Ohio Environmental Protection Agency

Biological and Water Quality Study of Southwest Ohio River Tributaries, 2014

Butler, Hamilton, Brown, and Clermont Counties, Ohio

Division of Surface Water

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Executive Summary

Rivers and streams in Ohio support a variety of uses such as recreation, water supply, and aquatic life. Ohio EPA evaluates streams to determine appropriate use designations and also to determine if uses are meeting the goals of the federal Clean Water Act. In 2014, chemical, physical, and biological sampling was conducted on twenty-two selected streams in the Southwest Ohio River Tributaries study area (Table 1, Figure 2 and Figure 3). Aquatic life use designations had been previously verified for ten streams. Sampling of the remainder represented the initial assessment of these streams by Ohio EPA using approved protocols to assess aquatic life use designations and to evaluate biological community condition. The study area involved fourteen HUC 12 watershed assessment units and included streams in the upper reaches of Mill Creek (Butler County) and several direct tributaries of the Ohio River located in Hamilton, Clermont, and Brown counties. Sampling in the Mill Creek watershed primarily focused on evaluating the influence of Butler County Upper Mill Creek Water Reclamation Facility (UMCWRF). Sampling of the direct Ohio River tributaries was done to provide an assessment of conditions within each watershed and identify causes and sources where impairment was documented.

As a result of previous biological surveys, nine streams are listed in the Ohio Water Quality Standards (WQS) with the Warmwater Habitat (WWH) aquatic life use designation; one stream (Rapid Run) is listed as a Limited Resource Water. The WWH use was confirmed based on the 2014 survey results for eleven streams with previously unverified aquatic life use designations. Additionally, the WWH use is recommended for the unnamed tributary to Tenmile Creek (RM 3.58). Streams for which the WWH use was confirmed or recommended possessed habitat, chemical and hydrologic characteristics capable of maintaining healthy fish and macroinvertebrate communities in the absence of significant human impact.

In total, 38% of the sites sampled in 2014 were impaired for aquatic life use (Figure 1). The majority of the impairment was documented within the Mill Creek watershed and was attributed to polluted storm water runoff and wastewater treatment plant effluent (Table 2). Sources of storm water derived pollutants are widely variable and, as such, definitively identifying the causes of partial/nonattainment of designated or recommended aquatic life uses was problematic. However, nutrient enrichment and chronic toxicity likely played a role. Away from intensely urbanized areas, natural intermittent flow conditions affected a small number of sites where biological communities were not meeting expectations.

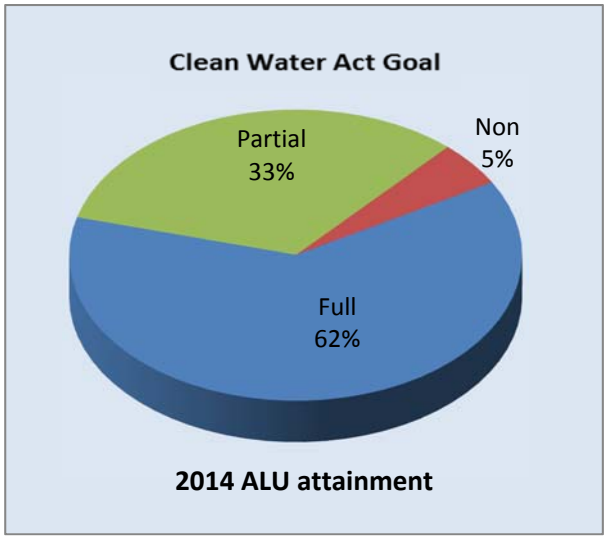


Figure 1. Of the sites sampled in the study area, 62% met the designated or recommended aquatic life use (ALU) biocriteria.

No changes in habitat or biological index scores attributable to the Mill Creek Confluence Project (Twin Creek Preserve) were observed. As described above, urban runoff and/or treated wastewater were the primary influences on fish and macroinvertebrates within the project area. Measurable improvement to the fish community may become apparent in subsequent years as the channel aggrades and stabilizes and riparian vegetation becomes more fully established. It appears less likely that the macroinvertebrate community will benefit significantly without some improvements in Mill Creek and East Fork water quality.

Recreational use attainment was evaluated at 29 locations in the Southwest Ohio River Tributary study area. All streams assessed are designated Primary Contact Recreation (PCR) waters, except Rapid Run, which is assigned the Secondary Contact Recreation use. Evaluation of *E. coli* bacteria results revealed thirteen locations that exceeded the applicable geometric mean criterion for attainment of the PCR use. The highest exceedance of the bacteria criterion was located on Tenmile Creek at RM 1.18, with a geometric mean value of 2317 cfu/100 ml. Probable sources of bacteria were a reflection of surrounding land use; inadequate on-site sewage treatment in lightly populated areas and urban runoff and storm sewers in population centers. Additionally, combined sewer overflow (CSO) outlets and a sewer system high-rate treatment (HRT) facility were identified as sources in Muddy Creek.

Chemical water quality parameters were measured at 41 in-stream locations and three wastewater treatment plant (WWTP) discharges. There were no WQS criteria exceedances for metals, apart from a couple of high iron values. Isolated WQS exceedances, mainly due to low dissolved oxygen and elevated temperature, were found in upper Mill Creek and Muddy Creek and occurred more frequently among streams in Clermont County and western Brown County. Mean nutrient levels were elevated at all monitoring locations in Mill Creek and East Fork Mill Creek downstream from the Butler County UMCWRF and in Town Run downstream from the Glendale WWTP. Phosphorus levels were elevated at sampling locations in Muddy Creek. Nutrient parameters were significantly elevated at Bear Creek RM 5.30 compared with similar streams in the study area. The impact appeared to be a localized result of cattle immediately upstream from the site.

Sediment contamination measured at eight sites was reflective of land use and legacy contamination. East Fork Mill Creek near Crescentville at Crescentville Road (RM 0.76) and Town Run (RM 16.91) downstream from the Glendale WWTP at Chester Road were the most contaminated sediment sites for metals and other inorganic contaminants. Elevated sediment ammonia concentration was common throughout the study area. PAHs were detected at six of the eight sediment sites; concentrations were highest at sites located in urban or industrial areas where these compounds are more likely to be present in storm water or had accumulated from legacy impacts. As depositional areas where fine grained sediment accumulates were neither a predominant nor significant habitat type at any of the sampling locations, effects on aquatic life were considered nominal.

Table 1. Southwest Ohio River Tributaries study area biological and water quality sampling locations, 2014.

Site Number*	Stream Name	RM	Drainage (sq mi)	Latitude	Longitude
1	MUDDY CREEK NEAR CHEVIOT @ EBENEZER RD.	5.40	7.60	39.1347000	-84.6511000
2	MUDDY CREEK NEAR CINCINNATI @ HILLSIDE RD.	1.96	12.10	39.1222000	-84.6875000
3	RAPID RUN NEAR CINCINNATI @ BENDER RD.	1.15	5.80	39.1025000	-84.6539000
4	MILL CREEK E OF HAMILTON @ LIBERTY-FAIRFIELD RD.	26.35	3.90	39.3793690	-84.4783760
5	MILL CREEK NEAR PORT UNION @ ST. RT. 747	22.06	20.60	39.3373810	-84.4623800
6	MILL CREEK NEAR CRESCENTVILLE @ CRESCENTVILLE RD.	18.69	27.00	39.2992000	-84.4344000
7	MILL CREEK 30 FT. UPST. CONFL E. FK. MILL CREEK	17.96	32.50	39.2897000	-84.4344000
8	MILL CREEK NE OF GLENDALE @ KEMPER RD.	17.61	44.80	39.2844000	-84.4331000
9	MILL CREEK AT SHARONVILLE @ SHARON RD.	16.57	50.50	39.2693410	-84.4321460
10	TOWN RUN (16.91) DST. GLENDALE WWTP @ CHESTER RD.	0.67	2.10	39.2742000	-84.4442000
11	E. FK. MILL CREEK NEAR WEST CHESTER @ WEST CHESTER RD.	3.17	5.00	39.3260000	-84.4152000
12	E. FK. MILL CREEK NEAR WEST CHESTER @ ALLEN RD.	1.85	8.10	39.3133730	-84.4264150
13	E. FK. MILL CREEK UPST. BUTLER CO. UPPER MILL CREEK WWTP	1.15	9.00	39.3038710	-84.4311920
14	E. FK. MILL CREEK NEAR CRESCENTVILLE @ CRESCENTVILLE RD.	0.76	9.20	39.2989000	-84.4297000
15	E. FK. MILL CREEK NEAR CRESCENTVILLE @ MOUTH	0.01	9.70	39.2897000	-84.4336000
16	FIVEMILE CREEK @ FIVE MILE RD.	2.37	3.40	39.0534100	-84.3719000
17	EIGHTMILE CREEK NEAR CINCINNATI @ U.S. RT. 52	0.18	3.90	39.0333000	-84.3328000
18	TENMILE CREEK SW OF AMELIA, DST. POND RUN RD.	3.61	5.70	39.0085060	-84.2594140
19	TENMILE CREEK NEAR PALESTINE @ U.S. RT. 52	1.17	12.60	39.0075000	-84.3011000
20	TRIB. TO TENMILE CREEK (3.58) SW OF AMELIA @ ST. RT 749	0.01	3.50	39.0089280	-84.2594690
21	NINEMILE CREEK UPST. WWTP @ LOCUST CORNER RD.	0.79	8.10	39.0296000	-84.3110000
22	TWELVEMILE CREEK @ LAUREL-LINDALE RD.	6.44	6.80	38.9678000	-84.2011000
23	TWELVEMILE CREEK @ FAGINS RUN RD DST FAGINS RUN	2.08	18.30	38.9674200	-84.2695350

Site Number*	Stream Name	RM	Drainage (sq mi)	Latitude	Longitude
24	LITTLE INDIAN CREEK E OF MOSCOW, ADJ. LAUREL MOSCOW RD.	0.85	4.90	38.8678870	-84.2181400
25	BOAT RUN SE OF NEW RICHMOND @ U.S. RT. 52	0.20	3.60	38.9256660	-84.2562590
26	BIG INDIAN CREEK NEAR MT. OLIVE @ BRAUN RD, UPST. BEECH RUN	8.70	5.40	38.8813230	-84.1061140
27	BIG INDIAN CREEK S OF POINT ISABEL @ ST. RT. 222	6.90	10.80	38.8757030	-84.1297920
28	BIG INDIAN CREEK E OF POINT PLEASANT @ ST. RT. 743	4.89	27.4	38.8800000	-84.1608000
29	BIG INDIAN CREEK AT POINT PLEASANT @ ST. RT. 756	1.71	37.70	38.8897000	-84.2081000
30	N. FK. INDIAN CREEK @ LAUREL - POINT ISABEL RD.	0.93	10.90	38.8992000	-84.1731000
31	MAPLE CREEK N OF NEVILLE @ MAPLE CREEK RD.	1.62	7.70	38.8221940	-84.2070430
32	BEAR CREEK @ CHILO CEMETERY-MCKENDREE CHAPEL RD.	5.30	4.80	38.8200000	-84.1367000
33	BEAR CREEK NW OF CHILO, ADJ. BEAR CREEK RD.	2.43	7.70	38.8078000	-84.1653000
34	CROOKED RUN AT CHILO @ OLD CARNTOWN RD.	0.70	0.90	38.7927800	-84.1316770
35	BULLSKIN CREEK NE OF CEDRON @ DUNBAR RD.	4.38	27.7	38.8103000	-84.0414000
36	BULLSKIN CREEK @ FELICITY CEDRON RURAL RD.	2.96	48.00	38.8008000	-84.0586000
37	E. BR. BULLSKIN CREEK NNW OF HIGGINSPORT @ LANG RD.	4.70	15.80	38.8305400	-83.9830690
38	E. BR. BULLSKIN CREEK NW OF HIGGINSPORT @ DUNBAR RD.	0.40	15.8	38.8105850	-84.0355620
39	M. BR. BULLSKIN CREEK SE OF FELICITY, UPST. BULLSKIN RD.	0.05	5.4	38.8190630	-84.0413880
40	W. BR. BULLSKIN CREEK NE OF FELICITY @ MT. ZION RD.	4.65	5.70	38.8684510	-84.0355550
41	W. BR. BULLSKIN CREEK E OF FELICITY @ RICHEY RD.	0.59	25.00	38.8358000	-84.0517000

*The color of the site number corresponds to the narrative biological score (blue is exceptional to very good (meets EWH goals), green is good to marginally good (meets WWH goals) yellow is fair, orange is poor and red is very poor (fair, poor and very poor do not meet the biological integrity goal of the Clean Water Act).

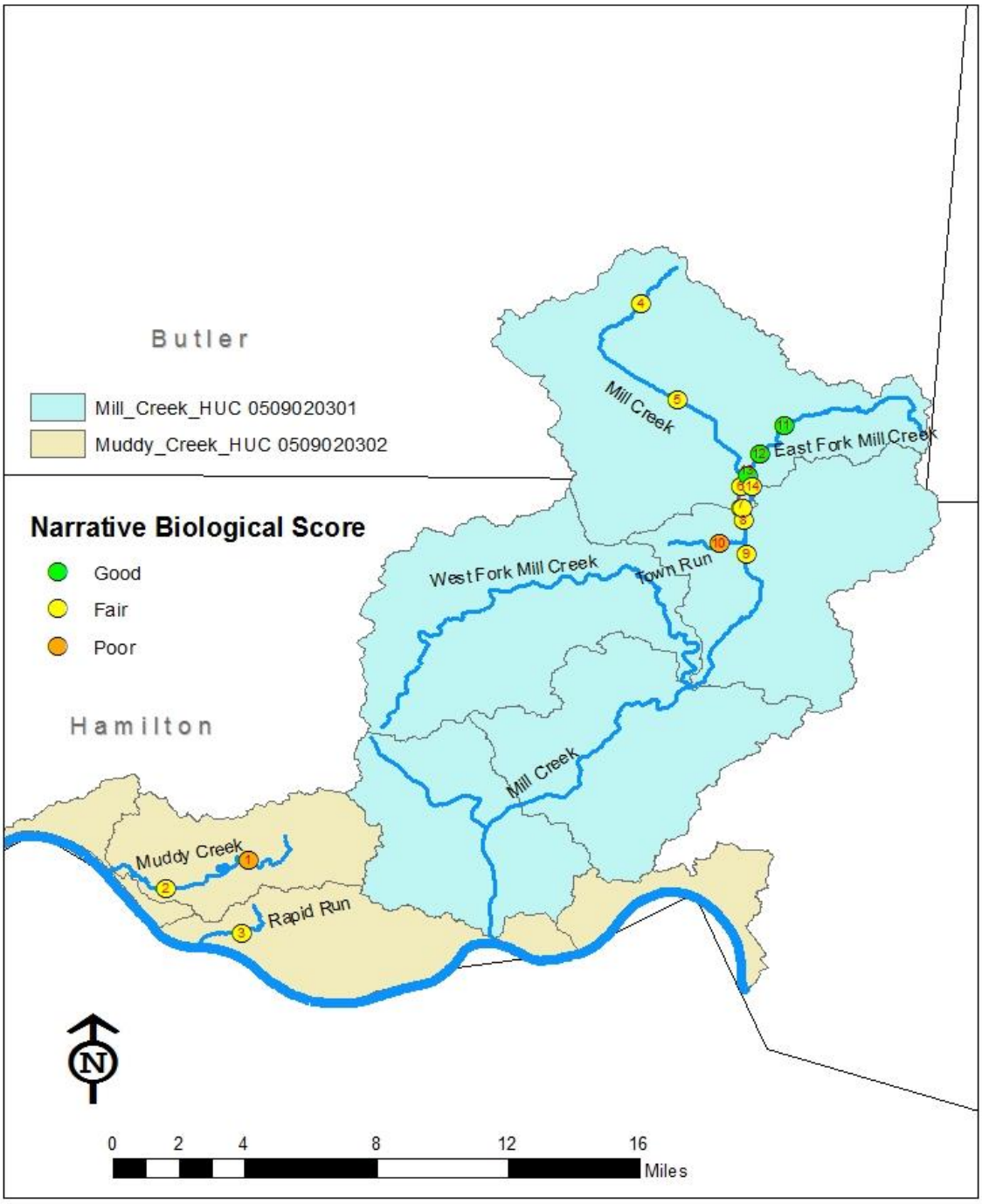


Figure 2. Aquatic life use attainment status of Mill Creek and Muddy Creek HUC 10 watershed sites in the Southwest Ohio River Tributaries study area, 2014. Site numbers and narrative biological score categories equate to sites as listed in Table 1.

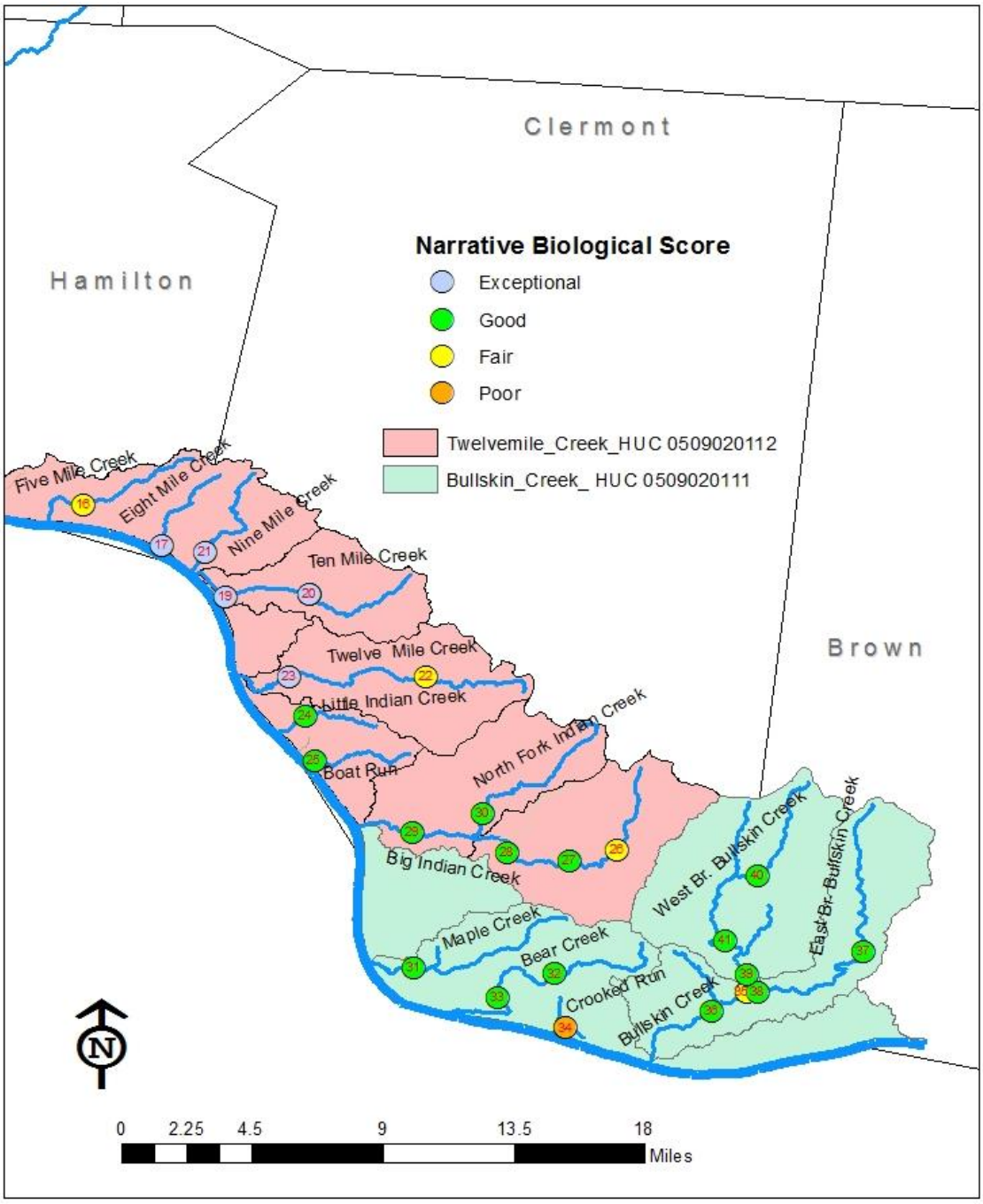


Figure 3. Aquatic life use attainment status of Twelvemile Creek and Bullskin Creek HUC 10 watershed sites in the Southwest Ohio River Tributaries study area, 2014. Site numbers and narrative biological score categories equate to sites as listed in Table 1.

Table 2 Aquatic life use attainment status for stations sampled in the Southwest Ohio River Tributaries study area based on data collected June-October, 2014. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat of the stream to support a biotic community. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. NA = not applicable.

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
Fivemile Creek (10-001-000) WWH existing										
@ Five Mile Rd.	302685	2.37	3.4	32*	NA	MG[ns]	57.50	PARTIAL	Flow alteration, Other (total toxics)	Urban runoff/ Storm sewers
Eightmile Creek (10-002-000) WWH existing										
@ U.S. Rt. 52	609010	0.18	3.9	50	NA	VG	62.00	FULL		
Tenmile Creek (10-003-000) WWH existing										
Dst. Pond Run Rd.	302687	3.61	5.7	52	NA	G	63.30	FULL		
@ U.S. Rt. 52	609050	1.17	12.6	46	NA	VG	73.80	FULL		
Trib. to Tenmile Creek (3.58) (10-003-001) WWH recommended										
@ St. Rt 749	302686	0.01	3.5	50	NA	VG	56.80	FULL		
Ninemile Creek (10-004-000) WWH existing										
@ Locust Corner Rd.	X01W01	0.79	8.1	54	NA	VG	80.00	FULL		
Twelvemile Creek (10-006-000) WWH existing										
@ Laurel-Lindale Rd.	X01W13	6.44	6.8	32*	NA	MG[ns]	71.00	PARTIAL	Intermittent /interstitial flow	General natural conditions
@ Fagins Run Rd Dst Fagins Run	302534	2.08	18.3	50	NA	VG	77.80	FULL		

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
Little Indian Creek (10-010-000) WWH existing										
Adj. Laurel Moscow Rd.	302692	0.85	4.9	48	NA	G	73.50	FULL		
Boat Run (10-011-000) WWH existing										
@ U.S. Rt. 52	302688	0.20	3.6	48	NA	MG[ns]	67.80	FULL		
Big Indian Creek (10-012-000) WWH existing										
@ Braun Rd, Upst. Beech Run	302691	8.70	5.4	32*	NA	MG[ns]	65.50	PARTIAL	Intermittent /interstitial flow	General natural conditions
@ St. Rt. 222	302689	6.90	10.8	40	NA	G	59.80	FULL		
@ St. Rt. 743	X01W04	4.89	27.4	38[ns]	8.27[ns]	MG[ns]	58.30	FULL		
@ St. Rt. 756	609080	1.71	37.7	44	8.49	G	60.80	FULL		
North Fork Indian Creek (10-016-000) WWH existing										
@ Laurel - Point Isabel Rd.	X01W06	0.93	10.9	42	NA	VG	57.00	FULL		
Maple Creek (10-021-000) WWH existing										
@ Maple Creek Rd.	302693	1.62	7.7	52	NA	MG[ns]	68.00	FULL		
Bear Creek (10-023-000) WWH existing										
@ Chilo Cemetery-Mckendree Chapel Rd.	X01W11	5.30	4.8	40	NA	G	64.30	FULL		
Adj. Bear Creek Rd.	X01W12	2.43	7.7	52	NA	G	63.00	FULL		
Crooked Run (10-024-000) WWH existing										
Crooked Run at Chilo @ Old Carntown Rd.	302694	0.70	0.9	--	--	P*	--	--	Impounded (Ohio River backwater)	

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
Bullskin Creek (10-027-000) WWH existing										
@ Dunbar Rd.	X01W07	4.38	27.7	40	7.24*	MG[ns]	62.00	PARTIAL	Intermittent/intermittial flow, Nutrient enrichment-biological indicators	Natural, Agriculture
@ Felicity Cedron Rural Rd.	X01W08	2.96	48.0	36[ns]	8.73	VG	68.00	FULL		
East Branch Bullskin Creek (10-030-000) WWH existing										
@ Lang Rd.	302696	4.70	10.5	36[ns]	NA	VG	62.00	FULL		
@ Dunbar Rd.	302695	0.40	15.8	44	NA	VG	61.50	FULL		
Middle Branch Bullskin Creek (10-031-000) WWH existing										
Upst. Bullskin Rd.	302697	0.05	5.4	40	NA	G	49.00	FULL		
West Branch Bullskin Creek (10-032-000) WWH existing										
@ Mt. Zion Rd.	302698	4.65	5.7	--	--	MG[ns]	--	--		
@ Richey Rd.	X01W09	0.59	25.0	42	8.53	G	61.50	FULL		
Mill Creek(23-001-000) WWH existing										
@ Liberty-Fairfield Rd.	Q01S19	26.35	3.9	48	NA	F*	64.00	PARTIAL	Nutrient enrichment biological indicators, Other (total toxics)	Urban runoff/ Storm sewers

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
@ St. Rt. 747	Q01W08	22.06	20.6	35*	8.10[ns]	48	55.50	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	Urban runoff/ Storm sewers
@ Crescentville Rd.	Q01W05	18.69	27.0	31*	6.00*	40	69.80	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	Urban runoff/ Storm sewers
Upst. Confl E. Fk. Mill Creek	Q01W03	17.96	32.5	32*	6.43*	46	62.80	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	Urban runoff/ Storm sewers
@ Kemper Rd.	Q01S17	17.61	44.8	31*	6.87*	42	66.30	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	Municipal Point Source
@ Sharon Rd.	600400	16.57	50.5	31*	6.28*	46	70.50	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	SSO, Municipal Point Source

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
Town Run (23-001-014) WWH existing										
@ Chester Rd.	Q01S02	0.67	2.1	34*	NA	P*	61.80	NON	Organic enrichment-biological indicators	Municipal point Source
East Fork Mill Creek (23-006-000) WWH existing										
@ West Chester Rd.	Q01G01	3.17	5.0	46	NA	MG[ns]	64.30	FULL		
@ Allen Rd.	600460	1.85	8.1	40	NA	MG[ns]	51.30	FULL		
Upst. Butler Co. Upper Mill Creek WWTP	301418	1.15	9.0	38[ns]	NA	G	50.80	FULL		
@ Crescentville Rd.	Q01P01	0.76	9.2	28*	NA	44	63.00	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	Municipal point Source
@ Mouth	Q01S24	0.01	9.7	31*	NA	36	60.80	PARTIAL	Nutrient enrichment-biological indicators, Other (total toxics)	Municipal point Source
Muddy Creek (23-007-000) WWH existing										
@ Ebenezer Rd.	Q01K23	5.40	7.6	24*	NA	P*	44.80	NON	Nutrients, Other (total toxics)	CSO, Unsewered areas
@ Hillside Rd.	609040	1.96	12.1	32*	NA	MG[ns]	55.30	PARTIAL	Nutrients, Other (total toxics)	CSO, Unsewered areas

Stream/ Location	Station Code	River Mile[a]	Drainage (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status	Cause	Sources
Rapid Run (23-008-000) LRW existing										
@ Bender Rd.	Q01K24	1.15	5.8	28	NA	F	62.30	FULL		

a- River Mile (RM) represents the Point of Record (POR) for the station, and may not be the actual sampling RM.

b- MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.

c- A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

ns- Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).

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

Biological Criteria Eastern Corn Belt Plains			
Index – Site Type	**EWH**	**WWH**	**MWH**
IBI – Headwaters	50	40	24
IBI – Wading	50	40	24
IBI – Boat	48	42	24
MIwb – Wading	9.4	8.3	6.2
MIwb – Boat	9.6	8.5	5.8
ICI	46	36	22

Biological Criteria Interior Plateau				
Index – Site Type	**EWH**	**WWH**	**MWH**	**LRW**
IBI – Headwaters	50	40	24	18
IBI – Wading	50	40	24	18
IBI – Boat	48	38	24	16
MIwb – Wading	9.4	8.1	6.2	4.5
MIwb – Boat	9.6	8.7	5.8	5.0
ICI	46	30	22	8

Beneficial Use Designations and Recommendations

The streams in the Southwest Ohio River Tributaries study area currently listed in the Ohio WQS are assigned the Warmwater Habitat (WWH) aquatic life use designation with the exception of Rapid Run which is designated Limited Resource Water (LRW). Aquatic life use designations had been previously verified for nine streams (Table 3). Sampling of the remainder represented the initial assessment of these streams by Ohio EPA using approved protocols to assess aquatic life use designations and evaluate biological community condition. The study area involved 14 HUC 12 watershed assessment units and included the upper reaches of Mill Creek (Butler County) and several direct tributaries to the Ohio River located in Hamilton, Clermont, and Brown counties.

Twelve streams in the study area were evaluated for unverified or undesignated aquatic life and recreation use status in 2014 (Table 3). Significant findings include the following:

- The WWH aquatic life use should be assigned to all previously unverified WWH streams including Fivemile Creek, Eightmile Creek, Boat Run, Little Indian Creek, North Fork Indian Creek, Maple Creek, Crooked Run, East Branch Bullskin Creek, West Branch Bullskin Creek, Middle Branch Bullskin Creek, and Muddy Creek.

- Biological and habitat assessments confirmed the WWH use designation is appropriate for the unnamed tributary to Tenmile Creek (RM 3.58).

- All sampled streams, with the exception of Rapid Run, should retain the Primary Contact Recreation (PCR) use. Rapid Run should retain the Secondary Contact Recreation (SCR) use. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) uses apply to all the study area streams.

- Crooked Run is a small stream that is currently listed as a State Resource Water (SRW) within the Crooked Run Nature Preserve. It is recommended that the SRW use designation be replaced with a General High Quality Water (GHQW) antidegradation classification in keeping with Ohio Administrative Code (OAC) Chapter 3745-1-05 (B)(25).

Table 3. Waterbody use designation recommendations for the Southwest Ohio River Tributaries study area. Designations based on the 1978 and 1985 Ohio Water Quality Standards appear as asterisks (*). A plus sign (+) indicates a confirmation of an existing use and a triangle (▲) denotes a new recommended use based on the findings of this report.

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Fivemile creek		*/+							*/+	*/+		*/+		
Eightmile creek		*/+							*/+	*/+		*/+		
Ninemile creek		+							+	+		+		
Tenmile creek		+							+	+		+		
Unnamed tributary at Temnile Creek RM 3.58		△							△	△		△		
Pond run		*							*	*		*		
Twelvemile creek		+							+	+		+		
Fagin run		*							*	*		*		
Ferguson run		*							*	*		*		
Briggs run		*							*	*		*		
Little Indian creek		*/+							*/+	*/+		*/+		
Boat run		*/+							*/+	*/+		*/+		
Indian creek		+							+	+		+		
Dry run		*							*	*		*		
Colclaser run		*							*	*		*		
Sugar creek		*							*	*		*		
North fork		*/+							*/+	*/+		*/+		
Stony fork		*							*	*		*		
Bee run		*							*	*		*		
Little Indian creek		*							*	*		*		
Ray run		*							*	*		*		
Maple creek		*/+							*/+	*/+		*/+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Vinegar run		*							*	*		*		
Bear creek		+							+	+		+		
Crooked run - within Crooked run preserve	o	*/+							*/+	*/+		*/+		
- all other segments		*/+							*/+	*/+		*/+		
Patterson run		*							*	*		*		
Ryan run		*							*	*		*		
Bullskin creek - Clermont-Brown county line to the Ohio river		+							+	+		+		
- all other segments		+							+			+		
Big run		*							*	*		*		
Slickaway run		*							*	*		*		
East branch		*/+							*/+	*/+		*/+		
Middle branch		*/+							*/+	*/+		*/+		
West branch		*/+							*/+	*/+		*/+		
Painter fork		*							*	*		*		
Muddy Creek		*/+							*/+	*/+		*/+		
Rapid run (Ohio river RM 500.74)							+		+	+			+	Irretrievable habitat modification
Mill creek - headwaters to I-275 (RM 17.9)		+							+	+		+		
- I-275 to Center Hill rd. (RM 7.9)		+							+	+		+		
Town run (Mill creek RM 16.93)		+							+	+		+		
East fork (Mill creek RM 17.95) - headwaters to Butler county upper Mill creek WWTP (RM 1.07)		+							+	+		+		
- upper Mill creek WWTP to the mouth		+							+	+		+		

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.

Introduction

Forty-six stream sampling locations were evaluated in the Southwest Ohio River Tributaries study area in Butler, Hamilton, Brown, and Clermont Counties in 2014 (Table 1, Figure 4). In the upper Mill Creek watershed, six sites on the mainstem of Mill Creek were sampled as well as six locations along the East Fork Mill Creek and two locations along Town Run. Two other direct Ohio River tributaries in the Mill Creek basin, Muddy Creek and Rapid Run, were also sampled.

A total of 19 National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into the upper Mill Creek watershed or the Southwest Ohio River Tributaries within Hamilton, Clermont, and Brown counties. In the upper Mill Creek watershed, two NPDES permitted facilities discharging sanitary wastewater were sampled; the Butler County Upper Mill Creek Water Reclamation Facility (WRF) on East Fork Mill Creek, and the Glendale Wastewater Treatment Plant (WWTP) on Town Run.

Further upstream on the Ohio River, in Clermont and Brown counties, the tributaries Big Indian Creek and Bullskin Creek, were sampled, as well as ten other smaller tributaries along the same stretch of the Ohio River. Five sites were sampled on Big Indian Creek. Two sites on the Bullskin Creek mainstem were sampled as well as five samples on tributaries including West Branch Bullskin, Middle Branch Bullskin, and East Branch Bullskin creeks.

Figure 4. Southwest Ohio River tributaries study area, 2014.

The smaller tributaries sampled included Fivemile, Eightmile, Ninemile, Tenmile Twelvemile, Maple, and Bear creeks, as well as Boat and Crooked runs. The Clermont County Ninemile Creek WWTP and the Clermont County Felicity WWTP on a tributary to Bear Creek were also sampled.

During 2014, Ohio EPA conducted a water resource assessment of 21 selected streams in the Southwest Ohio River Tributaries study area using standard Ohio EPA protocols as described in Appendix Table A. Included in this study were assessments of the biological, surface water and recreation (bacterial) condition. A total of 40 biological, 46 water chemistry, one fish tissue, and 28 bacterial stations were sampled. Some or all of the biological, chemical and bacteria raw data can be downloaded from the National Water Quality Monitoring Council's Water Quality Portal (WQP) at the following link: http://waterqualitydata.us/. PDFs of the raw data are also available in a companion appendix table document associated with this report.

Specific objectives of the evaluation at study area sampling location were to:

- assess the present biological conditions by evaluating fish and macroinvertebrate communities,
- identify the relative levels of organic, inorganic, and nutrient parameters in the sediments and surface water,
- evaluate influences from known potential sources, including NPDES outfall discharges and unsewered communities,
- assess physical habitat influences on stream biotic integrity,
- determine recreational water quality,
- compare present results with historical conditions,

- evaluate the appropriateness of existing use designations and assign uses to undesignated streams,
- determine beneficial use attainment status,
- collect fish samples for the Ohio Sport Fish Tissue Monitoring Program, and
- evaluate pre- and post- construction conditions for watershed improvement (Section 319 funded) projects.

Study Area Description

Upper Mill Creek Watershed

The 2014 upper Mill Creek basin study area included two 10-digit Hydrologic Unit Code watersheds (HUCs) and four 12-digit watershed assessment units (WAUs): 0509020301 (01 and 03) and 0509020302 (02 and 03). The 12-digit WAUs in the study area included the East Fork Mill Creek-Mill Creek and Sharon Creek-Mill Creek WAUs within the Mill Creek HUC, and the Dry Creek-Ohio River and Muddy Creek WAUs within the Muddy Creek-Ohio River HUC. The study focused on the East Fork Mill Creek HUC. A portion of the Sharon Creek-Mill Creek WAU covering the Mill Creek mainstem to RM 16.57 (at Sharon Road) and Town Run, which enters Mill Creek at RM 16.91, were included to assist evaluations of contributions from area WWTPs.

Mill Creek flows 28.1 miles from the headwaters in southeastern Butler County through central Hamilton County to the confluence with the Ohio River. The Mill Creek watershed drains an area of 166.2 square miles and is located in the Interior Plateau (IP) ecoregion. Along its course, the stream has an average gradient of 11.9 feet per mile (ODNR, 2001). Most of Mill Creek flows atop a buried valley aquifer composed of highly permeable sand and gravel from past glacial deposits and outwash. The upper Mill Creek area, the portion of Mill Creek within the 2014 study, is immediately north of the southern terminus of the Wisconsinian glacial boundary.

The geomorphological features of the Muddy Creek HUC include typically high-gradient streams on the hillsides draining to the Ohio River. They are generally underlain by thinly inter-bedded shales and limestone. Muddy Creek, which drains an area of 16.6 square miles, has an average gradient of 52.2 feet per mile. Rapid Run, the other stream within the HUC sampled in the study, drains 6.54 square miles, and is even steeper with an average gradient of 100 feet per mile (ODNR, 2001).

The sewers in the Muddy Creek and Rapid Run watersheds are a combination of combined and sanitary sewers operated by the Metropolitan Sewer District of Greater Cincinnati (MSDGC). In the combined sewer system, the sewers take domestic sewage, industrial, and storm flows (Table 5). The sanitary sewer systems were not designed to accept storm water, and a separate storm sewer system was installed. However, additions to the systems have resulted in flows over the design flows for the collection systems. This results in combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs). In addition, the high flows exceed the pumping rate of lift stations in the collection systems. This results in pump station overflows (PSOs). According to a review of MSDGC's GIS maps on May 22, 2015, in the Rapid Run area, there are four SSOs and one CSO. In the Muddy Creek area, there are three CSOs, four SSOs, and four PSOs. These overflows contribute fecal bacteria, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and nutrients to the stream. These overflows are being addressed under a Consent Decree with U.S. EPA and Ohio EPA. The CSOs are also covered under NPDES permit 1PX00022.

The sewers in the Mill Creek watershed are also a combination of combined and sanitary sewers. The village of Glendale has separate sanitary and storm sewers; both sewer systems discharge to Town Run, which confluences with Mill Creek at RM 16.91. According to a review of MSDGC's GIS maps on May 26, 2015, MSDGC does not have any CSOs but has three SSOs in the Mill Creek watershed in the study area upstream from Sharon Road. The SSOs contribute fecal bacteria, BOD, COD, and nutrients to the stream. These sanitary overflows are also part of the system being addressed under the Consent Decree with U.S. EPA and Ohio EPA. The bulk of the sewer overflows to Mill Creek attributable to the MSDGC service area are downstream from the upper Mill Creek study area.

Table 4. Sampling locations and types of sampling for the Southwest Ohio River Tributaries study area, 2014 (listed by basin and stream code).

Station Code	Location Description	River Mile	Drain Area	Aquatic Life Use	Latitude	Longitude	Sampling
Mill Creek (23-001)							
Q01S19	MILL CREEK E OF HAMILTON @ LIBERTY-FAIRFIELD RD.	26.35	3.90	WWH	39.37939	-84.47832	C,B,F,Mq
Q01W08	MILL CREEK NEAR PORT UNION @ ST. RT. 747	22.06	20.60	WWH	39.33738	-84.46238	C,MQ,F2
Q01W05	MILL CREEK NEAR CRESCENTVILLE @ CRESCENTVILLE RD.	18.69	27.00	WWH	39.29920	-84.43440	C,D,N,B,MQ,F2,Sd,Sn
Q01W03	MILL CREEK 30 FT. UPST. CONFL E. FK. MILL CREEK	17.96	32.50	WWH	39.28970	-84.43440	C,MQ,F2
Q01S17	MILL CREEK NE OF GLENDALE @ KEMPER RD.	17.61	44.80	WWH	39.28440	-84.43310	C,D,N,B,MQ,F2,Sd
600400	MILL CREEK AT SHARONVILLE @ SHARON RD.	16.57	50.50	WWH	39.26934	-84.43215	C,D,N,B,MQ,F2,Sd,T
Q01S04	GLENDALE WWTP 001 OUTFALL TO TOWN RUN (16.91)	0.92	1.90	---	39.27231	-84.44731	C,B
Q01S02	TOWN RUN (16.91) DST. GLENDALE WWTP @ CHESTER RD.	0.67	2.10	None	39.27420	-84.44420	C,D,N,F,Mq,Sd
East Fork Mill Creek (23-006)							
Q01G01	E. FK. MILL CREEK NEAR WEST CHESTER @ WEST CHESTER RD.	3.17	5.00	WWH	39.32600	-84.41520	C,F,Mq
600460	E. FK. MILL CREEK NEAR WEST CHESTER @ ALLEN RD.	1.85	8.10	WWH	39.31337	-84.42642	C,D,N,F,Mq
301418	E. FK. MILL CREEK NEAR WEST CHESTER UST WWTP	1.15	9.00	WWH	39.30387	-84.43119	F,Mq
Q01E01	BUTLER CO. UPPER MILL CR REGIONAL WWTP OUTFALL	1.07	9.00	---	39.30294	-84.43123	C,B
Q01P01	E. FK. MILL CREEK NEAR CRESCENTVILLE @ CRESCENTVILLE RD.	0.76	9.20	WWH	39.29890	-84.42970	C,D,N,B,MQ,F2,Sd,Sn
Q01S24	E. FK. MILL CREEK NEAR CRESCENTVILLE @ MOUTH	0.01	9.70	WWH	39.28970	-84.43360	C,MQ,F2
Rapid Run (23-008)							
Q01K24	RAPID RUN NEAR CINCINNATI @ BENDER RD.	0.70	6.32	LRW	39.10302	-84.66154	C,B,F,Mq

Station Code	Location Description	River Mile	Drain Area	Aquatic Life Use	Latitude	Longitude	Sampling
Muddy Creek (23-007)							
Q01K23	MUDDY CREEK NEAR CHEVIOT @ EBENEZER RD.	5.4	7.60	WWH*	39.13470	-84.65110	C,B,F,Mq
609040	MUDDY CREEK NEAR CINCINNATI @ HILLSIDE RD.	1.96	12.10	WWH*	39.12220	-84.68750	C,D,N,B,F,Mq,Sd,Sn
Bullskin Creek (10-027)							
X01W07	BULLSKIN CREEK NE OF CEDRON @ DUNBAR RD.	4.38	27.70	WWH	38.81030	-84.04140	C,D,N,MQ,F2
X01W08	BULLSKIN CREEK @ FELICITY CEDRON RURAL RD.	2.96	48.00	WWH	38.80080	-84.05860	C,D,N,B,MQ,F2,Sd,Sn
West Branch Bullskin Creek (10-032)							
302698	W. BR. BULLSKIN CREEK @ MT. ZION RD.	4.65	5.74	WWH*	38.86845	-84.03556	C,B,F,Mq
X01W09	W. BR. BULLSKIN CREEK E OF FELICITY @ RICHEY RD.	0.59	25.00	WWH*	38.83580	-84.05170	C,B,MQ,F2
Middle Branch Bullskin Creek (10-031)							
302697	MIDDLE BRANCH BULLSKIN CR UPST BULLSKIN RD	0.05	5.40	WWH*	38.81906	-84.04139	C,B,F,Mq
East Branch Bullskin Creek (10-030)							
302696	E. BR. BULLSKIN CREEK @ LANE OFF LANG RD	4.7	10.50	WWH*	38.83054	-83.98307	C,B,F,Mq
302695	E. BR. BULLSKIN CREEK @ DUNBAR RD	0.4	15.80	WWH*	38.81059	84.03556	C,F,Mq
Crooked Run (10-024)							
302694	CROOKED RUN @ OLD CARNTOWN RD	0.7	0.86	WWH*	38.79278	-84.13168	C,F,Mq
Bear Creek (10-023)							
X01W11	CHILO CEMETERY-McKENDREE CHAPEL RD.	5.3	4.80	WWH*	38.82000	-84.13670	C,F,Mq
X01W12	BEAR CREEK NW OF CHILO, ADJ. BEAR CREEK RD.	1.72	7.80	WWH	38.80158	-84.16011	C,B,F,Mq
302762	CLERMONT CO. FELICITY WWTP OUTFALL TO TRIB TO BEAR CREEK (RM 6.85)	0.1	0.09	---	38.83206	-84.10324	C,B

Station Code	Location Description	River Mile	Drain Area	Aquatic Life Use	Latitude	Longitude	Sampling
302763	TRIB TO BEAR CREEK (RM 6.85) 650 ft. DST FELICITY WWTP	0.12	0.55	WWH*	38.83079	-84.10440	C,F Mq
Maple Creek (10-021)							
302693	MAPLE CREEK @ MAPLE CREEK RD	1.62	7.70	WWH*	38.82219	-84.20704	C,B,F,Mq
Little Indian Creek (10-010)							
302692	LITTLE INDIAN CREEK E OF MOSCOW, ADJ LAUREL MOSCOW RD	0.85	4.90	WWH*	38.86789	-84.21814	C,B,F,Mq
Big Indian Creek (10-012)							
302691	BIG INDIAN CREEK @ BEECH RD, UPST BEECH RUN	8.7	5.40	WWH	38.88132	-84.10611	C,F,Mq
302689	BIG INDIAN CREEK @ SR 222	6.9	10.80	WWH	38.87570	-84.12979	C,F,Mq
X01W04	BIG INDIAN CREEK E OF POINT PLEASANT @ ST. RT. 743	4.89	27.40	WWH	38.88000	-84.16080	C,D,N,B,MQ,F2
609080	BIG INDIAN CREEK AT POINT PLEASANT @ ST. RT. 756	1.71	37.70	WWH	38.88970	-84.20810	C,D,N,B,MQ,F2,Sd,Sn
X01W06	N. FK. INDIAN CREEK @ LAUREL - POINT ISABEL RD.	0.93	10.90	WWH*	38.89920	-84.17310	C,B,F,Mq
Boat Run (10-011)							
302688	BOAT RUN @ US 52	0.2	3.65	WWH*	38.92567	-84.25626	C,B,F,Mq
Twelvemile Creek (10-006)							
X01W13	TWELVEMILE CREEK @ LAUREL-LINDALE RD.	6.44	6.80	WWH	38.96780	-84.20110	C,F,Mq
302534	TWELVEMILE CREEK @ FAGINS RUN RD, DST FAGINS RUN	2.08	18.30	WWH	38.96742	-84.26954	C,D,N,B,F,Mq,Sd,Sn
Tenmile Creek (10-003)							
302687	TENMILE CREEK DST POND RUN RD	3.61	5.66	WWH	39.00851	-84.25941	C,F,Mq
609050	TENMILE CREEK NEAR PALESTINE @ U.S. RT. 52	1.23	12.80	WWH	39.00798	-84.30060	C,D,N,B,F,Mq
302686	TRIB. TO TENMILE CREEK (3.58) ADJ. COLE RD	0.01	3.50	WWH*	39.00893	-84.25947	C,F,Mq

Station Code	Location Description	River Mile	Drain Area	Aquatic Life Use	Latitude	Longitude	Sampling
Ninemile Creek (10-004)							
X01W01	NINEMILE CREEK UPST. WWTP @ LOCUST CORNER RD.	0.79	8.10	WWH	39.02960	-84.31100	C,D,N,B,F,Mq
X01E03	CLERMONT CO. NINEMILE CREEK WWTP 001 OUTFALL TO NINEMILE CRK	0.19	8.40	---	39.02330	-84.31560	C,B
Eightmile Creek (10-002)							
609010	EIGHTMILE CREEK NEAR CINCINNATI @ U.S. RT. 52 (OLD KELLOGG)	0.2	3.70	WWH	39.03441	-84.33226	C,B,F,Mq
Fivemile Creek (10-001)							
302685	FIVEMILE CREEK @ FIVEMILE RD	2.37	3.38	WWH	39.05341	-84.37190	C,F,Mq

C - Water chemistry sampling
D - Datasonde ® site
N - Nutrient site
B - Bacteria site
Sn - Sentinel site
Sd - Sediment site
L - Lake site
T - Fish tissue site
F2 - Two pass fish site
F - Single pass fish site
MQ - Macroinvertebrate quantitative site
Mq - Macroinvertebrate qualitative site

CSOs and SSOs were located upstream from the sampling locations in Muddy Creek and Rapid Run, and SSOs were located upstream from the sampling location on Mill Creek at Sharon Road (RM 16.57) (Table 5).

Table 5. CSO/SSO overflow locations upstream from sampling locations in Muddy Creek, Rapid Run, and Mill Creek.

CSO/SSO ID Number	*SSO or CSO*	*HUC 12*	*Downstream Ohio EPA Sampling Locations (Station Code)*
915A	*SSO*	*50902030103*	*600400*
1025	*SSO*	*50902030103*	*600400*
1635	*SSO*	*50902030103*	*600400*
522	*CSO*	*50902030203*	*Q01K23 and 609040*
518	*CSO*	*50902030203*	*Q01K23 and 609040*
198	*CSO*	*50902030203*	*Q01K23 and 609040*
1061	*SSO*	*50902030203*	*Q01K23 and 609040*
523	*CSO*	*50902030202*	*Q01K24*
1061	*SSO*	*50902030202*	*Q01K24*

When Ohio EPA first assessed the study area with the 1992 survey, the upper reaches of the watershed in Butler County still contained significant areas of agricultural land. Significant development of the area has occurred since then, including the development of the Union Center area along I-75. The majority of the area has been developed, but a small area of agriculture remains in the western portion of the watershed in Liberty Township (Jin et al. 2013).

There is an active watershed group working on improving the upper Mill Creek watershed. The Mill Creek Watershed Council of Communities has separate state-endorsed watershed action plans for lower and upper Mill Creek. The group has been instrumental in the establishment of six watershed improvement projects along East Fork Mill Creek between 2002 and 2014. Projects ranged from bioretention basins and restored wetlands to in-stream restoration structures such as Newbury riffles. The 2014 survey will be used to evaluate pre-construction conditions for the Wildermuth Stream and Wetland Restoration on the East Fork Mill Creek, and post-construction habitat improvements that are related to the West Chester Service Center Bio-retention Swales on Mill Creek and the Mill Creek Confluence Project (Twin Creek Preserve).

Southwest Ohio River Tributaries

The 2014 southwest Ohio tributaries study area covered two 10-digit HUCs and ten 12-digit WAUs; 0509020111 (03, 04, 06 and 07); 0509020112 (01-04, 06 and 08). The two 10-digit HUCs were Twelvemile Creek-Ohio River, which covers most of southern Clermont County, and Bullskin Creek-Ohio River, which covers southeastern Clermont County and southwestern Brown County. One sampling location, on Five Mile Creek, was located in the southeast corner of Hamilton County. Direct Ohio River tributaries within the study area included Fivemile, Eightmile, Ninemile, Tenmile, Twelvemile, , Big Indian, Little Indian, Maple, Bear, and Bullskin creeks, as well as Boat and Crooked runs.

The larger streams, Twelvemile, Big Indian, and Bullskin creeks, have drainage areas of 19.6, 40.0, and 52.9 square miles, and average gradients of 40.5, 39.0, and 30.6 feet per mile, respectively. The other streams are smaller with drainage areas less than ten square miles and generally higher gradients which range up to 102 and 141 feet per mile in Boat Run and Little Indian Creek, respectively. (ODNR, 2001).

According to the Ohio Department of Natural Resources (ODNR), the tributaries drain “an area in which the surface material is dense glacial till of Illinoian age. The underlying bedrock, which is exposed at many places in the valley, is the impervious shale and limestone of Ordovician age. With such a geologic environment, it is reasonable to expect extremely low dry-weather flows in the streams” (Schiefer2002).

The land use in the tributary watersheds is mostly forest and agriculture (Figure 5). The proportion between forest and agriculture has been shifting from more agriculture to more forest over the past 20 years. The amount of urban land is less than 10% of the area for most of the watersheds. The amount of urbanized area increases closer to Cincinnati, the Tenmile Creek WAU is over 20% urban and the Ninemile Creek WAU is over 40% urban.

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

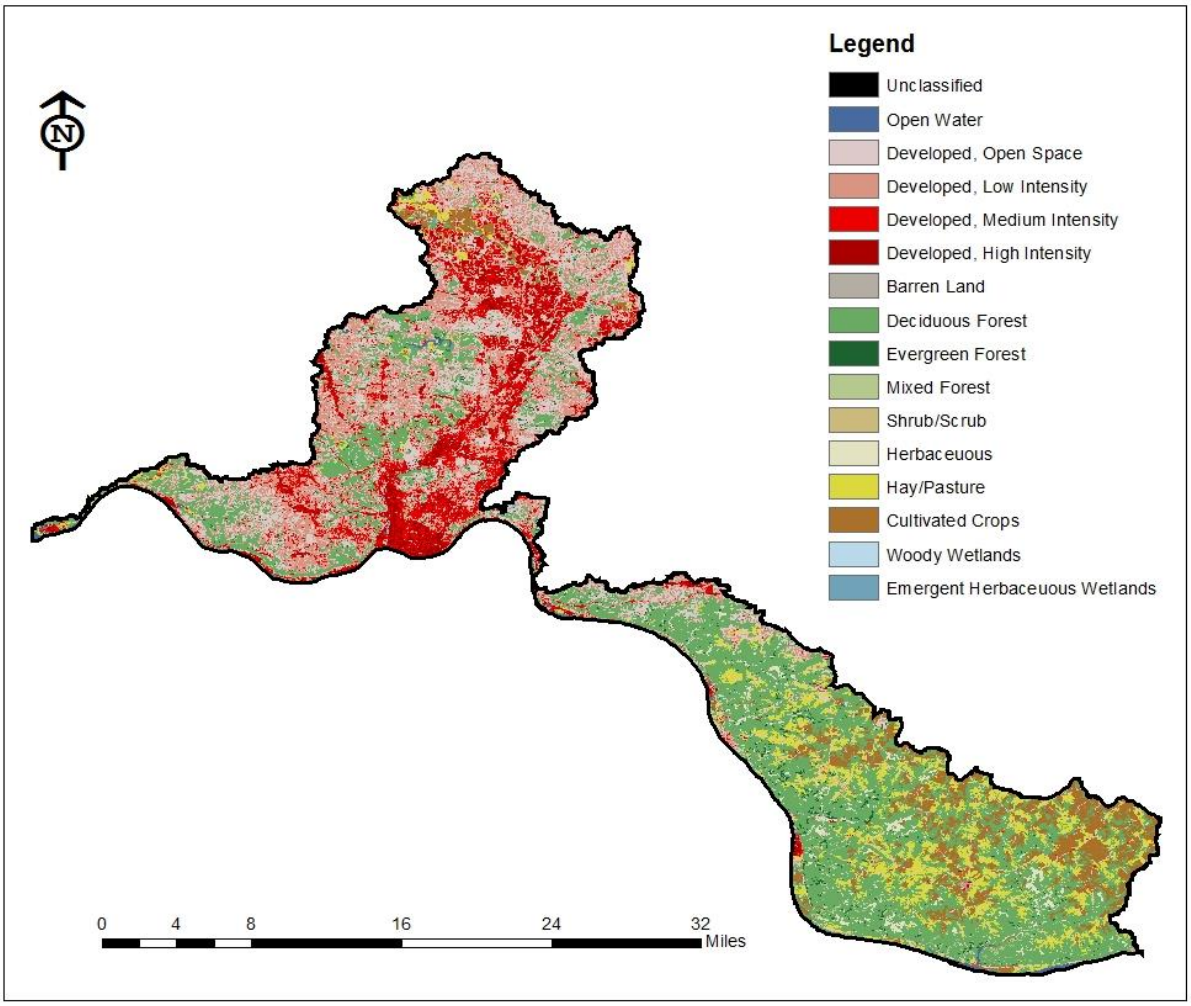


Figure 5. Land use within the Southwest Ohio River Tributaries study area (NLCD 2011).

Pollutant Loadings

Summaries of Evaluated Permitted Dischargers

Information for publicly owned wastewater treatment plants (WWTPs) discharging to streams in the Southwest Ohio River Tributaries study area was gathered from electronic discharge monitoring reports (eDMRs) and agency files. eDMR data were summarized for the years 2004 through 2013. Third quarter plant flows, and third quarter effluent concentrations of ammonia nitrogen, total phosphorus and total suspended solids are emphasized, as the third quarter (of the calendar year) represents the critical condition in terms of stream flow. The selected parameters either represent overall plant performance (flows and suspended solids) or potential stress to the receiving waters (ammonia nitrogen and total phosphorus). Plant performance is also gauged by examining the number of violations, both numeric violations of permit limits (frequency), and the number of required observations that were failed to be reported (code). Table 6 lists the 20 dischargers within the study area, and compares median annual to the respective plant's average design capacity. A comparison of the median flow to the design average helps show whether the plant is near its design capacity. More specific information on the larger, more significant dischargers follows the table.

Table 6. Summaries of permitted facilities that discharge to the Southwest Ohio River Tributaries study area based on data submitted from monthly operating reports, 2004-2013.

Watershed Facility	Avg Flow (MGD) 2013	Design Flow (MGD)	Receiving Stream	County	Permit Expires	River Mile
Chestnut Lane MHP	0.0032	0.0039	Fagin Run tributary	Clermont	12-31-2017	Headwater to Fagin Run
Felicity WTP	0.0060	-	Bullskin Creek (Ohio River backwater)	Clermont	01-31-2016	0.010
Felicity WWTP	0.1700	0.2500	Bear Creek tributary	Clermont	11-30-2011	0.730
June Berry WWTP	0.0005	<0.025	Eight or Nine Mile Creek tributary	Hamilton	-	0.05
Breezy Point WWTP	0.0056	<0.025	Eight Mile Creek tributary	Hamilton	11-30-2011	0.010
Hilltop Estates MHP	0.0350	0.0750	Fagin Run tributary	Clermont	10-31-2018	1.000
Hi-View Estates MHC WWTP		0.0378	Twelve Mile	Clermont	04-30-2019	8.78
Lakeside Estates MHP	0.0200	0.0304	Ferguson Run	Clermont	05-31-2019	1.25

Watershed Facility	Avg Flow (MGD) 2013	Design Flow (MGD)	Receiving Stream	County	Permit Expires	River Mile
Laurel Bell Apartments WWTP	-	0.0026	Colclaser Run tributary	Clermont	5-31-2012	0.35; ~1.6
Monroe Elem School	0.0041	0.0096	Boat Run tributary	Clermont	04-30-2017	2.6; headwater
Nine Mile Creek WWTP	1.5100	3.000	Nine Mile Creek (Ohio River Backwaters)	Clermont	07-31-2018	0.180
Pierce Union Batavia WTP	0.6700	0.0300	Ten Mile Creek	Clermont	08-31-2013	1.000
Tall Timbers MHP	0.0300	0.0530	Briggs Run	Clermont	11-30-2016	5.22; 0.68
Tradewinds MHP	0.0200	0.0555	Ten Mile Creek	Clermont	03-31-2017	`7.4
Upper Mill Creek Watershed Facility	Avg Flow (MGD) 2013	Design Flow (MGD)	Receiving Stream	County	Permit Expires	River Mile
Airy Pointe Condo Assoc. WWTP	0.0100	0.0160	West Fork	Hamilton	03-31-2017	Headwater 4.7
Finishing Technology Inc.	0.0005	-	Mill Creek	Hamilton	-	~22.1
Glendale WWTP	0.6800	0.7500	Town Run	Hamilton	02-28-2018	0.920
Glendale Water Treatment Plant	0.0172	batch	Mill Creek	Hamilton	09-30-2016	16.57
Upper Mill Creek WRF	8.6800	16	East Fork Mill Creek	Hamilton	7-31-2017	1.000
Xtek Inc. Plant No 2	0.1300	batch	Mill Creek tributary	Hamilton	01-31-2015	1.05; 16.91
Chestnut Lane MHP	0.0032	0.0039	Fagin Run tributary	Clermont	12-31-2017	Headwater to Fagin Run

The Village of Glendale WWTP-Permit #-IPB00012 (expires February 28, 2018) Receiving Stream: Town Run-RM-0.92-Outfall 001 Latitude:39.272222; Longitude: 84.446389

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PB00012.pdf

A northern suburb of Cincinnati, the village of Glendale's WWTP is located at 528 East Sharon Road in Hamilton County. The village's original facility was in operation in the 1920s and was extensively upgraded in 1987 and 2010 as mandated by the Ohio EPA. The facility serves a population of approximately 2,188 people. The sewage treatment plant consists of influent pumping, flow equalization, screening, grit removal, anoxic tank, vertical loop aeration, final clarification, ultraviolet disinfection and post aeration. The average design flow is 0.75 MGD with a peak design of 3.0 million gallons per day (MGD).

The village's separate sanitary sewer system has had a historical problem with excessive inflow and infiltration (I/I) of storm water, which has led to overflows and bypasses in the sanitary sewer system and at the treatment plant. In November 2010, there was a six-million-dollar upgrade to the facility. In 2012, Glendale received operator technical assistance from Ohio EPA's Compliance Assistance Unit, to aid the facility in returning to compliance with the permit conditions. A 2012 inspection noted unsatisfactory ratings in NPDES permit violations, facility bypassing, noncompliance notifications and lack of flow meter calibration, which raised questions about reported discharge flows. Currently, Glendale is upgrading two clarifiers for extended capacity during heavy rain events. During the spring of 2014, Glendale made improvements at the treatment plant to eliminate bypasses; increased maintenance of the sanitary sewer system; and completed upgrades to the EQ basins, which will help eliminate most bypasses to the creek. Infiltration and inflow (I/I) elimination efforts are underway; the Village is conducting smoke testing for the third year throughout the collection system and disconnecting downspouts connected to the sanitary sewer. During very heavy rain events, they can still bypass out of the equalization basin (EQ) which have reduced overflows after the upgrade.

NPDES numeric limit violations were evaluated at outfall 001 from 2010 to 2014. Data indicated 82 violations of primarily nitrogen and phosphorus reported for those five years. There were no code or frequency violations. Permit limit violations were described as being the result of adjustments to the air and mixing throughout the plant. The facility now has access to portable sludge dewatering, which gives operations staff more flexibility with solids wasting. Phosphorus is now controlled by ferric chloride in order to meet phosphorus limits.

The Village of Glendale Water Treatment Plant-Permit #-1IW00029*AD (expires September 30, 2016)-Receiving Stream: Mill Creek-RM-16.57-Outfall 001 Latitude: 39.268889; Longitude: 84.429167

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1IW00029.pdf

The village of Glendale Water Treatment Plant (WTP) is located at 2779 East Sharon Rd in Glendale, Ohio in Hamilton County. Glendale has one of the first water plants in Ohio and has been in operation since 1912. This WTP is served by deep wells supplied by the Miami Valley Aquifer, approximately 200' below the ground. The WTP consists of two production wells, a flocculation tank, four settling tanks in series, four rapid sand filters, clear well, and a water distribution booster pump. Solids are withdrawn from the settling tank once a day. The rapid sand filters are backwashed on Tuesdays and Fridays. Once pumped from the aquifer, the water is mixed with lime in a series of tanks and filters. As the lime attaches itself to the hard minerals, it becomes heavy and sinks to the bottom of the tanks. The lime wastewater generated from these processes is discharged to three settling lagoons operated in series. The settled clear water is discharged to Mill Creek, while the solids (predominately lime) are reused by Duke Energy power plants for their air scrubber emission system.

NPDES numeric limit violations were evaluated at outfall 001 from 2010 to 2014. There were no limit violations reported for those five years with two frequency violations in 2011.

The Upper Mill Creek Water Reclamation Facility -Permit #-IPK00016 (expires July 31, 2017) Receiving Stream: East Fork of Mill Creek-RM-1.0-Outfall 001 Latitude; 39.30000: Longitude; 94.433333

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PK00016.pdf

The Upper Mill Creek facility is located at 6055 Centre Park Drive, West Chester, Ohio, in Butler County. Wet stream processes consist of influent pumping, screening and grit removal, secondary treatment using oxidation ditches and rotating biological contactors, final clarification, tertiary filtration, UV disinfection and post-aeration. The facility has a design flow of 16 MGD. In 2014, the average daily flow was 8.81 MGD, which is nearly half of the design capacity. There are 24 industrial users, 14 being significant, that contribute a flow of 0.685 MGD to the facility. There was a plant expansion in 2006 that included upgrading the Influent Pump Station to address SSOs just outside of the treatment plant on Windisch Road. Since the expansion there have only been two overflows at that site - one in 2009 and the other in 2013.

In 2011, an eight-acre wetland was constructed in this project area that served as flood control and a nutrient sink. In 2012, a collaborative effort restructured a portion of both the East Fork Mill Creek and the Mill Creek mainstem near Sharonville. This project helped restore the streams using natural channel design, which ultimately will aid in increasing the assimilative capacity of each stream.

The 2013 Sanitary Sewer Overflow Annual Report reported sanitary collection system overflows (#301-306) that continue discharging to Mill, East Fork and Sharon creeks (Table 7). In 2013, Procter and Gamble began contributing effluent containing glycerin, which ultimately was described as stabilizing and benefiting the wastewater facility's nutrient removal capabilities. Nutrient loading reductions have been achieved through improved operational strategies and chemical-addition efforts. Butler County has done several things over the past few years to reduce nutrients in the WWTP discharge, such as operational modifications within the WWTP to optimize nutrient treatment and also outreach to local industry in order to reduce influent phosphorus.

Table 7. Upper Mill Creek Water Reclamation Facility sanitary collection system overflow locations and reported 2013 discharges (#301-306)

SSO number	Street	Stream	Quantity (MG)
301	Liberty Bell	Tributary to Mill creek	0.008
302	Fields Ertel	Ground	
303	At facility	East Fork Mill Creek	0.268
304	Windisch Rd	" "	0.015
305	Ham.-Mason Rd	Tributary to Mill Creek	0.001
306	5161 Fields Ertel	Tributary to Sharon Creek	0.005

NPDES numeric limit violations were evaluated at outfall 001 from 2010 to 2014. Data indicated 35 violations of primarily nitrogen and phosphorus prior to 2012. There were no code or frequency violations. Permit limit violations were described as being the result of adjustments to the air and mixing throughout the plant. Ohio EPA conducted acute toxicity testing (bioassays) at Upper Mill Creek outfall 001 with effluent, upstream and mixing zone waters. The sampling events were generally unannounced and were conducted in December 2008, April 2009, November 2010 and April 2011. The 2011 composite sample was acutely toxic to the microcrustacean *Ceriodaphnia dubia*.

Nine Mile Regional WWTP-Permit#-IPK00008 *LD (July 31, 2018)-Receiving Stream: Nine Mile Creek-Ohio River Backwater-RM-0.18-Outfall 001 Latitude:39.025; Longitude:84.316944
http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PK00008.pdf

The Nine Mile Regional WWTP is located at 560 Locust Corner Road, New Richmond, Ohio, Clermont County. Nine Mile Creek WWTP is an activated sludge sewage treatment plant. The treatment process consists of coarse screening followed by fine screening, secondary treatment by oxidation ditches, secondary clarification, and disinfection by ultraviolet light. An upgrade in 2010 involved a new influent screen. The average design daily flow is 3.0 MGD. Over the past four years, the average daily flow from this facility is 1.42 MGD, almost half of the design for the facility. Approximately 3000 customers are served by the Nine Mile WWTP.

During the summer of 2014, Nine Mile violated their permit when mechanical failures allowed solids accumulation in the final clarifier. These solids migrated over to the post aeration basins and eventually to the final effluent. These conditions were documented during one of the Ohio EPA sampling events. Since Ohio EPA has enacted the annual SSO reporting format in 2005, the Nine Mile collection system has 11 unique ID# overflow stations. There have not been any spills due to heavy rainfall events. All spills have been associated with loss of power, equipment failure, pipe deterioration, or blockages. Of all the spill points, Beechmont South Lift Station is by far the largest facility (on the Nine Mile System) based on gallons per day of raw wastewater received.

SSO locations that are still active include the following areas:

#ID 301- Vineyard Hills Lift Station-to unnamed tributary of Ohio River which can surcharge 15,000 gallons of raw sewage in 1.5 hours.
#ID 302-Beechmont South Lift Station-#302-Trib to Eight Mile Creek -An overflow surcharging one hour can release approximately 40,000 gallons.
Manhole at 6959 Royal Oaks Subdivision to the ground. Doesn't list a waterbody.
#ID 306-Massey Court Lift Station-Tributary to Nine Mile Creek.
#ID 338 or Manhole 9020-tributary to Ninemile Creek-54,000 gal over two hours.

Wastewater management challenges in the Nine/Ten Mile planning area include the following:

-collection system improvements aimed at providing adequate capacity to collect, convey, and treat existing and projected flows, including the elimination of surcharging and overflows,
-effective management of wastewater in areas generally located to the south of the existing service area within the Ten Mile drainage divide, and
-provision for excess flow equalization at the Nine Mile WWTP. (Wastewater Master Plan-Clermont County,2010- *http://wrd.clermontcountyohio.gov/2-WWMPU_Report.pdf*).

NPDES numeric limit violations were evaluated at outfall 001 from 2010 to 2014. Data indicated four violations due to a clarifier down for repairs. There were no code or frequency violations.

Ohio EPA conducted acute toxicity testing (bioassays) at Nine Mile outfall 001 with effluent, upstream and mixing zone waters. The sampling events were generally unannounced and were conducted in May and September 2007, November 2009 and April 2010. The 2007 composite sample was acutely toxic to the test organisms. Clermont County contracted with a test laboratory in 2008 in order to conduct whole effluent toxicity (WET) testing at the Nine Mile Creek WWTP. Results from all four quarters indicated no mortality in either test specimen. Testing of effluent, near field and upstream samples in 2012 produced mixed results for the Nine Mile Creek WWTP. Upstream endpoints revealed no toxicity, while near field and facility effluent both resulted in minor toxicity to the test organism.

The Village of Felicity WWTP-Permit #1PH00011GD (expires December 31, 2016) Receiving Stream: Unnamed Tributary of Bear Creek-Headwater region of tributary which is a pond-RM-0.73-Outfall 001 Latitude: 38.831944; Longitude: 84.103333

http://wwwapp.epa.ohio.gov/dsw/permits/doc/1PH00011.pdf

The village of Felicity WWTP is located at 771 Prather Road, Felicity, Ohio in Clermont County. The facility is an activated sludge sewage treatment plant consisting of coarse screening, secondary treatment by the extended aeration process, secondary clarification, and disinfection by ultraviolet light. The daily design flow for this facility is 0.25 MGD, serving a population of approximately 461. Over the past four years the average daily flow from this facility is approximately 0.171 MGD. Upgrades for this facility occurred in 1992 and 1999

The tributary of Bear Creek's headwaters is a small impoundment with a surface area of approximately 70,000 square feet. There are 221 service connections with 185 residential customers. Extreme wet weather events can cause a surcharge on the system overflowing to the ground at the influent Parshall Flume.

The SR 756 Lift Station was upgraded by in-house maintenance personnel in January of 2011. The original station had a pump design for 10 horsepower (hp) and 180 gallons per minute (GPM). The upgrade increased the size of the pumps to 15 hp and 300 GPM. Since the new pumps were installed, the only SSO event occurred on March 02, 2012, due to a tornado disrupting the electrical supply. The station was placed back in full

operation with a portable generator and ran until the electrical power was restored. The station no longer overflows during rainfall events.

NPDES numeric limit violations were evaluated at outfall 001 from 2010 to 2014. Data indicated that one violation of ammonia-N was reported for those five years.

The Village of Felicity Water Treatment Plant (WTP)-Permit #-IY00127*DD (expires January 31, 2016) Receiving Stream: Bullskin Creek- final effluent after slow surface sand filters prior to discharge to Bullskin Creek (Ohio River backwaters)-RM-0.01-Outfall 001 Latitude: 38.778611; Longitude: 84.089167

The village of Felicity WTP is located at 284 State Route 133 in Felicity, Ohio in Clermont County. The facility was built in 1956 and upgraded in 1997 and 2000. This facility treats well water for iron and manganese. The permit is for discharge of backwash waste after filtering through a potassium permanganate filter (red filters) and chlorination. The backwash wastewater is then sent through surface sand filters and discharged to Bullskin Creek at its confluence with the Ohio River. Discharged flow is estimated at 150,000 gallons average daily flow and 340,000 gallons peak daily flow.

NPDES numeric limit violations were evaluated at outfall 001 from 2010 to 2014. Data indicated 12 total violations of iron and manganese reported for those five years. Operations staff attributed permit limit violations to operational problems caused by extremely cold temperatures.

Surface Water Quality

Upper Mill Creek Watershed

Surface water chemistry samples were collected from the upper Mill Creek study area from May through November 2014 at seventeen locations (4). The study area covered Mill Creek upstream from Sharon Creek at RM 16.57, including East Fork Mill Creek and Town Run. The study area also included nearby tributaries to the Ohio River west of Cincinnati, Muddy Creek and Rapid Run. Stations were established in free-flowing sections of the stream and were primarily collected from bridge crossings. Surface water samples were collected directly into appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Collected water was preserved using appropriate methods, as outlined in the Surface Water Field Sampling Manual (for water column chemistry, bacteria and flows) (Ohio EPA 2013).

USGS gage data from Mill Creek at Carthage was used to show flow trends in the Mill Creek watershed during the 2014 survey (Figure 6). Flow during dates when water samples and bacteria samples were collected in the study area are indicated on the graph. Flow conditions during most of the summer field season, July through September, were typical for that time of year. Earlier in the survey, in May and June, several high flows were higher than the historic median and low flows were lower than normal. Water samples were collected over a variety of flow conditions during the field season. Bacteria samples were collected separately during the recreation use season (May 1 through October 31) and were typically collected during low flows.

Surface water samples were analyzed for metals, nutrients, organics (organochlorine and carbamate pesticides, acid and chlorinated acid herbicides, and glyphosate), bacteria, pH, temperature, conductivity, dissolved oxygen (D.O.), percent D.O. saturation, and suspended and dissolved solids (Appendix Tables B and C). Parameters which were in exceedance of the Ohio WQS criteria are reported in Table 8. Bacteriological samples were collected from ten locations, and the results are reported in the recreation use section. Datasonde® water quality recorders were placed at seven locations to monitor hourly levels of dissolved oxygen, pH, temperature, and conductivity (Appendix Table D). Datasonde® results are reported in the water quality sonde exceedance summary and trophic evaluation sections.

WQS exceedances of field-measured parameters were found in isolated instances in Mill Creek and Muddy Creek. Dissolved oxygen exceedances were found in one event in Mill Creek at RM 18.69 and during two events in Muddy Creek at RM 5.4. The water quality standard for temperature was exceeded during one sampling event in Mill Creek at RM 17.96. (Table 8)

Metals were measured at each water sampling location with seventeen parameters tested (Appendix Table B). No metal exceedances were found within the Mill Creek study area.

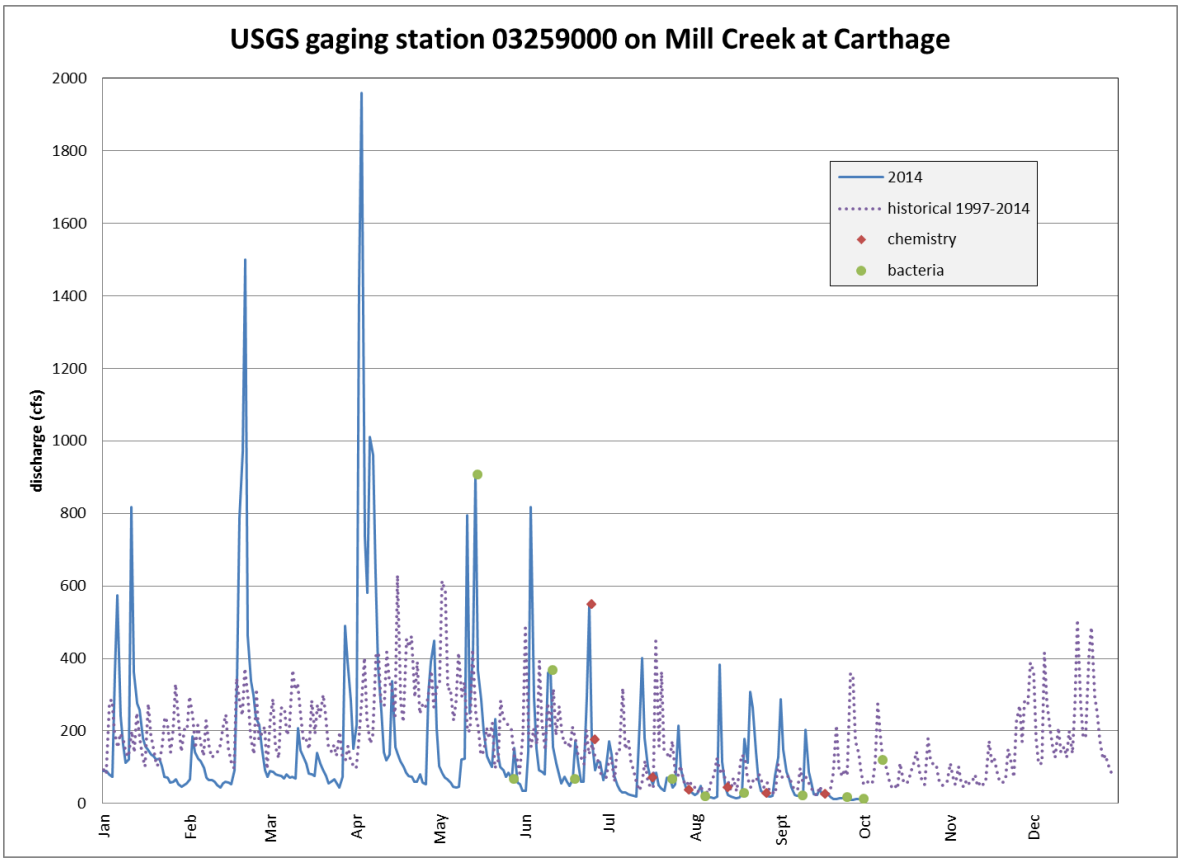


Figure 6. Mean daily flows in Mill Creek at the USGS gage at Carthage, 2014.

Table 8. Exceedances of Ohio WQS criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data are available) for chemical/physical water parameters measured in grab samples taken from the Southwest Ohio River Tributaries study area, May-October, 2014. Bacteria exceedances are presented in the Recreation Use Section.

Stream (use designations [b])		**Parameter (value)**
12-digit WAU [a]	**River Mile**	**(units are µg/l for metals and organics, C° for temperature, and mg/l for dissolved oxygen)**
Mill Creek (WWH, PCR, AWS, IWS)		
01-01	18.69	Dissolved oxygen (4.97‡)
01-01	17.96	Temperature (29.34*)
Muddy Creek (WWH, PCR, AWS, IWS)		
02-03	5.4	Dissolved oxygen (4.8‡, 3.54‡‡)
Bullskin Creek (WWH, PCR, AWS, IWS)		
11-04	4.38	Temperature (29.6**)
11-04	2.96	Temperature (28.32*, 32.2**) Iron-T (5260∞)
West Branch Bullskin Creek *(WWH, PCR, AWS, IWS)*		
11-03	4.65	Dissolved oxygen (4.97‡)
11-03	0.59	Temperature (32**)
Middle Branch Bullskin Creek *(WWH, PCR, AWS, IWS)*		
11-03	0.05	Temperature (30.2**)
East Branch Bullskin Creek *(WWH, PCR, AWS, IWS)*		
11-04	4.7	Dissolved oxygen (2.65‡‡, 3.6‡‡, 3.86‡‡)
11-04	0.4	Temperature (28.6*)
Crooked Run (WWH, PCR, AWS, IWS)		
11-06	0.7	Dissolved oxygen (2.05‡‡, 3.26‡‡, 3.17‡‡, 2.67‡‡, 1.85‡‡, 4.47‡)
Maple Creek (WWH, PCR, AWS, IWS)		
11-06	1.62	Dissolved oxygen (4.63‡, 4.55‡)

Stream (use designations [b])		Parameter (value) (units are µg/l for metals and organics, C° for temperature, and mg/l for dissolved oxygen)
12-digit WAU [a]	**River Mile**	
Big Indian Creek (WWH, PCR, AWS, IWS)		
12-01	8.7	Dissolved oxygen (2.92‡‡)
12-01	6.9	Temperature (27.99*, 27.83*) Dissolved oxygen (3.67‡‡)
12-02	1.71	Temperature (28.69*)
Boat Run (WWH, PCR, AWS, IWS)		
12-03	0.2	Dissolved oxygen (4.53‡)
Twelvemile Creek (WWH, PCR, AWS, IWS)		
12-04	2.08	Iron-T (7980∞) 4,4'-DDT (0.0085#)
Fivemile Creek (WWH, PCR, AWS, IWS)		
12-08	2.37	Temperature (27.98*)

a See Table 3

b **Use designations:**

Aquatic Life Habitat	Water Supply	Recreation
MWH - modified warmwater habitat	IWS - industrial water supply	PCR - primary contact
WWH - warmwater habitat	AWS - agricultural water supply	SCR - secondary contact
LRW – limited resource water	PWS- public water supply	BWR -bathing water

* exceedance of numerical criteria for prevention of chronic toxicity (CAC).

** exceedance of numerical criteria for prevention of acute toxicity (AAC).

*** exceedance of numerical criteria for prevention of lethality (FAV).

exceedance of numerical criteria for the protection of human health (non-drinking-protective of people against adverse exposure to chemicals via eating fish).

∞ exceedance of agricultural water supply criterion.

‡ value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the LRW minimum 24-hour average D.O criterion (3.0 mg/l) as applicable.

‡‡ value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the LRW minimum at any time D.O. criterion (2.0 mg/l) as applicable.

Nutrients measured at each water sampling location included ammonia-N, nitrate+nitrite-N, total phosphorus, orthophosphorus and total Kjeldahl nitrogen (TKN). Summary statistics for nutrients measured in the upper Mill Creek watershed are detailed in Table 9. Mean nutrient levels were elevated at all monitoring locations in Mill Creek and East Fork Mill Creek downstream from the Butler County Upper Mill Creek Regional Water Reclamation Facility (WRF)and in Town Run downstream from the Glendale WWTP (Figure 7, Figure 8). Nutrient levels in the corresponding effluent samples collected from the wastewater treatment plants were below the permit limits.

Nutrient levels were compared to nutrient target values developed by Ohio EPA in the document *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999). The geometric mean for total phosphorus of 0.10 mg/L at the most upstream East Fork Mill Creek sampling location, at West Chester Rd (RM 3.17), was above the target value of 0.08 mg/L. Otherwise, all East Fork Mill Creek and Mill Creek sampling locations upstream from the Butler County Upper Mill Creek Regional WRF were below the total phosphorus and nitrate+nitrite-N target levels (Table 9).

Basin-specific nitrate+nitrite-N and total phosphorus target values of 2.5 and 0.25 mg/L, respectively, were generated for the 2004 TMDLs for Mill Creek (Ohio EPA, 2004). During the 2014 survey, in East Fork Mill Creek, the total phosphorus geometric means for sampling locations upstream from the Butler County Upper Mill Creek Regional WRF were less than the TMDL target values and levels downstream from the WRF were above the TMDL target values. All total phosphorus geometric means for sampling locations in Mill Creek were below the TMDL target values, including the two sampling locations downstream from the confluence with East Fork Mill Creek (Figure 9).

The total phosphorus in Town Run downstream from the Glendale WWTP (0.32 mg/L) also exceeded the TMDL target of 0.25 mg/L; however, nitrate+nitrite-N did not (Figure 9, Figure 10).

The Muddy Creek sampling locations were downstream from CSO outlets and a sewer system high-rate treatment (HRT) facility. Phosphorus levels were elevated at sampling locations in Muddy Creek; however, nitrate+nitrite-N levels were below nutrient target levels. The total phosphorus mean of 0.318 mg/L at Ebenezer Rd (RM 5.4) also exceeded the TMDL target value of 0.25 mg/L; the nitrate+nitrite-N level did not exceed the TMDL target value. At the Rapid Run sampling location along Bender Road (RM 1.15), neither total phosphorus nor nitrate+nitrite-N levels exceeded the nutrient or TMDL target levels (Table 9).

Table 9. Nutrient sampling results in upper Mill Creek, Muddy Creek, and Rapid Run, May-October, 2014. Values from WWTP final effluents are italicized in red. Values above applicable nutrient targets are highlighted in yellow. Values also above ecoregion specific target values from the 2004 Mill Creek TMDL report are highlighted in orange.

Stream (Aquatic Life Use Designation [a])					Nitrate-Nitrite-N (mg/l)		Phosphorus-T (mg/l)	
RM	AU [b]	Location	Drainage Area (mi^2)	No. Samples	Geometric Mean [c]	Target*/**	Geometric Mean [c]	Target*/**
Mill Creek (WWH)								
26.35	01-01	Liberty-Fairfield Rd.	3.9	6	0.346	1.0/2.5	0.038	0.08/0.25
22.06	01-01	St. Rt. 747	20.6	6	0.423	1.0/2.5	0.059	0.10/0.25
18.69	01-01	Crescentville Rd.	27.0	9	0.193	1.0/2.5	0.060	0.10/0.25
17.96	01-01	30 Ft. Upst. confluence with E. Fk. Mill Creek	32.5	6	0.130	1.0/2.5	0.052	0.10/0.25
17.61	01-03	Kemper Rd.	44.8	6	1.677	1.0/2.5	0.226	0.10/0.25
16.57	01-03	Sharon Rd.	50.5	6	1.678	1.0/2.5	0.239	0.10/0.25
East Fork Mill Creek (WWH)								
3.17	01-01	West Chester Rd.	5.0	6	0.191	1.0/2.5	0.100	0.08/0.25
1.85	01-01	Allen Rd.	8.1	7	0.140	1.0/2.5	0.075	0.08/0.25
1.15	01-01	Upst. Butler Co. Upper Mill Creek WWTP	9.0	6	0.112	1.0/2.5	0.068	0.08/0.25
1.07	*01-01*	*Butler Co. Upper Mill Creek WWTP final effluent*	*9.0*	*6*	*4.218*	*na*	*0.407*	*na*
0.76	01-01	Crescentville Rd.	9.2	9	2.098	1.0/2.5	0.320	0.08/0.25
0.01	01-01	At mouth	9.7	6	3.535	1.0/2.5	0.322	0.08/0.25
Town Run (RM 16.91) (WWH)								
0.92	*01-03*	*Glendale WWTP final effluent*	*1.9*	*6*	*3.000*	*na*	*0.354*	*na*
0.67	01-03	Chester Rd.	2.1	7	1.701	1.0/2.5	0.323	0.08/0.25
Rapid Run (LRW)								
1.15	02-02	Bender Rd.	5.8	6	0.488	1.0/2.5	0.043	0.080/0.25
Muddy Creek (WWH)								
5.40	02-03	Ebenezer Rd.	7.6	5	0.134	1.0/2.5	0.318	0.08/0.25
1.96	02-03	Hillside Rd.	12.1	8	0.147	1.0/2.5	0.092	0.08/0.25

Statewide ALU Targets	Headwater			Wadeable			Small River			Large River		
	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
NO_3-NO_2-N (mg/l)	1.0	0.5	1.0	1.0	0.5	1.6	1.5	1.0	2.2	2.0	1.5	2.4
Phosphorus-T (mg/l)	0.08	0.05	0.34	0.10	0.05	0.28	0.17	0.10	0.25	0.30	0.15	0.32

* Nutrient target per Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams –Tables 1 and 2, (Ohio EPA, 1999).

** Mill Creek basin specific target values from 2004 TMDL (0.25 % 2.5 mg/l total phosphorus and NO_3+NO_2, respectively)

a Use designations (aquatic life)
- MWH – modified warmwater habitat
- WWH - warmwater habitat
- EWH - exceptional warmwater habitat
- Undesignated (WWH criteria apply to 'undesignated' surface waters)
- LRW – limited resource water (WWH criteria used for evaluation)

b AU – Assessment Unit

c Geometric mean calculated from data collected from May 1 - October 31, 2014.

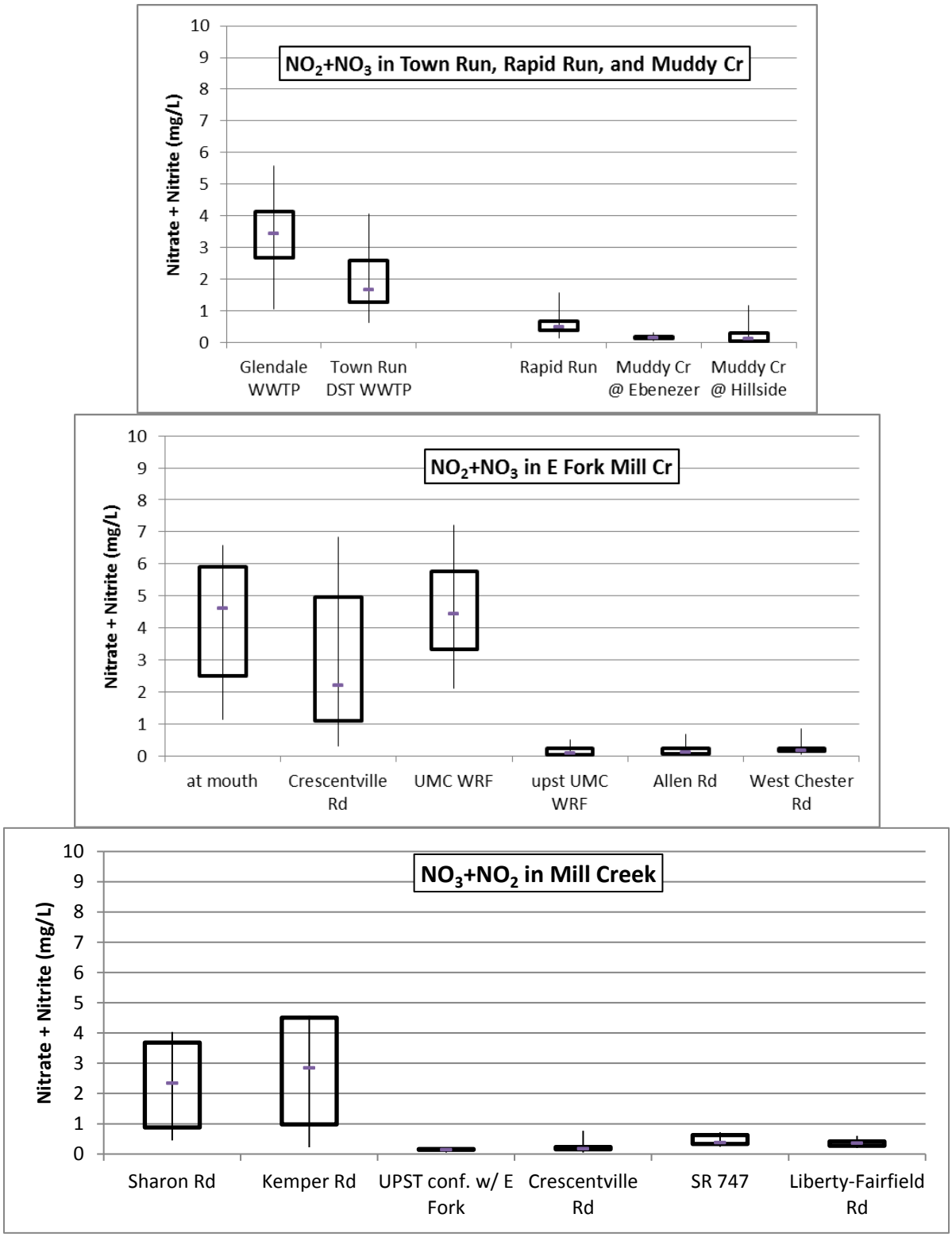


Figure 7. Nitrate+Nitrite-N levels in samples collected from the upper Mill Creek basin and direct Ohio River tributaries west of Cincinnati, 2014.

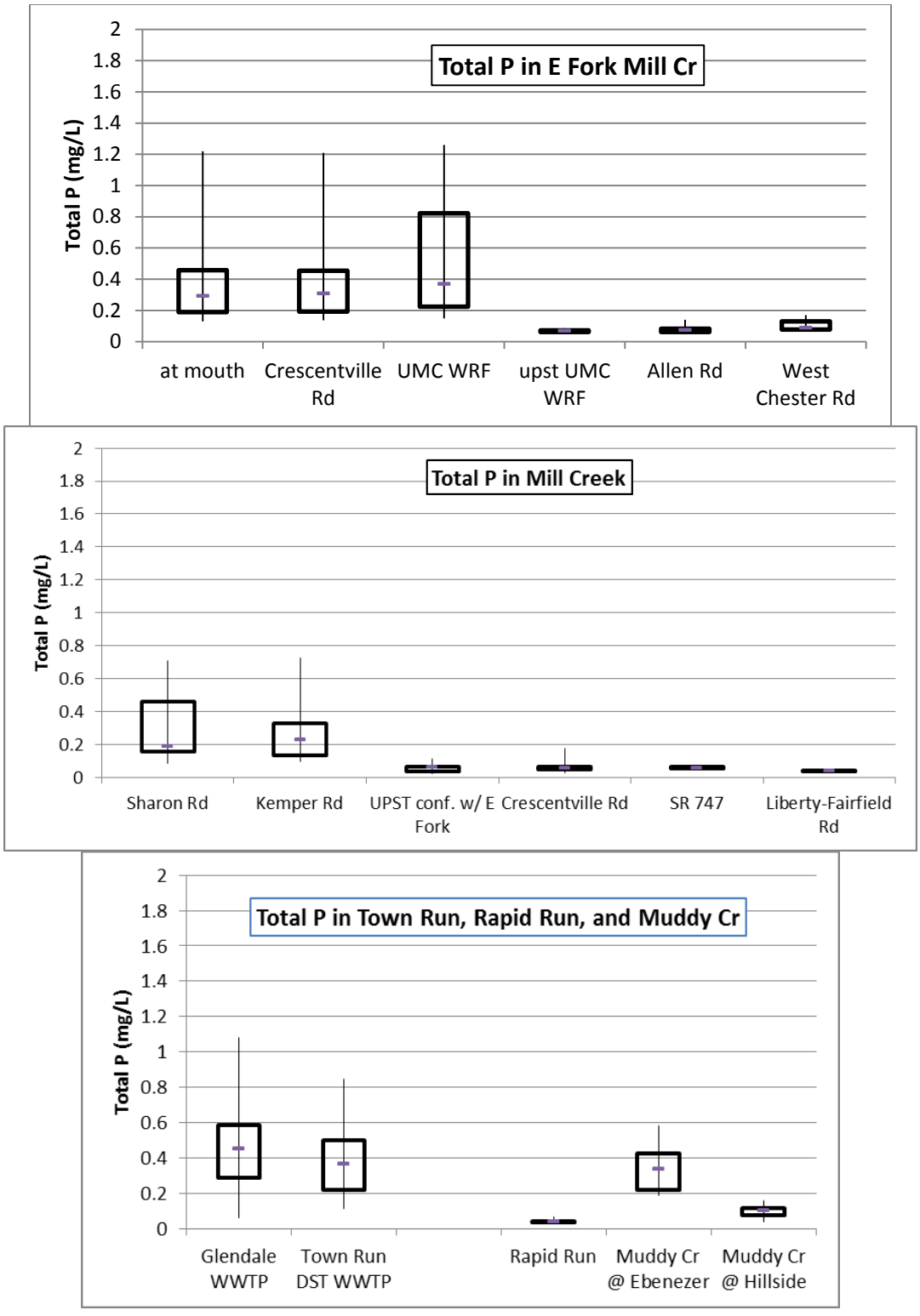


Figure 8. Total phosphorus levels in samples collected from the upper Mill Creek basin and direct Ohio River tributaries west of Cincinnati, 2014.

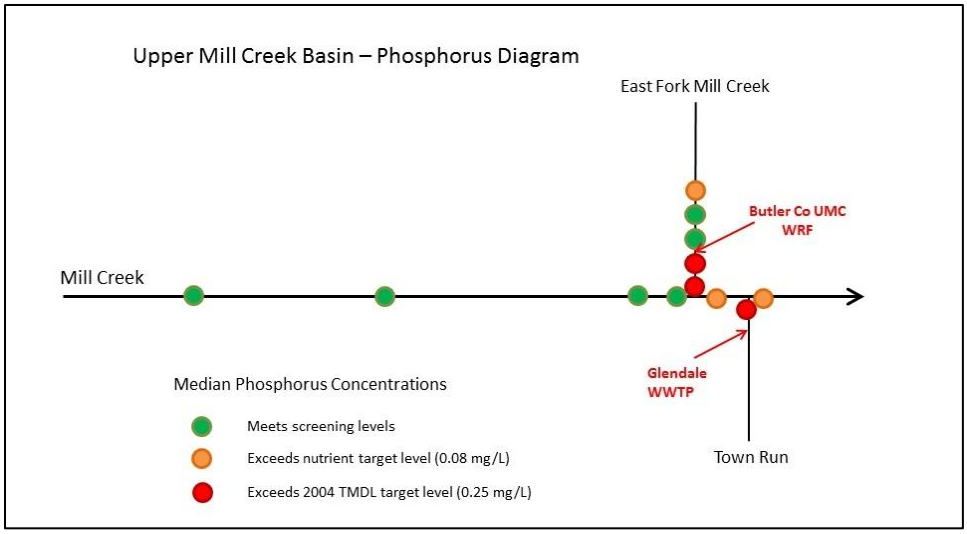


Figure 9. Upper Mill Creek basin phosphorus diagram, 2014

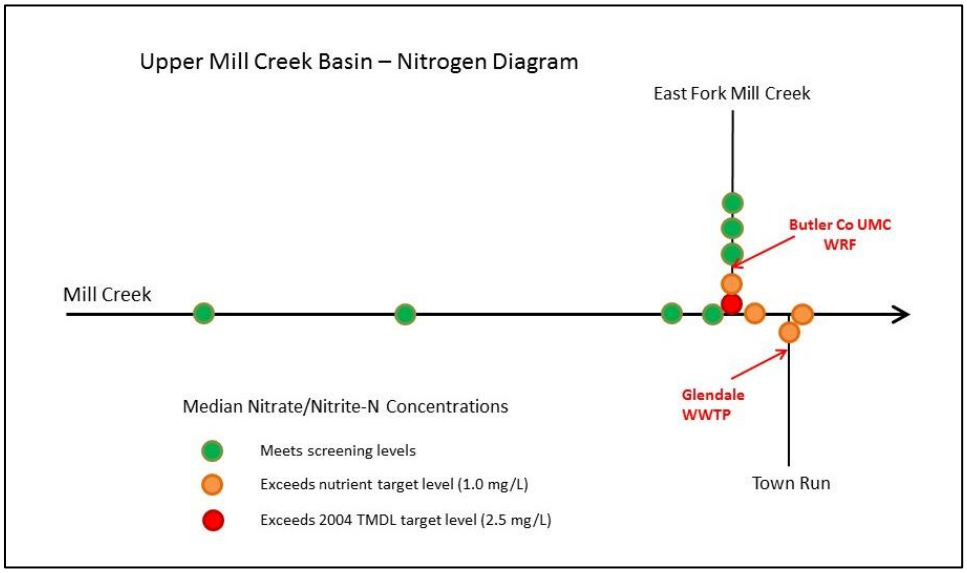


Figure 10. Upper Mill Creek basin nitrogen diagram, 2014

In the upper Mill Creek area and Muddy Creek, organic parameters, including organochlorine and carbamate pesticides, acid and chlorinated acid herbicides, and glyphosate, were measured at three sampling locations, one each in Mill Creek (RM 18.69), East Fork Mill Creek (RM 0.76) and Muddy Creek (RM 1.96). Organics were analyzed during eight sampling events over the seven months from April to October. Most pesticides were detected only once or twice. Fourteen pesticides were detected. None of the detections exceeded the criteria for the seven of those pesticides which have established water quality criteria. (Table 10)

Mill Creek had the greatest number of detections of different pesticides. The May sample from Mill Creek had the greatest number of pesticides (6) (Figure 11), all of which were herbicides (Appendix Table C).

Figure 12 shows the different proportions of different classes of pesticide between the sites. Glyphosate (Roundup) was only detected at the Muddy Creek site, and only during one event, on April 22, 2014. No organochlorine pesticides were detected at the Muddy Creek site. However, pesticides from this class were detected in Mill Creek and East Fork Mill Creek, and included γ-BHC (Lindane), endosulfan, and hexachlorobenzene.

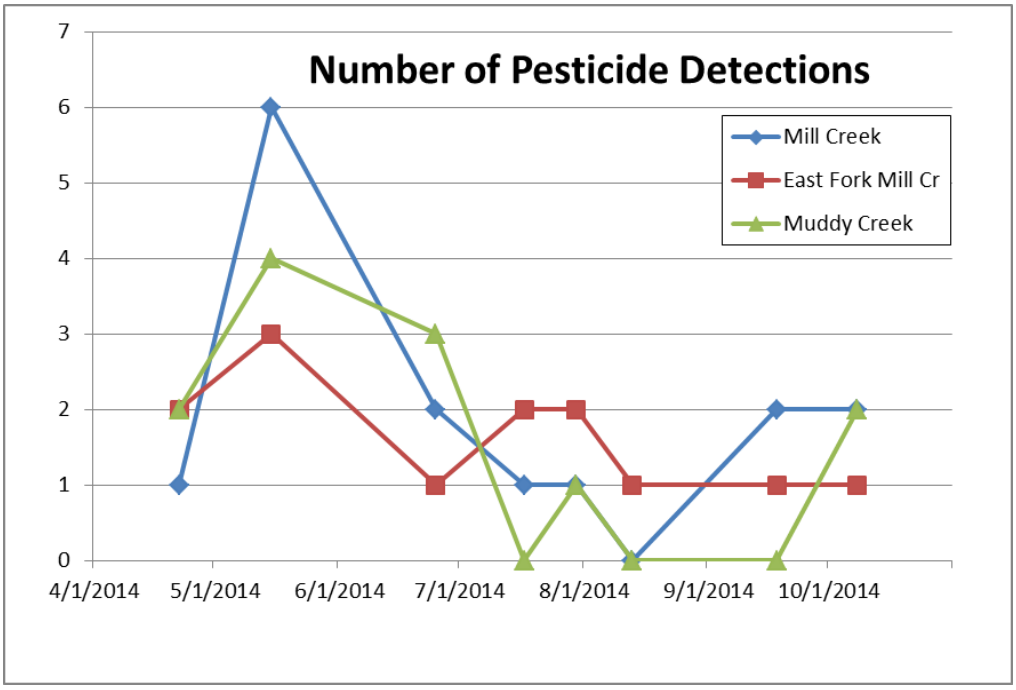


Figure 11. Number of pesticide detections in the upper Mill Creek basin and Muddy Creek, 2014.

Southwest Ohio River Tributaries

Surface water chemistry samples were collected from 28 sites in the portion of the Southwest Ohio River Tributaries study area in Clermont County and eastern Brown County. Three sentinel locations were collected from April through November, 2014. Twenty-five locations were collected during the regular sampling season from June to September (Figure 1, Table 4). Stations were established in free-flowing sections of the stream and were primarily collected from bridge crossings. Two sites were the outfall discharges from the Ninemile Creek WWTP and Felicity WWTP in Clermont County. In all, 19 different streams were sampled.

Streams in the Ohio River tributary study area are developed in glacial deposits from the Illinoian Ice Age which are deeply leached glacial drift that will flow over limestone beds near the Ohio River. The Wisconsin glacier did not reach this part of Ohio, but its outwash and aeolian sediment did. The majority of streams sampled (22/26) (85%) were in headwater streams having a drainage area less than 20 mi^2. The three sentinel sites were located at wadeable sites having a drainage area between 20-200 mi^2. These small streams have high gradients (30-141 ft/mi) and are flashy during heavy spring and winter rainfall events. In the dry summer months, the flow is greatly diminished due to limited groundwater recharge from the deeply narrow valleys. Principal tributaries are Bullskin Creek (52.9 mi^2), Indian Creek (40.0 mi^2), West Branch Bullskin Creek (27.7 mi^2) and Twelvemile Creek (19.6 mi^2). Minor tributaries are East Branch Bullskin Creek (16.3 mi^2), Tenmile Creek (13 mi^2), Maple Creek (9.48 mi^2), Bear Creek (9.02 mi^2), and Ninemile Creek (8.48 mi^2).

There are no USGS gaging stations near these tributaries, although Ohio EPA did conduct stream flow measurements on selected tributaries. These were used to determine the flow regime during sampling events.

Surface water samples were analyzed for metals, nutrients, polychlorinated biphenyls (PCBs), semi-volatile organic compounds, organochlorinated pesticides, bacteria, pH, temperature, conductivity, dissolved oxygen (D.O.), percent D.O. saturation, and suspended and dissolved solids (Appendix Tables B and C). Exceedances of Ohio WQS criteria were mainly due to low dissolved oxygen (17 events) and elevated temperature (11 events) recorded in July and August. Parameters which were in exceedance of the Ohio WQS criteria are reported in Table 8. Bacteriological samples were collected from eight locations, and the results are reported in the recreation use section. Datasonde® water quality recorders were placed at seven locations to monitor hourly levels of dissolved oxygen, pH, temperature, and conductivity (Appendix Table D).

Metals were measured at 29 locations with seventeen parameters tested (Appendix Table B). No metals exceedances were found within the study area.

The only chemical exceedances found in the watershed were at Twelvemile Creek (Iron-T 7980 µg/l and 4,4-DDT 0.0085 µg/l) and Bullskin Creek (Iron 5260 µg/l). All chemical exceedances were related to high stream flows on May 15, 2014 where Bullskin Creek had 88 mg/l and Twelvemile Creek had 236 mg/l of suspended solids in the water column.

The Tributary to Bear Creek (RM 0.55) site was heavily influenced by nutrients presumably from the Felicity WWTP 0.1 miles upstream. (Mean value total phosphorus=3.535 mg/l, nitrate+nitrite-N=18.97 mg/l). The water-column phosphorus levels in Bear Creek were elevated downstream from the confluence with the unnamed tributary. This is most likely caused by the influence of the Felicity WWTP, since there does not appear to be any other significant nutrient sources upstream in Bear Creek.

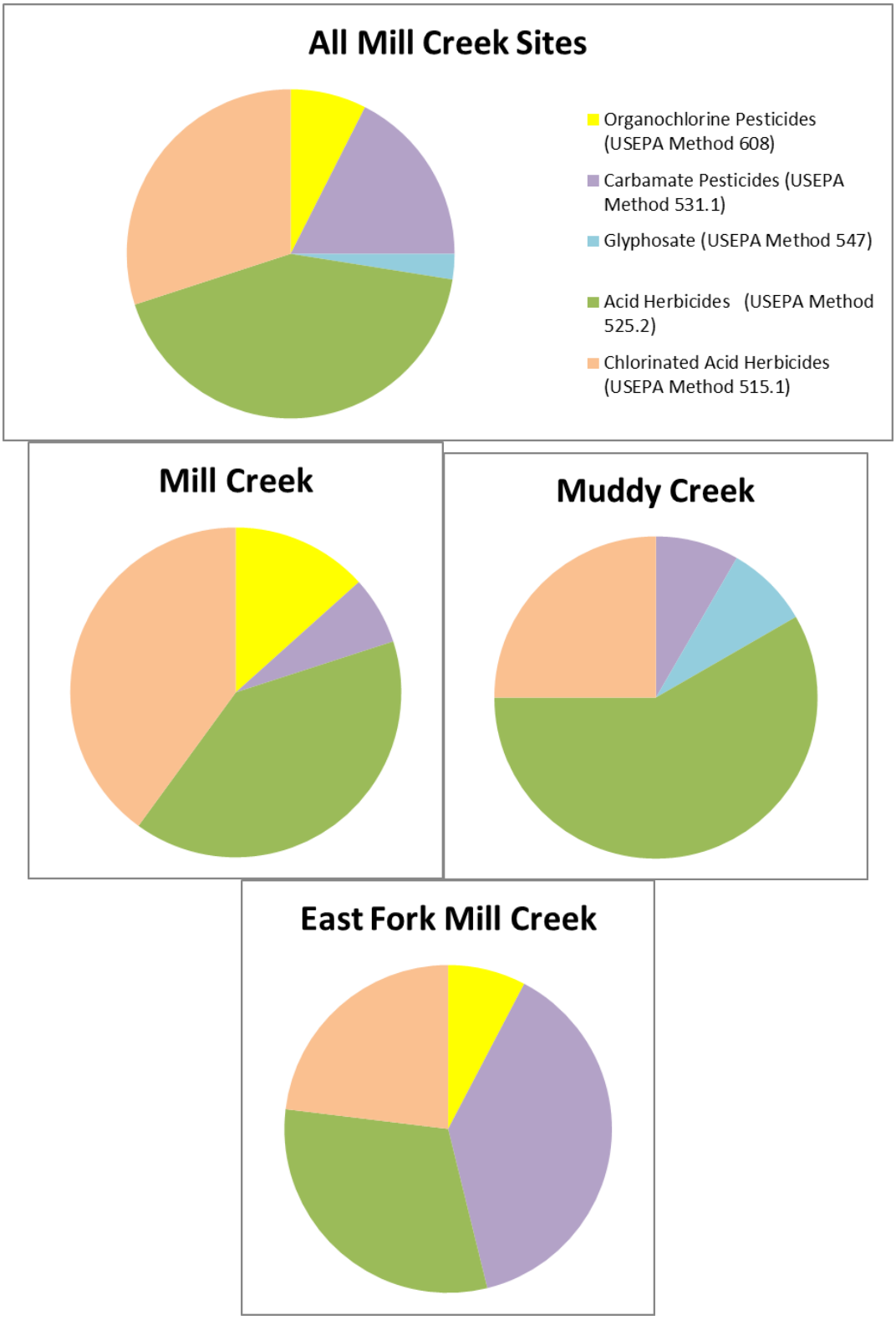


Figure 12. Frequency of pesticide detections by class in the upper Mill Creek basin and Muddy Creek, 2014.

Table 10. Frequency of pesticides detected in stream water samples in the Southwest Ohio River Tributaries study area, 2014. (Number of water quality criteria exceedances/Number of detections)

Parameter	Mill Creek, E. Fork Mill Creek, and Muddy Creek WAU 05090203-__-__)			Bullskin Creek, Big Indian Creek, and Twelvemile Creek (WAU 05090201-__-__)			
	01-01	01-01	02-03	11-04	12-02	12-04	
	Mill Creek RM 18.69	East Fork Mill Creek RM 0.76	Muddy Creek RM 1.96	Bullskin Creek RM 2.96	Big Indian Creek RM 1.71	Twelvemile Creek RM 2.08	
α-Hexachlorocyclohexane	-	-	-	0/4	0/2	0/4	0/10
δ-Hexachlorocyclohexane*	-	-	-	-	-	*/1	*/1
γ-Hexachlorocyclohexane (LIndane)	-	0/1	-	-	-	0/1	0/2
2,4-D	0/5	0/2	0/2	0/1	-	0/1	0/11
4,4-DDE	-	-	-	0/1	0/1	-	0/2
4,4'-DDT	-	-	-	-	-	1/1	1/1
Acetechlor*	*/1	-	-	*/1	*/1	*/2	*/5
Alachlor	-	-	-	0/1	-	-	0/1
Aldicarb sulfone	-	0/3	-	-	-	-	0/3
Aldicarb sulfoxide	-	0/2	-	-	-	-	0/2
Atrazine*	*/1	-	*/1	*/2	*/2	*/3	*/9
Bis(2-Ethylhexyl)adipate*	*/1	*/1	*/1	*/1	-	-	*/4
Bis(2-Ethylhexyl)phthalate	0/2	0/3	0/5	0/2	0/4	0/2	0/18
Butachlor*	-	-	-	*/1	-	-	*/1
Dicamba*	*/1	*/1	*/1	-	-	-	*/3
Endosulfan I	0/1	-	-	-	-	-	0/1
Endrin	-	-	-	-	-	0/2	0/2
Glyphosate*	-	-	*/1	-	-	-	*/1
Hexachlorobenzene	0/1	-	-	-	-	0/1	0/2
3-Hydroxycarbofuran*	*/1	-	*/1	-	*/1	*/1	*/4
Methomyl*	-	-	-	-	-	*/1	*/1
Metribuzin*	-	-	-	*/1	-	*/1	*/2
Metolachlor*	-	-	-	*/3	*/1	*/1	*/5
Simazine*	*/1	-	-	-	-	-	*/1
TOTAL	**0/15**	**0/13**	**0/12**	**0/18**	**0/12**	**1/22**	

* Parameter was detected but no applicable water quality criterion is available.

The WWTP discharge also elevated the water column phosphorus and nitrogen level downstream at Bear Creek RM 5.3 (Mean value total phosphorus=1.940 mg/l, nitrate+nitrite-N 7.57 mg/l). However, the Bear Creek site met its WWH use designation based on biological assessment results.

The Crooked Run site in Chilo (RM 0.7) was only evaluated for benthic organisms and they were assessed as poor. This site failed to meet the WQS criterion for dissolved oxygen in all five rounds of sampling. Nutrients (total nitrogen and total phosphorus) were not elevated; one manganese result on August 26 was elevated at 1520 µg/l during a moderate flow in the creek.

Four sites were in partial attainment of the designated or recommended WWH aquatic life use. The site at Twelvemile Creek at Laurel-Lindale Rd. RM 6.44 had an unknown influence that suppressed the IBI into the fair range. During a low flow period of September 17, the COD was 276 mg/l but the D.O. was 8.8 mg/l. The other three sites in partial attainment did not have a chemistry component to explain the decline in the fish community.

Water Quality Sonde Exceedance Summary

Multi-parameter water quality sondes were deployed to monitor temperature, dissolved oxygen (D.O.), pH and specific conductance (conductivity). Temperature, D.O. and pH are influenced by diel patterns. These diel patterns have the greatest impact for streams during certain critical conditions that include stable, low streamflow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in streamflow. The water quality sondes collect readings hourly to monitor parameters throughout the diel cycle. Grab readings differ because they only represent one point on the diel curve. While they are effective at characterizing water quality parameters that change based on hydrologic regime or season, they can miss or not fully characterize parameters that exhibit diel patterns. When the diel fluctuations are of concern, continuous monitoring at regular intervals throughout the diel cycle is needed to characterize the parameter of concern.

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

Dissolved oxygen responds in a similar diel pattern to temperature, as they are affected by similar factors. In addition, D.O. trends are directly dependent on temperature. At high temperatures the solubility of oxygen in water decreases, resulting in an inverse relationship. Without the influence of other environmental conditions, this would cause the two parameters to follow opposite trends. However, the dissolved oxygen 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 due to dissolved oxygen concentrations reaching super saturation during the day and subsequently depleting by respiration at night. The result is a diel trend that typically reaches a maximum in the early evening and a minimum the following morning. In some cases dissolved oxygen does not exhibit strong diel trends in low flow, warm conditions. Either primary productivity is limited or decomposition of organic matter in the stream is controlling the dissolved oxygen concentrations. Sonde monitoring contributes to the body of evidence to identify dissolved oxygen trends that are more influenced by primary productivity or decomposition.

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

Fourteen sites in the Southwest Ohio River Tributaries study area were sampled with water quality sondes to represent the general watershed area as well as areas of concern (i.e. point sources or historically impaired areas). Targeted sampling occurred around wastewater treatment facilities for Glendale (Ohio EPA Permit #1PB00012) and Butler County (Ohio EPA Permit #1PK00016), with the remaining monitoring sites chosen for HUC-12 coverage. The study area includes a range of developed land uses; therefore, potential point and nonpoint source impacts were both investigated. Sampling with continuous monitoring sondes was completed during the critical conditions for both of these sources.

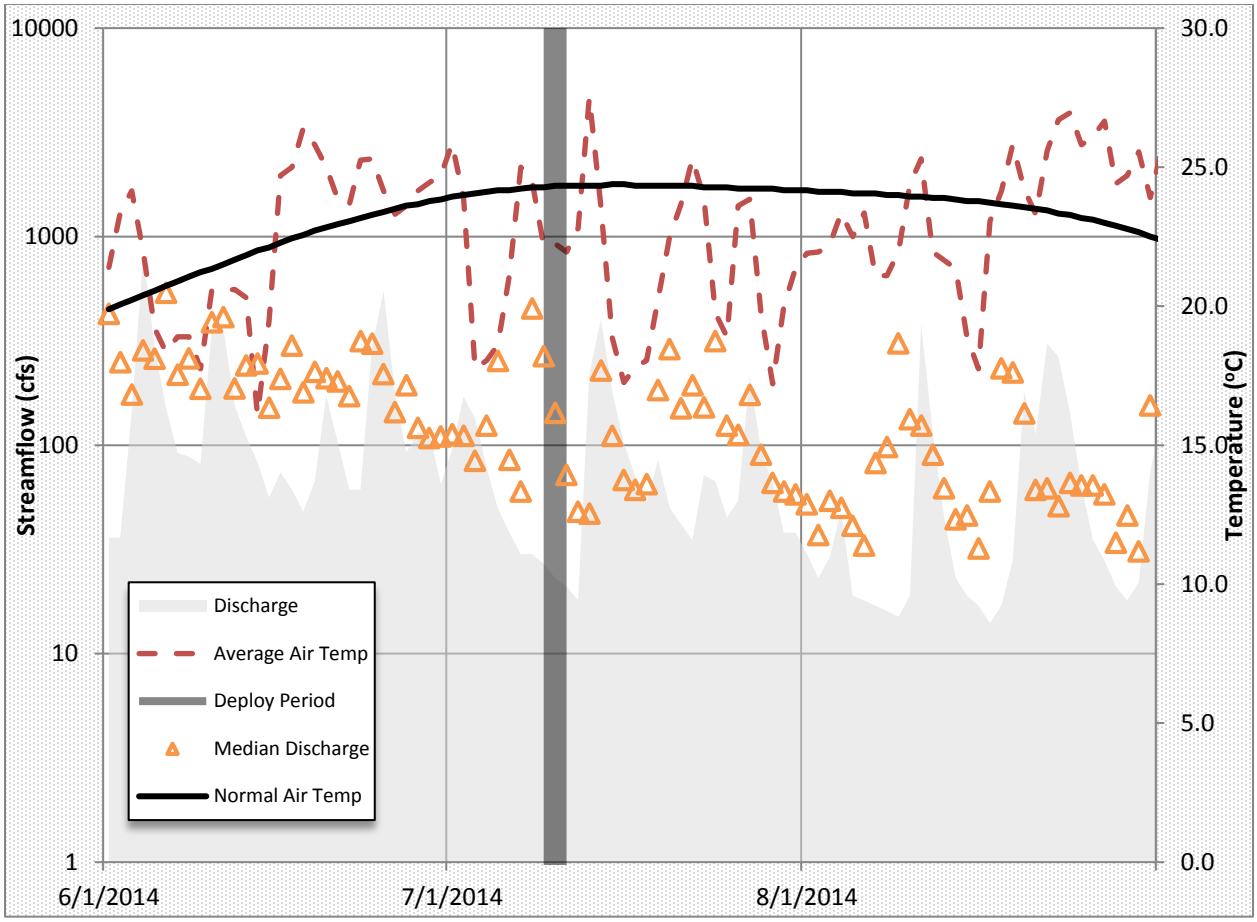


Figure 13. Graph of average daily streamflow relative to the daily median streamflow (USGS 03259000 Mill Creek at Carthage OH) including the average and normal daily air temperature (NOAA - GHCND:USW00093812) for the summer sampling season.

Critical conditions for temperature and dissolved oxygen are times when flows are low, temperatures are high, and daylight is long. These are the times that streams are most sensitive to organic and nutrient enrichment. To capture these conditions, sondes are typically deployed in low flow conditions from June to September. Sondes were deployed July 9-11, 2014 (Figure 13) in the Southwest Ohio River Tributaries study area. This timeframe included below normal stream flow and air temperatures, which were the trends for the 2014 sampling period. June through September of 2014 rarely saw average air temperatures above 25˚C. In spite of this fact, stream conditions during sampling remained indicative of the critical condition.

Continuous monitoring sondes were also deployed in early 2015 in the urbanized upper Mill Creek watershed. This study aimed to capture the effects of winter road salt/brine application on conductivity concentrations. Sondes were deployed at six locations on Mill Creek, East Fork Mill Creek and Town Run from February 27 – March 17. These six sites are a subset of the 14 previously visited. Warming temperatures, in addition to the season's first significant rain event, led to rapid melting and stream flow increases on March 1, 2015 (Figure 14). This deployment successfully captured the first significant runoff event of the year.

Summary plots of all data collected are included in Appendix Table D of this document. The plots are of hourly readings taken for temperature, dissolved oxygen, pH, and specific conductance.

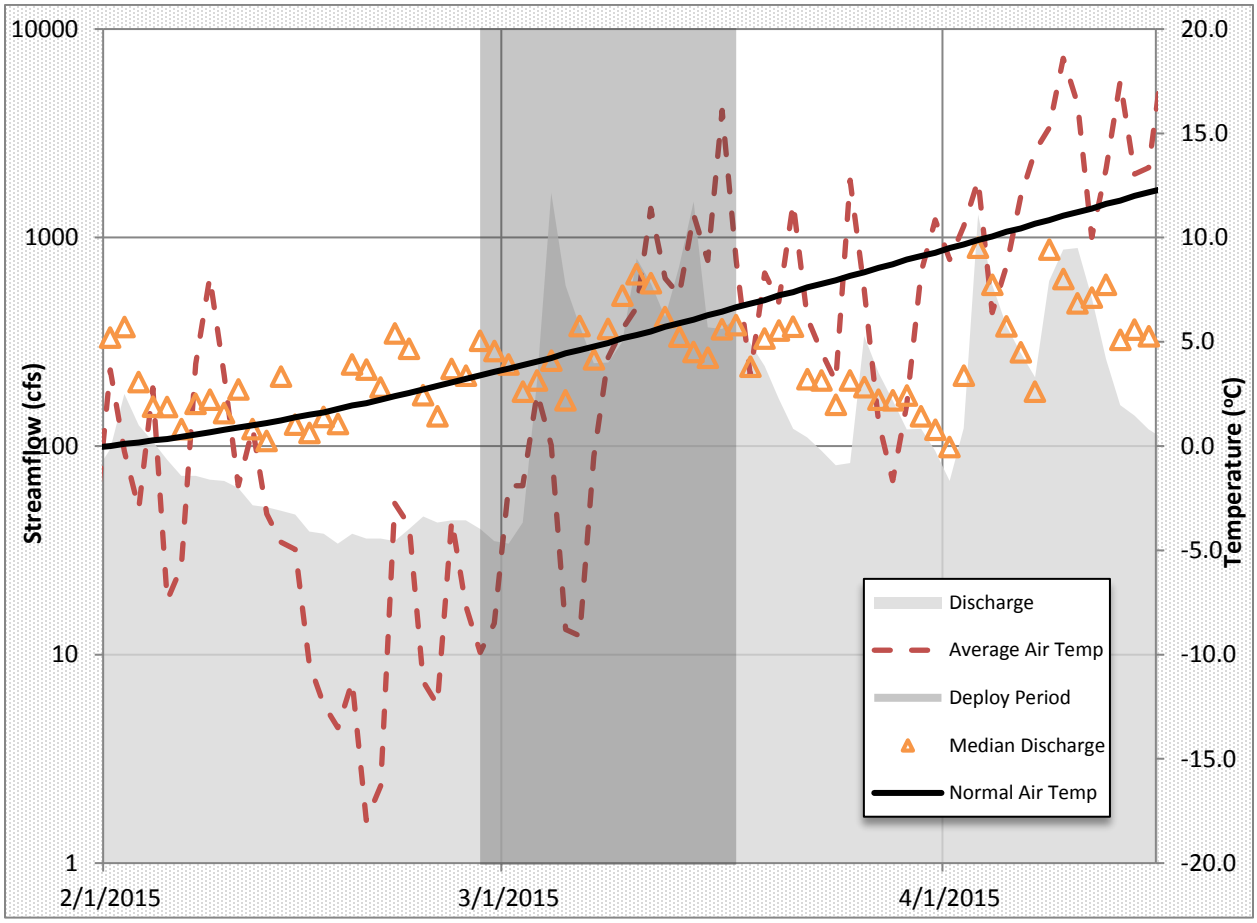


Figure 14. Graph of average daily streamflow relative to the daily median streamflow (USGS 03259000 Mill Creek at Carthage OH) including the average and normal daily air temperature (NOAA - GHCND:USW00093812) for winter runoff sampling.

Ohio promulgates the WQS through OAC Chapter 3745-1. The data collected during sonde deployments are sufficient to evaluate exceedances of the WQS criteria for the protection of aquatic life for maximum daily temperature, minimum dissolved oxygen, 24-hour average dissolved oxygen, pH, and specific conductance. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. The 24-hour average dissolved oxygen criterion is compared to a rolling 24-hour average calculated for the duration of the deployment. An exceedance of the water quality criterion does not

represent stream impairment; rather if biological impairment is present the exceedances help develop a body of evidence that identifies the conditions that are stressing aquatic life. A summary of the exceedances is presented in Table 11. The table includes descriptions of exceedances that are made based on Ohio EPA staff's knowledge of specific sites.

Temperature exceedances of the general Ohio River basin criteria occurred in Bullskin Creek (RMs 4.38 and 2.96), Big Indian Creek (RM 1.71) and Muddy Creek (RM 1.96) during the July sonde deployment. All of these systems have similar land use and geomorphology, with shale and limestone dominated bedrock and naturally wide stream channels. The streams' wide and shallow glide habitats lead to increased surface area and less effective riparian shading. Both of these conditions increase potential for solar radiation. Although air temperatures were not particularly high during the study, clear skies and low flow resulted in water temperatures exceeding 30°C.

In Bullskin Creek (RM 4.38) and Muddy Creek (RM 1.96), the aforementioned light availability combined with a supply of nutrients to increase primary production. Because of the productivity in these systems, sondes measured wide diel swings in D.O. at both sites. Exceedances of the minimum D.O. criterion occurred in the troughs of these swings, overnight and in the early morning hours. In Bullskin Creek, the D.O. trough was of sufficient duration to pull the 24-hour rolling average below 5.0 mg/L for nine consecutive hours.

The upper Mill Creek watershed can be separated from others in the study area due to its urban land use and finer silt/loam surficial geology. The streams within its watershed are narrower, deeper and generally more shaded; therefore, no temperature exceedances were captured. The lower stream temperatures also help buffer dissolved oxygen, which never exceeded the minimum or average criteria.

Specific conductance readings in the Mill Creek watershed, however, did exceed the 2,400 µS/cm standard. Sonde measurements taken during low and high flow conditions demonstrated the effects of both point and nonpoint sources on the Mill Creek system. During the July low flow sonde deployment, East Fork Mill Creek downstream from the Butler County Upper Mill Creek Water Reclamation Facility exceeded the standard for 10 consecutive hours. Because the stream is dominated by effluent, it is sensitive to high levels of dissolved solids from the plant during low flow conditions.

During the winter high flow deployment, specific conductance exceedances were pervasive. Abnormally cold weather in January and February necessitated frequent application of anti-icers like road salt and brine. The sonde deployment captured the first significant rain event of the year. This rain event led to rapid melting of existing snow and ice, which augmented runoff caused by the precipitation alone. Conductivity exceedances persisted in Mill Creek, East Fork Mill Creek (RM 1.85), and Town Run for multiple days after flows began to rise. Readings in Town Run reached a maximum of 11,263 µS/cm. Because other sites consistently peaked around 5,000 µS/cm, it is likely that there were discharges in Town Run contributing additional load. In East Fork Mill Creek, on the other hand, discharge from the WWTP was less conductive than runoff, actually diluting stream concentrations.

Table 11. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring. Sondes were deployed at 14 sites from July 9 – 11, 2014, and 6 sites from February 27 – March 17, 2015. Exceedances occurring during the winter deployment are indicated in bold in the table.

Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria. The duration is the count of consecutive hours that exceeded the criteria and is presented in parenthesis after the measure of magnitude. Applicable water quality criteria include: minimum dissolved oxygen (D.O.)[a], average D.O.[b], maximum temperature[c], pH[d] and specific conductance[e].

RM	Location	Parameter (D.O. in mg/L, Temp in °C, Sp. Cond. in uS/cm)	Comments
Bullskin Creek		***Warmwater Habitat (Existing)***	
4.38	NE of Cedron @ Dunbar Rd.	Temp max: 30.7 (4), 29.6 (3)	Wide channel with limited shading
		D.O. min.: 2.4 (13), 1.0 (11)	Excess primary production
		D.O. avg.: 4.5 (9)	
2.96	@ Felicity Cedron Rural Rd.	Temp max: 31.7 (3), 29.8 (2)	Wide channel with limited shading
Big Indian Creek		***Warmwater Habitat (Existing)***	
4.89	E of Point Pleasant @ SR 743	None	
1.71	At Point Pleasant @ SR 756	Temp max: 29.7 (3), 30.2 (4)	Wide channel with limited shading
Twelvemile Creek		***Warmwater Habitat (Existing)***	
2.08	@ Fagins Run Rd. dst Fagins Run	None	
Tenmile Creek		***Warmwater Habitat (Existing)***	
1.17	Near Palestine @ US Rt. 52	None	
Ninemile Creek		***Warmwater Habitat (Existing)***	
0.79	Upst WWTP @ Locust Corner Rd.	None	
Mill Creek		***Warmwater Habitat (Existing)***	
18.69	Near Crescentville @ Crescentville Rd.	**Sp. Cond.: 5,887 (105)**	Urban runoff, road salt/brine
17.61	NE of Glendale @ Kemper Rd.	**Sp. Cond.: 2,520 (10), 5,031 (57)**	Urban runoff, road salt/brine
16.57	At Sharonville @ Sharon Rd.	**Sp. Cond.: 2,897 (26), 5,534 (59), 2,760 (30)**	Urban runoff, road salt/brine

RM	Location	Parameter (D.O. in mg/L, Temp in °C, Sp. Cond. in uS/cm)	Comments
East Fork Mill Creek		***Warmwater Habitat (Existing)***	
1.85	Near West Chester @ Allen Rd.	**Sp. Cond.: 2,657 (4), 4,040 (24), 4,278 (18)**	Urban runoff, road salt/brine
0.76	Near Crescentville @ Crescentville Rd.	Sp. Cond.: 2,581 (10)	WWTP contributions
		Sp. Cond.: 3,131 (6) *	Urban runoff, road salt/brine
Town Run		***Warmwater Habitat (Existing)***	
0.67	Dst. Glendale WWTP @ Chester Rd.	**Sp. Cond.: 11,263 (108), 5,309 (71), 4,470 (3)**	Urban runoff, road salt/brine; Upstream discharges
Muddy Creek		***Warmwater Habitat (Existing)***	
1.96	Near Cincinnati @ Hillside Rd.	Temp max: 30.3 (2)	Wide channel with limited shading
		D.O. min.: 3.6 (5), 3.7 (3)	Excess primary production

Notes:
[a] The General Ohio River basin daily maximum temperature criteria apply; See OAC 3745-1-07, Table 7-14(G).
[b] Applicable minimum 24-hour average D.O. criteria - WWH: 5.0 mg/l
[c] Applicable minimum D.O. criteria - WWH: 4.0 mg/l
[d] The criteria for pH is 6.5-9.0 S.U.
[e] The criteria for specific conductivity is 2400 µS/cm.
*Only a subset of data kept due to sensor fouling.

Trophic Evaluation

Two trophic states exist for streams, the autotrophic state and the heterotrophic state (Dodds 2007). Generally, the autotrophic state represents primary production and the heterotrophic state represents respiration. The trophic status is generally split into three categories- oligotrophic, mesotrophic, and eutrophic (Dodds *et al.* 1998). Oligotrophic systems are described as having low nutrients, low algal biomass and high clarity. Conversely, eutrophic systems are rich in nutrients, have high algal biomass, and have high swings of dissolved oxygen (D.O.). Mesotrophic systems have intermediate characteristics between oligotrophic and eutrophic systems. The transition from oligotrophic to eutrophic generally reflects a system that has shifted from heterotrophic dominance to autotrophic dominance and the process is commonly referred to as eutrophication. For the purposes of this evaluation, eutrophication is defined as the process by which a stream becomes enriched with nutrients resulting in high chlorophyll-*a* concentrations and wide diel swings of D.O. Therefore, the focus for identifying eutrophication requires effective monitoring of the autotrophic state, which is dictated by primary production. The objective of a trophic status evaluation is to identify streams that are exhibiting eutrophication.

Ohio and other states have been developing nutrient reduction strategies in recent years to address cultural eutrophication (USEPA 2015, Ohio EPA 2014, Miltner 2010, Heiskary and Markus 2003). Wide diel ranges of D.O. are associated with eutrophication, which is caused by excessive photosynthesis (O_2 production) during daylight hours and ongoing respiration, including decomposition (O_2 consumption), at night. The most

recent investigations by Ohio EPA has identified a diel range of 6.5 mg/L D.O. as a threshold indicative of eutrophication in Ohio streams (Ohio EPA 2014).

Benthic (or attached) algae are monitored as the primary algal community in wadeable streams and small rivers, while sestonic (or suspended) algae is monitored as the primary algal community in large rivers. However, stream factors such as width-depth ratio and longitudinal gradient may have a stronger influence on whether sestonic or benthic algae dominate the algal community than the stream size. Therefore, sestonic algae typically dominate streams defined as large rivers, and benthic algae typically dominate small streams. With that in mind, chlorophyll-*a* is used as an indicator of the level of benthic production primarily in smaller stream systems, and as an indicator of the concentration of sestonic organisms primarily in large rivers. The most recent work by Ohio EPA in assessing benthic chlorophyll-*a* concentrations identified break points for low, moderate, and high categories (Ohio EPA 2014). The low-moderate category breakpoint is identified as 182 mg/m^2 and the moderate-high category is identified as 320 mg/m^2. A review of studies on sestonic chlorophyll-*a* by Dodds (2006), which included some midwestern streams, and work in Ohio (Miltner 2010) suggest that concentrations of 40-100 µg/l sestonic chlorophyll-*a* identify eutrophic conditions while concentrations >100 µg/l indicate hyper-eutrophic conditions.

Years ago, in pursuit of developing a nutrient strategy, Ohio EPA published a report (Ohio EPA 1999) that analyzed associations between nutrient concentrations and performance of aquatic organisms. The report proposed statewide water quality criteria (Table 12 and Table 13). The data that is collected throughout the biological assessment season is summarized using a geometric mean for comparison to the target concentrations.

Table 12. Phosphorus concentrations proposed for the protection of aquatic life (Ohio EPA 1999). All units are in mg/L.

	WWH	EWH	MWH
Headwaters (<20 mi^2)	0.08	0.05	0.34
Wadeable (20 - 200 mi^2)	0.10	0.05	0.28
Small River (200 - 1000 mi^2)	0.17	0.10	0.25
Large River (>1000 mi^2)	0.30	0.15	0.32

Table 13. Nitrate+nitrite-N concentrations proposed for the protection of aquatic life (Ohio EPA 1999). All units are in mg/L.

	WWH	EWH	MWH
Headwaters (<20 mi^2)	1.0	0.5	1.0
Wadeable (20 - 200 mi^2)	1.0	0.5	1.6
Small River (200 - 1000 mi^2)	1.5	1.0	2.2
Large River (>1000 mi^2)	2.0	1.5	2.4

The proposed criteria were never adopted into rule; however, they can serve as benchmarks to identify elevated nutrient levels in streams. The presence of elevated nutrients increases the risk of eutrophication in streams but cannot alone serve to identify eutrophication. More recent work relative to developing nutrient criteria is considering risk levels relative to ratios between the macro-nutrients of nitrogen and phosphorus (D. Dudley, personal correspondence, Aug. 13, 2014).

Seasonality is an important consideration when examining eutrophication. Two factors influencing eutrophication are linked to seasonality, light availability and temperature. When streams are turbid due to storm events, light penetration is not adequate to allow enough production of algae to cause eutrophic conditions. Dodds (2006) documents streams experiencing eutrophication in late spring/early summer before leaf canopy shades a stream. Then those same streams have drops in algal production, ameliorating the deleterious effect of excess nutrients once the canopy shades the stream channel. Streams that are of sufficient width or lack a wooded riparian due to anthropogenic management practices (i.e., channelization) do not have adequate canopy coverage to subdue photosynthetic primary production. Photosynthesis is a chemical reaction that is impacted by temperature; however, the kinetics are complicated because they involve biological organisms that have optimal temperature ranges as well. Dauta and others (1990) examined four freshwater algae species and found maximal growth at 25 – 30 ^{o}C and a reduction in growth to the point of being insignificant around 10 ^{o}C. These factors complicate the definition of a critical time period for monitoring algae as indicators of eutrophication. However, D.O. is most impacted during summer low flows due to warmer temperatures and limited reaeration. While this may not always correspond to maximum algal biomass, Ohio EPA typically samples chlorophyll-*a* and diel D.O. at the same time. The advantage of coupling the two sampling efforts is that the algae sampled represent the productivity captured in the diel D.O. trend. In addition, while D.O. and chlorophyll-*a* sampling targets low-flow critical conditions, ideal conditions are not always achieved. If conditions during a survey are less than ideal, an additional sampling event is often planned to capture low flow conditions.

For the purpose of trophic status evaluation, Ohio EPA designates 'nutrient sites' where benthic/sestonic chlorophyll-*a* concentrations and diel DO ranges are monitored. These sites coincide with grab sampling for chemistry that is then used to characterize the seasonal nutrient availability.

In the Southwest Ohio River Tributaries study area, nutrient sampling was completed at 14 sites. To assess the trophic state at these sites, water quality sondes monitored D.O. on an hourly basis and both benthic and sestonic chlorophyll-*a* concentrations were sampled from July 9-11, 2014. Sampling events are expected to represent the potential of primary production. Therefore, the largest D.O. range found in these sampling events is used in the summary figures. The hourly samples from a 24-hour diel cycle are summarized in box plots that identify the minimum, maximum, average, median, 75th percentile and 25th percentile of values measured. If benthic or sestonic algae were sampled in multiple surveys, the value corresponding to the highest D.O. range is shown. The complete sonde and chlorophyll-*a* dataset are reported in Appendices D and E, respectively.

Instream nutrient concentrations are also considered as a contributing factor for assessing the trophic state. To assess nutrient concentrations, the geometric mean of the samples collected from May 1 – October 31, corresponding to the biological assessment season, is calculated. Total phosphorus and nitrate+nitrite-N are considered for comparison to the targets in Table 12 and Table 13. The critical data for assessing the trophic state are presented in Figure 15 and Figure 16. Figure 15 represents the six sites assessed within the upper Mill Creek watershed, and Figure 16 represents the eight sites on other direct Ohio River tributaries.

D.O. ranges and chlorophyll-*a* concentration are the primary indicators of eutrophication. If both indicators fall into an elevated range, there is strong evidence that the stream is exhibiting an advanced eutrophic

state. If one or the other indicator is in an elevated range, there is evidence of a system imbalance but it is less conclusive regarding a eutrophic state. Some of the reasons for inconclusive results could be less than ideal sampling conditions or one sample misrepresenting the total character of the stream. After these two indicators identify the location of the stream on the trophic spectrum, nutrient concentrations in the stream are evaluated. The response to nutrient inputs varies from stream to stream so using nutrient concentrations as an assessment endpoint is not always effective. However, if elevated nutrients are present, the risk of eutrophication increases. The sites are assessed following this logic and sites demonstrating eutrophication are identified.

The upper Mill Creek watershed is characterized by urban drainage and prevalence of point sources. East Fork Mill Creek at RM 0.76, Town Run at RM 0.67, and Mill Creek downstream from the East Fork confluence all have upstream wastewater discharges and an abundance of nutrients, with total phosphorus and nitrate+nitrite-N levels well above the recommended in-stream targets (Figure 15). Sites assessed on East Fork Mill Creek show a sharp increase in nutrient concentrations upstream to downstream, but similar benthic chlorophyll-*a* numbers and a decrease in D.O. swings. The Upper Mill Creek WRF contribution to flow between these sites creates vastly different conditions downstream, where the waterway is considerably deeper and, therefore, has less light available in the benthic zone. The downstream site is also cooler, with maximum temperatures dropping from 26.3 °C (RM 1.85) to 23.4 °C (RM 0.76). Stream depth, moderate shading, and cooler water temperatures decrease the potential for benthic algal growth and ameliorate some effects of added nutrients.

In the mainstem of Mill Creek, nutrient concentrations increase considerably downstream from its confluence with East Fork Mill Creek. The deep, cool, shaded conditions present in East Fork Mill Creek are also present in the mainstem at RMs 18.69 and 17.61, where benthic chlorophyll-*a* concentrations are right on the low/moderate threshold. The substrates at these sites are mostly sandy with some gravel, making representative sampling difficult with existing methods. Dissolved oxygen swings at RM 17.61 are above 6.5 mg/L, so benthic sampling may not have captured the full condition at that site. Mill Creek at RM 16.57 has a higher percentage of appropriate substrate (gravel) and is within a wider, shallower stream reach, increasing the potential for algal growth. This is the first site downstream from the Upper Mill Creek WRF that has these growing conditions, and benthic chlorophyll-a values here (615 mg/m^2) are well above the high threshold.

Town Run, like East Fork Mill Creek, is dominated by wastewater and has nutrient levels well above targets. However, the Glendale WWTP on Town Run does not contribute the quantity of water seen on the East Fork, and the stream remains small and shallow. Substrates are primarily sand with some gravel. Where gravel exists, benthic chlorophyll-*a* values are high (375 mg/ m^2). Because these substrates are fairly sparse, high concentrations are not paired with large D.O. ranges.

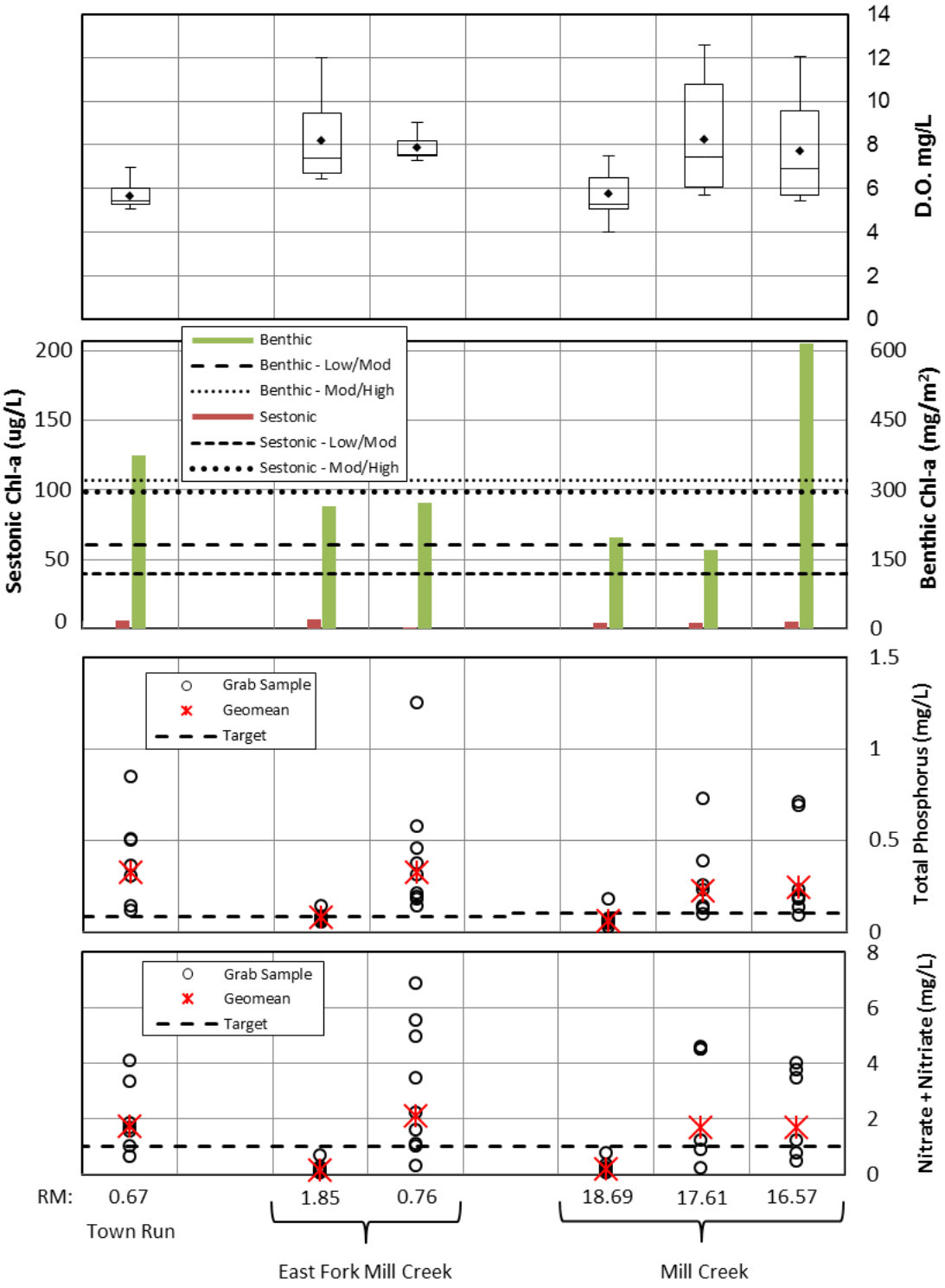


Figure 15. Longitudinal representation of D.O., benthic/sestonic chlorophyll-a, total phosphorus, and nitrate+nitrite-N for a trophic assessment of the upper Mill Creek watershed. Relevant targets for chlorophyll-a and nutrient concentrations are presented on the respective plots.

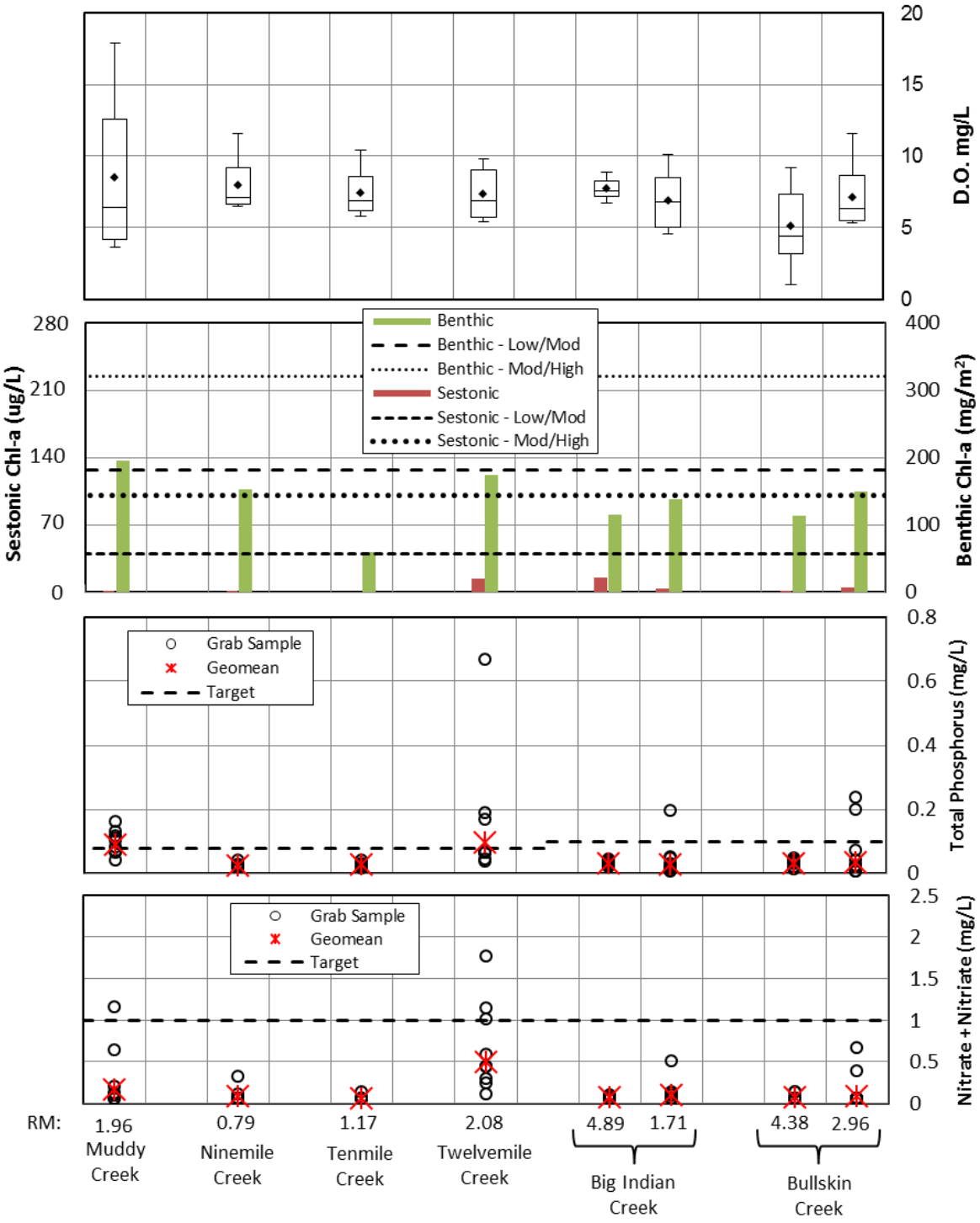


Figure 16. Longitudinal representation of D.O., benthic/sestonic chlorophyll-*a*, total phosphorus, and nitrate+nitrite-N for a trophic assessment of several direct Ohio River tributaries. Relevant targets for chlorophyll-*a* and nutrient concentrations are presented on the respective plots.

Of the remaining streams in the study, most have D.O. swings and chlorophyll-*a* values within the normal/low range. Dissolved oxygen ranges greater than 6.5 mg/L were measured in Bullskin Creek (RM 4.38) and Muddy Creek (Figure 16). Both of these sites have slab/bedrock substrates, high width-depth ratios and very low stream flow during the summer sampling period. The small amount of water per surface area means that a low/moderate level of primary production will have a larger effect on dissolved oxygen concentrations. This is demonstrated by Muddy Creek's D.O. range of 14.3 mg/L while its chlorophyll-a concentration is only 195 mg/m^2.

Surface Water Quality Trends

Ohio EPA previously conducted intensive biological and water quality studies of the Mill Creek basin in 1992, 1997 and 2002. June through September stream flows for 1992, 1997, 2002, and 2014, as measured by the USGS gage station in the Mill Creek at Carthage (RM 10.5), are compared in Figure 17. Daily flows were generally higher in 2014 compared to 2002 and 1997. 1992 had high flows in the same range as 2014, however, the periods of low flow in 1992 were lower. Median flows of 36 cfs (1992), 28 cfs (1997 and 2002) and 34 cfs (2014) were measured for the four-month period (June through September). On specific water chemistry sampling days, the lowest flows occurred in 2002 with respective median and maximum flows of 26.5 cfs and 96 cfs (2002). In the other years, median and maximum flows were 35.5 cfs and 300 cfs (1997), 34 cfs and 1700 cfs (1992), and 41.5 cfs and 548 cfs (2014).

A comparison of 1992, 1997, 2002, and 2014 median water chemistry results for select parameters in the upper Mill Creek basin is presented in Table 14. In the upper Mill Creek mainstem, water samples were collected from four sites in 1992, five sites in 1997 and 2002, and six sites in 2014. There are three sites common to all four surveys (RMs 26.35, 17.61, and 16.57). In East Fork Mill Creek, water samples were collected from four sites in 1997, and five sites in 1992, 2002, and 2014. There were three sites common to all surveys (RMs 1.85, 0.77, and 0.01).

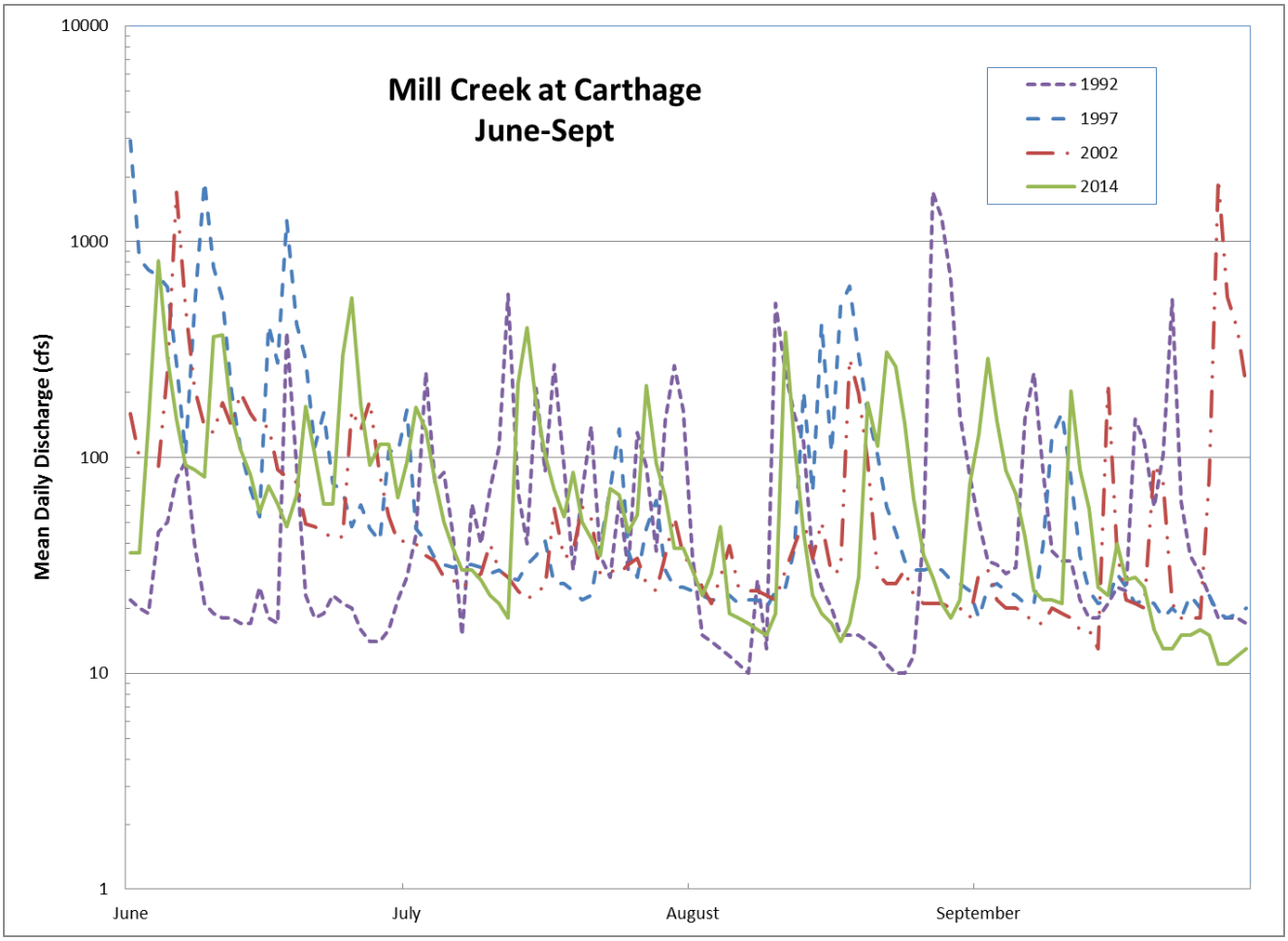


Figure 17. Flow hydrographs (1992, 1997, 2002, 2014) for Mill Creek at Carthage (RM 10.5).

On Town Run, one common site (RM 0.70) was sampled during the 1992, 2002, and 2014 surveys. The site is downstream from the Glendale WWTP discharge, and was characterized by consistently elevated concentrations of ammonia and phosphorus.

In Town Run, total phosphorus concentrations at the site were elevated in all three survey years but decreased from 1.69 to 0.36 mg/l from 2002 to 2014. Nitrate+nitrite-N concentrations were also elevated in all three survey years, but decreased from 4.04 mg/l in 1992 to 1.52 and 1.66 mg/l in 2002 and 2014, respectively. TKN and ammonia-N concentrations were higher in 2002 than 1992 but then decreased appreciably from 2002 to 2014. TKN decreased from 5.7 to 0.70 mg/l, and ammonia-N decreased from 3.35 to 0.08 mg/l, from 2002 to 2014. Much of the improvements in nutrient levels can be attributed to upgrades at the Glendale WWTP.

The 2002 survey reported elevated copper concentrations upstream and downstream from the Glendale WWTP discharge. However, copper levels in Town Run did not exceed the WQS criterion in 2014.

In Mill Creek, nitrogen concentrations increased downstream from the confluence with East Fork Mill Creek and the Butler County Upper Mill Creek WRF discharge (Figure 18).

Table 14. Median nutrient and conductivity results from Ohio EPA surveys, 1992-2014.

Stream / Site Location	RM	Phosphorus (total) (mg/l)				NO3+NO2-N (mg/l)				Total Kjeldahl-N (mg/l)				Conductivity (µmhos/cm)				NH_3-N (mg/l)			
		1992	1997	2002	2014	1992	1997	2002	2014	1992	1997	2002	2014	1992	1997	2002	2014	1992	1997	2002	2014
Mill Creek																					
Liberty Fairfield Rd	26.35	0.04	0.05	0.07	0.04	0.23	0.1	0.33	0.37	0.2	0.2	0.42	0.33	782	776	823	918	0.025	0.025	0.025	0.025
SR 747	22.06	-	-	-	0.06	-	-	-	0.39	-		-	0.42	-	-	-	799	-	-	-	0.04
Rialto Rd	20.98	-	0.14	0.1	-	-	0.44	0.22	-	-	0.26	0.51	-	-	642	461	-	-	0.025	0.025	-
Windisch Rd	19.05	0.16	-	-	-	0.85	-	-	-	0.4	-	-	-	644	-	-	-	0.025	-	-	-
Crescentville Rd	18.69	-	0.28	0.09	0.06	-	0.91	0.27	0.18	-	0.4	0.54	0.38	-	642	515	596	-	0.05	0.06	0.025
UPST confl w/ E Fk Mill Creek	17.96	-	-	-	0.06	-	-	-	0.15	-	-	-	0.37	-	-	-	685	-	-	-	0.025
Kemper Rd	17.61	1.58	1.99	1	0.23	4.29	3.42	0.57	2.86	1.6	0.8	1.98	0.68	944	1032	1250	1353	0.46	0.1	0.31	0.025
Sharon Rd	16.57	1.28	1.28	0.99	0.19	3.97	1.99	1.11	2.35	1.4	0.75	1.85	0.85	921	890	1170	1223	0.34	0.31	0.49	0.05
East Fork Mill Creek																					
Barrett Rd	4.69	0.16	0.14	0.08	-	0.24	0.1	0.12	-	0.4	0.2	0.45	-	656	652	831	-	0.025	0.025	0.025	-
Station Rd	3.78	0.12	-	-	-	0.34	-	-	-	0.4	-	-	-	738	-	-	-	0.025	-	-	-
West Chester Rd	3.19	-	-	0.1	0.09	-	-	0.12	0.18	-	-	0.34	0.37	-	-	819	932	-	-	0.025	0.025
Allen Rd	1.85	0.13	0.19	0.13	0.08	0.38	0.17	0.1	0.12	0.3	0.2	0.39	0.42	705	678	695	874	0.025	0.025	0.025	0.025
UPST Butler Co UMC WRF	1.15	-	-	-	0.07	-	-	-	0.09	-	-	-	0.36	-	-	-	771	-	-	-	0.025
Butler Co Upper Mill Cr WRF effluent	1.07	-	*3.07*	*1.65*	*0.37*	-	*4.8*	*0.41*	*4.44*	-	*1.1*	*1.83*	*1.26*	-	*1220*	*1360*	*1850*	-	*0.17*	*0.15*	*0.025*
Crescentville Rd	0.77	2.99	3.12	1.54	0.31	7.77	3.89	0.32	2.20	2.4	1.05	1.83	1.14	1110	1165	1360	1611	0.67	0.16	0.21	0.025
near mouth	0.01	2.88	2.97	1.65	0.29	7.3	3.76	0.72	4.61	2.5	0.75	2	0.90	1080	1115	1380	1702	0.89	0.14	0.31	0.04
Town Run																					
Upstream Glendale WWTP	0.93	-	-	0.16	-	-	-	0.545	-	-	-	1.03	-	-	-	2585	-	-	-	0.05	-
Glendale WWTP effluent	0.92	-	-	-	*0.45*	-	-	-	*3.44*	-	-	-	*0.79*	-	-	-	*950*	-	-	-	*0.08*
DST Glendale WWTP (Chester Rd)	0.7	1.72	-	1.69	0.36	4.04	-	1.525	1.66	2.5	-	5.7	0.70	890	-	1018	968	1.33	-	3.35	0.08

Table: Median chemical results from Ohio EPA 1997, 2002, and 2014 water quality surveys of the Upper Mill Creek watershed

1997 and 2002 data from 2004 TMDL document

<0.05 ND

concentration greater than target concentration from "Associations" document (0.08 & 1.0 mg/L total P & NO3NO2)

concentration greater than target from 2004 TMDLs (0.25 & 2.5 mg/L total P & NO3NO2)

In 1992, 1997, and 2002, concentrations of ammonia-N recorded in the mainstem Mill Creek increased downstream from the confluence of East Fork Mill Creek (RM 17.95) and remained elevated downstream from the Town Run confluence (RM 16.93) (Table 14). In 2014, ammonia-N concentrations were less than analytical detection limits downstream at Kemper Road and averaged 0.05 mg/l at Sharon Road.

While nitrate-nitrite-N concentrations also increased at RM 17.61 in all survey years and remained at higher levels downstream, concentrations were unusually low in 2002 compared to the other surveys. The reverse was observed for TKN and ammonia-N. In 2002, at RM 17.61 TKN and ammonia-N concentrations were notably higher than in 1997 and 2014.

The same trends in water chemistry results are shown in East Fork Mill Creek as in Mill Creek. Levels are lower in the upper reaches and increase downstream from the Butler County Upper Mill Creek WRF discharge (Figure 19).

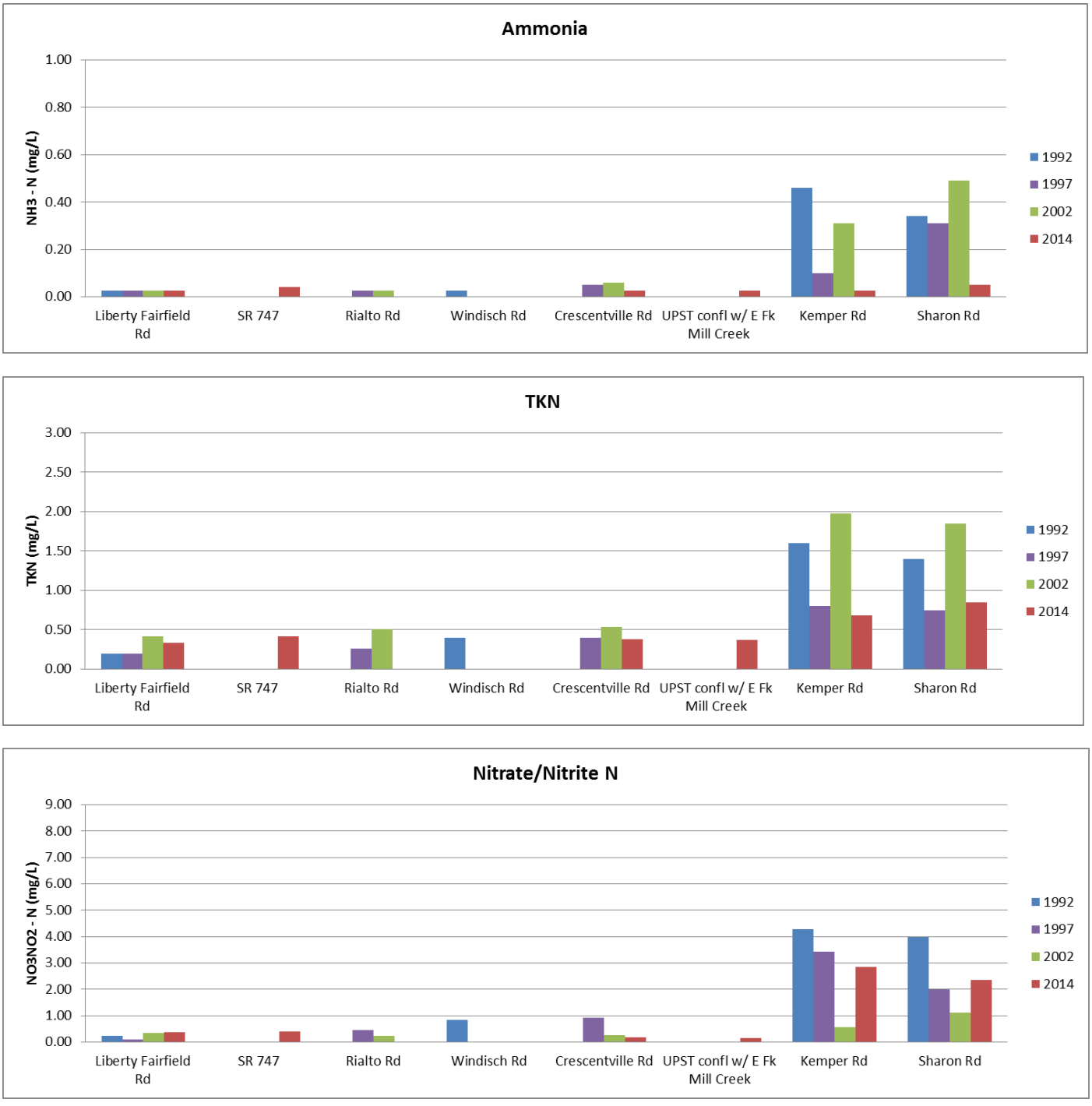


Figure 18. Median nitrogen results from Ohio EPA water quality surveys of the upper Mill Creek mainstem, 1992, 1997, 2002, and 2014.

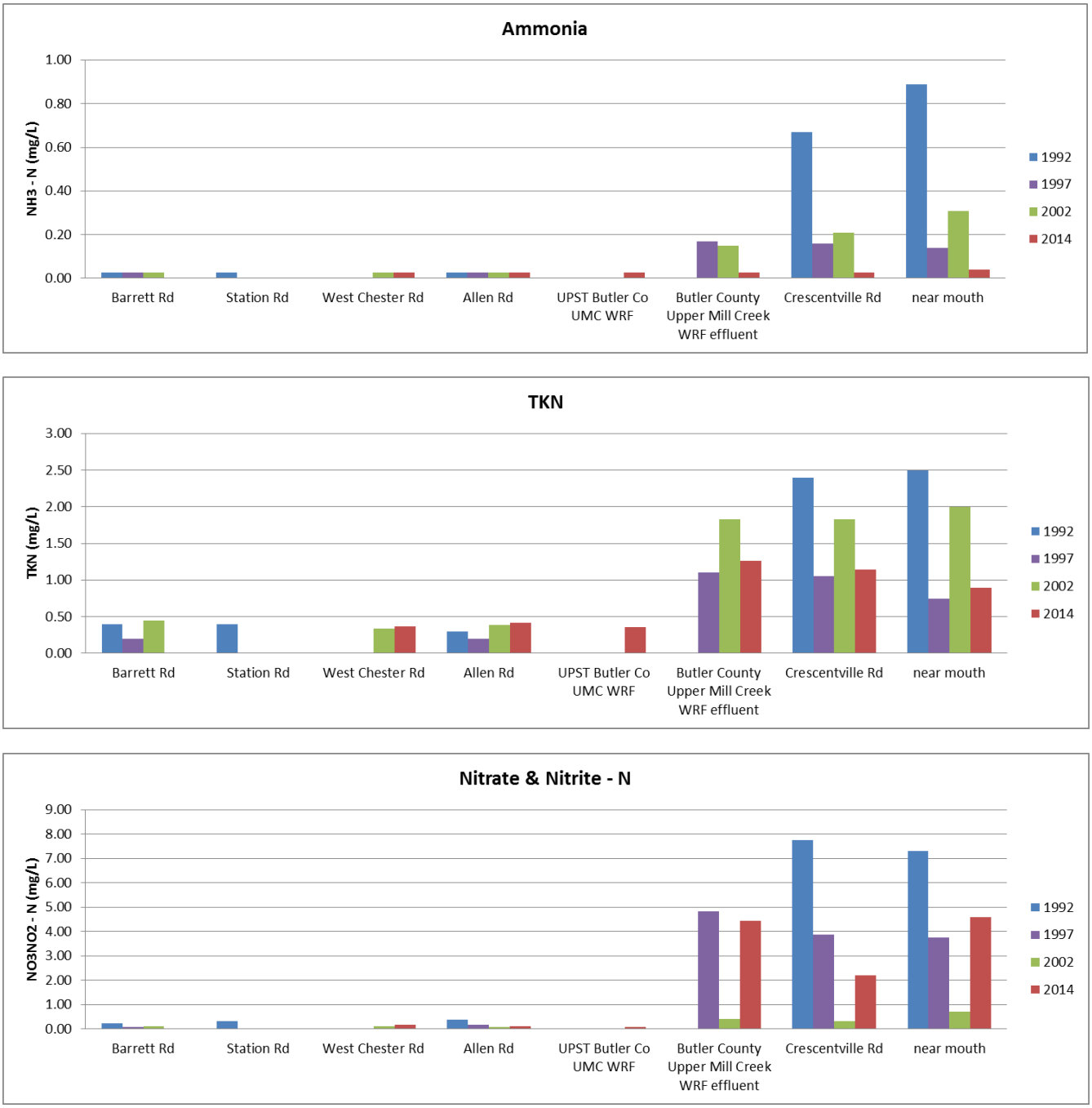


Figure 19. Median nitrogen results from Ohio EPA water quality surveys of the East Fork Mill Creek, 1992, 1997, 2002, and 2014.

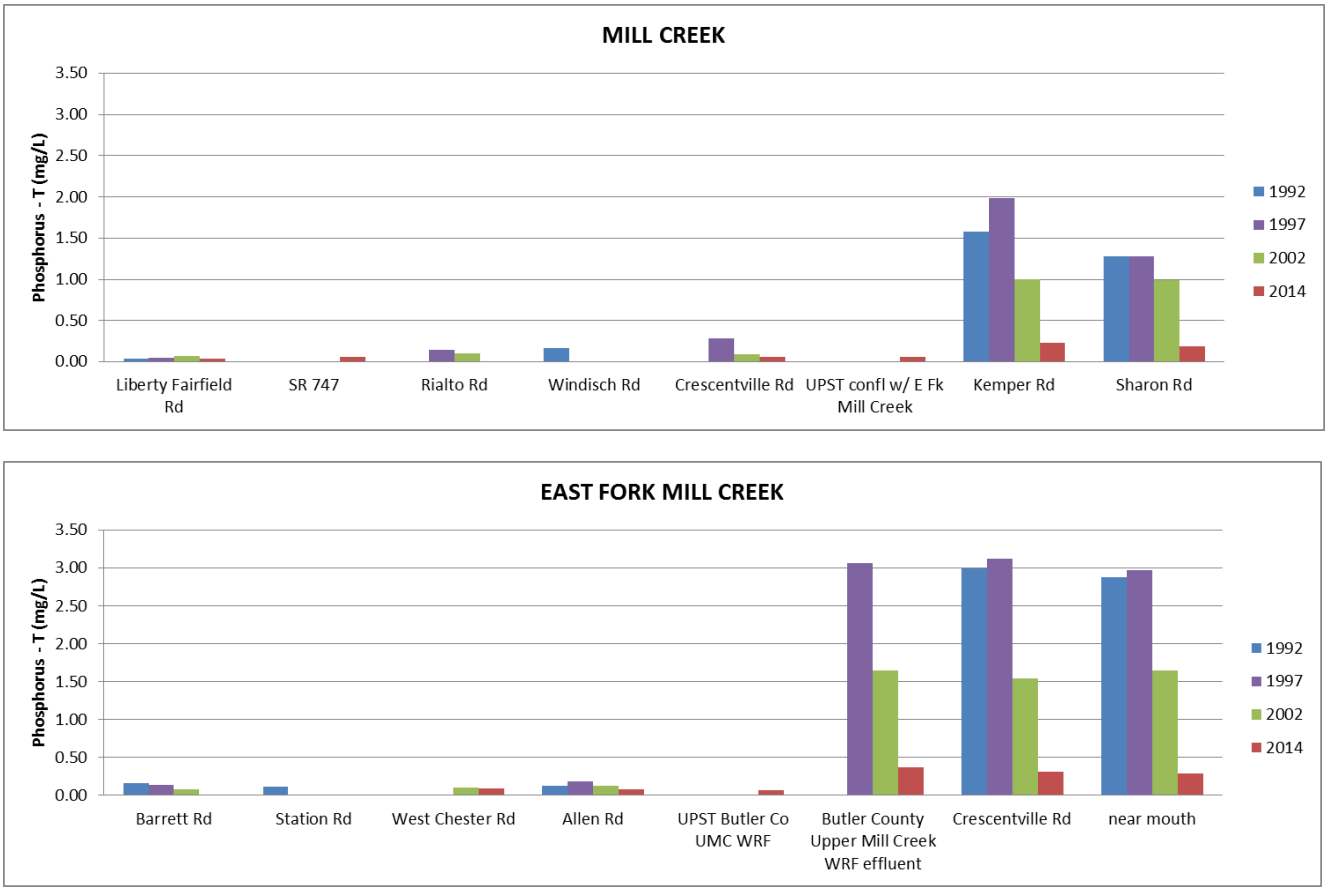


Figure 20. Median total phosphorus results from Ohio EPA water quality surveys in the upper Mill Creek watershed, 1992, 1997, 2002, and 2014.

Phosphorus levels were lower in the upper reaches of East Fork Mill Creek and increased downstream from the Butler County Upper Mill Creek WRF in all four survey years. Likewise, phosphorus levels were lower in the upper reaches of Mill Creek and increased downstream from the confluence with East Fork Mill Creek (and the WRF) in all four survey years. However, in 2014, concentrations downstream from the WRF were almost a magnitude lower than previous years, with median concentrations in Mill Creek at Kemper Road declining from 1.99 mg/l in 1997 to 0.23 mg/l in 2014 (Figure 20).

As can be seen in Table 14, conductivity levels also increased downstream from the Butler County Upper Mill Creek WRF in all four survey years. Conductivity levels are a reflection of TDS (total dissolved solids) concentration. The WWTP was the apparent source since total dissolved solids (TDS) levels were strongly correlated with both sulfate and chloride in the Mill Creek portion of the study area (Figure 21). Had the correlation occurred more strongly with chloride alone, road salt or an industrial discharge might have been a more likely source.

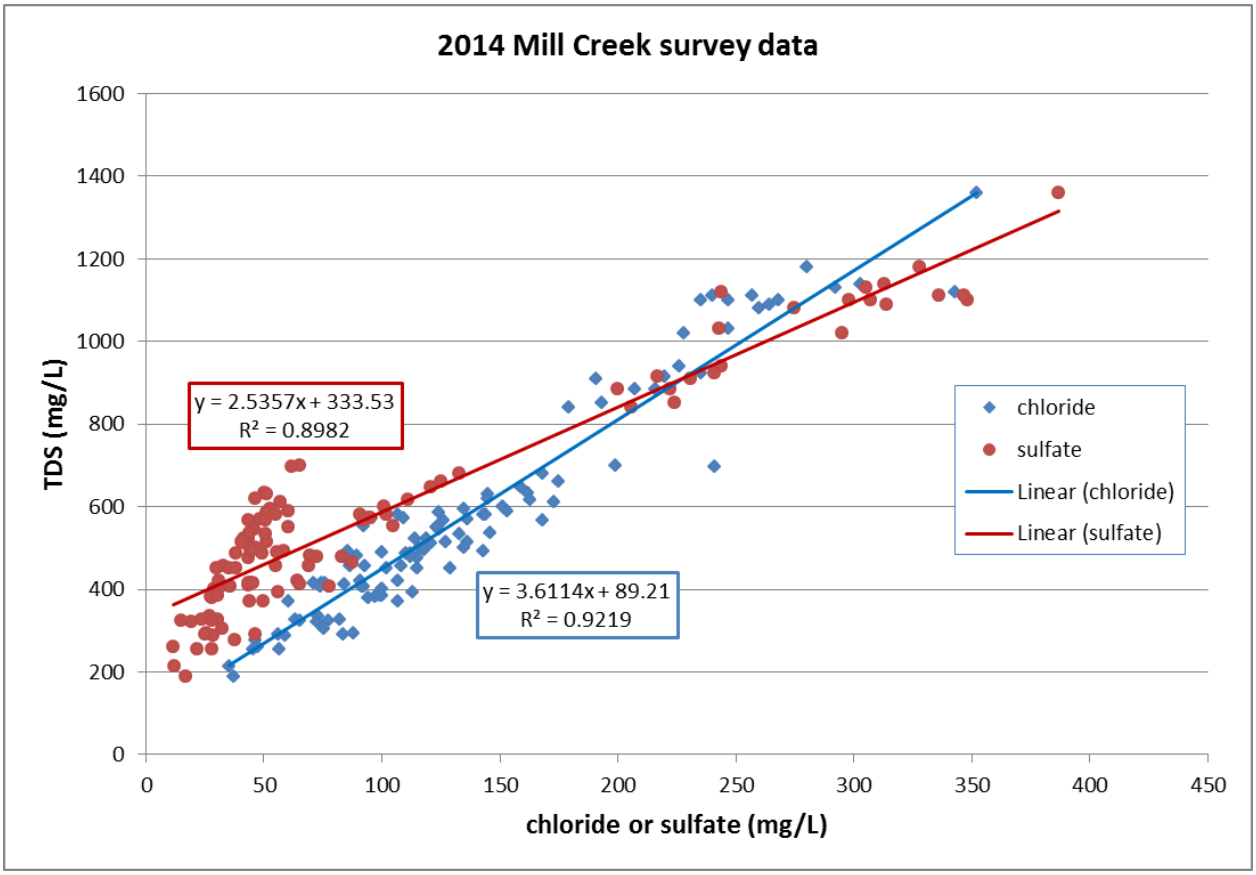


Figure 21. Relationship between total dissolved solids (TDS) and chloride and sulfate ions in the upper Mill Creek watershed, 2014.

Sediment

In summary, sites assessed in the Southwest Ohio River Tributaries study area did not have significant sediment contamination. East Fork Mill Creek near Crescentville at Crescentville Road and Town Run (RM 16.91) downstream from the Glendale WWTP at Chester Road were the most contaminated sediment sites for metals and other inorganic contaminants. For organic parameters, legacy pesticides and their degradation products were found at five sites and low level PCBs were found at two sites. Polycyclic aromatic hydrocarbons (PAHs) were detected at 75% (6/8) of sites, but only three sites had concentrations over the MacDonald Probable Effect Concentration (PEC).

A total of eight surficial sediment samples were collected in the Southwest Ohio River Tributaries study area. Three were collected on the upper Mill Creek mainstem, and one each on Big Indian Creek, Bullskin Creek, Muddy Creek, East Fork Mill Creek, and Town Run. Twelvemile Creek was excluded from sediment sampling by the limited amount of fine grained material present at the site. Samples were analyzed for metals, volatile organic compounds, semi-volatile organic compounds, PCBs, pesticides, and nutrients (Table 15).

Sediment collection involved looking for freshly deposited sediment in the stream bed with a bias toward fine grained material (<60 microns, silt, clay, muck,). Fine grained depositional areas were not a predominant substrate type at any of the sampling locations; however, fine substrates were common

along the river margins. For this reason, depositional zones on both sides of the stream channel were sampled in an attempt to collect a composite sample representative of the stream segment. Samples were collected with a stainless steel scoop and composited in a stainless steel bucket. The samples were placed in the appropriate containers and placed in a cooler at $<6^0$C.

A hierarchy of guidelines is used to evaluate organic compound results. Sediment organic samples were evaluated using the MacDonald Sediment Quality Guidelines (SQG) (2000) and the USEPA Region V RCRA Ecological Screening Levels (ESL) (USEPA 2003). MacDonald SQGs are consensus-based sediment guidelines designed to evaluate eco-toxic effects. The USEPA Region V RCRA ESLs are considered protective benchmarks. The MacDonald PEC evaluates the most contaminated organics and indicates that adverse effects are likely to occur in benthic sediments. The RCRA ESL evaluates the lesser contaminated sediment results to determine if the level of contamination meets or exceeds the protective benchmark.

Ohio Specific Sediment Reference Values (SRVs) were developed as guidelines by Ohio EPA to identify representative background sediment metal concentrations for lotic water bodies (Ohio EPA 2003). Sediment samples were collected from reference sites throughout the state that have been used historically to develop the biological criteria as part of the Ohio WQS. These reference sites were selected as being representative of the least impacted conditions in the watershed. SRVs are site-specific background metal concentrations based on ecoregion and identify whether a site has been contaminated. SRVs are not codified as criteria in the Ohio Water Quality Standards.

Sediment metal samples were evaluated using the Ohio SRV and the MacDonald SQG. Sediment metals detected between the MacDonald Threshold Effect Concentration (TEC) and PEC, but below the Ohio SRV will defer to Ohio's SRV. This will apply to arsenic, cadmium, copper and nickel. Sediment metals exceeding the MacDonald PEC (adverse effects usually or always occur) are referenced in Table 15.

Sediment nutrients

The sediment ammonia guideline (100 mg/kg) is the Ontario open water disposal guidelines equivalent to the lowest effect level (Persuad 1993). The sediment phosphorus guideline (2000 mg/kg) is the Ontario open water disposal guideline equivalent to the severe effect level, causing disturbances in the benthic community. Both guidelines were developed for harbors and are used only for reference in this document. The comparison of lake sediment toxicity to river sediment toxicity is not equivalent, but is still used in lieu of any criterion established for stream sediment.

Elevated ammonia above the Ontario open water sediment disposal guideline of 100 mg/kg was common throughout the study area in 2014. The ammonia averaged 173.25 mg/kg with 87.5% of individual samples over the guideline. Rainfall was above average for Cincinnati in 2014, with July recording 7.54 inches of rain compared to the average of 3.86 inches (WeatherDB 2015). Runoff from agricultural sources likely contributed to some of the ammonia issues in 2014. The highest sediment ammonia in the survey was recorded in Big Indian Creek at Point Pleasant at St. Rt. 756.

Seventy-five percent of the sediment phosphorus results were above the Ontario open water disposal guideline of 2000 mg/kg, with the highest reported result (3400 mg/kg) at the sampling location on Town Run (RM 16.91). This location is located downstream from the Glendale WWTP, which likely contributed to the high phosphorus result.

Sediment Metals

Glacial outwash and tills make up much of the sediments in the Southwest Ohio River Tributaries study area. The parent rock is limestone with varying amounts of calcium and magnesium. As might be expected, calcium and magnesium levels over the Ohio SRV were detected in sediments from some of the sites sampled. Calcium was detected over the Ohio SRV in 37.5% (3/8) of sites and magnesium was detected over the Ohio SRV in 12.5% (1/8) of the sites. Manganese and strontium were found in sediment at Mill Creek at Sharonville Road in levels slightly above the Ohio SRV levels.

Sediment Organic Chemicals

Dieldrin

Dieldrin is a persistent organic pollutant that bioaccumulates in the environment. Dieldrin was used alone as an insecticide but can also be the toxic oxidation byproduct of aldrin (used as a termiticide). Dieldrin was banned from use in the United States in 1974 and aldrin was banned from use in 1987. Dieldrin was found in sediments at one site in the study area. Dieldrin was detected in the "not protective" range of the ESL in Town Run (RM 16.91), downstream from the Glendale WWTP, meaning the concentration found may be harmful to aquatic life. Its presence in the sediment may be legacy contamination.

PAHs

PAHs are the most common organic compounds found in sediments in the Southwest Ohio River Tributaries study area. PAHs represent a large class of suspected carcinogens that are freely discharged into the environment. Miles of PAH-laden bitumen act as a binder in asphalt roads. Coal tar emulsion-based sealers consisting of 50% PAH compounds that would otherwise be classified as a hazardous waste (KO87) are routinely applied to driveways and parking lots as a topical coating in the watershed. Internal combustion engines release PAHs into the air as incomplete combustion by-products of burning hydrocarbons. Crankcase oil leaked from these engines contains PAHs. Atmospheric deposition of PAHs from home heating fires and coal power plants also are large contributors. All these PAH sources make their way into storm water draining into the rivers in the study area. PAHs were detected at six of the eight sediment sites (Table 15). Three of those six sites had PAH sediment concentrations over the MacDonald PEC. These sites were located in urban or industrial areas where these compounds are more likely to be present in storm water. The high concentration of PAHs may suggest the overall need for better storm water management in lieu of any effects on aquatic life.

DDT

Dichlorodiphenyltrichloroethane (DDT) was banned from use in the United States in 1972. This pesticide was used extensively in agriculture starting in 1950 and peaked in use by 1959. There are three types of DDTs- the parent compound DDT and the degradation byproducts of dehalogenation (DDD and DDE). DDT and DDD were detected in Mill Creek sediments near Crescentville, and DDE was detected in Town Run sediments at RM16.91. The values at both of these sites were above the USEPA ESL protective benchmark but below the MacDonald PEC.

Table 15. Chemical parameters measured above screening levels in samples collected by Ohio EPA from surficial sediments in the Southwest Ohio Rivers Tributaries study area, 2014. Contamination levels were determined for parameters using Ohio Sediment Reference Values (SRVs, 2008), consensus-based sediment quality guidelines (MacDonald, et.al. 2000) and ecological screening levels (USEPA 2003). Shaded numbers indicate values above the following: SRVs (blue), Threshold Effect Concentration –TEC (yellow), Probable Effect Concentration – PEC (red) and Ecological Screening Levels (orange).

Parameter	MILL CREEK AT SHARONVILLE @ SHARON	MILL CREEK NE OF GLENDALE @ KEMPER	MILL CREEK NEAR CRESCENTVILLE @	BIG INDIAN CREEK AT POINT PLEASANT	BULLSKIN CREEK @ FELICITY CEDRON	MUDDY CREEK NEAR CINCINNATI	E. FK. MILL CREEK NEAR CRESCENTVILLE @	TOWN RUN (16.91) DST. GLENDALE WWTP @
Aluminum (mg/kg)	7740	6250	7710	11200	6810	11500	5080	5580
Arsenic (mg/kg)	4.42	4.47	5.69	4.43	5.39	7.01	5.29	5.34
Barium (mg/kg)	54	59.4	64.1	88.1	70.6	57.2	42.3	70.8
Calcium (mg/kg)	128000	72200	52200	67600	24500	107000	271000	131000
Cadmium (mg/kg)	0.593	0.42	0.455	0.334	0.426	0.433	0.439	0.542
Chromium (mg/kg)	18.8	11	10.1	12.5	10.8	15	18.4	9.64
Copper (mg/kg)	13.4	13.1	10.1	12	7.43	0.7	10.7	23.3
Iron (mg/kg)	19300	14000	15200	21900	16400	28800	15000	12800
Lead (mg/kg)	16.1	14.8	21.6	13.8	12.3	23.1	20.3	26.5
Magnesium (mg/kg)	24200	18700	11400	5310	4020	6900	31700	46800
Manganese (mg/kg)	729	483	536	1140	743	726	826	612

Parameter	MILL CREEK AT SHARONVILLE @ SHARON	MILL CREEK NE OF GLENDALE @ KEMPER	MILL CREEK NEAR CRESCENTVILLE @	BIG INDIAN CREEK AT POINT PLEASANT	BULLSKIN CREEK @ FELICITY CEDRON	MUDDY CREEK NEAR CINCINNATI	E. FK. MILL CREEK NEAR CRESCENTVILLE @	TOWN RUN (16.91) DST. GLENDALE WWTP @
Mercury (mg/kg)	0.05	<0.043	0.038	<0.046	0.027	0.038	<0.053	0.086
Nickel (mg/kg)	32	12.7	10.3	17	9.7	15.9	15.4	12.6
Potassium (mg/kg)	<1430	<1500	<986	1630	<1200	2730	<1870	<1580
Selenium (mg/kg)	<1.43	<1.50	<0.99	<1.62	<1.20	<1.07	<18.7	<1.58
Sodium (mg/kg)	<3560	<3750	<2460	<4060	<3010	<2690	<4670	<3960
Strontium (mg/kg)	204	105	94	105	51	283	466	128
Zinc (mg/kg)	76.4	98.8	69.4	65.8	40.3	86.5	73.1	109
2-Acetylamino fluorine (mg/kg)	0.59							
4, 4'-DDD (µg/kg)			14.0					
4,4'-DDE (µg/kg)								11.1
4,4'-DDT (µg/kg)			38.0					
Alpha-Chlordane (µg/kg)								19.2

Parameter	MILL CREEK AT SHARONVILLE @ SHARON	MILL CREEK NE OF GLENDALE @ KEMPER	MILL CREEK NEAR CRESCENTVILLE @	BIG INDIAN CREEK AT POINT PLEASANT	BULLSKIN CREEK @ FELICITY CEDRON	MUDDY CREEK NEAR CINCINNATI	E. FK. MILL CREEK NEAR CRESCENTVILLE @	TOWN RUN (16.91) DST. GLENDALE WWTP @
Benz[a] anthracene (mg/kg)		1.41				1.12		2.32
Benzo[b] fluoranthene (mg/kg)	0.67							
Benzo[a] pyrene (mg/kg)		1.86				0.99		2.93
Benzo[b] fluoranthene (mg/kg)		2.6				1.09		3.31
Benzo[g,h,i] perylene (mg/kg)		1.78				0.76		2.48
Benzo[k] fluoranthene (mg/kg)		1.68				1.01		2.36
Chrysene (mg/kg)	0.70	2.43				1.45	0.57	3.31
Dieldrin (µg/kg)								11.7
Fluoranthene (mg/kg)	1.47	4.47	0.91			3.3	1.19	7.51
Gamma-Chlordane (µg/kg)	8.7					9.4		22.4

Parameter	MILL CREEK AT SHARONVILLE @ SHARON	MILL CREEK NE OF GLENDALE @ KEMPER	MILL CREEK NEAR CRESCENTVILLE @	BIG INDIAN CREEK AT POINT PLEASANT	BULLSKIN CREEK @ FELICITY CEDRON	MUDDY CREEK NEAR CINCINNATI	E. FK. MILL CREEK NEAR CRESCENTVILLE @	TOWN RUN (16.91) DST. GLENDALE WWTP @
Indeno[1,2,3-cd]pyrene (mg/kg)		1.47						2.02
Penta chlorophenol (mg/kg)		1.41						
Phenanthrene (mg/kg)		1.49				1.27		2.73
Pyrene (mg/kg)	1.11	3.52	0.73			2.6	0.95	5.48
PCB-1254 (µg/kg)	791							110
PCB-1260 (µg/kg)	66.9							
NH_3-N	120	230	140	300	210	56	110	220
TOC(%)	3.7	3.4	2.2	2.9	1.4	2.1	2.5	5.7
pH (SU)	7.5	7.8	7.4	7.4	7.4	7.6	8	7.4
P-T	2040	2520	3280	1250	1300	2770	621	3400
%FGM	49.5	52.1	63.8	49.5	63.6	66	42	46.4

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column. New revisions to the recreation use rules in Ohio became effective on January 4, 2016. However, as sampling to assess the recreation use for the Southwest Ohio River Tributaries study area was designed and carried out when the previous rules were in effect, the assessment of data and determination of recreation use attainment status provided in this section were based on the prior rules.

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

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

Most of the streams of the Southwest Ohio River Tributaries study area evaluated in this survey are designated with the Primary Contact Recreation (PCR) use in OAC Rules 3745-1-17 and 3745-1-30. The exception is Rapid Run which is designated with the Secondary Contact Recreation (SCR) use. Water bodies with a designated recreational use of PCR "...are waters that, during the recreation season, are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking and SCUBA diving" [OAC 3745-1-07 (B)(4)(b)]. There are three classes of PCR use to reflect differences in the potential frequency and intensity of use. Streams designated PCR Class A typically have identified public access points and support, or potentially support, primary contact recreation. Streams designated PCR Class B support, or potentially support, occasional primary contact recreation activities. Streams designated PCR Class C support, or potentially support, infrequent primary contact recreation activities such as, but not limited to, wading. All streams assessed for recreation use during this survey, other than Rapid Run, are designated Class B PCR waters. Water bodies with a designated recreational use of SCR " are waters that result in minimal exposure potential to water borne pathogens because the waters are: rarely used for water based recreation such as, but not limited to, wading; situated in remote, sparsely populated areas; have restricted access points; and have insufficient depth to provide full body immersion, thereby greatly limiting the potential for water based recreation activities" [OAC 3745-1-07 (B)(4)(c)]. The *E. coli* criteria that apply to PCR Class A, B, or C streams include a geometric mean criterion of 126, 161, or 206 colony forming units (cfu)/100 ml, respectively, to

be met during the recreation season. The *E. coli* criterion that applies to SCR streams includes a geometric mean of 1030 cfu/100 ml to be met during the recreation season. The geometric mean is based on two or more samples and is used as the basis for determining attainment status when more than one sample is collected.

Summarized bacteria results are listed in Table 16. Twenty-nine locations in the Southwest Ohio River Tributaries study area were sampled for *E. coli* eight to thirteen times, from May 15th-October 8th, 2014. Evaluation of *E. coli* results revealed that 14 of the 29 locations attained the applicable geometric mean criterion, and, thus, were in full attainment of the recreation use. The highest exceedance of the bacteria criterion was collected from a Tenmile Creek sample at RM 1.18, with a geometric mean value of 2317 cfu/100 ml.

Bullskin Creek and its tributaries, along with Twelvemile, Tenmile and Ninemile creeks, lay in watersheds that are mostly forest and agriculture, and are not serviced by centralized sewage treatment systems. Sources of *E. coli* contamination in these areas can be attributed to pasture and cropland runoff, with agricultural activities possibly including land application of manure and biosolids as well as livestock production. These areas also contain failing HSTS as well as discharging systems. Tenmile and Ninemile creeks are in slightly more urban areas, and urban runoff may also be a contributing factor to the non-attainment in those creeks.

The causes of non-attainment in the upper Mill Creek watershed and Muddy Creek sampling areas are most likely urban runoff and overflows. In the upper Mill Creek, Metropolitan Sewer District of Greater Cincinnati (MSDGC) has three SSOs, located upstream from Town Run and Sharon Road. In Muddy Creek, MSDGC also has three CSOs, four SSOs, and four PSOs. Along with BOD, COD and nutrients, these SSOs, CSOs and PSOs are known to contribute fecal bacteria to the streams. Discharging HSTS are also located in the Muddy Creek area. All MSDGC overflows are being addressed under a Consent Decree with U.S. EPA and Ohio EPA. CSOs are also covered under NPDES permit 1PX00022.

Table 16. A summary of *E. coli* data for locations sampled in the Southwest Ohio River Tributaries study area, May 15-October 8, 2014. Recreation use attainment is based on comparing the recreation season geometric means to the applicable Primary Contact Recreation (PCR) Class B or Secondary Contact Recreation criteria.

Location	River Mile	Recreation Use*	# of Samples	Geometric Mean†	Maximum Value	Recreational Attainment Status	Potential Source(s) of Bacteria
HUC 050902011103							
West Branch Bullskin Creek	4.65	PCR Class B	9	200	48400	No	Multiple
West Branch Bullskin Creek	0.59	PCR Class B	9	195	1730	No	Multiple
Middle Branch Bullskin Creek	0.5	PCR Class B	9	40	24100	Yes	N/A
HUC 050902011104							
Bullskin Creek	2.96	PCR Class B	12	218	48400	No	Multiple
East Branch Bullskin Creek	4.7	PCR Class B	9	212	2420	No	Multiple
HUC 050902011106							
Bear Creek	1.72	PCR Class B	8	164	488	No	Multiple
Maple Creek	1.62	PCR Class B	10	148	326	Yes	
Clermont Co. Felicity WWTP Outfall	0.65	PCR Class B	4	198	579	N/A	WWTP
HUC 050902011107							
Little Indian Creek	0.85	PCR Class B	8	98	387	Yes	N/A
HUC 050902011201							
Big Indian Creek	4.89	PCR Class B	12	139	12300	Yes	N/A
HUC 050902011202							
Big Indian Creek	1.71	PCR Class B	9	47	248	Yes	N/A
North Fork Indian Creek	0.93	PCR Class B	9	145	687	Yes	N/A
HUC 050902011203							
Boat Run	0.2	PCR Class B	9	68	980	Yes	N/A
HUC 050902011204							
Twelvemile Creek	2.08	PCR Class B	12	340	11600	No	Multiple
HUC 050902011206							
Tenmile Creek	1.18	PCR Class B	9	2317	260000	No	Multiple
HUC 050902011208							
Ninemile Creek	0.79	PCR Class B	8	640	219000	No	Multiple
Clermont County Ninemile Creek WWTP 001 Outfall	0.19	N/A	9	59	649	N/A	N/A

Location	River Mile	Recreation Use*	# of Samples	Geometric Mean†	Maximum Value	Recreational Attainment Status	Potential Source(s) of Bacteria
Eightmile Creek	0.2	PCR Class B	9	51	694	Yes	N/A
HUC 0902030101							
Mill Creek	26.35	PCR Class B	9	150	6900	Yes	N/A
Mill Creek	18.69	PCR Class B	12	483	8210	No	Urban Runoff/ Storm Sewers
Butler Co. Upper Mill Creek Regional WWTP 001 Outfall	1.07	N/A	9	12	27.5	N/A	N/A
East Fork Mill Creek	0.76	PCR Class B	13	385	4490	Yes	N/A
HUC 050902030103							
Mill Creek	17.61	PCR Class B	10	272	3110	No	
Mill Creek	16.57	PCR Class B	9	604	8700	No	
Glendale WWTP 001 Outfall	0.92	N/A	9	10	95.9	N/A	N/A
HUC 050902030202							
Rapid Run	0.70	SCR	9	61	1410	Yes	N/A
HUC 050902030203							
Muddy Creek	5.4	PCR Class B	9	835	968000	No	CSO/ Discharging Systems
Muddy Creek	1.96	PCR Class B	13	876	48400	No	CSO/ Discharging Systems

* -Recreation class may include primary contact recreation classes (PCR A, B or C); bathing waters (BW); or secondary contact recreation (SCR).

† -Attainment status is determined based on the seasonal geometric mean. The status cannot be determined at locations where fewer than two samples were collected during the recreation season.

N/A- WWTPs are not evaluated in terms of attainment or non-attainment.

Inland Lakes Monitoring

The Ohio EPA inland lakes monitoring and assessment strategy focuses on evaluating chemical conditions near the surface and physical conditions in the water column of inland lakes. Physical profile measurements are summarized either for the entire water column or the epilimnion depending on thermal stratification. The sampling target consists of an even distribution of a total of ten sampling events divided over a two-year period and collected during the index period of May 1 – September 30. Key parameters used to determine the attainment status of lakes include chlorophyll-*a*, ammonia-N, dissolved oxygen, pH, total dissolved solids and various metals. Other parameters used to evaluate the degree of support or non-support includes Secchi depth, total phosphorus and total nitrogen. Details of the sampling protocol are outlined in *Inland Lakes Sampling Procedure Manual*, Appendix 1 of the *Surface Water Field Sampling Manual (for water quality parameters and flows)* (Ohio EPA 2013), available at http://epa.ohio.gov/Portals/35/documents/Lake_Sampling_Procedures.pdf

Presently, lakes in Ohio are designated as Exceptional Warmwater Habitat (EWH) with respect to the aquatic life habitat use designation. Revisions to Ohio's WQS that would change the aquatic life use from EWH to Lake Habitat (LH) were proposed for adoption in December, 2011, but were subsequently withdrawn. Specific details concerning the progress of revisions to Ohio's Water Quality Standards involving the proposed Lake Habitat aquatic life use and associated criteria can be found at http://www.epa.ohio.gov/dsw/rules/draftrules.aspx as information becomes available. Chemical criteria specific to the LH aquatic life use for the previously-proposed Water Quality Standards rules are presented in the 2012 Integrated Report available at http://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Winton Lake (Latitude 39.26085; Longitude -84.50928)

A water quality survey of Winton Lake was conducted by Ohio EPA in 2013 and 2014 as a part of the Division of Surface Water's Inland Lakes Monitoring Program. Winton Lake has a surface area of 183-acre (74 ha) with approximately eleven miles of shoreline. The lake is owned by the Army Corp of Engineers and is leased to Great Parks of Hamilton County (previously the Hamilton County Park District). The lake is located in Hamilton County at 1025 Winton Rd, Cincinnati, Ohio 45231. Winton Lake is located within the Interior Plateau (Northern Bluegrass) ecoregion.

The lake is situated in Winton Woods Park, approximately four miles west of the city of Sharonville and I-75, approximately 12 miles north of the city of Cincinnati and 10 miles southeast of the city of Hamilton (Figure 22). The West Fork of Mill Creek, which is the primary stream that feeds Winton Lake, originates near the intersection of Galbraith Road and Colerain Avenue in Hamilton County. The approximately 30 square mile watershed for Winton Lake is largely comprised of residential areas interspersed with typical commercial retail areas. The park provides an array of recreational activities including boating, fishing, a Frisbee golf course, fitness trail, picnicking, two golf courses, a marina, a campground, and a 100-acre demonstration farm.

History and Description

Winton Lake, formerly West Fork Mill Creek Lake and also known as Winton Woods Lake, came into being when the U.S. Army Corps of Engineers (Louisville District) completed construction of the flood control dam in 1952. Lake depth can vary from about 12 to 20 feet depending on storm water flow into the lake, with the deepest parts generally in the historic stream channel that also defines the generally sinuous

nature of the lake. Winton Lake exists as a cooperative management effort between the Army Corp of Engineers and Great Parks of Hamilton County.

The lake features a boathouse for rentals of rowboats, pedal boats, motorboats, pontoon boats, canoes, kayaks and stand-up paddleboards. Private motorboats are not permitted but motors up to six horsepower can be used with rental boats.

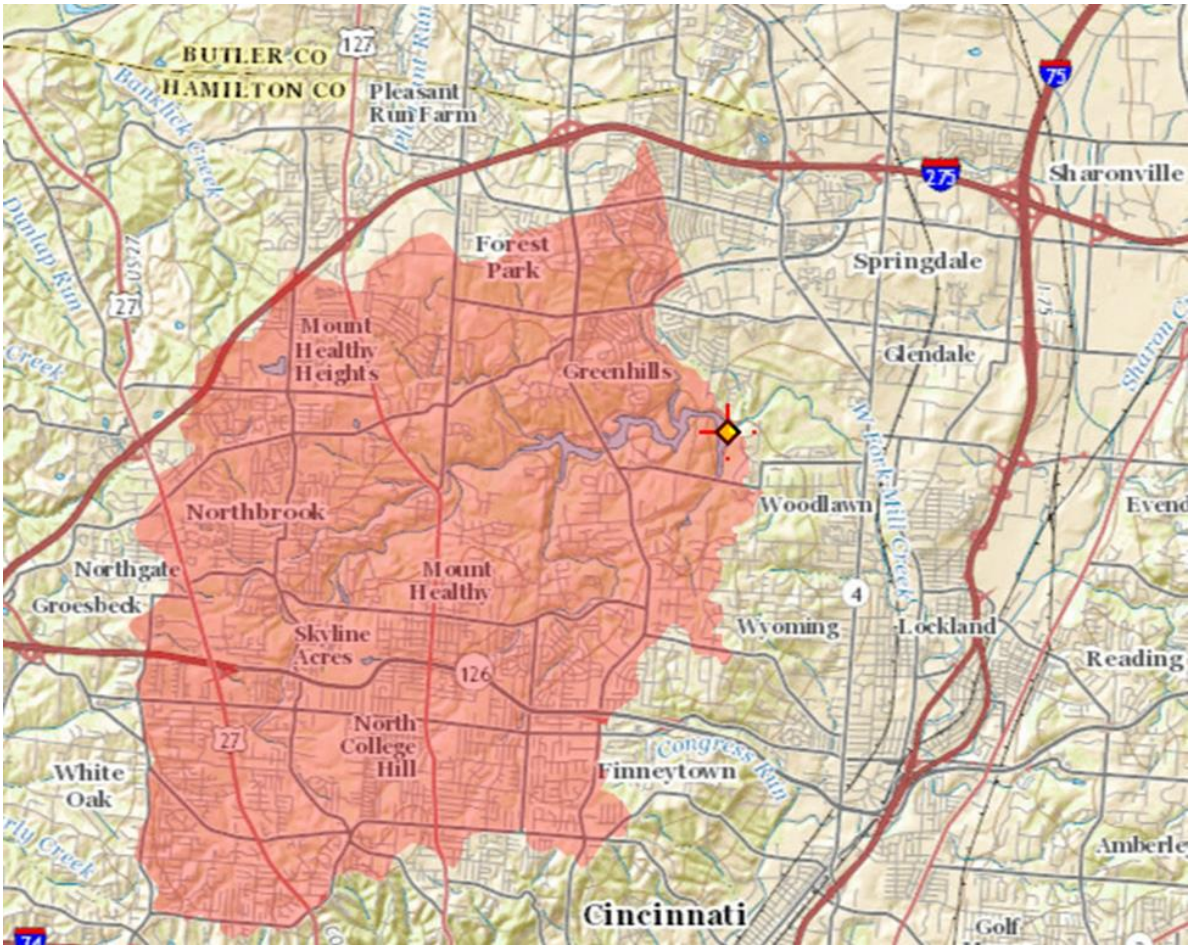


Figure 22. Drainage area tributary to Winton Lake (from USGS StreamStats).

Residence Time Index (RTI) is used to differentiate linear, more riverine (lotic) systems from rounder, more lacustrine (lentic) systems. The RTI is derived by dividing the surface area of an impounded body of water by its associated drainage area (both in square miles) and then multiplying the quotient by 1,000. In general, RTI values ≥0.5 are considered to be lentic systems (lakes) and RTI values <0.5 are considered to be lotic "run of river" impoundments. Winton Lake has an RTI of 9.53.

Great Parks of Hamilton County stocks the lake annually. Species include blue, shovelhead and bullhead catfish, as well as pan fish and fingerling stockings of largemouth bass and yellow perch. Channel catfish are stocked in the summer. In March and October, when cooler water temperatures provide increased dissolved oxygen content throughout the water column, the lake is stocked with rainbow trout.

Rehabilitation of an approximately 65-year old aerial sanitary sewer at several places on the lake began over the course of the study period from 2013 to 2014. The existing aerial sewer began to fail in several places along the run that cuts through Winton Woods. The rehabilitation work involved the use of land and water-based equipment, including barges, cranes and tow boats. The project replaced sewer segments consisting of two 60-inch diameter aerial crossings totaling approximately 1,000 linear feet, a 300 foot, 48-inch diameter aerial section, and a 30-inch aerial section approximately 220 feet long. The project also provided reinforcement of the existing support structures.

Water Quality

Water samples were collected at one location near the dam at station L-1 (Lat. 39.26, Long. -84.50). Water chemistry samples were collected at L-1 five times both in 2013 and 2014, and bacteria samples were collected five times each in 2013 and 2014 near the dock of the campground (Figure 23). Also, sediment grab samples were collected one time each in 2013 and 2014 at the L-1 site.

Bacteria sample results exceeded the recreation use criteria for Primary Contact Recreation in May and July of both 2013 and 2014, but the two-year geometric mean of all results met the LH criteria.

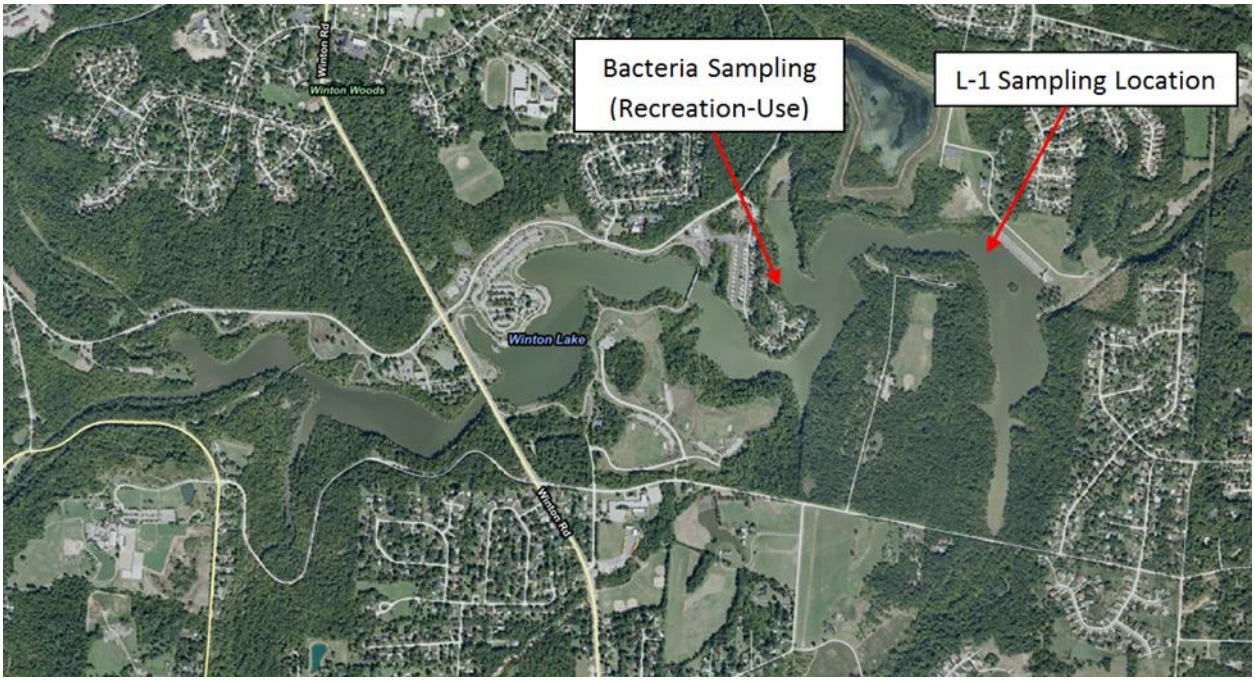
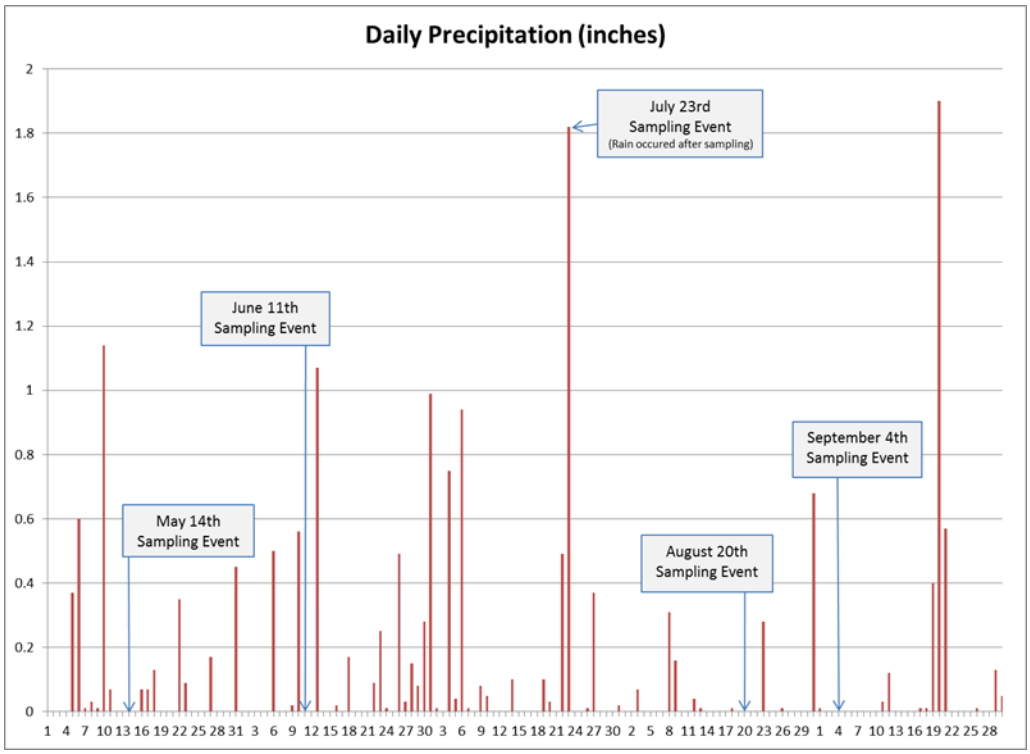


Figure 23. Winton Lake bacteria and water quality sampling locations, 2013 and2014 (Arial imagery courtesy of ESRI).

Inconsistent rainfall in the region made it difficult to determine the effects of storms on the water chemistry during both sampling seasons. Total rainfall amounts during the lake survey period yielded approximately 22 inches in 2013 and approximately 19 inches in 2014. NOAA's historical average monthly rainfall total for May through September is approximately 20 inches and the average monthly rainfall for the period is approximately 4 inches. Figure 24 shows rainfall data from the Butler County Regional Airport weather station relative to sampling dates.

Secchi readings ranged from 0.31-0.60 meters with a median value of 0.42 meters for the study period. All readings were significantly less than the proposed minimum criterion of 1.19 meters. Without good

correlation between Secchi readings and chlorophyll-*a* results, turbidity likely is associated with sediment inflow during rain events and sediment resuspension characteristic to shallow lakes. Recreational boating likely is not a causative factor as boat motor horsepower is restricted and private



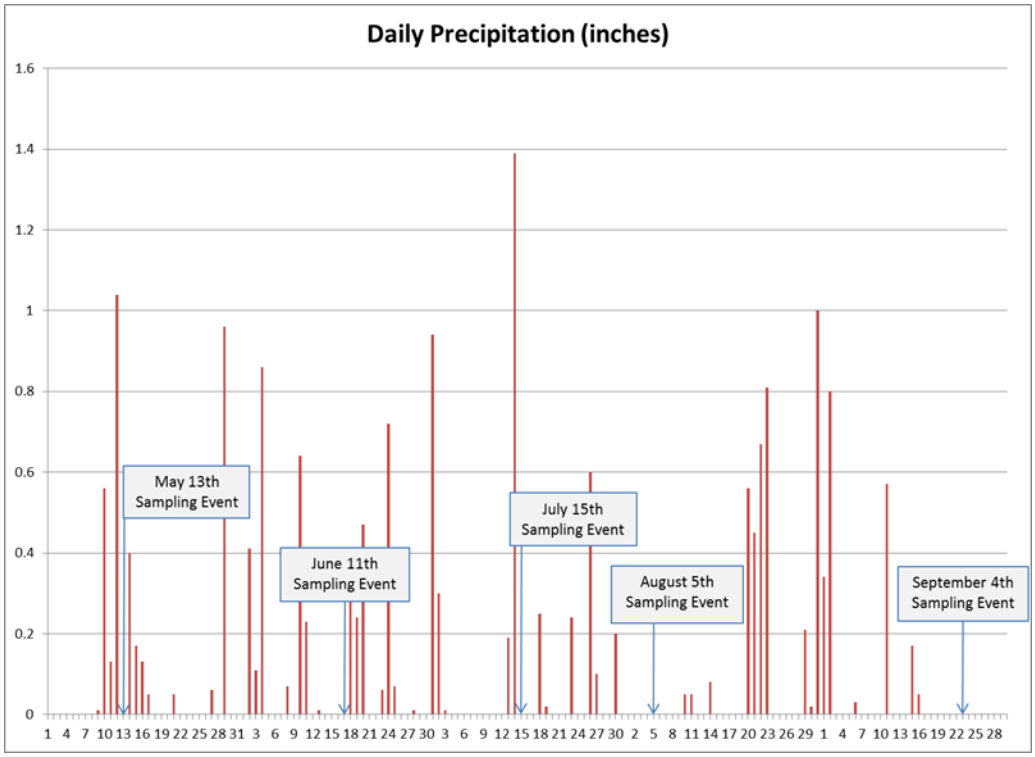


Figure 24. Daily precipitation records for Butler County Regional Airport (approximately 5 miles north of Winton Lake) from May through September 2013 (upper) and 2014 (lower).

motorboats are not permitted. Secchi disc readings appeared to react to the higher precipitation and related TP loadings in 2013 compared to 2014. Other variables such as algal density and recreationally-created turbidity can also play a role in reduced Secchi depth readings. However, with limited motor horsepower requirements and non-beach lakes such as Winton Lake, it is unlikely that turbidity is due to recreation. Using Carlson's (1977) formula to predict trophic state based on Secchi readings alone, Winton Lake would be considered hypereutrophic.

Because there was no discernible thermal stratification of the water column, the averages of all dissolved oxygen measurements in each month were used in assessing LH attainment criterion in Table 20. The lake is impaired for the proposed LH use designation for dissolved oxygen based on greater than ten percent (80%) of all monthly average measurements being below 6.0 mg/l. The mean dissolved oxygen concentration was below 5.0 mg/l for each month of 2013 and only reached the minimum criterion of 6.0 mg/l in June and September of 2014. The typical relationship between dissolved oxygen levels and depth is attributed to oxygen-consumption being greatest near the bottom of a lake due to intense bacterial decomposition in a highly organic environment.

Phosphorus concentrations were generally higher during the wetter 2013 year than the subsequent sampling year of 2014 (Figure 25). Sources of phosphorus to a lake can be external and/or internal. External sources include point and nonpoint contributions, whereas internal sources are typically linked to lake sediment resuspension, redox-related mobility and biogenic cycling.

Phosphorus concentrations were at levels that place Winton Lake on the Watch List since lakes with an average phosphorus concentration greater than 0.05 mg/l are considered nutrient-rich. The "Watch List" is a narrative description utilized in the proposed Lake Habitat standards (Table 20). Values on the Watch List are factored into the process that is used to prioritize a lake for further monitoring. This is further

supported with Carlson's TSI for phosphorus, which categorizes Winton Lake (based on two-year median phosphorus concentrations) as eutrophic.

Chlorophyll-*a* is both a useful and a simple estimator of phytoplankton biomass, replacing the historical use of algal cell number or cell volume. Phytoplankton is used as an indicator organism for the health of a lake based on primary productivity. Monitoring chlorophyll-*a* levels is a direct way of tracking algal growth, including cyanobacteria. Nitrate (NO_3-N), chlorophyll-a, and phosphorus concentrations can be highly variable during lake seasonal cycles. For the trophogenic zone of shallow lakes, such as Winton Lake, one might expect concentrations would be lower during periods of water column stability and then increase during vertical mixing events driven by wind and high flows. However, phosphorus and chlorophyll-*a* sampling results for Winton Lake were fairly flat, indicative of generally low nutrient input (Figure 25, Figure 26).

Periodic elevated chlorophyll-*a* concentrations are not necessarily disconcerting; it is the persistence of elevated levels that is problematic and the reason annual medians for chlorophyll-*a* are evaluated. Elevated chlorophyll-a can reflect an increase in nutrient loads, particularly when rain has flushed nutrients into the lake. Higher chlorophyll-*a* levels are also common during the summer months when water temperatures and light levels increase.

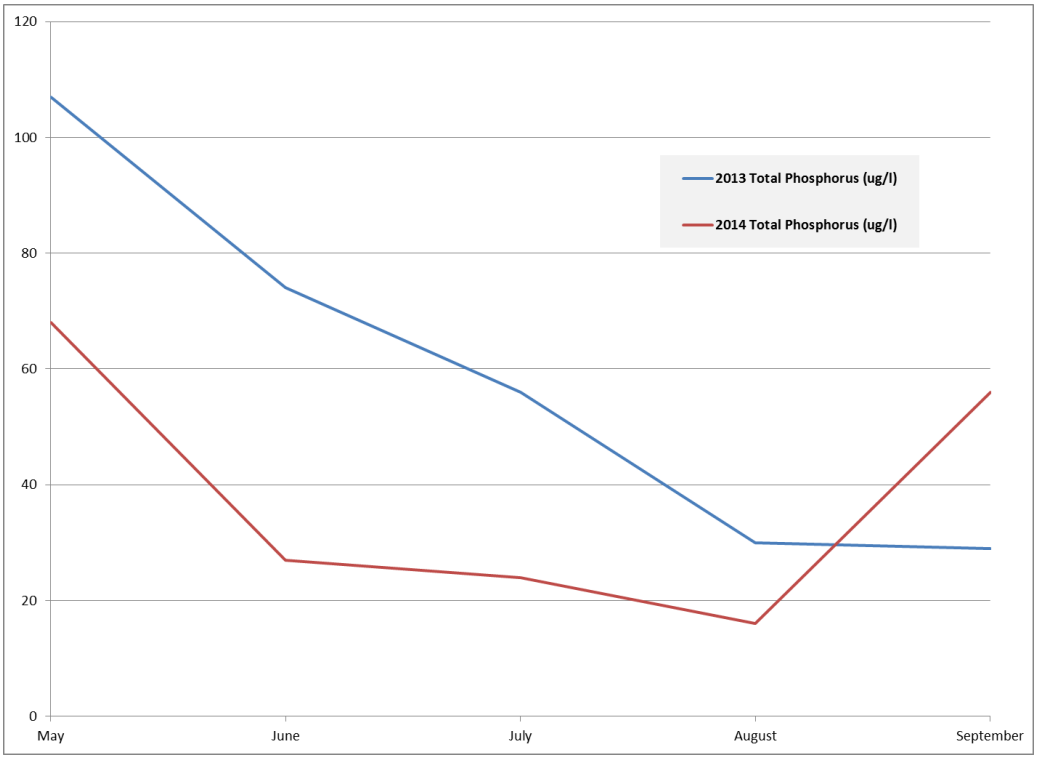


Figure 25. Phosphorus concentrations of Winton Lake surface samples, 2013 and 2014.

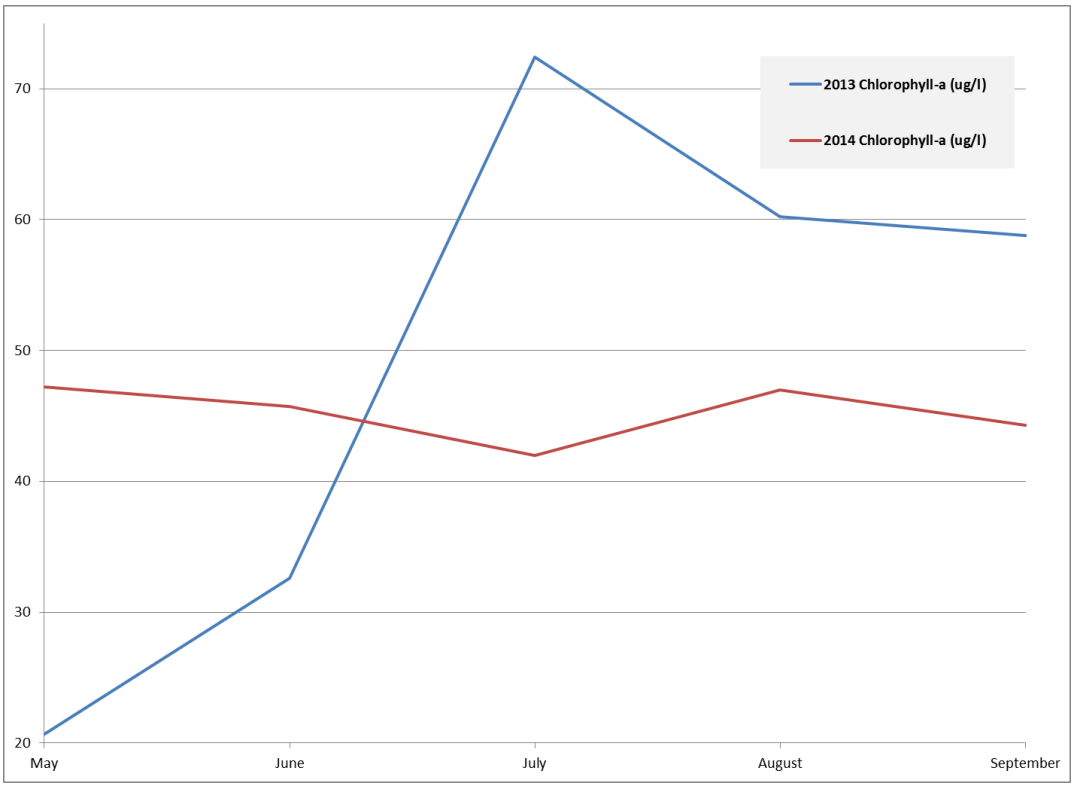


Figure 26. Chlorophyll-a concentrations of Winton Lake surface samples, 2013 and 2014.

When evaluating combined years of 2013 and 2014, Winton Lake's two-year median chlorophyll-*a* concentration of 46 ug/l shows it is impaired according to the proposed Lake Habitat criterion of 14 ug/l (Table 20). Using Carlson's TSI, based on median Chlorophyll-*a*, Winton Lake is considered near the hypereutrophic state. Both chlorophyll-*a* and Secchi depth are long-accepted methods for estimating the amount of algae and relative primary production in lakes.

For reference, the harmful algal bloom problems at Grand Lake St. Mary's are associated with triple-digit chlorophyll-*a* results whereas reference lakes, such as Lake Vesuvius (Southeast Ohio), have concentrations mostly below 10 ug/l.

Despite the consistently elevated chlorophyll-*a* readings during the study period, especially in 2014, no obvious algal blooms were observed in 2013 or 2014. Also, there were no significant populations of macrophytes noted.

While photosynthetic pigments, like chlorophyll-*a*, are measured as a surrogate for algal biomass, calculated average algal biovolumes can be utilized in the construction of the ecological history of a given body of water. Ecological history is useful for establishing goals in ongoing water monitoring programs. It is not uncommon to see a diverse assemblage of phytoplankton, including cyanobacteria, in Ohio lakes and reservoirs. Although various environmental factors can affect normative pattern, phytoplankton species and group dominance is typically seasonal. As demonstrated with Winton Lake during both sampling seasons, algal succession generally commences with diatoms, then green algae and later blue-green algae. The decline of phytoplankton in lakes from spring maximums to the onset of summer populations is often associated with reduction of nutrients being responsible for slower algal growth.

For Winton Lake, an effective lake management strategy would be to target reduction in total phosphorus levels that will likely also address both the chlorophyll-*a* and Secchi depth issues associated with phytoplankton production**.** Regardless of the complicated lake nutrient dynamics, efforts should be directed toward identifying and controlling springtime sources of phosphorous - likely associated with fertilizers applied to golf courses and residential lawns.

Table 17. Assessment of lake data collected from Winton Lake L-1, 2013 and 2014, using the proposed Lake Habitat aquatic life use, associated criteria and Recreation Use. Note - As of the finalization of this report, the proposed Lake Habitat use and these criteria have not been adopted into the Ohio Water Quality Standards and the assessments provided in this table should be considered as examples of how the adopted use and criteria would be applied. The proposed criteria are used to present lake assessment results in the Integrated Report to the U.S. EPA; the most recent reports are available at http://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.)

	Parameter							
	Chl-a (ug/l)	Secchi Depth (M)	T-Nitrogen (ug/l)	T-Phos (ug/l)	DO (mg/l)	pH (SU)	NH3 (mg/l)	E. coli (cfu/100 ml)
	Proposed Lake Habitat Criteria (Interior Plateau Ecoregion)				Base Aquatic Life Use Criteria			
Sampling Date	14 median	1.19 min.	688 median	34 median	6.0	6.5-9	pH & temp dependent	126
5/14/2013	20.7	0.31	610	107	3.9	7.59	0.096	326
6/11/2013	32.6	0.35	590	74	2.0	7.58	0.025	17
7/23/2013	72.4	0.52	940	56	2.6	7.60	0.025	199
8/20/2013	60.2	0.60	560	30	5.2	8.24	0.025	2
9/4/2013	58.8	0.41	870	29	4.7	7.93	0.025	47
5/13/2014	47.2	0.50	670	68	5.7	8.25	0.025	1120
6/17/2014	45.7	0.45	580	27	6.0	7.93	0.025	99
7/15/2014	42	0.42	570	24	4.9	7.94	0.025	276
8/5/2014	47	0.41	690	16	2.7	7.41	0.025	5
9/23/2014	44.3	0.46	770	56	7.3	8.21	0.025	BDL
2013 & 2014 Results	median	median	median	median	% not meeting	% meeting	% meeting	2-year Geometric mean
	46 ug/l	**0.42 M**	**640 ug/l**	**43 ug/l***	**80 %**	**100 %**	**100 %**	**63 cfu/100 ml**
Narrative	**Non-support**	**Watch list**	**Support**	**Watch list**	**Non-support**	**Support**	**Support**	**Support**

* This Watch List status is based on the median value being above the proposed criteria but below 50 ug/l, which is considered to be a nutrient-rich condition.

Physical Habitat Assessment

Most of the locations visited during the 2014 Southwest Ohio River Tributaries survey possessed the necessary compliment of habitat features to support faunas typical of streams within the region (Figure 27). No site was recently channelized, but Mill Creek and East Fork Mill Creek were historically and extensively channelized. Because the upper Mill Creek system is hemmed-in by suburban, commercial and industrial land uses, little chance for passive recovery (via erosion to create new features) exists, and the habitat is consequently simplified and much reduced. In the East Fork, modified features exceed warm water features at three of four sites (Table 18). The one exception was for a recently completed restoration project at the confluence of the mainstem and the East Fork, where modified attributes equaled warm water attributes. However, the restoration project has the potential to continue to improve local habitat conditions as the stream aggrades and reforms natural habitat features. The only other stream to possess more modified features than warm water features was Muddy Creek, a highly urbanized stream where storm water denuded the channel.

It is important to note that raw QHEI scores tend to lack sensitivity to storm water-induced habitat degradation. For example, the QHEI score for the Muddy Creek site at Hillside Road (STORET 609040; RM 1.96) is 55.3; this is a score that would generally indicate sufficient habitat quality to support a warm water assemblage in the absence of other significant perturbations. However, the effect of storm water is better observed in the ratio of modified attributes to warm water attributes, where there are twice as many modified attributes as warm water attributes, a level that is likely to preclude a typical warm water fauna. Similarly, the QHEI score of 55.5 for Mill Creek at SR 747 (STORET Q01W08; RM 22.06) belies the fact that modified attributes outnumber warm water attributes 2:1.

For the remainder of the streams, where historic channelization was nonexistent or highly localized, the presence of modified attributes simply reflects bedrock being the dominant substrate. Because bedrock resists erosion, pools tend to be shallow, riffles nonexistent, and thalwegs ill-defined. Despite these natural limitations, the habitat in these streams should not be limiting in the absence of other stressors. Indeed, relative to expectations derived from reference sites, 17 survey sites have fish IBI scores that deviate appreciably from the expected, and 16 of those have identified stressors (Figure 27).

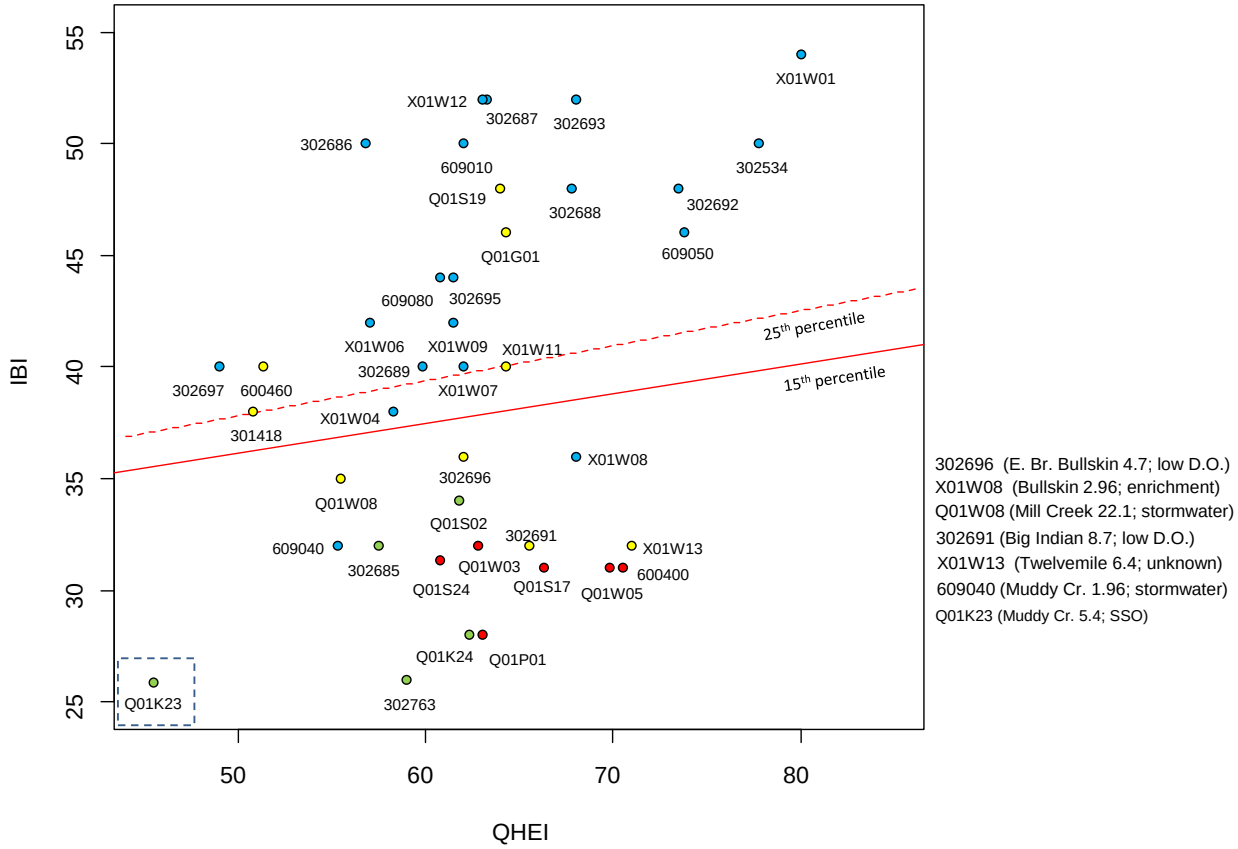
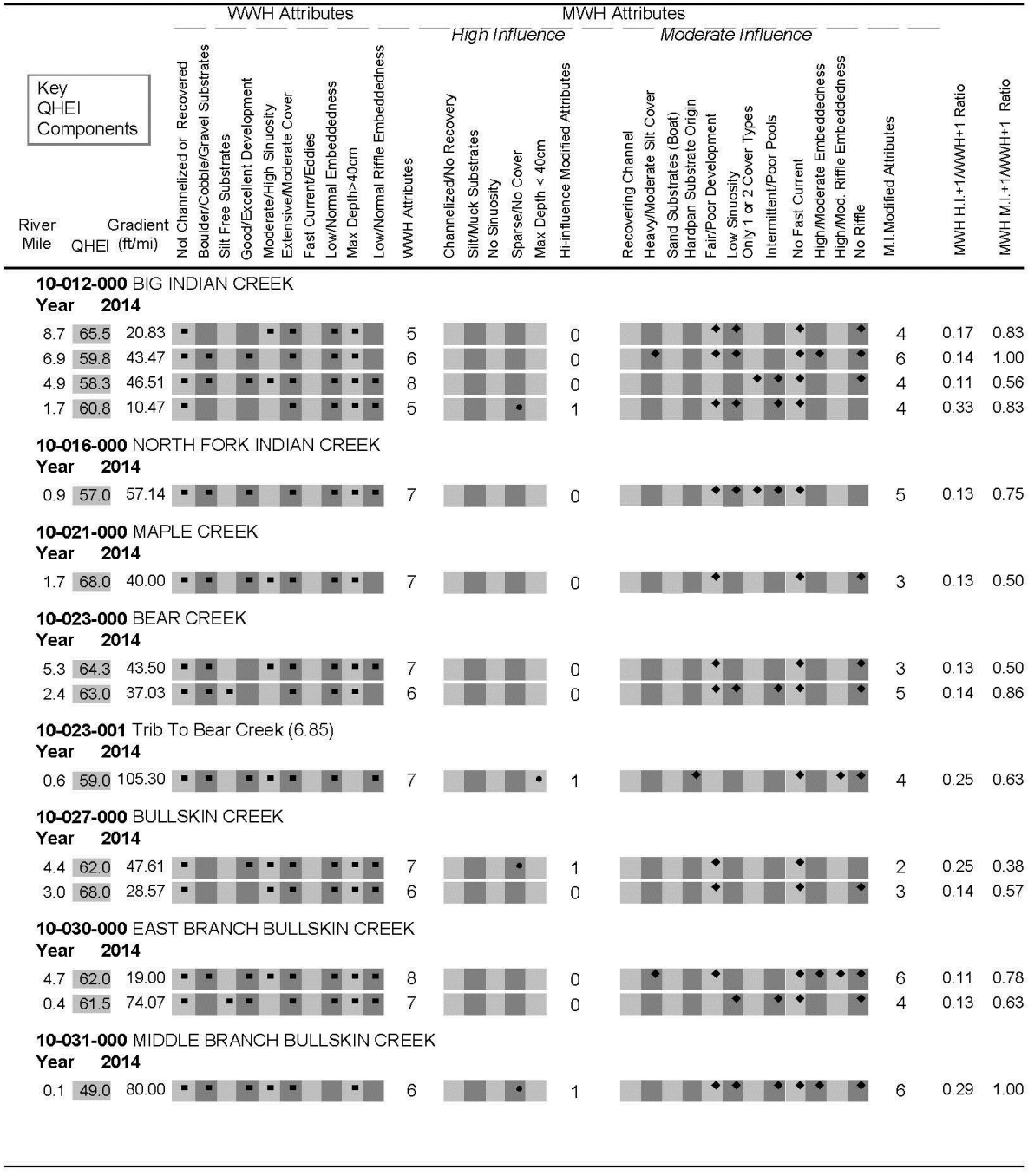


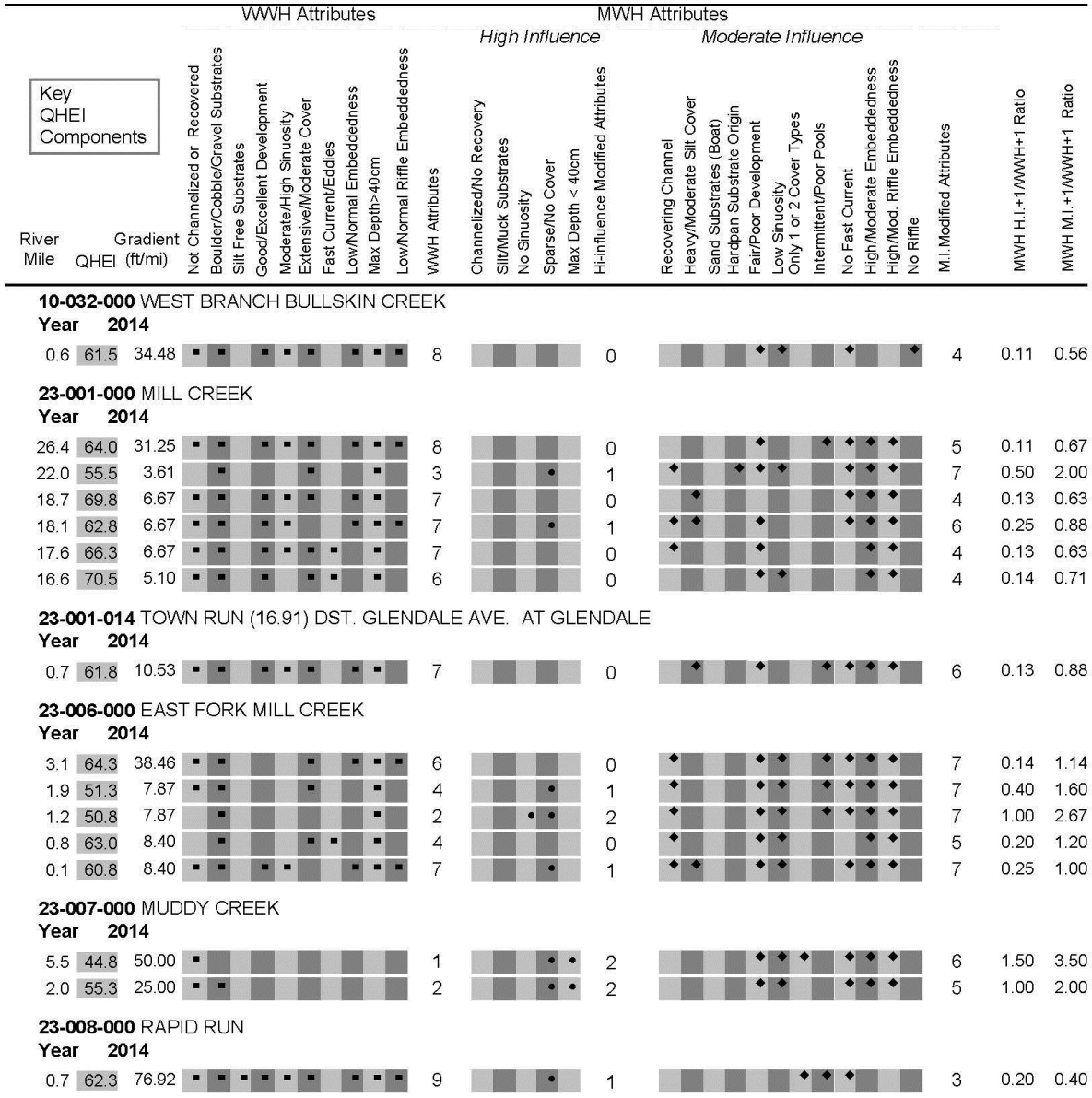
Figure 27. Fish IBI scores plotted by QHEI scores for sites sampled in the Southwest Ohio River Tributaries study area, 2014. The red lines show IBI percentiles as continuous function of QHEI scores for ecoregional reference sites. Sites plotted below the 15th percentile are likely underperforming relative to extant habitat quality. Red sites are from the mainstem of Mill Creek and the East Fork of Mill Creek, green sites are highly urbanized small streams. The other sites falling below the 15th percentile are annotated on the side of the plot.

Table 18. Qualitative Habitat Evaluation Index (QHEI) scores and macrohabitat features of river and streams contained within the Southwest Ohio River Tributaries study area, 2013.

River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth>40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
			WWH Attributes											MWH Attributes																				
														High Influence						*Moderate Influence*														
10-001-000 FIVEMILE CREEK																																		
Year 2014																																		
2.4	57.5	45.45	▪	▪				▪		▪	▪	▪	6			•			1	◆				◆	◆			◆				4	0.29	0.71
10-002-000 EIGHTMILE CREEK																																		
Year 2014																																		
0.2	62.0	47.61	▪	▪			▪			▪	▪	▪	6			•			1	◆				◆	◆			◆				4	0.29	0.71
10-003-000 TENMILE CREEK																																		
Year 2014																																		
3.7	63.3	76.92	▪	▪		▪		▪		▪	▪	▪	7						0					◆	◆		◆	◆				4	0.13	0.63
1.2	73.8	12.04	▪	▪		▪	▪	▪	▪	▪	▪	▪	9						0					◆					◆	◆		3	0.10	0.40
10-003-001 Trib. To Tenmile Creek (3.58)																																		
Year 2014																																		
0.0	56.8	66.66	▪	▪		▪		▪		▪	▪	▪	7			•			1					◆		◆	◆					3	0.25	0.50
10-004-000 NINEMILE CREEK																																		
Year 2014																																		
0.8	80.0	30.30	▪	▪		▪	▪	▪	▪	▪	▪	▪	9						0													0	0.10	0.10
10-006-000 TWELVEMILE CREEK																																		
Year 2014																																		
6.4	71.0	39.21	▪		▪	▪	▪	▪		▪	▪	▪	8						0						◆			◆				2	0.11	0.33
2.1	77.8	11.29	▪	▪		▪	▪	▪		▪	▪	▪	8						0									◆				1	0.11	0.22
10-010-000 LITTLE INDIAN CREEK																																		
Year 2014																																		
0.9	73.5	35.08	▪	▪		▪		▪		▪	▪		6						0						◆			◆			◆	3	0.14	0.57
10-011-000 BOAT RUN																																		
Year 2014																																		
0.2	67.8	95.23	▪	▪		▪	▪	▪		▪	▪	▪	8						0					◆				◆	◆		◆	4	0.11	0.56

Key QHEI Components


WWH Attributes
MWH Attributes
High Influence
Moderate Influence
Key
QHEI
Components
River Mile
Gradient
QHEI
(ft/mi)
Not Channelized or Recovered
Boulder/Cobble/Gravel Substrates
Silt Free Substrates
Good/Excellent Development
Moderate/High Sinuosity
Extensive/Moderate Cover
Fast Current/Eddies
Low/Normal Embeddedness
Max Depth>40cm
Low/Normal Riffle Embeddedness
WWH Attributes
Channelized/No Recovery
Silt/Muck Substrates
No Sinuosity
Sparse/No Cover
Max Depth < 40cm
Hi-influence Modified Attributes
Recovering Channel
Heavy/Moderate Silt Cover
Sand Substrates (Boat)
Hardpan Substrate Origin
Fair/Poor Development
Low Sinuosity
Only 1 or 2 Cover Types
Intermittent/Poor Pools
No Fast Current
High/Moderate Embeddedness
High/Mod. Riffle Embeddedness
No Riffle
M.I.Modified Attributes
MWH H.I.+1/WWH+1 Ratio
MWH M.I.+1/WWH+1 Ratio
10-012-000 BIG INDIAN CREEK
Year 2014
8.7 65.5 20.83 5 0 4 0.17 0.83
6.9 59.8 43.47 6 0 6 0.14 1.00
4.9 58.3 46.51 8 0 4 0.11 0.56
1.7 60.8 10.47 5 1 4 0.33 0.83
10-016-000 NORTH FORK INDIAN CREEK
Year 2014
0.9 57.0 57.14 7 0 5 0.13 0.75
10-021-000 MAPLE CREEK
Year 2014
1.7 68.0 40.00 7 0 3 0.13 0.50
10-023-000 BEAR CREEK
Year 2014
5.3 64.3 43.50 7 0 3 0.13 0.50
2.4 63.0 37.03 6 0 5 0.14 0.86
10-023-001 Trib To Bear Creek (6.85)
Year 2014
0.6 59.0 105.30 7 1 4 0.25 0.63
10-027-000 BULLSKIN CREEK
Year 2014
4.4 62.0 47.61 7 1 2 0.25 0.38
3.0 68.0 28.57 6 0 3 0.14 0.57
10-030-000 EAST BRANCH BULLSKIN CREEK
Year 2014
4.7 62.0 19.00 8 0 6 0.11 0.78
0.4 61.5 74.07 7 0 4 0.13 0.63
10-031-000 MIDDLE BRANCH BULLSKIN CREEK
Year 2014
0.1 49.0 80.00 6 1 6 0.29 1.00


WWH Attributes
MWH Attributes
High Influence
Moderate Influence
Key
QHEI
Components
River Mile
Gradient
QHEI
(ft/mi)
Not Channelized or Recovered
Boulder/Cobble/Gravel Substrates
Silt Free Substrates
Good/Excellent Development
Moderate/High Sinuosity
Extensive/Moderate Cover
Fast Current/Eddies
Low/Normal Embeddedness
Max Depth>40cm
Low/Normal Riffle Embeddedness
WWH Attributes
Channelized/No Recovery
Silt/Muck Substrates
No Sinuosity
Sparse/No Cover
Max Depth < 40cm
Hi-influence Modified Attributes
Recovering Channel
Heavy/Moderate Silt Cover
Sand Substrates (Boat)
Hardpan Substrate Origin
Fair/Poor Development
Low Sinuosity
Only 1 or 2 Cover Types
Intermittent/Poor Pools
No Fast Current
High/Moderate Embeddedness
High/Mod. Riffle Embeddedness
No Riffle
M.I.Modified Attributes
MWH H.I.+1/WWH+1 Ratio
MWH M.I.+1/WWH+1 Ratio
10-032-000 WEST BRANCH BULLSKIN CREEK
Year 2014
0.6 61.5 34.48 8 0 4 0.11 0.56
23-001-000 MILL CREEK
Year 2014
26.4 64.0 31.25 8 0 5 0.11 0.67
22.0 55.5 3.61 3 1 7 0.50 2.00
18.7 69.8 6.67 7 0 4 0.13 0.63
18.1 62.8 6.67 7 1 6 0.25 0.88
17.6 66.3 6.67 7 0 4 0.13 0.63
16.6 70.5 5.10 6 0 4 0.14 0.71
23-001-014 TOWN RUN (16.91) DST. GLENDALE AVE. AT GLENDALE
Year 2014
0.7 61.8 10.53 7 0 6 0.13 0.88
23-006-000 EAST FORK MILL CREEK
Year 2014
3.1 64.3 38.46 6 0 7 0.14 1.14
1.9 51.3 7.87 4 1 7 0.40 1.60
1.2 50.8 7.87 2 2 7 1.00 2.67
0.8 63.0 8.40 4 0 5 0.20 1.20
0.1 60.8 8.40 7 1 7 0.25 1.00
23-007-000 MUDDY CREEK
Year 2014
5.5 44.8 50.00 1 2 6 1.50 3.50
2.0 55.3 25.00 2 2 5 1.00 2.00
23-008-000 RAPID RUN
Year 2014
0.7 62.3 76.92 9 1 3 0.20 0.40

Biological Quality – Fish

Overview

Fish assemblages sampled during the 2014 Southwest Ohio River Tributaries survey are broadly split into two groups over an environmental gradient characterized by increasing levels of urban land use, pollutants associated with storm water, and wastewater loadings (Figure 28). Additional partitioning, characterized by dominant land use, wastewater loadings and water quality, resulted in four subcategories (Figure 28). In terms of land uses, the first group is characterized by a large percentage of agricultural or mixed land uses in the surrounding catchment, the second group features a high percent of forest cover, the third group is from small drainage areas with highly urbanized catchments, and the fourth group can be described as larger urbanized catchments with wastewater effluent (Figure 29). This latter group is essentially formed by sites sampled from Mill Creek and the East Fork Mill Creek downstream from the Butler County Upper Mill Creek Water Reclamation Facility (UMCWRF). Water quality generally follows suit with land use in that sites with mixed land uses had water quality that was intermediate between sites with high percentages of forest cover and those with high amounts of urban land use or wastewater (Figure 29 and Figure 30). The relationship between land use and water quality is especially noticeable in the distributions of chloride within the groupings in that chloride concentrations in the urbanized groups (groups 3 and 4) are uniformly elevated, those in the forested group (group 2) are typical of background levels, and the concentrations in the intermediate group (group 1) span a wide range. Within the intermediate group, sites with elevated chloride concentrations are primarily located in the upper Mill Creek catchment, where land use is mixed between agriculture and urban or residential. Relative numbers, biomass, and species collected per location are presented in Appendix Table E and IBI and MIwb scores are presented in Appendix Table F.

Metals and indicators of nutrient and organic enrichment follow a similar pattern across the groups, (Figure 30 and Figure 31); however lead was detected only in samples collected from sites in group 4, and copper was elevated beyond background levels in all group 3 sites. The iron WQS criterion protecting the agricultural water supply beneficial use was exceeded once each at Twelvemile Creek (RM 2.08) and Bullskin Creek (RM 2.96). No other metal concentrations recorded exceeded an applicable WQS criterion; however, chronic toxicity was noted in two effluent samples collected from the UMCWRF, one in 2014 and the other in 2012, as well as in samples collected from the 801 upstream monitoring location (i.e., upstream from the plant's outfall). Acute (96 hour tests on fathead minnows [*Pimephales promelas*]) and chronic (7 day tests on fathead minnows) toxicity has been recorded from the 801 monitoring station dating back to at least 2002. Metals are not directly implicated in the observed toxicity. Rather, the elevated metals concentrations are emblematic of increasing anthropogenic stress, and the observed toxicity likely results from a combination of pollutants. The effect of increasing stress associated with urban storm water, storm water-derived pollutants and effluent loadings not only partitions fish assemblages in ordination space, but also results in sequentially diminished Index of Biotic Integrity scores (Figure 32). Water quality as the primary agent driving separation in IBI scores is reinforced by the observation that habitat quality is relatively uniform between groups (Figure 32).

Mill Creek (23-001-000), East Fork Mill Creek(23-006-000), and Town Run(23-001-014)

IBI scores recorded from fish samples collected in the mainstem of Mill Creek (upstream from Sharonville Road) show incremental improvement in 2011 and 2014 relative to samples collected between 1992 and 2002. Typical of stressed systems, site to site and year to year variability is high, but the general longitudinal profile is similar between years, with IBI scores decreasing down the run of the river

coincidental with increasing levels of anthropogenic stress (Figure 33). A habitat restoration project upstream from the confluence with the East Fork Mill Creek may be having a positive influence, though the full effect of the restoration on biology may not be apparent for at least several years until the channel aggrades and riparian vegetation becomes more fully established.

Similar to the mainstem, IBI scores recorded from East Fork Mill Creek show site to site and year to variability, but tend to decrease down the run of the creek coincidental with increasing levels of anthropogenic stress (Figure 33). However, unlike the mainstem, no incremental improvement was evident, though conditions at least have not deteriorated. The habitat restoration project at the confluence with the mainstem, again, likely will not show a detectable positive influence on IBI scores for several years. Relative to the UMCWRF, IBI scores in 2014 decreased at the site located downstream from the plant, but the amount of decrease was consistent with past observations.

The fish assemblage sampled in Town Run downstream from the Glendale WWTP reflected the highly urbanized nature of the catchment, but fish were numerous and stoneroller minnows were the most abundant species sampled, suggesting that the Glendale plant added no additional stress to the system.

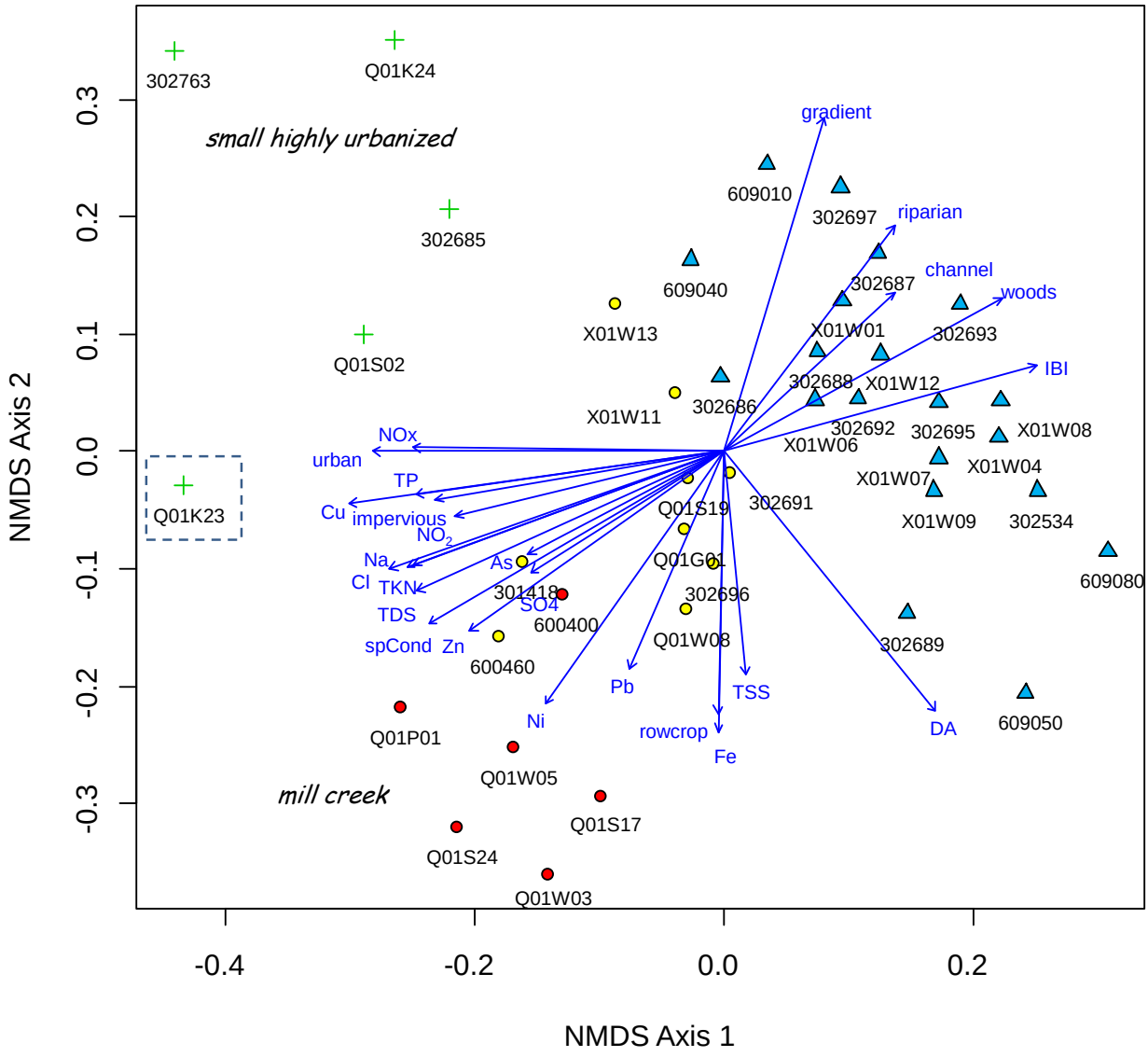


Figure 28. Sites sampled during the 2014 Southwest Ohio River Tributaries survey arrayed in ordination space based on similarities of fish assemblages. Color coding was determined through hierarchical clustering, and the two-dimensional representation is given by nonmetric multidimensional scaling (NMDS). The overlay of environmental variables shows the relative correlation with the axes, as denoted by the length of the arrows, and the direction of the arrows shows the degree to which correlation is shared by the two axes (e.g., NOx is highly correlated with axis 1, and not correlated with axis 2; drainage area (DA) is correlated with both axes). Only environmental variables that have a significant ($p<0.010$) relationship with one or both axes are plotted. Note that site Q01K23, Muddy Creek at Ebenezer Road, actually plots out to -0.8 on axis 1, and would have a long arrow representing ammonia nitrogen pointing to it if drawn to scale.

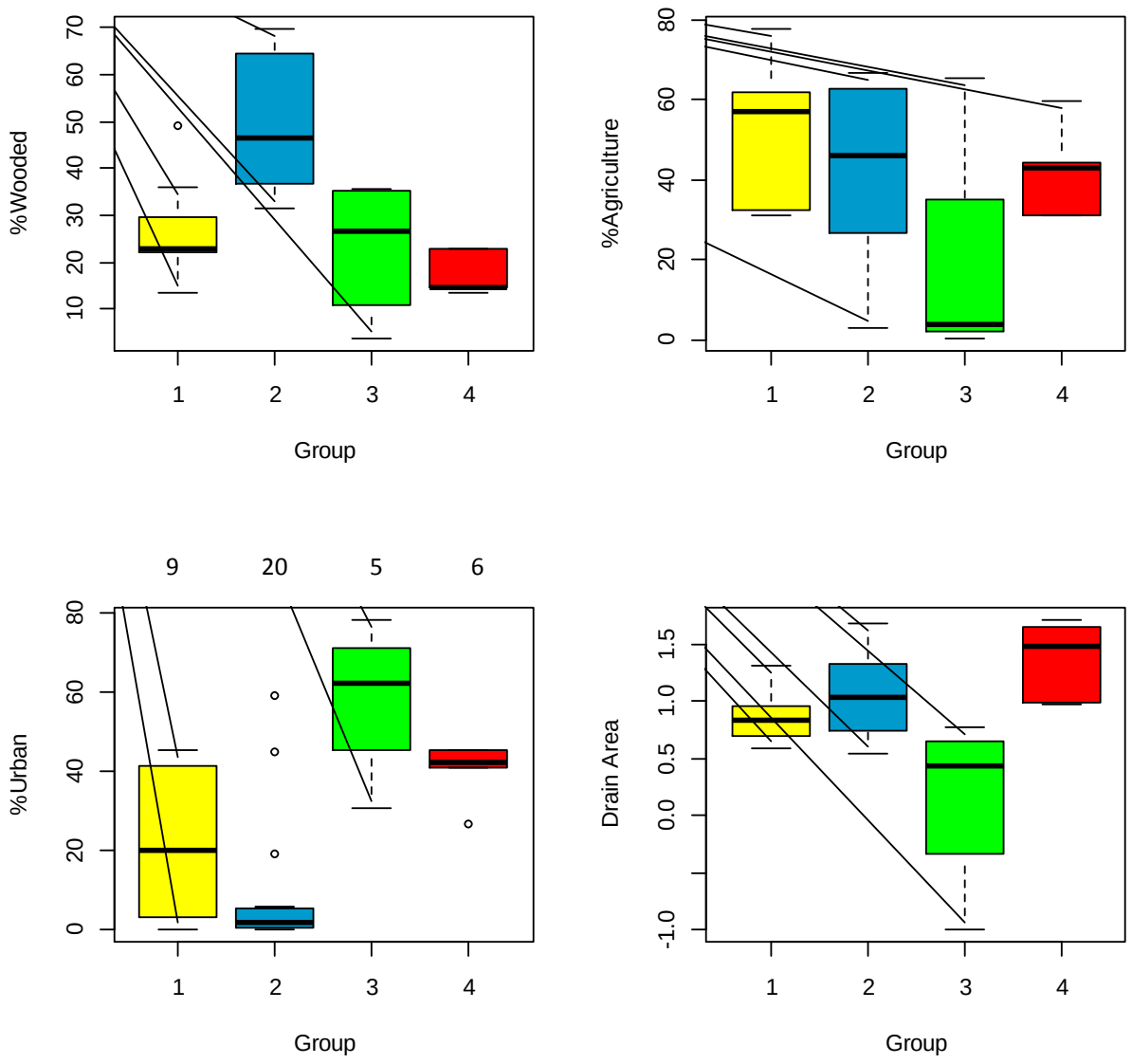


Figure 29. Distributions of land cover and drainage areas within site groups identified through cluster analysis of fish assemblages sampled during the 2014 Southwest Ohio River Tributaries survey. The number of sites within each group is arrayed along the top of the percent urban

land cover plot. Note that percent urban is defined here as the sum of all land cover classes defined as urban in the 2006 National Land Cover Data set (Fry et al. 2011).

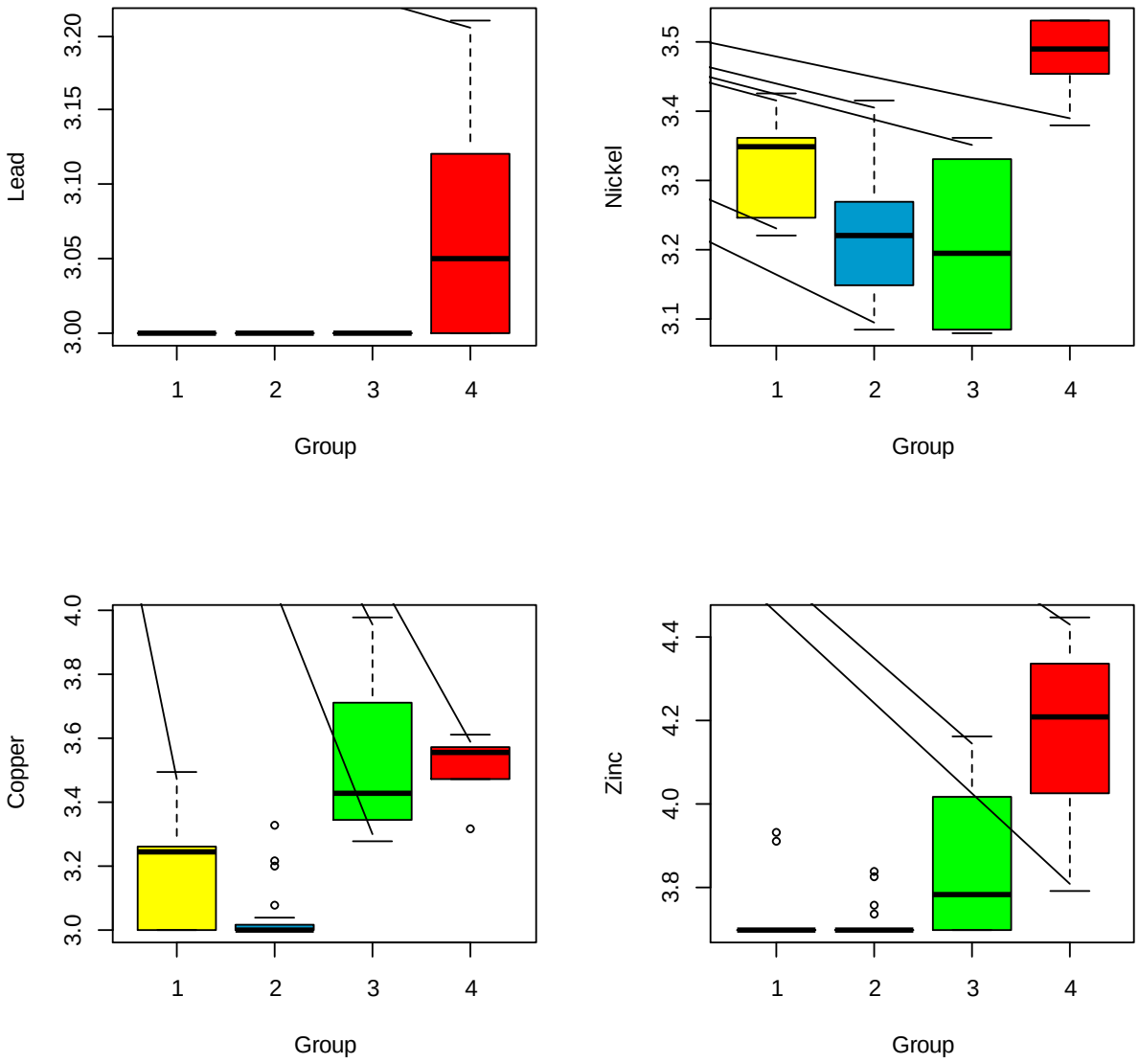


Figure 30. Distributions of metal concentrations (log10 ug/l) within site groupings based on cluster analysis of the fish assemblages sampled during the 2014 Southwest Ohio River Tributaries survey.

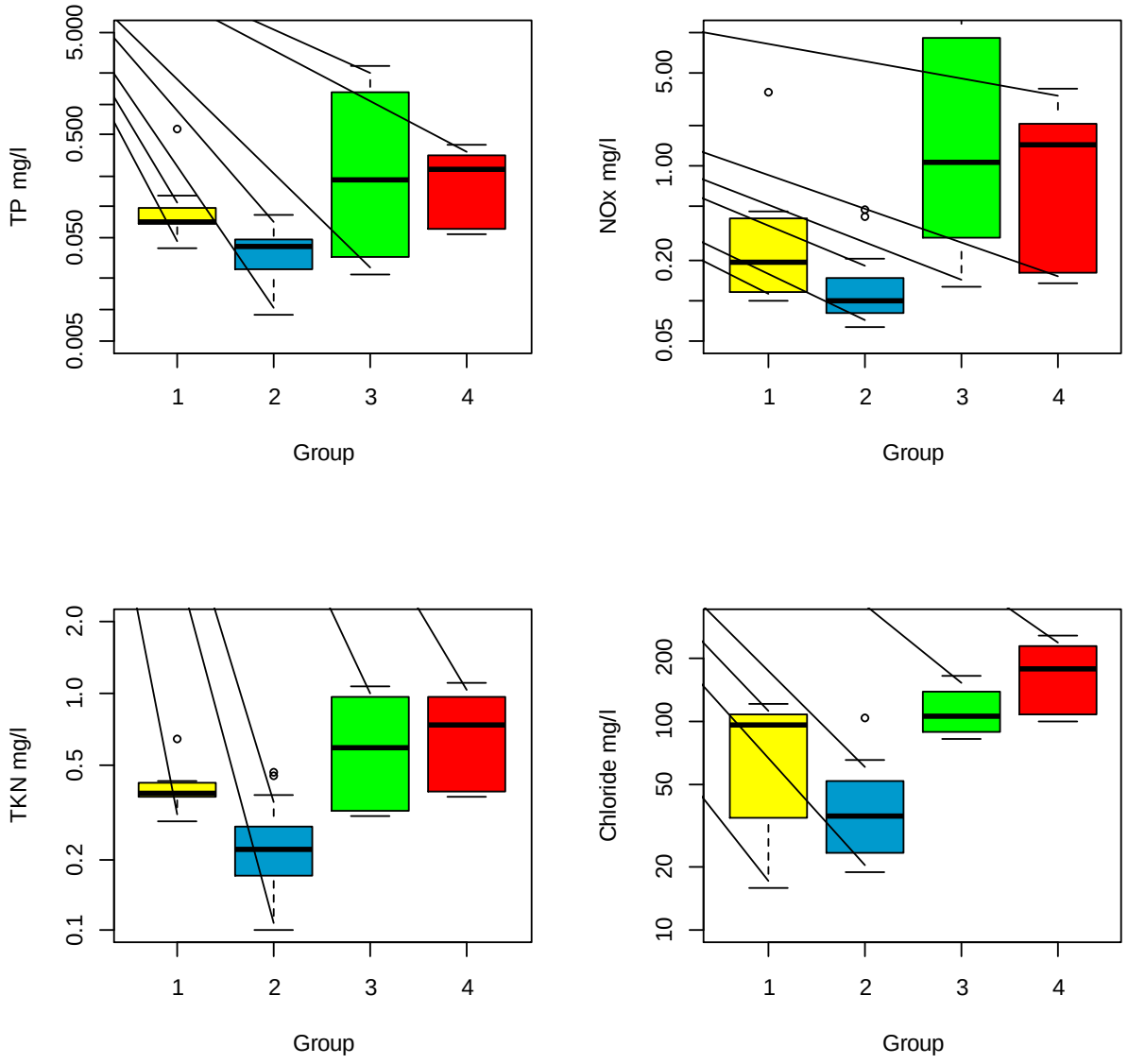


Figure 31. Distributions of total phosphorus (TP), oxidized nitrogen (NOx), Kjeldahl nitrogen (TKN), and chloride within site groupings identified through cluster analysis of fish assemblages sampled during the 2014 Southwest Ohio River Tributaries survey.

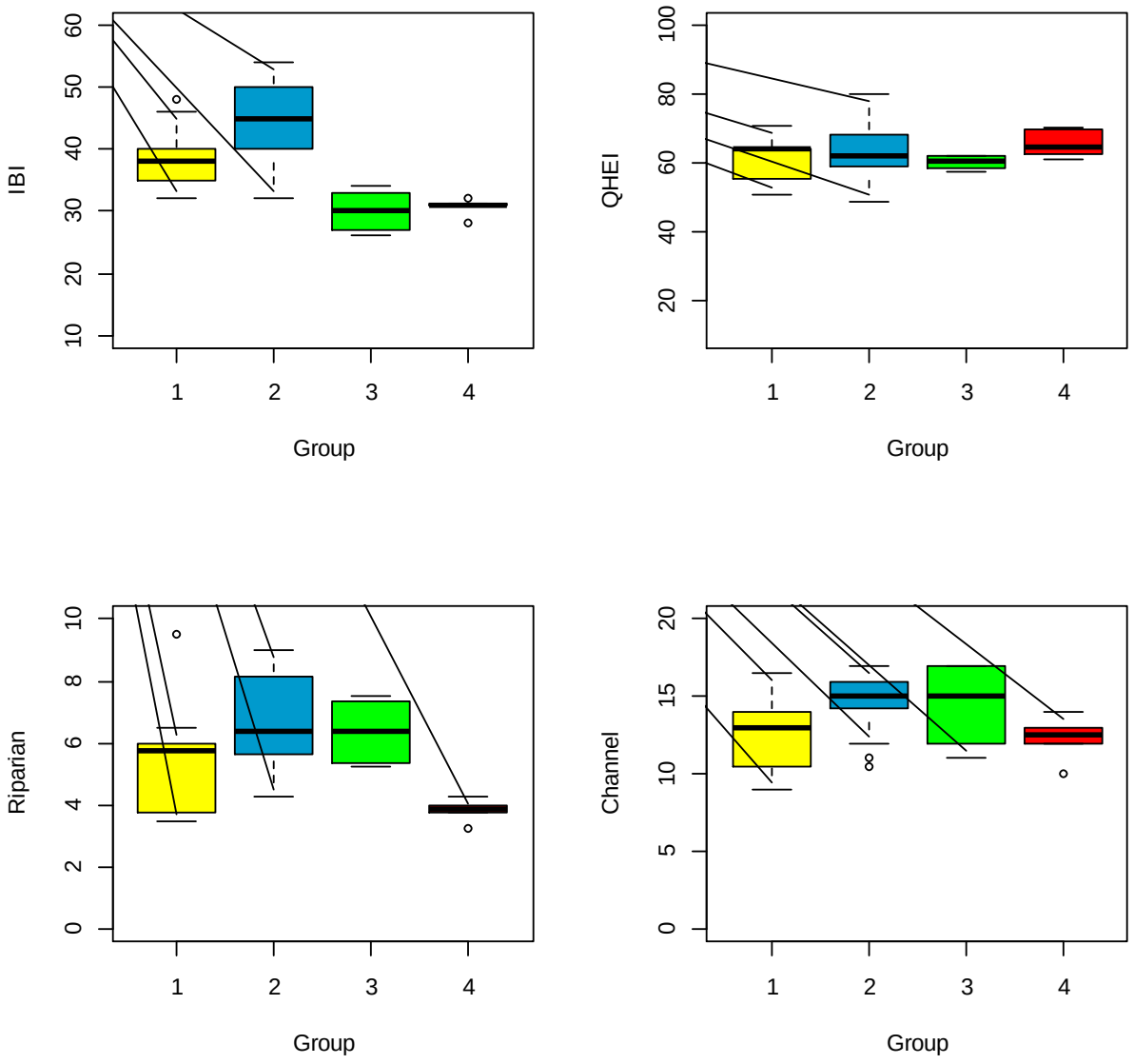


Figure 32. Distributions of fish IBI scores, QHEI scores, and two component metric scores of the QHEI with site grouping identified by cluster analysis of fish assemblages sampled during the 2014 Southwest Ohio River Tributaries survey.

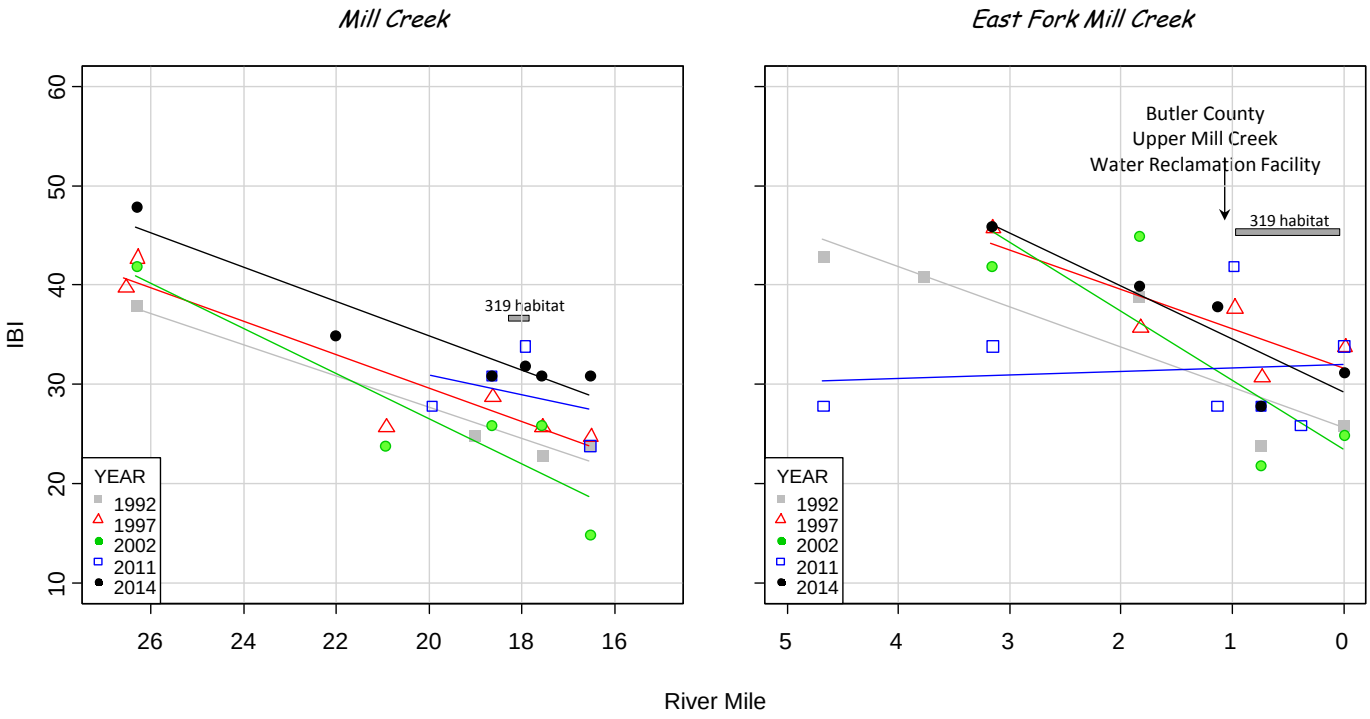


Figure 33. Longitudinal profiles of IBI scores for Mill Creek and the East Fork Mill Creek by sampling year. Note that the IBI scores for the two sites upstream from river mile 3 on the East Fork in 2011 were collected with a backpack electrofishing unit.

Muddy Creek (23-007-000) and Rapid Run (23-008-000)

Muddy Creek and Rapid Run are small urban streams that are subject to combined sewer overflows. Two sites were sampled on Muddy Creek, one at Ebenezer Road (Q01K23; RM 5.4) and the other at Hillside Road (609040; RM 1.96). The site at Ebenezer Road was clearly impacted by organic enrichment as only one species of fish, the highly tolerant green sunfish, was collected at the site. The geometric mean ammonia nitrogen concentration at this site was 0.116 mg/l, no concentration was less than or at the detection limit, and the maximum value was 0.235 mg/l. Clearly, sewage is entering into the creek, and an active sanitary sewer overflow (SSO) is located upstream from the Ebenezer Road site. Fortunately, the creek flows through a lightly developed area allowing the water quality and biology to recover significantly, though not fully, at Hillside Road.

Direct Ohio River Tributaries East of Cincinnati (*See Figure 34*)

HUC 050902011208: Fivemile (10-001-000), Eightmile (10-002-000) and Ninemile (10-004-000) Creeks
The site sampled on Fivemile Creek (STORET 302685; RM 2.37) supports a fish assemblage that is similar to other sites classified as characterizing small urban streams, and is rated as being in fair condition. The geometric mean chloride concentration, at 113 mg/l, is considerably above background concentrations typical for headwaters (90th percentile of reference sites = 89 mg/l). The upper flanks of both Eightmile Creek and Ninemile Creek are urbanized, but the main bodies of each watershed are largely forested, allowing for amelioration of storm water impacts. As such, the fish assemblage measured in Eightmile Creek at US 52 (STORET 609010; RM 0.18) is rated as being in excellent condition, as is the fish assemblage measured from Ninemile Creek at Locust Corner Road (STORET X01W01, RM 0.79).

HUC 050902011206: Tenmile Creek (10-003-000) and Trib. to Tenmile Creek @ RM3.58 (10-003-001)
Land cover in the Tenmile Creek catchment is nearly 70 percent forest, and 22% pasture or hay. Fish IBI scores measured at three locations within the catchment (Table 19) all rate as very good or exceptional.

HUC 050902011204: Twelvemile Creek (10-006-000)
Land cover in the Twelvemile Creek catchment is a mix of forest (51%) and agricultural land uses (45%), with forest cover juxtaposed along the stream network. Normally this would all but guarantee a high degree of biological integrity; however, the site sampled at Laurel-Lindale Road (X01W13; RM 6.44) inexplicably resulted in a fish assemblage that rated as fair (IBI=32). Nothing untoward appears in the water chemistry, leaving the most plausible explanation for the depressed community being limited flows over primarily bedrock substrates (*i.e.*, natural). The site sampled downstream from Fagins Run Road (302534; RM 2.08), where flow was not limiting, supports a fish assemblage rated as exceptional.

HUC 050902011203 Boat Run (10-011-000)
Forest makes up approximately 69% of the land cover in the catchment upstream from the sampling location on Boat Run (STORET 302688; RM 0.2 – upstream from US 52); not surprisingly, the condition of the fish assemblage, as noted by an IBI of 48, rates near exceptional.

HUCs 0509020112 02 & 01 Big Indian Creek (10-012-000) and N. Fk. Big Indian Creek (10-016-000)
The Big Indian Creek catchment comprises two hydrologic units. The upper unit (01), includes one site on Big Indian Creek sampled at Braun Road (STORET 302691, RM 8.7) where the fish IBI was lower than expected given the available habitat, and did not meet the WWH biocriterion. A dissolved oxygen measurement of 2.9 mg/l was noted on 7/16/2014. The other two sites sampled in the upper unit have fish biotic indices either meeting the applicable biocriterion, or rate as marginal but consistent with available habitat quality. Two sites sampled in the lower unit (02) support fish assemblages in good condition.

HUC 050902011107 Little Indian Creek (10-010-000)
One site was sampled on Little Indian Creek at Laurel Moscow Road (STORET 302692, RM 0.85), where the fish IBI scored 48 (very good).

HUC 050902011106 Maple Creek (10-021-000) and Bear Creek (10-023-000)
Three sites were sampled within the Bear Creek hydrologic unit, one on Maple Creek, and two on Bear Creek. All three sites support fish assemblages meeting the applicable biocriterion. One mixing zone sample collected immediately downstream from the Felicity WWTP (NPDES 1PH00011) in a small (drainage area ~ 0.1 mi^2), unnamed tributary did not show overt toxicity to the fish assemblage.

HUCs 0509020111 04 & 03 Bullskin Creek (10-027-000), M. Br. Bullskin Creek (10-031-000), W. Br. Bullskin Creek (10-032-000), and E. Br. Bullskin Creek (10-030-000)

The Bullskin Creek catchment includes a relatively high percentage of agricultural land uses (~65%), and the lower reaches of the Bullskin mainstem is characterized by long stretches of exposed bedrock with limited flow. Consequently, the stream is sensitive to effects from modest levels of nutrient enrichment. Indeed, despite relatively low nutrient concentrations (0.08 mg/l DIN; 0.028 mg/l TP), and low levels of benthic chlorophyll (113 mg/m^2), the daily range in dissolved oxygen concentration at Dunbar Road (STORET X01W07; RM 4.38) was 8.2 mg/l with a minimum of 1.0 mg/l. The condition of the fish assemblage reflected this stress with a lower than expected MIwb score (7.76 expected; 7.24 observed) that did not meet the applicable biocriterion. Additionally, the site at Felicity-Cedron Road (STORET

X01W08, RM 2.96) had a lower than expected IBI score (38.5 expected; 36 observed), though the score was within the range of non-significant departure from the WWH biocriterion.

Two sites were sampled on the East Branch Bullskin Creek. The fish assemblage at the site sampled off Dunbar Road (STORET 302695; RM 0.4) was rated as good and had an IBI of 44. The site sampled off Lang Road had a marginal fish assemblage (IBI=36), coincidental with low dissolved oxygen. The cause of the low dissolved oxygen is unknown.

Two sites sampled in the upper unit (03), one on the Middle Branch, the other on the West Branch, both supported fish assemblages that met or exceeded the applicable biocriterion.

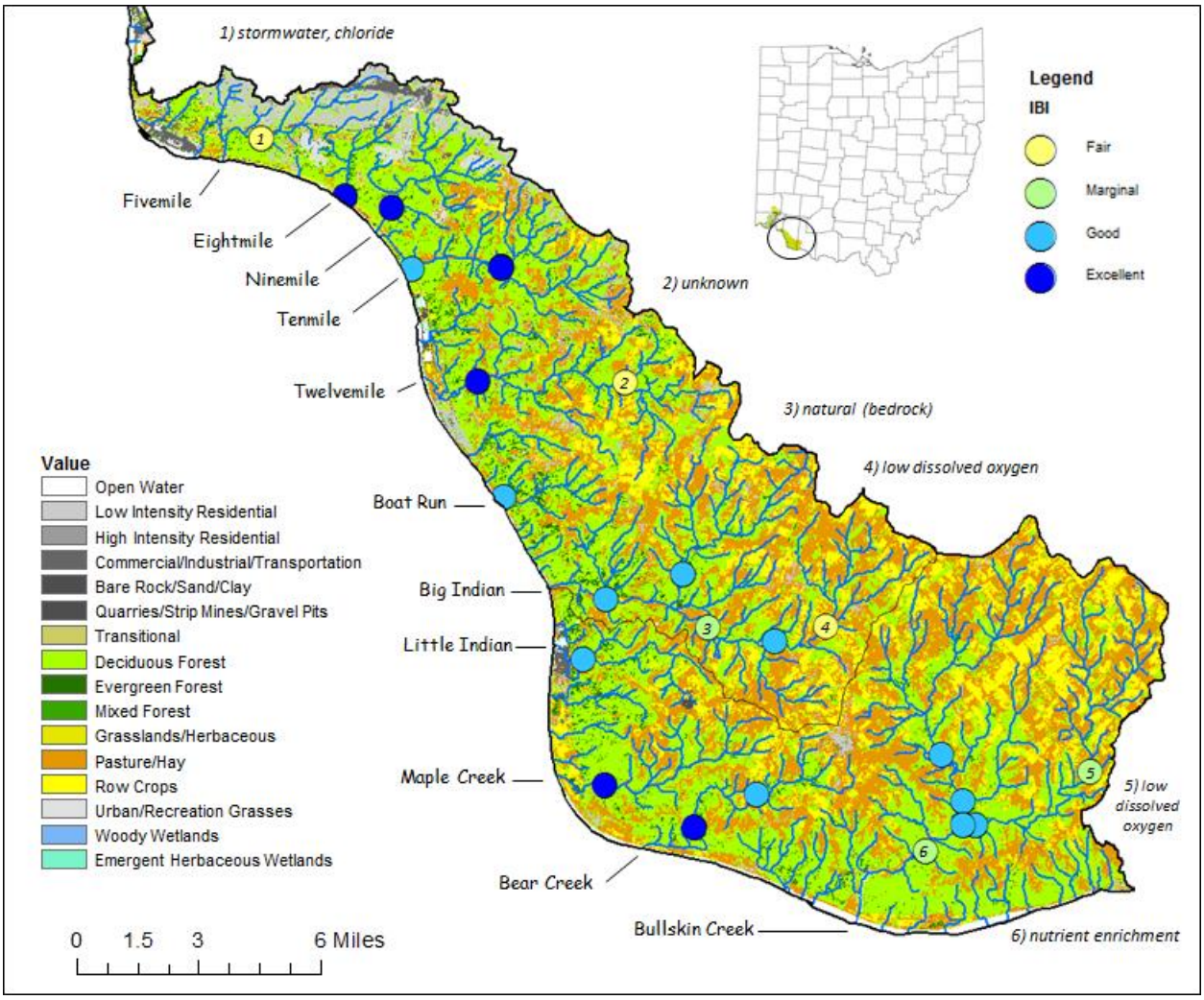


Figure 34. IBI scores from sites sampled in the Southwest Ohio River Tributaries study area east of Cincinnati, 2014. IBI scores are plotted by narrative range and location. Scores that are less than “Good” are annotated with the suspected stress

Table 19. Attributes of fish samples collected from the Southwest Ohio River Tributaries study area, 2014. Applicable Interior Plateau ecoregion WWH biocriteria: IBI = 40; MIwb=8.1.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives IBI : MIwb
10-001-000 Fivemile Creek								
Warmwater Habitat								
2.37	7.0		310.0	842.0	57.5	32		Fair : NA
10-002-000 Eightmile Creek								
Warmwater Habitat								
0.18	10.0		396.0	442.0	62.0	50		Exceptional : NA
10-003-000 Tenmile Creek								
Warmwater Habitat								
3.61	13.0		1890.0	2206.0	63.3	52		Exceptional : NA
1.17	18.0		301.7	430.3	73.8	46		Very Good : NA
10-003-001 Trib. to Tenmile Creek (3.58)								
Warmwater Habitat (Recommended)								
0.01	13.0		1286.0	1658.0	56.8	50		Exceptional : NA
10-004-000 Ninemile Creek								
Warmwater Habitat								
0.79	14.0		886.0	1098.0	80.0	54		Exceptional : NA
10-006-000 Twelvemile Creek								
Warmwater Habitat								
6.44	8.0		658.0	1282.0	71.0	32		Fair : NA
2.08	21.0		1392.0	1516.0	77.8	50		Exceptional : NA
10-010-000 Little Indian Creek								
Warmwater Habitat								
0.85	17.0		750.0	1246.0	73.5	48		Very Good : NA
10-011-000 Boat Run								
Warmwater Habitat								
0.20	12.0		1398.0	1612.0	67.8	48		Very Good : NA
10-012-000 Big Indian Creek								
Warmwater Habitat								
8.70	11.0		718.0	1360.0	65.5	32		Fair : NA
6.90	15.0		460.0	700.0	59.8	40		Good : NA
4.89	15.0	7.8	1003.0	1468.0	58.3	38	8.3	Marginal : Good
1.71	18.5	28.0	1243.0	1367.0	60.8	44	8.5	Good : Good

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives IBI : MIwb
10-016-000	**North Fork Indian Creek**							
Warmwater Habitat								
0.93	16.0		1324.0	2154.0	57.0	42		Good : NA
10-021-000	**Maple Creek**							
Warmwater Habitat								
1.62	17.0		890.0	1524.0	68.0	52		Exceptional : NA
10-023-000	**Bear Creek**							
Warmwater Habitat								
5.30	12.0		1000.0	2094.0	64.3	40		Good : NA
2.43	15.0		580.0	874.0	63.0	52		Exceptional : NA
10-027-000	**Bullskin Creek**							
Warmwater Habitat								
4.38	18.0	12.5	1174.0	1230.0	62.0	40	7.2	Good : Fair
2.96	16.5	10.8	966.4	1624.3	68.0	36	8.7	Marginal : Good
10-030-000	**East Branch Bullskin Creek**							
Warmwater Habitat								
4.70	11.0		396.0	608.6	62.0	36		Marginal : NA
0.40	14.0		870.0	944.0	61.5	44		Good : NA
10-031-000	**Middle Branch Bullskin Creek**							
Warmwater Habitat								
0.05	11.0		838.0	1438.0	49.0	40		Good : NA
10-032-000	**West Branch Bullskin Creek**							
Warmwater Habitat								
0.59	18.0	5.3	748.0	1052.0	61.5	42	8.5	Good : Good
23-001-000	**Mill Creek**							
Warmwater Habitat								
26.35	13.0		844.0	1018.0	64.0	48		Very Good : NA
22.06	14.5	4.4	621.0	888.8	55.5	35	8.1	Fair : Good
18.69	10.0	2.3	102.0	176.0	69.8	31	6.0	Fair : Fair
17.96	10.0	4.1	183.6	281.3	62.8	32	6.4	Fair : Fair
17.61	13.0	3.1	238.0	377.0	66.3	31	6.9	Fair : Fair
16.57	10.5	1.9	260.0	378.0	70.5	31	6.3	Fair : Fair

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives IBI : MIwb
Town Run 23-001-014								
Warmwater Habitat								
0.67	6.0		422.0	966.0	61.8	34		Fair : NA
23-006-000 East Fork Mill Creek								
Warmwater Habitat								
3.17	12.0		886.0	1084.0	64.3	46		Very Good : NA
1.85	9.0		1132.0	1268.0	51.3	40		Good : NA
1.15	10.0		1113.2	1232.1	50.8	38		Marginal : NA
0.76	9.0		108.0	208.0	63.0	28		Fair : NA
0.01	8.7		124.3	234.0	60.8	31		Fair : NA
23-007-000 Muddy Creek								
Warmwater Habitat								
5.40	1.0		0.0	110.8	44.8	24		Poor : NA
1.96	11.0		1614.0	2810.0	55.3	32		Fair : NA
23-008-000 Rapid Run								
Limited Resource Water								
1.15	5.0		420.0	744.0	62.3	28		Fair : NA

Biological Quality – Macroinvertebrates

Macroinvertebrate community condition was assessed at 41 locations on 22 streams in 2014 (Table 20). Qualitative sampling was conducted at all locations. Additionally, seven sites on the East Branch Mill Creek and Mill Creek were evaluated with quantitative sampling protocols. Macroinvertebrate collection results by station and Invertebrate Community Index (ICI) metric scoring are presented in Appendix Tables H and I, respectively.

The macroinvertebrate communities of Mill Creek and the East Branch Mill Creek were affected by polluted storm water runoff and effluent from the Upper Mill Creek Water Reclamation Facility (UMCWRF). The macroinvertebrate community was in fair condition at the uppermost Mill Creek location (RM 26.35). This site was subject to water quality impacts associated with urban watersheds. One notable component of the community was a large number of blackflies of the genus *Simulium*. Blackflies are filter feeders and their presence in high density was an indication the fine particulate organic matter in the water column. ICI scores were in the good to exceptional range at the remaining four mainstem sites (RMs 22.06 to 16.57). Sampling in the East Branch upstream from the UMCWRF produced marginally good to good benthic communities and ICI scores downstream were in the good to exceptional range. However, ICI metric scoring tendencies at mainstem and East Branch sites influenced by the UMCWRF revealed abnormal and mixed responses and concurrent qualitative sampling of natural habitats at the same sites also suggested somewhat lower quality macroinvertebrate community condition.

Mayfly diversity, in particular, was impacted in the East Branch and mainstem of Mill Creek, both in the scoring of mayfly-related metrics of the ICI and field observations of their diversity and abundance from natural habitats. Mayfly abundance was noticeably reduced downstream from the UMCWRF on the natural substrates at East Branch RM 0.76; no mayflies were recorded at RM 0.01. Mayflies as a group have been shown to be particularly sensitive to elevated total dissolved solids (TDS) and conductivity (Pond et. al. 2006, Pond, GJ. 2010, and Ohio EPA 2008). East Branch Mill Creek median TDS values more than doubled below the Upper Mill Creek Regional WWTP from 467 mg/l at RM 1.15 to 1080 mg/l at RM 076; corresponding median specific conductance values increased from 770.5 micromhos/cm to 1611.5 micromhos/cm. For context, the current Ohio statewide WWH aquatic life WQS criterion for TDS of 1500 mg/l equates to a specific conductivity at 25°C of 2400 micromhos/cm. During the July low flow sonde deployment, conductivity downstream from the WWTP exceeded the 2400 micromhos/cm threshold for 10 consecutive hours. This pattern was repeated on Mill Creek downstream from the confluence with the East Branch. By comparison, the average TDS concentration and specific conductivity for relatively undisturbed forested sites in the study area were 321 mg/l and 521 micromhos/cm, respectively.

Evaluating year to year trends in macroinvertebrate communities is often complicated when trying to compare a combination of quantitative and qualitative sampling results between various sites and years. A recent attempt to resolve this problem has resulted in the development of a predictive Invertebrate Community Index (pICI) that uses a combination of attributes derived from taxa collected from the natural substrates[1] (Ohio EPA 2015). The pICI values calculated from Mill Creek macroinvertebrate samples show incremental improvement in 2014 in the upper reach of the study area relative to samples collected between 1992 and 2011 (Figure 35). Conditions in the lower third of the surveyed reach have improved relative to 1992 but site to site pICI results are variable in subsequent sampling years. This reflects instability in the macroinvertebrate community related to general urban impacts, as well as, effluent dominated low flow conditions downstream from the East Branch Mill Creek.

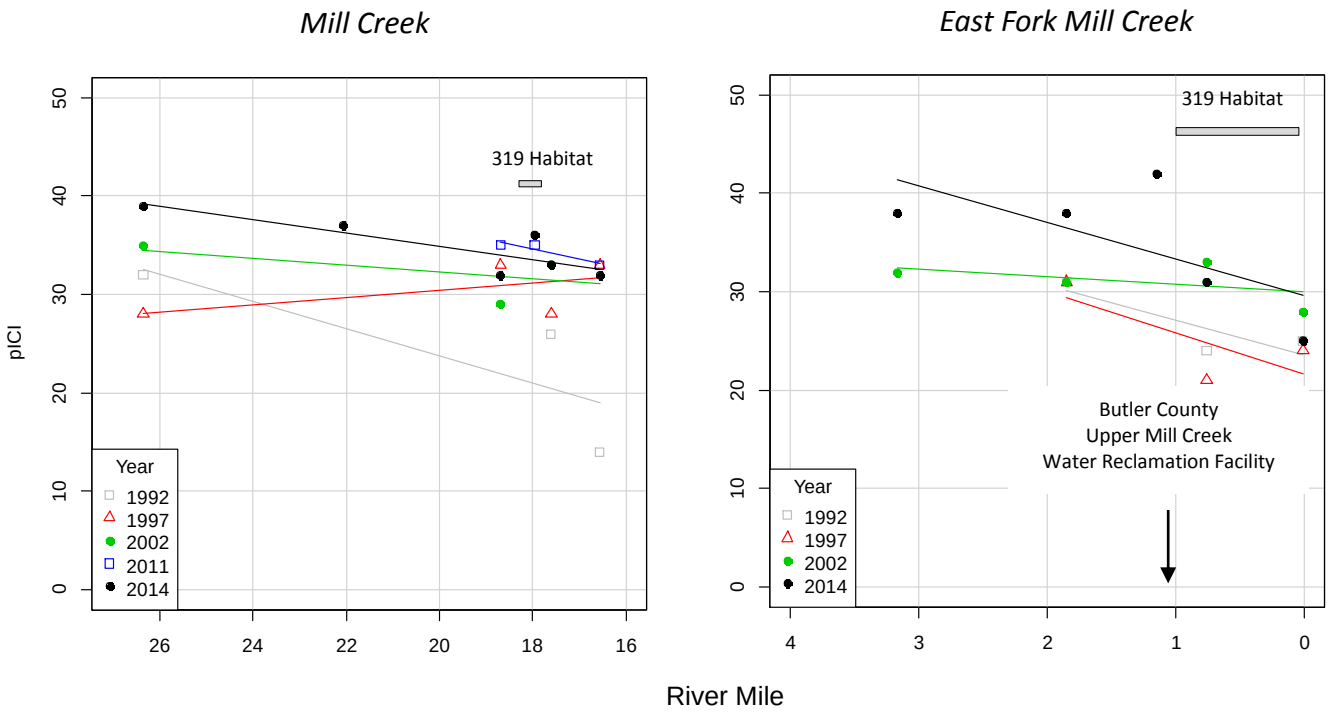


Figure 35. Longitudinal profiles of pICI scores for Mill Creek and the East Fork Mill Creek by sampling year. Note that pICI scores are used solely to permit comparison of sites with a mix of narrative evaluation and ICI scores and not as an alternative determinant of aquatic life use attainment.

[1]The pICI is formed by a nonlinear combination of total taxa richness (TR), EPT taxa richness (EPT), percent of taxa listed as tolerant (PTOL), percent of taxa listed as predators (PPRED), and drainage area (DA). The equation is: 21.110+0.108TR+2.103*EPT-0.050*EPT2-0.003*PCTOL2-0.115*PCPRED+1.016*DA. The pICI is used to make a continuous variable based on presence/absence data collected at all sites, as a mix of rank data (*i.e.*, from narratives) and continuous data (ICI scores) and is not amenable to statistical analysis. Narrative assessments of qualitative data and ICI scores derived from quantitative data remain the gold standard for assessing aquatic life use status. (Ohio EPA 2015.)

East Fork Mill Creek pICI results show a general decline in the macroinvertebrate community relative to increasing drainage area and anthropogenic stresses. Immediately downstream from the UMCWRF, pICI values were marginally better in 2002 and 2014 relative to earlier surveys but were comparable near the confluence with the mainstem. There has, as yet, been no appreciable change in the macroinvertebrate community owing to habitat enhancement within the Mill Creek Confluence Project (Twin Creek Preserve). To this point, it appears the water quality issues related to the UMCWRF discharge is masking any benefit potentially realized by the completion of this project.

The macroinvertebrate assemblage in Town Run downstream from the Glendale WWTP was in poor condition. Given the highly urbanized nature of the catchment, it was difficult to specifically ascribe additional impact due to the WWTP. Facultative and tolerant midges, leeches and flatworms predominated. No sensitive taxa were collected. Soft black sediment noted along the stream margins suggested a release of solids from the WWTP prior to the sampling event in mid-July.

The fair macroinvertebrate community in Rapid Run met LRW expectations. Overall, diversity was low and the assemblage was reflective of flashy flows and broken bedrock stream channel.

Muddy Creek is subjected to inputs from CSOs, unsewered residential discharges, and urban runoff. Two sites were sampled on Muddy Creek at RMs 5.4 and 1.96. The upper site supported a poor macroinvertebrate assemblage. No sensitive taxa were recorded and only one EPT (Ephemeroptera, Plecoptera, Trichoptera) taxon was collected. Significant, albeit partial, assimilation of the pollution inputs was evident at RM 1.96. Qualitative sampling produced four sensitive taxa and overall reflected a marginally good macroinvertebrate community; however, urban runoff influence on stream flow and water quality likely continued to limit the community diversity.

Crooked Run is a small stream that is currently listed as a State Resource Water within the Crooked Run Nature Preserve. The Preserve encompasses a stream reach that is an Ohio River backwater. Sampling of Crooked Run occurred at the upper limit of the backwater. Immediately upstream from this point, the stream bed contained intermittent pools. The macroinvertebrate community in the sampled reach was in poor condition owing to impounded condition. Just 17 taxa were recorded at the site. It was notable, however, that a mysis shrimp, *Taphromysis louisianae*, was collected. The backwater portion of Crooked Run was where this species was first recorded in the Ohio River drainage (Reeder and Hardin 1992). The Ohio EPA database has one additional record from Ohio Brush Creek near the confluence with the Ohio River. Based on macroinvertebrate sampling results, it is recommended that the State Resource Water use designation be replaced with a General High Quality Water antidegradation classification in keeping with OAC Chapter 3745-1-05 (B)(25).

The remaining 16 streams sampled in the Bullskin Creek and Twelvemile Creek HUC 10 watersheds supported marginally good to very good macroinvertebrate assemblages. The majority of these sites were minimally influenced by human disturbance, yet none attained expectations to merit consideration for Exceptional Warmwater Habitat (EWH) status. Naturally occurring low flow frequently resulted in intermittent or nearly intermittent conditions often in association with shallow bedrock streambeds. One site where anthropogenic alteration in the watershed was evident was Fivemile Creek at RM 2.37. The macroinvertebrate community in Fivemile Creek was in marginally good condition and was likely influenced by degraded water quality and high flow scouring due to urban storm water. Six EPT taxa were collected at RM 2.37. Similar evidence of scouring was observed on Eightmile Creek but land use was a more forested watershed. The community was in very good condition; including 12 EPT taxa.

Table 20. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Southwest Ohio River Tributaries study area, June to October, 2014[a].

River Mile	Drainage (mi^2)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT[a]	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI[b]	Current (fps)	Predominant Taxa[c]
10-001-000		Fivemile Creek									
2.37	3.40	25		25	6	4	2		MG^{ns}		midges(F), baetid mayflies(F)
10-002-000		Eightmile Creek									
0.18	3.90	31		31	12	8	2		VG		midges(F), blackflies(F), isopods(MT)
10-003-000		Tenmile Creek									
3.61	5.70	32		32	12	7	5		G		midges(F), riffle beetles(F)
1.17	12.60	51		51	15	8	14		VG		midges(F)
10-003-001		Trib to Tenmile Creek (3.58)									
0.01	3.50	49		49	15	8	9		VG		midges(F)
10-004-000		Ninemile Creek									
0.79	8.10	44		44	12	8	9		VG		midges(F), baetid mayflies(MI,F)
10-006-000		Twelvemile Creek									
6.44	6.8	29		29	8	4	7		MG^{ns}		dryopid beetles(MI,F), midges(F)
2.08	18.3	48		48	13	9	13		VG		caddisflies(F), heptageniid mayflies(F)
10-010-000		Little Indian Creek									
0.85	4.90	48		48	11	6	11		G		midges(F)
10-011-000		Boat Run									
0.20	3.60	28		28	10	5	6		MG^{ns}		midges(F), caenid mayflies(F)

River Mile	Drainage (mi^2)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT[a]	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI[b]	Current (fps)	Predominant Taxa[c]
10-012-000		Big Indian Creek									
8.70	5.40	43		43	7	5	19		MG[ns]		midges(F), caenid mayflies(F)
6.90	10.80	46		46	10	6	18		G		midges(F), caenid mayflies(F)
4.89	27.4	40		40	9	7	10		MG[ns]		midges(F), caenid mayflies(F)
1.71	37.70	46		46	12	7	14		G		midges(F)
10-016-000		North Fork Indian Creek									
0.93	10.90	45		45	13	9	9		VG		midges(F), caenid mayflies(F)
10-021-000		Maple Creek									
1.62	7.70	30		30	8	3	6		MG[ns]		midges(F), heptageniid mayflies(F)
10-023-000		Bear Creek									
5.30	4.80	49		49	13	7	12		G		midges(F), caenid mayflies(F)
2.43	7.70	43		43	12	7	13		G		midges(F), mayflies(F)
10-024-000		Crooked Run									
0.70	0.90	17		17	0	0	10		P*		amphipods(F), midges(MT)
10-027-000		Bullskin Creek									
4.38	27.7	45		45	9	5	11		MG[ns]		midges(F), caenid mayflies(F)
2.96	48.00	48		48	13	11	12		VG		midges(F), caenid mayflies(F)
10-030-000		East Branch Bullskin Creek									
0.40	15.80	50		50	16	11	9		G		midges(F)
0.4	15.8	50		50	16	11	9		VG		baetid mayflies(F)

River Mile	Drainage (mi^2)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT[a]	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI[b]	Current (fps)	Predominant Taxa[c]
10-031-000		Middle Branch Bullskin Creek									
0.05	5.4	39		39	10	8	11		G		midges(F), baetid mayflies(F)
10-032-000		West Branch Bullskin Creek									
4.65	5.70	39		39	9	5	9		MG^{ns}		midges(F)
0.59	25.00	52		52	12	6	15		G		midges(F)
23-001-000		Mill Creek									
26.35	3.90	40		40	10	4	6		F*		midges(F), blackflies(F), baetid mayflies(F)
22.06	20.60	72	40	56	8	4	15	882	48	0.50	midges(F), hydropsychid caddisflies(F)
18.69	27.00	46	29	34	6	2	8	2011	40	1.38	midges(F), hydropsychid caddisflies(F)
17.96	32.50	72	44	54	9	0	21	2062	46	0.30	midges(F)
17.61	44.80	60	39	38	8	2	15	1525	42	0.70	midges(F), hydropsychid caddisflies(F)
16.57	50.50	55	40	37	6	3	12	1372	46	0.50	midges(F), hydropsychid caddisflies(F), flatworms(F)
23-001-014		Town Run									
0.67	2.1	28		28	3	0	9		P*		midges(F,T), leeches(MT,T), flatworms(F)
23-006-000		East Fork Mill Creek									
3.17	5.00	44		44	9	4	8		MG^{ns}		midges(F), blackflies(F), baetid mayflies(F)
1.85	8.10	41		41	10	6	10		MG^{ns}		midges(F), baetid mayflies(F), caenid mayflies(F)
1.15	9	51		51	12	7	11		G		midges(F), caenid mayflies(F)
0.76	9.20	48	29	36	5	2	10	1887	44	0.50	midges(F), hydropsychid caddisflies(F)

River Mile	Drainage (mi^2)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT[a]	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI[b]	Current (fps)	Predominant Taxa[c]
0.01	9.70	36	26	28	4	1	12	2388	36	1.30	midges(F)
23-007-000		Muddy Creek									
5.40	7.60	23		23	1	0	11		P*		midges(F)
1.96	12.10	32		32	8	4	6		MG[ns]		midges(F), baetid mayflies(F)
23-008-000		Rapid Run									
1.15	5.80	23		23	4	1	7		F		midges(F), baetid mayflies(F), flatworms(F)

Ecoregion Biocriterion: Eastern Corn Belt Plains (ECBP)			
INDEX	MWH	WWH	EWH
ICI	22	36	46
Ecoregion Biocriterion: Interior Plateau			
INDEX	MWH	WWH	EWH
ICI	22	30	46

a - Qual. EPT=Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness.

b- Narrative assessment used in lieu of ICI score based on qualitative sampling data when no quantitative data are collected (VG-very good, G-good, MG-marginally good, F-fair, P-poor).

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

[ns]- Nonsignificant departure from applicable biocriterion .

* Significant departure from applicable biocriterion; poor and very poor results are underlined.

Fish Tissue Contamination

Ohio has been sampling streams annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium, and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site-specific current or historic sources. For more information about the chemicals analyzed, how fish are collected, or the history of the fish contaminant program, see State Of Ohio Cooperative Fish Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program, Ohio EPA, January 2010 (http://www.epa.state.oh.us/portals/35/fishadvisory/FishAdvisoryProcedure10.pdf). Fish contaminant data are primarily used for three purposes: 1) to determine fish advisories; 2) to determine attainment with the Ohio Water Quality Standards (WQS); and 3) to examine trends in fish contaminants over time.

Fish advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (e.g., two meals a week, one meal a month, do not eat), and a fish advisory is issued for applicable species and locations. Because mercury mostly comes from nonpoint sources, primarily aerial deposition, Ohio has had a statewide one meal a week advisory for most fish since 2001. Most fish are assumed to be safe to eat once a week unless specified otherwise in the fish advisory, which can be viewed at http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx.

The minimum data requirement for issuing a fish advisory is 3 samples of a single species from within the past 10 years. In Mill Creek, no species met this requirement in 2016, so there were no updates to the existing advisories. The previous advisories for Mill Creek remain in effect and are listed below.

Mill Creek (Cincinnati)	Interstate 275 to the Ohio River (Hamilton County)	Striped Bass Hybrid	Month	PCBs

For Mill Creek, there were previous advisories in place for hybrid striped bass prior to the 2014 data. There is not enough of the most recent data (2014) to draw a conclusion as to whether or not additional consumption advisories should be administered. Further sampling effort and gathering of a larger subset of samples is needed to gauge further analysis.

Other than the hybrid striped bass advisory noted above, the statewide advisories apply for all species in Mill Creek, which are: 1) two meals a week for sunfish (e.g., bluegill) and yellow perch, 2) one meal a week for most other fish, and 3) one meal a month for flathead catfish 23" and over, and northern pike 23" and over.

Fish tissue/human health use attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health WQS criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health criteria are presented in water column concentrations of µg/Liter, and are then translated into fish tissue concentrations in mg/kg. [See Ohio's 2010 Integrated Report, Section E (http://www.epa.state.oh.us/portals/35/tmdl/2010IntReport/Section%20E.pdf) for further details of this conversion.]

In order to be considered in attainment of the Ohio WQS human health criteria, the sport fish caught within a HUC12 must have a weighted average concentration of the geometric means for all species less than 1.0 mg/kg for mercury, and less than 0.054 mg/kg for PCBs.

Within the Mill Creek area, available fish tissue data were limited to determine attainment status. At least two samples from trophic level 3 fish and two samples from trophic level 4 fish are needed. For the Mill Creek study area, sufficient data for assessment were only collected in one HUC12 unit (West Fork—Mill Creek), which was in attainment for mercury in fish tissue but impaired for PCBs in fish tissue. More details are provided below in Table 21.

Table 21. Changes to the Mill Creek 303(d) Watershed Assessment Units (HUC12s) based on a review of fish tissue data collected in 2014.

HUC 12	Results (Previous IR)	Results (Current IR)	Pass/Fail	Cause of Impairment	Assessment Unit Name	PCBs (ppm)	PCBs Threshold	Hg (ppm)	Hg Threshold	Trophic Level 3 Sample Size	Trophic Level 4 Sample Size
50902030103	5h	5h	Unknown	NA	Sharon Creek-Mill Creek	Cannot calculate (No TL 4 sampes)	0.054	Cannot calculate (No TL 4 sampes)	1	4	0
50902030104	5h	5h	Unknown	NA	Congress Run-Mill Creek	0.186	0.054	0.114	1	2	1
50902030105	5	5	Fail	PCBs	West Fork-Mill Creek	0.336	0.054	0.199	1	4	2

Fish contaminant trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish, and mercury concentrations have been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct that is released to air and/or surface water.

For this reason, it is useful to compare the results from the survey presented in this TSD with the results 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 be increasing, decreasing, or staying the same in a water body or watershed.

Fish tissue had previously been collected from Mill Creek in 1992 and 2010. The main comparative focus will be on what was collected in 2010 versus the carp sample that was collected in 2014. In 2010, samples were collected from trophic levels 3 and 4 fish. The lone common carp sample collected in 2014 does not provide enough data for clear analysis of fish contaminant trends. The 2014 sample had 0.343 mg/kg of total PCBs, which was an increase from the 2010 samples collected from locations further downstream. Based upon the group data trend, it can be inferred that PCB accumulation increases further downstream despite the unusual highly contaminated

fish sample that was collected at river mile 16.57 in 2014 (Figure 36). In examining the average PCB accumulation in species over time PCBs have decreased considerably since 1992 (Figure 37).

Mercury analysis of the 2014 carp sample was reported at 0.106 ppm, which showed a decrease from the 2010 carp sample at river mile 16.5 (0.116 ppm). No trends in mercury contamination are observed in the data (Figure 37).

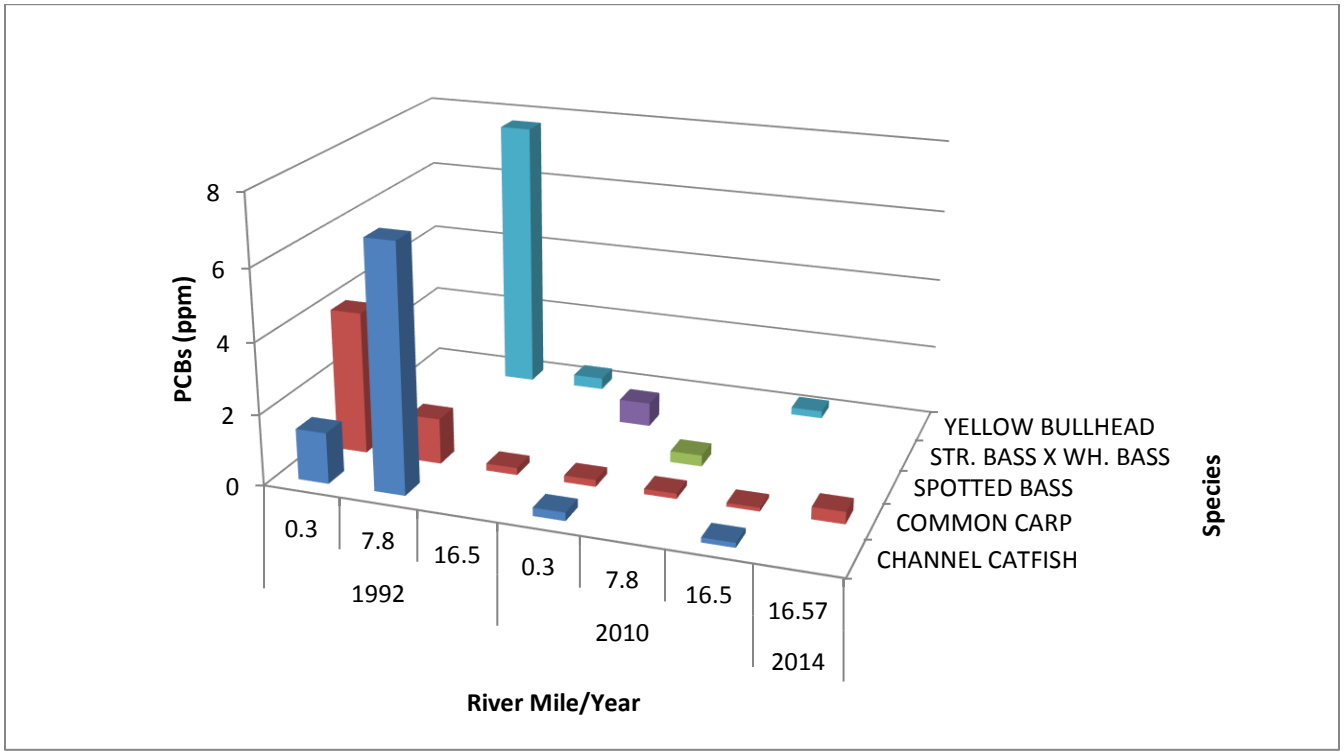


Figure 36. Average total PCBs contamination arranged by year and river mile for Mill Creek. Accumulation of PCBs have shown large reductions since the 1990s.

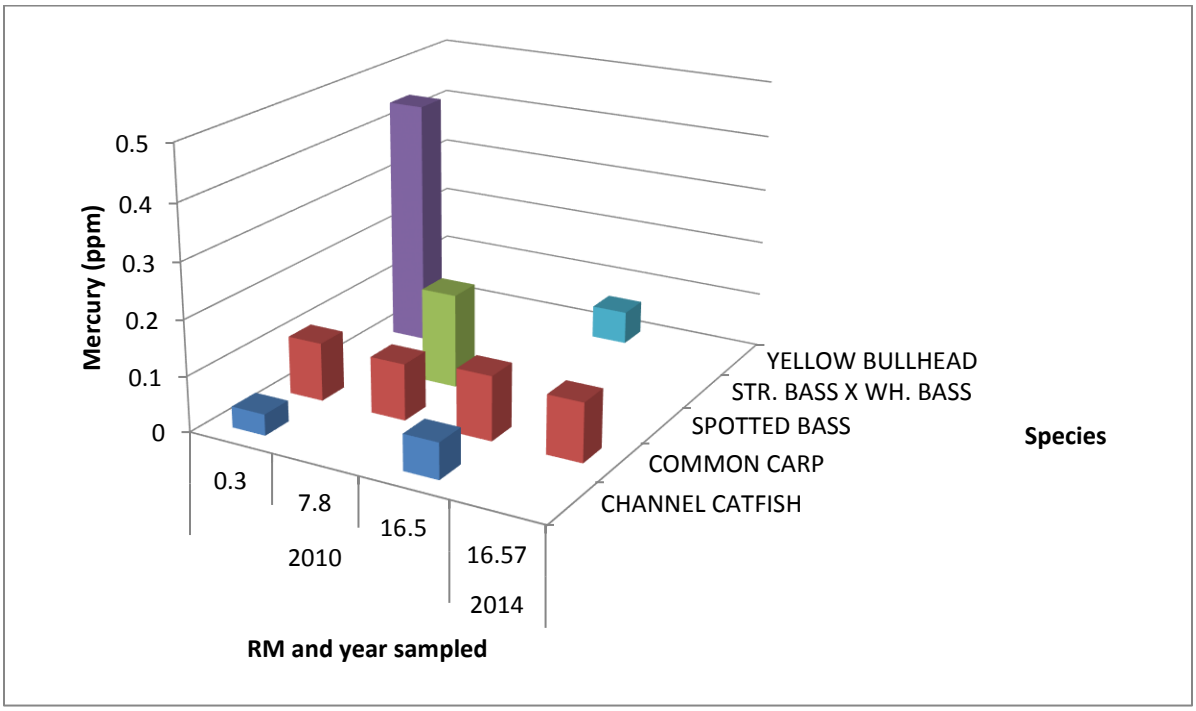


Figure 37. Average mercury for all species collected arranged by River Mile (RM) and year for Mill Creek. No spatial trends are observed. Mercury contamination in common carp stayed fairly consistent through the system. Hybrid striped bass indicate higher mercury levels, but this due predominately to their piscivorous diet. Even then, hybrid striped bass remain below the advisory level for mercury. No mercury data was analyzed for the 1992 sampling event.

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