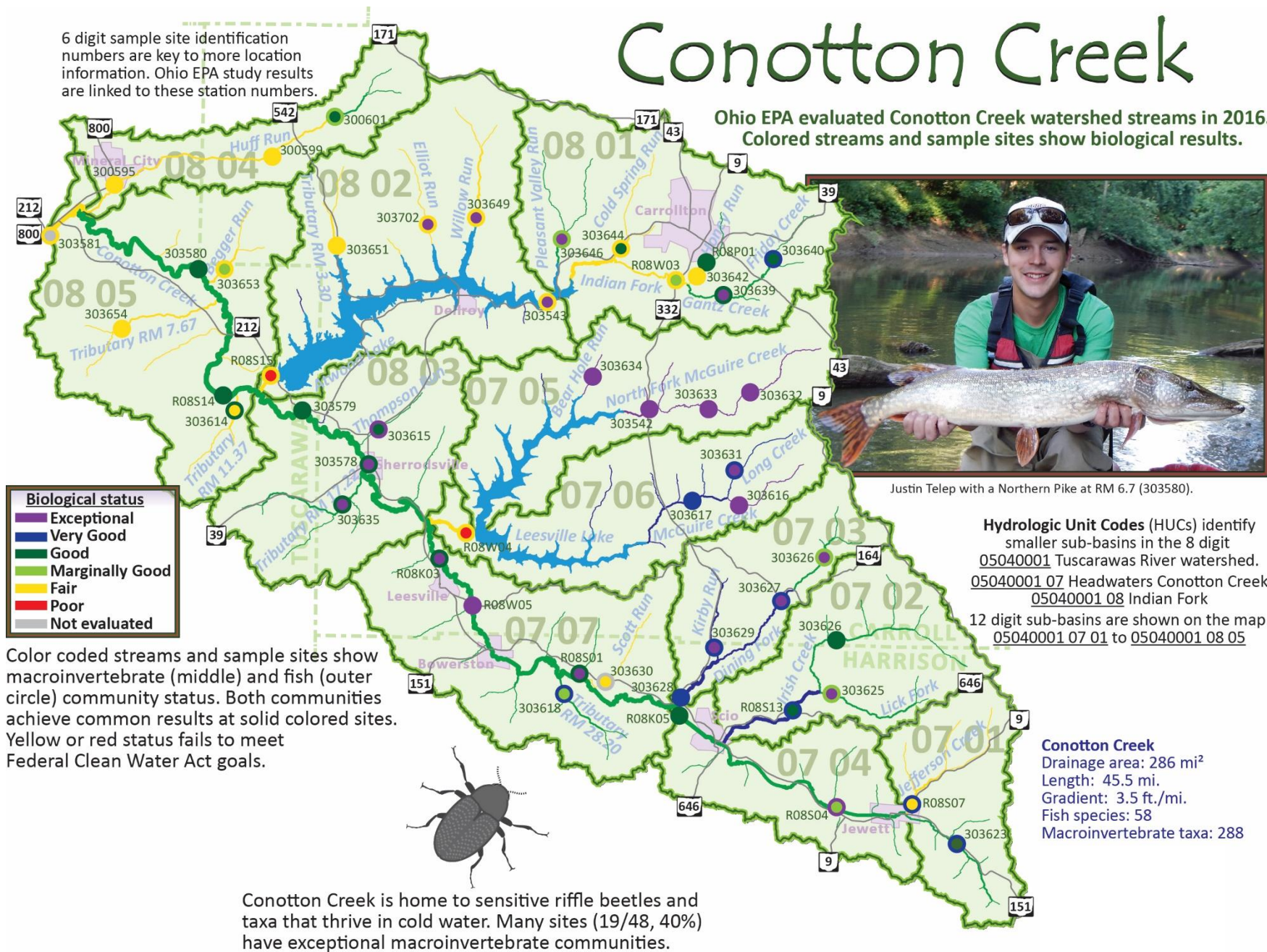


Figure 3 – The Conotton Creek basin showing station locations, biological status, and sub-basins delineated by 12-digit HUCs.

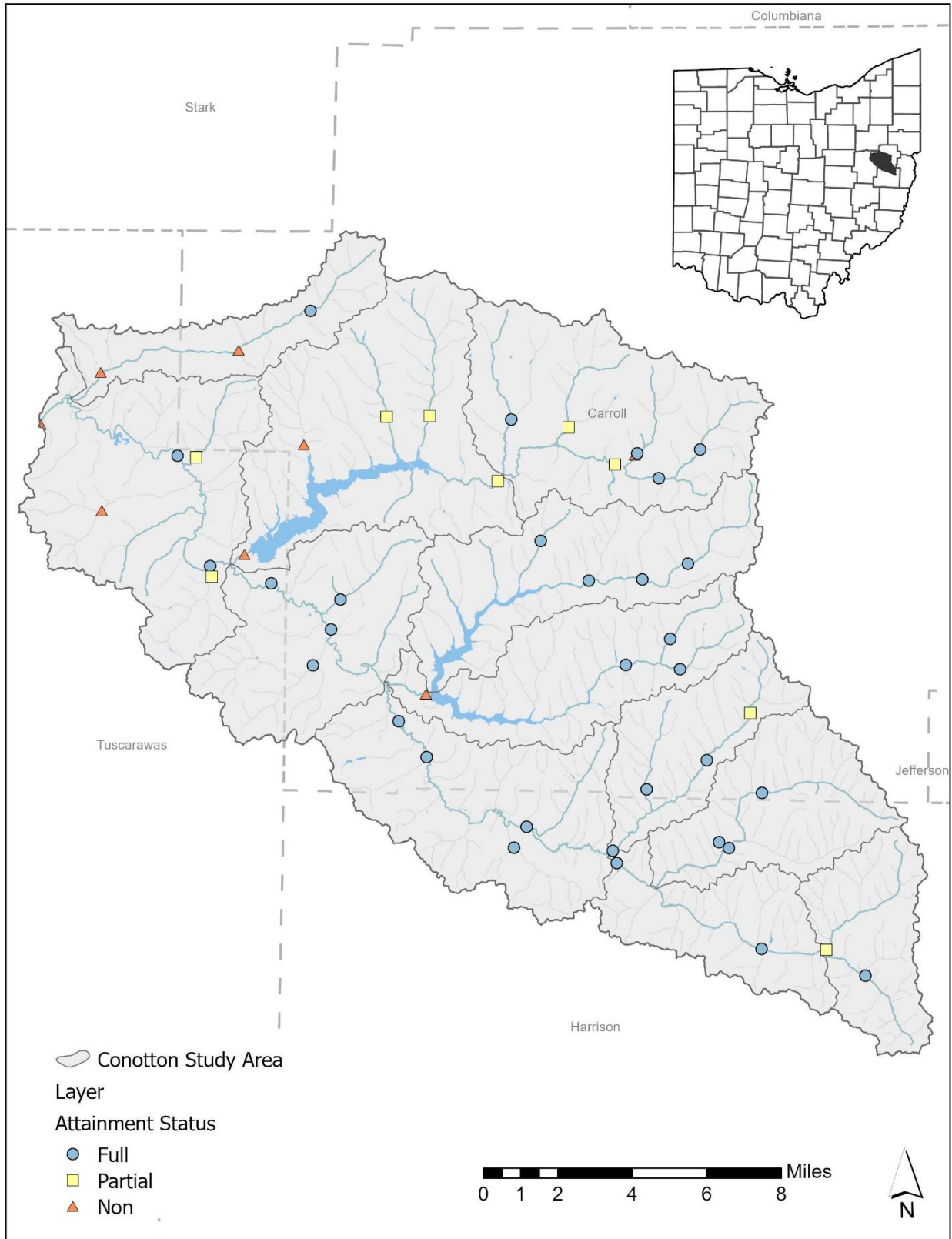


Figure 4 – Map summarizing the aquatic life use attainment status in the Conotton Creek and Selected Tributaries watershed in 2016.

Table 1 – Attainment status of the existing or recommended aquatic life uses for the Conotton Creek basin, Western Allegheny Plateau (WAP) ecoregion, 2016. Symbology and ecoregional biocriteria follow.

Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	Q	Status	Causes	Sources
Headwaters Upper Conotton Creek 05040001 07 01										
Conotton Creek WWH										
303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	48	-	Good	48	Full		
Jefferson Creek WWH										
R08S07	High St., Jewett Park	0.2	6.5	46	-	Fair*	44	Partial	TDS (Specific Conductivity)	Abandoned Mine Lands
Irish Creek 05040001 07 02										
Irish Creek WWH, CWH recommended ust. Lick Fork (RM 3.09)										
303624	from CR 35, Branch Rd.	5.0	6.7	44	-	Good	48	Full		
Irish Creek WWH										
R08S13	SR 646, Scio New Rumley Rd.	2.1	14.9	46	-	Good	51	Full		
Lick Fork CWH recommended										
303625	TR 135, Burrier Rd.	0.2	5.0	40	-	Exceptional	55	Full		
Dining Fork 05040001 07 03										
Dining Fork EWH recommended										
303626	from TR 382, Pontiff Rd.	6.3	3.1	40*	-	Exceptional	54	Partial	Habitat Alterations	Riparian Vegetation
303627	TR 645, Tartan Rd.	4.3	6.3	48 ^{ns}	-	Exceptional	61	Full		
303628	SR 151, Scio-Bowerston Rd.	0.2	14.7	46 ^{ns}	-	V. Good ^{ns}	57	Full		
Kirby Run EWH recommended										
303629	adj. SR 332, Scio Rd.	0.7	3.4	48 ^{ns}	-	Exceptional	65	Full		
Headwaters Middle Conotton Creek 05040001 07 04										
Conotton Creek WWH										
R08S04	CR 50, New Rumley Rd.	37.8	17.5	50	-	M. Good ^{ns}	48	Full		
R08K05	CR 80, Leffler Rd.	32.6	48.0	45	9.5	Good	61	Full		
North Fork McGuire Creek 05040001 07 05										
North Fork McGuire Creek EWH recommended										
303632	TR 354, Pebble Rd.	9.4	4.1	50	-	Exceptional	79	Full		
303633	CR 19, Autumn Rd.	7.7	6.9	50	-	Exceptional	85	Full		
303542	SR 322, Scio Rd.	6.0	11.3	52	-	Exceptional	68	Full		
Bear Hole Run EWH recommended										
303634	CR 54, Canyon Rd.	1.7	1.4	50	-	Exceptional	59	Full		
McGuire Creek 05040001 07 06										
McGuire Creek EWH recommended ust. RM 7.57 (at unnamed tributary confluence near SR 332, Scio Rd.)										
303616	adj. CR 17, Aster Rd.	9.9	2.7	52	-	Exceptional	57	Full		
303617	TR 374, Plymouth Rd.	8.3	7.1	47 ^{ns}	-	V. Good ^{ns}	62	Full		

Table 1 continued.

Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	Q	Status	Causes	Sources
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Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	Q	Status	Causes	Sources
McGuire Creek WWH recommended (continued)										
R08W04	dst. Leesville Lake dam	1.4	48.0	38*	7.9 ^{ns}	<u>12</u> *	53	NON	Toxicity	Hydrostructure Flow Regulation/ Modification
Long Creek EWH recommended										
303631	CR 8, Alamo Rd.	0.7	1.7	48 ^{ns}	-	Exceptional	58	Full		
Headwaters Lower Conotton Creek 05040001 07 07										
Conotton Creek WWH										
R08S01	CR 25, Conotton Rd.	29.1	70.0	43 ^{ns}	8.9	46	54	Full		
R08W05	SR 164, Amstedam Rd.	23.7	87.0	51	10.3	46	72	Full		
R08K03	CR 22, Azalea Rd. (<i>Boat</i>)	22.1	89.0	41	9.3	48	45	Full		
Scott Run (not assessed for attainment status)										
303630	SR 151, Scio-Bowerston Rd.	0.7	3.1	-	-	Fair	-	-		
Conotton Creek Tributary (RM 28.20) WWH recommended										
303618	CR 43, Bower Rd.	0.6	3.8	48	-	M. Good ^{ns}	49	Full		
Cold Spring Run-Indian Fork 05040001 08 01										
Indian Fork WWH recommended										
R08W03	SR 332, Scio Rd.	13.9	12.3	36*	-	M. Good ^{ns}	71	Partial	Nutrients	Municipal WWTP
Gantz Creek WWH recommended										
303639	TR 354, Pebble Rd.	1.2	7.3	44	-	Exceptional	65	Full		
Friday Creek WWH recommended										
303640	CR 66, Chase Rd.	1.2	3.5	46	-	Good	51	Full		
Honey Run WWH recommended										
R08P01	ust. Carrollton WWTP/ tributary	0.8	3.4	44	-	Good	75	Full		
303642	dst. Carrollton WWTP	0.6	3.8	36*	-	Fair*	78	NON	Nutrients Copper	Municipal WWTP
Cold Spring Run WWH recommended										
303644	from SR 39, Roswell Rd.	0.6	5.9	36*	-	Good	56	Partial	Habitat Alterations	Riparian Vegetation
Pleasant Valley Run WWH recommended										
303646	TR 147, Folsam Rd.	1.5	6.5	42 ^{ns}	-	Exceptional	56	Full		
Pleasant Valley Run-Indian Fork 05040001 08 02										
Indian Fork WWH recommended										
303543	from SR 39, Roswell Rd.	9.0	33.5	30*	8.5	46	55	Partial	Flow Regime Modification	Impoundment
R08S15	dst. Atwood Lake dam @ SR 212	0.5	70.0	34*	7.2*	<u>8</u> *	53	NON	Toxicity	Hydrostructure Flow Regulation/ Modification
Willow Run WWH recommended										
303649	CR 29, Bedrock Rd.	1.5	7.7	30*	-	Exceptional	43	Partial	Flow Regime Modification	Channelization
Table 1 continued.										
Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	Q	Status	Causes	Sources
Elliot Run WWH recommended										

Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	Q	Status	Causes	Sources
303702	CR 69, Clay Rd.	1.4	3.5	30*	-	Exceptional	32	Partial	Flow Regime Modification	Channelization
Indian Fork Tributary (RM 3.30) WWH recommended										
303651	SR 542	1.4	3.4	28*	-	Fair*	41	NON	Sedimentation	Abandoned Mine Lands
Thompson Run-Conotton Creek 05040001 08 03										
Conotton Creek WWH										
303578	SR 39, Church St, Sherrodsville	17.0	156.2	44	8.9	50	77	Full		
303579	TR 394, Miller Hill Rd.	13.9	165.3	45	9.0	40	53	Full		
Conotton Creek Tributary (RM 17.22) WWH recommended										
303635	pipeline	1.0	6.3	44	-	Very Good	72	Full		
Thompson Run WWH recommended										
303615	from SR 39, Roswell Rd.	0.7	3.7	52	-	Good	59	Full		
Huff Run 05040001 08 04										
Huff Run WWH recommended										
300601	TR 170, Heritage Rd.	7.8	3.3	40	-	Good	70	Full		
300599	CR 36, Brass Rd.	5.5	6.5	35*	-	Low Fair*	59	NON	TDS (Specific Conductivity)	Abandoned Mine Lands
300595	CR 90, New Cumberland Rd.	1.3	11.8	28*	-	Low Fair*	70	NON	TDS (Specific Conductivity)	Abandoned Mine Lands
Dog Run-Conotton Creek 05040001 08 05										
Conotton Creek WWH										
R08S14	CR 90, New Cumberland Rd. (Boat)	11.4	241.0	36 ^{ns}	8.8	40	59	Full		
303580	from TR 399, Marsh Rd. (Boat)	6.7	261.8	40	8.9	40	58	Full		
303581	Zoarville Station trail TR 390	0.2	286.0	33*	7.9*	-	56	(NON)	Flow Regime Modification	Hydrostructure Flow Regulation/ Modification
Conotton Creek Tributary (RM 11.37) WWH recommended										
303614	TR 320, Dawn Rd.	0.3	4.6	44	-	Fair*	48	Partial	Sedimentation	Hydrostructure Flow Regulation/ Modification
Conotton Creek Tributary (RM 7.67) WWH recommended										
303654	TR 388, Brown Hill Rd.	2.9	3.8	32*	-	Fair*	60	NON	TDS (Specific Conductivity)	Abandoned Mine Lands
Beggar Run WWH recommended										
303653	CR 90, New Cumberland Rd.	0.5	4.0	33*	-	M. Good ^{ns}	47	Partial	TDS (Specific Conductivity)	Abandoned Mine Lands

- (*Boat*) Boat criteria *only* apply to Conotton Creek at RMs 22.1, 11.4, 6.7 and 0.2.
- a** The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi²).
- b** Narrative evaluation used in lieu of ICI (Exceptional; Very Good; Good; M. Good=Marginally Good; Fair; Low Fair; Poor; Very Poor).
- *** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
- ns** Nonsignificant departure from biocriterion (≤ 4 IBI or ICI units; ≤ 0.5 MIwb units).
- (NON) Macroinvertebrate assessment was precluded at Conotton Creek RM 0.2 by deep and periodically impounded stream flow conditions. Attainment status represented by one organism group is shown in parentheses

Table 2 – Narrative ranges and WWH biocriteria (bold) for the Conotton Creek study area, Western Allegheny Plateau (WAP) ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide.

Headwater IBI	Wading IBI	MIwb	Boat IBI	MIwb	ICI	Narrative Evaluation
50-60	50-60	≥ 9.4	48-60	≥ 9.6	46-60	Exceptional
46-49	46-49	8.9-9.3	44-47	9.1-9.5	42-44	Very Good
<i>Western Allegheny Plateau</i>						
44-45	44-45	8.4-8.8	40-43	8.6-9.0	36-40	Good
40-43	40-43	7.9-8.3	36-39	8.1-8.5	32-34	Marginally Good
28-39	28-39	5.9-7.8	26-35	6.4-8.0	14-30	Fair
18-27	18-27	4.5-5.8	16-25	5.0-6.3	8-12	Poor
12-17	12-17	0-4.4	12-15	0-4.9	≤ 6	Very Poor

Overview: Conotton Creek Watershed

To determine the beneficial use attainment status of streams and impoundments relevant to Ohio's Water Quality Standards (WQS), ambient biological, water column chemical, sediment, and bacteriological sampling was conducted in the Conotton Creek basin from April to October 2016 (Figure 4). This study area included Conotton Creek from its origin upstream from Jewett to its confluence with the Tuscarawas River (286 mi²). Sampling was conducted on Indian Fork (70.3 mi²) and McGuire Creek (49.6 mi²) and notable tributaries including Dining Fork (14.7 mi²), Irish Creek (18.8 mi²), Jefferson Creek (6.6 mi²), and Huff Run (13.9 mi²). Seven sampling sites, not included in this assessment, were distributed between Atwood and Leesville Lakes. Altogether, 49 biological, 47 water chemistry, nine sediment chemistry, 24 multi-parameter water quality sonde, and 47 bacteria sampling stations were encompassed by 58 monitoring locations in the study area (Figure 5, Table 3). Some locations were situated specifically to assess performance of National Pollution Discharge Elimination System (NPDES) permitted entities within the study area.



Figure 5 - Location of the Conotton Creek watershed.

Principal study objectives were to:

- 1) Assess the physical, chemical, and biological integrity of all Conotton Creek basin streams draining four square mile or larger areas.
- 2) Complete a beneficial use attainment analysis for studied waterbodies, including 10 streams not previously designated for aquatic life use and 14 designated WWH streams but not previously verified.
- 3) Evaluate potential impacts from oil well development, coal mining, and agriculture.
- 4) Determine the influence of potential pollution from municipal WWTPs, unsewered communities, and industrial sources.
- 5) Characterize contemporary water quality conditions in reference to Conotton Creek basin sampling conducted in 1982, 1984, 1989, 1989, 1998 and 2010.

The findings of this evaluation may factor into Ohio EPA regulatory actions (e.g., NPDES permits, Director's Final Findings and Orders or the Ohio Water Quality Standards – Ohio Administrative Code 3745-1). Data obtained in this investigation is fundamental to Total Maximum Daily Load (TMDL) allocations and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] reports).

Conotton Creek

Ohio EPA evaluated Conotton Creek watershed streams in 2016. Colored streams and sample sites show biological results.

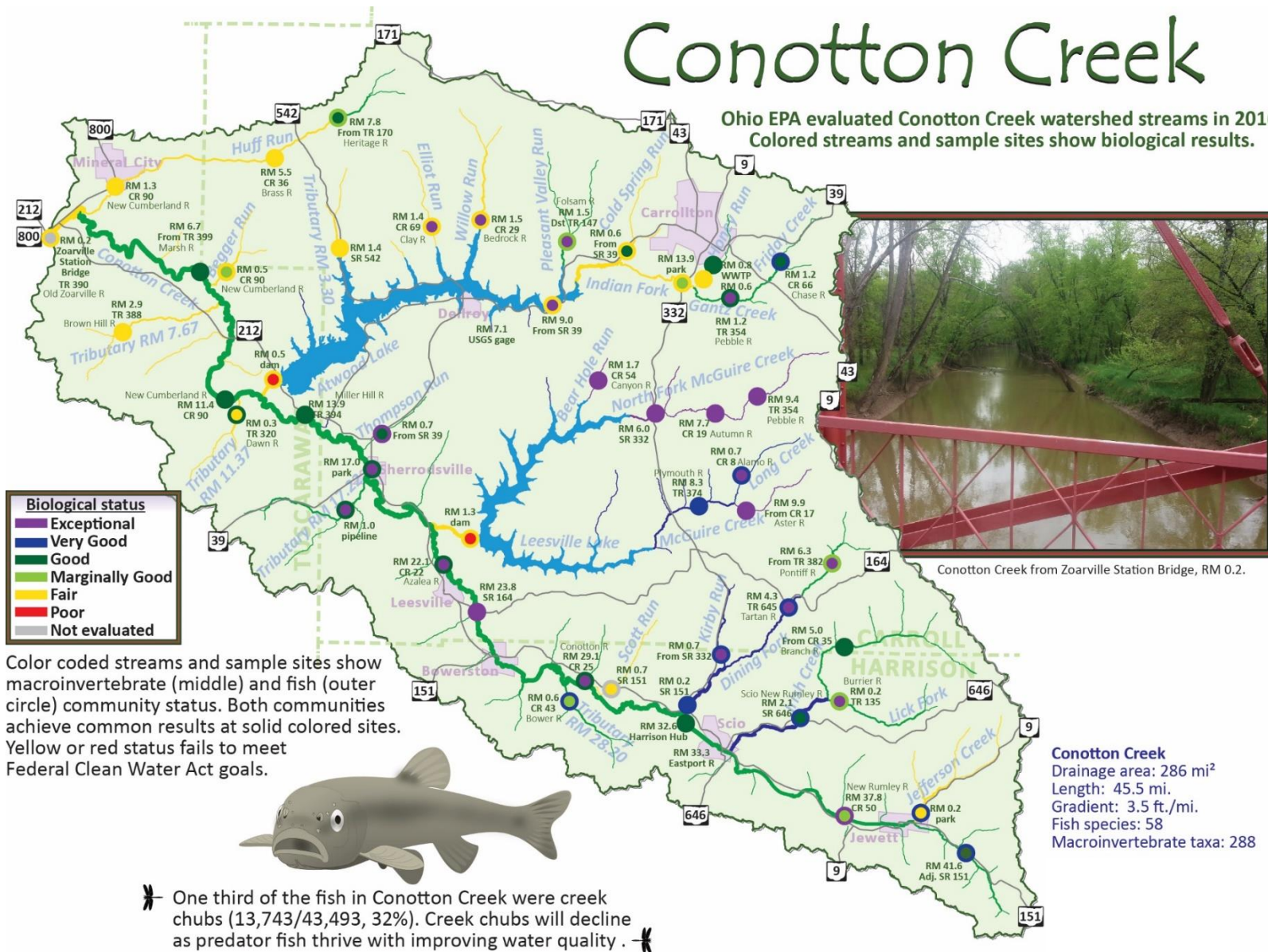


Figure 6 – Sampling locations for the 2016 biological survey of the Conotton Creek watershed.

Table 3 – Sampling locations in the 2016 Conotton Creek study area. Sampling types are listed below.

HUC 12	Station	Location	RM	Mi ²	Latitude	Longitude	Sampling Type
Conotton Creek (17-100-000) WWH existing							
50400010701	303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	40.3578	-80.9751	F, M, C, B
50400010704	303721	adj. W. Main St. (Jewett)	38.8	16.5	40.3671	-81.01083	D, N
50400010704	R08S04	at CR 50, New Rumley Rd.	37.8	17.5	40.3689	-81.0278	F, M, C, O, S, D, B, N
50400010704	303541	at Eastport Rd.	33.3	46.8	40.3964	-81.0895	C, D, B, Sn, N
50400010704	R08K05	ust. Scio WWTP at Harrison Hub Rd.	32.6	48.0	40.4033	-81.1008	F2, MQ, C, O, S, B, D, N
50400010704	303724	dst. Scio WWTP adj. CR 80 (Leffler Rd.)	32.2	48.7	40.4039	-81.1007	D, N
50400010707	R08S01	at CR 25, Conotton Rd.	29.1	70.0	40.4178	-81.1464	F2, MQ, C, B
50400010707	R08S16	at Bowerston at SR 151	25.3	82.0	40.4283	-81.1881	D, N
50400010707	R08W05	at SR 164, Amsterdam Rd.	23.8	87.0	40.4456	-81.1969	F2, MQ, C, D, B, N
50400010707	R08K03	at CR 22, Azalea Rd.	22.1	89.0	40.4597	-81.2108	F2, MQ, C, D, B, Sn, N
50400010803	R08S12	NW of Leesville at SR 212	20.5	142.0	40.4750	-81.2183	D
50400010803	303578	at SR 39, Church St., Sherrodsville Park	17.0	156.2	40.4958	-81.2447	F2, MQ, C, B
50400010803	303579	at TR 394, Miller Hill Rd.	13.9	165.3	40.5139	-81.2748	F2, MQ, C, D, B, N
50400010805	303715	ust. Atwood Regional WWTP	11.65	237.0	40.5226	-81.3007	D, N
50400010805	R08S14	at CR 90, New Cumberland Rd.	11.4	241.0	40.5211	-81.3058	F2, FT, MQ, C, O, S, D, B, N
50400010805	303580	from TR 399, Marsh Rd.	6.7	261.8	40.5641	-81.3217	F2, FT, MQ, C, B
50400010805	303581	at Zoarville Station Bridge, TR 390	0.2	286.0	40.5772	-81.3915	F2, FT, MQ, C, B
Tributary to Conotton Creek (RM 28.20) (17-100-002) Undesignated ALU							
50400010707	303618	at CR 43, Bower Rd.	0.6	3.8	40.4099	-81.1529	F, M, C, B
Tributary to Conotton Creek (RM 17.22) (17-100-003) Undesignated ALU							
50400010803	303635	at pipeline	1.0	6.3	40.4819	-81.2542	F, M, C, B
Tributary to Conotton Creek (RM 11.37) (17-100-004) Undesignated ALU							
50400010805	303614	at TR 320, Dawn Rd.	0.3	4.6	40.5169	-81.3051	F, M, C, B
Tributary to Conotton Creek (RM 7.67) (17-100-005) Undesignated ALU							
50400010805	303654	at TR 388, Brown Hill Rd.	2.9	3.8	40.5434	-81.3608	F, M, C, B
Huff Run (17-101-000) Unverified WWH							
50400010804	300601	at TR 170, Heritage Rd.	7.8	3.7	40.6198	-81.2529	F, M, C, B
50400010804	300599	at CR 36, Brass Rd.	5.5	6.5	40.6051	-81.2899	F, M, C, B
50400010804	R08P07	E of Mineral City at driveway off CR 110	2.1	10.9	40.5991	-81.3506	D, N
50400010804	300595	at CR 90, New Cumberland Rd. USGS gage	1.3	11.8	40.5972	-81.3605	F, M, C, O, S, D, B, Sn, N
Beggar Run (17-102-000) Unverified WWH							
50400010805	303653	at CR 90, New Cumberland Rd.	0.5	4.0	40.5634	-81.3123	F, M, C, O, S, B
Thompson Run (17-104-000) Unverified WWH							
50400010803	303615	from SR 39, Roswell Rd.	0.7	3.7	40.5072	-81.2392	F, M, C, B
McGuire Creek (17-106-000) Unverified WWH							

HUC 12	Station	Location	RM	Mi ²	Latitude	Longitude	Sampling Type
50400010706	303616	adj. CR 17, Aster Rd.	9.9	2.7	40.4783	-81.0670	F, M, C, B
50400010706	303617	at TR 374, Plymouth Rd.	8.3	7.1	40.4803	-81.0947	F, M, C, B
50400010706	303706	opposite Dyewood Rd.	7.55	10.3	40.4774	-81.1073	D, N
50400010706	R08W04	dst. Leesville Lake dam @ USGS gage	1.3	49.6	40.4703	-81.1981	F2, MQ, C, B
50400010706	R08S17	at CR 22, Azalea Rd.	0.8	49.6	40.4713	-81.2047	D
Long Creek (17-106-001) Undesignated ALU							
50400010706	303631	at Alamo Rd	0.7	1.7	40.4901	-81.0717	F, M, C, B
North Fork McGuire Creek (17-107-000) Unverified WWH							
50400010705	303632	at TR 354, Pebble Rd.	9.4	4.1	40.5192	-81.0622	F, M, C, B
50400010705	303633	at CR 19, Autumn Rd.	7.7	6.9	40.5134	-81.0855	F, M, C, B
50400010705	303542	at SR 322, Scio Rd. USGS gage	6.0	11.3	40.5133	-81.1129	F, M, C, O, S, D, B, Sn, N
Bear Hole Run (17-108-000) Unverified WWH							
50400010705	303634	at CR 54, Canyon Rd. USGS gage	1.7	1.4	40.5290	-81.1370	F, M, C by USGS
Scott Run (17-109-000) Unverified WWH							
50400010707	303630	at SR 151, Scio-Bowerston Rd.	0.7	3.1	40.4164	-81.1362	F, M, C, B
Indian Fork (17-110-000) Unverified WWH							
50400010801	R08W03	at SR 332, Scio Rd.	13.9	12.3	40.5583	-81.0986	F, M, C, O, S, B
50400010801	303543	adj. SR 39 (private lane)	9.0	33.5	40.5525	-81.1585	F2, MQ, C, O, D, B, Sn, N
50400010802	R08S15	dst. Atwood Lake dam @ SR 212 USGS gage	0.5	70.0	40.5256	-81.2883	F2, MQ, C, D, B
Honey Run (17-110-001) Undesignated ALU							
50400010801	R08P01	ust. Carrollton WWTP and tributary	0.6	3.4	40.5625	-81.0872	F, M, C, B, D, N
50400010801	303642	dst. Carrollton WWTP and tributary	0.5	3.8	40.562035	-81.0884	F, M, C, B, D, N
Tributary to Indian Fork at RM 3.30 (17-110-004) Undesignated ALU							
50400010802	303651	at SR 542, USGS gage	1.4	3.4	40.5680	-81.2572	F, M, C by USGS
Elliot Run (17-111-000) Unverified WWH							
50400010802	303702	at CR 69, Clay Rd.	1.4	3.5	40.5782	-81.2148	F, M, C, B
Willow Run (17-113-000) Undesignated ALU							
50400010802	303649	at CR 29, Bedrock Rd. USGS gage	1.5	7.7	40.5782	-81.1928	F, M, C by USGS
Pleasant Valley Run (17-114-000) Unverified WWH							
50400010801	303646	at TR 147, Folsam Rd.	1.5	6.5	40.5764	-81.1512	F, M, C, B
Cold Spring Run (17-115-000) Unverified WWH							
50400010801	303644	from SR 39, Roswell Rd.	0.6	5.9	40.5730	-81.1219	F, M, C, B
Gantz Creek (17-117-000) Unverified WWH							
50400010801	303639	at TR 354, Pebble Rd.	1.2	7.3	40.5526	-81.0763	F, M, C, B
Friday Creek (17-117-001) Undesignated ALU							
50400010801	303640	at Chase Rd.	1.2	3.5	40.5636	-81.0549	F, M, C, B
Dining Fork (17-118-000) Unverified WWH							
50400010703	303626	from TR 382, Pontiff Rd.	6.3	3.1	40.4608	-81.0316	F, M, C, B

HUC 12	Station	Location	RM	Mi ²	Latitude	Longitude	Sampling Type
50400010703	303627	at TR 645, Tartan Rd.	4.3	6.3	40.4427	-81.0541	F, M, C, B
50400010703	303628	at SR 151, Scio-Bowerston Rd.	0.2	14.7	40.4080	-81.1027	F, M, C, O, S, D, B, N
Kirby Run (17-119-000) Unverified WWH							
50400010703	303629	adj. SR 332, Scio Rd.	0.7	3.4	40.4317	-81.0850	F, M, C, B
Irish Creek (17-120-000) WWH verified							
50400010702	303624	from CR 35, Branch Rd.	5.0	6.7	40.4296	-81.0262	F, M, C, B
50400010702	R08S13	at SR 646, Scio New Rumley Rd.	2.1	16.1	40.4053	-81.0478	F, M, C, O, S, D, B, N
Lick Fork (17-121-000) Undesignated ALU							
50400010702	303625	at TR 135, Burrier Rd.	0.2	5.0	40.4108	-81.0486	F, M, C, B
Jefferson Creek (17-123-000) WWH verified							
50400010701	R08S07	at High St., Jewett Park	0.2	6.5	40.3681	-80.9950	F, M, C, D, B, N

B- bacteria sampling	F2- two pass fish sampling	N- nutrient site (benthic chlorophyll- α and diel DO)
C- water chemistry sampling	FT- fish tissue sampling	O- Organic water chemistry sampling
D- DataSonde® continuous monitors	M- macroinvertebrate qualitative sampling only	S- sediment sample
F- single pass fish sampling	MQ- macroinvertebrate quantitative sampling	Sn- sentinel site

Study Area Description

Conotton Creek drains the southwestern half of Carroll County and northern fractions of Harrison and Tuscarawas Counties (Figure 5). With a headwater high point northwest from Germano (1366 FAMSL, feet above mean sea level) and a Tuscarawas River confluence low point (868 FAMSL), the Conotton Creek basin ranges over 498 feet in elevation. As this elevation change suggests, many Conotton Creek tributaries have high gradients. But Conotton Creek does not (Table 4). Based on a digital elevation map, the U.S. Geological Survey (USGS, *StreamStats* ([usgs.gov](https://www.usgs.gov))) calculates the average fall in Conotton Creek is 3.45 ft/mi between locations at 10% and 85% along the longest flow path. This and other gradients differ from those presented in the *Gazetteer of Ohio Streams* (ODNR 2001) because newer map technology affords better resolution. The digital determination and incrementation of the longest flow path is also a more consistent methodology. For comparison, values reported in the *Gazetteer* and those from *StreamStats* are shown in Table 4. Remarkably, hand planimetered drainages from the *Gazetteer* including those from the 1967 *Supplement* (Cross) were the same as *StreamStats* computations.

Conotton Creeks low gradient and unique geologic circumstances make the basin ideal for flood water storage. The Muskingum Watershed Conservancy District (MWCD) in cooperation with the U.S. Army Corps of Engineers (USACE) maintain Atwood and Leesville lakes and areas that may be impounded by Dover dam on the Tuscarawas River. To prevent flooding in Dover, Coshocton, Zanesville and Marietta, water may be retained in the Conotton Creek basin consistent with the 916 FAMSL Dover Dam spillway elevation. On such occasions, discharge from Atwood Lake to Indian Fork and from Leesville Lake to McGuire Creek is also restricted. Thus, flows necessary to redistribute sediment or that are capable of much erosion rarely occur in Conotton Creek despite the nearly 500 feet of elevation change encompassed by the watershed.

Dover Dam on the Tuscarawas River is at a unique location. Prior to glaciation, the dams' site was a watershed divide (hill) between northerly flowing streams. The larger stream flowing from the Dover area was joined by Conotton Creek vicinity tributaries near Navarre. During the glacial period, flow in the larger stream was checked by an ice front downstream (north) from the Conotton Creek tributary confluence. Consequently, the larger stream reversed course and flowed south. In so doing, the geomorphic processes of both the larger stream and those in the Conotton Creek area were influenced such that the tributaries became more depositional. During the final glaciation, the northerly confluence was blocked causing a lake to form in the tributary valleys. Eventually, this lake breeched the divide by cutting a narrow valley from Zoarville to Dover where it once again joined the larger south flowing stream. With the glaciers last retreat, outwash deposition in the Navarre area caused the larger stream to shift its course to flow south in the former lower channel of the Conotton Creek vicinity tributaries. This action left the Tuscarawas River flowing southerly in an ancient deep, outwash filled, rather wide valley and then through the constricted, bedrock-based Dover Dam reach. After this, the course is again returned to a deep, rock filled, broad valley (Lamborn 1956).

The result is that Dover Dam is strategically positioned to impede an inordinate amount of stream flow. Although the propitious location was apparent to early millers, would be dam builders were thwarted until advances in concrete technology and engineering made the edifice possible. Constructed in 1935, the dam has withstood floods that would have washed away any lesser structure. Even so, the possibility the dam might slide on its bedrock base prompted installation of an improved \$60 million anchoring system in 2015.

In January 2005, the highest pool of record (907.4 FAMSL) backed water two miles up the Tuscarawas River and 18 miles up Conotton Creek creating depositional conditions upstream from Sherrodsville. Routine pools

above 880 FAMSL (RM 6.3) often check Conotton Creek flow throughout its lower reach. Less frequent pools approaching 900 FAMSL (RM 15.4) extend backwater conditions to the base of Atwood Dam and impound Conotton Creek nearly to Sherrodsville.

A 2008 flood filled Atwood Lake to its highest recorded depth (935 FAMSL) while volume at Leesville Lake essentially equaled its long standing 1948 pool of record (969 FAMSL). Locally heavy rainfall in 2018 and again in 2019 resulted in similar exceedances of both Lake's surveillance pool levels. Leesville Lake achieved its largest size ever on June 25, 2019 at 971 FAMSL. From an aquatic habitat perspective, what's important about this episodic flood abatement is its success. Without Atwood, Leesville, and albeit the temporary Dover Lakes, scouring flood power would rearrange Conotton Creek bedload sediment. The finest material would be exported to the flood plain. In effect, cleansing the remaining aggregate and restoring the filtering function of the stream's few riffles.

Instead, not only is the power of nearly half of the Conotton Creek mainstem subjugated to the flow muting qualities of Dover Lake, but the sediment redistributing forces of the two largest tributaries have been eliminated. Thus, Conotton Creek has the flow strength of a stream perhaps half its actual size. Conotton Creek just doesn't measure up to its 286 mi² size or the aberrant pool depths it possesses. Furthermore, during the geologic period, the entire basin accumulated an abundance of lacustrine silt and none of the rejuvenating properties offered by pulses of outwash received by many other unglaciated streams. So, in addition to its undersized flow functions, Conotton Creek is challenged by sediment worthy of a much larger stream.

Conotton Creek's glacial lake heritage also left it with another handicap, particularly low gradient. As the crow flies, Conotton Creek is much shorter than the meandering course it follows downstream from Jewett. In a straight vector line, the USGS *StreamStats* software calculates it's 25 miles from Jewett to the Tuscarawas River confluence. Add ten miles when traveling the contorted path Conotton Creek has eroded back and forth across its valley floodplain. Over that route, the 3.45 ft/mi drop is less than most similar sized Ohio streams. Thus, Conotton Creek has little inherent erosive energy, it is naturally challenged by excessive quantities of fine sediment, and flood forces have little power to redistribute aggregate. In sum, the Conotton Creek mainstem and downstream courses of lower reach tributaries are exceptionally silty.

Situated within the Western Allegheny Plateau (WAP) ecoregion, the most upstream headwaters of Conotton Creek and principal tributaries between Jefferson Creek and Indian Fork arise along the Flushing Escarpment. This prominent ridge runs roughly parallel with the Ohio River from Columbiana to Monroe Counties separating its direct tributaries from those which first connect within the Muskingum River basin. East from the Escarpment, wide hilltops, fewer small streams, and less total relief give some regularity to the high gradient Ohio River tributaries between Little Beaver and Sunfish Creeks. West from the escarpment, watersheds are more dissected, valley floors are wider, and the more mature streams are deeply intrenched (Stout and Lamb 1938). These stream basins, Wills, Stillwater, Conotton and Sandy Creeks, include nine of the 14 original MWCD flood control projects (Huntington 1938).

Underlain by Pennsylvanian period bedrock, the rugged, rural appearance of the Conotton Creek watershed belies the areas long history of industrial prominence. Economic boom times associated with growth in resource extraction have routinely preceded bust periods of business contraction. With the drilling of Ohio's first horizontal Utica/Point Pleasant shale oil and gas well in 2011, the Conotton Creek basin soon became the epicenter of an economic juggernaut. Although most of the plausible horizontal well sites were established

and the first phases of the Utica East Ohio Gathering and Williams Harrison Hub Fractionation Facility with adjacent railroad yard were operational, pipelines and other petroleum processing infrastructure were under construction throughout the 2016 summer sampling period.

The impressive amount of oil and gas infrastructure in the Conotton Creek basin defies cursory summation. The large Utica East Ohio Gathering complex along Conotton Creek downstream from Scio, processes natural gas liquids and facilitates transport. The Scio and Kilgore Compressor Stations and Leesville Cryogenic Processing Plant are additional components of the new multi-site natural gas industry complex. New natural gas power plants in Carrollton and Harrison County are further developments spurred by abundant natural gas supply. The billions of dollars that have been invested in the Conotton Creek watershed coincident with the continuing oil and gas boom far exceed any previous local economic growth period.

The grid like arrangement of dots in Figure 6, especially noticeable in the downstream third of the watershed, generally represent older conventional oil wells. The clustered appearance of dots particularly in the upper reach of the watershed centered around Scio reflect an even earlier era of economic exuberance. Some 1,000 oil wells were drilled in and near the village. The Scio populace swelled from about 900 before oil discovery to 12,000 soon after the turn of the century. The pool was exhausted by 1902. As Scio returned to its former population size, it was left with a plethora of abandoned wells; lingering reminders of what might have seemed like a drilling epidemic.

Coal mining has occurred throughout the watershed (Figure 7). Underground mines were prevalent along the northern and western basin borders. Tuscarawas County coal mining began in 1810 along the Tuscarawas River and its tributaries. Production was limited until the Ohio and Erie Canal, completed in 1833, provided a means to transport the coal to a market. By 1835, Tuscarawas County coal shipments routinely arrived in Cleveland. Carroll County coal mining began in 1853 but was also limited until railroad spurs reached the area in the mid-1870s. Mineral City and Dellroy (Cannonsburg) populations boomed with coal mine development. Both were inhabited by less than 200 people before rail service and both increased to more than 900 citizens a decade later in the mid-1880s. Economic depression and labor disputes in the mid-1890s marked the advent of the bust period that extended into the 1920s as the coal was eventually played out. Abandoned drift mines, underground reservoirs of polluted water, and spoil piles are legacies of that exploitation.

In the 1920's, steam shovels made strip mining possible. Capable of efficiently removing overlying soil and rock strata to expose one or more coal seams, steam shovels helped meet the country's growing fuel needs. Increased fuel use during and after World War II coincided with further development of large earthmoving equipment. Recognition that earthmoving and coal mining were having unacceptable environmental consequences led to passage of the Ohio Coal Strip Mine Land Reclamation Act in 1947. Miners were expected to be licensed and bonded and vegetation was required to be planted on properties after mining ceased. Rules enacted in 1965 called for spoil bank grading and impoundment or backfill over coal faces at the bottom of highwalls. These stipulations failed to meet public demand for more complete mine site restoration.

Amendments in 1972 became a model for the 1977 Federal Surface Mining Control and Reclamation Act (SMCRA). The 1972 legislation required land surfaces to be restored to contours that were present before mining. Significant financial, severance tax, and pollution abatement rules were adopted. Retrospectively, mining and related permits prior to 1972 are now termed "pre-law" or "A law" (colored pink or red in Figure 7). In 1975, Ohio's Surface Mine "C" Law (colored yellow in Figure 7) applied broad restoration expectations to all mineral surface mines not already addressed by the 1972, "B" law. Then, the 1981, Federal Coal Mining and

Regulation “D” Law (colored green in Figure 7) introduced further refinements to coal permits, plans, and reclamation rules. Contemporary coal mines operate according to “D” law guidance.

Knowledge of this permitting scheme is useful for interpreting the types of reclamation completed at and the associated environmental influences posed by particular mines. For instance, the pink underground and red strip mines in the Huff Run basin were associated with severe environmental degradation. Grants totaling millions of dollars have been expended in the basin to individually remediate former mine sites. In 2016, a half mile long reach of Huff Run downstream from Mineral City was abandoned and a new channel was created. The abandoned channel receives acidic drainage from the immediate hillside. The bypassed channel is intended to isolate the reach from acidic runoff and provide better stream substrate quality.

Other streams including Beggar Run, Conotton Creek tributaries with confluences in the lower 12-mile reach, tributaries in the Indian Fork basin, and streams near Jewett were similarly affected by abandoned coal mines. Although these streams have benefited from a long period of natural attenuation, directed efforts to restore ecological function are needed to overcome lingering coal mine toxicity.

In 2016, one coal mine near Mineral City was considered operational. It subsequently closed and no coal mining has occurred in the Conotton Creek watershed since 2020. However, permits for many acres of coal mining have been issued. In the event of favorable circumstances, coal mining could proceed at those permitted sites.

In addition to coal, clay was also historically mined underground. Near Lindentree, the Hoover Coal and Clay Company processed Lower Kittanning clay for general refractory purposes. Two Mineral City firebrick plants used Lower Kittanning clay supplied by the Federal Clay Products Company. In all, some 26 underground mines were operated within the Huff Run watershed alone.

Since 1929, the Bowerston Shale Company has produced clay products for commercial and residential use. Shale and clay sourced from company mines are combined in the manufacture of different colored brick. The facility is located adjacent to Conotton Creek immediately upstream from Bowerston.

Established in 1933, the Scio Pottery Company was known nationally for ceramic plates, bowls, cups, and other dinnerware. For the town and the companies one thousand employees, a 1947 fire was a devastating loss. In solidarity with the uninsured business, the local community worked together to rebuild the operation. They continued making dinnerware until 1985. Presently, cement is blended and packaged at the site on the western outskirts of Scio.

Table 4 – Conotton Creek and principal tributary characteristics. Stream length, gradient and drainage area were taken from the Gazetteer of Ohio Streams (ODNR 2001). The drainage area of Conotton Creek upstream from its tributary appears in the far-right column Cross 1967). The average fall between locations at ten and 85 percent along the longest flow path were obtained from the USGS StreamStats web site.

Stream	Flows into	Length	Flow path	Gradient	10% to 85%	Drainage	Conotton C
		miles		ft/mi		mi ²	
Conotton Creek	Tuscarawas River	38.7	45.5	9.5	3.45	286	
Huff Run	Conotton Creek	9.9	11	19.3	20.0	13.90	271
Indian Fork	Conotton Creek	18.9	20.7	12.1	7.47	70.30	167
Willow Run	Indian Fork	4.8	6.11	25.2	34.0	8.99	
Pleasant Valley Run	Indian Fork	4.4	5.53	32.7	42.4	8.00	

Stream	Flows into	Length	Flow path	Gradient	10% to 85%	Drainage	Conotton C
Gantz Creek	Indian Fork	4.6	5.76	30.8	30.1	8.33	
McGuire Creek	Conotton Creek	11.8	16.3	26.3	12.0	49.60	92.4
N Fk McGuire Creek	McGuire Creek	12.6	14.2	23.1	15.3	26.60	
Dining Fork	Conotton Creek	8.0	8.72	38.9	26.4	14.70	48.1
Irish Creek	Conotton Creek	7.6	10.1	35.9	19.9	18.80	27.8
Lick Fork	Irish Creek	4.0	4.47	59.8	43.1	5.05	
Jefferson Creek	Conotton Creek	4.6	5.12	33.5	45.7	6.56	7.49

Land Use

The Conotton Creek watershed is among Ohio's more forested areas (60%, Figure 8, Table 5). Unsustainable agricultural practices in the beginning of the 20th century contributed to excessive erosion and flooding. Many depleted farms were acquired by the MWCD in pursuit of flooding relief. Agricultural land use now covers 30% of the basin. Development or water (1.7%) occupies the remainder. (Quick Stats: quickstats.nass.usda.gov).

Oil and Gas Wells within the Conotton Creek Watershed

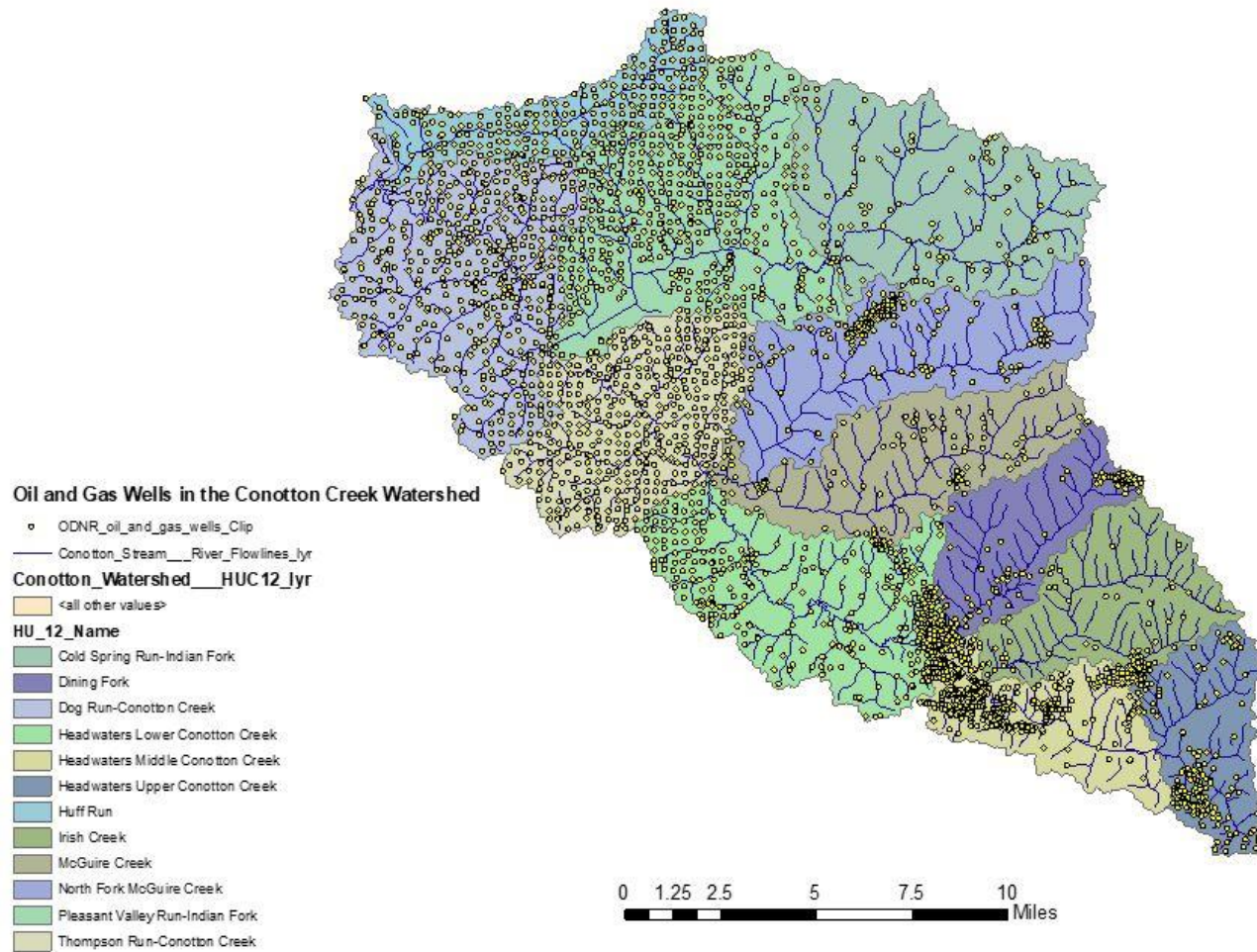


Figure 7 – Locations of ODNR oil and gas wells within the Conotton Creek watershed, 2016.

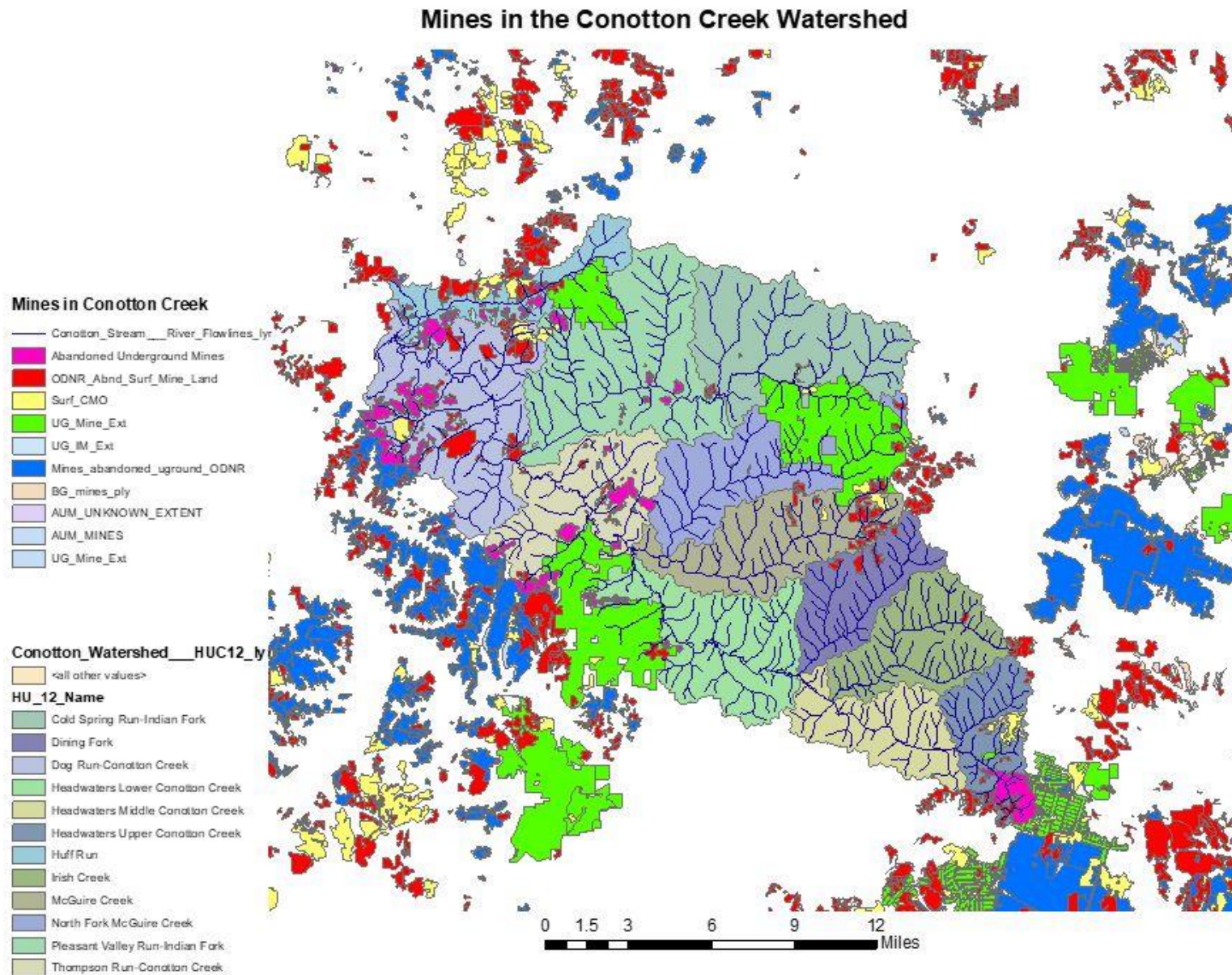


Figure 8 – The locations of several mine types within the Conotton Creek watershed, 2016.

Conotton Creek Watershed Land Use

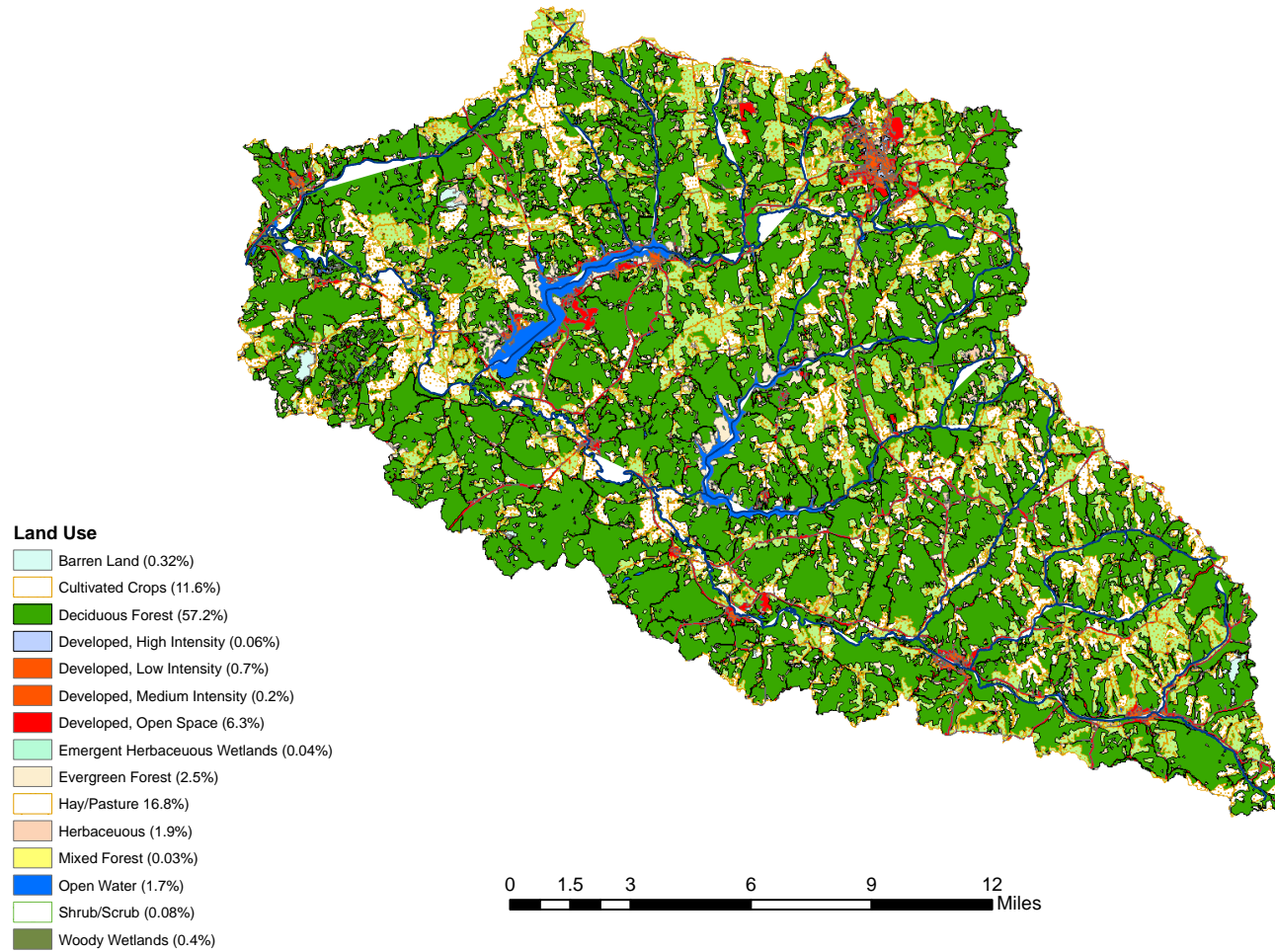


Figure 9 – Land use types in the Conotton Creek watershed, 2016.

Table 5 – Land use types in the Conotton Creek study area, 2016.

Cover classification	% of watershed area	Total area (mi ²)
Barren	0.32%	0.90
Crop	11.62%	33.25
Hay/Pasture	16.82%	48.13
Deciduous Forest	57.21%	163.68
Evergreen Forest	2.54%	7.27
Mixed Forest	0.03%	0.10
Herbaceous	1.95%	5.57
Herbaceous Wetlands	0.04%	0.12
Woody Wetlands	0.44%	1.27
Shrub/Scrub	0.08%	0.23
Developed, High Intensity	0.06%	0.17
Developed, Medium Intensity	0.21%	0.60
Developed, Low Intensity	0.66%	1.90
Developed, Open Space	6.26%	17.92
Water	1.74%	4.99
Total	100.00%	286.11

Census Data

According to the 2010 census, approximately 137,282 people reside in the Conotton Creek watershed. Population densities range from 39 people/mi² in Harrison County to 163 people/mi² in Tuscarawas County. About 3,241 people live in the Village of Carrollton where population density is as high as 1,322 people/mi². Total population across the three primary counties (Carroll, Harrison, and Tuscarawas) is expected to drop six percent (nearly 1,600 people) between 2010 and 2030. Each county is anticipated to have comparable population loss.

Wastewater Discharge Overview

Any direct discharge to a water body is required by the Federal Clean Water Act (CWA) to have a National Pollutant Discharge Elimination System (NPDES) permit. An NPDES permit stipulates operational, monitoring and reporting requirements and sets numerical limitations on the amount of specified pollutants authorized for discharge. Discharge Monitoring Report (DMR) results are routinely submitted to Ohio EPA. Table 6 lists selected NPDES permitted facilities and related summary information.

Too numerous to mention are the Home Sewage Treatment System (HSTS) discharges. Ohio Department of Health rules require local health districts to evaluate and participate in permitting of HSTS discharges. Some NPDES facilities are considered major dischargers based on the volume (more than one million gallons per day or MGD) or type of waste discharged. All other individual NPDES permitted facilities are considered minor dischargers. All NPDES facilities in the Conotton Creek watershed were minor dischargers. An interactive map with NPDES facility locations, permit information, and compliance history is at:

<http://oepa.maps.arcgis.com/apps/webappviewer/index.html?id=25cf405adc3444139f4b410e69a2bbc9>.

Jewett WWTP discharges to UT to Conotton Creek, OPA00084

The village of Jewett operates a controlled discharge lagoon, wastewater treatment works located northeast from SR 141 and SR 35 in Harrison County. Built in 1997 to serve 700 residents, the WWTP discharges to an unnamed tributary to Conotton Creek (RM 38.91) at RM 0.36. Discharge is limited to ninety gallons per minute (90 gpm) for each cubic foot per second (one cfs) of Conotton Creek stream flow (this is a 5:1 dilution). Flow upsteam from the WWTP discharge is measured by the Village at the 801-monitoring station. No effluent is permitted when Conotton Creek flow is less than one cfs.

The plant consists of influent comminutor and influent pumps, flow splitter, two aerated lagoons, storage lagoon, effluent weir, and flow monitoring. The sanitary and storm water collection systems are completely separate. There were no industrial dischargers to the WWTP. A December 2014 facility inspection determined one of the two lagoons was not operational, an unreported overflow had occurred, influent comminutor improvements were deficient, and the final outfall location signage was inadequate. In March 2015, the village indicated that corrective actions had occurred and offered a plan to resolve outstanding permit violations. A February 2017 facility inspection evaluation revealed reporting lapses. By November 2017, Village compliance with those concerns was acknowledged in an Ohio EPA resolution of violations (ROV) letter.

Scio WWTP discharges to Conotton Creek, PB00058, 200,000 gpd

The village of Scio WWTP is located on Allensworth Drive, northeast from SR 151 in Harrison County. Built in 1978 to serve 871 residents, the WWTP was last upgraded in 1996. Designed to treat 200,000 gallons per day (gpd) of domestic sanitary wastewater, the facility discharges to Conotton Creek at RM 32.8.

The plant consists of influent grinder, one oxidation ditch, secondary clarification, UV disinfection, and Parshall flume flow measurement. The sanitary and storm water collection systems are completely separate. There are no industrial dischargers to the WWTP. An August 2015 facility inspection determined excessive inflow and infiltration (I/I) resulted in inadequate wastewater treatment. Recurrent sanitary sewer overflows (SSOs) were attributed to I/I issues. In December 2015, the Village indicated that corrective actions, including equipment problems associated with total suspended solids (TSS) permit violations, had been completed. This progress was recognized in a partial ROV letter from Ohio EPA in September 2016. In December 2016, the Village stipulated an I/I assessment had been accomplished and a reduction plan was initiated. Ohio EPA accepted the plan in a February 2017 ROV letter.

Bowerston WWTP discharges to Conotton Creek, OPA00083, 51,000 gpd

The village of Bowerston WWTP is located east from SR 212, just north from SR 151 in Harrison County. Built in 1981 to serve 398 Bowerston Village and 111 Monroe Township residents, the WWTP is designed to treat 51,000 gpd of domestic sanitary wastewater. The discharge is to Conotton Creek at RM 25.21.

The plant consists of an influent pump station, bar screen and flow splitter, two aerated lagoons, two chlorination/dichlorination tanks, an effluent weir, and flow monitoring. The sanitary and storm water collection systems are completely separate. Two industrial facilities, neither of which is a significant or categorical user, discharge sanitary wastewater to the WWTP. An October 2016 Ohio EPA ROV letter acknowledged the Village for maintenance and planning progress at the facility. Duckweed growth in the aerated lagoons was associated with permit violations in 2017 and it remains a concern presently addressed via manual removal.

Germano WTP discharges to Jefferson Creek, 01Z00022, 1800 gpd

The Harrison Co. Water and Sewer District – Germano Water Treatment Plant (WTP) is located at 90500 Mill Rd., about one third of a mile southwest from SR 9 in Harrison County. Built in 1969, the WTP was modified in 2015 to provide drinking water for 160 nearby area residents. A few times weekly, discharge from slow sand, backwash filters enters Jefferson Creek at RM 3.92. Facility iron and manganese load limitations are based on a maximum 4,000 gpd flow rate. Average flow is estimated at about 1,800 gpd if the discharge was more frequent. Treatment plant by-passes and sand filter maintenance issues noticed in July 2016 were resolved in September 2017.

Table 6 – Selected NPDES facilities, discharge volume, location, treatment type, and sanitary sewage overflows (SSOs) in the Conotton Creek basin, 2011 to 2016. Median, 95th percentile, and applicable permitted concentrations of monitored parameters (oxygen demand, nutrients, and suspended solids in mg/L, total recoverable metals in µg/L; except total low-level mercury in ng/L) in discharged effluent is presented where applicable.

Facility / System/ SSOs	Permit #	MGD	Discharge RM	County
Parameter	Q ₂	P _{95%}	Permitted Monthly Mean (Maximum)	
Jewett WWTP	OPA00084	batch	Conotton Ck. Trib. (RM 38.91)	Harrison
Batch discharger 90 gpm/1 cfs stream flow (5:1 dilution), System wide SSOs, no reported discharge				
DO	9.4	13.9		
CBOD ₅	10.7	27.4	25	
NH ₃ -N	1.7	5.4		
TSS	31	55	65	
Scio WWTP	OPB00058	0.2	Conotton Cr. RM 32.8	Harrison
System wide SSOs, 5 discharge events, each lasting 2.5 days, 2011-2016.				
DO	8.0	10.0	>5.0	
CBOD ₅	3.4	12.1	15 summer/ 25 winter	
NH ₃ -N summer/ winter	0.1/ 1.9	1.2/ 3.8		
NO ₃ +NO ₂ -N	19.2	26.8		
TP	2.1	3.1		
TSS	13	36	20 summer/ 30 winter	
Leesville WWTP	3PA00039	0.025	Conotton Cr. RM 23	Carroll
System wide SSOs, no reported discharge				
DO			>6.0	(2019-2024)
NH ₃ -N summer/ winter			1.0 summer/ 3.0 winter	(2019-2024)
TSS			12	(2019-2024)
Bowerston WWTP	OPA00083	0.051	Conotton Cr. RM 25.21	Harrison
System wide SSOs, no reported discharge				
DO	7.5	11.8	>5.0	
CBOD ₅	22.1	35	25	
NH ₃ -N summer	15.5	22.7		
TP	2.8	3.8		
Chlorine	0.01	0.05	(0.038)	
TSS	18	38	30	
Atwood Regional WSD	3PQ00100	0.65	Conotton Cr. RM 11.37	Tuscarawas
WWTP. System wide SSOs, 4 discharge events, each lasting 1.25 days, 2011-2016.				
DO	10.0	7.5	>5.0	(2017-2022)
NH ₃ -N summer/ winter	0.07/0.08	0.64/0.22	1.5 summer/ 5.0 winter	(2017-2022)
TSS	0.9	4.9	8.0	(2017-2022)
Harrison WSD Germano WTP	OIZ00022	0.0018	Jefferson Ck. RM 3.92	Harrison
Fe	67	1204	1000 (2000)	
Mn	35	398	1000 (2000)	
TSS	3	1834	30 (45)	
Carrollton WWTP	3PC00027	0.75	Honey Run RM 0.5	Carroll
Tertiary treatment, UV disinfection. System wide SSOs discharge to Honey Run and Indian Fork, 107 discharge events, each lasting 2.7 days, 2011-2016.				
DO	8.8	10.6	>6.0	
CBOD ₅	4.6	19.1	7.3	
NH ₃ -N summer/ winter	0.9/ 1.5	1.6/ 2.1	1.1 summer/ 2.9 winter	
NO ₃ +NO ₂ -N	3.4	8.9		
Carrollton WWTP (contd.)				

Facility / System/ SSOs Parameter	Permit # Q ₂	MGD P _{95%}	Discharge RM Permitted Monthly Mean (Maximum)	County
TP	1.8	3.3	1.0	
Cu	6.7	12	18 (28)	
Pb	4.3	27	17 (341) not in 2021 permit	
Hg	3.2	20.3	12 (1700) not in 2021 permit	
Ni	ND	1.7	not in 2021 permit	
Zn	72.2	132.2	230 (244) not in 2021 permit	
TSS	5.2	14.6	8.8	
Mineral City WWTP	OPB00053	0.15	Huff Run RM 1.7	Tuscarawas
UV disinfection. System wide SSOs, 7 discharge events, each lasting 1.75 days, 2011-2016.				
DO	7.8	10.2	>5.0	
CBOD ₅	2.0	5.8		
NH ₃ -N summer/ winter	ND	0.4/ 0.1		
NO ₃ +NO ₂ -N	11	16.8		
TP	2.2	4.4		
Cr	1.8	3.2		
Cu	11.1	14.9		
Pb	0.5	0.7		
Hg	6.0	7.3		
Ni	12.7	23.8		
Zn	46.7	49.4		
TSS	2.7	11.4		

Carrollton WWTP discharges to Honey Run, 3PC00027, 750,000 gpd

The village of Carrollton WWTP is located at 193 Alamo Rd., about one half mile south from SR 322 in Carroll County. With a 650,000 gpd treatment design capacity, the membrane bioreactor WWTP currently operates at about half that flow rate. The discharge is to Honey Run at RM 0.54. Sewage sludge is treated within a 94,500-gallon aerobic digester tank, a 18,000-gallon decant tank, and six sewage sludge drying beds (one bed is used for dewatered sewage sludge storage). Two additional two sewage sludge drying beds are not currently utilized for dewatering sewage sludge. The WWTP has approximately three years of onsite sewage sludge storage capacity.

Mineral City WWTP discharges to Huff Run, OPB00053, 150,000 gpd

The Tuscarawas Co. Metropolitan Sewer District – Mineral City WWTP is located at 5241 Lindentree Rd., about one quarter mile east from SR 800 in Tuscarawas County. Built in 1973 to serve 830 Mineral City area residents, the facility was upgraded in 2008. Designed to treat 0.150 MGD of domestic sanitary wastewater, the WWTP discharges to Huff Run at 1.62 RM.

The plant primary treatment units include bar screening, grit removal and fine screening. Secondary treatment is provided by two aeration tanks and two clarifiers followed by UV disinfection and post aeration. The sanitary and storm water collection systems are completely separate. There are no industrial dischargers to the WWTP. An October 2017 facility inspection determined all treatment units were operational and no effluent violations had been reported in the recent three-year review period.

Water Chemistry Results

Five surface water samples were collected from each of the 12 mainstem and 35 tributary free-flowing stream locations in the Conotton Creek study area from April through October 2016 (Table 3 and Figure 5). Samples were collected directly into appropriate containers or from a bridge deployed, properly prepared, bucket when high flows or barriers made conditions unwadeable. Collected water was preserved as outlined in *Surface Water Field Sampling Manual for water quality parameters and flows*. (OHIO EPA, 2015) and then delivered to Ohio EPA's Environmental Services laboratory. Surface water was analyzed for metals, nutrients, pH, specific conductance (SC), dissolved oxygen (D.O.), percent D.O. saturation, total suspended solids (TSS) and total dissolved solids (TDS). A handheld field meter was used to obtain instantaneous stream temperature, pH, SC, D.O. and percent D.O. saturation measurements each time a surface water sample was collected. Bacteria was cultured from surface water samples at 47 locations. All water column chemical and physical assessment results are in Appendix F. Bacteriological results are in Appendix I.

All sites within any 12-digit HUC were sampled on the same day to facilitate comparison of that data under similar streamflow. Sampling captured various flow conditions during the study. These samples represent about one or two percent of a calendar year. Therefore, chemistry monitoring trends in respect to linear profiles and over time should be understood as a series of snapshots, recognizing higher and lower concentrations likely occurred. Ohio EPA evaluates biological community status to address the gaps inherent to chemistry sampling. In the most literal sense, aquatic species incorporate the chemistry of their surroundings such that biological communities are reliable representatives of long-term water quality trends. Consequently, Ohio EPA uses water chemistry data to discern potential aquatic community stressors and plausible limiting factor sources.

A hydrograph showing water and bacteria sample dates from the McGuire Creek U.S. Geological Survey (USGS) gage near Leesville was indicative of general flow trends (Figure 9). Flows in May were above normal. During the remainder of the field season, flow was either at or less than the historic average. See [Recreation Use Results](#) for further bacteria data discussion.

Twenty-four chemistry sample sites were also monitored hourly with multi-parameter water quality sondes to obtain diel (24-hour) temperature, D.O., pH and SC profiles. Diel temperature, D.O. and pH patterns inform awareness of potentially critical conditions for aquatic life during stable, low stream flows. Although SC is not subject to the same diel influences, this parameter is a useful flow indicator. Typical water chemistry samples differ from long term sonde deployments because those only represent one point on the diel curve. While effective at characterizing water quality parameters that change based on hydrologic regime or season, single samples can miss or not fully characterize parameters that exhibit diel patterns. Where the diel fluctuations are of interest, continuous, regular interval, monitoring is recommended to characterize conditions represented by parameters of concern.

Diel temperature patterns reflect air temperature, solar radiation, baseflow (groundwater), discharge, and shading. In general, diel fluctuations in temperature increase as baseflow, discharge, and shading decrease. The inverse is also true.

Dissolved oxygen trends are directly dependent on temperature. At high temperatures, the solubility of oxygen in water decreases resulting in an inverse relationship between temperature and solubility of oxygen

in water. Without the influence of other environmental conditions, this would cause the two parameters to follow opposite trends. However, the D.O. 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; D.O. concentrations reach super saturation during the day and subsequently deplete 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, D.O. does not exhibit strong diel trends in low flow, warm conditions. Either primary productivity is limited, or stream organic matter decomposition is controlling the D.O. concentrations. Sonde monitoring contributes to the body of evidence used to identify D.O. trends that are influenced by primary productivity or decomposition.

Diel patterns in pH are also reflective of primary productivity. Carbon dioxide, dissolved in water to form carbonic acid, is consumed during photosynthesis raising stream pH. The result is a maximum pH value observed at a similar time to the maximum D.O.

Critical conditions for aquatic life are associated with higher temperatures, lower D.O., low flows, and when daylight is long. During these periods, effects from organic and nutrient enrichment are most pronounced. To characterize these conditions, sondes are typically deployed during low-flow conditions from June to September.

Two extensive, identical sonde deployments occurred during the 2016 Conotton Creek study; the July 3-5, survey was replicated August 23-25, with all sensors spanning a time window of 42-51 hours. In the 2016 May-October period, weather was generally hotter and drier than normal, and the sampled conditions were ideal for assessing low-flow stress (Figure 10), survey periods are shown in light-shaded vertical bands). Daily streamflow was typically below the long-term median from mid-May until early September and both monitoring surveys were conducted in very low streamflow. Antecedent streamflow for both surveys was also low, and without any local peak events. While air temperatures were generally above normal for most of the period, it did cool for both survey periods. In the July survey, air temperature declined to 4°C below normal, and declined to normal for the August survey. Water temperature also responded similarly (Figure 10, dashed blue line) by cooling approximately 2°C for both surveys. Summary time plots showing hourly temperature, D.O., pH and SC measurements of all data are presented in Appendix H. During sonde deployments, benthic and sestonic (water column) chlorophyll- α concentrations were measured at selected sites to evaluate trophic status and to identify possible nutrient enrichment conditions.

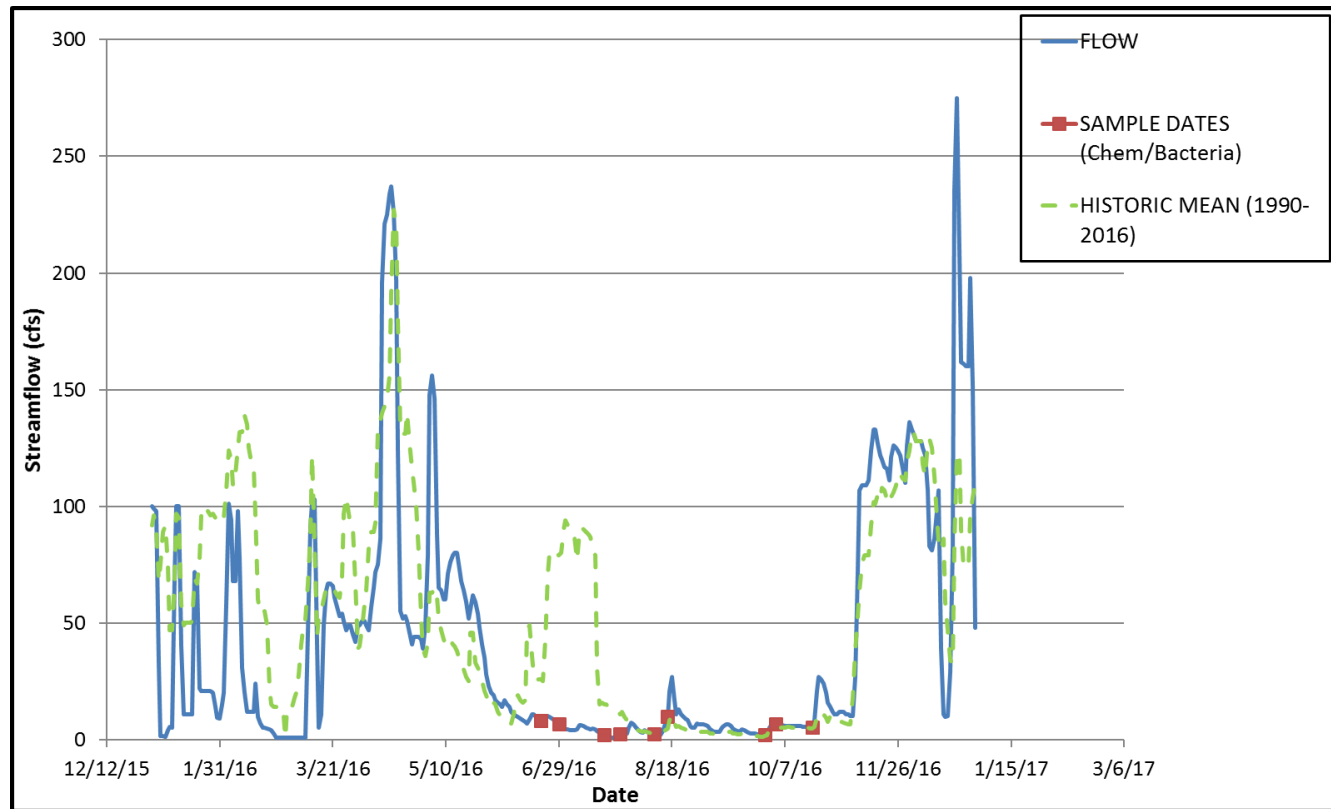


Figure 10 – Daily average flow conditions in the Conotton Creek at the USGS gage 03120500 at Leesville in 2016 (USGS, 2016). Chemistry sampling activities are indicated on the plot.

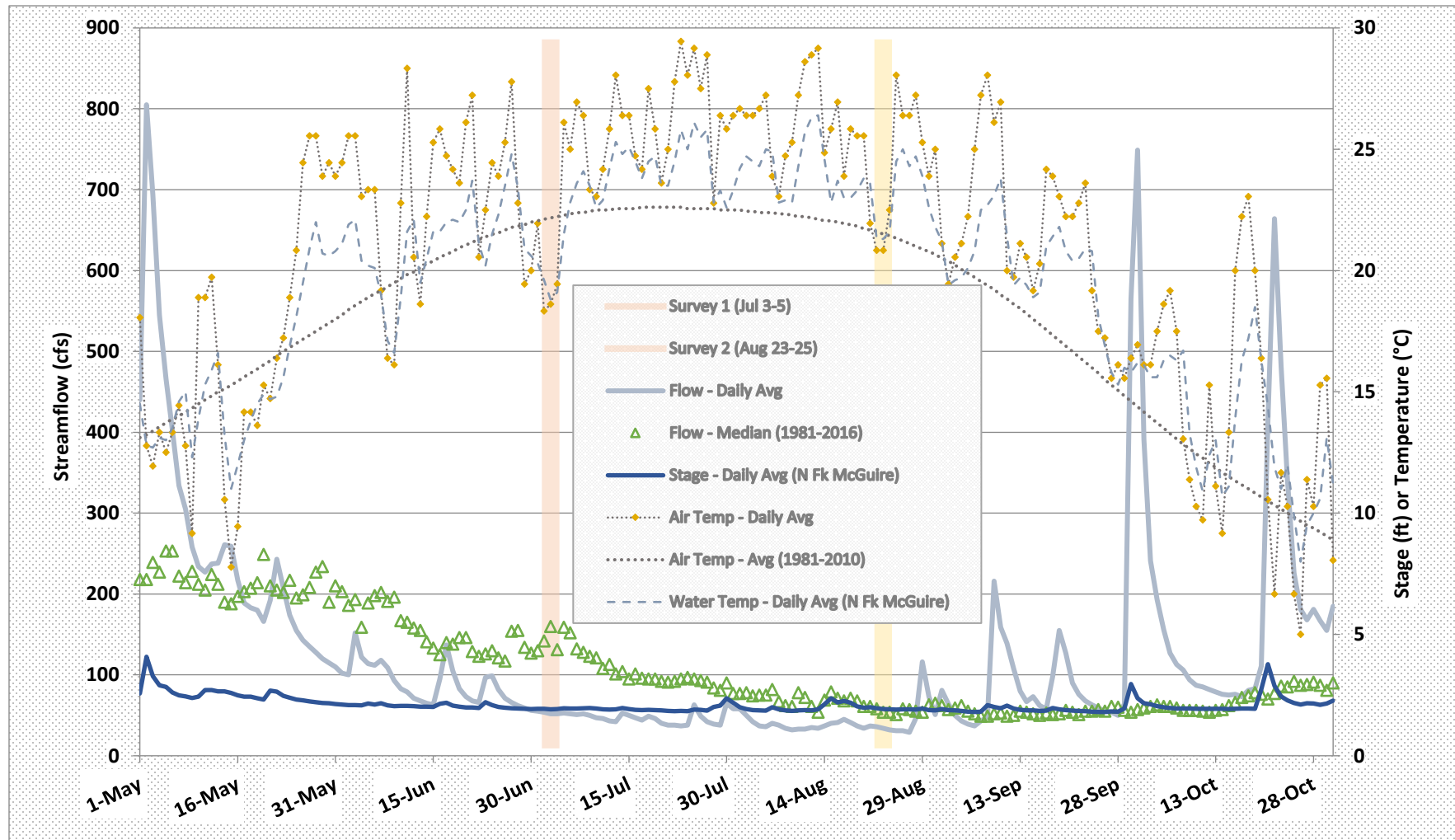


Figure 11 – Average daily streamflow (cfs) relative to the daily median streamflow (1981-2016, cfs) from a gage in an adjacent watershed: USGS 03117500 Sandy Creek at Waynesburg OH (253 mi²). Within the Conotton Creek watershed, streamflow magnitude is indicated by average daily stage (gage height, ft) at USGS 03119971 North Fork McGuire Creek near Carrollton OH (11.3 mi²). For this same gage, average daily water temperature (°C) is presented. Also shown are the average and normal (1981-2010) daily air temperature (°C) (NOAA GHCND: USW00004852 at New Philadelphia – Clever Field OH) for the sampling season. All data represent the period May 1 to October 31, 2016. Sonde survey dates (3-day period) are shown as shaded vertical bars.

Water Quality Criteria Exceedances

Water quality standards (WQS) are promulgated through Ohio Administrative Code (OAC) Chapter 3745-1. Surface water sampling results outside the bounds specified by WQS criteria are listed in Table 7. The data collected during sonde deployments are sufficient to evaluate WQS exceedances for the protection of aquatic life for: maximum daily temperature, minimum at any time D.O., 24-hour average D.O., 24-hour average pH, and 24-hour average SC. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. Water quality criteria exceedances and elevated data recorded by sondes are reported in Table 8 and Table 9. It is relevant to note an exceedance of the water quality criteria does not represent stream impairment; rather, if aquatic community impairment is present, exceedances contribute to a body of evidence used to identify stressful biological conditions.

There were no temperature exceedances at any site during the sampling period. The abundance of forested land (60%, Figure 8, Table 5) in the Conotton Creek watershed was credited for stream temperature moderation. Wooded areas promote rainwater infiltration leading to sustained groundwater derived baseflow and provide critical riparian shading. Collectively, all were important factors for maintaining cool stream temperatures across the basin. Average three-day sonde records for Conotton Creek water temperatures ranged between 20.6 to 23.6°C in July 2016 and 19.1 to 23.5°C in August 2016. Excluding two sites downstream from dam outflows, tributary stream temperatures ranged between 21.1 to 23.3°C in July 2016 and 19.3 to 22.7°C in August 2016. Water temperatures at sites downstream from the dams were notably cooler. Those values ranged between 13.5 to 16.4°C in July 2016 and 13.7 to 18.5°C in August 2016. Outflow from Atwood Lake was 3 to 5°C warmer than that from the deeper Leesville Lake.

Exceedance of the D.O. water quality criteria are noted by values less than the absolute minimum (WWH<4.0 mg/L) or by sonde records averaged over a rolling 24-hour time window (WWH<5.0 mg/L). Surface water sampling determined low D.O. exceedances occurred in Huff (RM 1.3) and Scott runs (RM 0.7). Field meter instantaneous D.O. readings were below the average criterion once at four sites and twice at another in 2016. No exceedances of the minimum or average criteria were detected by sondes at any of the 24 monitored locations during July or August 2016. This positive outcome was likely attributable to low organic pollution, abundant stream structure to provide reaeration, and ample groundwater intrusion. The latter factor was attributed to large areas of natural land cover and appreciable riparian corridors. However, some sites exhibited wide D.O. ranges; a signature of nutrient enrichment. Elevated D.O. records occurred in both July and August 2016 sonde surveys. Very high D.O. (ranging above 6 mg/L) was documented in Conotton Creek upstream (RM 38.8) and downstream (RM 37.8) from Jewett during both sonde deployments. All other Conotton Creek sites exhibited acceptable D.O. profile ranges. Among tributaries, elevated D.O. ranges (4-6 mg/L) during in both surveys were present in Jefferson Creek (RM 0.2) and in McGuire Creek upstream from Leesville Lake (RM 7.55). Elevated D.O. in July in Honey Run upstream from the Carrollton WWTP (RM 0.8) was consistent with excessive benthic chlorophyll growth. This indication of enrichment is discussed in the **Stream Trophic Status** section.

The pH criteria include high, low, and a range for 24-hr average values (6.5 to 9.0 s.u.). Surface water sampling registered a high pH value in Conotton Creek downstream from Jewett (RM 37.8) consistent with the locations routinely elevated D.O. meter values (9.1 to 13.2 mg/L, Table 14). A low pH was recorded in Huff Run at CR 90 (RM 1.3) along with the previously mentioned low D.O. and numerous other extreme values (Table 10 to Table 15). Although no pH excursions were recorded in the July sonde survey, values

approaching the lower pH limit were detected at two Huff Run locations (RM 2.1 and RM 1.3). In the August sonde survey, a lower boundary exceedance occurred in Huff Run at RM 1.3 while low pH values (6.5 s.u.) were registered at RM 2.1. Values in Indian Fork, downstream from Atwood Lake (RM 0.5, pH=6.6 s.u.), also approached the lower pH criterion in the July survey and were only slightly improved in the August survey (6.8 s.u.). One exceedance of the upper pH criterion was obtained in McGuire Creek upstream from Leesville Lake (9.1 s.u.) during the August survey.

Table 7 – Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical and physical parameters measured in the Conotton Creek study area, 2016. Assessment is based on current Ohio WQS use designations or WWH for undesignated water bodies.

Location	River Mile (Station)	Parameter
Conotton Creek at CR 50, New Rumley Rd.	37.8 (R08S04)	pH (9.1 s.u. ^d)
Huff Run at TR 170, Heritage Rd.	7.8 (300601)	SC (3285 μ S/cm ^a)
Huff Run at CR 90, New Cumberland Rd.	1.3 (300595)	D.O. (1.67 mg/L ^a) pH (5.5 s.u. ^c)
Beggar Run at CR 90, New Cumberland Rd.	0.5 (303653)	TDS (1640, 1750 mg/L ^b)
Honey Run dst. Carrollton WWTP and Tributary	0.5 (303642)	Copper (17.7, 19.8 μ g/L ^a)
Scott Run at SR 151, Scio-Bowerston Rd.	0.7 (303630)	D.O. (2.54 mg/L ^a)
Dining Fork at TR 645, Tartan Rd.	4.3 (303627)	Copper (16.4 μ g/L ^a)

Table 8 – Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring in the Conotton Creek study area, 2016. Assessment is based on current Ohio WQS use designations. Remarkably, with very low streamflow, D.O. concentrations remained above the minimum and average water quality criteria at all 24 sonde deployment locations during both three-day surveys.

Location	River Mile (Station)	Parameter
Huff Run at CR 90, New Cumberland Rd.	1.3 (300595)	pH July #1 (6.4 s.u. ^c) August #38 (6.2 s.u. ^c)
McGuire Creek opposite Dyewood Rd.	7.5 (303706)	pH August #1 (9.1 s.u. ^d)

- a Exceedance of the aquatic life Outside Mixing Zone Maximum (OMZM) water quality criterion (for D.O., below minimum).
- b Exceedance of the aquatic life Outside Mixing Zone Average (OMZA) water quality criterion (for D.O., below 24-hour average).
- c Exceedance of the aquatic life OMZ Minimum water quality criterion for pH (6.5 s.u.).
- d Exceedance of the aquatic life OMZ Maximum water quality criterion for pH (9.0 s.u.).
- c Exceedance of the aquatic life OMZ Minimum water quality criterion for pH (6.5 s.u.).
- d Exceedance of the aquatic life OMZ Maximum water quality criterion for pH (9.0 s.u.).

Sondes were deployed at the same 24 locations (Table 3, D) on July 3-5 (42-50 hours) and August 23-25, 2016 (42-51 hours).

Sonde water quality monitors record hourly measurements throughout deployment duration. Thus, exceedances are presented as a measure of magnitude and duration. Magnitude is presented as the most extreme value that exceeded the criteria in parenthesis after the duration. The duration is the count of consecutive hours that exceeded the criteria. Exceedances are listed in the parameter column. Applicable water quality criteria include: minimum DO, average DO, maximum temperature, pH and SC.

Specific conductance greater than 2400 μ S/cm exceeds the outside mixing zone maximum (OMZM) aquatic life use criterion specified in OAC 3745-1. The SC OMZM was exceeded in Huff Run at TR 170 (RM 7.8). Conductivity exhibits less diel influence compared to previously discussed parameters. Generally, SC concentrations increase with declining streamflow as groundwater becomes proportionally more of the baseflow. Mean SC surface water concentrations from Huff Run at RM 5.5 (1,315 μ S/cm), RM 1.3 (1,305 μ S/cm), and from Beggar Run at RM 0.5 (1,729 μ S/cm) were elevated, but all sample values were less than the criterion (Table 10). These sites, downstream from abandoned coal mines, also exhibited high mean sulfate surface water concentrations (540, 728, and 927 mg/L, respectively). Likewise, sonde monitoring returned

elevated SC concentrations from Huff Run (1,500-1,700 $\mu\text{S}/\text{cm}$) during both surveys. Elevated SC was recorded in August from Conotton Creek at sites bracketing the Jewett WWTP (RM 38.8 and RM 37.8, SC=850-900 $\mu\text{S}/\text{cm}$). High SC values were present during both sonde surveys in Jefferson Creek (RM 0.2, 950-1,150 $\mu\text{S}/\text{cm}$) and at Honey Run sites bracketing the Carrollton WWTP (RM 0.8 and RM 0.6, SC=750-850 $\mu\text{S}/\text{cm}$). Specific conductance at sites downstream from Atwood and Leesville lakes was unremarkable during both sonde surveys. Sulfide oxidation in lake hypolimnetic outflows was anticipated to increase SC. The unexpected observations were further affirmed by low sulfate concentrations in relevant surface water samples.

Table 9 – Elevated chemical and physical parameter values derived from diel monitoring in the Conotton Creek study area, 2016.

Location	River Mile (Station)	Parameter
Conotton Creek adj. W. Main St. (Jewett)	38.8 (303721)	D.O. July & August (high range) SC July & August (\bar{x} =866 & 908 $\mu\text{S}/\text{cm}$)
Conotton Creek at CR 50, New Rumley Rd.	37.8 (R08S04)	D.O. July & August (high range) SC July & August (\bar{x} =844 & 827 $\mu\text{S}/\text{cm}$)
Huff Run E of Mineral City at driveway off CR 110	2.1 (R08P07)	pH July & August (\bar{x} =6.7 & 6.6 s.u.) SC July & August (\bar{x} =1589 & 1693 $\mu\text{S}/\text{cm}$)
Huff Run at CR 90, New Cumberland Rd.	1.3 (300595)	pH July (\bar{x} =6.6 s.u.) SC July & August (\bar{x} =1523 & 1608 $\mu\text{S}/\text{cm}$)
McGuire Creek opposite Dyewood Rd.	7.5 (303706)	D.O. July & August (high range)
Honey Run ust. Carrollton WWTP and tributary	0.6 (R08P01)	D.O. July (high range) SC July & August (\bar{x} =763 & 769 $\mu\text{S}/\text{cm}$)
Honey Run dst. Carrollton WWTP and tributary	0.5 (303642)	SC July & August (\bar{x} =798 & 834 $\mu\text{S}/\text{cm}$)
Jefferson Creek at High St., Jewett Park	0.2 (R08S07)	D.O. August (high range) SC July & August (\bar{x} =963 & 1160 $\mu\text{S}/\text{cm}$)

High Beggar Run SC concentrations occurred with TDS exceedances of the aquatic life use OMZ average criterion (1,500 mg/L) in two surface water samples (1,640 and 1,750 mg/L). These additional data further affirm the likely influence from historic coal mine operations.

In surface water, dissolved copper concentrations exceeding the aquatic life use OMZ maximum criterion (OAC 3745-1-35-9, hardness dependent $\approx 15.0 \mu\text{g}/\text{L}$) are occasionally detected in consequence of excessive copper sulfate application to control lentic aquatic vegetation growth. The less common lotic detection of dissolved copper is likely to be associated with wastewater effluent or related to urban land use runoff perhaps associated with biocide use (lumber preservatives, antifouling treatments, pesticides etc.) As such, repetitive elevated dissolved copper concentrations downstream (and in effluent samples) from the Carrollton WWTP were indicative of inadequate treatment. A single detection of copper (16.4 $\mu\text{g}/\text{L}$) in Dining Fork at RM 4.3 (TR 645, Tartan Rd., 303627) was less explicable. Aside from numerous farms, the rural upstream drainage area included the Kilgore compressor station, at least five horizontal well pads, and just as many large ponds. Recognizing the persistent toxicity of copper in an aquatic environment, efforts to address these exceedances are encouraged.

Resource Extraction Markers

Concurrent with this study, the USGS completed *Baseline Water Quality of an Area Undergoing Shale-Gas Development in the Muskingum River Watershed, Ohio, 2015-16* (Covert, Jagucki, and Huitger, 2018 pubs.usgs.gov/sir/2018/5113/sir20185113.pdf). The USGS evaluated water quality in the Atwood, Leesville, and four other MWCD lake basins, all within the heart of Ohio's horizontal oil well development region. They

analyzed 62 parameters including two radionuclides six times at 30 sites to discern whether recent industrial activities were affecting water quality. Ohio EPA assessed biological communities in Bear Hole and Willow Runs and in the Tributary to Indian Fork at RM 3.3 among the eleven USGS sample locations within the overlapping study areas.

The USGS determined the bicarbonate-oriented water in the Conotton Creek basin differed principally based on the presence of chloride anions. With stream sample values ranging from 2.1 to 76.1 mg/L ($Q_2=10.7$ mg/L), Atwood Lake basin sites returned the highest chloride concentrations in their study. Similarly, bromide, a component of oil and gas well waste fluid, was routinely present in samples from all five Atwood Lake, Indian Fork subbasin stream sample locations. Otherwise, bromide was limited to thirteen detections (>30 $\mu\text{g/L}$) distributed among eleven other stream sites in the USGS study. Covert, Jagucki, and Huitger (2018) called attention to the fact that one active and two plugged waste brine injection wells and the highest concentration of conventional oil and gas wells in their study area were within the catchments of three of the Indian Fork subbasin sample sites. However, they were careful to note that “correlation does not equate to causation” and data were insufficient to discern between these plausible sources.

The USGS contrasted the chloride and mixed bicarbonate Atwood Lake basin water with calcium-bicarbonate water prominent in the Leesville Lake basin. Following work by Whittemore (2007; 1995; 1988), binary mixing curves prepared by the USGS show chloride in the McGuire Creek subbasin likely emanated from road salt runoff and septage. Covert, Jagucki, and Huitger (2018) further explained many Carroll and Harrison townships allowed well waste brine to be used for road dust suppression. Although, some townships discontinued the practice after the study was completed.

Conotton Creek basin bromide contamination extended beyond that noticed by the USGS. Aside from Elliot Run and the Indian Fork Tributary at RM 3.30, extremely high bromide concentrations were also evident in Huff, Beggar, and Thompson Runs and in the Conotton Creek Tributary at RM 17.22 (Table 10). Bromide concentration increased in Conotton Creek longitudinally downstream from the historic Scio well field (Figure 6). This pattern was contrasted by chloride contamination which appeared to emanate from Carrollton. The highest chloride concentration in the USGS study (76.1 mg/L) was recorded in Indian Fork upstream from Atwood Lake. In that reach, Ohio EPA also documented a similar chloride concentration (74.6 mg/L) and another that was greater (85.5, $\bar{x}=62$ mg/L, Table 10). From there, the average chloride concentration in Indian Fork increased upstream (RM 13.9 $\bar{x}=78$ mg/L) and at both Honey Run sample sites ($\bar{x}=106$ and 109 mg/L). Likewise, chloride concentrations in Cold Spring Run ($\bar{x}=74$ mg/L) and in Friday Creek ($\bar{x}=44$ mg/L) were excessive. From its hilltop setting, streams flowing in every direction from Carrollton convey chloride concentrations beyond the 90th percentile of all comparable values measured by Ohio EPA (Table 11). Obviously, imprudent use of road salt is discouraged. Similarly, elevated chloride in Kirby Run ($\bar{x}=48$ mg/L) adjacent to a state route was not coincidental.

Consistent with other investigations (Covert, Jagucki, and Huitger, 2018; Haefner and Simonson, 2010; Pfaff et al., 1981), sulfate and specific conductivity are generally accepted as markers for coal mining influences. Extreme SO_4^{2-} and SC concentrations were present in the most upstream reach of Conotton Creek along with Jefferson Creek and in a lower reach tributary at RM 7.67 as well as in Beggar and Huff runs (Table 10). As shown in Figure 7 (pink), these streams, at the extreme ends of the Conotton Creek basin, are in proximity to abandoned underground mines. Thompson Run also drains a former underground mine. Elevated SO_4^{2-} and SC values indicate Thompson Run continues to be affected by that legacy source of contamination.

Dissolved metals often accompany leachate from coal mines and may also be associated with well waste brines (Table 12). High aluminum, iron, and manganese concentrations detected in a mid-August series of chemistry samples in the upper McGuire Creek subbasin were accompanied by elevated TSS values. A localized rainstorm was credited for this spike in runoff related parameters. Conceptually, compared to normal stream water, rainwater with a lower pH mobilized metals and carried more eroded particles. The extreme values imply the runoff encountered atypical landscape conditions such as a “gob pile” of mine tailings or caused an overflow from an underground cavity.

Similar circumstances in late September mobilized metals and increased TSS in the Dining Fork subbasin. In this runoff event, dissolved copper was detected at RM 4.3 (16.4 µg/L), but not at bracketing sites (RMs 6.3 and 0.2). The perplexity was further confounded by lower dissolved metal and TSS concentrations at the middle site (RM4.3) compared to values at nearby stations (RMs 6.3 and 0.2). Collectively, the values were not as extreme as those noted in the McGuire Creek basin and association with any particular landscape condition or plausible source was not forthcoming.

Dissolved metal concentrations in Scott Run were erratic. Samples collected the day after the elevated upper McGuire Creek mid-August series were also indicative of a runoff event in Scott Run. Likewise, the late September elevated Dining Fork subbasin values were reflected in Scott Run chemistry results. Additionally, a mid-July storm that had negligible influence in nearby basins helped Scott Run register some high dissolved metal concentrations including an iron value (15,000 µg/L) three times more than the agricultural use criterion (5,000 µg/L). Dissolved copper was also present in that sample (8.1 µg/L). These aberrant values were at odds with those from two June samples when results were typical for the area. Since the Scott Run sample site was immediately downstream from a cattle pasture, the possibility that cows trampling in the stream may have exacerbated water quality conditions was plausible. The importance of an alternate water source for the livestock and the benefit of fencing those animals away from the stream were manifest at this site.

Table 10 – Average total dissolved solids (TDS), total suspended solids (TSS), selected salt ion concentrations, and specific conductivity (SC) in the Conotton Creek watershed, 2016 (Including USGS data noted for three locations). Values greater than WAP ecoregion reference sites 90th percentile are shaded. Values greater than WAP 95th percentile for all sites are underlined. WAP percentile values are presented in Table 11. Bold, italicized TDS values exceed the WWH OMZA criterion (1500 mg/L). All average SC values were less than the WWH OMZA criterion (2400 $\mu\text{S}/\text{cm}$). Values were typically calculated from five samples (5x). Atypical sampling frequency is indicated with location (4x or 7x). Where results were less than method detection limits (MDL) or otherwise calculated from atypical sampling frequency, values are averaged from the number of superscript indicated positive samples.

Station	Stream / Location	RM	Mi ²	TDS	TSS	Br	Cl	SO ₄ ⁻²	SC
				mg/L	$\mu\text{g}/\text{L}$		mg/L	$\mu\text{S}/\text{cm}$	
Headwaters Upper Conotton Creek 05040001 07 01									
Conotton Creek WWH									
303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	464	25	33	22	179	682
Headwaters Middle Conotton Creek 05040001 07 04									
R08S04	CR 50, New Rumley Rd. (7x)	37.8	17.5	651	11 ^{3x}	26	22	314	908
303541	Eastport Rd. (11x)	33.3	46.8	384	39	33 ^{7x}	23	140	596 ^{10x}
R08K05	CR 80, Leffler Rd. (7x)	32.6	48.0	415	21 ^{6x}	34 ^{5x}	24	154	600
Headwaters Lower Conotton Creek 05040001 07 07									
R08S01	CR 25, Conotton Rd.	29.1	70.0	354	26	60	30	111	576
R08W05	SR 164, Amstedeam Rd. (7x)	23.7	87.0	327	20	48 ^{5x}	27	91	499
R08K03	CR 22, Azalea Rd. (12x)	22.1	89.0	305	63	53 ^{8x}	26	87	498 ^{11x}
Thompson Run-Conotton Creek 05040001 08 03									
303578	SR 39, Church St, Sherrodsville Park	17.0	156.2	264	15 ^{4x}	64	23	67	415
303579	TR 394, Miller Hill Rd. (7x)	13.9	165.3	259	15	72 ^{5x}	24	62	405
Dog Run-Conotton Creek 05040001 08 05									
R08S14	CR 90, New Cumberland Rd. (7x)	11.4	241.0	240	16	72 ^{5x}	26	53	388
303580	from TR 399, Marsh Rd. (3x)	6.7	261.8	281	62	81	28	78	451
303581	Zoarville Station trail TR 390 (4x)	0.2	286.0	392	19 ^{3x}	99	30	155	594
Headwaters Upper Conotton Creek 05040001 07 01									
Jefferson Creek WWH									
R08S07	High St., Jewett Park (7x)	0.2	6.5	807	10 ^{4x}	26	24	404	1071
Irish Creek 05040001 07 02									
Irish Creek WWH, CWH recommended ust. Lick Fork (RM 4.63)									
303624	from CR 35, Branch Rd.	5.0	6.7	224	9 ^{3x}	22 ^{3x}	18	56	349
R08S13	CR 136, Lambert Rd. (7x)	2.6	14.9	199	28 ^{6x}	22 ^{4x}	16	36	318
Lick Fork CWH recommended									
303625	TR 135, Burrier Rd.	0.2	5.0	189	11 ^{4x}	20 ^{1x}	15	26	313 ^{4x}
Dining Fork 05040001 07 03									
Dining Fork EWH recommended									
303626	from TR 382, Pontiff Rd.	6.3	3.1	199	57	22 ^{2x}	36	19	329
303627	TR 645, Tartan Rd.	4.3	6.3	222	7 ^{4x}	22 ^{2x}	26	28	325
303628	SR 151, Scio-Bowerston Rd. (7x)	0.2	14.7	201	35	30	28	22	339
Kirby Run EWH recommended									
303629	adj. SR 332, Scio Rd.	0.7	3.4	238	8 ^{3x}	28	48	18	419
Headwaters Lower Conotton Creek 05040001 07 07									
Scott Run (not assessed for attainment status)									
303630	SR 151, Scio-Bowerston Rd.	0.7	3.1	208	88 ^{4x}	36	21	14	308
Conotton Creek Tributary (RM 28.20) WWH recommended									
303618	CR 43, Bower Rd.	0.6	3.8	180	32	26	10	17	289
McGuire Creek 05040001 07 06									
McGuire Creek WWH recommended, EWH recommended ust. RM 7.57									

Station	Stream / Location	RM	Mi ²	TDS	TSS	Br	Cl	SO ₄ ⁻²	SC
				mg/L	µg/L		mg/L	µS/cm	
303616	adj. CR 17, Aster Rd.	9.9	2.7	281	9 ^{3x}	34	13	48	494
303617	TR 374, Plymouth Rd.	8.3	7.1	244	9 ^{3x}	30	11	36	405
R08W04	dst. Leesville Lake dam (7x)	1.4	48.0	139	ND	ND	11	12	194
Long Creek EWH									
303631	CR 8, Alamo Rd.	0.7	1.7	249	27 ^{4x}	28	10	42	416
North Fork McGuire Creek 05040001 07 05									
North Fork McGuire Creek EWH recommended									
303632	TR 354, Pebble Rd.	9.4	4.1	209	28 ^{3x}	29	20	25	353
303633	CR 19, Autumn Rd.	7.7	6.9	193	53 ^{3x}	23	15	20	312
303542	SR 322, Scio Rd. (12x)	6.0	11.3	175	48 ^{10x}	24 ^{10x}	15	21	297 ^{11x}
Bear Hole Run EWH recommended									
303634	CR 54, Canyon Rd. (USGS 6x)	1.7	1.4	119 ^{10x}	SSC 28	11 ^{1x}	7	19	185
Thompson Run-Conotton Creek 05040001 08 03									
Conotton Creek Tributary (RM 17.22) WWH recommended									
303635	pipeline	1.0	6.3	192	13 ^{3x}	111	25	22	329
Thompson Run WWH recommended									
303615	from SR 39, Roswell Rd.	0.7	3.7	330	20 ^{1x}	137	28	97	507
Cold Spring Run-Indian Fork 05040001 08 01									
Indian Fork WWH recommended									
R08W03	SR 332, Scio Rd.	13.9	12.3	359	25 ^{4x}	55	78	38	624
Pleasant Valley Run-Indian Fork 05040001 08 02									
303543	from SR 39, Roswell Rd. (12x)	9.0	33.5	274	49	78 ^{10x}	62	29	504 ^{11x}
R08S15	dst. Atwood Lake dam, SR 212 (7x)	0.5	70.0	140	13	37 ^{5x}	24	14 ^{5x}	262
Cold Spring Run-Indian Fork 05040001 08 01									
Gantz Creek WWH recommended									
303639	TR 354, Pebble Rd.	1.2	7.3	254	22 ^{3x}	32	35	23	393
Friday Creek WWH recommended									
303640	CR 66, Chase Rd.	1.2	3.5	264	12 ^{3x}	31	44	29	458
Honey Run WWH recommended									
R08P01	ust. Carrollton WWTP/ trib. (7x)	0.8	3.4	426	6 ^{3x}	75	109	47	724
303642	dst. Carrollton WWTP (7x)	0.6	3.8	459	14	70	106	47	801
Cold Spring Run WWH recommended									
303644	from SR 39, Roswell Rd.	0.6	5.9	292	10	38	74	18	508
Pleasant Valley Run WWH recommended									
303646	TR 147, Folsam Rd.	1.5	6.5	160	9 ^{2x}	23 ^{4x}	12	16	285
Pleasant Valley Run-Indian Fork 05040001 08 02									
Willow Run WWH recommended									
303649	CR 29, Bedrock Rd. (USGS 6x)	1.5	7.7	131	SSC 19	55 ^{5x}	12	19	220
Elliot Run WWH recommended									
303702	CR 69, Clay Rd.	1.4	3.5	156	10 ^{4x}	164	25	18	268
Indian Fork Tributary (RM 3.30) WWH recommended									
303651	SR 542 (USGS 6x)	1.4	3.4	210	SSC 21	170	28	34	357
Dog Run-Conotton Creek 05040001 08 05									
Conotton Creek Tributary (RM 11.37) WWH recommended									
303614	TR 320, Dawn Rd.	0.3	4.6	184	27	79	19	21	325
Conotton Creek Tributary (RM 7.67) WWH recommended									
303654	TR 388, Brown Hill Rd.	2.9	3.8	610	14 ^{3x}	32	15	269	866
Dog Run-Conotton Creek 05040001 08 05 (continued)									
Beggar Run WWH recommended									
303653	CR 90, New Cumberland Rd.	0.5	4.0	1536	6 ^{4x}	136	14	927	1729
Huff Run 05040001 08 04									
Huff Run WWH recommended									

Station	Stream / Location	RM	Mi ²	TDS	TSS	Br	Cl	SO ₄ ⁻²	SC
				mg/L	µg/L		mg/L	µS/cm	
300601	TR 170, Heritage Rd.	7.8	3.3	210	ND	211	37	21	928
300599	CR 36, Brass Rd.	5.5	6.5	1036	7 ^{2x}	139	26	540	1315
300595	CR 90, New Cumberland Rd. (10x)	1.3	11.8	1161	34 ^{6x}	92	24	728	1305 ^{9x}

Table 11 – Ohio EPA drainage area stratified WAP ecoregion reference sites 90th percentile values, all sites 90th percentile values and all sites 95th percentile values for total dissolved solids (TDS), total suspended solids (TSS), selected salt ion concentrations, and specific conductivity (SC). Recent inclusion of bromide analysis has generally occurred at headwater and wading sites. Small river bromide percentiles were omitted respecting present data paucity.

Parameter	Symbol	Unit	Headwaters	Wading	Small River
			(< 20 mi ²)	(20-200 mi ²)	(200-1000 mi ²)
			<i>P</i> _{90%} reference sites	<i>P</i> _{90%} all sites	<i>P</i> _{95%} all sites
Total Dissolved Solids	TDS	mg/L	395 (940) <u>1380</u>	580 (1100) <u>1650</u>	565 (616) <u>740</u>
Total Suspended Solids	TSS	µg/L	17 (25) <u>51</u>	47 (35) <u>67</u>	40 (67) <u>107</u>
Bromide	Br	µg/L	83 (175) <u>309</u>	180 (131) <u>168</u>	Insufficient data
Chloride	Cl	mg/L	42 (48) <u>74</u>	46 (60) <u>115</u>	66 (65) <u>81</u>
Sulfate	SO ₄ ⁻²	mg/L	144 (540) <u>815</u>	204 (639) <u>965</u>	195 (282) <u>375</u>
Specific conductivity	SC	µS/cm	614 (1260) <u>1720</u>	888 (1540) <u>2030</u>	884 (931) <u>1083</u>

Stream Trophic Status

Nutrient enrichment is a widespread surface water impediment in Ohio. High nutrient concentrations accelerate primary productivity and decomposition cycles resulting in stressful supersaturated or low D.O. conditions, resource depletion, and production of harmful byproducts, for example, hypoxia or the various toxins released by harmful algal blooms (HABs). Inorganic nitrogen (NO₃+NO₂-N) needed for algal and plant growth is generally available in Ohio waters. This nitrate, often present beyond limiting thresholds, does not necessarily lead to more primary productivity. Instead, total phosphorous (TP) concentrations are frequently limiting. In Ohio, high stream TP concentrations are correlated with pollution tolerant, less diverse biological communities and vice versa (OHIO EPA, 1999). Nutrient enrichment deters Ohio's surface water uses, degrading aquatic community fitness, preventing recreation, and threatening human health via jeopardized public drinking water supplies.

Nutrients including ammonia-N (NH₃-N), nitrate+nitrite-N (NO₃+NO₂-N), total Kjeldahl nitrogen (TKN), and TP along with D.O. and pH were measured at 47 study area locations (Table 14). These results were considered with sonde data obtained from 24 study area sites where benthic algae was obtained for measurement of chlorophyll- α concentrations. Miltner (2010) has shown that dissolved inorganic nitrogen (DIN; sum of NH₃-N and NO₃+NO₂-N), TP, and chlorophyll- α density measurements are associated with diel D.O. fluctuations and the health of Ohio's aquatic biological communities. The measured change points informed Ohio EPA's weight of evidence approach and are used to determine the degree to which aquatic life is threatened or impaired by nutrient enrichment.

Table 12 – Average selected dissolved metal concentrations in the Conotton Creek watershed, 2016 (Including USGS data noted for three locations). Values greater than WAP ecoregion reference sites 90th percentile are shaded. Values greater than WAP 95th percentile for all sites are underlined. WAP percentile values are presented in Table 13. Bold aluminum values exceed the U.S. EPA maximum criterion (Al: 750 µg/L). All average iron values were less than the agricultural use OMZA criterion (Fe: 5000 µg/L). Values were

typically calculated from five samples (5x). Atypical sampling frequency is indicated with location (4x or 7x). Where results were less than method detection limits (MDL) or otherwise calculated from atypical sampling frequency, values are averaged from the number of superscript indicated positive samples.

Station	Stream / Location	RM	Mj ²	Al	Ba	Fe	Mg	Mn	Na	Sr
				µg/L		mg/L		µg/L	mg/L	
Headwaters Upper Conotton Creek 05040001 07 01										
Conotton Creek WWH										
303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	585 ^{2x}	60	790	27.7	237	15	385
Headwaters Middle Conotton Creek 05040001 07 04										
R08S04	CR 50, New Rumley Rd. (7x)	37.8	17.5	286 ^{1x}	63	363	44.7	224	16	577
303541	, Eastport Rd. (11x)	33.3	46.8	798 ^{8x}	66	1741	23.1	350	15	317
R08K05	CR 80, Leffler Rd. (7x)	32.6	48.0	601 ^{3x}	64	1000	25.0	282	16	356
Headwaters Lower Conotton Creek 05040001 07 07										
R08S01	CR 25, Conotton Rd.	29.1	70.0	732 ^{3x}	69	1630	20.2	440	20	307
R08W05	SR 164, Amstedam Rd. (7x)	23.7	87.0	457 ^{5x}	63	1120	17.7	363	18	282
R08K03	CR 22, Azalea Rd. (12x)	22.1	89.0	857	70	2398	17.0	519	17	268
Thompson Run-Conotton Creek 05040001 08 03										
303578	SR 39, Church St, Sherrodsville	17.0	156.2	310 ^{3x}	55	1051	14.0	524	16	239
303579	TR 394, Miller Hill Rd. (7x)	13.9	165.3	381 ^{3x}	58	1251	13.7	515	16	231
Dog Run-Conotton Creek 05040001 08 05										
R08S14	CR 90, New Cumberland Rd.	11.4	241.0	394 ^{3x}	66	2046	12.5	1045	17	207
303580	from TR 399, Marsh Rd. (3x)	6.7	261.8	732	71	2707	15.9	786	20	229
303581	Zoarville Station trail TR 390 (4x)	0.2	286.0	298 ^{3x}	60	1324	23.4	1188	21	281
Headwaters Upper Conotton Creek 05040001 07 01										
Jefferson Creek WWH										
R08S07	High St., Jewett Park (7x)	0.2	6.5	234 ^{2x}	59	363	52.8	121	19	683
Irish Creek 05040001 07 02										
Irish Creek WWH, CWH recommended ust. Lick Fork (RM 4.63)										
303624	from CR 35, Branch Rd.	5.0	6.7	ND	49	703	11.3	172	12	168
R08S13	CR 136, Lambert Rd. (7x)	2.6	14.9	545 ^{3x}	49	1293	9.4	257	11	153
Lick Fork CWH recommended										
303625	TR 135, Burrier Rd.	0.2	5.0	325 ^{2x}	46	809	8.5	157	9	138
Dining Fork 05040001 07 03										
Dining Fork EWH recommended										
303626	from TR 382, Pontiff Rd.	6.3	3.1	715 ^{4x}	34	1511	7.8	259	21	137
303627	TR 645, Tartan Rd.	4.3	6.3	219 ^{1x}	37	607	9.2	226	17	155
303628	SR 151, Scio-Bowerston Rd. (7x)	0.2	14.7	715 ^{4x}	51	1479	9.1	359	19	163
Kirby Run EWH recommended										
303629	adj. SR 332, Scio Rd.	0.7	3.4	305 ^{1x}	56	665	9.5	175	31	173
Headwaters Lower Conotton Creek 05040001 07 07										
Scott Run (not assessed for attainment status)										
303630	SR 151, Scio-Bowerston Rd.	0.7	3.1	1797 ^{4x}	89	4182	9.1	672	14	153
Conotton Creek Tributary (RM 28.20) WWH recommended										
303618	CR 43, Bower Rd.	0.6	3.8	1079 ^{3x}	63	2398	8.0	312	8	147
McGuire Creek 05040001 07 06										
McGuire Creek WWH recommended, EWH recommended ust. RM 7.57										
303616	adj. CR 17, Aster Rd.	9.9	2.7	221 ^{1x}	56	428	16.4	150	19	300
303617	TR 374, Plymouth Rd.	8.3	7.1	219 ^{2x}	66	580	13.0	297	14	254
R08W04	dst. Leesville Lake dam (7x)	1.4	48.0	ND	56	1201	5.7	2571	7	102
Long Creek EWH recommended										
303631	CR 8, Alamo Rd.	0.7	1.7	1390 ^{1x}	53	939	12.5	193	10	248
North Fork McGuire Creek 05040001 07 05										
North Fork McGuire Creek EWH recommended										

Station	Stream / Location	RM	Mj ²	Al	Ba	Fe	Mg	Mn	Na	Sr
				µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L
303632	TR 354, Pebble Rd.	9.4	4.1	1560 ^{1x}	42	1308	10.2	606	13	212
303633	CR 19, Autumn Rd.	7.7	6.9	2450 ^{1x}	37	1374	8.1	248	12	166
303542	SR 322, Scio Rd. (12x)	6.0	11.3	1715 ^{4x}	41 ¹¹	1644	7.9 ^{11x}	231 ^{11x}	12 ^{11x}	162 ¹¹
Bear Hole Run EWH recommended										
303634	CR 54, Canyon Rd. (USGS 6x)	1.7	1.4	24	22	52	4.9	26	5	82
Thompson Run-Conotton Creek 05040001 08 03										
Conotton Creek Tributary (RM 17.22) WWH recommended										
303635	pipeline	1.0	6.3	387 ^{1x}	50	1010	11.1	500	16	195
Thompson Run WWH recommended										
303615	from SR 39, Roswell Rd.	0.7	3.7	382 ^{1x}	49	990	19.1	550	20	251
Cold Spring Run-Indian Fork 05040001 08 01										
Indian Fork WWH recommended										
R08W03	SR 332, Scio Rd.	13.9	12.3	385 ^{4x}	66	786	13.1	196	64	286
Pleasant Valley Run-Indian Fork 05040001 08 02										
303543	from SR 39, Roswell Rd. (12x)	9.0	33.5	827	71	2026	11.0	315	47	214
R08S15	dst. Atwood Lake dam, SR 212 (7x)	0.5	70.0	305 ^{2x}	45	3087	6.8	2165	15	107
Cold Spring Run-Indian Fork 05040001 08 01										
Gantz Creek WWH recommended										
303639	TR 354, Pebble Rd.	1.2	7.3	525 ^{2x}	42	829	9.6	171	30	200
Friday Creek WWH recommended										
303640	CR 66, Chase Rd.	1.2	3.5	341 ^{1x}	37	469	11.6	188	34	235
Honey Run WWH recommended										
R08P01	ust. Carrollton WWTP/ trib. (7x)	0.8	3.4	ND	67	338	14.0	188	78	339
303642	dst. Carrollton WWTP (7x)	0.6	3.8	312 ^{5x}	101	398	15.7	118	92	366
Cold Spring Run WWH recommended										
303644	from SR 39, Roswell Rd.	0.6	5.9	263 ^{2x}	90	787	12.4	169	47	207
Pleasant Valley Run WWH recommended										
303646	TR 147, Folsam Rd.	1.5	6.5	ND	66	1004	8.9	431	16	133
Pleasant Valley Run-Indian Fork 05040001 08 02										
Willow Run WWH recommended										
303649	CR 29, Bedrock Rd. (USGS 6x)	1.5	7.7	12	32	151	6.6	121	11	99
Elliot Run WWH recommended										
303702	CR 69, Clay Rd.	1.4	3.5	200 ^{1x}	49	1287	7.5	384	16	170
Indian Fork Tributary (RM 3.30) WWH recommended										
303651	SR 542 (USGS 6x)	1.4	3.4	17	62	67	9.2	98	18	193
Dog Run-Conotton Creek 05040001 08 05										
Conotton Creek Tributary (RM 11.37) WWH recommended										
303614	TR 320, Dawn Rd.	0.3	4.6	513	96	1980	10.9	635	14	163
Conotton Creek Tributary (RM 7.67) WWH recommended										
303654	TR 388, Brown Hill Rd.	2.9	3.8	524 ^{1x}	30	932	30.8	365	53	534
Beggar Run WWH recommended										
303653	CR 90, New Cumberland Rd.	0.5	4.0	ND	28	327	144.6	608	23	904
Huff Run 05040001 08 04										
Huff Run WWH recommended										
300601	TR 170, Heritage Rd.	7.8	3.3	ND	63	632	9.3	259	19	176
300599	CR 36, Brass Rd.	5.5	6.5	ND	51	1065	71.4	1298	35	883
300595	CR 90, New Cumberland Rd. (10x)	1.3	11.8	2070 ^{1x}	24	4872	77.2	8202	25	702

Table 13 – Ohio EPA drainage area stratified WAP ecoregion reference sites 90th percentile values, all sites 90th percentile values and all sites 95th percentile values for selected dissolved metal concentrations.

Parameter	Symbol	Unit	Headwaters(< 20 mi ²)	Wading (20-200 mi ²)	Small River(200-1000 mi ²)
			<i>P</i> _{90%} reference sites (<i>P</i> _{90%} all sites)	<i>P</i> _{90%} all sites	<i>P</i> _{95%} all sites
Aluminum	Al	µg/L	330 (860) <u>2310</u>	743 (991) <u>2193</u>	824 (1330) <u>2052</u>
Barium	Ba	µg/L	86 (91) <u>107</u>	94 (92) <u>109</u>	74 (91) <u>105</u>
Iron	Fe	µg/L	1084 (2110) <u>4229</u>	1606 (1940) <u>3715</u>	1600 (2580) <u>4005</u>
Magnesium	Mg	mg/L	20 (52) <u>81</u>	21 (71) <u>110</u>	31 (36) <u>47</u>
Manganese	Mn	µg/L	286 (1400) <u>2980</u>	371 (1100) <u>1840</u>	329 (750) <u>1040</u>
Sodium	Na	mg/L	28 (55) <u>98</u>	80 (101) <u>151</u>	51 (55) <u>77</u>
Strontium	Sr	µg/L	418 (800) <u>1490</u>	614 (1275) <u>2673</u>	380 (712) <u>965</u>

Along the Conotton Creek mainstem, wide D.O. diel fluctuations (>6.5 mg/L) occurred both upstream (RM 38.8, adj. W. Main St., 303721) and downstream from the Village of Jewett WWTP (RM 37.8, CR 50, R08S04) during both July and August sonde surveys (Figure 11 and Figure 12). Benthic chlorophyll- α density was also high upstream from the Jewett WWTP during the July survey, but not for the August survey. Jefferson Creek enters upstream from these two sites. While Jefferson Creek nutrient concentrations were low at the mouth (RM 0.2, High St., R08S07), the D.O. range was high (Figure 13 and Figure 14). Jefferson Creek D.O. exhibited particularly greater range in the August survey. These findings suggest that Jefferson Creek and Conotton Creek headwaters likely contribute to the enriched conditions surrounding the Jewett WWTP.

The lagoon treatment system operated by Jewett discharges sporadically, just several times annually. The facility is not expected to include total P, ortho-P, or nitrate+nitrite-N in Discharge Monitoring Reports (DMR). However, DMR ammonia-N values were very high. In November 2016, two DMR ammonia-N concentrations averaged 0.62 mg/L. An Ohio EPA lagoon sample determined discharge TP (1.98 mg/L) could also be quite enriched.

Table 14 – Average selected nutrient concentrations, dissolved oxygen (D.O.) and pH in the Conotton Creek watershed, 2016 (including USGS data noted for three locations). Values (in mg/L or pH standard units) greater than WAP ecoregion reference sites 90th percentiles are shaded. Values greater than WAP 95th percentiles for all sites are underlined. D.O. and pH. values less than WAP ecoregion reference sites 10th percentiles are lightly shaded. D.O. and pH less than WAP 95th percentiles for all sites are in bold. WAP percentile values are presented in Table 15. Values were typically calculated from five samples (5x). Atypical sampling frequency is indicated with location (4x or 7x). Where results were less than method detection limits (MDL) or otherwise calculated from atypical sampling frequency, values are averaged from the number of superscript indicated positive samples.

Station	Stream / Location	RM	Mi ²	NH ₃ -N	NO ₃ +NO ₂ -N	TKN	TP	D.O.	pH
Headwaters Upper Conotton Creek 05040001 07 01									
Conotton Creek WWH									
303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	0.06 ^{4x}	0.43	0.59	0.06	7.9	7.9
Headwaters Middle Conotton Creek 05040001 07 04									
R08S04	CR 50, New Rumley Rd. (7x)	37.8	17.5	0.07 ^{3x}	0.67	0.45	0.03	11.0 ^{6x}	8.3
303541	Eastport Rd. (11x)	33.3	46.8	0.09 ^{9x}	0.58	0.62 ^{10x}	0.15	7.3 ^{9x}	7.7 ^{10x}
R08K05	CR 80, Leffler Rd. (7x)	32.6	48.0	0.09 ^{5x}	0.43	0.45 ^{6x}	0.06	8.2	7.8
Headwaters Lower Conotton Creek 05040001 07 07									
R08S01	CR 25, Conotton Rd.	29.1	70.0	0.10 ^{4x}	0.64	0.46	0.07	7.5	7.5
R08W05	SR 164, Amsterdam Rd. (7x)	23.7	87.0	0.10	0.45	0.69	0.06	7.6	7.6
R08K03	CR 22, Azalea Rd. (12x)	22.1	89.0	0.10 ^{10x}	0.53 ^{10x}	0.76 ^{11x}	0.09	7.2 ^{10x}	7.5 ^{11x}
Thompson Run-Conotton Creek 05040001 08 03									
303578	SR 39, Church St, Sherrodsville	17.0	156.2	0.09 ^{3x}	0.33	0.37	0.03 ^{3x}	7.2	7.4
303579	TR 394, Miller Hill Rd. (7x)	13.9	165.3	0.07	0.34	0.52	0.04	7.9 ^{6x}	7.5
Dog Run-Conotton Creek 05040001 08 05									
R08S14	CR 90, New Cumberland Rd. (7x)	11.4	241.0	0.27	0.51	0.59	0.07	6.9 ^{6x}	7.3
303580	from TR 399, Marsh Rd. (3x)	6.7	261.8	0.13	0.59	0.44	0.08	7.1	7.6
303581	Zoarville Station trail TR 390 (4x)	0.2	286.0	0.10	0.67	0.40	0.04	6.7	7.5
Headwaters Upper Conotton Creek 05040001 07 01									
Jefferson Creek WWH									
R08S07	High St., Jewett Park (7x)	0.2	6.5	0.07 ^{5x}	0.94	0.81	0.04	8.6	8.0
Irish Creek 05040001 07 02									
Irish Creek WWH, CWH recommended ust. Lick Fork (RM 4.63)									
303624	from CR 35, Branch Rd.	5.0	6.7	0.06 ^{1x}	0.51 ^{3x}	0.64 ^{3x}	0.03	8.5	7.9
R08S13	CR 136, Lambert Rd. (7x)	2.6	14.9	0.09 ^{5x}	0.55 ^{6x}	0.58 ^{6x}	0.06	7.8	7.8
Lick Fork CWH recommended									
303625	TR 135, Burrier Rd.	0.2	5.0	0.11 ^{4x}	0.77	0.47 ^{4x}	0.05	8.4	7.9
Dining Fork 05040001 07 03									
Dining Fork EWH recommended									
303626	from TR 382, Pontiff Rd.	6.3	3.1	0.05 ^{2x}	1.00	0.53	0.09	9.4	7.7
303627	TR 645, Tartan Rd.	4.3	6.3	0.07 ^{3x}	0.59	0.34	0.03	7.8	7.6
303628	SR 151, Scio-Bowerston Rd. (7x)	0.2	14.7	0.09	0.67	0.51	0.05	7.8	7.6
Kirby Run EWH recommended									
303629	adj. SR 332, Scio Rd.	0.7	3.4	0.06 ^{1x}	0.33	0.44	0.03	7.4	7.7
Headwaters Lower Conotton Creek 05040001 07 07									
Scott Run (not assessed for attainment status)									
303630	SR 151, Scio-Bowerston Rd.	0.7	3.1	0.20	0.41	1.94	0.15	5.1	7.4
Conotton Creek Tributary (RM 28.20) WWH recommended									
303618	CR 43, Bower Rd.	0.6	3.8	0.19	0.72	1.08	0.18	8.1	7.6

Table 14 continued.

Station	Stream / Location	RM	Mi ²	NH ₃ -N	NO ₃ +NO ₂ -N	TKN	TP	D.O.	pH
McGuire Creek 05040001 07 06									
McGuire Creek WWH recommended, EWH recommended ust. RM 7.57									
303616	adj. CR 17, Aster Rd.	9.9	2.7	0.06 ^{1x}	0.21	0.30 ^{3x}	0.03	8.0	7.9
303617	TR 374, Plymouth Rd.	8.3	7.1	0.09 ^{4x}	0.48	0.37	0.04 ^{4x}	7.6	7.8
R08W04	dst. Leesville Lake dam (7x)	1.4	48.0	0.48	0.12 ^{2x}	0.82	0.04	8.6 ^{5x}	7.5 ^{6x}
Long Creek EWH recommended									
303631	CR 8, Alamo Rd.	0.7	1.7	ND	0.34 ^{4x}	0.40 ^{4x}	0.07 ^{4x}	7.7	7.9
North Fork McGuire Creek 05040001 07 05									
North Fork McGuire Creek EWH recommended									
303632	TR 354, Pebble Rd.	9.4	4.1	0.09 ^{4x}	0.30	0.49	0.06 ^{4x}	6.3	7.8
303633	CR 19, Autumn Rd.	7.7	6.9	ND	0.24	0.62 ^{3x}	0.06	7.6	7.9
303542	SR 322, Scio Rd. (12x)	6.0	11.3	0.09 ^{4x}	0.40 ^{10x}	0.61 ^{11x}	0.08	8.6 ^{9x}	8.0 ¹⁰
Bear Hole Run EWH recommended									
303634	CR 54, Canyon Rd. (USGS 6x)	1.7	1.4	0.02	0.94	TN1.21 ^{4x}	0.04	9.9	7.5
Thompson Run-Conotton Creek 05040001 08 03									
Conotton Creek Tributary (RM 17.22) WWH recommended									
303635	pipeline	1.0	6.3	0.08 ^{4x}	0.15 ^{4x}	0.66	0.04	5.5	7.4
Thompson Run WWH recommended									
303615	from SR 39, Roswell Rd.	0.7	3.7	0.08	0.26	0.48 ^{3x}	0.03	8.0	7.4
Cold Spring Run-Indian Fork 05040001 08 01									
Indian Fork WWH recommended									
R08W03	SR 332, Scio Rd.	13.9	12.3	0.08 ^{4x}	3.76	0.62	0.63	9.5	7.8
Pleasant Valley Run-Indian Fork 05040001 08 02									
303543	from SR 39, Roswell Rd. (12x)	9.0	33.5	0.11	1.44	0.70	0.18	7.2	7.6
R08S15	dst. Atwood Lake dam, SR 212 (7x)	0.5	70.0	1.01	0.12 ^{2x}	1.37	0.16	8.6	7.3
Cold Spring Run-Indian Fork 05040001 08 01									
Gantz Creek WWH recommended									
303639	TR 354, Pebble Rd.	1.2	7.3	0.06 ^{3x}	0.59	0.50	0.05	9.6	7.9
Friday Creek WWH recommended									
303640	CR 66, Chase Rd.	1.2	3.5	0.11 ^{3x}	0.47	0.96	0.04	8.3	7.7
Honey Run WWH recommended									
R08P01	ust. Carrollton WWTP/ trib. (7x)	0.8	3.4	0.07 ^{5x}	0.68	0.33 ^{6x}	0.04	8.0	7.8
303642	dst. Carrollton WWTP (7x)	0.6	3.8	0.08 ^{6x}	7.75	0.85	1.34	8.0	7.7
Cold Spring Run WWH recommended									
303644	from SR 39, Roswell Rd.	0.6	5.9	0.07 ^{3x}	0.73	0.52	0.04	10.3	7.9
Pleasant Valley Run WWH recommended									
303646	TR 147, Folsam Rd.	1.5	6.5	0.10 ^{4x}	0.37	0.35	0.03	8.0	7.7
Pleasant Valley Run-Indian Fork 05040001 08 02									
Willow Run WWH recommended									
303649	CR 29, Bedrock Rd. (USGS 6x)	1.5	7.7	0.03	0.65 ^{5x}	TN0.91 ^{5x}	0.03	9.7	7.8
Elliot Run WWH recommended									
303702	CR 69, Clay Rd.	1.4	3.5	0.08 ^{4x}	0.40	0.26 ^{4x}	0.03 ^{4x}	9.7	7.7
Indian Fork Tributary (RM 3.30) WWH recommended									
303651	SR 542 (USGS 6x)	1.4	3.4	0.07	0.66	TN 1.14	0.04	9.6	7.9
Dog Run-Conotton Creek 05040001 08 05									
Conotton Creek Tributary (RM 11.37) WWH recommended									
303614	TR 320, Dawn Rd.	0.3	4.6	0.08	0.26 ^{4x}	0.84	0.05	5.8	7.3
Conotton Creek Tributary (RM 7.67) WWH recommended									
303654	TR 388, Brown Hill Rd.	2.9	3.8	0.06 ^{3x}	0.20	0.42 ^{3x}	0.03 ^{4x}	9.7	7.8
Beggar Run WWH recommended									
303653	CR 90, New Cumberland Rd.	0.5	4.0	0.05 ^{2x}	0.20	0.42	0.02	7.9	7.7
Huff Run 05040001 08 04									
Huff Run WWH recommended									

Station	Stream / Location	RM	Mi ²	NH ₃ -N	NO ₃ +NO ₂ -N	TKN	TP	D.O.	pH
300601	TR 170, Heritage Rd.	7.8	3.3	0.06 ^{3x}	0.69	0.73	0.04	8.3	7.7
300599	CR 36, Brass Rd.	5.5	6.5	0.09	0.23	0.66	0.02	8.9	7.5
300595	CR 90, New Cumberland Rd. (10x)	1.3	11.8	0.13	0.77	0.45	0.05	7.4	6.7 ^{9x}

Table 15. Ohio EPA drainage area stratified WAP ecoregion reference sites 90th percentile values, all sites 90th percentile values, and all sites 95th percentile values for selected nutrients, dissolved oxygen, and pH. For dissolved oxygen and pH, the contrasting 10th and 5th percentile values are presented in the underlying row.

Parameter	Symbol	Unit	Headwaters	Wading	Small River
			(<20 mi ²)	(20-200 mi ²)	(200-1000 mi ²)
			<i>P</i> _{90%} reference sites (<i>P</i> _{90%} all sites) <i>P</i> _{95%} all sites		
Ammonia	NH ₃ -N	mg/L	0.08 (0.15) <u>0.27</u>	0.10 (0.15) <u>0.29</u>	0.10 (0.13) <u>0.26</u>
Nitrate+Nitrite-N	NO ₃ +NO ₂ -N	mg/L	0.65 (1.13) <u>2.16</u>	1.39 (1.65) <u>3.55</u>	1.91 (2.10) <u>2.71</u>
Total Kjeldahl Nitrogen	TKN	mg/L	0.38 (0.71) <u>0.97</u>	0.52 (0.80) <u>1.07</u>	0.64 (0.71) <u>0.89</u>
Total Phosphorus	TP	mg/L	0.07 (0.10) <u>0.25</u>	0.14 (0.19) <u>0.39</u>	0.27 (0.21) <u>0.28</u>
Dissolved Oxygen	D.O.	mg/L	9.6 (10.2) <u>11.4</u>	9.6 (10.5) <u>12.0</u>	11.9 (9.2) <u>10.0</u>
<i>P</i> _{10%} (<i>P</i> _{10%}) <i>P</i> _{5%}			5.5 (5.1) <u>4.3</u>	5.3 (5.6) <u>4.9</u>	5.9 (5.4) <u>4.8</u>
“power of hydrogen”	pH	s.u.	8.3 (8.2) <u>8.4</u>	8.3 (8.2) <u>8.4</u>	8.4 (8.2) <u>8.3</u>
<i>P</i> _{10%} (<i>P</i> _{10%}) <i>P</i> _{5%}			7.1 (7.1) <u>6.8</u>	7.3 (7.3) <u>7.1</u>	7.7 (7.4) <u>7.2</u>

Other Conotton mainstem sites were stable and showed no signs of enrichment given that the D.O. range and benthic chlorophyll- α density were both low throughout the segment. The upstream and downstream bracketing of final effluent from the Scio, Bowerston, Leesville, and Atwood Regional WWTPs showed no change in nutrient status and no indication of downstream enrichment.

Among tributaries, the Jefferson Creek August D.O. diel range (above 7 mg/L) was the most extreme. However, water chemistry indicators of nutrient enrichment were not remarkable, and a single benthic chlorophyll- α collection density was low. The opposite condition was documented in Honey Run at sites bracketing the Carrollton WWTP (Figure 13 and Figure 14). The well forested area surrounding the facility was credited for moderating sunlight and thus precluding wide D.O. swings as well as checking prolific algal growth. Even so, Honey Run benthic chlorophyll- α density was elevated, likely in response to nutrient abundance.

Although upstream from the Carrollton WWTP geometric mean (\bar{x}_{geom}) nutrient values were elevated (NO₃+NO₂-N \bar{x}_{geom} =0.5 mg/L, TP \bar{x}_{geom} =0.04 mg/L), downstream sample concentrations were alarming (NO₃+NO₂-N \bar{x}_{geom} =7.5 mg/L, TP \bar{x}_{geom} =1.25 mg/L). Two effluent samples confirmed the high nitrate+nitrite-N (\bar{x} =11.1 mg/L) and TP (\bar{x} =2.4 mg/L) concentrations emanated from the WWTP. The facility DMR nitrate+nitrite-N values were similar, but TP concentrations were significantly less. The combination of ample DIN and TP concentrations in Honey Run represented a high risk for aquatic life use impairment attributable to the Carrollton WWTP discharge. Downstream in Indian Fork, nutrient concentrations remained stressful, albeit at a moderated level (Figure 15).

Despite the moderate risk inferred from DIN and TP concentrations, high amounts of ammonia-N downstream from Atwood Lake (\bar{x} =1.01 mg/L) were sufficient to be considered toxic to aquatic life. Similarly, routine release of ammonia-N downstream from Leesville Lake (\bar{x} =0.48 mg/L) was at least chronically stressful.

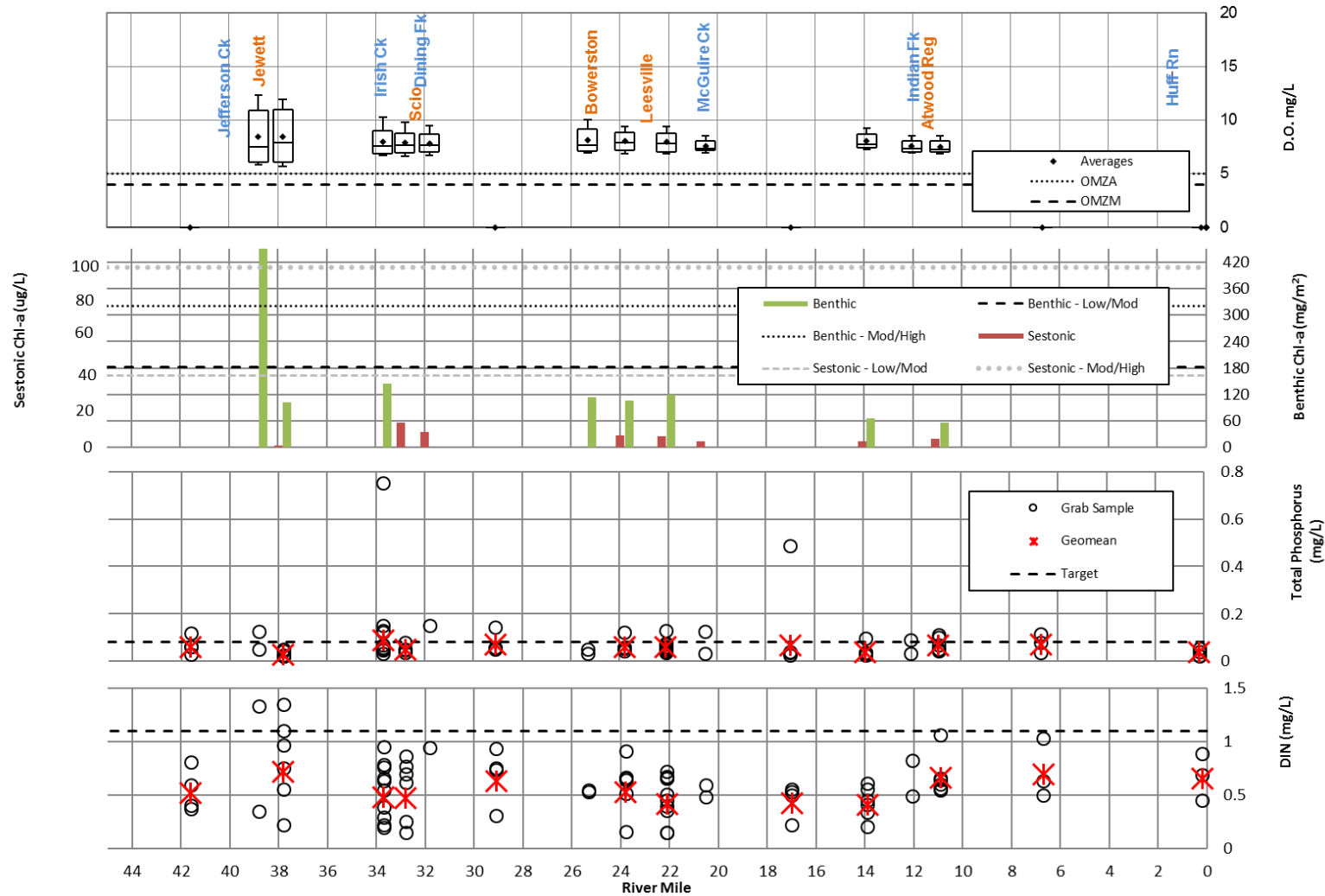


Figure 12 – Longitudinal representation of dissolved oxygen (D.O.) concentrations and chlorophyll-a (sestonic and benthic) densities based on the **July 3-5, 2016** sonde deployment with total phosphorus and dissolved inorganic nitrogen (DIN) chemistry values obtained during the June 15 to October 15, 2016 survey period to support a trophic assessment of **Conotton Creek** from RM 41.6 (upstream from the Village of Jewett) to RM 0.2 (near the mouth). Relevant water quality standards and targets are shown with each parameter. Locations of WWTPs (in brown) and selected tributaries (in blue) are labeled on the D.O. plot.

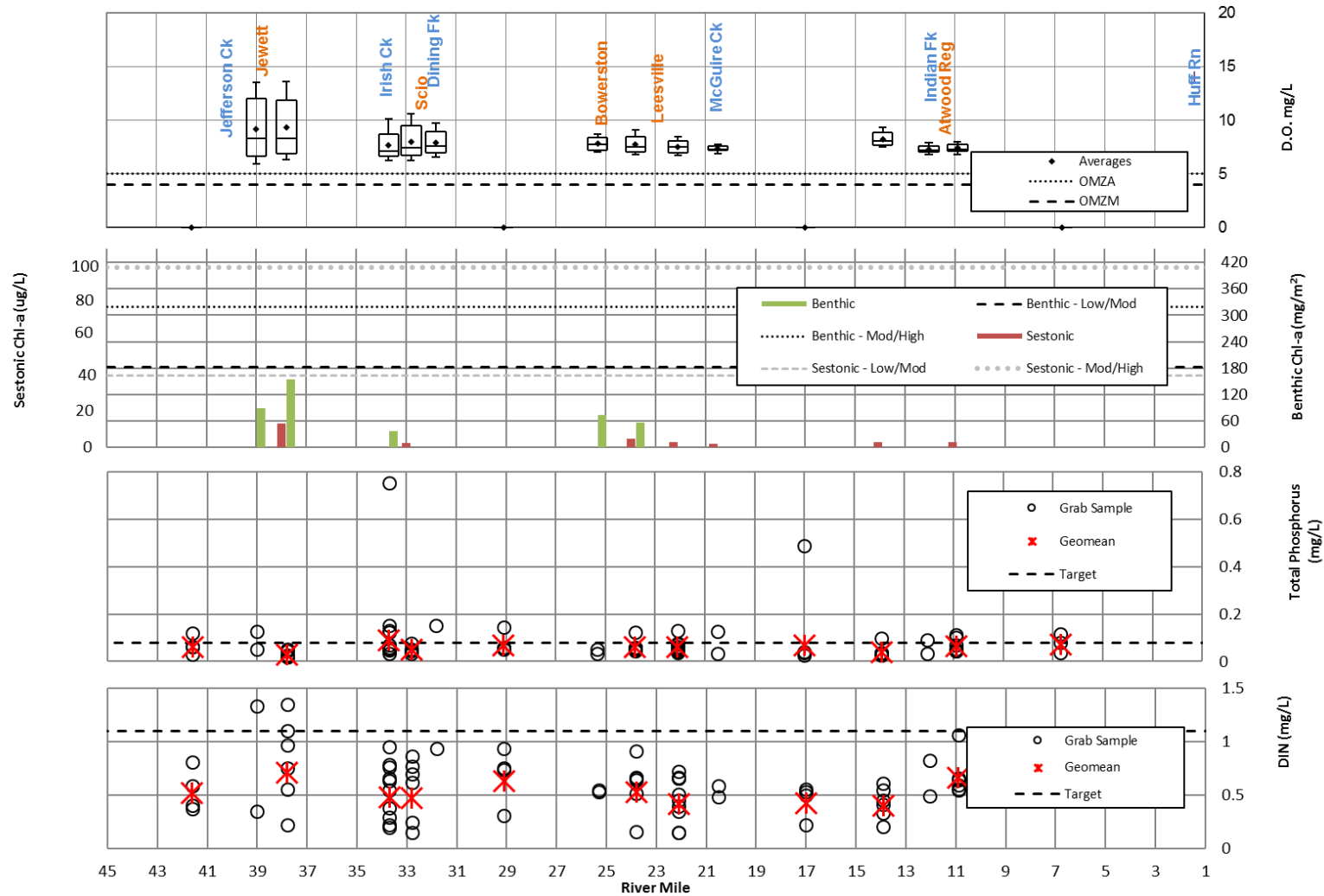


Figure 13 – Longitudinal representation of dissolved oxygen (D.O.) concentrations and chlorophyll-a (sestonic and benthic) densities based on the **August 23-25, 2016** sonde deployment with total phosphorus and dissolved inorganic nitrogen (DIN) chemistry values obtained during the June 15 to October 15, 2016 survey period to support a trophic assessment of **Conotton Creek** from RM 41.6 (upstream from the Village of Jewett) to RM 0.2 (near the mouth). Relevant water quality standards and targets are shown with each parameter. Locations of WWTPs (in brown) and selected tributaries (in blue) are labeled on the D.O. plot.

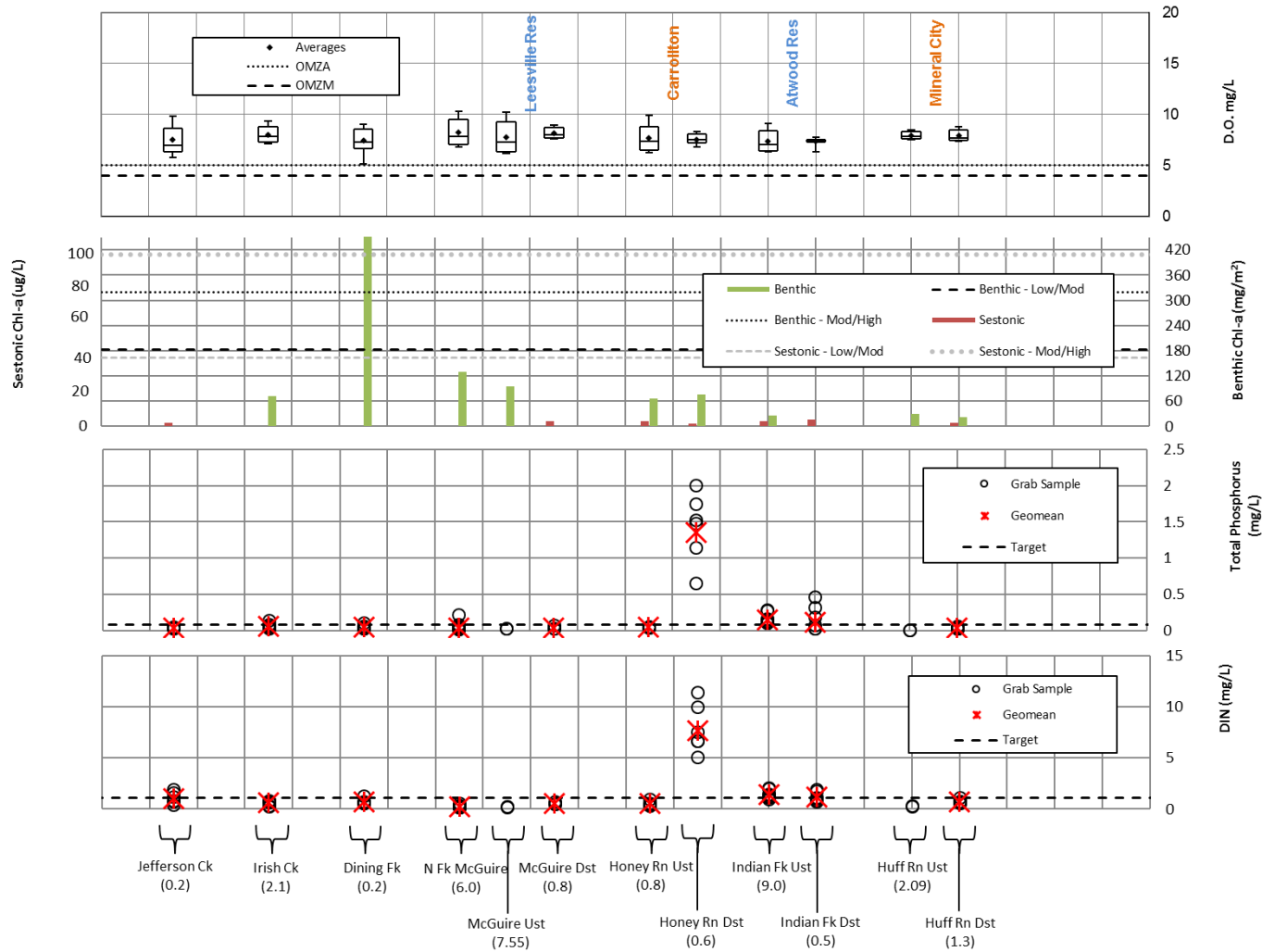


Figure 14 – Comparison of dissolved oxygen (D.O.) concentrations and chlorophyll-a (sestonic and benthic) densities based on the July 3-5, 2016 sonde deployment with total phosphorus and dissolved inorganic nitrogen (DIN) chemistry values obtained during the June 15 to October 15, 2016 survey period to support a trophic assessment of **selected Conotton Creek tributaries**. Relevant water quality standards and targets are shown with each parameter. Locations of Leesville and Atwood Lakes (in blue) and of Carrollton and Mineral City WWTPs (in brown) are noted on the D.O. plot.

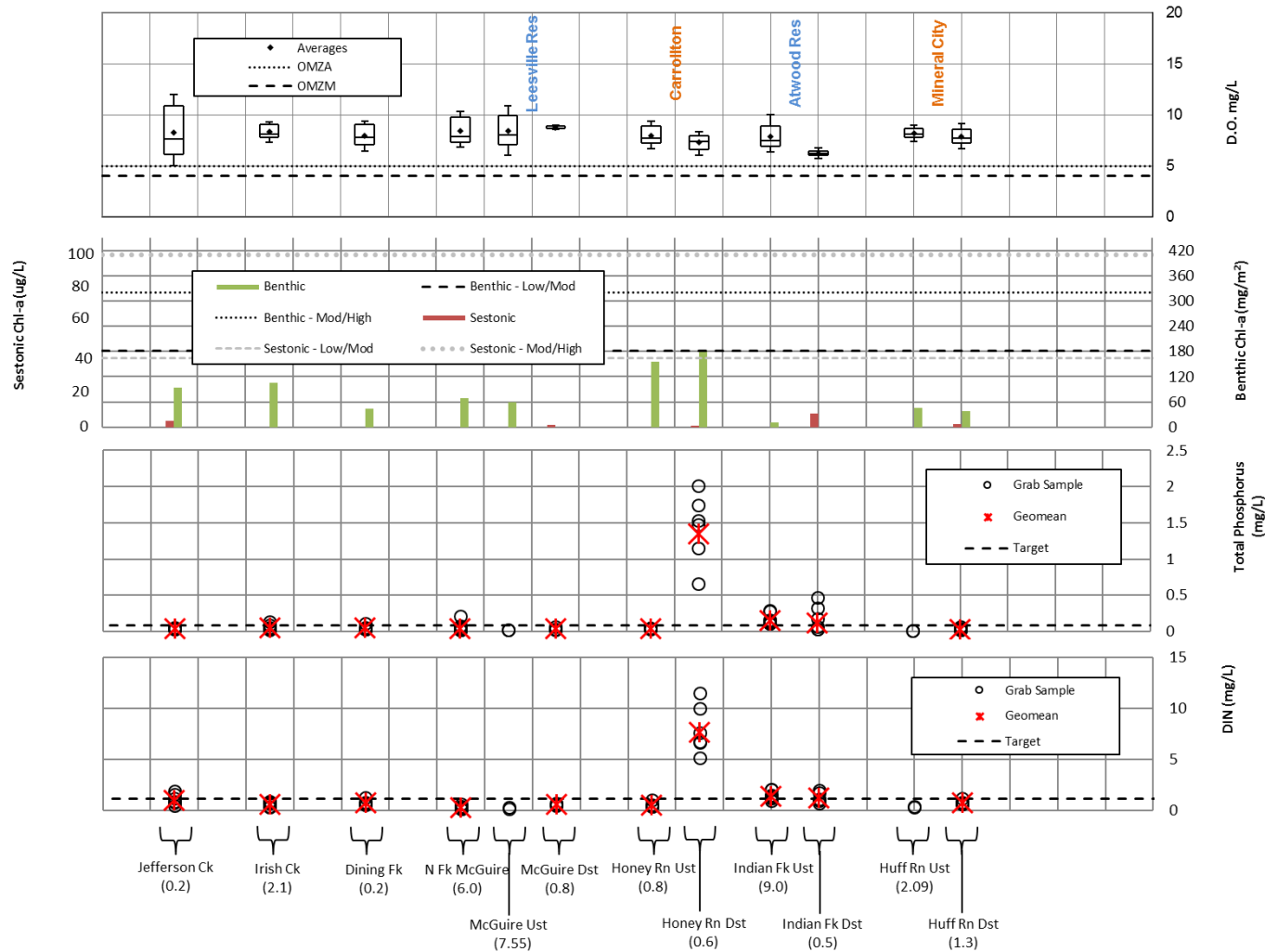


Figure 15 – Comparison of dissolved oxygen (D.O.) concentrations and chlorophyll-a (sestonic and benthic) densities based on the **August 23-25, 2016** sonde deployment with total phosphorus and dissolved inorganic nitrogen (DIN) chemistry values obtained during the June 15 to October 15, 2016 survey period to support a trophic assessment of **selected Conotton Creek tributaries**. Relevant water quality standards and targets are shown with each parameter. Locations of Leesville and Atwood Lakes (in blue) and of Carrollton and Mineral City WWTPs (in brown) are noted on the D.O. plot.

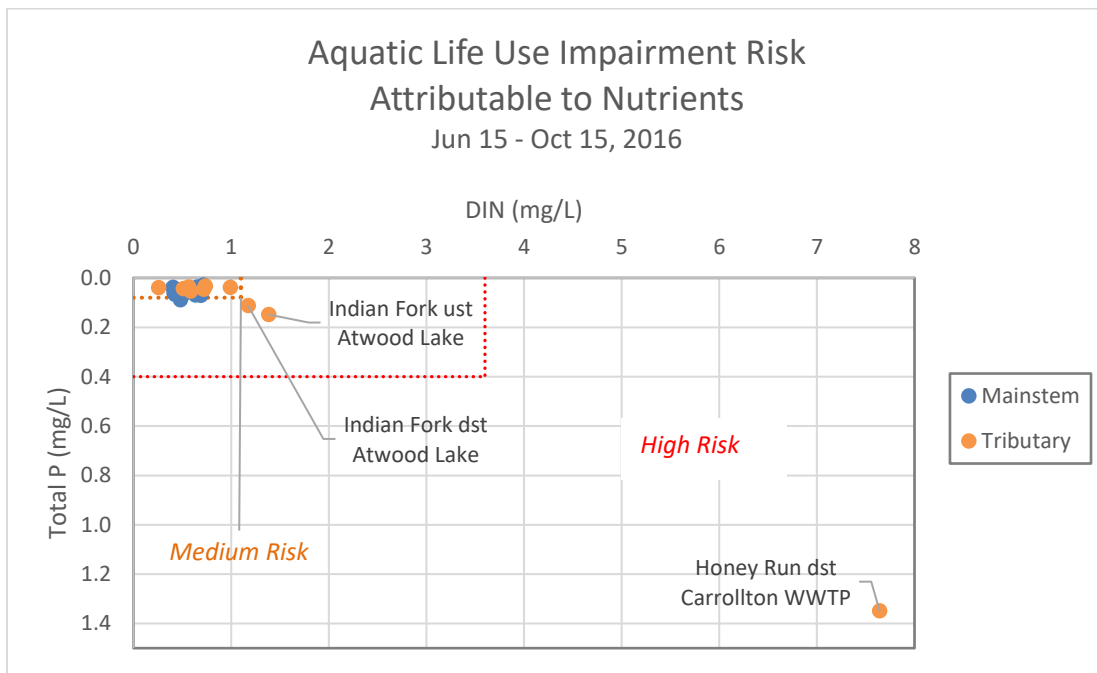


Figure 16 – Geometric mean concentrations (mg/L) of dissolved inorganic nitrogen (DIN) and total phosphorus (Total P) in the Conotton Creek study area, 2016. High risk (red) and medium risk (orange) boundaries segregate sites where aquatic life is likely to experience nutrient stress. Nutrient enrichment in Honey Run downstream from the Carrollton WWTP presented a high risk for aquatic life use impairment. Continuing downstream in Indian Fork through Atwood Lake, nutrient stress was a moderate risk for aquatic life. Nutrients presented a low risk to aquatic life at most Conotton Creek study sites.

Sediment Quality

Surficial sediment samples were collected at nine locations in the Conotton Creek watershed in 2016 and at three Huff Run sites in 2009 (Table 16 and Appendix G). All samples were analyzed for percent solids and metals. The presence of semi-volatile organic constituents [base neutral acid extractables (BNAs) and polycyclic aromatic hydrocarbons (PAHs)] and polychlorinated biphenyls (PCBs) was evaluated for just 2016 samples. Sampling locations were selected to determine background sediment quality, to assess the impact from plausible sources, and to evaluate downstream transport. Samples were collected following the *Sediment Sampling Guide and Methodologies, 3rd Edition* (OHIO EPA, 2012). Sample collection focused on depositional areas of fine grain material. The goal was to collect a representative sample that was composed of more than 30% silt and clay particles. These fine-grained particles are physically, chemically, and biologically reactive because they hold more interstitial water and have unbalanced electrical charges that can attract contaminants. One composite sample was created for each location. Sampling staff waded each stream in proximity (<50m) to the site bridge crossing or road access, collected scoops of depositional material wherever it could be found, and mixed all subsamples together in a stainless-steel pan.

Sediment sample results were evaluated using Tier I procedures for aquatic life described in *Guidance on Evaluating Sediment Contaminant Results* (OHIO EPA, 2010) and “Sediment Sampling Data Quality Objectives for Biological and Water Quality Studies,” in *Surface Water Field Sampling Manual for water quality parameters and flows* (OHIO EPA, 2015). Numeric sediment quality guidelines (SQGs) were developed by Ohio EPA to identify representative background sediment metal concentrations for lotic water bodies. These *Sediment Reference Values* (SRVs), discussed in *Ecological Risk Assessment Guidance Document* (Ohio EPA, 2018), were based on samples from sites that had served similarly in the development of biological criteria for aquatic life use assessment. The ecoregion specific SRVs are not codified in Ohio WQS. However, a result greater than an SRV suggests contamination may exist.

MacDonald, Ingersoll, and Berger (2000) present values for 28 chemicals of concern in “Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems”. Their SQGs define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to occur.

Potassium, selenium, and sodium were not present in method detectable amounts in sediment samples from the Conotton Creek basin obtained in 2016, nor in 2009. Likewise, sediment from three 2016 mainstem Conotton Creek locations appeared normal without any discrepancies. The area’s coal mining heritage was evident in high iron concentrations present in the North Fork McGuire Creek and in Huff Run. Since 1996, the Huff Run Watershed Restoration Partnership has worked to improve area water quality. Despite completing a dozen remedial projects, arsenic, nickel, and zinc sediment concentrations have routinely exceeded Ohio SRVs or TECs and were deemed likely to exert aquatic community stress.

South from and adjacent to Huff Run, Beggar Run also had modestly elevated amounts of nickel and zinc in sediment. But the low-level presence of PCB-1254 (0.043 mg/kg or 43.4 µg/kg) was unique. The Toxic Substances Control Act banned PCB distribution and use in 1979. Even so, the low bioavailability of chlorinated hydrocarbons which enables the various congeners to resist biodegradation has been evidenced by their environmental persistence. Brook trout eggs and fry exposed to water borne Aroclor 1254 (0.43 to 13 µg/L) were generally unaffected by the lowest studied dose (Mauck, Mehrle, and Mayer, 1978). Field-collected

copepods (*Microarthridion littorale*) exposed to Aroclor 1254 (251 to 4 mg/kg) contaminated sediment experienced mortality with high concentrations (83 mg/kg) and impaired reproduction at low concentrations (4 mg/kg, Dipinto, Coull, and Chandler, 1993). These studies and the TEC for total PCBs (59.8 µg/kg) suggest the amount detected in Beggar Run was unlikely to exert environmental stress.

Table 16 - Sediment detected metal and organic compound [polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)] concentrations (mg/kg dry weight) at selected Conotton Creek study area sites, 2016 and at Huff Run sites, 2009. Results greater than Ohio Sediment Reference Values (SRV, after parameter) are underlined. Results less than Threshold Effect Concentrations (TEC, in italics, after parameter and SRV) are unlikely to be harmful (MacDonald, Ingersoll, and Berger 2000). Italicized results exceed the TEC. Results exceeding the Probable Effect Concentration (PEC, in bold after TEC) appear in bold with gray shade. Results less than reporting limits (<RL) or for no applicable (NA) data are so indicated.

Parameter	SRV	TEC /PEC	2016									2009		
			Conotton Creek RM 37.8 (R08S04)	Conotton Creek RM 32.5 (R08K05)	Conotton Creek RM 11.4 (R08S14)	Irish Creek RM 2.6 (R08S13)	Dining Fork RM 0.2 (303628)	N. Fk. McGuire Creek RM 6.0 (303542)	Indian Fork RM 13.9 (R08W03)	Beggar Run RM 0.5 (303653)	Huff Run RM 1.3 (300595)	Huff Run RM 4.2 (300603)	Huff Run RM 2.8 (300596)	Huff Run RM 1.3 (300595)
% Solids			62.1	50.6	68.3	65	66	55.6	41.5	58.7	37.4	25.8	42.7	30.5
Aluminum	<u>53,000</u>		2,570	6,610	4,930	3,620	4,690	8,370	7,890	6,730	8,840	13,000	8,670	11,900
Arsenic	<u>19</u>	9.79 / 33.0	2.84	8.7	5.4	5.74	5.94	8.27	6.97	6.04	12.8	13.9	10.2	15.5
Barium	<u>360</u>		40	96.4	49.5	49	55.1	96.3	153	44.4	72	141	115	108
Cadmium	<u>0.8</u>	0.99 / 4.98	0.112	0.307	0.233	0.127	0.23	0.312	<u>1.16</u>	0.449	0.696	0.466	0.163	0.339
Calcium	<u>27,000</u>		5,370	6,180	1,110	1,230	1,420	3,460	9,490	3,810	3,950	3,740	3,040	4,180
Chromium	<u>53</u>	43.4 / 111	5.05	10.8	9.07	6.8	7.05	13.5	28.1	9.63	11.5	15.1	12.4	17.6
Copper	<u>33</u>	31.6 / 149	5.77	11.5	7.22	4.68	5.41	8.84	<u>36.4</u>	11.0	19.2	20.3	11.9	23.2
Iron	<u>51,000</u>		11,200	22,800	17,100	17,700	17,400	<u>57,400</u>	23,600	23,700	<u>145,000</u>	<u>169,000</u>	<u>59,200</u>	<u>125,000</u>
Lead	<u>47</u>	35.8 / 128	7.96	19.7	9.52	8.25	8.52	15	42.7	10.3	22.3	18.6	14.8	39
Magnesium	<u>9,900</u>		1,190	2,750	1,080	1,040	1,110	1,650	4,030	1,970	1,590	2,080	2,080	2,080
Manganese	<u>3,000</u>		522	1,120	382	702	851	1,400	1,450	5,270	1,370	1,840	1,880	2,000
Nickel	<u>61</u>	22.7 / 48.6	7.96	14.2	11.4	9.03	9.45	12.8	22.8	40.1	46.0	62.7	21.2	43.5
Strontium	<u>250</u>		<17	27	<17	<16	<16	<19	37	19	<28	<34	29	38
Zinc	<u>170</u>	121 / 459	33.2	73.3	59.2	39.2	54.1	79.2	157	109	<u>409</u>	<u>310</u>	86.5	<u>264</u>
Fluoranthene		0.42 / 2.23	<RL	<RL	<RL	<RL	<RL	<RL	4.6	<RL	<RL	NA	NA	NA
PCB-1254		0.06 / 0.68	<RL	<RL	<RL	<RL	<RL	<RL	<RL	0.043	<RL	NA	NA	NA

Aside from the PCB in Beggar Run, the only other organic compound detected in the 2016 study area was fluoranthene (4.6 mg/kg or 4,600 µg/kg) present in Indian Fork sediment at RM 13.9, SR 332, Scio Rd. (R08W03). The amount of this PAH exceeded the PEC (2,230 µg/kg) twice over and was an order of magnitude greater than the TEC (423 µg/kg).

Gendusa (1990) compared the effects of sediment and aqueous concentrations of fluoranthene on the survivability of Fathead Minnows (*Pimephales promelas*) and Channel Catfish (*Ictalurus punctatus*) along with observations of the sublethal toxicity to Bluegill Sunfish (*Lepomis macrochirus*). His doctoral study explored challenges associated with standard bioassay type testing. For instance, fluoranthene transformed during both sediment and aqueous tests and under various light exposures with an average loss of half (47.6 %) of the initial treatment concentration. Fluoranthene was differently toxic to the tested fish perhaps in respect to trophic characteristics. Sediment sourced fluoranthene killed all Fathead Minnows at roughly half the concentration (83.1 µg/L) needed for essentially full saturation of the aqueous solution (155.4 µg/L) which achieved 69% mortality. Conversely, Channel Catfish tolerated a higher sediment concentration (119.6 µg/L) before mortality, compared to the relatively low aqueous killing concentration (79.4 µg/L). The maximum aqueous fluoranthene concentration (280.1 µg/L) achieved by Gendusa occurred over an especially high sediment concentration (89,278 µg/kg). Sediment concentrations between 3,239.5 µg/kg and 553.5 µg/kg were associated with aqueous concentrations ranging from 14.8 µg/L to 26.2 µg/L respectively, as fluoranthene was liberated and lost over 96-hour intervals.

PAHs such as fluoranthene are all too common. Although natural sources such as incomplete combustion from a forest fire are plausible, anthropogenic contributors via gasoline derivatives, wood preservatives, and wastewater effluent are routinely affiliated with PAH contamination. Detection of fluoranthene in Indian Fork downstream from the Carrollton WWTP may reflect a relationship, but PAHs come from too many sources to be sure of such an allegation. However, the suite of elevated sediment metal concentrations also measured in Indian Fork at RM 13.9 suggested the relationship was more than coincidental. Copper (36.4 mg/kg) and cadmium (1.16 mg/kg) concentrations exceeded the SRV and TEC values. While lead (42.7 mg/kg) and zinc (157 mg/kg) concentrations were above the TEC and notably greater than values from nearby streams.

Collectively, the sediment in the reach of Indian Fork near RM 13.9 and in Honey Run downstream from the Carrollton WWTP appeared to store pockets of contamination that could exert toxic effects on aquatic life. Modification of Carrollton's wastewater treatment technology should be invoked to remediate this concern.

Physical Habitat for Aquatic Life

Stream habitat conditions were assessed at 48 Conotton Creek basin fish sampling sites in 2016 (Table 17). Based on the functional ability to support fish, each sites substrate, instream cover, and channel characteristics were scored 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 aquatic life use. And very good QHEI values above 75 are correlated with achievement of the EWH aquatic life use. 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.

Aquatic habitat conditions in Conotton Creek were marginally good at 11 mainstem locations (QHEI \bar{x} =57.6, Figure 16). Similar habitat qualities were observed at 36 tributary sites in the Conotton Creek watershed (QHEI \bar{x} =58.5). Generally, the low gradient Conotton Creek mainstem lacks functional riffles, is incised and bedload is comprised by an excessive amount of fine sediment. Tributary streams exhibited better riffle and pool development in consequence of typically higher gradients but were also subject to the variability of immediate land use influences. Tributaries in the McGuire Creek sub-basin, often flanked by wooded corridors, tended to have good habitat conditions. Streams in the Dining Fork and Irish Creek sub-basins were affected by unrestricted livestock access and drainage alterations. These agricultural practices were prone to affect marginally good stream habitat. Fair habitats were observed in direct tributaries to Atwood Lake where limited stream flow exacerbated the recovery of formerly channelized reaches. This array of land uses, historic mining, and contemporary oil and gas development combined in other stream sub-basins to often yield less than optimal habitat qualities.

Draining 286 mi², Conotton Creek might be expected to be wadeable throughout its course. Instead, downstream from Dining Fork, the mainstem is frequently too deep for wading. Likewise, historically channelized reaches near Scio are especially deep. A site downstream from Leesville (RM 22.0, Azalea Rd., CR 22, R08K03) was first accessed in a place between deeper pools to maintain wading sampling gear continuity. This reach was later determined to be at the upstream limits of the potential Dover Dam pool. It included an atypical shallow section overwhelmed by sand deposition and was excessively silty. Additionally, the site was found to be inordinately deep at the time of the first fish sample and the entire zone was curtailed to 125 meters long; 75 meters less than preferred. A second sample was completed with a boat immediately downstream from the first zone. The challenges of this sample location were manifest again farther downstream in Sherrodsville (RM 17.0, Sherrodsville Park, SR 39, 303578).

The location real estate axiom is particularly pertinent to dams. Early settlers were quick to notice any favorable stream bottleneck where a dam and mill could be erected. The lack of shallow riffle locations in Conotton Creek made the few tenable dam sites at Bowerston, Sherrodsville, and near New Cumberland especially prime property. Remnant hewn logs of the former Sherrodsville mill dam were still embedded in the substrate in 2016. Very good stream habitat here (QHEI=77.5), centered around the riffle that the dam was once anchored above. With large aggregate and wide-ranging flow dynamics created by an appreciable gradient drop, the smothering fine sediment typical at other sites had less influence here. As with the reach near Leesville, the wadeable part of Conotton Creek near Sherrodsville was limited by a deep downstream

pool and further confined by an upstream railroad bridge. Figure 16 shows the difference between the lack of a riffle at the Leesville site and the presence of one in Sherrodsville.

Unfortunately, riffle quality at sites downstream from Sherrodsville has been compromised by Dover Dam. Dover Dam on the Tuscarawas River can slow Conotton Creek flow anywhere within the reach downstream from Sherrodsville. For example, holding water behind Dover Dam at 880 FMSL will check Conotton Creek flow downstream from the Beggar Run confluence. At that time, backwater conditions also exist in the lower one-mile reach of Huff Run and in nearby mainstem tributaries. The slowed flow disrupts stream sediment transport capability. Consequently, substrate conditions in Conotton Creek and lower reach tributaries are prone to be excessively silty. Swales of sandy fines rising from deeper pools often infused with an abundance of tree limbs and woody debris acted as riffles in the reach affected by Dover Dam.

The sporadic aspect of prior Ohio EPA Conotton Creek assessments, five locations in five previous years, makes it difficult to posit any summary statements (Figure 16). No trend or definitive changes were evident. Perception of differences based on one or two sites can be misleading in the same way that reliance on an individual QHEI score is not as representative as an aggregate average is. In Figure 16, the 2016 QHEI score for the excessively sandy and silty reach that was devoid of a functional riffle near Leesville (RM 22.0) provides an impression that habitat declined at that site in comparison to prior assessments. However, previous evaluations did not encompass the reach overwhelmed by fines and the average of 2016 QHEI scores (60.4) at sites immediate to RM 22.0 (RM 29.1 to RM 13.9, n=5) is comparable to the earlier tabulations.

Good habitat conditions in Huff Run (QHEI \bar{x} =66.9) at three sites were consistent with previous observations. Ohio EPA and ODNR Division of Mineral Resources have completed 29 Huff Run habitat quality evaluations at 12 sites since 1997 (QHEI \bar{x} =65.5). Sampling occurred most frequently at RM 7.5, Heritage Rd. (TR 170, 300601) where QHEI scores ranged from 59.0 to 75.0 in six samples (\bar{x} =67.8) and at RM 5.5, Brass Rd. (CR 36, 300599) where five samples scored between 59.6 and 74.3 (\bar{x} =67.1). Orange, iron precipitate smothered Huff Run substrate at RM 5.5 and was apparent throughout the downstream reach. This symptom of acid mine drainage can impede aquatic life if flocculants restrict access to interstitial spaces in stream bed aggregate. The 2016 QHEI score (59.6) at RM 5.5 was lower than prior evaluations. The perceived decline at this site was attributed to the excessive amount precipitate that has been increasing there over time.

Although fish communities in a few other Conotton Creek tributaries were evaluated in 1984, those investigations occurred before the QHEI was developed and no habitat scores were developed retrospectively for those assessments.

Table 17 - Qualitative Habitat Evaluation Index (QHEI) matrix with warmwater habitat (WWH) and modified warmwater habitat (MWH) attribute totals and ratios for the Conotton Creek study area, 2016.

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															
									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					
Conotton Creek																																		
41.6	48.5	□	□	□	□			□		5			◇			1	○	○		○	○			○	○	○	○	○	○	○	○	7	0.33	1.50
37.8	48.3		□			□		□		3			◇	◇		2	○	○			○				○	○	○	○	○	○	○	6	1.00	2.00
32.5	61.3					□		□		2						0	○	○			○	○			○	○	○	○	○	○	7	0.67	3.00	
29.1	54.3					□		□		2						0	○	○			○	○			○	○	○	○	○	○	7	0.67	3.00	
23.7	72.1	□	□	□	□	□	□	□	□	7						0	○	○								○	○	○	○	○	3	0.13	0.63	
22.0	45.0	□			□	□	□	□	□	4		◇				1	○	○		○	○				○	○	○	○	○	○	6	0.40	1.60	
17.0	77.5	□	□	□	□	□	□	□	□	9						0	○	○								○				2	0.10	0.40		
13.9	53.0		□		□	□	□	□	□	4						0	○	○			○				○	○	○	○	○	6	0.40	1.60		
11.4	59.0	□	□		□	□	□	□	□	5						0	○	○			○				○	○	○	○	○	5	0.17	1.17		
6.7	58.5	□			□	□	□	□	□	4						0	○	○	○		○				○	○	○	○	○	6	0.20	1.40		
0.2	56.0	□	□		□	□	□	□	□	4				◇		1	○	○			○	○			○	○	○	○	○	6	0.40	1.60		
Jefferson Creek																																		
0.2	44.0		□					□		2	◇	◇	◇			3	○				○				○	○	○	○	○	5	1.33	2.33		
Irish Creek																																		
5.0	48.0				□			□		2		◇				1	○	○			○	○		○	○	○	○	○	○	8	1.00	3.33		
2.1	51.0				□	□		□		3						0	○	○		○	○				○	○	○	○	○	8	0.50	2.50		
Lick Fork																																		
0.2	55.3	□	□	□	□	□		□		6		◇				1	○				○				○	○	○	○	○	5	0.29	0.86		
Dining Fork																																		
6.3	54.0		□		□	□		□		4				◇	◇	2	○	○		○	○				○	○	○	○	○	7	0.80	1.60		
4.3	61.0	□	□		□	□		□		6						0	○				○	○			○	○	○	○	○	6	0.14	1.14		
0.2	57.0				□	□		□		4						0	○	○		○	○				○	○	○	○	○	7	0.40	1.80		
Kirby Run																																		
0.7	65.5	□	□	□	□	□		□		6						0	○								○	○	○	○	○	4	0.14	0.86		
Conotton Creek Tributary at RM 28.20																																		
0.6	49.5	□	□	□						3				◇	◇	2					○	○		○		○	○	○	○	6	0.75	1.75		
McGuire Creek																																		
9.9	57.0		□		□					2			◇	◇		2	○	○			○				○	○	○	○	○	6	1.33	2.33		
8.3	62.0	□	□		□					3					◇	1	○				○	○			○	○	○	○	○	6	0.50	2.00		
1.4	53.6	□	□		□			□	□	5						0	○	○		○	○			○	○	○	○	○	○	8	0.17	1.67		

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
Long Creek																																
0.7	58.0	□	□	□	□					4		◇			1	0	0						0	0	0	0	0	0	0	5	0.40	1.20
North Fork McGuire Creek																																
9.4	79.5	□	□	□	□	□		□	□	7						0	0	0								0	0		4	0.13	0.63	
7.7	85.5	□	□	□	□	□		□	□	8						0	0									0	0	0	3	0.11	0.44	
6.0	68.0	□	□	□	□	□		□	□	7						0	0		0						0	0	0	6	0.13	0.88		
Bear Hole Run																																
1.7	59.0	□	□		□	□		□		5						0	0		0					0	0	0	0	6	0.17	1.17		
Conotton Creek Tributary at RM 17.22																																
1.0	72.6	□		□	□	□		□		5						0	0	0	0						0	0	0	6	0.17	1.33		
Thompson Run																																
0.7	59.0	□	□	□	□	□		□		6		◇			1	0	0	0						0	0	0	0	7	0.29	1.29		
Indian Fork																																
13.9	71.0	□	□	□	□	□		□		6						0	0	0							0	0	0	5	0.14	1.00		
9.0	55.0	□		□	□	□		□		4		◇			1	0	0	0							0	0	0	6	0.40	1.60		
0.5	53.3	□	□		□	□		□		4						0	0	0	0	0					0	0	0	7	0.20	1.80		
Gantz Creek																																
1.2	65.8	□	□		□	□		□		5						0	0	0	0						0	0	0	6	0.17	1.17		
Friday Creek																																
1.2	51.5	□	□		□	□		□		4		◇			1	0	0	0	0					0	0	0	0	8	0.40	1.80		
Honey Run																																
0.8	75.5	□	□	□	□	□		□		6						0	0								0	0	0	4	0.14	0.71		
0.6	78.3	□	□	□	□	□		□		6						0	0								0	0	0	4	0.14	0.71		
Cold Spring Run																																
0.6	56.0	□	□		□	□		□		5		◇			1	0	0	0							0	0	0	6	0.33	1.17		
Pleasant Valley Run																																
1.5	56.5	□		□	□	□		□		4						0	0	0	0						0	0	0	6	0.20	1.60		
Willow Run																																
1.5	43.0	□								1		◇	◇	◇	3	0	0	0							0	0	0	6	2.00	4.00		
Elliot Run																																
1.4	32.0									0		◇	◇	◇	◇	4	0	0	0	0	0			0	0	0	0	8	6.00	10.0		
Indian Fork Tributary at RM 3.30																																
1.4	41.3	□		□		□		□		3		◇	◇		2	0	0	0	0					0	0	0	0	9	0.75	2.75		

Key QHEI types	WWH Attributes										MWH Attributes																					
	High Influence										Moderate Influence																					
	No Channelization or Recovered Boulder/ Cobble/ Gravel Substrates	Silt Free Substrates	Good/ Excellent Development	Moderate/ High Sinuosity	Extensive/ Moderate Cover	Fast Current/ Eddies	Low Normal Overall Embeddedness	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	
RM	QHEI																															
Conotton Creek Tributary at RM 11.37																																
0.3	48.5	□								2		◇				1	○	○			○	○			○	○	○			7	1.00	3.00
Conotton Creek Tributary at RM 7.67																																
2.9	60.5	□	□	□	□	□				6		◇				1	○	○			○				○	○	○			6	0.43	1.14
Beggar Run																																
0.5	47.0	□	□		□	□				4		◇	◇			2		○	○	○		○			○	○	○			7	0.60	1.80
Huff Run																																
7.8	70.5	□	□	□	□	□				6						0	○	○							○	○	○			5	0.14	0.86
5.5	59.6	□	□	□	□	□				5	◇					1	○	○	○	○				○	○	○	○			7	0.33	1.33
1.3	70.5	□	□	□	□	□				6						0	○	○					○			○	○			4	0.14	0.71

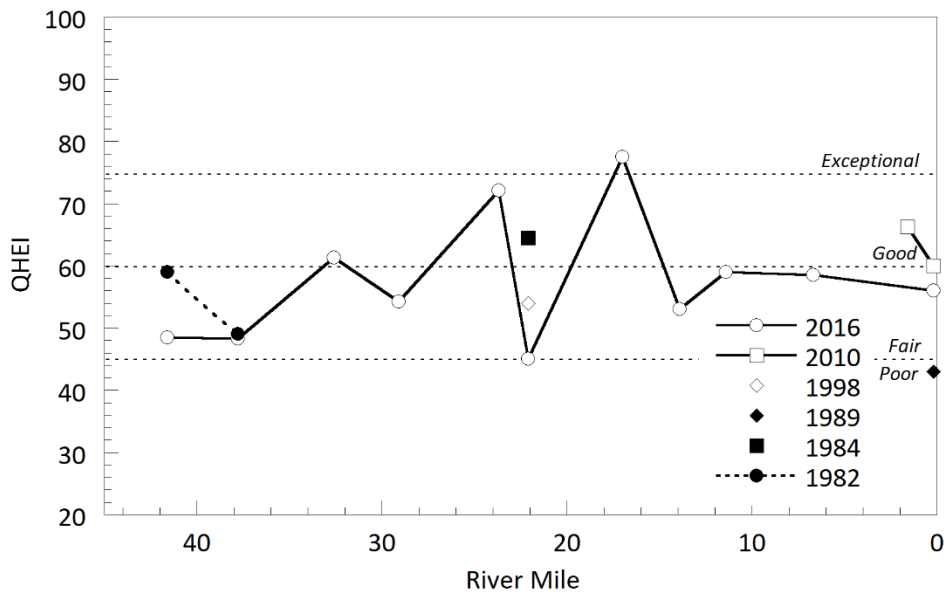


Figure 17 – Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in Conotton Creek, 1982-2016.

Fish Community

Ohio EPA collected 43,493 fish among 51 species and four hybrids in Conotton Creek and tributaries in 2016 (Table 18). The Conotton Creek mainstem was evaluated at 11 sites starting upstream from Jewett (RM 41.6) to the Tuscarawas River confluence (RM 0.2). Nine sites downstream from Scio (RM 32.6) were sampled twice. Cumulatively, 20 fish sampling passes were completed at mainstem locations. Tributary fish communities were evaluated at 37 sites. Six larger drainage area or selected tributary sites were sampled twice. In sum, 43 fish sampling passes were completed at tributary locations. Thirty-eight fish species were common across the watershed. Those and six species that were only at mainstem locations comprised 10,205 fish collected from Conotton Creek. Seven species were exclusive to tributary sites where an aggregate of 33,288 fish were collected. Overall, the Conotton Creek mainstem supported marginally good to good fish communities (IBI \bar{x} =43, MIwb \bar{x} =9.1, Figure 17). The collective performance at tributary locations was marginally good (IBI \bar{x} =42).

Recognizing the comprehensive approach and large numbers of fish, collection of only one individual of any species is an intriguing outcome for an Ohio EPA survey. Often, the plausible explanation includes a human factor such as an escapee from a bait bucket or pond stocking. An improbably large fish at a unique location might have been caught, adopted, and then released at a more convenient place. Otherwise, distinct habitat characteristics or the possibility of some other special circumstance is considered to explain the anomalous solo fish presence. Conceptually, an “endangered species” is a symptom of environmental instability. Obtaining one or two singular fish in a basin within the known species range is less compelling, unless the isolation should be construed as an indication of an unacceptable perturbation.

Collection of single specimens of six species and only two individuals of two other species in the Conotton Creek watershed in 2016 was deemed odd. And more so, because only one of these fish conformed with standard logic. Leesville Lake is renowned for its Muskellunge (*Esox masquinonogy*) population. Shallow Conotton Creek was an uncommon home for a musky at RM 11.4 in 2016. Incidentally, 29 Northern Pike (*Esox Lucius*) were also noted in Conotton Creek downstream from Indian Fork.

A Stonecat Madtom (*Noturus flavus*) in Sherrodsville was consistent with the remarkable habitat at a forgotten mill location (RM 17.0, QHEI=77.5). A mix of larger substrate with variable flow conditions offered functional habitat for many riffle or run oriented species at this site. Collection of only one madtom catfish in the Conotton Creek basin was perplexing. This location offered ideal habitat for River Chubs (*Nocomis micropogon*). A single River Chub was present in Indian Fork downstream from Atwood Lake. Its presence there, in the degraded water from the dam discharge, defied the fishes’ pollution intolerant characterization. Consistent with its pollution tolerant classification, a single Central Mudminnow (*Umbra limi*) was present in McGuire Creek downstream from Leesville Lake. The absence of this wetland-oriented species elsewhere in the Conotton Creek basin was only explained by its preference for a more glaciated region.

One Rainbow Darter (*Etheostoma caeruleum*) in a tributary confluent to Conotton Creek at RM 11.37 further confounded expectations. The species is abundant in some adjacent watersheds but is typically found in streams larger than the tributary. Goldfish (*Carassius auratus*) are not routinely present in nearby basins. The pollution tolerant fish can become naturalized where poor water quality inhibits competition from native species. It’s unlikely for an aquarium Goldfish to attain a size that would preclude its predation in most Ohio streams. Nevertheless, a yellowish-brown colored Goldfish about eight inches long was collected in Conotton Creek upstream from Bowerston (RM 29.1) in 2016. Coincidentally, Trautman (1981) reported Goldfish from Leesville Lake prior to 1980. Ohio EPA did not notice the species in 1984 or in 1998 during prior relevant

surveys. Regarding the other aforementioned species, Ohio EPA collected one Central Mudminnow in Huff Run in 2008 and one River Chub in Conotton Creek upstream from Huff Run (RM 1.6) in 2010.

The previous spurious collection of several other species was not replicated in 2016. Those fish also confound usual explanations. In particular, Trautman (1981) noted Spotted Suckers (*Minytrema melanops*) were present in Conotton Creek near and upstream from McGuire Creek prior to 1938. Ohio EPA documented Spotted Suckers in the same reach in 1984. None have been obtained since. A single Black Bullhead (*Ameiurus melas*) was also obtained in this reach in 1984. Another individual Black Bullhead was caught in Irish Creek in 1998. In 2016, single Black Bullhead were present in Dining Fork and in Indian Fork. Two individual Orangespotted Sunfish (*Lepomis humilis*) were collected from Cold Spring Run and from Pleasant Valley Run in 2016. Their presence seemed inexplicable. In contrast, Redear Sunfish (*Lepomis microlophus*), likely pond escapees, were first collected in 2016 at six different basin sites where more than one was frequent.

Seeking a pattern in these scattered sightings may be futile. Although the species in question are unlikely bait bucket returns or beneficiaries of other human intervention and the erratic presence of so many singular fish in the Conotton Creek watershed seems awry, tenable explanations were not forthcoming. Alternatively, some fish species exhibited trend like trajectories.

A single Smallmouth Bass (*Micropterus dolomieu*) in Conotton Creek upstream from McGuire Creek in 1984 may have foreshadowed the presence of eight of these fish dispersed amongst five mainstem sites in 2016. Trautman (1981) indicates Smallmouth Bass were present at a half dozen Conotton basin locations prior to 1955. Generally, this species prefers streams with a better array of substrate aggregate than Conotton Creek provided in 2016. The recent, albeit small, increase of Smallmouth Bass may indicate some water quality and substrate conditions have improved consistent with status quo implied by Trautman's records prior to 1955.

Trautman (1981) represented Silver Redhorse (*Moxostoma anisurum*) at four Conotton Creek sites between 1921 and 1954. The species was abundant at one site in 1984 ($\bar{x}=18$, $n=3$ samples). However, only one individual was collected from the same reach in 1998. Nine were obtained in 2010 from two sites downstream from the previously studied reach. In 2016, Silver Redhorse were frequent (185 were collected) at nine Conotton Creek sites downstream from Scio. Forty-five were caught in one sample from the reach studied in 1984 and in 1998. The fish was at least twice as abundant in the downstream reach compared to its presence in 2010.

The first records of Logperch Darters (*Percina caprodes*) in the watershed in 2016 further support a perception of improvement. A dozen Logperch Darters were present at a half dozen watershed sites. Smallmouth Bass, Silver Redhorse, and Logperch Darters are all sensitive to water quality degradation. Additionally, Quillback Carpsuckers (*Carpionodes carpio*) and Channel Catfish (*Ictalurus punctatus*) previously collected in 2010 were more prevalent in 2016. Trautman (1981) recorded Channel Catfish in the MWCD lakes, but Quillback Carpsuckers were not noticed.

Although prior Ohio EPA investigations in the Conotton Creek basin were not extensive, those records coupled with historic accounts provide a sufficient basis to infer Conotton Creek has experienced a tumultuous past from which it is now becoming more stable. The presence of Northern Pike at sites downstream from Indian Fork was consistent with extensive wetlands in upper reaches of the basin. However, the paucity of wetland-oriented species in proximity to marshy areas further suggested the effects of past stream modifications were extant. The fish community of Kirby Run exemplified the expected species otherwise absent at many wetland vicinity streams.

Grass Pickerel (*Esox americanus vermiculatus*), Golden Shiner (*Notemigonus crysoleucas*), and Pumpkinseed Sunfish (*Lepomis gibbosus*) typified the types of fish that should inhabit many upper Conotton basin reaches. Cool water indicative species including many Mottled Sculpin (n=33, *Cottus bairdii bairdii*), a Redside Dace (*Clinostomus elongatus*), and nine Least Brook Lamprey (*Lampetra aepyptera*) in Kirby Run suggested groundwater seepage occurred in pools and water filtering capacity was provided by riffles or wetland plants. The Kirby Run fish community included 22 species with good representation by minnow and darters, despite the fact that most of fish assemblage was tolerant (68%) of some water pollution.

Alternatively, a nearby tributary that joins Conotton Creek at RM 28.2 was only inhabited by 14 species. Some groundwater seepage there was inferred by a single Least Brook Lamprey and two Redside Dace. Wetland oriented fish were absent. Most fish at this site were pollution tolerant (80%).

The essence of this comparison is evident in Table 18. Both locations achieved very good IBI scores (48). Kirby Run habitat conditions (QHEI=65.5) were better than those of Conotton Creek Tributary at RM 28.1 (QHEI=49.5). Although both locations were predominated by similar species, the more diverse Kirby Run fish community included half as many total fish but nearly as many that were not pollution tolerant.

Differences in habitat between these locations accounted for this disparity in diversity. Habitat needed to support specific niches for species like Grass Pickerel was available in Kirby Run. Similarly, habitat conditions across the entire Conotton Creek watershed may account for some erratic collections and the improving fish species trends.

In broad terms, larger drainage locations in the Conotton basin lacked diversity in individual samples, were deficient of piscivores, and pollution intolerant fish were scarce. Five sucker species scored moderately at sites assessed with boat methods. These locations were within the reach influenced by backwater when Dover Dam on the Tuscarawas River is closed to moderate downstream flooding. Operation of the dam impedes sediment transport as the high flow conditions necessary to scour center channel substrates are muted by the backwater pool. In those instances, sediment in the water column drops out of suspension and is deposited in the lower reaches of Conotton Creek. The change in percentage of fish which require clean substrates to spawn over or forage amongst, called lithophils, declined by half from RM 6.7 (44%) to RM 0.2 (18%). A corresponding increase in the percentage of pollution tolerant fish at these sites was another factor of the increased downstream sediment deposition (RM 6.7, 20%-RM 0.2, 38%). These shifts were consistent with the impoundment degraded water quality conditions and accounted for the fair fish community performance at RM 0.2 (IBI=33, MIwb=7.9).

Fish communities at smaller drainage locations in the Conotton basin were influenced by land use practices and migratory barriers. Exceptional fish assemblages (IBI \bar{x} =51, n=4) in the North Fork McGuire Creek and Bear Hole Run benefited from extensively forested drainage areas. Isolated from other Conotton basin streams by Leesville Lake, biological integrity at North Fork McGuire Creek sites was achieved with different combinations of 21 fish species. One fourth of these were sensitive to pollution including Golden Redhorse (*Moxostoma erythrurum*), Northern Hogsucker (*Hypentelium nigricans*), Redside Dace, Greenside Darter (*Etheostoma blennioides*), and the uncommon headwater occurrence of a Logperch Darter. Rock Bass (*Ambloplites rupestris*), Common Shiners (*Luxilus cornutus*), Least Brook Lamprey and Mottled Sculpin were present at all North Fork McGuire Creek locations. These fish reflected the very good habitat qualities (QHEI \bar{x} =77.7, n=3) comprised by deep, permanent pools and persistent flow through riffles. Less embedded, large aggregate substrates were conducive to Rock Bass, otherwise absent at many other Conotton headwater sites.

Likewise, stable pools facilitated the presence of suckers not routinely encountered and supported especially large Common Shiner populations. The adequacy of interstitial voids was affirmed by darter and lamprey abundance. Shade of the forested canopy and floodplain connectivity were indicated by numerous sculpin and dace which prefer cooler water.

The extent to which other Conotton Creek headwater fish assemblages varied from the North Fork McGuire Creek community can generally be interpreted as a consequence of fewer wooded stream corridors, more agricultural riparian encroachment, or the persistence of toxic drainage from un-reclaimed coal mines. Very good McGuire Creek and Long Creek fish communities (IBI \bar{x} =49, n=3) lacked pollution sensitive suckers and Rock Bass. Few or no Common Shiners in some samples further suggested pool qualities were insufficient. Fewer lamprey and darters implied less functional interstitial pockets. Declining dace and sculpin abundance with increasing drainage size resulting from more sunlight and warming stream temperatures was consistent with land use differences between sub-basins. Collectively, 19 fish species were extant in McGuire Creek upstream from Leesville Lake. Fair habitat conditions (QHEI \bar{x} = 59.0, n=3) were documented in the sub-basin.

Very good Dining Fork sub-basin stream fish communities (IBI \bar{x} =46, n=4) were similar to those of McGuire Creek. An aggregate of 27 species in the sub-basin included those in Kirby Run with wetland affinities and some which tend to inhabit larger drainages. Banded Darters (*Etheostoma zonale*), Spotfin (*Cyprinella spiloptera*) and Sand Shiners (*Notropis stramineus*) at the most downstream site may have strayed from nearby Conotton Creek. Likewise, the few Northern Hog Suckers were perceived to be newcomers anticipating an improving habitat trend. Fair habitat qualities (QHEI \bar{x} = 59.4, n=4) in the Dining Fork sub-basin were like those in the adjacent McGuire Creek.

Fewer sculpin, no Redside Dace or Central Stonerollers (*Camptostoma anomalum*), and 20 total species in the Irish Creek watershed contributed to marginally good IBI scores (\bar{x} =43, n=3). Sand substrates smothered any larger aggregate in this basin that had less wooded corridor and more habitat degradation (QHEI \bar{x} = 51.4, n=3). Herbivorous stonerollers were displaced by the unstable sand bedload that offered no medium for algal growth.

Grouping the Jefferson Creek sampling site with the two most upstream Conotton Creek locations creates another comparative sub-basin. The 23 cumulative fish species in this area included sensitive species also present in the North Fork McGuire sub-basin but missing from drainages in between. Rock Bass and several other types of sunfish with modest numbers of Common Shiners were associated with deeper pools in this sub-basin. Greenside, another uncommon Logperch, and Banded Darters with Spotfin and Sand Shiners were consistent with earlier observations regarding unusual fish in smaller drainage areas and interstitial void functions. This assemblage supported very good IBI scores (IBI \bar{x} =48, n=3). Observation of the limited tree canopy, affirmed by no sculpin or Redside Dace, and few Blacknose Dace (*Rhinichthys obtusus*), as well as the impression of excessively silty substrates informed fair QHEI scores (\bar{x} = 46.9, n=3).

Among the McGuire Creek, Dining Fork, Irish Creek and upstream Conotton/ Jefferson Creek set of headwater sub-basins only the Conotton Creek mainstem contained coal fines in stream substrates. This evidence of upstream mining frequently co-occurs with excessive stream bedloads. It appears the fish community was performing better than habitat quality would predict in this upper reach area. That wasn't the case in 1982 when poor fish assemblages (IBI \bar{x} =27, n=3) were present at the same sites. Aside from a few Common Shiners and Western Blacknose Dace, none of the aforementioned species present in 2016 were

collected in 1982. Apparently, three decades of natural attenuation have ameliorated past impairment influences.

Coal fines were also present in Huff and Beggar Runs, Conotton Creek Tributaries at RM 17.22, RM 11.37 and RM 7.67, and in an Indian Fork Tributary at RM 3.3. Fair fish community performance at most sites in these streams demonstrated the continuing affects from former coal mines. Several spoil mounds of mine tailings were observed in the neighborhood. Some of these “gob piles” have been remediated in the Huff Run basin, but others exist as they did when the nearby mine was abandoned decades ago. Rainwater leached through these piles becomes contaminated with dissolved metals and turns acidic. Huff Run evidenced this by an orange precipitate which covered stream substrates. Alternatively, substrates were moderately silty but not orange in the Conotton Creek tributary at RM 7.67. Mine spoil flanked the stream along the upper reach of the sampling zone. Landowners reported the stream had no minnows previously. In 2016, both streams were predominated by pollution tolerant, pioneering fish. Likewise, these fish that can survive in degraded water quality and maintain a transient presence where variable conditions may cause displacement, were most abundant in other streams where coal fines were noticed. The fish community at the most upstream site on Huff Run was comprised by a modest number of pioneers and included Least Brook Lamprey. The absence of these long-term substrate inhabitants was correlated with probable mining influence in the Conotton Creek basin.

Least Brook Lamprey were present in the Conotton Creek tributaries at RM 17.22 and RM 11.37. Despite the presence of coal fines, it appeared water quality conditions were less affected by former mining. Diverse fish communities in both streams also included several darter species and pollution intolerant Redside Dace. Coal fines were not apparent in Elliot or Willow Run where fair fish communities might be perceived to allude to a mining heritage. However, Least Brook Lamprey were collected in both streams. Limited flow in these channelized ditches was a strong factor in reduced fish community diversity. Both streams were modified to facilitate agricultural drainage. Although adjacent agricultural land use ceased more than a decade ago, these low gradient streams lacked energy to regain functional habitat attributes.

Cold Spring Run was inhabited by 20 fish species including Least Brook Lamprey. The presence of some fish species was likely due to the proximity of Atwood Lake and better flow conditions implicit from the stream’s name. Yellow Perch (*Perca flavescens*) and Bluegill Sunfish (*Lepomis macrochirus*) were numerous. These pool-oriented species were joined by the incidental presence of an orangespotted, two pumpkinseed, and three Green Sunfish (*Lepomis cyanellus*). Largemouth Bass (*Micropterus salmoides*) and Gizzard Shad (*Dorosoma cepedianum*) were also more likely pool dwellers. Within a former cattle pasture, Cold Spring Run exhibited a deeply incised, tortuous meandering course. Numerous deep pools were extant in a stream that seemed unnatural because of them. Only two darter species and the lack of Mottled Sculpin seemed at odds with the channel name. Similarly, one Western Blacknose Dace and two Central Stonerollers were an impoverished representation of species that might have numbered in triple digits. The best explanation for the lack of typical minnows was bait for the many pool inhabitants. Habitat conditions in Cold Spring Run were not conducive to maintaining water quality consistent with the needs of an expected small stream fish assemblage.

The disparity in fish index scores at sites bracketing the Carrolton WWTP was due to the presence of Northern Hog Suckers exclusively upstream while creek chubs doubled in abundance downstream. Moderately pollution intolerant Hog Suckers upstream from the facility with Redside Dace merited a

moderate number of sensitive species metric score compared to the low score earned by just Redside Dace alone downstream. Otherwise, similar species inhabited both reaches of Honey Run except pollution tolerant fish were more abundant downstream. The numerical differences, especially by creek chubs, caused community proportional changes in lithophils, pioneers, and insectivores. Those changes signify the downstream substrates were siltier and more embedded, water quality was more variable, and the food web was simplified in comparison to conditions upstream from the outfall. The increased silty and embedded conditions downstream were visually apparent as well.

Indian Fork fish communities failed to achieve the biocriterion at three sample sites. The fish assemblage at the most upstream Indian Fork site was similar to the community immediately downstream from the Carrolton WWTP. It differed because Hog Suckers and Golden Redhorse gained a moderate sensitive species metric score, but the continued presence of only two darters at the larger drainage resulted in a low metric value. The proportional metric scores mirrored Honey Run downstream from the WWTP facility. And substrates were notably siltier than were observed in Gantz Creek upstream from the Honey Run confluence. Least Brook Lamprey were present in Gantz and Friday Creeks but were not collected in Honey Run or Indian Fork. In the Conotton Creek basin, Least Brook Lamprey were allied with substrate conditions. Absence of the species downstream from the Carrolton WWTP further affirmed the substrate degradation was likely influenced by the facility. It's also relevant to acknowledge only Johnny and Fantail Darters were collected at the aggregate of sites in the Indian Fork sub-basin upstream from Atwood Lake dam. It's probable that other darters were locally extirpated, and the lake now prevents recolonization.

Indian Fork at RM 9.0 upstream from Atwood Lake was free flowing. Nevertheless, during flood flows the stilling affect from lake backwater extends upstream causing excessive sedimentation to occur at RM 9.0. Two darter species and no pollution intolerant fish merited low metric scores at RM 9.0. Low top predator abundance and predominance by omnivores indicated the trophic structure of the fish assemblage had been simplified. The abundance of pool species and limited numbers of riffle-run oriented species was consistent with the impaired physical qualities. The silty, embedded conditions downstream from the Carrolton WWTP were further confounded here by reduced velocities at the time when a natural stream would dispel sediment in a restorative act. During floods, swift center channel flows rejuvenate riffle filtering function as fines are deposited in the flood plain. Extended backwater upstream from Atwood Lake dampens this self-healing process.

Indian Fork at RM 0.5 is downstream from Atwood Lake dam. The fish community at this site was like that of McGuire Creek at RM 1.3, downstream from the Leesville Lake dam. Both locations were populated by modest species richness and numerical abundance. Aside from the odd presence of a River Chub downstream from Atwood Lake, both sites lacked pollution intolerant species while sunfish were well represented. The lack of riffle-run type species at both locations was consistent with the affects from routine flow adjustment due to dam operations. Both sites were excessively silty and disturbed substrates smelled of hydrogen sulfide. Black organic sludge was particularly heavy downstream from Leesville Lake. In part, the dams were constructed to mitigate downstream flooding. Restricted flood flows in the reaches immediately downstream from these dams precluded needed sediment redistribution. Substrate oriented species downstream from Leesville Lake were confined to an artificial rip rap riffle immediate to a flow calibration weir. The presence of Mottled Sculpin within the large interstitial cervices suggested the water remains perennially cool.

Relative to stream size, Indian Fork (70 mi²) and McGuire Creek (48 mi²) are among the largest impoundments in Ohio. Both lakes encompass proportionally large amounts of the upstream sub-basins. Together, these dams exert consequential hydraulic influences on Conotton Creek. The effect is further exacerbated by downstream operation of Dover Dam. Artificial control of flow conditions in Conotton Creek is extensive. This disruption likely challenges expectations for the Conotton Creek presence of species typically found in other Ohio streams. It's important to understand this want of species is not about fish population preservation per se. Instead, the limited presence of many species indicates normal stream functions are debilitated. Normal stream functions are crucial to maintaining and enhancing water quality. Pulsed dam discharges and extended channel impoundment necessarily affect species distribution and confound better water quality.

Table 18 - Summary of fish community data based on wading, pulsed D.C. electrofishing samples collected in the Conotton Creek study area, 2016. 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 wading or 1000 meters for boat^B sites. Weights are not recorded and the Modified Index of well being is not applicable at headwater locations. All sites were in the Western Allegheny Plateau (WAP) ecoregion. Biocriteria and narrative ranges are in Table 2. Other descriptions and scientific names follow.

Stream RM	Mi ²	Total Species	Relative Number/less tolerants	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
Conotton Creek WWH								
41.6	3.8	16	1470/ 699	-	48.5	-	48	V Good
			Creek Chub (39%), Johnny Darter, Common Shiner, Central Stoneroller (11%)					
37.8	17.5	21	1403/ 678	-	48.3	-	50	Exceptional
			Creek Chub (31%), White Sucker (16%), Greenside Darter (12%), Johnny Darter (11%)					
32.6	48.0	28	1556/ 942	15.8	61.3	9.5	45	Except.-Good
			Creek Chub (15%), Johnny Darter, White Sucker (12%) Silverjaw Minnow (9%)					
29.1	70.0	30	691/ 390	26.9	54.3	8.9	43 ^{ns}	V Good-M Good
			Bluntnose Minnow (17%), White Sucker, Green Sunfish, (13%), Hog Sucker (11%)					
23.7	87.0	29	1833/ 1206	36.3	72.1	10.3	51	Exceptional
			Creek Chub (15%), Hog Sucker (10%), White Sucker (8%), Silverjaw Minnow (7%)					
22.1 ^B	89.0	31	852/ 580	127.4	45.0	9.6	42	Except.-V Good
			Golden Redhorse, White Sucker (17%), Silver Redhorse (11%), Bluntnose Minnow (9%)					
17.0	156.2	31	1055/ 655	17.7	77.5	8.9	44	V Good-Good
			Creek Chub (15%), Hog Sucker (12%), White Sucker (11%), Bluntnose & Silverjaw Minnow (10%)					
13.9	165.3	27	752/ 473	21.3	53.0	9.0	45	V Good-Good
			Creek Chub (25%), Hog Sucker (15%), White Sucker (19%), Fantail & Greenside Darter (9%)					
11.4 ^B	241.0	31	628/ 452	141.8	59.0	8.8	36 ^{ns}	Good-M Good
			Trout Perch (18%), Spotfin Shiner (11%), Carp (10%), White Sucker, Bluntnose Minnow (9%)					
6.7 ^B	261.8	23	324/ 258	79.9	58.5	8.9	40	Good
			Spotfin Shiner, Golden Redhorse (15%), Silver Redhorse, Hog Sucker (10%), Bluntnose M. (8%)					
0.2 ^B	286.0	26	256/ 165	181.9	56.0	7.9*	33*	Fair
			Carp (16%), Silver Redhorse (13%), Bluntnose Minnow (11%), Spotfin Shiner (8%)					
Jefferson Creek WWH								
0.2	6.5	20	1508/ 690	-	44.0	-	46	Very Good
			Blacknose Dace (31%), White Sucker (14%), Johnny Darter (12%), Bluegill Sunfish (11%)					
Irish Creek WWH, CWH recommended ust. Lick Fork (RM 4.63)								
5.0	6.7	14	2295/ 576	-	48.0	-	44	Good
			Creek Chub (44%), Blacknose Dace (28%), Fantail Darter (9%), Johnny Darter (8%)					
2.1	14.9	16	4836/ 2298	-	51.0	-	46	Very Good
			Creek Chub (28%), Silverjaw Minnow (17%), White Sucker (12%), Johnny Darter (11%)					
Lick Fork CWH recommended								
0.2	5.0	9	3039/ 1101	-	55.3	-	40 ^{ns}	M Good
			Creek Chub (37%), Blacknose Dace (26%), Johnny Darter (14%), Fantail Darter (13%)					
Dining Fork EWH recommended								
6.3	3.1	7	1413/ 507	-	54.0	-	40*	M Good
			Blacknose Dace (37%), Mottled Sculpin (34%), Creek Chub (21%), White Sucker (6%)					

Stream RM	Mi ²	Total Species	Relative Number/ less tolerants	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
4.3	6.3	18	2567/ 611	-	61.0	-	48 ^{ns}	Very Good
	Blacknose Dace (38%), Creek Chub (28%), White Sucker (14%), Mottled Sculpin (12%)							
0.2	14.7	22	2149/ 946	-	57.0	-	46 ^{ns}	Very Good
	Creek Chub (37%), Silverjaw Minnow (13%), White Sucker (12%), Johnny Darter (11%)							
Kirby Run EWH recommended								
0.7	3.4	22	2070/ 666	-	65.5	-	48 ^{ns}	Very Good
	Creek Chub (43%), Blacknose Dace (18%), Johnny Darter (8%), Mottled Sculpin (5%)							
Conotton Creek Tributary (RM 28.20) WWH recommended								
0.6	3.8	14	4320/ 849	-	49.5	-	48	Very Good
	Creek Chub (58%), Blacknose Dace (17%), Johnny Darter (13%), White Sucker (4%)							
McGuire Creek EWH recommended ust. RM 7.57 (at unnamed trib. confluence near SR 332, Scio Rd.)								
9.9	2.7	14	2829/ 1335	-	57.0	-	52	Exceptional
	Creek Chub (34%), Central Stoneroller, Mottled Sculpin (18%), Green Sunfish (11%)							
8.3	7.1	17	1811/ 1011	-	62.0	-	47 ^{ns}	Very Good
	Creek Chub (33%), Central Stoneroller (17%), Mottled Sculpin, Johnny Darter (10%)							
McGuire Creek WWH recommended dst. RM 7.57 (at unnamed trib. confluence near SR 332, Scio Rd.)								
1.4	48.0	16	670/ 346	17.9	53.6	7.9 ^{ns}	38*	M Good-Fair
	Bluegill Sunfish (21%), Creek C. (17%), Golden Shiner, Hybrid Sunfish (14%), Green Sunfish (13%)							
Long Creek EWH recommended								
0.7	1.7	10	1365/ 405	-	58.0	-	48 ^{ns}	Very Good
	Creek Chub (42%), Blacknose Dace (25%), Central Stoneroller (12%), Mottled Sculpin (8%)							
North Fork McGuire Creek EWH recommended								
9.4	4.1	16	11222/ 542	-	79.5	-	50	Exceptional
	Creek Chub (29%), Mottled Sculpin (15%), Central Stoneroller (14%), Bluntnose Minnow (13%)							
7.7	6.9	17	2840/ 1233	-	85.5	-	50	Exceptional
	Creek Chub (34%), Central Stoneroller (13%), Blacknose Dace (11%), Common Shiner (10%)							
6.0	11.3	19	3498/ 2148	-	68.0	-	52	Exceptional
	Creek Chub (20%), Central Stoneroller (18%), Common Shiner (15%), Bluntnose Minnow (10%)							
Bear Hole Run EWH recommended								
1.7	1.4	11	1316/ 372	-	59.0	-	50	Exceptional
	Creek Chub (49%), Blacknose Dace (17%), Mottled Sculpin (14%), White Sucker (5%)							
Conotton Creek Tributary (RM 17.22) WWH recommended								
1.0	6.3	20	1602/ 633	-	72.6	-	44	Good
	Creek Chub (27%), White Sucker (17%), Bluntnose Minnow (14%), Silverjaw Minnow (13%)							
Thompson Run WWH recommended								
0.7	3.7	15	660/ 350	-	59.0	-	52	Exceptional
	Creek Chub (30%), Mottled Sculpin, Johnny Darter (18%), Blacknose Dace (12%)							
Indian Fork WWH recommended								
13.9	12.3	20	3500/ 910	-	71.0	-	36*	Fair
	Creek Chub (39%), White Sucker (25%), Johnny Darter (8%), Silverjaw Minnow (6%)							
9.0	33.5	19	804/ 464	34.8	55.0	8.4	30*	Good-Fair
	White Sucker, Gizzard Shad (18%), Creek Chub (16%), Johnny Darter (10%)							
0.5	70.0	21	324/ 204	35.0	53.3	7.2*	34*	Fair
	Bluegill Sunfish (28%), White Sucker (23%), Yellow Perch (13%), Bluntnose Minnow (9%)							
Gantz Creek WWH recommended								

Stream RM	Mi ²	Total Species	Relative Number/ less tolerants	Relative Weight	QHEI	MIwb	IBI	Narrative Evaluation
Predominant species (percent of catch)								
1.2	7.3	14	5634/ 3786	-	65.8	-	44	Good
	Central Stoneroller (33%), Common Shiner (22%), White Sucker, Creek Chub (14%)							
Friday Creek WWH recommended								
1.2	3.5	14	2883/ 984	-	51.5	-	46	V Good
	Creek Chub (45%), Central Stoneroller (12%), Blacknose Dace (11%), White Sucker (9%),							
Honey Run WWH recommended								
0.8	3.4	15	5154/ 1821	-	75.5	-	44	Good
	Creek Chub (38%), Central Stoneroller (19%), White Sucker (11%), Blacknose Dace (10%)							
0.6	3.8	15	6432/ 1155	-	78.3	-	36*	Fair
	Creek Chub (55%), White Sucker (18%), Blacknose Dace (9%), Central Stoneroller (7%)							
Cold Spring Run WWH recommended								
0.6	5.9	20	1458/ 531	-	56.0	-	36*	Fair
	Creek Chub (31%), White Sucker (23%), Bluegill Sunfish (14%), Bluntnose Minnow (7%)							
Pleasant Valley Run WWH recommended								
1.5	6.5	15	5064/ 1797	-	56.5	-	42 ^{ns}	M Good
	Creek Chub (41%), Silverjaw Minnow (15%), Blacknose Dace (13%), Johnny Darter (9%)							
Willow Run WWH recommended								
1.5	7.7	12	609/ 225	-	43.0	-	30*	Fair
	Creek Chub (34%), White Sucker (21%), Johnny Darter, Silverjaw Minnow (13%)							
Elliot Run WWH recommended								
1.4	3.5	8	333/ 115	-	32.0	-	30*	Fair
	Creek Chub (49%), Johnny Darter (24%), Bluegill Sunfish (10%), White Sucker (9%)							
Indian Fork Tributary (RM 3.30) WWH recommended								
1.4	3.4	11	630/ 132	-	41.3	-	28*	Fair
	Creek Chub (57%), Bluntnose Minnow (14%), Bluegill Sunfish (10%), White Sucker (5%)							
Conotton Creek Tributary (RM 11.37) WWH recommended								
0.3	4.6	18	1418/ 272	-	48.5	-	44	Good
	Creek Chub (59%), White Sucker (13%), Johnny Darter (8%), Silverjaw Minnow (4%)							
Conotton Creek Tributary (RM 7.67) WWH recommended								
2.9	3.8	10	2273/ 61	-	60.5	-	32*	Fair
	Blacknose Dace (39%), Creek Chub (37%), Johnny Darter (10%), White Sucker (7%)							
Beggar Run WWH recommended								
0.5	4.0	13	771/ 167	-	47.0	-	33*	Fair
	Creek Chub (59%), Johnny Darter (11%), White Sucker (9%), Green Sunfish (8%)							
Huff Run WWH recommended								
7.8	3.3	13	2286/ 591	-	70.5	-	40 ^{ns}	M Good
	Creek Chub (23%), White Sucker (22%), Blacknose Dace (15%), Johnny Darter (10%)							
5.5	6.5	10	1491/ 486	-	59.6	-	35*	Fair
	Creek Chub (44%), Johnny Darter (22%), Blacknose Dace (17%), Fantail Darter (8%)							
1.3	11.8	12	311/ 36	-	70.5	-	28*	Fair
	Creek Chub (45%), Green Sunfish (16%), White Sucker (12%), Blacknose Dace (11%)							

RM: River mile.

22.1^B: The ^B superscript denotes a boat sample site.

41.6: The absence of a superscript denotes a wading sample site.

mi²: Drainage area in square miles.

Relative Number: Numerical abundance was normalized to report fish per 300 m or 1000 m for wading or boat sites, respectively.

Relative Number/ less (pollution) tolerants: 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.

Creek Chub (*Semotilus atromaculatus*),

Common Shiner (*Luxilus cornutus*),

White Sucker (*Catostomus commersonii*),

Silverjaw Minnow (*Notropis buccatus*),

Green Sunfish (*Lepomis cyanellus*),

Golden Redhorse, (*Moxostoma erythrurum*),

Fantail Darter (*Etheosotma flabellare*),

Spotfin Shiner (*Cyprinella spiloptera*),

Western Blacknose Dace (*Rhinichthys obtusus*),

Northern Mottled Sculpin (*Cottus bairdii bairdii*),

Hybrid Sunfish (*Lepomis hybrid*),

Yellow Perch (*Perca flavescens*),

Fathead Minnow (*Pimephales promelas*),

Brown Bullhead (*Ameiurus nebulosus*),

Johnny Darter (*Etheosotma nigurm*),

Central Stoneroller Minnow (*Campostoma anomalum*),

Greenside Darter (*Etheostoma blennioides*),

Bluntnose Minnow (*Pimephales notatus*),

Hog Sucker (*Hypentelium nigricans*),

Silver Redhorse (*Moxostoma anisurum*),

Trout Perch (*Percopsis omiscomaycus*),

Common Carp (*Cyprinus carpio*),

Bluegill Sunfish (*Lepomis macrochirus*),

Golden Shiner (*Notemigonus crysoleucas*),

Gizzard Shad (*Dorosoma cepedianum*),

Central Mudminnow (*Umbra limi*),

Yellow Bullhead (*Ameiurus natalis*),

E. Banded Killifish (*Fundulus diaphanus diaphanus*).

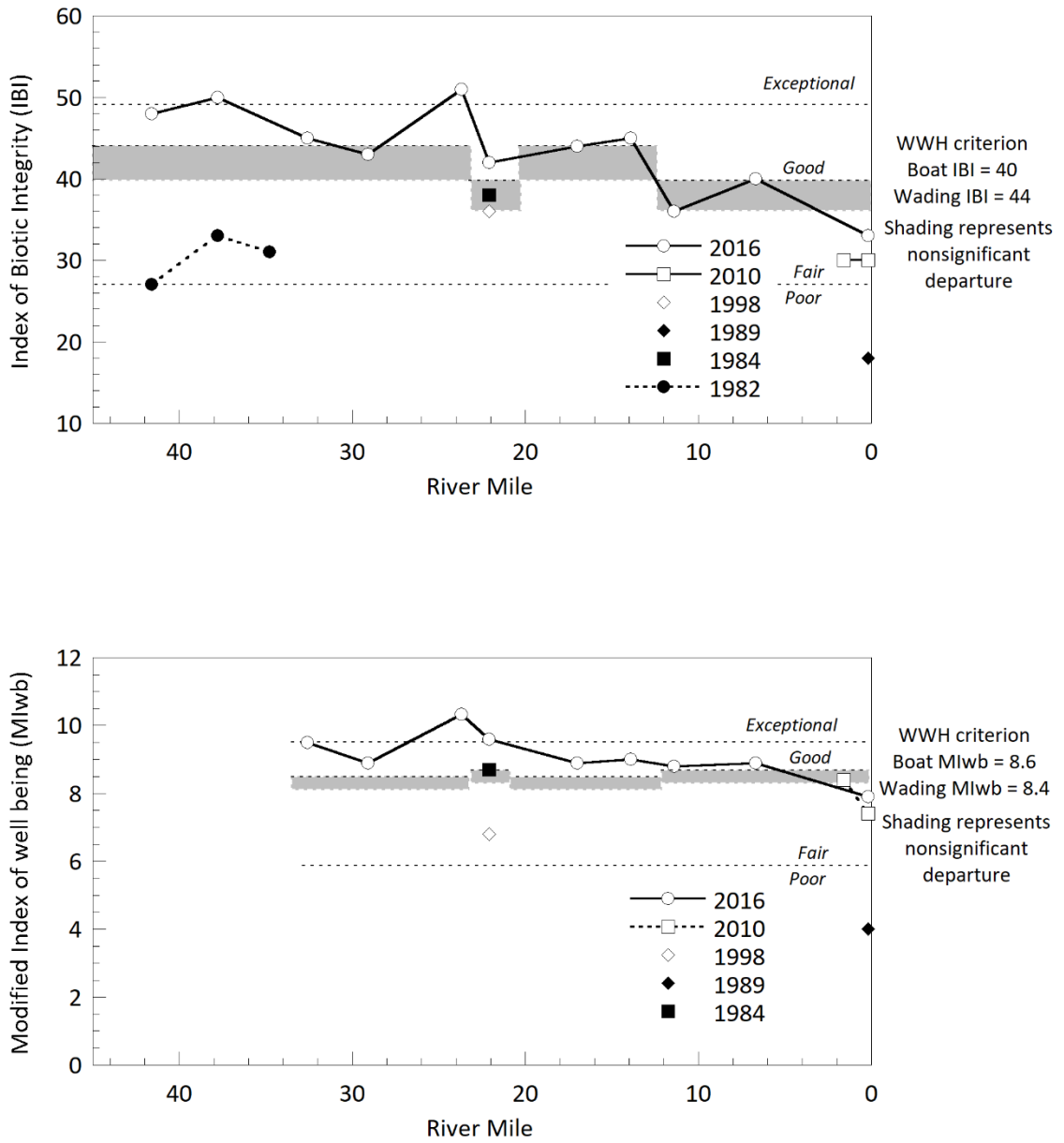


Figure 18 - Longitudinal performance of the Index of Biotic Integrity (IBI, upper plot) and of the Modified Index of well being (MIwb, lower plot) in Conotton Creek, 1984-2016.

Macroinvertebrate Community

Macroinvertebrate communities were evaluated at 48 stations in the Conotton Creek basin study area (Table 19, Appendices B and C). Community performance was evaluated as exceptional at 19 stations, very good at three, good at 12, and marginally good at four. Thus, macroinvertebrates at 79% of the 2016 Conotton Creek sample locations achieved the applicable biocriterion. Eight sites where fair and two where poor performance were determined did not achieve.

A strong groundwater connection was apparent throughout the watershed. Respectively, with ten, eight, six, and five coldwater macroinvertebrate taxa, Bear Hole Run, Lick Fork, Long, and Irish Creeks were deemed especially indicative of coldwater habitat (CWH, further discussed in the **Beneficial Use Recommendations** section, Table 25). Seven sites on six other streams were inhabited by three to four coldwater organisms. Aside from larger drainage area stations or those likely affected by legacy coal mine influences, coldwater taxa were present in every stream except Cold Spring Run.

Twenty-six intolerant or uncommonly collected sensitive taxa were documented during the survey (Table 20). A state listed species of concern, creek heelsplitter (*Lasmigona compressa*), was found in Beggar Run. This moderate size freshwater mussel (four inches) seems to occur most often in small wadeable or headwater streams; reaches where unionids are generally understudied. Its presence in Beggar Run where fine gravel and sand were prevalent was consistent with the species substrate preference. An uncommon minnow mayfly (*Plauditus punctiventris*) was noticed in Elliot Run. Bolton, Macy, DeWalt, and Jacobus (2019) explain this baetidae species was confused with another until an improved taxonomic key helped differentiate instar larvae.

The number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa are reported as total EPT when all organisms from both the quantitative or artificial and qualitative or natural substrates are considered. EPT taxa richness is generally considered to be representative of high-quality aquatic resources. Fourteen study area sample sites had 20 or more total EPT taxa including Conotton Creek at Azalea Road (RM 22.1, R08K03) where 26 total EPT taxa were registered. Only two EPT taxa were present in the reaches of McGuire Creek and Indian Fork downstream, respectively, from Leesville and Atwood Lakes. With only three or four total EPT taxa at two lower reach Huff Run sites, that stream was also depauperate of sensitive taxa.

All ten stations sampled on the Conotton Creek mainstem for aquatic macroinvertebrates met the existing WWH criterion (Figure 18). Five sampling locations (RMs 29.1, 23.7, 22.1, 13.9, and 11.4) had exceptional qualitative EPT (19-23) and sensitive (14-18) taxa diversity. While the site at RM 37.8 (CR 50, New Rumley Rd., R08S04) met the WWH criterion with a marginally good narrative evaluation. Just two mayfly taxa were found at RM 37.8, compared to seven at adjacent sites (RMs 41.6 and 32.5). Only five sensitive taxa, the least mainstem abundance, were collected there. The dearth of EPT and sensitive taxa at RM 37.8 were attributed to water quality stress. Numerous chemical parameters were elevated at this groundwater influenced site downstream from the Jewett WWTP.

Jefferson Creek, Irish Creek, and Lick Fork within the upper Conotton Creek watershed were sampled in 2016. Jefferson Creek had a fair macroinvertebrate community. This departure from the WWH criterion was attributed to water quality and habitat stress. Elevated chemical concentrations were documented at the channel modified site. Facultative macroinvertebrate taxa were most prevalent amongst both good Irish Creek communities. With the most taxa richness (82) among 2016 study sites and an abundance of moderately pollution intolerant taxa, the Lick Fork macroinvertebrate assemblage achieved an exceptional rating. The upstream site on Irish Creek (RM 5.0) and Lick Fork supported coldwater macroinvertebrate communities. Coldwater taxa were not present at the downstream Irish Creek site (RM 2.5).

The Dining Fork subwatershed had very good to exceptional macroinvertebrate communities. The most upstream site on Dining Fork at RM 6.3 had four coldwater taxa as part of an exceptional macroinvertebrate community. Twenty qualitative EPT taxa including two uncommon mayflies were part of an exceptional assemblage in Kirby Run.

The macroinvertebrate community in Scott Run was narratively evaluated as fair. Only 32 taxa with just one pollution sensitive organism were present in 2016. The low abundance was attributed to habitat alteration and water quality perturbation. The sample site within a cattle pasture exhibited habitat alteration due to unrestricted livestock access. Detection of increased dissolved metal concentrations at this location was likely due to nearby historic coal mining. Facultative macroinvertebrates predominated the marginally good community collected at one site on a tributary to Conotton Creek at RM 28.20.

Two Conotton Creek tributaries were sampled in the Thompson Run – Conotton Creek HUC. Thompson Run had a very good macroinvertebrate community. The tributary to Conotton Creek at RM 17.22 had a good macroinvertebrate community. High proportions of EPT and pollution sensitive taxa amongst the modestly abundant assemblages in this assessment unit differed from downstream sites where tolerant taxa were more numerous.

Upstream from Leesville Lake, six of seven sample sites in the McGuire Creek subwatershed had exceptional macroinvertebrate communities. The outlier community achieved very good status. The North Fork McGuire Creek, Bear Hole Run, and the Long Creek assemblages were each comprised by 20 to 22 qualitative EPT taxa. All 20 of the EPT taxa at the North Fork McGuire Creek RM 7.7 site (CR 19, Autumn Rd., 303633) were also considered pollution sensitive organisms. The 25 pollution sensitive taxa at Bear Hole Run were more numerous than at any other 2016 study site. Likewise, the ten coldwater taxa at Bear Hole Run were the most numerous in the study. Six coldwater taxa were collected in Long Creek. With 71 qualitative taxa, second most numerous in the study, it was surprising that the upstream North Fork McGuire Creek RM 9.4 (4.1 mi²) assemblage (TR 354, Pebble Rd., 303632) only included one coldwater taxa. Recognizing the sample sites on Bear Hole Run (1.4 mi²) and Long Creek (1.7 mi²) had the smallest drainage areas in the 2016 study, it's plausible that other upstream reaches in this high quality subwatershed might also support rich coldwater collections.

Table 19 - Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Conotton Creek basin, June to September 2016.

Station	RM	Dr. (mi ²)	Ar. Ql. Taxa	EPT Ql./Total	Sensitive taxa Ql./Total	Denisty Ql./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI ^a	Narrative Evaluation
Conotton Creek (17-100-000)										
303623	41.6	3.8	50	12	8	M	1	Midges (F)	-	G
R08S04	37.8	17.5	45	11	5	M	0	Blackflies (F), midges (T-F), flatworms (F), <i>Hydroptila</i> caddisflies (F)	-	MG
R08K05	32.5	48.0	64	15	11	L	0	Midges (MT-F), aquatic mites (F), and riffle beetles (F)	-	G
R08S16	29.1	70.0	58	21/22	15/18	M/1331	0	Midges (MT-F), hydropsychid caddisflies (F), heptageniid mayflies (MI)	46	E
R08W05	23.7 ^b	87.0	63	23/24	18/19	MH/989	0	Midges (F), hydropsychid caddisflies (F), flatworms (F), heptageniid mayflies (MI)	46	E
R08K03	22.1	89.0	62	23/26	18/21	MH/1166	0	Midges (T-F), hydropsychid caddisflies (F-MI), heptageniid mayflies (MI), flatworms (F)	48	E
303578	17.0	156.2	57	17/22	12/19	M/956	0	Heptageniid mayflies (MI), riffle beetles (F), midges (MT-MI)	50	E
303579	13.9	165.3	53	22/24	17/21	M/1150	0	Hydropsychid caddisflies (F-MI), aquatic mites (F), waterboatmen (F)	40	G
R08S14	11.4	241.0	55	19/21	14/17	L/637	0	Water boatmen (F) and aquatic mites (F)	40	G
303580	6.7	261.8	37	13/18	11/14	M/360	0	Caddisflies (MI) and scuds (F)	40	G
Jefferson Creek (17-123-000)										
R08S07	0.2	6.5	56	8	6	H	2	Midges (T-F), baetid mayflies (F), hydropsychid caddisflies (F-MI), beetles (T-F)	-	F
Irish Creek (17-120-000)										
303624	5.0	6.7	57	14	17	M	5	Diptera (F-MI) and hydropsychid caddisflies (F)	-	G/CW
R08S13	2.1	16.1	65	16	14	L	0	Midges (T-MI), hydropsychid caddisflies (F), and riffle beetles (F)	-	G
Lick Fork (17-121-000)										
303625	0.2	5.0	82	19	19	M	8	Hydropsychid caddisflies (F-MI), Diptera (MT-MI), and beetles (T-MI)	-	E/CW
Dining Fork (17-118-000)										
303626	6.3	3.1	67	17	24	ML	4	Hydropsychid caddisflies (MI-F) and midges (F-MI)	-	E
303627	4.3	6.3	53	19	16	L	2	Diptera (MI-MT), riffle beetles (F-MI), and hydropsychid caddisflies (MI)	-	E
303628	0.2	14.7	57	17	14	M	0	Midges (F-MI), aquatic mites (F), hydropsychid caddisflies (F)	-	VG
Kirby Run (17-119-000)										
303629	0.7	3.4	53	20	14	M	0	Hydropsychid caddisflies (F-MI), <i>Isonychia</i> mayflies (MI), <i>Chimarra</i> caddisflies (MI)	-	E
Scott Run (17-109-000)										

Station	RM	Dr. (mi ²)	Ar. Taxa	Ql. Taxa	EPT taxa Ql./Total	Sensitive taxa Ql./Total	Denisty Ql./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI ^a	Narrative Evaluation
303630	0.7	3.1	32	5	1		M	0	Beetles (F-T), Odonata (F-T), aquatic snails (F-T)	-	F
Tributary to Conotton Creek (28.20) (17-100-002)											
303618	0.6	3.8	54	10	7		MH	1	Midges (T-F), hydropsychid caddisflies (F), odonates (T-F), snails (T-F), Diptera (F), and beetles (F)	-	MG
McGuire Creek (17-106-000)											
303616	9.9	2.7	60	18	15		M	3	Mayflies (F-MI) and caddisflies (F-MI)	-	E
303617	8.3	7.1	54	16	13		ML	1	Hydropsychid caddisflies (F) and heptageniid mayflies (F)	-	VG
R08W04	1.3	49.6	30	1/2	1/1		H/1064	3	Midges (T-F)	<u>12</u>	P
Long Creek (17-106-001)											
303631	0.7	1.7	58	21	18		ML	6	Mayflies (F-MI) and caddisflies (F-MI)	-	E/CW
North Fork McGuire Creek (17-107-000)											
303632	9.4	4.1	71	22	14		M	1	Mayflies (F-MI), caddisflies (F-MI), and midges (MT-F)	-	E
303633	7.7	6.9	58	20	20		ML	2	Mayflies (F-MI), caddisflies (F-MI), midges (MI), and <i>Atherix lantha</i> flies (MI)	-	E
303542	6.0	11.3	55	22	16		M	0	Riffle beetles (F-MI), aquatic mites (F), baetid mayflies (F-MI), and hydropsychid caddisflies (F-MI)	-	E
Bear Hole Run (17-108-000)											
303634	1.7	1.4	61	20	25		M	10	<i>Chimarra</i> caddisflies (MI), hydropsychid caddisflies, Leptiphlebiae mayflies, <i>M. vicarium</i> mayflies (MI)	-	E/CW
Tributary to Conotton Creek (17.22) (17-100-003)											
303635	1.0	6.3	41	17	12		ML	0	Hydropsychid caddisflies (F), <i>Chimarra</i> caddisflies (MI), Diptera (F)	-	VG
Thompson Run (17-104-000)											
303615	0.7	3.7	54	16	9		M	1	Midges (F), hydropsychid caddisflies (F), beetles (F)	-	G
Indian Fork (17-110-000)											
R08W03	13.9	12.3	51	11	8		M	2	Beetles (MI-F) and midges (MI-MT)	-	MG
303543	9.0	33.5	47	12/13	9/11		L/958	0	Freshwater sponge (F), midges (F), baetid mayflies (F)	46	E
R08S15	0.5	70.0	30	1/2	0/1		M/1767	0	Midges (MT-T), aquatic worms (T), and flatworms (F)	<u>8</u>	P
Friday Creek (17-117-001)											
303628	1.2	3.5	54	14	11		ML	1	Midges (F), riffle beetles (F), snails (T-F), and lepticerid caddisflies (MI-F)	-	G
Gantz Creek (17-117-000)											
303639	1.2	7.3	69	22	19		M	2	Hydropsychid caddisflies, aquatic mites (F), beetles	-	E
Honey Run (17-110-001)											
R08P01	0.6	3.4	44	13	13		L	3	Hydropsychid caddisflies, aquatic mites (F), midges	-	G
303642	0.5	3.8	36	7	5		H	2	Midges, flatworms (F), hydropsychid caddisflies	-	F
Cold Spring Run (17-115-000)											

Station	RM	Dr. Ar. Ql. (mi ²)	Ar. Ql. Taxa	EPT taxa Ql./Total	Sensitive taxa Ql./Total	Denisty Ql./Qt.	CW Taxa	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI ^a	Narrative Evaluation
303644	0.6	5.9	56	13	10	M	0	Riffle beetles (F) and midges (F)	-	G
Pleasant Valley Run (17-114-000)										
303646	1.5	6.5	76	24	24	M	4	Diptera, hydroptychid caddisflies	-	E
Willow Run (17-113-000)										
303649	1.5	7.7	70	19	14	M	1	Midges, hydroptychid caddisflies, beetles	-	E
Elliot Run (17-111-000)										
303702	1.4	3.5	58	19	17	L	3	Aquatic mites (F), midges (MI-F), and hydroptychid caddisflies (F)	-	E
Tributary to Indian Fork (3.30) (17-110-004)										
303651	1.4	3.4	39	7	3	M	3	Beetles (F-T), Odonata (F-T), aquatic snails (F-T)	-	F
Tributary to Conotton Creek (11.37) (17-100-004)										
303614	0.3	4.6	44	10	7	L	0	Midges, and hydroptychid caddisflies	-	F
Tributary to Conotton Creek (7.67) (17-100-005)										
303654	2.9	3.8	52	9	6	M	1	Midges (F), hydroptychid caddisflies (F-MI), and aquatic mites (F)	-	F
Beggar Run (17-102-000)										
303653	0.5	4.0	51	10	9	ML	0	Midges (F), riffle beetles (F), <i>Lype diversa</i> caddisflies (MI)	-	MG
Huff Run (17-101-000)										
300601	7.8	3.7	57	16	15	L	0	Hydroptychid caddisflies (F), riffle beetles (MI-F), and midges (F)	-	G
300599	5.5	6.5	31	3	5	L	0	Diptera (F), aquatic mites (F)	-	LF
300595	1.3	11.8	22	4	1	M	0	Hydroptychid caddisflies (F), midges (T), scuds (F)	-	LF

RM: River Mile.

Dr. Ar.: Drainage Area

Ql.: 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.

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

CW: Cold Water.

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

^aICI values in parentheses are invalidated due to insufficient current speed over the artificial substrates. The station evaluation is based on the qualitative sample narrative evaluation.

^bSuspected disturbance by vandalism.

Table 20 - Uncommonly collected sensitive macroinvertebrate taxa and all freshwater mussel collection locations in the Conotton Creek basin, 2016.

Taxa	Collection Location by River Mile
Ephemeroptera	
<i>Anaoptilum minor group sp. 1</i>	Kirby Run RM 0.70; McGuire Cr. RM 8.30; N. Fk. McGuire Cr. RM 6.00, 7.70
<i>Plauditus punctiventris</i>	Elliot Run RM 1.40 (Bolton et al., 2019)

Taxa	Collection Location by River Mile
<i>Eurylophella</i> sp.	Dining Fork RM 6.30; Bear Hole Run RM 1.70
<i>Baetisca</i> sp.	Conotton Cr. RMs 32.50, 28.94, 23.68, 22.00, 17.00, 13.90, 11.36; Dining Fork RM 6.30; Elliot Run RM 1.40; Indian Fork RM 9.00; Kirby Run RM 0.70; McGuire Cr. RM 8.30; N. Fk. McGuire Cr. RM 7.70; Trib. to Conotton Cr. (17.22) RM 1.00; Trib. to Conotton Cr. (11.37) RM 0.30; Willow Run RM 1.50
Odonata	
<i>Stylurus</i> sp.	Conotton Cr. RM 23.68
Megaloptera	
<i>Nigronia fasciata</i> CW	Bear Hole Run RM 1.70
Trichoptera	
<i>Dolophilodes distinctus</i>	Bear Hole Run RM 1.70
<i>Ochrotrichia</i> sp.	Conotton Cr. RM 13.90
<i>Brachycentrus numerosus</i>	Conotton Cr. RMs 32.50, 28.94, 23.68, 22.00, 13.90, 11.36, 6.70
<i>Hydatophylax argus</i>	Bear Hole Run RM 1.70; Willow Run RM 1.50
<i>Goera</i> sp.	Bear Hole Run RM 1.70
<i>Lepidostoma</i> sp.	Lick Fork RM 0.20
Coleoptera	
<i>Optioservus ampliatus</i>	Dining Fork RM 6.30; Honey Run RM 0.63; Huff Run RM 7.85; Indian Fork RM 13.96; Pleasant Valley Run RM 1.50
<i>Optioservus trivittatus</i>	Bear Hole Run RM 1.70; Cold Spring Run RM 0.60; Dining Fork RMs 0.20, 4.30; Gantz Cr. RM 1.20; Irish Cr. RM 5.00; Jefferson Cr. RM 0.12; Kirby Run RM 0.70; Lick Fork RM 0.20; McGuire Cr RM 9.90; N. Fk. McGuire Cr. RMs 6.00, 7.70; Trib. to Conotton Cr. (28.20) RM 0.60
<i>Anchytarsus bicolor</i>	Dining Fork RM 6.30; Trib. to Conotton Cr. (28.20) RM 0.60
Diptera	
<i>Trissopelopia ogemawi</i>	Bear Hole Run RM 1.70
<i>Potthastia gaedii</i> group	N. Fk. McGuire Cr. RM 7.70
<i>Parakiefferiella n.sp. 5</i>	Beggar Run RM 0.50; Dining Fork RM 6.30; Long Cr. RM 0.70; Trib. to Conotton Cr. (7.67) RM 2.90; Trib. to Indian Fork (3.30) RM 1.40; Willow Run RM 1.50
<i>Xylotopus par</i>	Conotton Cr. RM 22.00; Huff Run RM 7.85; Long Cr. RM 0.70; N. Fk. McGuire Cr. RMs 7.70, 9.40; Pleasant Valley Run RM 1.50
<i>Parachironomus pectinatellae</i>	Cold Spring Run RM 0.60
<i>Cladotanytarsus vanderwulpi</i> group sp. 4	Cold Spring Run RM 0.60; Dining Fork RMs 4.30, 6.30; Irish Cr. RM 5.00
<i>Dicranota</i> sp.	Bear Hole Run RM 1.70; Dining Fork RM 6.30; Elliot Run RM 1.40; Honey Run RM 0.63; Irish Cr. RM 5.00; Long Cr. RM 0.70; McGuire Cr. RM 9.90; Pleasant Valley Run RM 1.50
<i>Limnophila</i> sp.	Friday Cr. RM 1.20
<i>Pseudolimnophila</i> sp.	Bear Hole Run RM 1.70; Dining Fork RM 6.30
<i>Ptychoptera</i> sp.	McGuire Cr. RM 1.38
Unionidae	

Taxa	Collection Location by River Mile
<i>Lasmigona compressa</i> - SC	Beggar Run RM 0.50

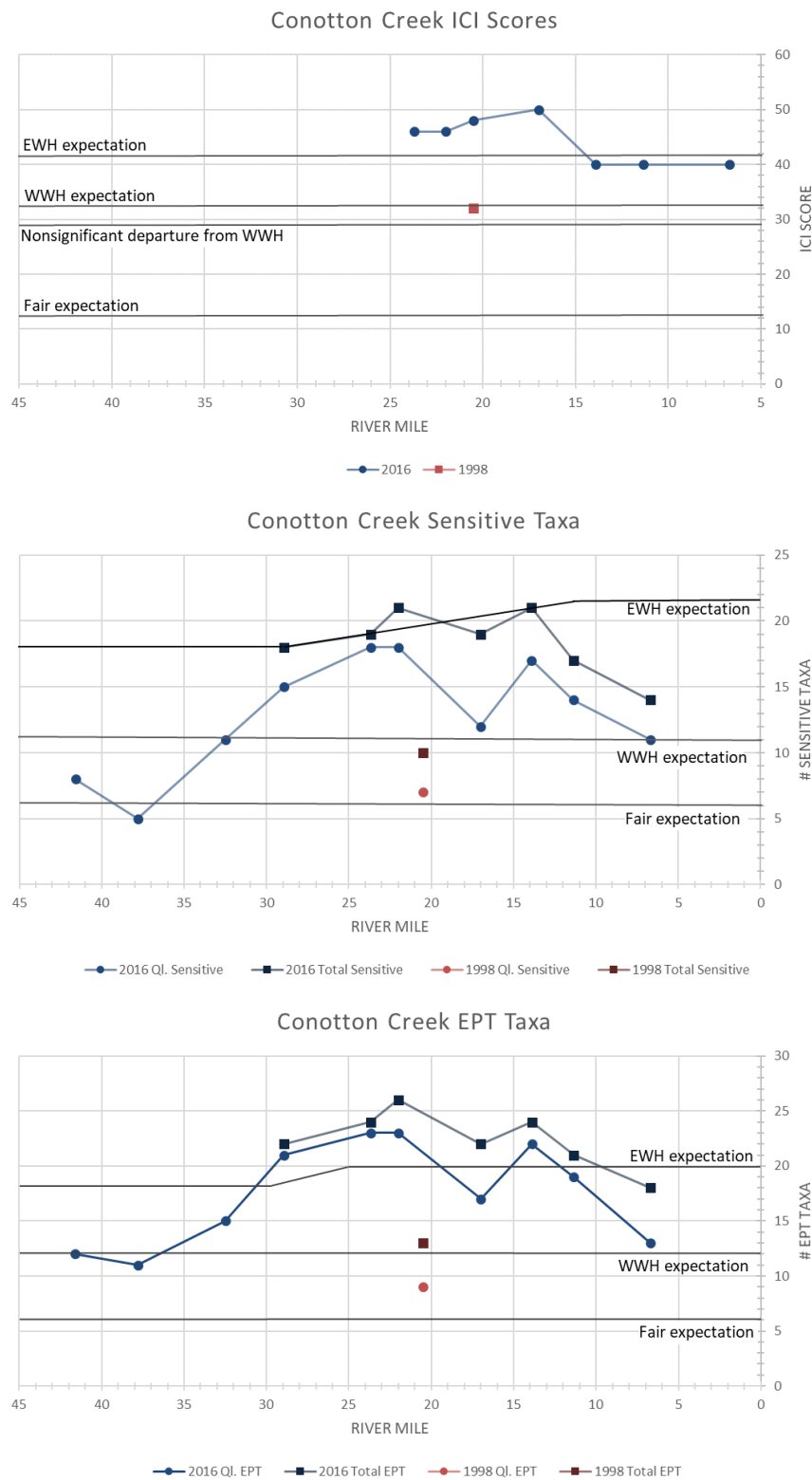


Figure 19 - Longitudinal trend of Invertebrate Community Index (ICI), qualitative and total number of sensitive taxa, and qualitative and total EPT taxa in Conotton Creek, 1998-2016.

Downstream from Leesville Lake, McGuire Creek (RM 1.4, R08W04) had a poor macroinvertebrate community (ICI=12). Similar poor results (ICI=8) were achieved downstream from Atwood Lake in Indian

Fork (RM 0.5, R08S15). Both locations were predominated by pollution tolerant organisms and the 30 qualitative taxa present at each site were among the least abundant in the 2016 study. Both Leesville and Atwood lakes discharged low quality water because the dam outlet structures release from the hypolimnion. During the late summer, both lakes stratify; water that is released from these lake bottoms often has high concentrations of ammonia and dissolved metals. These constituents can be acutely toxic to aquatic life.

Upstream from Atwood Lake, Indian Fork macroinvertebrate communities were assessed at two stations with marginally good (RM 13.9, SR 332, Scio Rd., R08W03) and very good (ICI=46, RM 9.0, from SR 39, Roswell Rd., 303543) results. Freshwater sponge and other facultative taxa predominated the RM 9.0 site. The near backwater conditions created by the low gradient channel and proximity to Atwood Lake were credited for the abundance of *Spongillidae spp.* as these organisms with a preference for clear water are often associated with lentic conditions. Beetle and midge taxa with a range of pollution tolerance were abundant at RM 13.9. Modest numbers of qualitative EPT (11) and sensitive (8) taxa were likely influenced by proximity to Honey Run and the Carrollton WWTP.

Indian Fork begins at the confluence (RM 14.24) of Honey Run and Gantz Creek. The Carrollton WWTP discharges to Honey Creek at RM 0.53. Friday Creek is a tributary (RM 1.64) to Gantz Creek. Upstream from the Carrollton WWTP, 13 EPT and 13 sensitive taxa were collected in Honey Creek, while downstream only seven EPT and five sensitive taxa were present. Elevated densities of tolerant and facultative organisms on the downstream natural substrates differed from the low densities observed upstream. Overall taxa abundance declined from 44 to 36 downstream. These declines in macroinvertebrate community diversity were attributed to stress from increased nutrient concentrations discharged by the Carrollton WWTP. Good macroinvertebrate community performance in Friday Creek improved downstream to exceptional in Gantz Creek. Strong flow and better habitat including more riparian forest in proximity to the Gantz Creek location were credited for the increased array of sensitive caddisfly taxa at the downstream site.

Cold Spring Run joins Indian Fork at RM 11.81. Facultative riffle beetles and midges were common at RM 0.6 (from SR 39, Roswell Rd., 303644) warranting a good community characterization. The sample location within a former livestock pasture was deeply incised with fewer riffles than similar size streams. The lack of stream name implied coldwater taxa was taken as further evidence of the degraded habitat quality.

Sites on four tributaries to Atwood Lake in the Indian Fork subwatershed were evaluated for macroinvertebrate community status. Exceptional performance in Pleasant Valley, Willow, and Elliot Runs contrasted with a fair assessment in an Indian Fork Tributary at RM 3.30. With 76 qualitative organisms, a third of which were pollution sensitive EPT taxa (24), the Pleasant Valley assemblage was among the most diverse in the 2016 study. The adjacent Willow Run community (70 qualitative taxa) differed with more pollution tolerant (17 vs. 13) and fewer coldwater taxa (1 vs. 4) than were collected in Pleasant Valley Run. Bookending these high-quality communities, the Elliot Run assemblage with 58 qualitative taxa was similar to Cold Spring Run with 56 organisms. However, with 19 EPT and 17 pollution sensitive taxa, the Elliot and Willow Runs assemblages mirrored each other. Whereas Cold Spring Run with 13 EPT and 10 pollution sensitive taxa lacked the community richness present in sister streams.

The fair macroinvertebrate performance in the Indian Fork Tributary at RM 3.30 (303651) contrasted further from its subbasin neighbor streams. Only 39 qualitative taxa and just seven EPT were found in the RM 3.30 Tributary. Facultative beetles, dragonfly larvae, and aquatic snails predominated the pollution tolerant assemblage. Limited to three pollution sensitive taxa, the Indian Fork Tributary at RM 3.30

macroinvertebrates appeared to be affected by water quality conditions. The sampling sites proximity to legacy coal mines known for contaminated discharges gave further credence to the supposition.

Continuing impacts from historic coal mines were apparent in all Conotton Creek lower reach tributaries. Mostly facultative midges predominated in the Conotton Creek Tributaries at RM 11.37 (303614), and at RM 7.67 (303654), and in Beggar Run (303653). *Polypedilum (P.) illinoense*, a pollution and toxicity tolerant midge, was common at the three sample sites in these streams. Ratios of sensitive to tolerant taxa less than one at all locations were indicative of environmental stress often due to degraded water quality. Conversely, the presence of *Rheotanytarsus pellucidus*, a pollution sensitive filter feeding midge, *Proclotron viridoculare*, a pollution sensitive minnow mayfly, and the afore mentioned creek heelsplitter (*Lasmigona compressa*) in Beggar Run suggested that stream had ameliorating water quality attributes which merited a marginally good evaluation. Those positive offsetting indicator species were absent in the RM 11.37 and RM 7.67 Conotton Creek Tributaries where fair macroinvertebrate performance was recorded. In those streams, the presence of *Baetis intercalaris*, a minnow mayfly associated with at least modest flow, contrasted with the species absence in Beggar Run, implied stronger perennial flow may exist in the unnamed Tributaries.

Ohio EPA previously assessed Huff Run macroinvertebrate communities in 2012 and 2008 (Figure 19). Huff Run was sampled at three locations in 2016. Good macroinvertebrate assemblage performance at the most upstream site was in stark contrast with low fair downstream site evaluations. Overwhelmed by siltation, orange colored precipitate smothered and embedded the downstream substrates. This signature of acidic coal mine drainage and metal flocculant was prevalent throughout Huff Run at and downstream from RM 5.5 (CR 36, Brass Rd., 300599). Facultative fly larvae (Diptera) and aquatic mites, predominant at RM 5.5, were displaced by high densities of facultative hydroptychid caddisflies, scuds, and pollution tolerant midges at RM 1.3 (CR 90, New Cumberland Rd., 300595). The prevalence of these organisms in an assemblage of only 22 taxa, the least among 2016 study sites, was attributed to organic enrichment from inadequate sewage treatment.

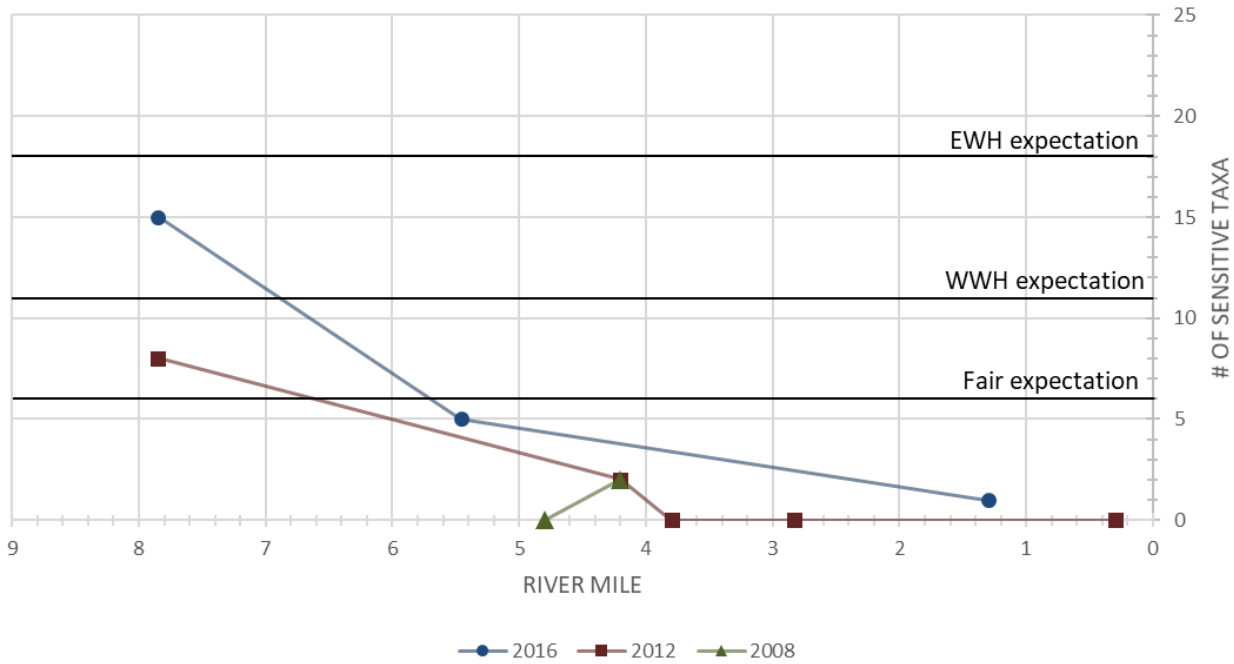
Following completion of several mine remediation projects, Huff Run macroinvertebrate assemblages were evaluated in 2008 at two locations. Half of the 16 taxa which comprised the poor community at RM 4.8 (Hope Rd., 300598) were pollution tolerant. The site was downstream from the 2005 Lindentree Project. Twenty taxa comprised a community narratively considered to be low fair at RM 4.2 (Adjacent Brass Rd., 300603). Two pollution sensitive types of caddisflies at this site were better than none at RM 4.8 (Figure 19, upper plot). The RM 4.2 location was downstream from the 2003 Linden Bioremediation Project and the 2006 Harsha North Project.

Several more mine remediation projects, including the 2008 Fern Hill, 2010 Thomas, and the 2011 Lyons II maintenance reconstruction were completed prior to a five-site macroinvertebrate assessment in 2012. Unfortunately, fewer taxa (16) at RM 4.2 were narratively deemed poor. Although two sensitive taxa persisted at the site, none were present at three downstream locations (Figure 19, upper plot). Marginally good performance at RM 7.8 (TR 170, Heritage Rd. 300601) represented a reach upstream from the historic coal mine influences. From 42 total and eight pollution sensitive taxa in 2012, the RM 7.8 macroinvertebrate community increased to 57 total and 15 pollution sensitive taxa in 2016. That good performance coincided with a doubling of EPT taxa from 8 in 2012 to 16 in 2016 (Figure 19, lower plot).

It's relevant to note, no overt efforts were made to improve water quality or habitat attributes in relation to the improvements registered by the macroinvertebrate assemblage at RM 7.8 prior to the 2016 study. Natural

attenuation may be credited for orchestrating subtle changes that led to biological enhancement. Huff Run at RM 4.2 and downstream resisted those factors and the concerted efforts to chemically improve water quality conditions. Although the 2016 lower reach Huff Run macroinvertebrates achieved low fair evaluations, dedicated efforts to address stream substrate sedimentation and removal of metal contaminated precipitate will be necessary to prompt further biological recovery.

Huff Run Qualitative Sensitive Taxa



Huff Run Qualitative EPT Taxa

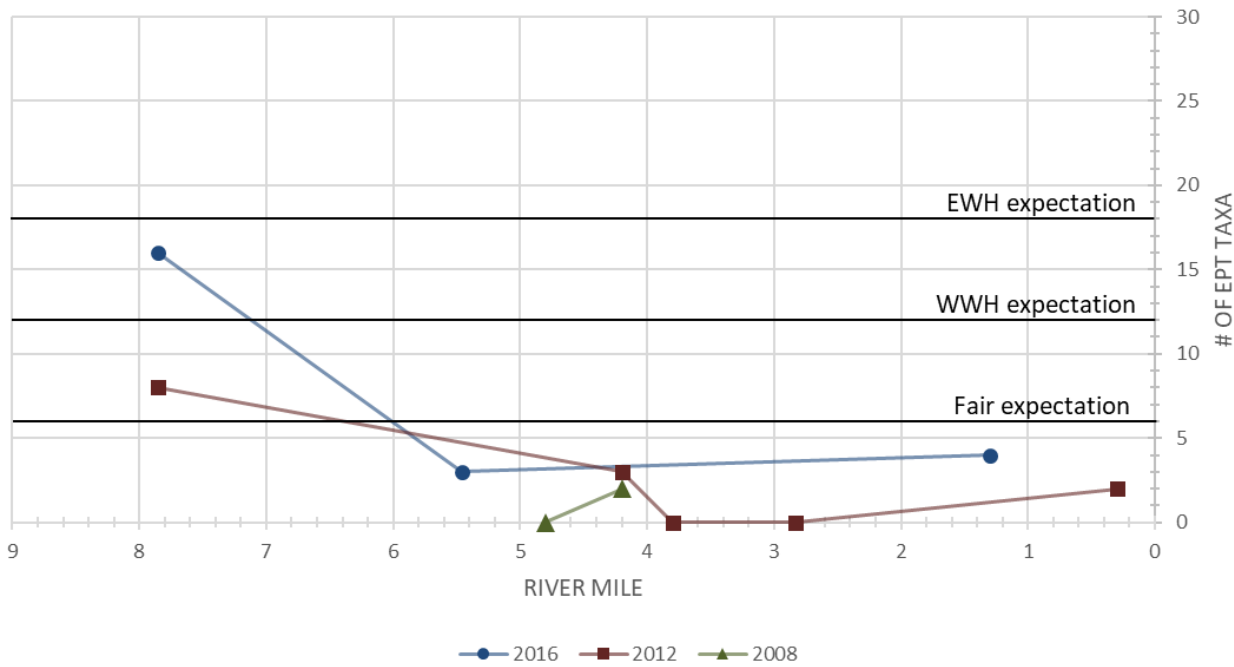


Figure 20 - Longitudinal trend of number of EPT and sensitive taxa in Huff Run, 2008-2016.

Aquatic Life Use Discussion

The drilling of Ohio's first horizontal Utica/Point Pleasant shale oil and gas well in 2011 initiated the newest boom in a long history of resource extraction within the Conotton Creek watershed. Previously, when the associated economic prosperity went bust, residual landscape impacts were common and leftover infrastructure remained strewn about. The current boom episode may offer an alternative ending. In 2016, no water quality impairment was attributed to contemporary oil and gas development or the attendant infrastructure. Legacy issues from former boom times did limit aquatic life use attainment (Table 21).

Within the eight-digit Tuscarawas River HUC (05040001, Figure 2), 23 sites were sampled in seven 12-digit Headwaters to Conotton Creek HUCs (07-01 to 07-07) and 25 sites were sampled in five 12-digit Indian Fork HUCs (08-01 to 08-06). Altogether, 31 sites (65%) attained the existing or recommended aquatic life use (ALU). Most ALU departure occurred in the Indian Fork HUC where 14 locations failed to achieve criteria compared to three sites in the 05040001 07 HUC.

In the headwaters to Conotton Creek HUC, poor macroinvertebrate community performance in McGuire Creek downstream from Leesville Lake (05040001 07 06, R08W04) resulted in WWH non-attainment. A fair macroinvertebrate assessment coupled with a very good fish community evaluation resulted in partial WWH attainment in Jefferson Creek in the Jewett Park (05040001 07 01, R08S07). Exceptional aquatic communities in the Dining Fork HUC (05040001 07 03) were flawed by a good fish assemblage at RM 6.3 (TR 382, Pontiff Rd., 303626). This departure made for partial attainment of the recommended EWH ALU. All North Fork McGuire Creek HUC (05040001 07 05) aquatic communities achieved exceptional scores and met the recommended EWH ALU. Generally good biological scores attained existing or recommended ALU criteria in the 05040001 07 02, 04, and 07 HUCs. Thus, full ALU attainment was registered in four of the seven Headwaters to Conotton Creek HUCs.

Only one of the five Indian Fork HUCs had similar attainment. At least good aquatic assemblage evaluations were noted at all four Thompson Run-Conotton Creek HUC (05040001 08 03) sample sites. Otherwise, at least two sites in non or partial attainment were documented in four other Indian Fork HUCs. Poor macroinvertebrate community performance in Indian Fork downstream from Atwood Lake (R08S15) echoed the WWH non-attainment associated with Leesville Lake. In the 05040001 08 02 HUC, non-attainment in the Indian Fork Tributary at RM 3.30 (SR 542, 303651) was due to fair scores achieved by both indicator assemblages, while just fair fish community scores in Indian Fork at RM 9.0 (from SR 39, Roswell Rd., 303543), in Willow Run (CR 29, Bedrock Rd., 303649), and in Elliot Run (CR 69, Clay Rd., 303702) were cause for partial WWH attainment. In the 05040001 08 01 HUC, both indicator assemblages achieved fair scores in Honey Run downstream from the Carrollton WWTP (R08P01) resulting in WWH non-attainment. Within the same HUC, fair fish community status in Indian Fork downstream from the Honey Run and Gantz Creek confluence (R08W03) and in Cold Spring Run (from SR 39, Roswell Rd., 303644) were the basis for partial WWH attainment.

At two of three sample locations in the Huff Run HUC (05040001 08 04), both macroinvertebrate and fish communities earned fair evaluations and both sites were in non-attainment of the recommended WWH ALU. Sampling occurred in three tributaries and at three mainstem sites in the Dog Run-Conotton Creek HUC (05040001 08 05). No suitable habitat was present for macroinvertebrate assessment at the most downstream mainstem site where fair fish community performance resulted in WWH non-attainment. Non-attainment of the recommended WWH ALU also occurred in the Conotton Creek Tributary at RM 7.67 (TR 388, Brown Hill

Rd., 303654) as both indicator groups registered fair evaluations. A fair macroinvertebrate community score in the Conotton Creek Tributary at RM 11.37 (TR 320, Dawn Rd., 303614) and a fair fish community score in Beggar Run (CR 90, New Cumberland Rd., 303653) were reasons for partial attainment of the respective recommended WWH ALU.

These administrative stream groupings provide a convenient way to summarize and compare status of similar size geographic areas. Grouping sites by common factors or unique attributes is an alternative way to review stream qualities. In the Conotton Creek basin, biological assemblages downstream from Atwood and Leesville Lakes were both affected by hypolimnetic water released from the associated dam discharge structures. Abandoned coal mines that continue to challenge aquatic life in Huff Run, in nearby small streams in the northwestern part of the watershed, and in Jefferson Creek. Conotton and Jefferson Creeks, Indian Fork, Cold Spring, Willow, and Elliot Runs had habitat and hydrologic alterations which skewed aquatic community performance. The Carrollton WWTP discharge limited downstream macroinvertebrate and fish populations in Honey Run and in Indian Fork. Lastly, the marginally good fish community at the most upstream Dining Fork sample site was enigmatic. Set against the recommended EWH ALU, the least rich fish assemblage in the 2016 study, comprised by just seven species, was apparently representative of singular circumstances.

Determination of the status of Dining Fork at RM 6.3 (TR 382, Pontiff Rd., 303626) necessarily begins with an assessment of the appropriate ALU designation. While WWH may be regarded as a baseline, demonstration of an aquatic community's exceptional qualities is generally expected before the EWH ALU is recommended. This practice recognizes the distinction between good assemblages which achieve WWH biocriteria, very good assemblages which exceed the WWH baseline, and exceptional assemblages which meet EWH expectations. Those differences were evident across the Conotton Creek watershed. Exceptional performance was documented at seven sites in the McGuire Creek subbasin upstream from Leesville Lake (IBI \bar{x} =50, ICI \bar{x} =Exceptional). Very good to good assemblages were present at seven sites in the upper Conotton and Irish Creek subbasins (IBI \bar{x} =46, ICI \bar{x} =good). Thus, EWH or WWH (or CWH) respectively, are appropriate ALUs for those subbasin reaches.

Located between the McGuire and Irish Creek subbasins, aquatic community performance at four sites in the Dining Fork watershed was very good to exceptional (IBI \bar{x} =46, ICI \bar{x} =Exceptional). Collectively, the Dining Fork assemblages demonstrated EWH attainment. However, by allowance of the range of non-significant departure, the marginally good fish community at the most upstream site (IBI=40) barely achieved the WWH criterion (IBI=44, \pm 4). That variance was more consequential in recommending EWH for Dining Fork because it presumes the deviation from at least very good performance derived from an identifiable impairment. Then again, recommending WWH would under value the consistently exceptional Dining Fork drainage macroinvertebrate assemblages. The challenge here was that the upstream Dining Fork fish community presented few overt signs of impairment.

The dearth of fish species was at least one indication that the upstream Dining Fork assemblage was atypical. More so because several of those missing at the upstream site were present downstream and at nearby similar drainage area locations. Those missing fish included species with an affinity for pools such as Redside Dace, Common Shiner, and sunfish types, as well as some with specific under crevice spawning requirements including Bluntnose Minnow (*Pimephales notatus*) or Fantail Darter. The lack of Blackside (*Percina maculata*) and Greenside Darters was also notable. The absence of these species coincided with some site-specific habitat conditions. Dining Fork at RM 6.3 was the only location in the 2016 Conotton Creek study where

bedrock was a prevalent substrate. The location was further qualified for having the lowest QHEI pool metric score in the study area.

Since mixed aggregates are generally more conducive to fish diversity, attention is given when arranging fish sampling zones to avoid substantial bedrock reaches. Bedrock was at least present at several study area sites. Compared to the extensively embedded, silty substrates at downstream Dining Fork sites, the less silty, moderately embedded conditions at the upstream site also featured large boulders strewn throughout reaches of cobble substrate. The prevalence of the larger rock reaches was especially noticeable because the sampling zone pools were only shin deep (< 40cm). A small amount of water circulated around the large rocks. Stream flow was insufficient to overtop most aggregate, so riffles were not functional.

Table 21 - Attainment status of the existing or recommended aquatic life uses for the Conotton Creek basin, Western Allegheny Plateau (WAP) ecoregion, 2016. Symbology follows Table 2. Ecoregional biocriteria are presented in Table 2.

Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	QHEI	Status	Causes	Sources
Headwaters Upper Conotton Creek 05040001 07 01										
Conotton Creek WWH										
303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	48	-	Good	48.5	Full		
Headwaters Middle Conotton Creek 05040001 07 04										
R08S04	CR 50, New Rumley Rd.	37.8	17.5	50	-	M. Good ^{ns}	48.3	Full		
R08K05	CR 80, Leffler Rd.	32.6	48.0	45	9.5	Good	61.3	Full		
Headwaters Lower Conotton Creek 05040001 07 07										
R08S01	CR 25, Conotton Rd.	29.1	70.0	43 ^{ns}	8.9	46	54.3	Full		
R08W05	SR 164, Amstedeam Rd.	23.7	87.0	51	10.3	46	72.1	Full		
R08K03	CR 22, Azalea Rd. (Boat)	22.1	89.0	41	9.3	48	45.0	Full		
Thompson Run-Conotton Creek 05040001 08 03										
303578	SR 39, Church St, Sherrodsville	17.0	156.2	44	8.9	50	77.5	Full		
303579	TR 394, Miller Hill Rd.	13.9	165.3	45	9.0	40	53.0	Full		
Dog Run-Conotton Creek 05040001 08 05										
R08S14	CR 90, New Cumberland Rd. (Boat)	11.4	241.0	36 ^{ns}	8.8	40	59.0	Full		
303580	from TR 399, Marsh Rd. (Boat)	6.7	261.8	40	8.9	40	58.5	Full		
303581	Zoarville Station trail TR 390	0.2	286.0	33*	7.9*	-	56.0	(NON)	Flow Regime Modification	Hydrostructure Flow Regulation/ Modification
Headwaters Upper Conotton Creek 05040001 07 01										
Jefferson Creek WWH										
R08S07	High St., Jewett Park	0.2	6.5	46	-	Fair*	44.0	Partial	TDS (Specific Conductivity)	Abandoned Mine Lands
Irish Creek 05040001 07 02										
Irish Creek WWH, CWH recommended ust. Lick Fork (RM 3.09)										
303624	from CR 35, Branch Rd.	5.0	6.7	44	-	Good	48.0	Full		
Irish Creek WWH										
R08S13	SR 646, Scio New Rumley Rd.	2.1	14.9	46	-	Good	51.0	Full		
Lick Fork CWH recommended										
303625	TR 135, Burrier Rd.	0.2	5.0	40	-	Exceptional	55.3	Full		
Dining Fork 05040001 07 03										
Dining Fork EWH recommended										
303626	from TR 382, Pontiff Rd.	6.3	3.1	40*	-	Exceptional	54.0	Partial	Habitat Alterations	Riparian Vegetation
303627	TR 645, Tartan Rd.	4.3	6.3	48 ^{ns}	-	Exceptional	61.0	Full		
303628	SR 151, Scio-Bowerston Rd.	0.2	14.7	46 ^{ns}	-	V. Good ^{ns}	57.0	Full		
Kirby Run EWH recommended										
303629	adj. SR 332, Scio Rd.	0.7	3.4	48 ^{ns}	-	Exceptional	65.5	Full		
Headwaters Lower Conotton Creek 05040001 07 07										

Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	QHEI	Status	Causes	Sources
Scott Run (not assessed for attainment status)										
303630	SR 151, Scio-Bowerston Rd.	0.7	3.1	-	-	Fair	-	-		
Conotton Creek Tributary (RM 28.20) WWH recommended										
303618	CR 43, Bower Rd.	0.6	3.8	48	-	M. Good ^{ns}	49.5	Full		
McGuire Creek 05040001 07 06										
McGuire Creek EWH recommended ust. RM 7.57 (at unnamed tributary confluence near SR 332, Scio Rd.)										
303616	adj. CR 17, Aster Rd.	9.9	2.7	52	-	Exceptional	57.0	Full		
303617	TR 374, Plymouth Rd.	8.3	7.1	47 ^{ns}	-	V. Good ^{ns}	62.0	Full		
McGuire Creek WWH recommended dst. RM 7.57 (at unnamed tributary confluence near SR 332, Scio Rd.)										
R08W04	dst. Leesville Lake dam	1.4	48.0	38*	7.9 ^{ns}	12*	53.6	NON	Toxicity	Hydrostructure Flow Regulation/ Modification
Long Creek EWH recommended										
303631	CR 8, Alamo Rd.	0.7	1.7	48 ^{ns}	-	Exceptional	58.0	Full		
North Fork McGuire Creek 05040001 07 05										
North Fork McGuire Creek EWH recommended										
303632	TR 354, Pebble Rd.	9.4	4.1	50	-	Exceptional	79.5	Full		
303633	CR 19, Autumn Rd.	7.7	6.9	50	-	Exceptional	85.5	Full		
303542	SR 322, Scio Rd.	6.0	11.3	52	-	Exceptional	68.0	Full		
Bear Hole Run EWH recommended										
303634	CR 54, Canyon Rd.	1.7	1.4	50	-	Exceptional	59.0	Full		
Thompson Run-Conotton Creek 05040001 08 03										
Conotton Creek Tributary (RM 17.22) WWH recommended										
303635	pipeline	1.0	6.3	44	-	Very Good	72.6	Full		
Thompson Run WWH recommended										
303615	from SR 39, Roswell Rd.	0.7	3.7	52	-	Good	59.0	Full		
Cold Spring Run-Indian Fork 05040001 08 01										
Indian Fork WWH recommended										
R08W03	SR 332, Scio Rd.	13.9	12.3	36*	-	M. Good ^{ns}	71.0	Partial	Nutrients	Municipal WWTP
Pleasant Valley Run-Indian Fork 05040001 08 02										
303543	from SR 39, Roswell Rd.	9.0	33.5	30*	8.5	46	55.0	Partial	Flow Regime Modification	Impoundment
R08S15	dst. Atwood Lake dam @ SR 212	0.5	70.0	34*	7.2*	8*	53.1	NON	Toxicity	Hydrostructure Flow Regulation/ Modification
Cold Spring Run-Indian Fork 05040001 08 01										
Gantz Creek WWH recommended										
303639	TR 354, Pebble Rd.	1.2	7.3	44	-	Exceptional	65.8	Full		
Friday Creek WWH recommended										
303640	CR 66, Chase Rd.	1.2	3.5	46	-	Good	51.5	Full		
Honey Run WWH recommended										
R08P01	ust. Carrollton WWTP/ tributary	0.8	3.4	44	-	Good	75.5	Full		

Station	Stream / Location	RM	Mi ²	IBI	MIwb ^a	ICI ^b	QHEI	Status	Causes	Sources
303642	dst. Carrollton WWTP	0.6	3.8	36*	-	Fair*	78.3	NON	Nutrients Copper	Municipal WWTP
Cold Spring Run <i>WWH recommended</i>										
303644	from SR 39, Roswell Rd.	0.6	5.9	36*	-	Good	56.0	Partial	Habitat Alterations	Riparian Vegetation
Pleasant Valley Run <i>WWH recommended</i>										
303646	TR 147, Folsam Rd.	1.5	6.5	42 ^{ns}	-	Exceptional	56.5	Full		
Pleasant Valley Run-Indian Fork 05040001 08 02										
Willow Run <i>WWH recommended</i>										
303649	CR 29, Bedrock Rd.	1.5	7.7	30*	-	Exceptional	43.0	Partial	Flow Regime Modification	Channelization
Elliot Run <i>WWH recommended</i>										
303702	CR 69, Clay Rd.	1.4	3.5	30*	-	Exceptional	32.0	Partial	Flow Regime Modification	Channelization
Indian Fork Tributary (RM 3.30) <i>WWH recommended</i>										
303651	SR 542	1.4	3.4	28*	-	Fair*	41.3	NON	Sedimentation	Abandoned Mine Lands
Dog Run-Conotton Creek 05040001 08 05										
Conotton Creek Tributary (RM 11.37) <i>WWH recommended</i>										
303614	TR 320, Dawn Rd.	0.3	4.6	44	-	Fair*	48.5	Partial	Sedimentation	Hydrostructure Flow Regulation/ Modification
Conotton Creek Tributary (RM 7.67) <i>WWH recommended</i>										
303654	TR 388, Brown Hill Rd.	2.9	3.8	32*	-	Fair*	60.5	NON	TDS (Specific Conductivity)	Abandoned Mine Lands
Beggar Run <i>WWH recommended</i>										
303653	CR 90, New Cumberland Rd.	0.5	4.0	33*	-	M. Good ^{ns}	47.0	Partial	TDS (Specific Conductivity)	Abandoned Mine Lands
Huff Run 05040001 08 04										
Huff Run <i>WWH recommended</i>										
300601	TR 170, Heritage Rd.	7.8	3.3	40	-	Good	70.5	Full		
300599	CR 36, Brass Rd.	5.5	6.5	35*	-	Low Fair*	59.6	NON	TDS (Specific Conductivity)	Abandoned Mine Lands
300595	CR 90, New Cumberland Rd.	1.3	11.8	28*	-	Low Fair*	70.5	NON	TDS (Specific Conductivity)	Abandoned Mine Lands

- Boat*) Boat criteria *only* apply to Conotton Creek at RMs 22.1, 11.4, 6.7 and 0.2.
- a** The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi²).
- b** Narrative evaluation used in lieu of ICI (Exceptional; Very Good; Good; M. Good=Marginally Good; Fair; Low Fair; Poor; Very Poor).
- *** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
- ns** Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
- (NON) Macroinvertebrate assessment was precluded at Conotton Creek RM 0.2 by deep and periodically impounded stream flow conditions. Attainment status represented by one organism group is shown in parentheses

Table 22 – Narrative ranges and WWH biocriteria (bold) for the Conotton Creek study area, Western Allegheny Plateau (WAP) ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide.

Headwater IBI	Wading IBI	MIwb	Boat IBI	MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	48-60	≥9.6	46-60	Exceptional
46-49	46-49	8.9-9.3	44-47	9.1-9.5	42-44	Very Good
<i>Western Allegheny Plateau</i>						
44-45	44-45	8.4-8.8	40-43	8.6-9.0	36-40	Good
40-43	40-43	7.9-8.3	36-39	8.1-8.5	32-34	Marginally Good
28-39	28-39	5.9-7.8	26-35	6.4-8.0	14-30	Fair
18-27	18-27	4.5-5.8	16-25	5.0-6.3	8-12	Poor
12-17	12-17	0-4.4	12-15	0-4.9	≤6	Very Poor

Despite these fish habitat limitations, the 67 macroinvertebrate taxa at the site, including 24 pollution sensitive types and four indicative of cold water, were among the richest macroinvertebrate assemblages in the 2016 study (Table 19). Seven sensitive taxa were among the least frequently collected (i.e., rare, Table 20). Together, these attributes ranked the upper Dining Fork macroinvertebrate community performance among the top five in the Conotton Creek watershed. That characterization was further distinguished, recognizing that 40% of the basin macroinvertebrate assemblages achieved exceptional assessments. Thus, the disparity between fish and macroinvertebrate community evaluations in Dining Fork at RM 6.3 was difficult to reconcile.

Nevertheless, fish habitat deficiencies were apparent. Overall, Dining Fork exhibited fair habitat conditions (QHEI \bar{x} =59.4, n=4). Only the most upstream site lacked deeper pools. Bedrock substrate was also exposed in Dining Fork at RM 4.3 (TR 645, Tartan Rd., 303627). Habitat at that site included a deep pool (1m) upstream from a steep cascade where the course dropped about one meter over a ten-meter reach. The shallow flow around larger rocks observed at RM 6.3 was apparent downstream from the cascade at RM 4.3. Although the RM 4.3 site was siltier, all the above-mentioned pool, riffle, and under crevice spawning fish species were modestly abundant.

Conceivably, the less silty, more exposed bedrock at RM 6.3 might have been related to land use upstream and immediate to the site. Scouring flows had eroded outside bends and undercut the grass covered stream banks all along the overly incised channel. The adjacent parcels were formerly pastured or perhaps used as crop fields. In 2016, the farmhouse was vacant while the driveway provided access to recently built industrial oil and gas infrastructure. Further flow regime changes or other future alterations might enable the reach to retain some pool forming aggregate.

More broadly, it's reasonable to expect EWH attainment in Dining Fork considering streams in adjacent subbasins support exceptional aquatic communities. The exceptional biological index scores at McGuire Creek subbasin sites upstream from Leesville Lake (IBI \bar{x} =50, ICI \bar{x} =Exceptional, n=7) were matched by those from contiguous Yellow Creek headwater locations sampled in 2005 (IBI \bar{x} =50, ICI \bar{x} =Exceptional, n=9, Ohio EPA, 2008). Collectively, aquatic community performance in Elk Lick, Elk Fork, Elkhorn Creek, Trail Run, Gault Run, and Center Fork combined with that from Dining Fork and upper McGuire Creek (IBI \bar{x} =49, ICI \bar{x} =Exceptional, n=20) rivals the best headwater assemblage in Ohio. In that group, the marginally good fish performance in upper Dining Fork was the lowest outlier.

These oppositely allied streams flow down from a ridge, delineated by SR 9, between Harlem Springs, through Kilgore, to Germano. Further south, Stout and Lamb (1938) noticed the broad hilltops and narrow steep valleys east from the ridge, differed from the narrow hilltops and broad lower valleys in areas to the west. These disparities are most evident on the Flushing 1:62,500 topographic map (USGS, 1903). Compared to the closely spaced contour lines west from Flushing, it appears as though every other line to the east was skipped. These distinctions are not as apparent where the Flushing escarpment divides the headwaters of Conotton and Yellow creeks. Ground water elevation contour lines mapped on the *Potentiometric Surface of the Consolidated Aquifers in Carroll County* (Angle, 2006) appear tightly spaced on both sides of SR 9.

Ground water trapped over low permeable silt and clay layers in saturated zones and in bedrock fractures is continuously released into headwater streams on both sides of the Flushing escarpment. The persistence and water quality of these springs is witnessed by the resident aquatic life. As shown on maps in *A Naturalists Guide to the Fishes of Ohio* (Rice and Zimmerman, 2019), streams flowing down the SR 9 ridge are a state epicenter for the convergence of Redside Dace and Least Brook Lamprey populations. Regarding the 20 sampling locations clustered near the ridge, pollution intolerant Redside Dace were present at all but two sites on the Yellow Creek side and were only absent at two of three Dining Fork sites on the Conotton Creek

side. Four of the implicit Yellow Creek sites lacked Least Brook Lamprey. Those filter feeding fish were present at all the Conotton Creek sites. Mottled Sculpin were collected at every one of the 20 sites. These species all attest to the strong spring flow throughout the area.

The similarities among these sites make it difficult to deduce a clear rationale for the lack of fish species in upper Dining Fork. Considering the aggregate of 20 small drainage sites ($\bar{x}=5.3 \pm 3.3 \text{ mi}^2$, 1.4-14.7 mi^2) in the Harlem Springs and Kilgore area, 16 fish species were typically found ($\bar{x}=16.2 \pm 5.0$, 7-29) in nominally good stream habitat conditions (QHEI $\bar{x}=63.4 \pm 9.0$, 52-85.5). Blacknose Dace and Creek Chub were at every site. White Sucker were at all except the Long Creek site. Aside from the upper Dining Fork location, the Long Creek location was the only other site lacking Fantail Darter. Central Stoneroller Minnow were present everywhere except in upper Dining Fork and Bear Hole Run. The single Johnny Darter in upper Dining Fork was common at other sites except Elk Fork. The theme here isn't that various sites were odd for not being inhabited by a single otherwise universally distributed fish, rather that the upper Dining Fork site was particularly remiss for the lack of many species (i.e., Redside Dace, Fantail Darter, Central Stoneroller Minnow) that were common in the area. Expectation that some of those fish should have been at RM 6.3 Dining Fork is logical, as is the recommended EWH ALU.

The more compelling revelation this data supports is that these exceptional aquatic communities exist despite the lack of appreciable habitat. This seems unsustainable. The groundwater contribution is not a sufficiently reliable "deposit" in a continuing era of climate change. Fortunately, it's a situation where small habitat "investments" (i.e., livestock fencing, soil erosion reduction, riparian vegetation improvement) are certain to reap measurable water quality "rewards." Ultimately, at this nexus of so many outstanding small streams, inhabited by an array of exceptional aquatic assemblages, it is only appropriate to expect more, not less from the area where Conotton and Yellow Creeks divide.

From the Flushing escarpment, the westerly flowing Friday and Gantz Creeks were also home to aquatic communities that benefited from cold spring origins. As such, the absence of Mottled Sculpin in both streams seemed odd. In Ohio, Mottled Sculpin and Redside Dace are indicators of CWH conditions. Collection of the pollution intolerant Redside Dace in Friday and Gantz Creeks along with the typical species noticed at the 20 adjacent headwater locations, made the lack of Mottled Sculpin disconcerting. The perplexity continued in Cold Spring Run where both, Redside Dace and mottled sculpin, were missing. In fact, a blank void marks the Indian Fork and Huff Run subbasins on the Mottled Sculpin distribution map in *A Naturalists Guide to the Fishes of Ohio* (Rice and Zimmerman, 2019). The fish has been collected in surrounding streams but is locally extirpated in the Conotton Creek basin downstream from and within the Indian Fork subbasin.

In the fall of 1946, the Ohio Division of Conservation in cooperation with MWCD determined the Atwood Lake fish population was undesirable. Writing in the *Ohio Conservation Bulletin*, Mark White (1956) explained "The lake was drained and the watershed treated to destroy fish life in the headwaters. After about ten weeks the control valves were closed to store new water without fish. This rehabilitation story has been told many times in the Bulletin. The short version is that nature wasn't agreeable with the Division's plan. A new fish population grew exactly like the one that was destroyed in 1947." The bluegill and crappie remained stunted, and carp continued to roil the water.

Ohio EPA has documented 29 fish species extant upstream from Atwood Lake including Johnny and Fantail Darters. Four other darters, endemic in the Conotton Creek basin, were absent in the Indian Fork subbasin upstream from Atwood Lake. As these darters were also absent from Huff Run, historic land use rather than the 1947 rotenone treatment was considered the most likely cause for the darter and sculpin local extirpations. That said, the inference to headwater treatment and implied frequency were unsettling and merit consideration in watersheds where species are missing upstream from Ohio managed fishing lakes.

Atwood Lake was considered the least eutrophic among 20 large Ohio impoundments evaluated by the U.S. EPA in 1973 (U.S. EPA, 1975). Like the study results following the Division of Conservation's rotenone treatment (Wright, 1954), the U.S. EPA determined Atwood Lake was phosphorus limited. However, phosphorus loading from Indian Fork was 2.5 times more than appropriate. The U.S. EPA determined the Carrollton WWTP delivered one fourth of the annual phosphorus load to Atwood Lake. Low D.O. and a wide range of concentrations (0.3 - 13.1 mg/L) were accompanied by pH values (7.4 - 9.4 s.u.) indicative of nutrient enrichment.

The Carrollton WWTP continued to be a source of nutrient enrichment in 2016. High nutrient concentrations (RM 0.6, 303642, $\text{NO}_3+\text{NO}_2\text{-N}$ $\bar{x}_{geom}=7.5$ mg/L, TP $\bar{x}_{geom}=1.25$ mg/L) downstream from the facility were associated with ALU impairment (Figure 15). Exceedances of Ohio WQS for copper (17.7, 19.8 $\mu\text{g/L}$) were also measured in that reach of Honey Run. These parameters were allied with high TDS (RM 0.8, R08P01 $\bar{x}=426$ and 459 mg/L), SC ($\bar{x}=724$ and 801 $\mu\text{S/cm}$), and chloride concentrations ($\bar{x}=109$ and 106 mg/L) at both Honey Run sample sites (respectively).

Pollution tolerant and facultative macroinvertebrate densities increased downstream from the facility. Total taxa richness was greater upstream from the WWTP where twice as many EPT and sensitive types were collected. These traits were mirrored by the fish assemblage. The proportional increase in pollution tolerant Creek Chubs downstream from the facility, contrasted by the unique presence of moderately pollution intolerant Hog Suckers at just the upstream site, made consequential differences in fish community index scores. With less than 2,500 acres of upstream catchment area, addition of the discharge (<0.75 MGD) from the Carrollton WWTP had profound influence on the Honey Run aquatic biota. These impacts were unmoderated by the mostly "urban" drainage perpetually stressed by chronic chloride contamination.

Urban contaminants were evident in Indian Fork sediment downstream from Honey Run (Table 16). Amounts of copper (36.4 mg/kg) and cadmium (1.16 mg/kg) in sediment at RM 13.9 (SR 332, Scio Rd., R08W03) were more than Ohio SRV concentrations. Those values with lead (42.7 mg/kg) and zinc (157 mg/kg) measurements all exceeded TEC concentrations. Further concerning was the detection of a PAH compound, fluoranthene (4.6 mg/kg or 4,600 $\mu\text{g/kg}$), at twice the PEC concentration (2,230 $\mu\text{g/kg}$). Collectively, Indian Fork sediment at RM 13.9 was certainly capable of exerting toxic effects on aquatic life. Furthermore, substrates were noticeably siltier downstream from the Carrollton WWTP in Honey Run and in Indian Fork in comparison to upstream implicit "control" sites.

This sediment stress was exacerbated by WWTP nutrient loading and the background of chloride-tinged water. Nutrients at RM 13.9 ($\text{NO}_3+\text{NO}_2\text{-N}$ $\bar{x}=3.76$ mg/L, TP $\bar{x}=0.63$ mg/L) remained enriched and chloride ($\bar{x}=78$ mg/L) was excessive despite dilution provided by flow from Gantz Creek. The additional drainage area at RM 13.9 was favorable to aquatic assemblage richness. The marginally good macroinvertebrate community, comprised by 51 taxa including 11 EPT and eight pollution sensitive types, achieved the biocriterion. While fish community richness increased to include three suckers and three sunfish among 20 total species, the proportional abundance of pollution tolerant and pioneering types remained high like the assemblage immediately downstream from the WWTP. That and low percentages of insectivorous fish at both locations were primary factors that kept both communities from achieving the biocriteria. Alternatively, with better water quality in Gantz Creek, low percentages of tolerant and pioneering species coupled with modest insectivore abundance resulted in metric scores that achieved the biocriterion.

Although several stressors were contributory to fair fish community performance in Indian Fork at RM 13.9, similarities with the assemblage downstream from the Carrollton WWTP were compelling. Furthermore, macroinvertebrate community improvement with distance from the facility was construed to imply sediment degradation was not overtly limiting. Over the six mile stream course from the Carrollton WWTP to Indian

Fork at RM 9.0 (from SR 39, Roswell Rd., 303543), nutrient concentrations declined ($\text{NO}_3+\text{NO}_2\text{-N}$ \bar{x} =1.44 mg/L, TP \bar{x} =0.18 mg/L, n=12), but were still quite similar to values documented at a corresponding location in the 1973 U.S. EPA study ($\text{NO}_3+\text{NO}_2\text{-N}$ \bar{x} =1.62 mg/L, TP \bar{x} =0.45 mg/L, n=14, U.S. EPA, 1975). Incidentally, low D.O. and a wide range of concentrations (0.03 - 12.11 mg/L) as well as extreme pH values (6.72 – 9.48 s.u.) were also recorded at two analogous Atwood Lake sampling sites in 2016.

Despite lower nutrient and chloride (\bar{x} =62 mg/L) concentrations at RM 9.0, the Indian Fork fish assemblage remained impaired. Fish were consistent with the fluctuating backwater conditions and degraded substrate quality caused by Atwood Lake impoundment. The moderate proportion of pollution tolerant fish seemed to match the predominance of facultative macroinvertebrates at the site. Both aquatic communities were comprised by lentic associated species. Colonization of the artificial substrate sampler contributed to the very good macroinvertebrate score (ICI=46). Whereas the general simplification of the expected lotic fish community only achieved fair to good index scores (MIwb=8.4, IBI=30).

Lentic water quality in both Atwood and Leesville Lakes has profound influence on downstream lotic conditions. The U.S. Army Corps of Engineers (USACE) Huntington District *Annual Water Quality Report 2016* noted low D.O. and high dissolved metals in the outflow from both Atwood and Leesville Lakes “could be rectified in the future with the addition of a trash rack weir. This structural modification could be completed as soon as 2018 (USACE, 2016).” The *Annual Water Quality Report 2022* tempered that optimism. The modification installed in 2015 in the Tappan Lake outlet structure, which improved outflow water quality, was not as easily retrofit at Atwood or Leesville Lakes. The USACE is continuing to study this concern (USACE, 2022).

Annually, both lakes become thermally stratified with anoxic hypolimnions. Predictable redox reactions decompose organic matter, liberating phosphorus, ammonia, manganese, iron, and sulfide from lake sediments. Consequently, hypolimnetic water discharged to Indian Fork or McGuire Creek often has limited D.O. with high nutrient and dissolved metals concentrations. When pH skews toward acidity (<7 s.u.), those constituents are frequently accompanied by toxic hydrogen sulfide. Aside from outlet structure modification, nutrient inflow reduction would help check algal growth, thus diminishing the amount of oxygen needed for algae decomposition.

While sulfur is essential for most aerobic life, its presence as hydrogen sulfide is potentially toxic. The U.S. EPA hydrogen sulfide criterion continuous concentration (CCC) for aquatic life is 2.0 $\mu\text{g/L}$. Since the human nose can detect the rotten egg smell at 0.5 $\mu\text{g/L}$, simply noticing the odor from an aquatic environment is reason for concern. Furthermore, human sensitivity is unreliable. Leaving that area is prudent. Sulfate reduction is the principal means of aquatic environmental hydrogen sulfide production (Dunnette, Chynoweth, and Mancy, 1985). Because manganese and iron have higher redox potentials, those elements are usually detected where hydrogen sulfide is produced.

Redox reactions also occur in lotic waters. The interface where anoxic groundwater and oxygenated surface water mix, typically within the top fraction of stream substrate is the hyporheic zone. The presence of anoxic hyporheic microzones where nitrogen compound and redox reactions are facilitated in concert with hydraulic variation and microbial growth is a novel line of study (Chowdhury et al., 2020; Briggs et al., 2015). Aquifer characteristics (Hancock, Boulton, and Humphreys, 2005), streambed morphology (Kaufman et al., 2017), organic matter availability (Stegen et al., 2016), and temperature (Storey, Howard, and Williams, 2003) are factors which control the complex biogeochemical fluxes within the hyporheic zone.

Hyporheic zone biogeochemical assessment and the requisite specialized equipment were beyond the scope of the 2016 Conotton Creek study. However, data from the multi-parameter sondes deployed July 5 to 7 and August 23 to 25 offer some inferential insights about stream bottom conditions. Discrepancies between

samples drawn or “grabbed” from the water column and sonde data tended to show more stability, but some harsher conditions, were evident closer to the stream substrates. For example, grab sample pH values were higher than sonde records individually and in aggregate. On August 25, comparable pH values from Indian Fork (grab=7.11 s.u., sonde=6.88 s.u.) and McGuire Creek (grab=7.24 s.u., sonde=7.14 s.u.) followed the pattern in mean pH values from grab and both sonde deployments for both streams (Indian Fork grab pH \bar{x} =7.28, 7.0– 7.58 s.u., n=7; sonde pH \bar{x} =6.81, 6.64 – 6.94 s.u., n=91, McGuire Creek grab pH \bar{x} =7.49, 7.24– 7.75 s.u., n=6; sonde pH \bar{x} =7.19, 7.09 – 7.31 s.u., n=91). Broadly, water at the streambed was two times more acidic in both streams. Streambed temperatures were similar (Indian Fork sonde \bar{x} =17.4, 15.7 – 19.5°C, n=91, McGuire Creek sonde \bar{x} =13.7, 12.1 – 15.8°C, n=91). And D.O. decreased with depth, especially in Indian Fork (Indian Fork sonde D.O. \bar{x} =6.7, 5.6 – 7.8 mg/L, n=91, McGuire Creek sonde D.O. \bar{x} =8.4, 7.4– 9.1 mg/L, n=91).

Bluegill Sunfish are rarely the most abundant species in an Ohio EPA stream sample. Yet, those and other sunfish comprised nearly half (45%) of the Indian Fork collection downstream from Atwood Lake (RM 0.5, R08S15) and more than half (58%) of the McGuire Creek collection downstream from Leesville Lake (RM 1.4, R08W04). Both downstream sample zones included compacted, shallow riffles, devoid of obligate species. Single Blackside Darters in both downstream reaches were not regarded as obligate riffle dwellers. The fish has a swim bladder, uncommon in darters, and is most often found near woody debris usually within pool to glide conditions. Those aspects aptly described the downstream reaches where individual Blackside Darters were noted. Otherwise, two Johnny Darter, a Fantail Darter, and 14 Mottled Sculpin were obtained from a solitary pile of large rip rap, apparently meant to check erosive head cutting, in proximity to a flow weir and USGS gage in the downstream McGuire Creek reach. The restricted presence of those fish within an artificial structure made their absence from expected habitat puzzling.

The overwhelming predominance of tolerant macroinvertebrates was not nuanced by taxa with unique traits. Among 66 total taxa at both sites, Indian Fork with 39 and McGuire Creek had 41, 16 taxa were uniquely present on the artificial substrate samplers, 29 were only collected from natural substrates, and 20 were common to both substrates. Anchored within the best run conditions, the quantitative samplers were preferentially colonized by flow-oriented macroinvertebrates. The absence of many taxa common throughout the Conotton Creek watershed was attributed to harsh water quality as confirmed by many extreme parameter measurements.

Downstream from both lakes, ammonia concentrations were toxic to aquatic life in Indian Fork (\bar{x} =1.01, 0.22 – 1.81 mg/L, n=7) and chronically stressful in McGuire Creek (\bar{x} =0.48, 0.39 – 0.59 mg/L, n=7). Dissolved metal concentrations in both streams were typical for anoxic lake bottom conditions (Indian Fork: Mn \bar{x} =2,165, 243 – 3,310 μ g/L, n=7, Fe \bar{x} =3,087, 1,050 – 6,210 μ g/L, n=7; McGuire Creek Mn \bar{x} =2,571, 1,770 – 4,480 μ g/L, n=7, Fe \bar{x} =1,201, 602 – 1,700 μ g/L, n=7). Water temperatures downstream from both lakes were consistently cold (Indian Fork: \bar{x} =17.3, 15.4 – 20.1°C, n=7, McGuire Creek \bar{x} =13.7, 12.6 – 14.7°C, n=6). Effective reaeration was accomplished by both dam spillway aprons (Indian Fork D.O. \bar{x} =8.6, 6.4 – 12.0 mg/L, n=6, McGuire Creek D.O. \bar{x} =8.6, 7.7– 11.0 mg/L, n=5). The midday supersaturated D.O. values from both downstream reaches were not replicated in respective sonde data (Figure 14 and Figure 15), likely because the multi-parameter units, lying on the stream substrate, sample water from a lower depth compared to the “grab” samples.

The variances between fish, macroinvertebrates, and water column chemistry associated with near substrate versus closer to the surface conditions were further informed by observed stream habitat conditions. Black, organic sludge was infused throughout the foul-smelling McGuire Creek gravel and sand sediment downstream from Leesville Lake. Aquatic life was preferential to turbulent areas or mixing flows such as the artificial rip rap “riffle” or a shallow spot adjacent to the bank where flow from a hydrostatic pressure relief drain joined the stream. Hydrogen sulfide odor was especially prevalent in Indian Fork with a negligible discharge increase. Following some mid-August rainstorms, a three-centimeter flow rise, as shown on a staff

gage, was accompanied with distinct off gassing, noticeable 200 meters downstream from the dam outlet apron. Each downstream dam reach seemed sterile, lacked expected life, and was oddly devoid of young of year fish. Each was remarkably cold. Three facultative coldwater taxa in McGuire Creek exhibited more pollution tolerance than many other macroinvertebrates with low temperature preference. Indeed, the absence of strong coldwater indicator taxa at these, the two coldest, sites in the 2016 study area was another anomaly.

Cold water ameliorates the toxicity of ammonia, hydrogen sulfide, and many dissolved metals. Likewise, thresholds between anoxic or aerobic and acidity or alkalinity can tip the balance between innocuous or poisonous. The Indian Fork sonde acidic pH values were capable of sustaining hydrogen sulfide toxicity. The lack of stream bottom-oriented fish and general absence of macroinvertebrates correlated with such inhospitable hyporheic conditions. Indian Fork ambient ammonia concentrations could also have been perpetuated by benthic conditions and resulted in the displacement of associated aquatic life. Curiously, aquatic vegetation and algae were prolific in Indian Fork but nearly absent in McGuire Creek.

Differences in stream temperature, McGuire Creek averaged 3.6°C colder, perhaps due to Leesville Lakes deeper depth (48 ft. vs. Atwood Lake 42 ft.), may also have been sustained by groundwater infusion discrepancies. Property downstream from Leesville Lake remained spongy through the summer and flow from relief drains seemed perennial. Hydrostatic head pressure created by each lake was a strong inducement for groundwater movement. Plausible groundwater-surface water interactions were another aspect that likely influenced water quality and aquatic life in both downstream dam reaches (Banerjee and Ganguly, 2023). Upwelling groundwater through the hyporheic zone significantly diminishes aerobic respiration and denitrification potential consistent with the sustained ammonia concentrations and redox chemical parameter measurements (Trauth et al., 2013; Lewandowski et al., 2019; Krause et al., 2010)

Depopulated of expected aquatic life and preferentially toxic to riffle obligate fish species, Indian Fork and McGuire Creek downstream from respective dams exhibited similar water chemistry signatures typical for eutrophic lakes with hypolimnetic discharges. As the summer progressed, D.O. declined, concentrations of ammonia, manganese, and iron increased while available sulfate was diminished. Each of those elements could exert severe stress toward aquatic life survival. Additionally, the altered downstream hydrology has fostered hyporheic conditions which perpetuate the same chemical stress. Rectifying these limitations will likely require more than the welcomed changes planned for the dam outlet structures. As noticed in an early U.S. EPA (1975) study, both lakes were and are overly enriched.

Cold Spring Run (\bar{x} =22.6°C, n=4) was warmer than average corresponding 2016 summer daytime stream temperatures in the Conotton Creek watershed (\bar{x} =21.1°C, n=282). And despite its name, no coldwater indicative organisms were among the 56 total taxa comprising a good macroinvertebrate community at RM 0.6 (TR 147, Folsam Rd., 303644). With three uncommon taxa (Table 20), the assemblage included modest numbers of both pollution sensitive (10) and tolerant (12) taxa. No pollution sensitive fish were among the fair assemblage comprised by 20 species. Predominated by pollution tolerant fish (64%), the assemblage included an uncommon Orange Spotted Sunfish. Another Orange Spotted Sunfish was collected in nearby Pleasant Valley Run. Both were oddities since the small (< 4.5"), out-of-range western species isn't stocked in ponds.

Chloride concentrations in Cold Spring Run were extreme (\bar{x} =74 mg/L, Table 10). In Ohio, chloride concentrations greater than 52 mg/L are likely to exert detrimental effects to aquatic life (Miltner, 2021). The hazardous amount of chloride was accompanied by plenty of sodium (\bar{x} =47 mg/L, Table 12). As explained by Covert, Jagucki, and Huitger (2018) in a concurrent USGS study, this combination of sodium and chloride with less bromide is most associated with road salt applied for winter road safety. Axiomatically, increasing road safety has an opposite effect for aquatic life.

Although salt was a likely stressor, Cold Spring Run habitat conditions were regarded to be most limiting. Stream temperature is readily influenced by solar radiation. Streams need trees for more than shade. Leaf litter is an important food base and roots stitched together strengthen banks against erosion while offering protective cover for aquatic life. Cold Spring Run was deeply incised and treeless. Flood flows remained within channel. Redistributed silt and fines were retained, smothering stream substrate and challenging aquatic life functions. Restoring a forested riparian corridor is necessary for Cold Spring Run to achieve its namesake quality.

An entire volume of the journal *Science of the Total Environment* was devoted to fracking as “a controversial issue, mainly in the United States and Canada (Barcelo and Bennett, 2016).” The editors heralded the first report of “the direct effects of fracking on aquatic biodiversity with changes in stream fauna.” Arkansas researchers did find some correlations, but they cautioned; “Low statistical power and correlative analysis limit our ability to establish cause and affect relationships (Johnson et al., 2015).” Further analysis determined water withdrawal impoundments for hydraulic fracturing likely influenced in-stream algal production and sedimentation, but the linkages were difficult to quantify (Entrekin et al., 2018). Although unconventional natural gas development (fracking) wasn’t distinguished from a background of pastureland use, a sediment-specific risk model associated the impoundments with macroinvertebrate metric variance (Baker, Evans-White, and Entrekin, 2018).

It is unusual for a routine Ohio EPA biological and water quality study to have overlapping sample sites with a contemporary USGS water quality study. In this instance, Ohio EPA completed biological monitoring at three Atwood Lake tributaries, but only assessed one (Elliot Run) for water chemistry. Aside from associated cost savings, this study benefited from the expert water quality analysis presented in the USGS report, *Baseline Water Quality of an Area Undergoing Shale-Gas Development in the Muskingum River Watershed, Ohio, 2015-16* (Covert, Jagucki, and Huitger, 2018).

Covert, Jagucki, and Huitger (2018) show, “A brine signature potentially indicative of oil and gas contamination was detected in samples collected at two sites that contained active or plugged waste injection wells, or both.” These locations in an Indian Fork Tributary (RM 3.30) and Elliot Run had aquatic communities in non and partial attainment, respectively. Oil and gas markers were also present in Willow Run where a fair fish community resulted in partial attainment. Data provided by the USGS for the Indian Fork Tributary (RM 1.4, SR 542, 303651) included the highest bromide concentrations in the study area (\bar{x} =170, 41-388 $\mu\text{g/L}$, n=6, April 2015 to May 2016). Elliot Run (RM 1.4, CR 69, Clay Rd., 303702) USGS bromide concentrations (\bar{x} =94, 31-209 $\mu\text{g/L}$, n=6, April 2015 to May 2016) were less than those measured during this survey (\bar{x} =164 $\mu\text{g/L}$, 114-242 $\mu\text{g/L}$, n=5, June to October 2016). Willow Run (RM 1.5, CR 29, Bedrock Rd., 303649) USGS bromide concentrations (\bar{x} =50 $\mu\text{g/L}$, 20-91 $\mu\text{g/L}$, n=6, April 2015 to May 2016) were consistent with values from nearby sites where oil and gas development was prevalent.

Since it’s unlikely that a half dozen or more discrete water quality samples fully represent the range of a contaminant’s environmental presence, it’s reasonable to presume some instances of more extreme bromide exposure have occurred. The USGS addressed that interest by installing continuous stream stage and SC gages in the Indian Fork Tributary and in Willow Run. Comparison of discrete and continuous SC measurements revealed the individual samples captured most (71.3% and 67.8%, respectively) of the variance recorded by permanent gages. Still, sporadic SC spikes seemingly unrelated to flow were documented including an instance in Willow Run (Covert, Jagucki, and Huitger, 2018).

Covert, Jagucki, and Huitger (2018) tabulated the number of producing conventional oil and gas wells (121) in these Atwood Lake tributary basins. They noted the presence of a Utica/Point Pleasant shale oil and gas well in the Willow Run watershed, a plugged injection well in the Elliot Run watershed, and active and plugged

injection wells in the Indian Fork Tributary watershed. Townships in the Indian Fork Tributary and Elliot Run basins, encompassing 40.2 miles, permit well waste brine to be spread for road dust suppression. That treatment was permitted for a fraction (15.7%) of the Willow Run basin's 37 road miles. So, it's apparent the aquatic communities in these Atwood Lake tributaries have been exposed to bromide and other possible pollutants in the brine water produced from oil and gas wells.

Although the convenience of the USGS work argues for inclusion of bromide in the cause "box," that entry was checked by a 1,000 µg/L (1 mg/L) recommended water quality criterion (Canton, Wester, and Mathijssen-Spiekman, 1983). Bromide concentrations in the 2016 Conotton Creek study area ($\bar{x}=54$, <20-299 µg/L, n=268) were unlikely to exert aquatic life toxicity. However, as Covert, Jagucki, and Huitger (2018) explained, of 299 oil and gas wells in the entire Atwood Lake watershed, most (58%) were developed in the 1970s, while just 27 (9%) have been drilled since then. Two injection wells were plugged in the early 1980s, while the one in use in the Indian Fork Tributary basin began operation in 2002. Thus, it's possible that bromide laced well waste brine could have had toxic influence 50 years ago. If so and acknowledging Atwood Lake is a fish migration barrier, several species have been missing upstream for a half century.

Exceptional macroinvertebrate communities in Elliot and Willow Runs included 19 EPT taxa each and 17 or 14 pollution sensitive types, respectively. A fair macroinvertebrate assemblage in the Indian Fork Tributary included just seven EPT taxa and only three pollution sensitive organisms. Possibly related to more groundwater influenced flow, three coldwater taxa were collected in both Elliot Run and the Indian Fork Tributary. Whereas one coldwater associate was extant in Willow Run.

Creek Chubs ($\bar{x}=46.5\%$) predominated the depauperate, pollution tolerant ($\bar{x}=69.2\%$), fair fish assemblages in all three streams (Table 18). Fish species sensitive to pollution were absent from all three locations. Least Brook Lamprey were present in Elliot and Willow Runs, but not in the Indian Fork tributary. Gizzard Shad and Fathead Minnow (*Pimephales promelas*) were unique to the Indian Fork tributary. Bluntnose Minnow, the second most abundant species in the Indian Fork tributary (14%), were absent in Elliot Run and nominally present in Willow Run (0.8%). Disparity between the presence of filter feeding lamprey ammocoetes in Elliot and Willow Runs and the abundance of detritivores in the Indian Fork Tributary was attributed to habitat qualities. Likewise, the incidental presence of a Common Shiner (0.2%), a species indicative of deeper (>40 cm) pools, only collected in the Indian Fork tributary was taken to affirm functional differences in stream depth.

Differences in flow, stream depth, and substrate embeddedness were undistinguished by overall poor habitat scores (QHEI $\bar{x}=38.8$) recorded for the Atwood Lake tributaries. Consequent to drainage improvements completed decades ago, Willow and Elliot Runs were incised, shallow glides with little flow and insufficient gradient to reverse the morphological changes that made each stream inhospitable to typical fish communities. Having steeper gradient, adequate pool depth, and noticeably cool water, the Indian Fork Tributary was excessively silty. Active agricultural land use was more readily apparent in this sub-basin. And a likely mine influenced area was observed upstream from the Indian Fork Tributary sample site.

Within the 2,163 acre (3.38 mi²) drainage area upstream from the Indian Fork Tributary sample site, the USGS determined 186 acres (8.6%) had been surface mined and 26 acres (1.2%) spanned underground mines (Covert, Jagucki, and Huitger, 2018). As shown on [ODNR Mines of Ohio Viewer \(ohiodnr.gov\)](#) those values may have been juxtaposed, but the location of the red outlined former mine area was especially ill chosen regardless of the parcel size. Bisected by the Indian Fork Tributary about one and a half miles upstream from the RM 1.4 sample site, as depicted on Ohio EPA's [River Miles Index Map for Ohio \(arcgis.com\)](#), the property is identified as a strip mine on the tick marked USGS topo map. Pursuant to a 2011 visit, ODNR commented, "surface mine appears to have been reclaimed no problem found" (Site ID: 1003). Although overt problems

were unremarkable, successional revegetation appeared stymied. Barren patches were observed along SR 542 ([160 OH-542 - Google Maps](#)).

Noticing the stunted vegetation interspersed with barren heaps of gravelly aggregate, it was surprising that downstream chemistry sampling seemed to concur; mining related parameters were not remarkable. This area at the entrance to an underground mine (Code: CL-042) abandoned in 1946, seems a likely place where “gobs” of mine tailings would have been “piled.” Unreclaimed gob piles did leach toxicants in other places within the Conotton Creek study area.

In this ALU discussion, non-attainment has been associated with excessive nutrient loading from the Carrollton WWTP and with toxicity attributed to redox reactions in Atwood and Leesville Lakes and in the immediate downstream reach hyporheic zones. In the Conotton Creek basin, the severity of those influences was only matched by impacts from abandoned mine land. The presence of former coal mines in the Indian Fork Tributary sub-basin and ALU non-attainment was not a coincidence. Further discussion will highlight some of the mine derived stressors which affect aquatic life. However, water chemistry parameters that implicated mining influences were not evident in the Indian Fork Tributary.

Adoption of biocriteria in Ohio was predicated on an understanding of five principal factors of water resource integrity; namely: flow regime, chemical variables, energy source, habitat structure, and biotic factors. Awareness that chemical indicators of impairment alone were insufficient to characterize the range of influences that effect water resource integrity was an important reason for the development of numeric biological indices. Users were cautioned, “The common tendency in water resource management has been to make biological measurements fit the perceptions and use of chemical criteria, rather than the reverse (Ohio EPA 1988).”

As discussed by Arkansas researchers in several journal articles, discerning between the interaction of so many variables in the context of continuing Utica/Point Pleasant shale oil and gas development is dauntingly complex. As in Arkansas, many sensitive indicator organisms were extirpated before “fracking” began. Exceptional macroinvertebrate communities in Elliot and Willow Runs attested that many water quality aspects were suitable, while the fair fish assemblages were undoubtedly limited by inadequate stream habitat conditions. That dichotomy was not exhibited in the Indian Fork Tributary. Both indicator groups failed to achieve biocriteria. That noncompliance was more confounding because the presence of three coldwater taxa, a pool allied minnow, and physical characteristics supported a perception that habitat conditions were not as restrictive in the Indian Fork Tributary.

This comparison is further informed by aquatic communities and habitat quality in nearby Pleasant Valley Run. Full ALU attainment there was achieved by a remarkably rich macroinvertebrate assemblage (76 taxa) comprised by 24 pollution sensitive, 24 EPT, and four coldwater taxa. This exceptional community persisted regardless of fair habitat conditions (QHEI=56.2) marked by limited flow, an overabundance of sand substrate, and no effective riffles. The subpar habitat did seem to affect the marginally good fish assemblage (IBI=42). But the Pleasant Valley Run fish community demonstrated achievement of the biocriterion was possible despite the lack of several expected species in the Indian Fork drainage upstream from the Atwood Lake dam.

Like other Atwood Lake tributaries, Creek Chub (41%) and pollution tolerant fish (65%) predominated the Pleasant Valley Run assemblage. Unlike those sister streams, two pollution sensitive fish, Golden Redhorse and Redside Dace, were present in Pleasant Valley Run. Mathematically, collection of Golden Redhorse or Redside Dace at any of the three underperforming streams would not have sufficiently shifted metric scores enough to register achievement, but the absence of the species in all three streams was important.

Pleasant Valley Run had deep glides (>40 cm) and deeper pools (>1m). Those characteristics are critical for Golden Redhorse which continuously traverse short stream reaches foraging for invertebrates sifted from substrates. Although more tolerant than other redhorse types of some habitat degradation, the species is sensitive to excessive silt and turbidity. Redside Dace require cold, fresh water in deeper pools usually with undercut rootwads and a clean aggregate base. The pool associated Common Shiner (3.3%) was well represented in Pleasant Valley Run. Bluntnose Minnow (6.1%) and Least Brook Lamprey (2.2%) were also prevalent.

As puzzles go, Pleasant Valley Run had enough pieces to render an impression of adequate water quality. Many of those pieces, as represented by fish species, were missing in adjacent Atwood Lake tributaries. Water chemistry analysis by the USGS clearly implicated the oil and gas industry for impacts from well waste brine (Covert, Jagucki, and Huitger, 2018). Presently, that stress was not regarded to be as impactful as habitat deficiencies. Channel modifications have left Willow and Elliot Runs without the assimilative capacities which occur in pools as shown by the dearth of associated fish species. Excessively silty conditions in the Indian Fork Tributary were certainly attributable to the upstream course through mine spoil. The prevalence of detritivorous fish, scant representation by pool associated species, and a significant difference in macroinvertebrate presence was consistent with severe sediment impacts.

Notice of probable coal mining water quality impacts is often given by orange precipitate covering the stream substrate. This signature of acid mine drainage (AMD) occurs as rain induced dissolution of pyrite produces sulfuric acid which subsequently leaches metals from disturbed earth. Flow paths through mine spoil mounds or via underground cavities enable the solute to become more acidic or less if limestone is present to buffer the percolate. As the pH of the solute is affected, metal enrichment may increase, or metal salutes may be precipitated. An orange precipitate occurs where dissolved iron has been dropped from suspension consequent to an acidic drainage meeting a neutral receiving stream. Dissolved aluminum precipitates as a white flocculent. Kent State University researchers, Shaw, Yazbek, Singer, and Herndon (2020) investigated the dynamic interaction of solute concentrations and stream discharge to Huff Run.

Coal fines are less obtrusive than a stream bed carpeted in orange silt. Where historic mining occurred, chunks of coal were invariably tumbled downstream. Today, close examination of depositional areas will reveal small flecks of the lost "black gold." Occasionally, large hunks of coal are littered about. Coal hunks and chunks were observed in Huff Run, in the Conotton Creek Tributary (RM 7.67), and in the upper reach of the Conotton Creek mainstem. Coal fines were noticed in the Indian Fork Tributary (RM 3.30), Conotton Creek Tributaries (RM 17.22 and RM 11.37), Beggar Run, and in Conotton Creek from Sherrodsville, upstream. As much as percolated precipitates signify the influence of mining disturbed earth, coal fines report similar disturbance. The combination of excessive sediment bedload laced with potentially toxic metals can be devastating to aquatic life. Kent State University researchers, Singer, Jefferson, Traub, and Perdrial (2018) investigated hyporheic flow paths through metal contaminated sediment in Huff Run.

Ohio EPA determined Huff Run sediment metal concentrations were likely to exert aquatic community stress based on sampling in 2016 and 2009 (Table 16). Concentrations of arsenic, iron, nickel, and zinc in Huff Run sediment routinely exceeded Ohio *Sediment Reference Values* (SRVs) or *Threshold Effect Concentrations* (TECs). Beggar Run sediment contained nickel in excess of the TEC as well as a low concentration of PCB-1254 (0.043 mg/kg or 43.4 µg/kg). Concern for embedded and metal impacted sediment in Huff Run were the impetus for a stream restoration project completed in the fall of 2016. A new natural design channel was created from RM 1.2 to RM 0.7 to convey Huff Run downstream from CR 90, New Cumberland Rd. to the Conotton Creek confluence. The abandoned former channel remains to intercept acidic runoff from nearby mine spoil.

Huff Run mine spoil characteristics have been extensively considered by researchers from Kent State University and the University of Akron. Their work shows manganese was easily mobilized and that dissolved organic carbon influenced iron and aluminum transport (Singer et al., 2021). Smart and Singer (2023) determined clay particles were preferentially transported before larger quartz or sands were redistributed from spoil piles and the potential to leach solutes in toxic concentrations continues for decades after mine waste was deposited. Century old mine spoil covered in forest vegetation continues to be a possible source of nearby stream contamination (Herndon et al., 2019).

Elevated water chemistry parameters were associated with drainage from mined areas (Table 10 to Table 15). Dissolved iron concentrations in Huff and Beggar Runs and in Conotton Creek tributaries (RM 7.67 and RM 11.37) substantially increased with influence from an August rainstorm. Dissolved manganese exhibited a varied pattern in response to the runoff event. Manganese concentrations increased as typically expected in Beggar Run and in the Conotton Creek tributary (RM 7.67). But runoff apparently diluted baseflow manganese amounts in Huff Run and in the Conotton Creek tributary (RM 11.37). Dissolved magnesium is often used to gain an impression of baseflow characteristics. The August rainstorm exerted some dilution in Beggar Run and both Conotton Creek tributaries but had equivocal influence in Huff Run. Interestingly, Beggar Run exhibited extraordinarily elevated dissolved magnesium concentrations (\bar{x} =144.6 mg/L).

Those solutes in addition to high sulfate concentrations contributed to extreme TDS and SC values in Huff and Beggar runs and in the Conotton Creek tributary (RM 7.67). Pursuant to the August shower, TDS and SC declined and TSS concentrations increased as might be expected in Beggar Run and in the Conotton Creek tributary (RM 7.67), but the storm had little effect on those parameters in Huff Run. Furthermore, sulfate, TDS, and SC measurements in the Conotton Creek Tributary (RM 11.37) were not elevated and appeared unaffected by the rainstorm.

Declining with low flow conditions across the Conotton Creek basin, dissolved aluminum detection after August only occurred at eight locations including the Conotton Creek Tributary (RM 11.37). Excepting the high flow event, aluminum was not detected in the other mine drainages. A few other chemistry values merit notice. Dissolved copper (2.0 µg/L) and an elevated TSS concentration (51 mg/L) were part of the Conotton Creek Tributary (RM 11.37) storm sample. Concentrations of dissolved nickel (\bar{x} =31 µg/L) and zinc (\bar{x} =18 µg/L) were routinely (n=13) measured in Huff Run at RM 1.3 (CR 90, New Cumberland Rd., 300595). In July, low pH (5.5 s.u.) and D.O. (1.7 mg/L) values were recorded at that site.

Aside from the extreme parameter values which were likely stressors to aquatic life, the unexpected runoff results were odd. Dumouchelle and Schiefer (2002) included mean baseflow index (MBI) and groundwater recharge values for Huff Run in Appendix B of their report, *Use of Streamflow Records and Basin Characteristics to Estimate Ground-Water Recharge Rates in Ohio*. They commented, "One of the most difficult components of the hydrologic cycle to estimate is the rate at which precipitation reaches (recharges) the ground-water system." Although Conotton Creek was not among the 103 basins for which recharge rates were estimated, comparison of the Huff Run MBI (69.5) with those listed distinguished it among streams with the highest ratio of baseflow to streamflow. Huff Run is much smaller (12.3 mi²) than other high MBI (>65) listed basins and only four had higher index values.

Huff Run perennial flow is exceeded by the Mad River (at Urbana, MBI=81.1) and its tributary Buck Creek (at New Moorfield, MBI=75.2) and in Wheeling (below Blaine, MBI=69.6) and Short Creeks (near Dillonvale, MBI=71.4). The Mad River is Ohio's best stocked trout stream, whereas Wheeling and Short Creeks, like Huff Run, are recovering AMD basins. When surveyed in 2010, previously unknown populations of State listed Bluebreast (*Etheostoma camurum*) and Tippecanoe Darters (*Etheostoma tippecanoe*) were discovered in Wheeling and Short Creeks. By inference, Huff Run has much potential as AMD issues continue to be

mediated. Additionally, Dumouchelle and Schiefer (2002) present a soil-infiltration map which shows the previously discussed upper Dining Fork to Yellow Creek basin divide (Harlem Springs and Kilgore area, separated by the SR 9 ridge) to be an area with strong recharge potential.

Like the Mad River (Sheets and Yost, 1994), the strong baseflow in Huff Run may be influenced by limestone bedrock. Cummins and Sanderson (1947) provide a lithologic cross section (Plate 11) of a transect (G-H) that falls over Conotton Creek upstream from the Tuscarawas River. The lower reach of Conotton Creek cuts through a horizon of Putnam Hill limestone. Lamborn (1956) observed, “the Putnam Hill limestone is due to crop out at or close above the flood plain level along the Tuscarawas Valley and the valley of Huff Run but owing to surface slump and alluvial deposits few exposures have been noted along these valleys.”

Huff Run water chemistry values exhibited remarkable differences between the most upstream site at RM 7.8 (TR 170, Heritage Rd., 300601) and a central sample location at RM 5.5 (CR 36, Brass Rd., 300599). Upstream alkalinity concentrations (\bar{x} =92 mg/L) were doubled at RM 5.5 (\bar{x} =192 mg/L) but that buffering capacity was much reduced at RM 1.3 (\bar{x} =42 mg/L). Upstream dissolved calcium concentrations (\bar{x} =32 mg/L) were five times more at RM 5.5 (\bar{x} =160 mg/L) and remained so at RM 1.3 (\bar{x} =181 mg/L). Low upstream dissolved magnesium (\bar{x} =9 mg/L) substantially increased at RM 5.5 (\bar{x} =71 mg/L) and remained high downstream (\bar{x} =77 mg/L). Huff Run stream temperatures were the most stable in the study area and the linear sequence was unique for the decline at the central site (RM 7.8 \bar{x} =21.0 °C, RM 5.5 \bar{x} =20.6°C, RM 1.3 \bar{x} =21.3°C).

Collectively, those measurements affirmed an appreciable amount of groundwater entered Huff Run upstream from RM 5.5 (CR 36, Brass Rd., 300599). Mining related influences were also evident as increases in both calcium and magnesium cations routinely occur with AMD runoff. It's also possible that mitigation projects such as those installed at the nearby Lindentree site may have boosted alkalinity. However, the continuous presence of Redside Dace, at least since a 1997 Ohio EPA survey, supports the assertion the stream has remained cold.

Consistent with numerous “seep near creek” comments regarding Reach 6 appended to the Huff Run Watershed AMDAT Plan (Gannett Fleming, 2000), the *Potentiometric Surface of the Consolidated Aquifers in Carroll County* (Angle, 2006) map indicates a steep gradient exists along Huff Run extending to its headwater. There, groundwater is broadly dispersed at 1,050 FAMS L in Rose Twp. (section 6). Regarding Putnam Hill limestone, Lamborn (1956) commented, “In Section 6, Rose Township, Carroll County, near the county boundary line, this stone has a thickness of 3 feet 6 inches and is exposed at an altitude of 1,000 feet.”

Considering Lamborn's references to the same limestone “at or close above the flood plain level along ... the valley of Huff Run” and outcropping under the headwaters at 1,000 FAMS L it appears that the stream is well positioned to receive associated ameliorative effects. Limestone is credited for buffering AMD influences throughout the Monongahela and to a lesser extent in the Conemaugh formations. The underlying Allegheny formation has few limestone seams, and any buffering effects are easily overlooked. If groundwater flow was less noticeable, the limestone contribution in Huff Run and adjacent streams might have escaped attention. Instead, it was apparent that baseflow provided the highest pH values in Huff and Beggar Runs and in both Conotton Creek tributaries. Late September pH ranged from 7.26 s.u. at the most downstream Huff Run site to 7.92 s.u. in the Conotton Creek Tributary (RM 7.67). The downstream Huff Run RM 1.3 site was unique in the study area for having acidic pH (\bar{x} =6.7 s.u.) during most of the summer. Incidentally, Singer et al. (2018) also commented on limestone buffering and groundwater to surface water gains within the basin.

Specific conductance (SC) and TDS followed a similar pattern at these locations. Baseflows provided high SC and elevated TDS concentrations at each location during late September low flow conditions. Beggar Run, with a small drainage area (4.0 mi²), exhibited the highest SC (\bar{x} =1,729 μ S/cm) and TDS (\bar{x} =1,536 mg/L) concentrations in the study area throughout the summer and in September (SC= 1,964 μ S/cm, TDS=1,750

mg/L). This result from the interaction of groundwater with mining disturbed earth was stressful to aquatic life.

Mayfly taxa were strongly affected by the elevated ion concentrations in these streams (Figure 20). Six different mayflies were collected in Huff Run at RM 7.8. None were present at RM 5.5 or RM 1.3. Upstream Huff Run ion concentrations (SC \bar{x} = 928 μ S/cm, TDS \bar{x} =210 mg/L) were less than at RM 5.5 (SC \bar{x} = 1,315 μ S/cm, TDS \bar{x} =1,036 mg/L) and at RM 1.3 (SC \bar{x} = 1,305 μ S/cm, TDS \bar{x} =1,161 mg/L). A single moderately intolerant minnow mayfly species (*Procladius viridoculare*) was found in Beggar Run. The species, also at 20 other study locations, was well distributed in the Conotton basin. Another commonly encountered (28 sites in the Conotton basin) minnow mayfly species, (*Baetis intercalaris*), was present in the Conotton Creek Tributary (RM 7.67). The singular presence of this facultative mayfly was consistent with high ion measurements (SC \bar{x} = 866 μ S/cm, TDS \bar{x} =610 mg/L). In contrast, low ion concentrations (SC \bar{x} = 325 μ S/cm, TDS \bar{x} =184 mg/L) with seven mayfly taxa were registered in the Conotton Creek Tributary (RM 11.37).

Mayfly sensitivity to elevated ionic strength is well known as current research seeks to untangle the interaction of metals, salts, pH, and variance between field and laboratory observations (Daniels, Zipper, and Orndorff, 2014; Voss and Bernhardt, 2017; Cormier et al., 2013, Fornaroli et al., 2018; Pond, 2010; Pond et al., 2008). As shown in Figure 20, mining land use, WWTP discharge (Honey Run RM 0.6), and hypolimnetic lake outflow can restrict mayfly abundance. It is probable that ion concentrations associated with the latter sources exceeded mayfly tolerances despite not having been detected in survey samples. The Conotton Creek Tributary (RM 7.67), Cold Spring Run, and Honey Run at RM 0.8, upstream from the Carrollton WWTP were home to four mayfly taxa. Although good macroinvertebrate assemblages were present in the latter streams, high chloride concentrations suggested ionic strength was a threat to the limited mayfly presence.

Many macroinvertebrate taxa are threatened by salts formed from calcium, magnesium, sulfate, or bicarbonates in neutral to somewhat alkaline conditions. The U.S. EPA (2011) determined the chronic aquatic life benchmark value for conductivity (300 μ S/cm) in the WAP ecoregion should be sufficiently protective to avoid extirpation but recognized the mark would not preclude declines in abundance. The benchmark was based on environmental data from West Virginia where at least 25 different sample site occurrences of an organism were paired with appropriate SC measurements. With 163 qualified genera, species sensitivity distributions (SSD) were constructed by arraying the SC measurement accompanying an individual macroinvertebrate taxon's presence and noting the 95th percentile value (called an extirpation concentration, XC95). An SSD for a parameter is the array of 95th percentile values (XC95s) pertinent to all macroinvertebrate taxa. The fifth percentile of an SSD is referred to as the hazard effect concentration or HC5. The U.S. EPA (2011) derived HC5 for conductivity (300 μ S/cm) is "...expected to avoid the local extirpation of 95% of native species..."

The field-based SC benchmark offers a pragmatic approach that is challenging for laboratory methods to replicate (Soucek, Dickinson, and Norberg-King, 2022; Soucek et al., 2018; Orr and Buchwalter, 2020; Johnson et al., 2014). For example, Ohio's laboratory-based TDS statewide WWH aquatic life criterion (1,500 mg/L) is comparable to an SC value (2,400 μ S/cm at 25°C) eight times greater than the field-based benchmark. Consider TDS values in Table 10 and it's apparent Ohio's criterion is exceeded in the rarest of circumstances. It may be expected to avoid extirpation of the hardiest of native species. Reconciliation will come as laboratories are better able to rear sensitive test organisms and devise studies which include multiple exposure conditions.

Mayflies were also checked in Jefferson Creek (RM 0.2, High St., Jewett Park, R08S07) and in Conotton Creek at RM 37.8 (CR 50, New Rumley Rd., R08S04, Figure 20). Chemical parameter measurements at both locations were typical of nonacidic mine drainage (Table 10 to Table 15). Jefferson Creek joins Conotton Creek at RM 40.22 within the town of Jewett. The fair macroinvertebrate community in Jefferson Creek was predominated

by the highest abundance of pollution tolerant taxa (21) within the study area. Impacted by historic mine drainage, Jefferson Creek's harsh conditions were apparently sufficiently offset by Conotton Creek so that a marginally good macroinvertebrate assemblage was present downstream at RM 37.8. Although the downstream community achieved the biocriterion, it had the fewest total taxa among the mainstem macroinvertebrate collections. With just five pollution sensitive taxa, aquatic life was considered threatened in Conotton Creek at RM 37.8. As discussed in the **Stream Trophic Status** section, this location downstream from the Jewett WWTP was also stressed by nutrient enrichment. Efforts to remediate historic mine influences and to address excessive nutrient loading should be prioritized to protect Jewett ambient water quality.

The persistence of excessive dissolved substances in the Conotton Creek watershed remains as a legacy of coal mining. Land disturbance forced runoff to seek new flow paths, disrupting patterns established over geologic time scales. Soluble and insoluble particles were mobilized, often without regard to downstream consequences. Like TDS, stream sedimentation is pervasive in former coal mining regions. Unlike TDS, measuring and quantifying stream sedimentation is beyond the scope of a typical water quality study. Accounting for quantities of soil and disturbed earth unnaturally smothering stream substrates is generally limited to descriptive assessments and modeling estimates i.e., soil loss equations.

Excessive sedimentation was apparent throughout the Conotton Creek basin. Disruption of stream sediment transport was overtly obvious in reaches degraded by periodic inundation from Dover Dam backwater. Accessing the most downstream Conotton Creek site (RM 0.2, Zoarville Station trail, TR 390, 303581) by boat via a launch at the dam provided firsthand understanding of sediment transport inadequacy. The one and three-quarter mile long reach of the Tuscarawas River between the Conotton Creek confluence and the dam was too shallow to navigate in a john boat. Passage was only possible by physically dragging the boat over the silt infused, sandy, pea gravel stream base.

Perhaps it's expected that sediment should accumulate upstream from a dam. Dover Dam is normally operated as a flow through structure and no water is impounded unless upstream flow exceeds the capacity of the typically open gates. In such an event, a long linear pool forms extending up both the Tuscarawas River and into Conotton Creek. As the velocity of sediment laden water is stilled upon meeting the upstream limit of the dam pool, particles are dropped from suspension. In effect, more sediment is expected to accumulate farther from the dam compared to the presumably routinely swept channel closer to the structure. Either way, the amount of sediment accumulated upstream from Dover Dam has smothered normal stream substrates for 17 miles in Conotton Creek. The creek channel was egregiously sediment choked at RM 6.7 (from TR 399, Marsh Rd., 303580). Sticks and logs strewn amongst the sand substrate made passage impractical by the shallowest drafting canoe.

Conotton Creek was navigable at RM 11.4 (CR 90, New Cumberland Rd., R08S14). Although the better swept center channel was flanked by excessively silty bank margins, good water clarity suggested this reach was near the upper limits of the lowest frequency dam pools. That observation may have influenced the over development of the Conotton Creek Tributary (RM 11.37). The lower reach of the tributary had been excessively deepened along CR 90. Presumably this was done to alleviate any unnecessary flooding associated with the low frequency mainstem inundation.

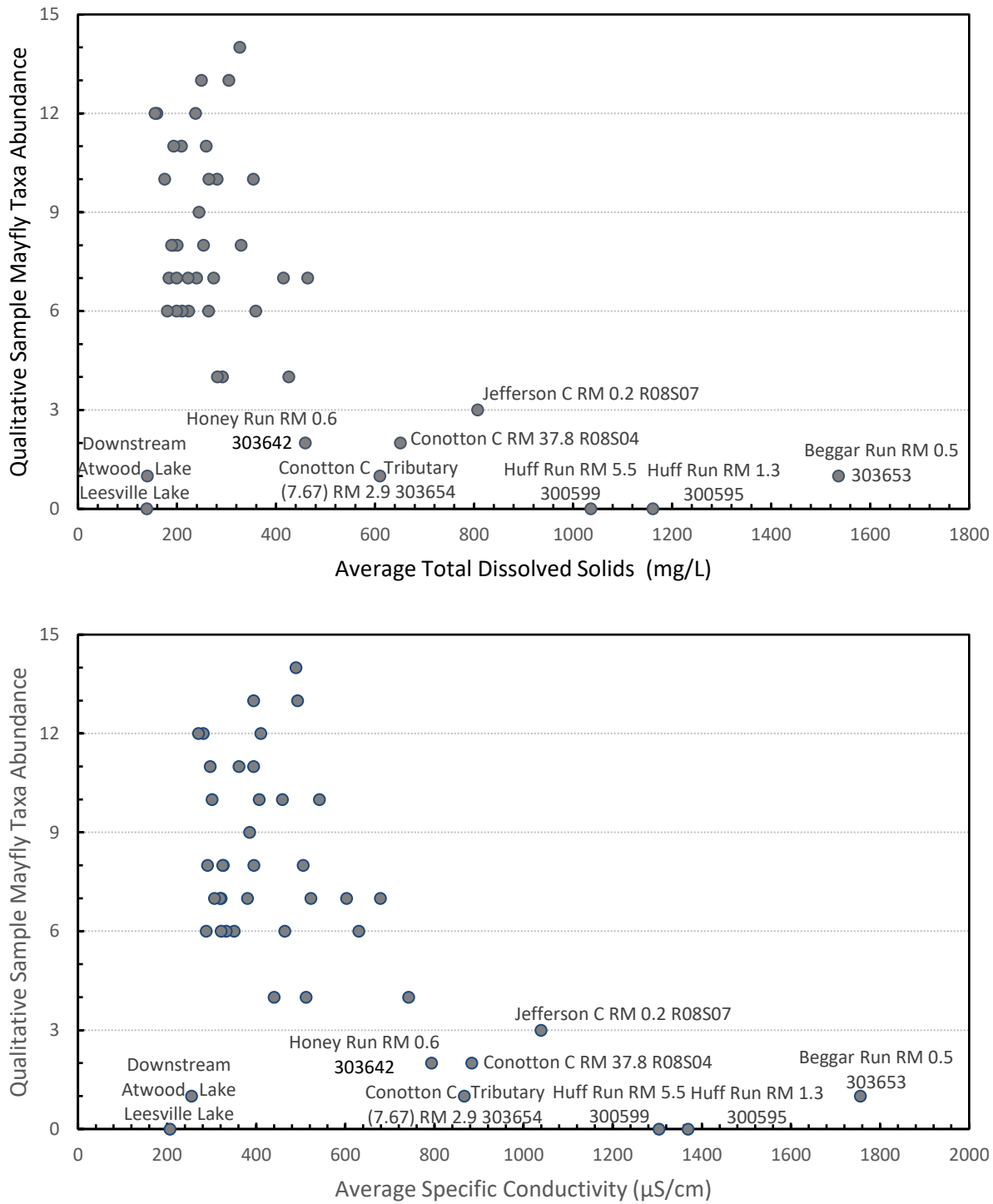


Figure 21 - Relationship of mayfly taxa abundance from qualitative sampling with average total dissolved solids (TDS, upper plot) and with average specific conductivity (SC, lower plot) in the Conotton Creek basin, 2016.

Attracted by the Conotton Creek Tributary's (RM 11.37) incised channel, beaver had taken advantage of the easily impounded reach to construct at least two dams near the RM 0.3 (TR 320, Dawn Rd., 303614) sample site. Repetitive flow disruptions by Dover Dam were further confounded by those due to beaver perturbations. The silt prone reach was excessively turbid as the continuously active beaver pursued their dam maintenance activities. Average TSS concentrations (\bar{x} =27 mg/L) exceeded the 90th percentile for WAP headwater streams (\bar{x} =25 mg/L).

Aside from the easily disturbed silt, the Conotton Creek Tributary (RM 11.37) also had areas of orange precipitate and coal fines attributed to historic mining operations. Yet, this stream differed from other mine impacted streams for lower SC values (\bar{x} = 325 μ S/cm), reasonable TDS concentrations (\bar{x} =184 mg/L), and seven mayfly taxa. Even so, the fair macroinvertebrate assemblage with low total abundance (44 taxa) and just seven sensitive taxa were similar for not achieving the biocriterion. That departure was attributed to the excessive silt that was trapped within the Conotton Creek Tributary (RM 11.37) channel. Ultimately, channel conveyance was impaired by operation of Dover Dam to alleviate downstream flooding.

Maps of the Conotton Creek basin illustrating the portion which Dover Dam is capable of flooding show the position of the Conotton Creek Tributary (RM 11.37) within the temporary backwater pool (Schmidt, 1962). Downstream from the Tributary, the Conotton Creek valley is broad, distinctly wider and appears capable of storing more water than Atwood Lake. Upstream from the tributary, the Conotton Creek valley is narrower and less frequently utilized for flood relief. Comparison of potentiometric surface and topographic maps indicates groundwater and Conotton Creek surface water have the same elevation where the valley begins to widen about a mile upstream from the Tributary. The coldest average stream temperatures in the basin were recorded in Thompson Run (\bar{x} =18.2°C), in the Conotton Creek Tributary (RM 7.67) (\bar{x} =18.5°C), and in Beggar Run (\bar{x} =18.8°C). Cold temperatures were noted in the Conotton Creek Tributary (RM 11.37) (\bar{x} =19.5°C) and the mainstem reach confluent to these tributaries was regularly a degree or more colder compared to upstream segments.

The Conotton Creek Tributary (RM 11.37) and Thompson Run supported several species which rely on cold water or continuous flow including mottled sculpin, Redside Dace, and Least Brook Lamprey. The only rainbow darter documented in the basin was obtained in the tributary and a Southern Redbelly Dace (*Chrosomus erythrogaster*) was present in Thompson Run. A minnow mayfly that is indicative of modest or stronger flow was collected in the Conotton Creek Tributary (RM 11.37). In sum, there was ample evidence that Conotton Creek gains a volume of cold flow in the reach downstream from Thompson Run continuing past Huff Run.

Northern Pike were collected from Conotton Creek in each sample at the three sites downstream from the RM 11.37 tributary (six sampling events). A single Muskellunge was documented in one downstream sample. These esocids are among the most prized sport fish. Leesville Lake is widely known for and attracts fishers from far and wide seeking to land a Muskellunge. With its cold inflow and meandering low gradient, Conotton Creek should have a reputation to rival its impounded tributary as a home for musky. Turbidity and sedimentation preclude that distinction.

Ohio EPA evaluated the Conotton Creek fish community at RM 0.2 (Zoarville Station trail, TR 390, 303581) in 1989. Fourteen fish species including one Northern Pike achieved poor index scores (IBI \bar{x} =18, MIwb \bar{x} =4.0, Figure 17). In 2010, 14 fish species including seven Northern Pike achieved fair index scores (IBI =30, MIwb =7.4). In 2016, 26 fish species including eleven Northern Pike achieved fair index scores (IBI \bar{x} =33, MIwb \bar{x}

=7.9). Over that 27-year period, it's apparent that environmental improvements have occurred. But those gains in fish diversity have included substantial increases in Common Carp (*Cyprinus carpio*) abundance. From the 1989 collections averaging five in a sample, the 2010 sample included seven, to the 2016 assessments that captured 23 and 11 ($\bar{x}=17$), Common Carp have benefited from water quality improvements.

Common Carp browse over stream bottoms, sifting silt and sand to strain blood worms (*Chironomid*), worms (*Oligochaeta*), and other tolerant macroinvertebrates from the substrate. With proficient taste and smell senses, the fish is well adapted to forage in darkness including conditions of extreme turbidity. Common Carp demonstrated their competitive ability to thrive in a new environment when Atwood Lake was first filled. Once established, Common Carp become too big for predation by other fish, including esocids. Common Carp at RM 0.2 averaged nine pounds (4,125 g). Furthermore, Common Carp foraging habits eliminate aquatic macrophytes critical for esocid life stages.

Water resource integrity requires attention to all factors that lead to its attainment. Unhappy with the fish in Atwood Lake, the Ohio Division of Conservation and MWCD attempted to "reboot" the system with rotenone in 1947. Yet, the Carrollton WWTP continued to add nutrients, habitat enhancement was overlooked, and the flow regime maximized recreational benefits. Apparently, managing the fish was considered sufficient to achieve success. Unfortunately, Common Carp prevailed.

The fair fish community in Conotton Creek at the confluence with the Tuscarawas River failed to meet the biocriteria because flood control management prioritized flow regime concerns over other water resource integrity components. Conotton Creek bedload transport is naturally challenged by low gradient, further hampered by flow restrictions, and remains exacerbated by untenable amounts of sediment delivered by historically disruptive land uses. Conotton Creek was unable to support fish species typically found at similar sites within the WAP ecoregion. Fish, as a biotic factor of water resource integrity, indicted other components were awry. It is insufficient to focus on the fish while overlooking the fact that normal stream functions were debilitated. Normal stream functions are necessary for water quality. Abnormal stream functions promote Common Carp abundance.

Recreation Use Results

E. coli samples were collected at 47 locations in the Conotton Creek study area in 2016 (Table 22). *E. coli* from these samples were cultured as colony forming units per 100 ml of water (cfu/100ml) to determine how abundant these microorganisms were in the environment. Generally, high *E. coli* colony counts are associated with warm-blooded animal (including human) waste from sources such as livestock, often with unimpeded stream access or via land application of manure; failing home sewage treatment systems (HSTS); municipal stormwater contaminated by illicit sanitary connections along with yard and pet waste; and from poorly operated WWTPs including unacceptable sanitary sewer overflows (SSOs). A high incidence of cultured *E. coli* colonies is taken to represent greater risk of pathogen exposure to people recreating in the water.

Attainment of recreation use criteria is especially important at places where people are at the greatest risk of pathogen exposure such as at a bathing beach. Although no one should excuse the presence of *E. coli* in a small stream, physical constraints which limit full body immersion are likely to offset the incidence of pathogen influence in a headwater reach. Similarly, dilution in large streams can be expected to mitigate bacterial pollution that might appear to overwhelm a smaller watercourse. Recreation use criteria are applicable from May 1 to October 31, presuming summer months are the prime period for related outdoor pursuits such as wading, swimming, and boating. However, people recreate throughout the year, and some choose to do so during stream conditions that are inherently dangerous regardless of pathogen exposure.

As techniques for using *E. coli* have improved, we've also become aware of limitations and caveats regarding sources, sampling strategies, and interpretation of resulting data. Soil and stream sediment can harbor and sustain *E. coli* and sometimes confound direct links to perceived sources. Storm runoff and stream flow conditions can move *E. coli*, foster microorganism growth, or expedite their demise. Subsequently, *E. coli* data should be understood within the context of many qualifying limitations.

Attainment of the recommended primary contact recreation (PCR) use occurred at two study area sites; each site was on a different stream. Limited bacteria presence in McGuire Creek downstream from Leesville Lake was attributed to the bottom release outlet structures at the lake. *E. coli* bacteria need oxygen. Outlet water often exhibited anoxic reducing conditions marked by high dissolved manganese (Table 12), ammonia, and TKN concentrations (Table 14). Additionally, Leesville Lake buffered the respective downstream sites from upstream bacteria sources.

Except for Irish Creek at RM 5.0 (Branch Rd., 303624), *E. coli* were obtained from all other study area locations on August 15 or 16. Toward mid-morning on August 15, a summer storm passed over the central and southern portions of the Conotton Creek watershed. Consequent to this storm runoff, the highest *E. coli* colony count for about half of the study sites was recorded. Based on an August 15 or 16

Table 23 - Attainment status of the recommended recreation uses for the Conotton Creek basin, 2016. The number (n) of samples obtained within a 90-day assessment period is followed by maximum (Max) and geometric mean quantities of E. coli colony forming units per 100 ml of water (cfu/100ml). The number of samples exceeding the statistical threshold value is shown as a percentage. Bold values exceed the pertinent criterion. Source key and recreation use criteria follow.

Station	Stream / Location	RM	Mi ²	n	Max	\bar{x}_{geom}	%>STV	Status	Source
Headwaters Upper Conotton Creek 05040001 07 01									
Conotton Creek PCR recommended									
303623	adj. SR 151, Jewett-Hopedale Rd.	41.6	3.8	3	1,200	597	66%	NON	Ls,HSTS
Headwaters Middle Conotton Creek 05040001 07 04									
R08S04	CR 50, New Rumley Rd.	37.8	17.5	6	1,200	334	33%	NON	Mixed
303541	Eastport Rd.	33.3	46.8	9	14,000	2,667	100%	NON	Town
R08K05	CR 80, Leffler Rd.	32.6	48.0	5	3,700	1,002	83%	NON	SSO,Town
Headwaters Lower Conotton Creek 05040001 07 07									
R08S01	CR 25, Conotton Rd.	29.1	70.0	7	7,300	1,078	100%	NON	Ls
R08W05	SR 164, Amsterdam Rd.	23.7	87.0	7	3,900	652	71%	NON	Mixed
R08K03	CR 22, Azalea Rd.	22.1	89.0	9	2,700	879	89%	NON	Ls
Thompson Run-Conotton Creek 05040001 08 03									
303578	SR 39, Church St, Sherrodsville	17.0	156.2	7	570	308	29%	NON	Town
303579	TR 394, Miller Hill Rd.	13.9	165.3	7	1,300	344	29%	NON	Ls
Dog Run-Conotton Creek 05040001 08 05									
R08S14	CR 90, New Cumberland Rd.	11.4	241.0	7	2,300	295	14%	NON	SSO, Ls
303580	from TR 399, Marsh Rd.	6.7	261.8	5	1,100	286	20%	NON	Ls,HSTS
303581	Zoarville Station trail TR 390	0.2	286.0	6	320	143	0%	NON	
Headwaters Upper Conotton Creek 05040001 07 01									
Jefferson Creek PCR recommended									
R08S07	High St., Jewett Park	0.2	6.5	3	4,100	1,701	100%	NON	Ls,HSTS
Irish Creek 05040001 07 02									
Irish Creek PCR recommended									
303624	from CR 35, Branch Rd.	5.0	6.7	2	410	395	0%	NON	Ls
R08S13	CR 136	2.1	14.9	6	10,000	1,416	100%	NON	Ls
Lick Fork PCR recommended									
303625	TR 135, Burrier Rd.	0.2	5.0	3	9,800	2,603	100%	NON	Ls
Dining Fork 05040001 07 03									
Dining Fork PCR recommended									
303626	from TR 382, Pontiff Rd.	6.3	3.1	3	1,100	894	100%	NON	Ls,HSTS
303627	TR 645, Tartan Rd.	4.3	6.3	3	2,300	1,491	100%	NON	Ls,HSTS
303628	SR 151, Scio-Bowerston Rd.	0.2	14.7	7	9,900	2,825	100%	NON	Ls
Kirby Run PCR recommended									
303629	adj. SR 332, Scio Rd.	0.7	3.4	6	5,200	1,102	83%	NON	Ls,HSTS
Headwaters Lower Conotton Creek 05040001 07 07									
Scott Run PCR recommended									
303630	SR 151, Scio-Bowerston Rd.	0.7	3.1	3	24,000	3,717	100%	NON	Ls
Conotton Creek Tributary (RM 28.20) PCR recommended									
303618	CR 43, Bower Rd.	0.6	3.8	3	11,000	1,583	100%	NON	Ls
McGuire Creek 05040001 07 06									
McGuire Creek PCR recommended									
303616	adj. CR 17, Aster Rd.	9.9	2.7	3	2,700	1,345	100%	NON	Ls,HSTS
303617	TR 374, Plymouth Rd.	8.3	7.1	3	1,200	630	66%	NON	Ls,HSTS
R08W04	dst. Leesville Lake dam	1.4	48.0	5	26	9	0%	Full	
Long Creek PCR recommended									
303631	CR 8, Alamo Rd.	0.7	1.7	3	17,000	2,894	100%	NON	Ls
North Fork McGuire Creek 05040001 07 05									

Station	Stream / Location	RM	Mi ²	n	Max	\bar{x}_{geom}	%>STV	Status	Source
North Fork McGuire Creek PCR recommended									
303632	TR 354, Pebble Rd.	9.4	4.1	3	4,600	1,492	100%	NON	Ls,HSTS
303633	CR 19, Autumn Rd.	7.7	6.9	3	7,700	720	33%	NON	Ls,HSTS
303542	SR 322, Scio Rd.	6.0	11.3	9	16,000	831	67%	NON	HSTS
Thompson Run-Conotton Creek 05040001 08 03									
Conotton Creek Tributary (RM 17.22) PCR recommended									
303635	pipeline	1.0	6.3	3	650	296	33%	NON	Ls,HSTS
Thompson Run PCR recommended									
303615	from SR 39, Roswell Rd.	0.7	3.7	3	1,000	447	33%	NON	Ls,HSTS
Cold Spring Run-Indian Fork 05040001 08 01									
Indian Fork PCR recommended									
R08W03	SR 332, Scio Rd.	13.9	12.3	7	2,600	979	100%	NON	Mixed
Pleasant Valley Run-Indian Fork 05040001 08 02									
303543	from SR 39, Roswell Rd.	9.0	33.5	9	18,000	707	67%	NON	Ls,HSTS
R08S15	dst. Atwood Lake dam, SR 212	0.5	70.0	6	170	36	0%	Full	
Cold Spring Run-Indian Fork 05040001 08 01									
Gantz Creek PCR recommended									
303639	TR 354, Pebble Rd.	1.2	7.3	3	690	620	100%	NON	Ls,HSTS
Friday Creek PCR recommended									
303640	CR 66, Chase Rd.	1.2	3.5	3	4,900	1,764	100%	NON	HSTS
Honey Run PCR recommended									
R08P01	ust. Carrollton WWTP/ tributary	0.8	3.4	7	5,200	1,257	100%	NON	Mixed
303642	dst. Carrollton WWTP	0.6	3.8	7	1,700	941	100%	NON	SSO,Mixed
Cold Spring Run PCR recommended									
303644	from SR 39, Roswell Rd.	0.6	5.9	3	2,200	1,011	100%	NON	Mixed
Pleasant Valley Run PCR recommended									
303646	TR 147, Folsam Rd.	1.5	6.5	3	860	578	100%	NON	Ls,HSTS
Pleasant Valley Run-Indian Fork 05040001 08 02									
Elliot Run PCR recommended									
303702	CR 69, Clay Rd.	1.4	3.5	3	1,300	1,025	100%	NON	Ls,HSTS
Dog Run-Conotton Creek 05040001 08 05									
Conotton Creek Tributary (RM 11.37) PCR recommended									
303614	TR 320, Dawn Rd.	0.3	4.6	3	1,800	864	67%	NON	HSTS
Conotton Creek Tributary (RM 7.67) PCR recommended									
303654	TR 388, Brown Hill Rd.	2.9	3.8	3	2,900	956	100%	NON	Ls,HSTS
Beggar Run PCR recommended									
303653	CR 90, New Cumberland Rd.	0.5	4.0	5	3,200	1,270	100%	NON	Ls,HSTS
Huff Run 05040001 08 04									
Huff Run PCR recommended									
300601	TR 170, Heritage Rd.	7.8	3.3	3	1,700	713	33%	NON	Ls,HSTS
300599	CR 36, Brass Rd.	5.5	6.5	3	620	339	33%	NON	Ls,HSTS
300595	CR 90, New Cumberland Rd.	1.3	11.8	8	4,400	893	38%	NON	SSO,Mixed

Sources of bacteria close to the site include:

- Ls- Livestock.
- HSTS- Home Sewage Treatment Systems.
- Town- Clustered residential areas including pet waste.
- Mixed- Rural areas with a mix of LS, HSTS, and often near a town.
- SSO- Sanitary Sewer Overflows have occurred at the Scio, Atwood Regional, Carrollton, and Mineral City WWTP's.

Recreation Use Criteria in <i>E. coli</i> colony forming units per 100 ml of water (cfu/100ml).		
	90-day geometric mean criterion	Statistical Threshold Value
Primary Contact Recreation (PCR)	$\bar{x}_{geom}=126$ cfu/100ml	STV=410 cfu/100ml
Secondary Contact Recreation (SCR)	$\bar{x}_{geom}=1,030$ cfu/100ml	STV=1,030 cfu/100ml
During the May 1 to October 31 recreation period, the geometric mean of <i>E. coli</i> counts shall be less than the relevant criterion and the corresponding STV shall not be exceeded in more than 10 percent of the samples taken within any ninety-day time span.		

sample, *E. coli* cfu/100ml were most abundant at 25 of 47 stations. These sites were generally aligned with the mainstem or positioned in track with the storm event. At northern sites that weren't influenced by the August rainstorm, the corresponding highest *E. coli* counts tended to occur sporadically between June 28 through July 6. Sample timing was also pertinent. For instance, Thompson Run *E. coli* were most abundant on June 28 (*E. coli*=1,000 cfu/100ml) as sampling on August 15 (*E. coli*=320 cfu/100ml) occurred at 10:30 a.m., before the rainstorm began. Sampling on August 15 at 11:15 a.m. in Conotton Creek RM 17.22 Tributary returned the highest *E. coli* count (*E. coli*=650 cfu/100ml) of three from this location. However, the count could have been more, if the sampling occurred later in the day, as evidenced by extreme values from Long Creek (12:15 p.m., *E. coli*=17,000 cfu/100ml) and the North Fork McGuire Creek (RM 9.4-12:35 p.m. *E. coli*=4,600 cfu/100ml, RM 7.7-12:40 p.m. *E. coli*=7,700 cfu/100ml, RM 6.0-12:45 p.m. *E. coli*=16,000 cfu/100ml).

Although *E. coli* counts from the August 15-16 sample series specifically resulted in non-attainment of the recommended recreational use for many sites, those results are important for understanding where *E. coli* and by inference, where pathogenic exposure risk was greatest. Attempting to arrange sampling to avoid high flow events is counterproductive to that end. And it's not pragmatic. Chemical and bacteria sampling is a full-time summer field season effort. It's simply untenable to schedule sampling to accommodate the weather.

Weather during the 2016 summer field season was generally cooperative. As shown in Figure 9 and Figure 10, the mid-August storm was a unique event. It had a small effect on flow compared to spring, fall, and winter hydrograph records. When all 228 study area *E. coli* samples were rank ordered by results, Scott Run at RM 0.7 (SR 151, 303630 *E. coli* $\bar{x}_{geom}=3,717$, max=24,000 cfu/100ml), Dining Fork at RM 0.2 (SR 151, 303628 *E. coli* $\bar{x}_{geom}=2,825$, max=9,900 cfu/100ml), and Conotton Creek at RM 33.3 (Eastport Rd., 303541 *E. coli* $\bar{x}_{geom}=2,667$, max=14,000 cfu/100ml) were the most bacterially polluted sites in 2016. Although high values were determined, the maximum counts at these sites were not associated with the mid-August storm. Instead, bacteria at each location were routinely augmented by obvious sources.

The Scott Run and Dining Fork sample sites were both adjacent to cattle pastures. Livestock with stream access can degrade water quality in numerous ways. In 2018, the Environmental Protection Agency of Ireland considered these factors in *Impact of Cattle Access to Watercourses: Literature Review on Behalf of the COSAINT Project* (O'Callaghan et al., 2018, [Research_Report_260.pdf \(epa.ie\)](#)). Summarizing 26 studies where fencing was used to prevent cows from accessing streams, the authors asserted there were ambiguous results regarding specific outcomes. Fencing generally reduced sedimentation and microbial loads. Nutrient abatement, hyporheic zone recovery, and biological responses related to exclusion fencing were less certain. Even so, drawing from the more than 250 reviewed references, the conclusive consensus was that cows weren't helpful to water quality.

The prevalence of fine sediment and increased suspended solids are associated with *E. coli* persistence in the environment (Petersen and Hubbart, 2020). Although hyporheic zone functions can be detrimental to bacteria as demonstrated in McGuire Creek downstream from Leesville Lake and in Indian Fork downstream from Atwood Lake, this active area at the water-sediment interface can alternatively, foster *E. coli* growth. Cattle induced hyporheic zone bioturbation influences *E. coli* environmental persistence by increasing stream erosion and perpetuating solids suspension. The highest TSS concentrations in the 2016 study area were from Scott Run (\bar{x} =88, max=282 mg/L) and Dining Fork (RM 6.3, TR382, 303626 \bar{x} =57, max=211 mg/L and RM 0.2, SR 151, 303628 \bar{x} =35, max=106 mg/L, Table 10). As with bacteria, the mid-August storm did lead to elevated TSS concentrations, but the maximum values in both subbasins were registered on other dates.

Some of the fencing success ambiguity alluded to in the O'Callaghan et al. (2018) review was due to management practices with inseparable results. Fencing was often accompanied by provision of alternative water supplies, waste storage lagoons, riparian planting, and adoption of nutrient management plans. The concurrent practices made it difficult to stipulate how much fencing alone improved water quality. Ohio EPA considered the success of various agricultural conservation practices in three decadal periods between 1981 to 2013 (Miltner, 2015). Ohio EPA too, determined that grouping fencing with related best management practices (BMPs) improved a statistical model. Habitat, water quality, and biological data from 642 HUC 12 subbasins was paired with land use, baseflow index values, soil characteristics, and Natural Resources Conservation Service (NRCS) BMP records to discern which variables were most influential. In Ohio, fencing with related water and forage BMPs have reduced ambient nitrogen concentrations. Improving substrate scores cooccurred with fence related BMP implementation and declining nitrogen loads. Collectively, fencing livestock outside riparian corridors and adoption of related BMPs are recommended to also abate the high *E. coli* presence in the Conotton Creek watershed.

Nine *E. coli* samples were collected from Conotton Creek at RM 33.3 (Eastport Rd., 303541) in the village of Scio. Six (67%) of those *E. coli* samples produced *E. coli* counts of 2,000 cfu/100ml or more. The routinely high *E. coli* presence upstream from the Scio WWTP indicated inadequately treated household sewage was discharged directly to Conotton Creek. Overflows of the village sanitary sewer system were reported to occur several times annually. Recognizing that other sources including pet waste, upstream livestock, and wildlife are also implicated by the regular frequency of high *E. coli* counts in Scio should not be misconstrued. The direct discharge of human waste to Conotton Creek is a serious health threat to anyone who contacts the contaminated water.

Similar sanitary sewer overflows (SSOs) were reported from Carrollton, Mineral City, and in the area served by the Atwood Regional Water and Sewer District. No SSOs were reported from Jewett, Bowerston, or Leesville. The importance of correcting SSO issues was apparent at Atwood Lake. In 2011, the USGS completed a microbial source study to determine where fecal contamination at the Atwood Lake beach originated from (Buckeye and Tappan lakes were also assessed, Francy and Stelzer, 2012). Because the Atwood area is serviced by a central sewer collection system, the USGS speculated that wastewater was unlikely to be a source of the detected human-associated *Bacteroides* marker. Thus, they attributed the 14% occurrence of that marker to be from those swimming at the Atwood Lake beach. Markers for cows (57%) and dogs (43%), but not for gulls (birds, 0%) were also detected at Atwood Lake.

Francy et al. (2013) continued pathogen assessment at Ohio recreational lakes in 2012. Additional data including several pathogens were used to validate models developed to predict when unhealthy conditions

may occur. A strong correlation between *E. coli* and turbidity ($r=0.47$) was documented in Atwood Lake. Increases from morning to afternoon *E. coli* presence were attributed to swimmer shedding and *E. coli* resuspension from beach sediment. *Cryptosporidium* and adenovirus, *eaeA* (*E. coli*) were present in Atwood Lake. Overall, the bathing water recreation use beach action value (235 cfu/100ml) was exceeded in one fourth (25%) of the 2011-2012 Atwood Lake samples.

Excluding *E. coli* samples from McGuire Creek downstream from Leesville Lake and in Indian Fork downstream from Atwood Lake, 217 *E. coli* counts were completed in the 2016 Conotton Creek study area. Only four samples were less than the PCR geometric mean criterion (*E. coli* $\bar{x}_{geom}=126$ cfu/100ml). One fourth (26%) of the *E. coli* sample results were less than the PCR STV criterion (*E. coli*=410 cfu/100ml). In other words, three fourths of the *E. coli* samples exceeded thresholds that are acceptable at a frequency less than ten percent.

Recognizing there are many ways to qualify *E. coli* data and the nuance of that interpretation might allow or be less forgiving, it is reasonable to assert *E. coli* were too abundant in the Conotton Creek watershed. Furthermore, there are many easily implemented solutions to begin to curtail the causes. Pet owners can properly dispose pet waste. Livestock owners can keep their stock out of streams and arrange for watering following recommended BMPs. Homeowners can make sure their septic is correctly treated via a functional HSTS or an appropriate connection to a central sewer system. Similarly, stormwater management is everyone's concern. Yard waste and trash belong in compost piles and rubbish bins, not in street gutters or tossed over a stream bank. Small acts toward cleanup will help create the swimmable conditions we will all benefit from.

Fish Tissue Sampling, Consumption Advisories, and Human Health Beneficial Use Attainment

Fish contaminant data are used to determine safe meal frequencies (e.g., two meals per week, one meal per month, do not eat), and fish consumption advisories are issued for applicable species and locations. Ohio has had a statewide advisory for fish since 2001, primarily due to ubiquitous mercury contamination from aerial deposition. The following statewide advisory applies when there are either no or insufficient data: sunfish (e.g., bluegill) and Yellow Perch – two meals per week, Northern Pike and flathead catfish greater than 23” – one meal per month, and all other species – one meal per week. Ohio’s sport fish consumption advisory can be viewed at <https://odh.ohio.gov/know-our-programs/ohio-sport-fish-consumption-advisory>. The minimum data requirement for issuing a fish advisory is three samples of a single species from within the past ten years.

Based on fish tissue samples collected in 2016 (Table 23), the statewide consumption advisory advice applies to all species and all sections of the Conotton Creek study area. Sufficient samples of Rock Bass (n = 3) were collected in 2016 to determine whether a more or less restrictive advisory was necessary for Conotton Creek; however, tissue contaminant results indicated that the statewide advice of one meal/week is sufficient for Rock Bass. The minimum required sample size to determine advisory status was not met for any other species. Therefore, the statewide advisory applies to all other Conotton Creek study area species. The statewide advisory applied to Conotton Creek is typical, as historically, no other advisories have been in place for this location.

Table 24 – Information and mercury and total PCB concentration for fish tissue samples collected in 2016 for the Conotton Creek survey. All samples were analyzed as skin off fillet composites.

Year	Lab ID	Site Name	RM	Species	Trophic Level	HUC12	Mercury (µg/kg)	Total PCBs (µg/kg)
2016	444069/ 444074	CONOTTON CR @ ZOARVILLE BRIDGE	0.2	COMMON CARP	3	05040001 08 05	129	2414
2016	444070/ 444075	CONOTTON CR @ ZOARVILLE BRIDGE	0.2	ROCK BASS	3	05040001 08 05	153	53.5
2016	444071/ 444076	CONOTTON CR @ MARSH RD	6.7	ROCK BASS	3	05040001 08 05	167	<20.0
2016	444072/ 444077	CONOTTON CREEK S OF NEW CUMBERLAND @ CO. RD. 90	11.36	ROCK BASS	3	05040001 08 05	104	<19.9
2016	444073/ 444078	CONOTTON CREEK S OF NEW CUMBERLAND @ CO. RD. 90	11.36	COMMON CARP	3	05040001 08 05	67	<19.9

On top of the fish tissue collected as part of this survey, the Ohio Department of Natural Resources (ODNR) collected and analyzed fish tissue from Atwood Lake in 2016. The ODNR typically collects fish tissue samples from Ohio’s inland lakes and from Lake Erie to support the state’s fish consumption advisory program. A sufficient number of bluegill, common carp, largemouth bass, Rock Bass, saugeye, and white crappie samples were analyzed to determine if consumption advisories outside of the statewide guidance were

necessary for this reservoir. Results indicated that advisories less restrictive than the statewide guidance were recommended for bluegill, common carp, largemouth bass, saugeye, and white crappie (Table 24).

Table 25 – Fish consumption advisories for Atwood Lake published April 2017.

Species	Advisory (advisory chemical)
Common Carp	2/week (mercury)
Largemouth Bass	2/week (mercury)
Bluegill	Unrestricted
Saugeye	Unrestricted
White Crappie	Unrestricted

Human Health Use (Fish Tissue) Attainment

In addition to determining safe meal frequencies, fish contaminant data are used to determine attainment with the human health water quality criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health water quality criteria are presented in water column concentrations of $\mu\text{g}/\text{Liter}$ and are then translated into fish tissue concentrations in $\mu\text{g}/\text{kg}$. [See

<https://epa.ohio.gov/static/Portals/35/tmdl/2018intreport/SectionE.pdf>) for further details of this conversion.]

Between 2007 and 2016, at least two samples from trophic level (TL) 3 and two from TL 4 were needed to calculate Human Health (Fish Consumption) attainment status. To be considered in attainment of the water quality standards, sport fish caught within an assessment unit must have a weighted average concentration of the geometric means for all species below $350 \mu\text{g}/\text{kg}$ for mercury and below $23 \mu\text{g}/\text{kg}$ for PCBs.

In the Human Health portion of the 2016 Integrated Report, all the Watershed Assessment Units sampled in this survey were classified as Category 3 (Insufficient Data). Using fish tissue data collected by ODNR from Atwood Lake in 2016, impairment status for one of these Watershed Assessment Unit (WAU 05040001 08 02) was updated in the 2018 Integrated Report. This assessment unit was determined to be Unimpaired, with levels of total PCBs and mercury below the threshold level upon which water quality standard criteria are based. Additional data were collected in another Watershed Assessment Unit (WAU 05040001 08 05) as part of the Conotton Creek study; however, inadequate samples existed to determine impairment status. This WAU and the remaining WAUs that were part of the Conotton Creek study area were classified as having Insufficient Data in the 2018 Integrated Report (Table 25).

Table 26 – Previous and current Human Health Attainment Status for watershed assessment units (WAUs) in the Conotton Creek study area, from the 2016 and 2018 Ohio Integrated reports (IRs), respectively, using fish tissue data from 2005-2014 (2016 IR) and 2007-2016 (2018 IR). Status 1 represents unimpaired watersheds (contaminant levels below impairment thresholds in fish tissue) and Status 3 represents insufficient data to assess the unit. No assessment units were Status 5, which represents watershed impairment (exceeding contaminant thresholds in fish tissue for the listed contaminant).

Assessment Unit	Previous Integrated Report Status (2016)	Current Integrated Report Status (2018)	Waterbody
05040001 07 01	3	3	Headwaters Upper Conotton Creek
05040001 07 02	3	3	Irish Creek
05040001 07 03	3	3	Dining Fork
05040001 07 04	3	3	Headwaters Middle Conotton Creek

05040001 07 05	3	3	North Fork McGuire Creek
05040001 07 06	3	3	McGuire Creek
05040001 07 07	3	3	Headwaters Lower Conotton Creek
05040001 08 01	3	3	Cold Spring Run-Indian Fork
05040001 08 02	3	1	Pleasant Valley Run-Indian Fork
05040001 08 03	3	3	Thompson Run-Conotton Creek
05040001 08 04	3	3	Huff Run
05040001 08 05	3	3	Dog Run-Conotton Creek

Fish Contaminant Trends

Fish contaminant levels can indicate pollution in the water column at levels lower than laboratory water concentration reporting limits but high enough to threaten human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain chemicals like PCBs and stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish (U.S. EPA 2020). Mercury concentrations have also been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct that is released into air and/or surface water (Hammerschmidt & Fitzgerald 2006; Janssen *et al.* 2019, Zananski *et al.* 2011).

For these reasons, it is useful to compare the results from the survey presented in this TSD with those of the previous survey(s) done in the study area. Recent data can be compared against historical data to determine whether contaminant concentrations in fish tissue appear to increase, decrease, or stay the same in a water body or watershed. The type of comparison between years depends on the contaminant and the way it concentrates in fish tissue based on feeding behaviors.

When evaluating mercury results, condensing samples by trophic level is often useful. Because mercury tends to increase with increasing position within the food web (that is, predator fish have higher mercury levels than herbivores and insectivores (GLSFCA 2007, Janssen *et al.* 2019), all sample results within a trophic level can be calculated as a yearly average and compared between years, making for an informative assessment while remaining concise.

However, this approach does not fare well for PCBs, which are more affected by the fat content of fish species rather than their trophic level (GLSFCA 1993). For example, trophic level 3 fish (insectivores) often include both some of the most-contaminated species for PCBs (benthic feeders such as catfish and carp), as well as some of the least-contaminated species for PCBs (pelagic feeders such as bluegill and other panfish). If the same species have been consistently collected in a body of water over the years, then the species' PCB concentration trends can be evaluated directly. However, if different species have been collected for years, other approaches must be considered. Therefore, PCB contamination trends are often assessed case-by-case to ensure the most reliable conclusions.

Previous analysis of fish tissue contamination in Conotton Creek occurred in 1997. During this time, one northern pike, two White Sucker, and three Rock Bass samples were collected and analyzed for contaminants. When comparing mercury concentrations in trophic level 3 species between the two sampling years (i.e., Northern Pike excluded), mercury concentrations in fish tissue samples from 1997 were not significantly different from those from 2016 ($p < 0.587$; Figure 21). In both years, mercury concentrations in all samples fell below the one meal/month consumption advisory threshold of 220 $\mu\text{g}/\text{kg}$ (Figure 21).

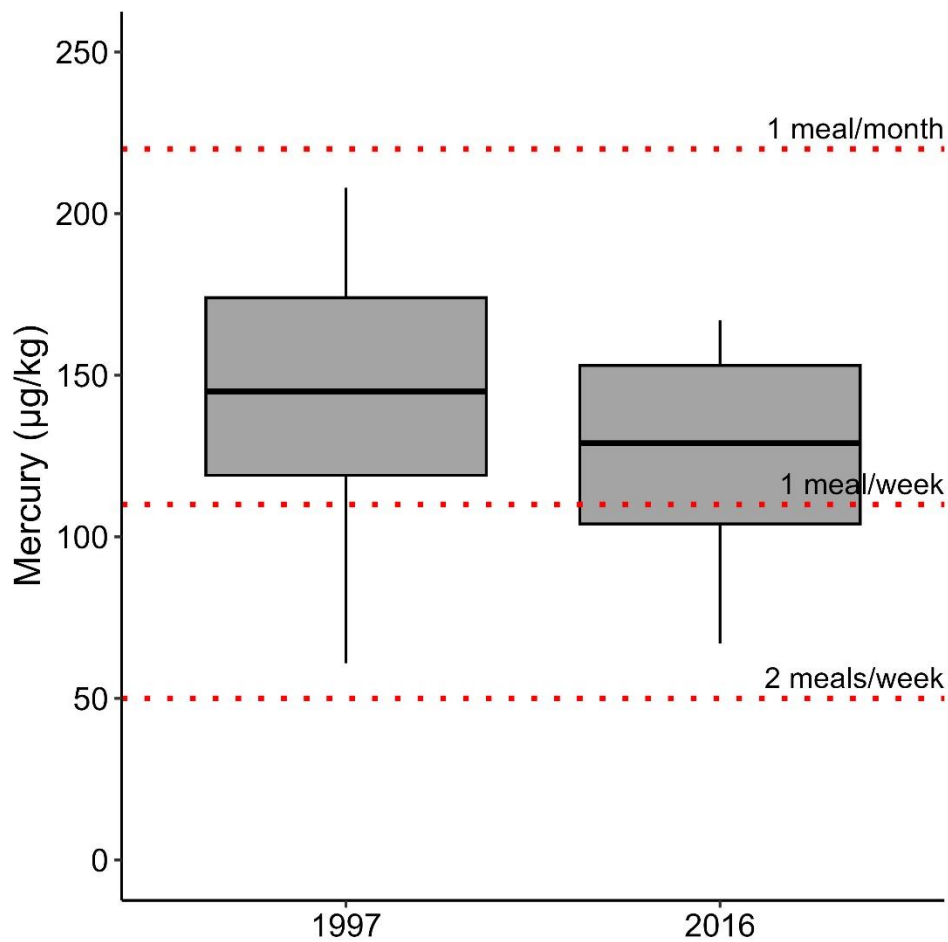


Figure 22 - Comparison of mercury concentrations in the tissue of Trophic Level 3 species from Conotton Creek in 1997 and 2016. Dotted red horizontal lines represent mercury thresholds for fish consumption advisories.

For PCBs, of the three Rock Bass tissue samples collected during the Conotton Creek survey in 2016, the total concentration in one sample was 53.5 ug/kg, and the concentrations were non-detectable in the others (Table 23). In the two Common Carp samples, the concentration of total PCBs was variable, with one sample having a high concentration of 2414 ug/kg and one having a non-detectable concentration (Table 23). Total PCBs in Conotton Creek fish tissue samples from 1997 were all non-detectable. However, the laboratory detection limits in 1997 (~ 50 ug/kg) were more than double that of the detection limits in 2016 (~20 ug/kg). Except for the one Common Carp sample that was extremely high in total PCBs, there was little evidence to suggest any significant change in total PCB concentrations in fish from Conotton Creek.

Beneficial Use Recommendations

Beneficial uses are core components of Water Quality Standards (WQS). Pursuant to a Use Attainability Analysis (UAA), a water body (stream or lake) may have one or several designated uses. Environmental protection is inherently concerned with the attainment status of those uses. Criteria adopted for that purpose are another core component of a WQS. For example, in Ohio we know some streams support greater biological diversity than is commonly encountered. Within a scheme of tiered aquatic beneficial uses, those streams with outstanding biological communities are assigned the Exceptional Warmwater Habitat (EWH) use. Comparison of a stream's biological assemblage, as measured by accepted indices, against Ohio's biocriteria provides evidence of the EWH use attainment status, e.g., full, partial, or non. Having been fully verified, the third component of a WQS, an antidegradation provision becomes enforceable.

This jargon and acronym rich paradigm was largely conceived to administer the Federal Water Pollution Control Act (FWPCA) amendments of 1972, later revised as the Clean Water Acts (CWA) of 1981 and 1987. Those acts established the National Pollution Discharge Elimination System (NPDES) of permits for discharge of pollutants to a water body. A stream designated for EWH aquatic life use has specific criteria and permit requirements conceived to maintain the beneficial use.

Tasked with implementing the NPDES permits, Ohio EPA needed a way to identify outfall locations and other features in a dendritic network. In 1983, the Planning and Engineering Data Management System for Ohio (PEMSO) was created using River Mile Index (RMI) codes. All Ohio streams shown on USGS 7.5 minute quadrangle topographic maps were marked in tenth mile segments. Further interpolation estimated hundredth increments within segments. That scheme is utilized herein to specify the distance between confluence nodes of a mainstem and its unnamed tributary or the relative position of sampling sites. Ohio EPA river mile maps are at: [River Miles Index | Ohio Environmental Protection Agency](#).

Conveniently, a list of those streams had been compiled by ODNR in 1954 (*Gazetteer of Ohio Streams*). That list became the basis for Ohio's Beneficial Use Designations in 1978 when each named stream was associated with Aquatic Life Habitat, Water Supply, and Recreation uses according to the best available information (Table 24). Now appearing in Ohio Administrative Code (OAC) rules 3745-1-08 to 3745-1-32, those original uses are designated with asterisks (*) unless a water body specific UAA has occurred as indicated by a plus sign (+). Results of this UAA study appear as (*+), to indicate the original use has now been verified or as a triangle to signify a previously undesignated use has been recommended.

Dog Run, Dellroy Creek, Town Creek, Holmes Run and an unnamed tributary to Conotton Creek with a confluence between those of Jefferson and Irish Creeks appear in gray because those streams have not been assessed. Those omissions from this study were purposeful. What's in a name? Some would argue a name gives standing. And perhaps it should. There are hundreds, maybe thousands, of Ohio streams which merit naming if some equivalent system was employed to do so. Such a system might disregard a few presently named streams for cause.

In 1998, Ohio EPA began selecting sampling sites based on drainage area. Sequential halving of drainage basin sizes was used to identify possible sampling locations. Geometrically dividing the 286 mi² Conotton basin yields sample sites at 143, 72, 36, 18, 9, 4.5, and 2.2 mi². When the rigor of that practice was tempered by pragmatic considerations such as basin shape and access, a series of best fit sites conforming to 70 mi² (2x), 50 mi² (2x), 13 mi² (6x), 6.5 mi² (11x) and 3.5 mi² (19x) were apparent for this

Table 27 - Waterbody use designations and recommendations for the Conotton Creek study area (OAC 3745-1-24). Designations based on the 1978 and 1985 Ohio Water Quality Standards are indicated with asterisks (*) while designations based on the results of a previous Ohio EPA biological assessment are symbolized using a plus sign (+). Verification of current designations based on this study are symbolized as (*+), while a triangle (▲) denotes a new/revised recommended use. Streams not assessed in this study are highlighted in gray.

Water Body Segment	Use Designations												Comments	
	Aquatic Life Habitat						Water Supply			Recreation				
	S R 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
Conotton creek - from Bowerston (RM 26.0) to the mouth		+							+	+			*/+	
Huff run		*/+							*/+	*/+			*/+	
Beggar run		*/+							*/+	*/+			*/+	
Unnamed tributary (Conotton Creek RM 7.67)		▲							▲	▲			▲	
Dog run		*							*	*			*	
Unnamed tributary (Conotton Creek RM 11.37)		▲							▲	▲			▲	
Indian fork - at RMs 3.0 and 3.7		*/+						o	*/+	*/+			*/+	PWS intakes - Atwood park (RM 3.0) and Atwood resort (RM 3.7)
- all other free flowing segments		*/+							*/+	*/+			*/+	
Unnamed tributary (Indian fork RM 3.30)		▲							▲	▲			▲	
Elliott run		*/+							*/+	*/+			*/+	
Dellroy creek		*							*	*			*	
Willow run (Messer run)		*/+							*/+	*/+			*/+	
Pleasant Valley run		*/+							*/+	*/+			*/+	
Cold Spring run		*/+							*/+	*/+			*/+	
Honey run		▲							▲	▲			▲	
Town creek		*							*	*			*	
Gantz creek		*/+							*/+	*/+			*/+	
Friday creek		▲							▲	▲			▲	
Thompson run		*/+							*/+	*/+			*/+	
Unnamed tributary (Conotton creek RM 17.22)		▲							▲	▲			▲	
Holmes run		*							*	*			*	
McGuire creek – headwaters to unnamed tributary (RM 7.57)			▲						*/+	*/+			*/+	
- all other free flowing segments		*/+							*/+	*/+			*/+	

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	
North fork		*	▲						*/+	*/+		*/+	
Bear Hole run		*	▲						*/+	*/+		*/+	
Long creek			▲						▲	▲		▲	
Unnamed tributary (Conotton creek RM 28.20)		▲							▲	▲		▲	
Scott run		*							*	*		*	
Dining fork		*	▲						*/+	*/+		*/+	
Kirby run		*	▲						*/+	*/+		*/+	
Irish creek – headwaters to Lick fork (RM 3.09)							▲		+	+		*/+	
- Lick fork (RM 3.09) to the mouth		+							+	+		*/+	
Lick fork							▲		*/+	*/+		*/+	
Snow creek		*							*	*		*	
Unnamed tributary		*							*	*		*	
Jefferson creek		+							+	+		*/+	

Snow Creek is the same stream as Irish Cr.

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

study. In typical fashion the number of sample sites increased so that 19 locations at 3.5 mi² would have been nearly twice as many if resources were available to sustain the effort at 1.75 mi² basin sizes. Lacking the personnel and budget to attempt an additional 35 to 40 sample sites, streams including Dog Run, Dellroy Creek, etc. were not assessed because their drainage areas were too small.

However, sampling did occur at an unnamed Conotton Creek tributary with a confluence at RM 17.22 (6.3mi²) and at several others. From a water resource perspective, pollutant loading, assimilative capacity, and similar hydrologic factors associated with drainage area are more compelling than the somewhat arbitrary inclusion on a list of named streams. Furthermore, the omission of Friday and Long Creeks while including Snow Creek call question to the adequacy of review, if any, of the 1978 WQS original list. Those and other oversights were carried forward in Ohio EPA stream lists and in the second edition of the *Gazetteer of Ohio Streams* (ODNR 2001) despite revisions on USGS topographic maps, in *Drainage Areas of Ohio Streams, Supplement to Gazetteer of Ohio Streams* (Cross, 1967), and elsewhere.

If this esoteric digression seems misplaced, the heart of the matter is exhibited by the unusual inclusion of an unnamed tributary among the Water Body Segments within Conotton Creek. Apparently, this stream joins the mainstem between the confluences of Jefferson and Irish Creeks. At least 22 different small rivulets could be the inferred unnamed water body. An administrative bottleneck precludes removing streams from Ohio WQS, as if those listings were beyond human error. That conviction would direct sampling resources toward Dog Run and the mystery tributary to avoid the gray highlight in Table 24. What's more, there's no assurance any of the unlisted streams, named or not (such as Friday and Long Creeks or five unnamed streams) would have been assessed, unless like the otherwise overlooked Honey Run, an NPDES permitted discharge attracted attention.

This forthright explanation is intended to quash any hint of slacking that gray shade in Table 24 might impart. Streams listed in Ohio WQS were not qualified with any rigor. The small subset of Conotton Creek water bodies make that obvious. Lick Fork was mislabeled as Snow Creek on the 1901 Cadiz 15-minute quadrangle map completed by the Ohio Cooperative Topographic Survey. The error was corrected on the 1960 Amsterdam 7.5 minute quadrangle map issued by the USGS. Nevertheless, the oversight continues to appear in Ohio WQS apparently to avoid the appearance of impropriety that removal might illicit. Just like any of the 22 plausible unnamed tributaries between Jefferson and Irish Creeks, Dog Run did not merit sampling effort in this study. No derision toward Dog Run or any of those 22 rivulets is suggested. In fact, insistence on listing Dog Run within Ohio's WQS while excluding all but one of those 22 unnamed tributaries seems overtly catty!

Scott Run was not assessed for Aquatic Life Use (ALU) attainment status because fish sampling within a fenced pasture could not be arranged. Water chemistry and macroinvertebrate sampling were accomplished via roadside access along SR 151. While attainment status has previously been determined based on one organism group results, e.g., macroinvertebrates or fish, reinterpretation of OAC provisions now expects an ICI score where fish assessment is absent to substantiate the ALU performance. The Scott Run qualitative macroinvertebrate evaluation, unaccompanied by an IBI score, was thus deemed inadequate for ALU attainment status determination.

Notice the opposite situation occurred at the most downstream Conotton Creek location (RM 0.2, Zoarville Station trail, TR 390, 303581). This site was assessed for ALU attainment status based solely on fish community performance. Suitable macroinvertebrate habitat for sampling was not available in the reach. There, IBI and MIwb scores were deemed sufficient for OAC requirements. The unequal interpretation of macroinvertebrate

assessment techniques (qualitative evaluation occurs at all locations regardless of the multiplate sampler deployment used for ICI scoring) is another administrative snafu worthy of attention. Clarification of OAC language would enable an ALU attainment status for Scott Run and other streams where circumstances precluded fish assessment. The infrequency of this situation, perhaps once or twice statewide each field season, nevertheless warrants revision.

Use attainability assessment occurred in Conotton, Jefferson, and Irish Creeks in 1982, 1984, and 1998. Warmwater habitat (WWH) was confirmed as the appropriate designation for those streams. Although Huff Run was evaluated in 1997, 2008, and 2012, a UAA was not completed. This 2016 survey was the first time Ohio EPA sampled any of the other Conotton Creek basin streams mentioned herein. This study verified or recommended uses for 18 streams presently listed in Ohio WQS. Eight unlisted streams with verified uses were recommended for inclusion in Ohio WQS.

The biological and habitat data for ten streams or stream segments supported verification of the current WWH designation, denoted in Table 24 as (*/+). These include the following streams: Huff Run, Beggar Run, Indian Fork, Elliott Run, Willow Run (previously mislabeled as Messer Run), Pleasant Valley Run, Cold Spring Run, Gantz Creek, Thompson Run, and McGuire Creek. In addition, seven previously undesignated streams were documented to support, or have the potential to support the WWH use designation, including unnamed tributaries to Conotton Creek at RMs 7.67, 11.37, 17.22 and 28.20, Honey Run, Friday Creek, and an unnamed tributary to Indian Fork at RM 3.30.

The biological and habitat data for six streams or stream segments supported the recommended EWH designation, denoted in Table 24 as (▲). Study area streams with exceptional biological assemblages included: McGuire Creek from its headwaters downstream to the unnamed tributary at RM 7.57 (near SR 332, Scio Rd.), North Fork McGuire Creek, Bear Hole Run, Long Creek, Dining Fork, and Kirby Run (Table 21). The highest habitat scores within the study area were recorded in the North Fork McGuire Creek (Table 17). Bear Hole Run, Long Creek, and Dining Fork upstream from Kirby Run (RM 1.78) were further notable for the presence of ten, six, and five macroinvertebrate taxa, respectively, and two fish species that were indicative of persistent cold stream temperatures (Table 25).

Cold water adapted fauna were sufficiently present in two other streams to merit the coldwater habitat (CWH) use recommendation, also denoted in Table 24 as (▲). Irish Creek from its headwaters downstream to Lick Fork (RM 3.09) and Lick Fork supported five and eight cold water indicative macroinvertebrate taxa, respectively, and Mottled Sculpin (Table 25). Although the aquatic communities in these streams were less diverse than those for which EWH designation was recommended, the abundance of organisms with affinity for cold water warrant efforts to maintain appropriate temperatures in CWH designated waterbodies.

Primary contact recreation (PCR) was the default use in the Conotton Creek basin when Ohio's WQS were assembled. With bathing beach locations at Atwood and Leesville Lakes, Conotton Creek is a less appealing choice for recreation. Although public parks in Bowerston and Sherrodsville are situated along the creek, steep banks prevent stream access. Conotton Creek's tortured, winding course and numerous log jams make for the slowest of boating adventures. However, the reach of Conotton Creek from Bowerston (RM 26.0) downstream to the Tuscarawas River confluence does provide opportunities for swimming and boating which verify the PCR use.

Upstream from Bowerston (RM 26.0), the Conotton Creek Trail affords hikers and bikers five covered bridges (with windows) to view the stream from in route over the 11.2-mile paved path to Jewett. While creek access is

certainly plausible, path travelers have universally contented themselves with observing the stream from the trail. Even so, Conotton Creek is large enough to be waded in throughout this upper reach. Likewise, other Conotton basin streams might invite an occasional stream stroll. The primary contact recreation (PCR) use includes wading, so applying PCR use for the entire basin ensures anyone recreating in the stream is protected, especially children that can make any body of water a full body immersion experience.

All evaluated streams were consistent with the agricultural and industrial water supply uses. Those uses were recommended for currently undesignated streams and otherwise verified for all evaluated streams.

Table 28 – Cold water adapted fauna within streams recommended for coldwater habitat (CWH) use in the Conotton Creek basin, 2016.

Stream	Macroinvertebrates	Fish
Bear Hole Run	<i>Leuctra sp.</i> , <i>Nigronia fasciata</i> , <i>Dolophilodes distinctus</i> , <i>Goera sp.</i> , <i>Oligostomis pardalis</i> , <i>Dicranota sp.</i> , <i>Trissopelopia ogemawi</i> , <i>Zavrelimyia (Z.) sp.</i> , <i>Parametriocnemus sp.</i> , <i>Polypedilum</i> <i>(Uresipedilum) aviceps</i>	Mottled Sculpin Redside Dace
Long Creek	<i>Leuctra sp.</i> , <i>Ceratopsyche slossonae</i> , <i>Dicranota sp.</i> , <i>Dixa sp.</i> , <i>Parametriocnemus sp.</i> , <i>Polypedilum (Uresipedilum) aviceps</i>	Mottled Sculpin Redside Dace
Dining fork – headwaters to Kirby Run (RM 1.78)	<i>Ceratopsyche slossonae</i> , <i>Anchytarsus bicolor</i> , <i>Dicranota sp.</i> , <i>Polypedilum (Uresipedilum) aviceps</i> , <i>Oligostomis pardalis</i>	Mottled Sculpin Redside Dace
Irish Creek – headwaters to Lick Fork (RM 4.63)	<i>Ceratopsyche slossonae</i> , <i>Dicranota sp.</i> , <i>Meropelopia sp.</i> , <i>Parametriocnemus sp.</i> , <i>Polypedilum (Uresipedilum) aviceps</i>	Mottled Sculpin
Lick Fork	<i>Leuctra sp.</i> , <i>Ceratopsyche slossonae</i> , <i>Oligostomis pardalis</i> , <i>Lepidostoma sp.</i> , <i>Zavrelimyia (Z.) sp.</i> , <i>Parametriocnemus sp.</i> , <i>Polypedilum (Uresipedilum) aviceps</i> , <i>Micropsectra sp.</i>	Mottled Sculpin

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