Table 2. Continued.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Caesar Creek (Exceptional Warmwater Habitat/Warmwater Habitat)						
23.7/13.9	9.9	2.6	0.0	0.0	7.3	*Comments:* ambient dissolved oxygen and phosphorus exceedences
13.9/0.0	13.9	0.0	0.1	0.0	13.8	*Causes:* unknown, reservoir releases, controlled flow *Sources:* Ceasar Creek Lake *Comments:* ambient temperature exceedence, fair macroinvertebrate assemblage
Dry Run (Warmwater Habitat)						
4.0/0.0	4.0	0.0	0.0	0.5	3.5	*Causes:* dissolved oxygen, siltation, low flow, unknown *Sources:* natural drought condition, unknown, land development *Comments:* ambient D.O. exceedence; reference site; declining quality
Turtle Creek (Warmwater Habitat)						
12.0/0.0	12.0	5.9	0.4	0.0	5.7	*Causes:* ammonia-N, metals (Cu), organic enrichment, nutrients, suspended solids, flow alteration (possible dewatering) *Sources:* Cincinnati Milacron, unknown source(s) of dewatering *Comments:* ambient temperature, D.O., pesticide, fecal bacteria, lead, copper, conductivity, total dissolved solids, ammonia, and phosphorus exceedences.
Muddy Creek (Warmwater Habitat)						
8.9/0.0	8.9	2.5	0.0	0.0	6.4	*Comments:* frequent NPDES violations by Mason WWTP, SSO overflows, ambient residual chlorine, phosphorus, fecal bacteria, copper, and pesticide exceedences.
Sycamore Creek (Warmwater Habitat)						
4.5/0.0	4.5	0.0	0.2	0.2	4.1	*Causes:* organic enrichment, metal (Hg), PAH's, nutrients, hydromodification *Sources:* Hamilton Co. MSD Sycamore Cr. WWTP and SSO overflows, land development, spills, urban runoff, sewerline construction, sludge deposits, unknown *Comments* : phosphorus, fecal bacteria, and pesticide exceedences
Stonelick Creek (Warmwater Habitat)						
22.9/0.0	22.9	3.1	3.3	0.0	16.5	*Causes:* sedimentation, nutrient enrichment, habitat modification, low flow *Sources:* agriculture, unknown *Comments:* natural drought condition; impoundment; unknown; spills acutely toxic to fish; ambient D.O. fecal bacteria, lead, and pesticide exceedences.
East Fork Little Miami River (Exceptional Warmwater Habitat)						
20.5/8.8	11.7	6.7	0.0	0.0	5.0	*Comments:* improving quality; ambient pesticide, temperature, phosphorus, and D.O. exceedences
8.8/0.0	8.8	5.2	2.2	0.0	1.4	*Causes:* sedimentation, nutrient enrichment, ammonia, possible toxicity (*i.e.*, waterwillow disappears downstream from Lower E.FK. WWTP), habitat *Sources:* Clermont Co. WWTPs and SSOs, agriculture, land development, lower gradient *Comments:* fish kills, spills, declining quality at some sites, ambient pesticide, temperature, fecal bacteria, phosphorus, and D.O. exceedences.

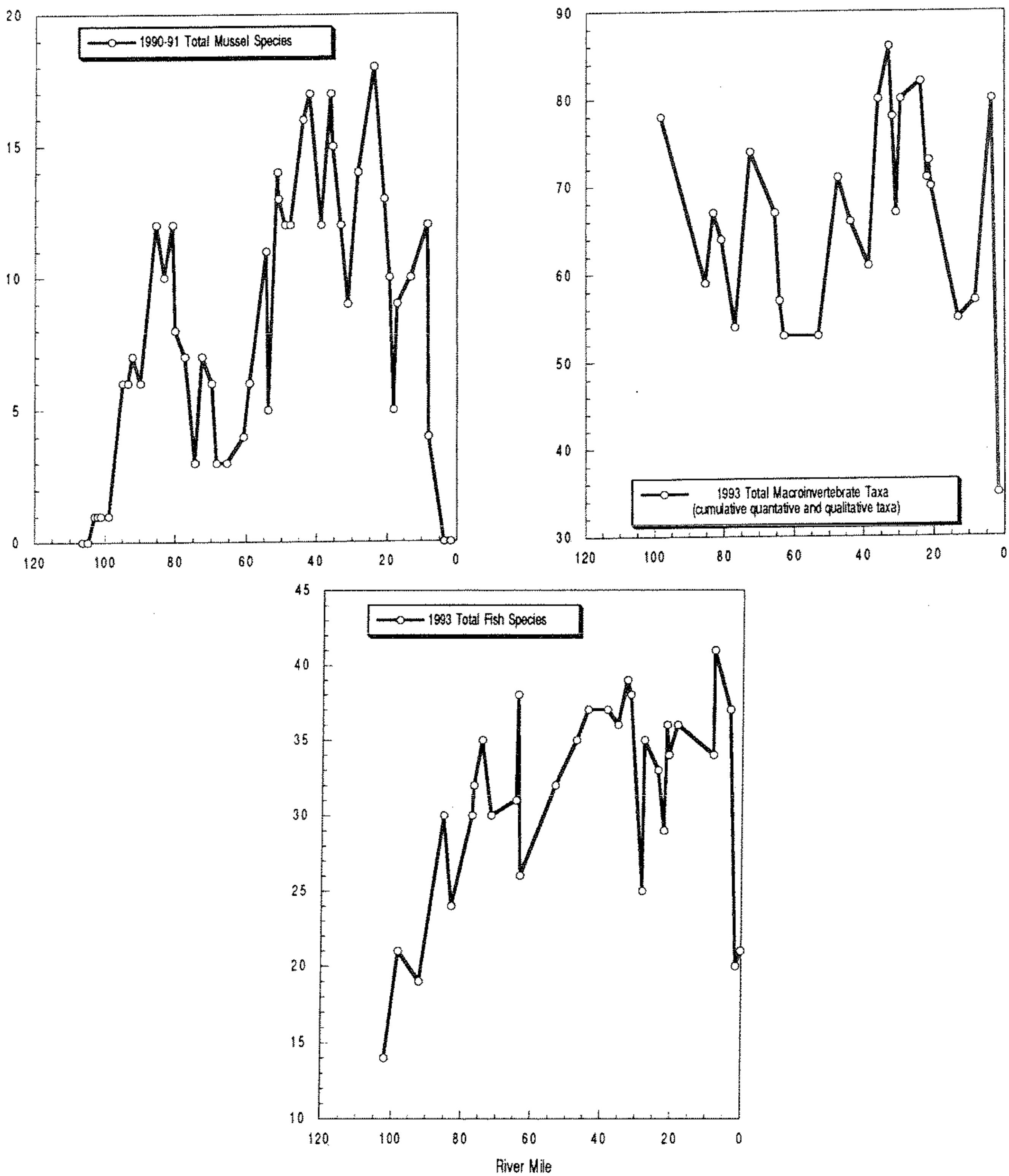

Figure 1. Longitudinal trends in the total cumulative number of aquatic macroinvertebrates (1993 Ohio EPA collections; upper left), Unionidae species, excluding subfossil shells (Hoggarth 1992; upper right), and fish species (1993 Ohio EPA; bottom) recently collected from the Little Miami River mainstem.

Table 3. Comparison of 1983[a] and 1993 biological index scores (Modified Index of Well-Being [MIwb], Index of Biotic Integrity [IBI], and Invertebrate Community Index [ICI]) and the aquatic life use attainment status for commonly sampled segments in the Little Miami River mainstem and East Fork.

Segment RM	MIwb 1983/1993 (Diff.)	IBI 1983/1993 (Diff.)	ICI 1983/1993 (Diff.)	Attainment Status 1983/1993 (Overall Change)
Upper Little Miami River				
102.1-101.3	- /-	35/33 (-2)	38/Except. (+8)	**NON**/PARTIAL (Improved)
98.9-98.3	7.8/7.8 (0.0)	29/35 (+6)	18/50 (+32)	**NON**/PARTIAL (Improved)
92.2-89.1	8.2/7.9 (-0.3)	32/35 (+3)	20/Except. (+26)	**NON**/PARTIAL (Improved)
86.4-85.3	8.7/9.0 (+0.3)	51/47 (-4)	36/46 (+10)	PARTIAL/FULL (Improved)
83.1	9.4/10.1 (+0.7)	49/45 (-4)	36/48 (+12)	PARTIAL/FULL (Improved)
80.8-77.3	8.4/10.3 (+1.9)	48/48 (0)	34/46 (+12)	PARTIAL/FULL (Improved)
76.2-74.5	8.9/10.5 (+1.6)	45/48 (+3)	38/44 (+6)	PARTIAL/FULL (Improved)
72.5-71.8	8.8/9.9 (+1.1)	45/52 (+7)	28/52 (+24)	PARTIAL/FULL (Improved)
66.6-64.7	6.9/9.0 (+2.1)	31/41 (+10)	34/44 (+10)	**NON**/PARTIAL (Improved)
63.4-63.0	6.9/8.5 (+1.6)	26/39 (+13)	36/46 (+10)	**NON**/PARTIAL (Improved)
53.9-53.2	8.6/9.3 (+0.7)	34/33 (-1)	38/40 (+2)	**NON**/PARTIAL (Improved)
Lower Little Miami River				
47.5	9.3/9.3 (0.0)	41/39 (-2)	-/VG	PARTIAL/PARTIAL (No Change)
44.2-43.7	9.2/9.8 (+0.6)	44/49 (+5)	32/48 (+16)	PARTIAL/FULL (Improved)
38.6	9.2/10.0 (+0.8)	48/47 (-1)	-/50	[FULL]/FULL [No Change]
36.0-35.5	9.5/10.2 (+0.7)	45/49 (+4)	42/VG [0]	FULL/FULL [No Change]
33.0-32.9	8.6/9.3 (+0.7)	39/47 (+8)	44/56 (+12)	PARTIAL/FULL (Improved)
31.9-30.7	9.3/11.0 (+1.7)	41/48 (+7)	44/52 (+8)	PARTIAL/FULL (Improved)
29.5-28.3	9.1/9.0 (-0.1)	39/34 (-5)	46/52 (+6)	PARTIAL/PARTIAL (No Change)
28.0-27.9	9.0/10.7 (+1.7)	41/50 (+9)	44/Except. (+2)	PARTIAL/FULL (Improved)
24.2-23.9	9.2/10.2 (+1.0)	42/47 (+5)	52/50 (-2)	PARTIAL/FULL (Improved)
20.9-20.6	8.9/9.6 (+0.7)	39/45 (+6)	40/58 (+18)	**NON**/FULL (Improved)
18.9-18.5	9.2/9.3 (+0.1)	39/40 (+1)	42/V. Good (0)	PARTIAL/PARTIAL [No Change]
13.3-13.1	8.4/8.8 (+0.4)	34/35 (+1)	44/V. Good (0)	PARTIAL/PARTIAL [No Change]
8.8-8.4	8.7/8.9 (+0.2)	41/33 (-8)	48/52 (+4)	PARTIAL/PARTIAL [No Change]
1.6	8.1/7.4 (-0.7)	35/33 (-2)	-/12	[**NON**]/**NON** [No Change]
0.4-0.2	7.5/7.3 (-0.2)	33/29 (-4)	-/Fair	[**NON**]/**NON** (No Change]
East Fork Little Miami River				
15.5-15.4	8.9/9.4 (+0.5)	45/45 (0)	46/54 (+8)	PARTIAL/FULL (Improved)
13.3-12.7	9.1/10.5 (+1.4)	40/47 (+7)	48/46 (-2)	PARTIAL/FULL (Improved)
12.4-11.5	9.2/11.1 (+1.9)	45/47 (+2)	50/-	FULL/[FULL] [No Change]
10.1-9.1	9.8/10.4 (+0.6)	49/44 (-5)	52/54 (+2)	FULL/FULL [No Change]
6.7-6.6	9.4/9.4 (0)	47/42 (-5)	52/46 (-6)	FULL/PARTIAL (**Decreased**)
4.7-4.1	10.3/10.1 (-0.2)	43/44 (+1)	48/44 (-4)	PARTIAL/FULL [Improved]
2.4-1.7	9.7/10.2 (+0.5)	40/36 (-4)	44/48 (+4)	PARTIAL/PARTIAL [No Change]
1.4-0.8	9.5/10.0 (+0.5)	46/39 (-7)	42/50 (+8)	FULL/PARTIAL (**Decreased**)

[a] the East Fork was previously sampled in 1982.

Study Area

Originating in southeastern Clark County, the Little Miami River flows 105.5 miles in a south-westerly direction into Greene, Warren, Clermont, and Hamilton counties to the confluence with the Ohio River east of Cincinnati (Figures 2 and 3). The 1757 square mile watershed also encompasses portions of Montgomery, Clinton, Brown, Highland, and Madison counties. The mainstem throughout the length falls at an average gradient of 6.5 feet per mile (from an elevation of 1137 to 448 feet above mean sea level). Major tributaries include the East Fork Little Miami River, Caesar Creek, Todd Fork, Massies Creek, Beaver Creek, Turtle Creek, Muddy Creek, O'Bannon Creek, and Sycamore Creek. The largest impoundments within the basin are Caesar Creek (6110 acres), East Fork (4600 acres; also called W.H. Harsha Lake), and Cowan Lake (720 acres).

The Little Miami River watershed was formed by three glacial events which left distinctive landforms including thick deposits of silt, sand, and gravel. The upper (northern) one-half of the watershed is in the Eastern Corn Belt Plains ecoregion which is characterized by level to gently sloping land. Eastern Corn Belt streams typically contain substrates predominated by coarse glacial material (*i.e.*, gravel, cobble, and boulders) and some are fed by springs which maintain permanent flow regimes even during extended periods of dry weather. The lower (southern) one-half of the watershed (south of Waynesville) is located in the Interior Plateau ecoregion which has a higher relief and higher gradient streams with predominately bedrock and bedrock fragment substrates. Most small Interior Plateau streams experience intermittent or interstitial flows during the late summer and fall months. Underlying bedrock within the Little Miami River watershed consists of various types of Silurian and Ordovician limestone and shale.

In addition to a State and National Scenic River designation, the Ohio Water Quality Standards (WQS; OAC 3745-1) list the current use designations for the Little Miami River as: Exceptional Warmwater Habitat (EWH); Agricultural and Industrial Water Supply; Primary Contact Recreation; and State Resource Water (SRW). Several tributaries also contain Public Water Supply designated segments. Wilmington and Fayetteville, located in the southeastern portion of the watershed, utilize surface waters for their drinking water supplies. Extensive ground water deposits are a result of the extensive glacial deposits in the basin, thus most communities rely on wells for their raw water source. The Little Miami River flows on top of a buried valley aquifer composed of highly permeable sands and gravel. The aquifer was designated a sole source aquifer (*i.e.*, requires additional review for any federal projects proposed on the surface) by U.S. EPA and produces yields which can exceed 100 to >500 gallons per minute (Durrell and Durrell 1979). Some communities also utilize water from the Caesar Creek and East Fork (W. H. Harsha) reservoirs due to increasing developmental pressures.

Land use within the watershed is predominantly agricultural, but is becoming increasingly suburban (Plate 14). The Little Miami River watershed is unique because it is one of Ohio's largest watershed with no large industrial discharges. The low flow regime of the Little Miami River and the many tributaries are, however, becoming increasingly dominated by municipal WWTPs (Plate 11). Currently, 24 NPDES permitted entities throughout the watershed discharged a combined total of 50.5 million gallons (1993 third quarter) of treated wastewater per day (*i.e.*, 50 MGD equals 77.4 cubic feet per second [cfs] of flow). The minimum recorded discharge rates at the two U.S. gaging stations located on the Little Miami River mainstem were 2.8 cfs at Oldtown [RM 80.6] in 1988 and 27.0 cfs at Milford [RM 13.07] in 1984). Of the 24 entities shown in Figure 22, twenty-two (22) municipal WWTPs discharged 99.2% of the total volume while two industries contributed the remaining 0.8%. This volume will increase substantially as WWTP flows throughout the watershed increase in response to numerous residential and commercial developments. Many communities are attempting to keep pace with the pace of development by increasing the capacity of water and sewage services. However, several WWTPs are operating at or above design capacity which has contributed to violations of NPDES permit limits.

In addition to increasing volumes of wastewater, changing land use patterns are also altering the rates and types of nonpoint source pollutants discharged within the watershed. Initial site preparations for construction results in accelerated rates of runoff, increased soil erosion, and the subsequent deposition of excess sediment in streams and rivers. Riparian encroachment is also a problem which adds to these types of problems. The NPDES general permit for construction sites and local efforts are an attempt to control and prevent adverse environmental impacts. Following construction, stormwater runoff from suburban areas typically enters streams quicker, yields higher volumes of water over a relatively short time, and contributes different pollutants (*e.g.*, combined sewer overflows (CSOs), de-icing chemicals applied to airport runways, heavy metals, etc.) than do rural areas.

Table 4. Stream characteristics and significant pollution sources which were directly evaluated in the Little Miami River study area.

Stream/River	Length (mi.)	Gradient (ft./mi.)	Drainage Area (sq./mi.)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Little Miami River	105.5	6.5	1755.3	Agriculture Urban Resource Extraction Composting	S. Charleston WWTP Xenia-Ford Rd.WWTP Sugarcreek WWTP Waynesville WWTP Lebanon WWTP Totes, Inc. Polk Run WWTP
Yellow Springs Creek	2.5	42.0	11.5	Agriculture, Urban	Yellow Springs WWTP
Oldtown Creek	31.2	10.09	10.0	Agriculture, Urban	
Massies Creek	9.5	22.0	86.6	Agriculture	
Beaver Creek	8.4	7.4	46.98	Agriculture, Urban Resource Extraction	Greene County Beaver Creek WWTP
Little Beaver Creek	9.0	18.8	25.97	Urban	Montgomery Co. Eastern Regional WWTP
Glady Run	6.3	26.5	14.0	Agriculture	Xenia-Glady Run WWTP
Newman Run	4.0	62.5	9.89	Agriculture, Urban	

Table 4. (continued)

Stream/River	Length (mi.)	Gradient (ft./mi.)	Drainage Area (sq./mi.)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Mill Run	5.8	40.7	8.74	Agriculture	
Anderson Fork	28.28	8.1	93.3	Agriculture	
Flat Fork	3.7	17.3	16.76	Agriculture	
Caesar Creek	33.9	10.6	238.6	Agriculture	
Dry Run	1.3	26.9	7.35	Agriculture	
Turtle Creek	12.0	23.5	65.55	Agriculture, Urban	Cincinnati Milacron
Muddy Creek	8.9	31.9	15.67	Agriculture, Urban	Mason WWTP
Simpson Creek	4.0	67.5	4.33	Agriculture, Urban	Warren Co. Lower L. Miami WWTP
Stonelick Creek	22.9	18.7	77.6	Agriculture In-place Pollutants	
Polk Run	5.5	62.0	10.89	Agriculture, Urban, Sewer Lines	
Sycamore Creek	4.5	65.8	24.45	Urban Sewer Lines	Hamilton Co. Sycamore Cr. WWTP
O'Bannon Creek	12.0	24.0	58.5	Agriculture Urban	Clermont Co. O'Bannon Cr. WWTP
East Fork Little Miami R.	81.7	7.6	500.7	Agriculture Urban Resource Extraction	Batavia WWTP Clermont Co. Middle E. F. WWTP Lower E. F. WWTP

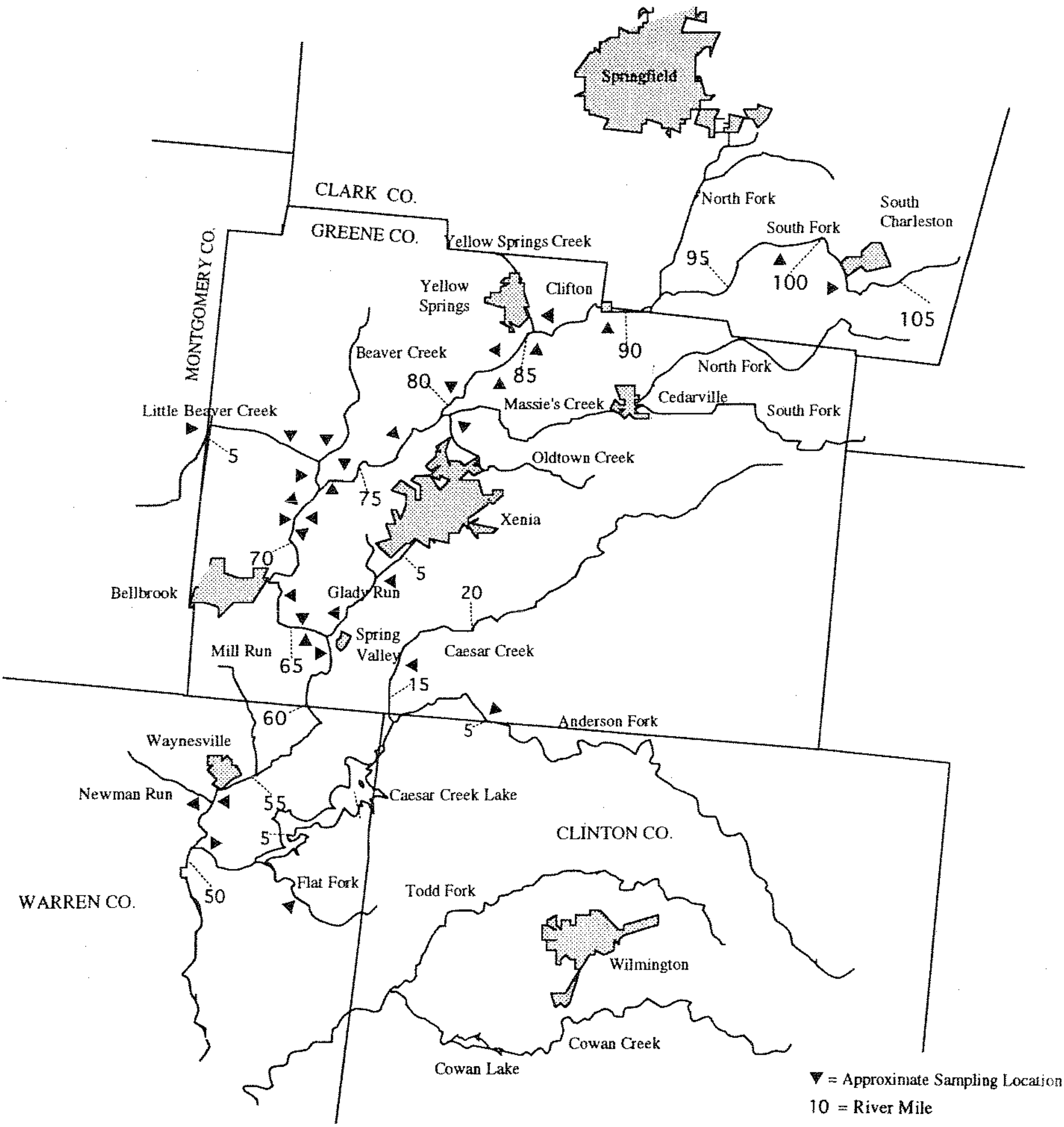

Figure 2. The upper portion of the Little Miami River study area showing principal streams and tributaries, population centers, and pollution sources.

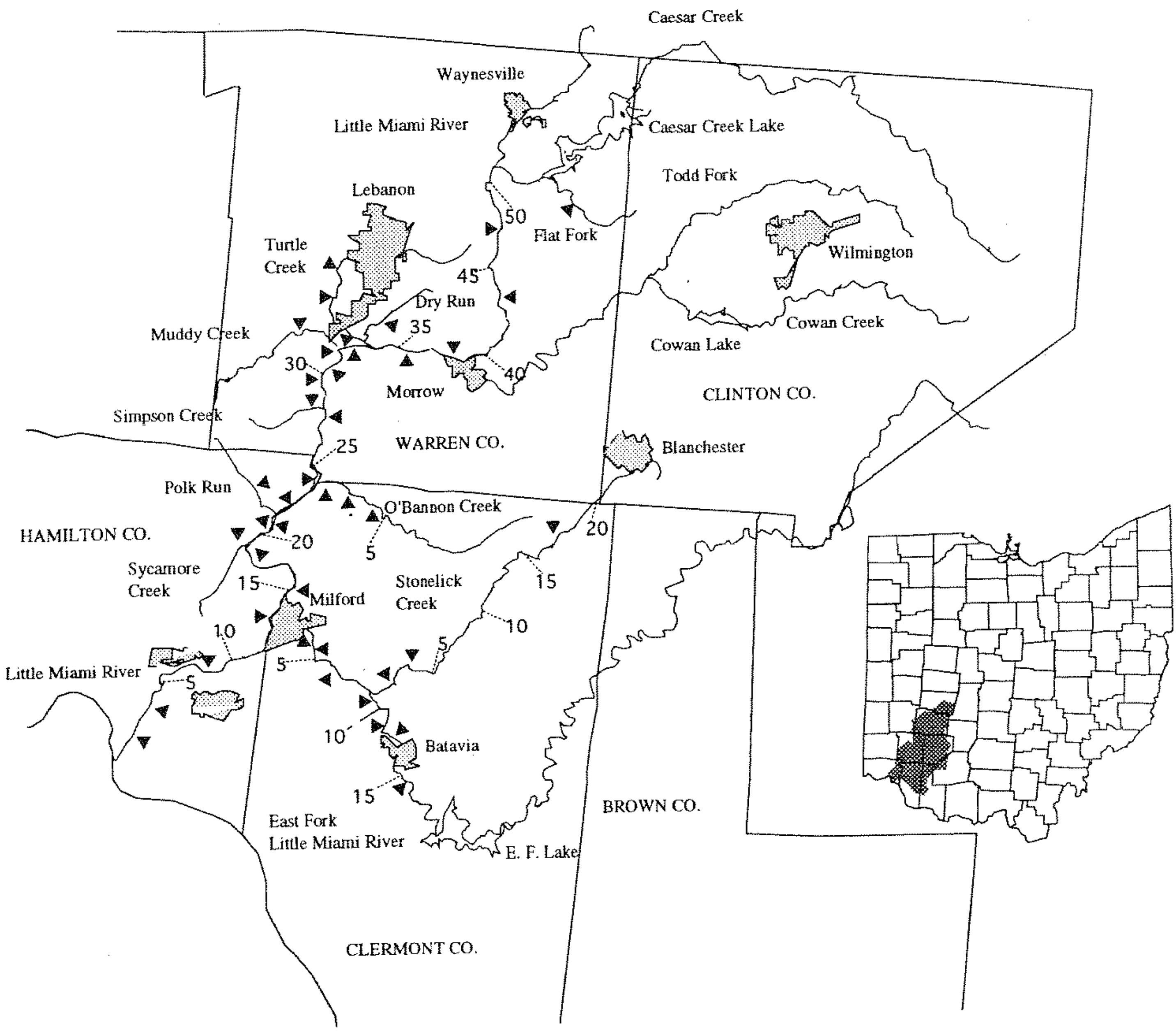

Figure 3. The lower portion of the Little Miami River study area showing principal streams and tributaries, population centers, and pollution sources.

Table 5. List of sampling locations (effluent sample - E; conventional water chemistry - C; organic water chemistry - CO; sediment metals chemistry - S; sediment organics - SO; datasonde - D; modeling - M; flow [USGS - Q, manual - QM]; macroinvertebrates - B; fish - F; and fish tissue - FT) in the Little Miami River study area, 1993. Italics denote effluent mixing zone sampling locations.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Little Miami River				
102.10	F	39°48'52"/83°39'20"	Ust. S.R. 42	S. Charleston
101.50	B	39°49'14"/83°39'36"	Clifton Rd. near S. Charleston	S. Charleston
101.30	C,CO	39°49'23"/83°39'40"	Clifton Rd. near S. Charleston	S. Charleston
98.98	C,S,SO	39°49'57"/83°41'40"	Dolly Varden Rd.	S. Charleston
98.80	B	39°49'47"/83°41'51"	Dst. Dolly Varden Rd.	S. Charleston
98.30	F	39°49'59"/83°41'40"	Dst. Dolly Varden Rd.	S. Charleston
92.20	F	39°48'21"/83°46'54"	Pitchin Rd.	Clifton
89.20	B	39°47'37"/83°49'22"	Ust. S.R. 72	Clifton
89.12	C	39°47'36"/83°49'28"	S.R. 72	Clifton
85.40	F	39°46'57"/83°52'30"	Grinnel Rd.	Yellow Spr.
85.38	C,CO,S,SO,M,D	39°46'57"/83°52'32"	Ust. Yellow Springs. Cr., Grinnel Rd.	Yellow Spr.
85.30	B	39°46'55"/83°52'34"	Grinnel Rd.	Yellow Spr.
83.63	M,D	39°46'02"/83°53'38"	Dst. Yellow Springs Creek	Yellow Spr.
83.14	C,CO,D	39°45'51"/83°54'06"	Dst. Yellow Sp. Cr., Jacoby Rd.	Yellow Spr.
83.10	B,F,FT	39°45'50"/83°54'15"	Dst. Yellow Sp. Cr., Jacoby Rd.	Yellow Spr.
80.63	C,Q	39°44'54"/83°55'53"	U.S. Rt 68	Xenia
80.60	B	39°44'52"/83°55'50"	U.S. Rt 68	Xenia
77.30	F	39°43'12"/83°58'00"	Ust. Xenia Ford Rd. WWTP	Xenia
77.00	*C,B,F*	*39°42'58"/83°58'12"*	*Xenia Ford Rd. WWTP mixing zone*	*Xenia*
76.80	F	39°42'51"/83°58'15"	Dst. Xenia Ford Rd. WWTP	Xenia
76.70	B	39°42'48"/83°58'22"	Dst. Xenia Ford Rd. WWTP	Xenia
76.43	C,CO,S,SO,D	39°42'35"/83°58'32"	Ust. Shawnee Cr., dst Xenia Fd. WWTP	Xenia
74.60	B	39°42'13"/83°59'57"	U.S. Rt. 35	Xenia
74.50	F	39°42'04"/83°59'57"	U.S. Rt. 35	Xenia
74.46	C	39°42'05"/83°59'58"	U.S. Rt. 35	Xenia
73.16	M,D	39°41'55"/84°01'10"	Ust. Beaver Cr. confluence	Bellbrook
72.30	C,CO,S,SO,M,D,B	39°41'29"/84°01'43"	Indian Ripple Rd.	Bellbrook
71.80	F	39°41'12"/84°01'56"	Dst. Indian Ripple Rd. at park	Bellbrook
71.70	M	39°41'04"/84°02'09"	Ust. single island	Bellbrook
70.97	M	39°40'35"/84°02'32"	Dst. unnamed tributary	Bellbrook
70.45	M,D	39°40'11"/84°02'38"	Ust. twin islands	Bellbrook
66.56	C	39°37'58"/84°03'05"	Lower Bellbrook Rd.	Bellbrook
65.60	B	39°37'14"/84°03'01"	S.R. 725	Waynesville
64.70	F	39°36'59"/84°01'57"	Ust. Greene Co. Sugar Cr. WWTP	Waynesville
64.40	*C,CO,B,F,FT*	*39°36'58"/84°01'42"*	*Greene Co. Sugar Cr. WWTP mix. zone*	*Waynesville*
64.28	C,CO,S,SO	39°36'57"/84°01'36"	Dst. Greene Co. Sugar Cr. WWTP	Waynesville
64.20	B,F,FT	39°36'57"/84°01'37"	Dst. Greene Co. Sugar Cr. WWTP	Waynesville
63.73	M,D	39°36'42"/84°00'59"	Ust. Glady Run	Waynesville

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Little Miami River, cont.				
63.40	F	39°36'12"/84°00'59"	Ust. Spring Valley Roadside Park	Waynesville
63.28	C,S,SO,M,D	39°36'20"/84°00'50"	Spring Valley Roadside Park	Waynesville
63.00	B	39°36'05"/84°00'49"	U.S. 42	Waynesville
53.50	F,FT	39°31'17"/84°05'30"	Dst. Waynesville WWTP	Waynesville
53.20	C,B	39°30'59"/84°05'36"	Dst. Waynesville WWTP	Waynesville
53.00	D	39°30'54"/84°05'41"	Dst. Waynesville WWTP	Waynesville
47.50	C,B,F	39°27'08"/84°05'54"	Oregonia Rd.	Oregonia
44.20	F	39°24'43"/84°06'14"	Ust. S.R. 350	Oregonia
43.76	C,CO,S,SO,D	39°24'23"/84°05'03"	S.R. 350, near Fort Ancient	Oregonia
43.70	B	39°24'22"/84°06'03"	Dst. S.R. 350, canoe access	Oregonia
38.66	C	39°21'25"/84°07'44"	S.R. 123	So. Lebanon
38.60	B,F,FT	39°21'22"/84°07'53"	Dst. S.R. 123	So. Lebanon
35.98	C,CO,S,SO,D	39°20'48"/84°10'26"	Stubbs Mill Rd.	So. Lebanon
35.90	B	39°21'48"/84°10'29"	Dst. Stubbs Mill Rd.	So. Lebanon
35.50	F	39°21'52"/84°11'02"	Dst. Stubbs Mill Rd.	So. Lebanon
32.95	C,M,D,QM	39°22'07"/84°13'31"	S.R. 48	So. Lebanon
32.90	B,F	39°22'06"/84°13'33"	Dst. S.R. 48	So. Lebanon
32.12	*E*	*39°22'06"/84°14'25"*	*Lebanon WWTP effluent*	*So. Lebanon*
32.10	*C,B,F,FT*	*39°21'57"/84°14'22"*	*Lebanon WWTP mixing zone*	*So. Lebanon*
32.00	B	39°21'54"/84°14'30"	Dst. Lebanon WWTP	So. Lebanon
31.96	C,CO,S,SO	39°21'53"/84°14'31"	Ust. Muddy Cr.	So. Lebanon
31.90	F,FT	39°21'51"/84°14'35"	Dst. Lebanon WWTP	So. Lebanon
30.72	C,M,D	39°23'07"/84°15'33"	Grandin Rd.	So. Lebanon
30.70	B	39°23'07"/84°15'32"	Grandin Rd.	So. Lebanon
29.46	C	39°20'23"/84°15'23"	Ust. Union Run, Dst. Kings Mill	Mason
29.20	M,D,B	39°20'12"/84°15'16"	End of Kings Mill Rd.	Mason
28.30	F	39°19'36"/84°15'09"	Ust. Foster-Maineville Rd.	Mason
28.20	M,D	39°19'17"/84°15'09"	Foster-Maineville Rd., ust. Simpson Cr.	Mason
28.00	C,CO,S,SO,QM,B	39°19'05"/84°15'05"	Dst. Simpson Cr.	Mason
27.90	F,FT	39°19'05"/84°15'06"	Dst. Simpson Cr.	Mason
27.56	M,D	39°18'46"/84°15'15"	0.58 mi. dst. Simpson Cr.	Mason
26.65	D	39°18'07"/84°15'24"	Adjacent Davis Rd.	Mason
25.24	M,D	39°16'60"/84°15'55"	Loveland Castle	Mason
24.50	M,D	39°16'36"/84°15'28"	Ust. of Loveland	Mason
24.10	C,CO,S,SO,QM	39°16'17"/84°15'34"	Ust. confluence of O'Bannon Cr.	Mason
23.90	B,F	39°16'07"/84°15'40"	Dst. O'Bannon Cr.; Loveland	Mason
22.20	*C,CO,B*	*39°15'04"/84°17'11"*	*Tote's mixing zone*	*Mason*
22.10	F	39°15'04"/84°17'05"	Dst. Tote's	Mason
21.81	M,D	39°15'05"/84°17'17"	Ust. Polk Run WWTP	Mason
21.80	*E*	*39°15'02"/84°17'22"*	*Polk Run WWTP eff.*	*Mason*

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Little Miami River, cont.				
21.50	F	39°14'58"/84°17'30"	Dst. Polk Run	Mason
21.45	C,M,D	39°14'48"/84°17'42"	Branch Hill-Guinea Rd.	Madeira
21.40	B	39°14'47"/84°17'43"	Dst. Polk Run	Madeira
20.90	F	39°14'15"/84°17'50"	Ust. and dst. I-275	Madeira
20.88	M,D	39°14'18"/84°17'52"	Dst. I-275	Madeira
20.60	C,QM,B	39°14'06"/84°17'28"	Lake Isabella Park canoe access	Madeira
19.23	M,D	39°13'31"/84°19'04"	Remington Rd.	Madeira
18.90	B	39°13'18"/84°19'05"	Dst. Sycamore Creek	Madeira
18.50	F,FT	39°12'47"/84°18'49"	Ust. Camargo Rd.	Madeira
18.14	C,CO	39°12'38"/84°18'44"	Camargo Rd.	Madeira
18.10	M,D	39°12'38"/84°12'05"	Dst. Carmago Rd.	Madeira
17.06	M,D,QM	39°12'38"/84°17'37"	Ust. RR bridge near Miamiville	Madeira
15.00	M,D	39°11'41"/84°16'53"	End of Lincoln St.; Camp Dennison	Madeira
13.30	F	39°10'50"/84°17'26"	Milford, OH; dst. Indian Hill WTP	Madeira
13.10	B	39°10'19"/84°17'44"	Ust. Wooster Pike	Madeira
13.07	C,Q	39°10'18"/84°17'55"	Wooster Pike	Madeira
8.80	B	39°08'10"/84°20'29"	Avoca Park	Madeira
8.30	F	39°08'11"/84°21'01"	Ust. and dst. Newtown Rd.	Madeira
8.14	C	39°08'13"/84°21'11"	Newtown Rd.	Madeira
8.00	F,FT	39°08'15"/84°21'16"	Dst. Newtown Rd., adj. Bass Island	Maderia
3.50	C,CO,S,SO,D,F,FT	39°06'36"/84°23'44"	Beechmont Ave.	Newport
3.40	B	39°06'30"/84°24'14"	Dst. Beechmont Ave.	Newport
1.60	B,F	39°05'07"/84°25'11"	Kellogg Ave.	Newport
1.45	C,CO,D	39°05'07"/84°25'17"	Kellogg Ave.	Newport
0.40	B	39°04'33"/84°25'52"	Ust. mouth	Newport
0.20	F	39°04'29"/84°25'51"	Ust. mouth	Newport
Yellow Springs Creek				
0.50	B,F	39°47'30"/83°52'49"	Ust. Yellow Springs WWTP	Yellow Spri.
0.44	C,M,D	39°47'28"/83°52'47"	Ust. Yellow Springs WWTP	Yellow Spr.
0.43	*E,B,F*	*39°47'27"/83°52'46"*	*Yellow Springs WWTP eff./mix. zone*	*Yellow Spr.*
0.42	*C*	*39°47'23"/83°52'42"*	*Yellow Springs WWTP mixing zone*	*Yellow Spr.*
0.30	B,F	39°47'12"/83°52'39"	Dst. Yellow Springs WWTP	Yellow Spr.
0.23	M,D	39°47'12"/83°52'38"	Dst. Yellow Springs WWTP	Yellow Spr.
0.10	C,CO,S,SO,M,D	39°47'10"/83°52'40"	Grinnel Rd.	Yellow Spr.
Oldtown Creek				
0.40	B	39°43'52"/83°56'07"	Dst. Brush Row Rd.	Xenia
0.10	C,CO,S,SO,F	39°44'18"/83°47'10"	Near mouth, near U.S. 68	Xenia

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
South Fork Massies Creek				
2.10	B	39°44'17"/83°45'58"	Dst. Weimer Rd.	Cedarville
1.10	B,F	39°44'09"/83°56'08"	Adj. quarry	Cedarville
Massies Creek				
0.30	B,F	39°44'10"/83°56'10"	Ust. U.S. 68	Xenia
0.25	C	39°44'08"/83°56'10"	U.S. 68	Xenia
Beaver Creek				
1.60	B,F	39°42'46"/84°01'24"	Dayton-Xenia Rd.	Bellbrook
1.57	C,S,SO	39°42'50"/84°01'16"	Dayton-Xenia Rd.	Bellbrook
1.13	M,D	39°42'37"/84°01'41"	Ust. Little Beaver Cr.	Bellbrook
1.04	C,S,SO	39°42'31"/84°01'41"	Dst. Little Beaver Cr., at U.S. 35	Bellbrook
0.50	B,F	39°42'12"/84°01'36"	Ust. Greene Co. Beaver Cr. WWTP	Bellbrook
0.41	M,D	39°42'06"/84°01'39"	Ust. Greene Co. Beaver Cr. WWTP	Bellbrook
0.40	*E*	*39°42'00"/84°01'40"*	*Greene Co. Beaver Cr. WWTP eff.*	*Bellbrook*
0.39	*C,B,F*	*39°42'01"/84°01'39"*	*Greene Co. Beaver Cr. WWTP mix. zone*	*Bellbrook*
0.30	F	39°41'54"/84°01'10"	Dst. Greene Co. Beaver Cr. WWTP	Bellbrook
0.20	C,CO,S,SO,B	39°41'53"/84°01'37"	Dst. Greene Co. Beaver Cr. WWTP	Bellbrook
0.01	M,D	39°41'45"/84°01'30"	At mouth	Bellbrook
Little Beaver Creek				
4.70	B,F	39°43'31"/84°06'13"	Ust. Mont. Co. E. Regional WWTP	Bellbrook
4.62	C,S,SO	39°43'35"/84°06'13"	Ust. Mont. Co. E. Regional WWTP	Bellbrook
4.57	*C,B,F*	*39°43'39"/84°06'12"*	*Mont. Co. E. Reg. WWTP mix. zone*	*Bellbrook*
4.53	C,CO,S,SO	39°43'41"/84°06'12"	Dst. Mont. Co. E. Regional WWTP	Bellbrook
4.40	B,F	39°43'38"/84°06'13"	Dst. Mont. Co. E. Regional WWTP	Bellbrook
2.10	F	39°43'23"/84°03'37"	North Fairfield Rd.	Bellbrook
2.00	B	39°43'21"/84°03'34"	North Fairfield Rd.	Bellbrook
1.95	C	39°43'22"/84°03'30"	North Fairfield Rd.	Bellbrook
0.10	B	39°42'36"/84°01'44"	Factory Rd.	Bellbrook
0.05	C,M,D	39°42'36"/84°01'43"	Factory Rd.	Bellbrook
Glady Run				
4.90	B,F	39°39'29"/83°58'57"	Ust. Xenia Glady Run WWTP swale	Xenia
4.82	C,S,SO,M	39°39'27"/83°58'00"	Ust. Xenia Glady Run WWTP swale	Xenia
4.75	C,CO,S,SO	39°39'26"/83°58'02"	Dst. Xenia Glady Run swale	Xenia
4.70	B,F	39°39'23"/83°58'05"	Dst. Xenia Glady Run swale	Xenia
4.08	M,D	39°39'01"/83°58'32"	Hedges Rd.	Xenia
2.08	M,D	39°37'58"/83°59'45"	Schnebly Rd. (north crossing)	Xenia
1.10	M,D	39°37'24"/84°00'20"	Schnebly Rd. (south crossing)	Waynesville
0.60	C,M,D	39°37'02"/84°00'37"	S.R. 725	Waynesville
0.30	B,F	39°37'01"/84°00'38"	Dst. S.R. 725	Waynesville

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Glady Run WWTP Swale				
0.30	B,F	39°39'39"/83°57'49"	Ust. Xenia Glady Run WWTP	Xenia
0.21	M,D	39°39'36"/83°57'52"	Ust. Xenia Glady Run WWTP	Xenia
0.20	*E,F*	*39°39'34"/83°57'54"*	*Xenia Glady Run WWTP eff./mix. zone*	*Xenia*
0.10	F	39°39'28"/83°57'54"	Ust. mouth	Xenia
0.01	M,D	39°39'26"/83°58'02"	At mouth	Xenia
Tributary to Glady Run				
0.01	M	39°37'02"/84°00'38"	At mouth (ust. from S.R. 725)	Waynesville
Mill Run				
0.59	C	39°32'30"/84°03'52"	U.S. Rt. 42	Waynesville
Newman Run				
0.30	B,F	39°31'06"/84°05'54"	Ust. S.R. 42	Waynesville
0.27	C,S,SO	39°31'04"/84°05'53"	Adj. Pekin-Waynesville Rd.	Waynesville
Anderson Fork				
5.00	B,F,	39°33'57"/83°54'08"	Ust. Old Winchester Trail	N. Burlington
4.90	C,CO,S,SO	39°33'59"/83°54'10"	Old Winchester Trail	N. Burlington
Flat Fork				
1.70	C,CO,S,SO,B,F	39°28'26"/84°02'46"	Oregonia Rd.	Oregonia
Caesar Creek				
16.52	C,CO,S,SO	39°37'26"/83°57'53"	Spring Valley Paintersville Rd.	N. Burlington
16.50	B,F	39°35'53"/83°57'58"	Spring Valley Paintersville Rd.	N. Burlington
0.15	C	39°29'34"/84°06'06"	Corwin Rd.	Oregonia
0.10	B,F	39°29'34"/84°06'07"	Dst. Corwin Rd., ust mouth	Oregonia
Dry Run				
1.80	B,F	39°23'02"/84°12'13"	Snook Rd.	Lebanon
1.79	C,CO,S,SO	39°23'01"/84°12'15"	Snook Rd.	Lebanon
Turtle Creek				
6.30	B,F	39°25'55"/84°13'26"	Ust. Glosser Rd.	Lebanon
6.23	C,CO,S,SO	39°25'53"/84°13'31"	Glosser Rd.	Lebanon
5.00	C	39°25'28"/84°14'28"	McClure Rd.	Lebanon
4.70	F	39°25'18"/84°14'37"	McClure Rd.	Lebanon
4.30	B	39°24'54"/84°14'23"	Dst. U.S. 42	Lebanon
0.70	C,S,SO,D	39°22'22"/84°13'47"	Mason Rd.	S. Lebanon
0.60	B,F	39°22'19"/84°13'45"	Ust. Cincinnati Milacron	S. Lebanon
0.58	*C,CO,S,SO*	39°22'18"/84°13'44"	*Cincinnati Milacron diffuser mix. zone*	*S. Lebanon*
0.57	D	39°22'19"/84°13'43"	Dst. Cincinnati Milacron diffuser	S. Lebanon
0.52	C,S,SO	39°22'19"/84°13'35"	S.R. 48	S. Lebanon
0.50	*B,F*	*39°22'18"/84°13'38"*	*Dst. Cincinnati Milacron diffuser*	*S. Lebanon*
0.40	B,F	39°22'19"/84°13'36"	Ust. S.R. 48	S. Lebanon
0.10	B,F	39°22'13"/84°13'12"	Ust. mouth	S. Lebanon
0.01	C,S,SO,D	39°22'11"/84°13'12"	At mouth, dst. Dry Run	S. Lebanon

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Muddy Creek				
3.50	M,D	39°22'18"/84°17'18"	S.R. 741, ust. Mason WWTP	Mason
3.24	*E*	*39°22'29"/84°17'05"*	*Mason WWTP eff.*	*Mason/Monroe*
2.50	C,CO,M,D,B	39°22'26"/84°16'30"	Mason-Morrow Rd.	Mason
1.60	F	39°22'37"/84°15'44"	Mason-Morrow Rd.	Mason
Simpson Creek				
0.15	M,D	39°19'17"/84°15'19"	Ust. Warren Co. Lower LMR WWTP	Mason
0.14	*E*	*39°19'17"/84°15'19"*	*Warren Co. Lower LMR WWTP eff.*	*Mason*
0.01	M,D	39°19'14"/84°15'12"	At mouth	Mason
O'Bannon Creek				
4.37	M	39°14'57"/84°12'05"	Gibson Rd.	S. Lebanon
2.57	*E*	*39°15'35"/84°13'20"*	*Clerm. Co. O'Bannon Cr. WWTP eff.*	*S. Lebanon*
0.26	M,D,QM	39°16'07"/84°15'21"	S.R. 48	Mason
Polk Run				
1.71	M	39°14'56"/84°17'37"	Loveland Rd.	Mason
Sycamore Creek				
0.50	B	39°13'24"/84°19'35"	Ust. Ham. Co. Sycamore Cr. WWTP	Madeira
0.40	C,S,SO,F	39°13'33"/84°19'28"	Ust. Ham. Co. Sycamore Cr. WWTP	Madeira
0.27	M,D,QM	39°13'29"/84°19'25"	Ust. Ham. Co. Sycamore Cr. WWTP	Madeira
0.26	*E,B,F*	*39°13'30"/84°19'26"*	*Sycamore Cr. WWTP mixing zone*	*Madeira*
0.25	*C*	*39°13'30"/84°19'25"*	*Sycamore Cr. WWTP mixing zone*	*Madeira*
0.20	F	39°13'13"/84°19'10"	Dst. Sycamore Cr. WWTP	Madeira
0.10	B	39°13'30"/84°19'15"	Dst. Sycamore Cr. WWTP	Madeira
0.05	C,CO,S,SO,M,D	39°13'32"/84°19'10"	Dst. Sycamore Cr. WWTP, near mouth	Madeira
Stonelick Creek				
20.00	F	39°15'23"/84°00'45"	Dst. Woodville-Mainville Rd.	Pleasant Plain
17.70	B	39°14'04"/84°02'30"	SR 133 and Martin Rd.	Newtonsville
16.74	C CO	39°13'33"/84°03'07"	S.R. 133	Newtonsville
16.70	F	39°13'33"/84°03'08"	S.R. 133, Stonelick Lake	Newtonsville
3.10	C,CO,F	39°08'21"/84°11'07"	Dst. Lick Fork	Goshen
2.90	B	39°08'12"/84°11'14"	Dst. Lick Fork	Goshen
1.20	F	39°07'16"/84°12'06"	U.S. Rt. 50	Batavia
1.00	C,CO,S,SO,B	39°07'21"/84°11'57"	U.S. Rt. 50	Batavia
East Fork Little Miami River				
15.60	C,CO,S,SO	39°03'36"/84°10'32"	S.R. 222	Batavia
15.50	B,F	39°03'45"/84°10'46"	Dst. S.R. 222	Batavia
13.35	*C,S,SO*	*39°04'55"/84°10'37"*	*Batavia WWTP mixing zone*	*Batavia*
13.30	B	39°05'04"/84°10'41"	Dst. Batavia WWTP	Batavia
12.70	B,F	39°05'20"/84°11'03"	Dst. Batavia WWTP, ust. ODNR access	Batavia
12.59	*C,S,SO*	*39°05'20"/84°11'18"*	*Clerm. Co. Mid. E.Fk. WWTP mix. zone*	*Batavia*
12.40	F	39°05'21"/84°11'25"	Dst. Clerm. Co. Middle E.Fk. WWTP	Batavia
9.20	B,F	39°07'02"/84°12'30"	Ust. Olive Branch-Stonelick Rd.	Batavia
9.10	C	39°07'08"/84°12'42"	Olive Branch-Stonelick Rd.	Batavia
6.70	B	39°08'08"/84°14'12"	Roundbottom Rd.	Goshen
6.60	F	39°08'17"/84°14'26"	Roundbottom Rd.	Goshen

Table 5. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
East Fork Little Miami River, cont.				
6.57	C,D	39°08'13"/84°14'17"	Roundbottom Rd.	Goshen
4.85	C,S,SO	39°08'51"/84°15'31"	Dst. Clerm. Co. Lower E.F. WWTP trib.	Madeira
4.70	B,F	39°08'54"/84°15'30"	Dst. Lower E.F. WWTP trib.	Madeira
4.30	D	39°09'17"/84°15'32"	Dst. Clerm. Co. Lower E.F. WWTP trib.	Madeira
4.00	C	39°10'17"/84°17'53"	S.R. 50 entrance to I-275	Madeira
2.50	D	39°10'01"/84°16'17"	I-275	Madeira
1.90	B	39°09'40"/84°16'48"	Dst. I-275	Maderia
1.70	F	39°09'42"/84°16'55"	Ust. Milford WWTP	Maderia
1.40	F	39°09'49"/84°17'05"	Dst. Milford WWTP	Maderia
0.80	B	39°09'23"/84°16'50"	South Milford Rd.	Madeira
0.77	C,CO,S,SO	39°09'20"/84°17'30"	Cleveland Ave., near Terrace Park C.C.	Madeira

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table 4 .

Determining Use Attainment Status

The attainment status of aquatic life uses (*i.e.,* FULL, PARTIAL, and **NON**) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-17). The biological community performance measures which are used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981).

Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1988). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of the aquatic life use is FULL if all three indices (or those available) meet the applicable biocriteria, PARTIAL if at least one of the indices does not attain and performance at least fair, and **NON** attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS.

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Macroinvertebrate Community Assessment

Macroinvertebrate assemblages were sampled quantitatively using multiple-plate artificial substrate samplers (modified Hester/Dendy [Plate 6]) in conjunction with a qualitative assessment of the available natural substrates. During the present study, macroinvertebrates collected from the natural substrates were also evaluated using an assessment tool currently in the developmental phase. This method relies on tolerance values derived for each taxon, based upon the abundance data for that taxon from artificial substrate (quantitative) samples collected throughout Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations where the taxon has been collected are weighted by its abundance on the artificial substrates. The mean of the weighted ICI scores for the taxon results in a value which represents its relative level of tolerance on the ICI scale of 0 to 60. For the qualitative collections in the Ottawa River study area, the median tolerance value of all organisms from a site resulted in a score termed the Qualitative Community Tolerance Value (QCTV). The QCTV shows potential as a method to supplement existing assessment methods using the natural substrate collections. Use of the QCTV in evaluating sites in the Little Miami River study area was restricted to relative comparisons between sites with no direct attempt to interpret quality of the sites or aquatic life use attainment status.

Fish Community Assessment

Fish assemblages were sampled using wading or boat method pulsed DC electrofishing gear (Plate 6). The wading method was used at a frequency of one or two samples at each site. The boat method was used at a frequency of two or three samples at each site. The specific electrofishing method and the number of samples for each sampling location are listed in Table 12.

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Fig. 4). The "magnitude" of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are also expressed as ADV/mile to normalize comparisons between segments and other streams and rivers.

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are the principal arbiter of aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria in the role of principal arbiter within a weight of evidence framework has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991a; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and the biological response signatures (Yoder and Rankin 1995) within the biological data itself. Thus the assignment of principal causes and sources of impairment in this report do not represent a true "cause and effect" analysis, but rather represent the association of impairments (based on response indicators) with stressor and exposure indicators whose links with the biosurvey data are based on previous research or experience with analogous situations and impacts. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified. The process is similar to making a medical diagnosis in which a doctor relies on multiple lines of evidence concerning patient health. Such diagnoses are based on previous research which experimentally or statistically linked symptoms and test results to specific diseases or pathologies. Thus a doctor relies on previous experience in interpreting symptoms (*i.e.*, multiple lines from test results) to establish a diagnosis, potential causes and/or sources of the malady, a prognosis, and a strategy for alleviating the symptoms of the disease or condition. As in medical science, where the ultimate arbiter of success is the eventual recovery and the well-being of the patient, the ultimate measure of success in water resource management is restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993) here we are referring to the process for identifying biological integrity and causes/sources associated with observed impairment, not whether human health and ecosystem health are analogous concepts.

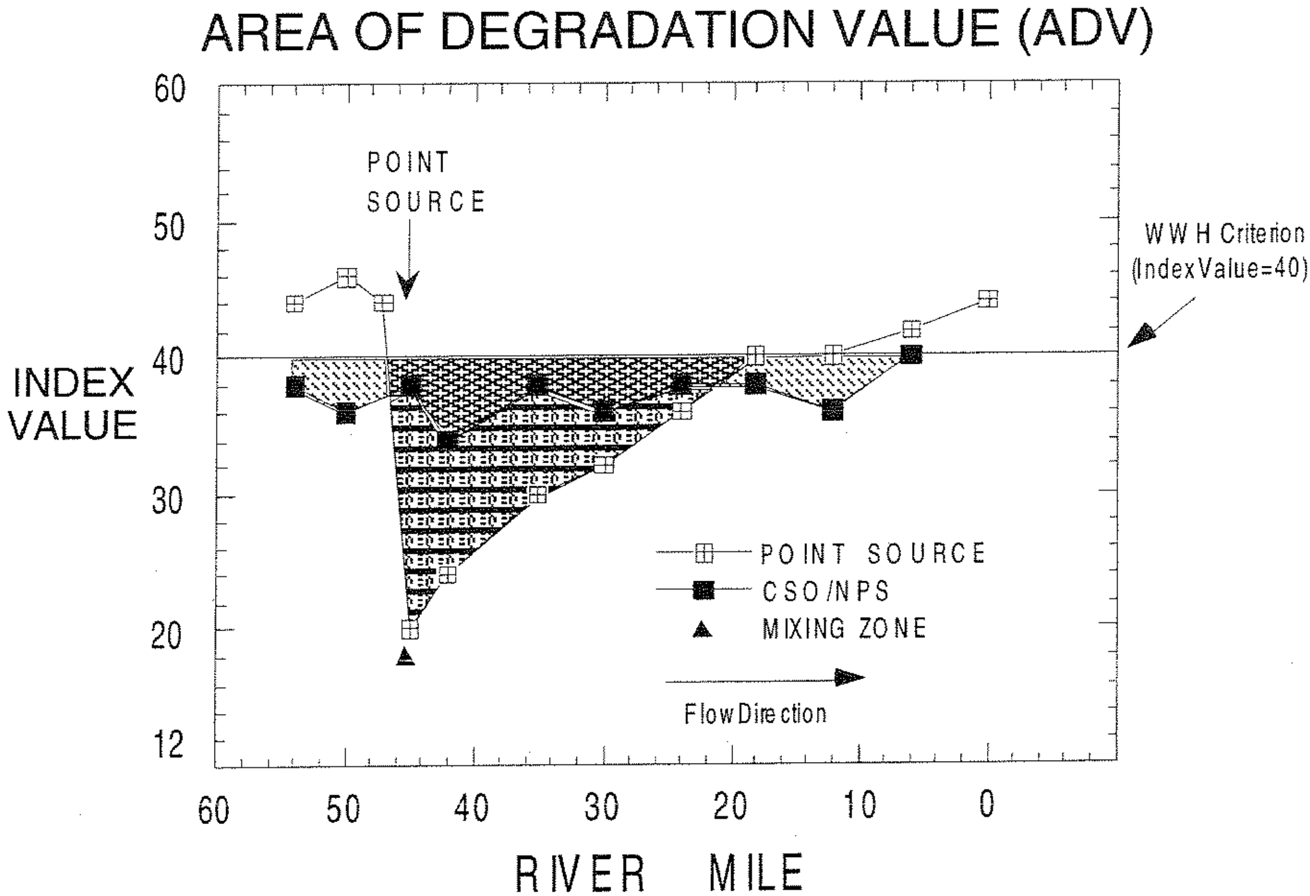

Figure 4. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

RESULTS AND DISCUSSION

Pollutant Loadings: 1979 - 1993 (Plates 11-12; Figures 5 - 25; Tables A-1 - A-2c)

Gilroy Ditch - South Charleston WWTP

- Initially constructed in 1938 and later expanded in 1969, the South Charleston WWTP utilizes secondary treatment which includes aeration, primary and secondary settling, chlorination, and aerobic sludge digestion. Flow equalization was added in 1990 along with additional clarifiers. The facility discharges to Gilroy Ditch at a design flow of 0.24 MGD. The latest census estimated the population at 1600 with a population equivalent of 2400. Separate sewers service 98-99% of the village with three lift stations, one with an overflow (outfall 002). Excessive flow to the WWTP due to inflow and infiltration is a major problem. South Charleston is in the process of obtaining finances for a recommended WWTP upgrade to address deficiencies within the existing sewer system.

- Average annual discharge flow from the WWTP from 1983 through 1993 ranged from 0.121 to 0.380 MGD. The average during 1992-93 was 0.210 MGD. Flow during the years 1987 and 1989-91 exceeded the design capacity of 0.24 MGD indicating that the plant was hydraulically overloaded. The hydraulic overloads in 1990 and 1991 may have been caused by above normal amounts of precipitation (USGS 1991, 1992).

- Total suspended solids (TSS) loadings (50th percentile values) showed gradual reductions over a 15 year span (1979-1993) and averaged 9.69 kg/day.

- Annual median (50th percentile) ammonia-N values for 1987-1993 (data is available only since 1987) exhibited a steady reduction with the most dramatic decline occurring after 1989 (Figure 5). Third quarter (July 1 - September 30) loadings exhibited a similar pattern for the same four years.

- Annual 5-day biochemical oxygen demand (BOD_5) loadings (50th percentile) ranged from 11.7-34.4 kg/day and demonstrated variability during 1979-1993 with no discernable trend. Annual median loadings in 1993 ($CBOD_5$ reported 1987-1993) were double those during the two previous years which corresponded to values reported during 1979-1989.

Massies Creek - Cedarville WWTP

- Constructed in 1952 and upgraded in 1971 (new plant), the Cedarville WWTP is a secondary treatment plant utilizing contact stabilization and chlorination. The collection system consists of separate sanitary sewers throughout 100% of the service area. Two lift stations with bypasses exist, but the frequency of overflows is unknown. The bypasses should be eliminated via an impending upgrade of the WWTP. Design capacity is 0.480 MGD and the discharge is to Massies Creek. The population averages 3,800 during June - September, but seasonally increases to 4800 when Cedarville College is in session.

- In 1967 the plant was recognized as being "seriously overloaded" with peak flows exceeding design flows by greater than 50%. In 1974 U.S EPA recommended adoption of a regular program of solids wasting in order to avoid the discharge of solids to Massies Creek. In 1984 Ohio EPA reiterated the need for an upgrade at the WWTP. A Municipal Compliance Plan for upgrading the facility was approved by Ohio EPA in 1988.

- In 1991 notice of violation (NOV) letters were sent to Cedarville for failure to submit required monthly operating reports (MOR) by the required date. Sludge management is a problem and is presently stored in the sludge lagoon for indefinite time periods. When the design capacity of the

WWTP is exceeded, biosolids are subsequently bypassed to Massies Creek. Detailed plans for a WWTP upgrade were to be submitted by November 15, 1993.

- Average annual flows reported in 1983 were 0.339 MGD and 0.340 MGD in 1993. Within a 10 year period flow values fluctuated between 0.255 - 0.431MGD. Discharge volume in 1989 and 1990 exceeded other years and was likely influenced by above normal precipitation. However, average flow data indicates that design capacity is not exceeded.

- Average annual ammonia-N loadings remained relatively stable from 1977-1981, but nearly doubled in 1982 and further increased in 1983 and 1984. Ammonia-N loadings then declined to 50% of the 1983 and 1984 values and stabilized to an annual average of 1.10 - 3.40 through 1992. In 1993 the highest annual average since 1976 was reported (7.36 kg/day), a further indication of WWTP problems (Figures 6-7).

- Average annual suspended solids demonstrated a pattern similar to ammonia-N in the early 1970s (Figure 7) In the late 1970s and early 1980s loadings increased by nearly 43% increasing to 52% by 1993.

- BOD_5 remained in the range of 12 to 14 kg/day from 1979 to 1987 and increased to nearly 39% during 1988-1990 (Figure 6). $CBOD_5$ loadings increased during 1991-1993 by 300% (3.89 to 26.8 kg/day) with the most significant increase in 1993.

- Bioassay testing showed acute toxicity to both fathead minnow *(Pimephales promelas)* and water fleas *(Ceriodaphnia dubia)* in August and September 1993.

Yellow Springs Creek - Yellow Springs WWTP

- Constructed in 1961, the Yellow Springs WWTP has secondary treatment consisting of extended aeration, secondary clarification, chlorination, and aerobic sludge digestion. An upgrade to the WWTP in July 1988 resulted in a design capacity of 0.600 MGD. The service area consists of separate sewers with 90% of the area sewered. The most recent census estimates the population at 3772 with a population equivalent of 3973 and only stagnant growth predicted. The WWTP's effluent flows through a series of cascading, high gradient falls in Camp Glen Helen (Plate 11) before splitting into several channels that enter Yellow Springs Creek over a 100 meter segment. One lift station with an overflow was reported, however, these should rarely occur due to the recent upgrades. Elimination of the lift station overflow is planned with the future upgrade of the WWTP. An upgrade to the internal bypass was recently approved which should provide more accurate conduit flow data and prevent solids washouts during high flows. Industrial input from Vernay Labs, Inc. (print shop), Yellow Springs Instruments (electronic instruments), and Antioch Publishing Co. comprises 2-4% of the WWTP inflow.

- The annual average flow over a 10-year period (1983-1993) has increased 2.5 times, but was much higher in 1980, 1990, and 1992. The volume of flow from the WWTP has shown a high degree of year-to-year variability.

- Median total suspended solids during 1979-1988 averaged 49.5 kg/day and declined to 25.5 kg/day after 1989 (Figure 8).

- BOD_5 loadings during 1979-1988 were variable averaging 65.8 kg/day. The highest values occurred during 1980-1988 with an average median value of 58.2 kg/day. Differences between the median and 95th percentile values indicated a high degree of variability in the final effluent quality.

- Median and 95th percentile ammonia-N loadings fluctuated widely (0.12-22.0 kg/day) over a nine-year period (1979-1988). Marked reductions in median values occurred during 1989-1992. Median and 95th percentile ammonia-N loadings varied widely and suggest a high degree of variability in WWTP efficiency. Values for ammonia-N during 1989-1993 were the lowest recorded since 1984.

Little Miami River - Xenia Ford Road WWTP

- Constructed in 1969 and upgraded in 1988, the Xenia-Ford Road plant is an advanced secondary WWTP consisting of secondary clarifiers, flow equalization, final clarification and dechlorination. The WWTP discharges directly to the Little Miami River with a design capacity of 3.600 MGD. Nearly 100% of the service area is sewered with separate sewers. Industrial contributions to the WWTP is approximately 0.05% of the inflow. The latest population census estimate is 25,000 with no reported population equivalent. One relatively inactive overflow exists at the equalization basin. Various efforts are on-going to reduce inflow/infiltration to the WWTP. The city has occasionally pumped from a manhole directly to Shawnee Creek during heavy rainfall events although this practice has been reduced.

- Conduit flows reported during 1983-1993 remained relatively stable with an annual average of 2.820 MGD. This average is approximately 43% below the design flow of 3.600 MGD.

- Ammonia-N loadings fluctuated during 1979-1988 at an annual average of 71.2 kg/day for the median value (Figure 10). The annual median loading decreased to 5.02 kg/day following a plant upgrade in 1988.

- Recent bioassay test results include acute toxicity to *Ceriodaphnia dubia* in the first day effluent grab sample in March 1992, effluent and receiving water samples were not acutely toxic in June 1992, and 5% mortality to fathead minnow *(Pimephales promelas)* in April 1993.

Little Beaver Creek - Montgomery County Eastern Regional WWTP

- Constructed in 1953 and expanded in 1958 and 1970, the Montgomery County Eastern Regional WWTP is a secondary treatment plant consisting of secondary clarification and activated sludge. A major 1988 modification included flow equalization tanks, secondary clarifiers, aerated channels, dechlorination, and post-aeration. Forty-two (42) overflows were also eliminated. The WWTP has a design flow of 13.0 MGD and discharges to Little Beaver Creek. The plant is served by separate sewers with 100% of the service area sewered. However, the extent of inflow/infiltration has not been quantified. The collection system contains 17 lift stations with no reported overflows or bypasses. The population is reported at 120,000 with saturated growth. The plant receives a 15% industrial input consisting of wastewater from General Motors-Delco (automotive parts manufacturer), Kodak Co., and a dairy.

- Average annual flows at this facility varied by nearly 1.500 MGD during 1983-1993 (7.560-14.90 MGD) which persisted after the addition of flow equalization in 1988. Average annual flow in 1991 and possibly 1992 were well above design capacity with reported flows of 14.90 and 22.20 MGD, respectively.

- Ammonia-N loadings exhibited a gradual reduction during 1979-1985 when loadings increased slightly during the next two years (Figure 9). Loadings were significantly reduced in 1988 due to a WWTP upgrade. Median ammonia-N averaged 8.62 kg/day during 1991-1993.

- BOD_5 loadings in the late 1970s and mid-1980s fluctuated between 650-1500 kg/day. $CBOD_5$ loadings declined from 605 kg/day to 250 kg/day during 1986-1993. With the exception of 1992, $CBOD_5$ during 1988-1993 remained in the 200 kg/day range.

- Median copper loadings ranged from 0.571-1.280 kg/day during 1979-1993 with no discernable trends. Values in 1993 were approximately the same as the prior 14 years.

- Recent bioassay test results reveal the following: 20% mortality to *Ceriodaphnia dubia* and no acute toxicity to fathead minnows was evident in 75% and 100% strength effluent in a U.S. EPA test in 1988; no adverse effects to either fathead minnows or *Ceriodaphnia dubia* in a 1990 Montgomery Co. test; no acute toxicity in a May 1993 Ohio EPA test; both the effluent and receiving water exhibited acute toxicity in April 1993 (chronic toxicity testing was recommended); and bioassay test results submitted by Montgomery Co. revealed six of 11 tests failed.

Beaver Creek - Greene County Beaver Creek WWTP

- Constructed in 1965 and upgraded in 1988, the Beaver Creek plant is a secondary plant served by separate sewers within 100% of the service area. The plant is equipped to perform basic secondary treatment processes utilizing secondary clarifiers, extended aeration tanks, and chlorination. Plans have been approved for ultraviolet light disinfection. The population is estimated at 32,784 (no equivalent population reported) with rapid growth predicted for the area. The plant discharges to Beaver Creek and has a design capacity of 4.600 MGD. A WWTP expansion is planned to handle excessive flows which have recently exceeded the design capacity. Industrial inputs are estimated at 2% and consist of significant flows from Elano (metal cleaner) and lesser contributions from Universal Technologies (transparency manufacturer), Kray International (govt. research facility), and JBK Manufacturing (pipe bending).

- Annual average flow during 1983-1993 increased 45% with the most substantial increases occurring during 1988-1993 (3.890 to 5.450 MGD). Design capacity was reached in 1991 and surpassed in 1992 and 1993.

- Loadings of ammonia-N increased during 1979-1981, but then declined during 1981-1987 (Figure 10). Even more dramatic reductions occurred in 1988 (following a plant upgrade) and again during 1991-1993 (median values of 25.78 and 5.67 kg/day, respectively).

- Median BOD_5 loads during 1976-1987 increased from 79 kg/day to 689 kg/day. Loadings of $CBOD_5$ decreased from 175 kg/day to 42 kg/day during 1987-1993.

- Bioassay test results showed the following: a composite sample was toxic to 50% of the *Ceriodaphnia dubia* after a 48 hr. exposure in March 1989; no acute toxicity to either species in any sample was evident in January 1989; and test results submitted by Greene Co. revealed three failures out of four tests.

Little Miami River - Greene County Sugar Creek WWTP

- Constructed in 1977 with a major modification in 1987, the Sugar Creek WWTP is a secondary treatment plant consisting of pre-aeration, secondary clarifiers, aerobic sludge digestion, and chlorination. Chlorination in the effluent is reportedly being replaced by ultraviolet light. The plant has a design capacity of 4.900 MGD and discharges directly to the Little Miami River. The collection system consists of separate sewers and 100% of the service area is sewered. Seven lift stations exist with no reported overflows or bypasses. Plans have been drafted to eliminate the lift stations in Montgomery County. Industrial inputs comprise <10% of the inflow with the most significant inputs from Dimco Gray (machine shop) and Union Camp (cardboard corrugator). Minor industrial contributors include Finishing Touch (furniture stripper), Marble Molders (sink-top manufacturers), and N/R labs (shampoo manufacturer).

- Average annual conduit flow during 1983-1993 increased by nearly 2 MGD (3.770 to 5.600

MGD; nearly 1 MGD/five years). The design capacity was exceeded beginning in 1990 and was nearly surpassed by 1 MGD in 1993.

- Median annual ammonia-N loadings varied widely ranging from 45 to 154 kg/day (Figure 10). Reductions in ammonia-N ensued during 1988-1990 (from 11 to 7 kg/day, respectively) a result of the WWTP upgrade in 1987. However, a substantial increase (300-600%) in loadings from 7.3 kg/day to 47 kg/day occurred between 1991 and 1993.

- Bioassay tests showed the following: no acute toxicity was observed in April 1989; no acute toxicity was observed in October 1992 (grab samples of 001 outfall) - *Ceriodaphnia dubia* was adversely affected (50%) in the mixing zone which was likely due to chlorine toxicity; no acute toxicity was observed in grab and composite samples during October 1992.

Glady Run Swale - Xenia-Glady Run WWTP

- Constructed in 1959 with a major modification in 1988, the Xenia-Glady Run WWTP is an advanced secondary treatment plant consisting of activated sludge, settling, and anaerobic digestion. The WWTP has a design capacity of 2.600 MGD and discharges to Glady Run (in the past a drainage swale to Glady Run received the final effluent). Glady Run has since merged with the swale, thus adding increased flow and greater dilution for the effluent. The estimated population is 25,000. The collection system serves 100% of the service area. There is one fairly inactive overflow from an equalization basin. Inflow from Bob Evans Co. occasionally creates blockages in the sewer line. Approximately 9% of the inflow consists of industrial wastewater all of which are classified as minor industrial users.

- Average annual WWTP flow during 1983-1986 was fairly stable (1.940-2.000 MGD), but exhibited an increase of nearly 60% during 1987-1993. Effluent flow is presently within 5% of design capacity.

- Median ammonia-N loadings during 1979-1988 averaged 70.1 kg/day (Figure 11). Marked reductions in ammonia-N loadings occurred after the 1988 WWTP upgrade resulting in an average median value of only 0.98 kg/day during 1989-1993.

- One bioassay test in February 1989 showed no acute toxicity to either test species in any sample.

Little Miami River - Waynesville WWTP

- Constructed in 1962 with a major modification in 1983, the Waynesville WWTP is a secondary treatment plant consisting of flow equalization, fixed film reactor (RBC), extended aeration, lime stabilization, and chlorination. Plans for ultraviolet light disinfection in lieu of chlorination are being evaluated. The WWTP discharges to the Little Miami River and has a design flow of 0.710 MGD with no reported overflows or bypasses. The population is 1,969 with moderate to rapid growth predicted for the area. The service area has separate sewers and 100% of the area is sewered. Industrial contributions from a minor industrial user comprises <1% of the inflow.

- Average annual conduit flow data during 1983-1993 shows a gradual increase from 0.271 to 0.492 MGD, an increase of 82% over 10 years. The facility is operating at less than 70% of the design capacity.

- Average annual loadings for BOD_5 during 1983-1987 increased nearly 2.5 times over the five year span. Loadings of $CBOD_5$ increased during 1988-1993 with annual median values ranging from 4.44 to 5.30 kg/day.

- With a few exceptions, median annual ammonia-N loadings exhibited reductions of nearly 600%

during 1983-1993 (Figure 11). Median loadings increased from 0.088 kg/day in 1991 to 0.715 kg/day in 1993.

- Bioassay tests showed the following results: no acute toxicity to either test species in any sample was evident in July 1993; <20% toxicity to fathead minnows was detected in a composite sample collected in September 1993; a September 14, 1993 grab sample revealed toxicity to 10% of the fathead minnows and 20% of *Ceriodaphnia dubia* and 5% of *Ceriodaphnia dubia* in a composite sample.

Turtle Creek - Cincinnati Milacron

- Cincinnati Milacron manufactures printed circuit boards and generates industrial wastewater. The treatment of process wastewater consists of ion exchange (added in 1993) and pH control (outfall 001). Sanitary wastewater (outfall 002) is treated with extended aeration and ultraviolet light disinfection. The total wastewater design flow capacity is 0.088 MGD (combined wastewater volume). Both outfalls currently discharge intermittently to Turtle Creek through a three outlet diffuser installed in 1993. The diffuser's plume occupies approximately one-third of Turtle Creek's width. For the past 6-7 years Cincinnati Milacron has operated on a 9-10 hours/day and five day/week production schedule. Occasional weekend work is performed, but no wastewater containing metals is produced. A higher volume of wastewater will soon be produced on tuesdays and thursdays due to the electrolysis copper line being in operation simultaneously with the copper electroplating line. Copper concentrations averaged 57 ug/l and nickel concentrations averaged 60 ug/l in outfall 002 during 1990-1993. These concentrations are 2-3 times higher than in the water drawn from their wells.

- Sanitary wastewater flow (002) remained the same (0.012 MGD) from 1979-1981, decreased from 1982-1989, then markedly increased from 1990-1993 (Figure 12). Process wastewater flow (001) increased gradually during 1976-1980 from 0.15 to 0.22 MGD. During 1981-1983 flows decreased to 0.05 MGD, but doubled during 1984-1987 (Figure 13). Effluent volume then gradually declined to an average of 0.07 MGD during 1989-1993.

- Annual average copper levels at outfall 001 averaged 0.972 kg/day during 1979-1982 and remained steady until 1988. Loadings decreased from an average of 0.791 to 0.099 kg/day in 1993. Third quarter, average annual copper loadings at 001 ((Figure 13) for years 1979-1987 fluctuated within a range of 0525-1.130 kg/day. Between 1988 and 1993 average loadings declined further from 0.401-0.046 kg/day, respectively.

- In April 1990 the OEPA issued a Director's "Findings and Orders" to initiate a biomonitoring program by December 1991. A Toxicity Reduction Evaluation (TRE) plan was discussed.

- Bioassay tests performed by Ohio EPA, Cincinnati Milacron, and others showed the following: 100% mortality to fathead minnows and *Ceriodaphnia dubia/affinis* was observed in 100% effluent in a 1983 Ohio EPA test; chronic toxicity to both test organisms was observed in a 1984 Battelle test; toxicity related to copper concentrations in the effluent were reported in 1987 by Wright State University ; acute toxicity to *Ceriodaphnia dubia* was observed in a 1992 Cincinnati Milacron test; acute toxicity to both fathead minnows and *Ceriodaphnia dubia* was observed in May 1993 no toxicity was observed from the 002 outfall; acute toxicity to both test organisms was observed in a combined outfall sample in July 1993 with toxicity persisting in the mixing zone; a definitive test (employed when sufficient mortality or other adverse effects allow determination of a median lethal concentration or median effect concentration) indicated acute toxicity to both test organisms in October 1993; all 21 tests submitted by Cincinnati Milacron were considered as failing (*i.e.*, >20% mortality observed).

Muddy Creek - Mason WWTP

- Constructed in 1962 and a major upgrade in 1989, the Mason WWTP is a secondary treatment plant consisting of an oxidation ditch, final settling, and ultraviolet light disinfection. The collection system is separate and serves 85% of the service area (population of 11,000). The WWTP discharges to Muddy Creek with a design flow of 2.500 MGD. Excessive inflow and infiltration have resulted in the need for flow equalization basins along with new pretreatment, clarifiers, a sludge press, and sludge digester. The lack of sludge removal is also a problem. Construction on some of these processes has been initiated while other projects are currently in review. While the collection system has a fairly active overflow to Muddy Creek, construction is underway to eliminate the overflow. Industrial inputs comprise approximately 47% of the total inflow volume.

- A Consent Order signed in June 1991 contains a schedule for Mason to upgrade the plant to meet final table NPDES permit limits and eliminate the separate sewer overflow by September 1995. Imminent requirements include handling and disposing of sludge in accordance with an approved sludge management plan and infiltration/inflow reduction.

- Annual average conduit flow over the past 10 years (1983-1993) increased by nearly 150%. Flow values were approaching design capacity in 1993.

- Annual median ammonia-N loadings during 1981-1993 were variable ranging from 0.15 to 21.5 kg/day with no obvious trends (Figure 14). The disparity between median and 95th percentile values indicate instability in treatment efficiency which remained apparent after the 1989 plant upgrade.

- The median annual suspended solids loading during 1985-1989 was 26.9 kg/day. Loadings increased during 1991-1993 with an average of 48.3 kg/day. Again, considerable variability occurred between the median and 95th percentile values.

- BOD_5 loadings during 1979-1993 showed no recognizable pattern with values ranging between 145 kg/day in 1981 to 5.37 kg/day in 1993. Loadings in 1992 and 1993 were below those of previous years.

- Bioassay tests showed the following: no acute toxicity to either species was evident in any sample in November 1992 or January 1993 and no acute toxicity was detected in the effluent and 5% mortality to *Ceriodaphnia dubia* occurred in mixing zone in March 1993.

Little Miami River - Lebanon WWTP

- Constructed as a new facility in 1987, the Lebanon WWTP is a secondary treatment plant with counter-current aeration, plastic media sludge drying beds, and chlorination. This facility replaced the original Lebanon WWTP which discharged to Turtle Creek. The collection system is separate with 60% of the service area sewered (population is 12,500). The discharge is to the Little Miami River with a design capacity of 3.000 MGD. Two lift stations exist with no reported bypasses or overflows. Industrial inputs comprise 30-35% of the inflow with the most significant contribution from Fuji Tech, Inc. The WWTP flow is presently operating at the design capacity.

- Annual average flow during 1983-1993 increased 3.5 times and reached design capacity in 1990. The flow doubled in 1988 and nearly doubled again in 1993 to 3.460 MGD. Design capacity was exceeded in three different years (1990, 1992 and 1993).

- Annual median ammonia-N loadings during 1979-1987 (old WWTP) were sporadic and averaged 29.1 kg/day (Figure 15). By 1988 (new WWTP) median loadings diminished significantly to an average of 3.23 kg/day during 1988-1993.

- Bioassay tests in April and May 1990 and April 1993 revealed no acute toxicity.

Simpson Creek - Warren County Lower Little Miami WWTP

- Constructed in 1981 and upgraded in 1992, the Lower Little Miami WWTP is a secondary treatment plant consisting of vertical loop reactor extended aeration, secondary clarification, and chlorination/dechlorination. The collection system is separate with 100% of the service area sewered (population is 12,500 with a population equivalent of 14,873). The WWTP discharges to Simpson Creek with a plant design capacity of 3.640 MGD. An upgrade and expansion was recently completed; however, the facility is already in the design phase to double capacity.

- Seventeen (17) lift stations exist with no reported overflows or bypasses. The plant receives approximately 6% industrial flows from one significant user, OTC (semi-conductor devices), and seasonally variable quantities of sanitary wastewater from the Kings Island Amusement Park.

- Annual average conduit flow increased nearly 300% during 1983-1993. Flow volume increased steadily from 1983 to 1991 with values ranging from 0.770 to 2.540 MGD, respectively. Following the upgrade in 1992, flow volume declined slightly to 2.220 MGD in 1993, well below the design capacity.

- Annual median ammonia-N loadings during 1981-1991 exhibited, for the most part, a gradual increase in loadings to Simpson Creek (Figure 15). Differences between the median and 95th percentiles were apparent even in 1992; however reported values for both were less than 2.0 kg/day in 1993.

- Bioassay tests showed the following: acute toxicity was evident in a first day grab of the effluent, but no acute toxicity was evident in the second day grab in March 1990; acute toxicity to *Ceriodaphnia dubia* after a 48 hour exposure in April 1990; no acute toxicity was evident to fathead minnows, but 10% toxicity to *Ceriodaphnia dubia* in a day-1 effluent grab occurred after a 48 hour exposure in May 1990; and test results submitted by Warren Co. revealed only two of 12 test failures.

O'Bannon Creek - Clermont County O'Bannon Creek WWTP

- Constructed in 1984, the O'Bannon Creek WWTP is a secondary treatment plant consisting of two stage aeration, rapid sand filters, and chlorination. The collection system is separate with 80% of the service area sewered (population is 11,400) with moderate to high growth predicted. The WWTP discharge is to O'Bannon Creek with a plant design capacity of 1.200 MGD. Occasional bypasses and overflows have been reported. Inflow/infiltration is significant at the WWTP and a plan is being developed to address this problem. Plans include flow equalization and parallel aeration.

- Average annual conduit flow mostly increased during 1984-1990 ranging between 0.949 to 1.380 MGD. Flow volume decreased somewhat during 1991-1993 averaging 1.200 MGD. Design capacity was exceeded by average annual flows in six of nine years.

- Ammonia-N loadings (median and 95th percentiles) demonstrated significant deviations in 1984 and 1985 were nearly equal during 1986-1990 and significantly lower (Figure 15). Data for one or both percentiles was missing for the period 1991-1993.

- Bioassay results revealed no toxicity in November 1992 or March 1993.

Little Miami R. (via U.T.) - Hamilton County MSD Polk Run WWTP

- Constructed in 1970 with a major modification in 1988 (new plant), the Polk Run WWTP is an advanced secondary treatment plant consisting of secondary clarification and chlorination/dechlorination. The 1988 upgrade and expansion increased the design capacity from 1.0 to 6.0 MGD. The 6.0 MGD design capacity is expected to be reached within the next two years and another expansion is being planned to meet the rapid growth projected for the area. The collection system is separate with 50% of the service area sewered (population is unreported). The facility discharges to an unnamed tributary of the Little Miami River approximately 50 feet upstream from the mainstem. Industrial flow from one minor user (Donisi Glass) accounts for approximately 5% of the inflow. The plant has seven lift stations with reported bypasses at four pump stations (Glen Lake and Harper Ave., Bears Run, and Polk Run). A plant bypass (due mostly to infiltration/inflow resulting from a heavy rainfall) in May 1990 discharged approximately one million gallons of wastewater.

- Polk Run is extending its service lines to cover annexed areas in the Twenty Mile area. The Taylor Street sewer replacement is designed to alleviate the inflow/infiltration problems. The Director's Findings & Orders require the identification of all sanitary sewer overflows by June 22, 1993. An order to require elimination of sanitary sewer overflows is pending.

- The average annual conduit flow from 1989-1993 ranged from 2.810 to 4.100 MGD and did not exceed the design capacity.

- Bioassay tests showed the following: acute toxicity was evident to *Ceriodaphnia dubia* in all effluent samples in March 1993 - acute toxicity (100% mortality) persisted into the mixing zone; the effluent and mixing zone were acutely toxic in May 1993 - 10-20% mortality to *Ceriodaphnia dubia* in grabs and composite samples and 85% mortality occurred in the mixing zone.

Sycamore Creek - Hamilton County MSD Sycamore Creek WWTP

- Constructed in phases (1954, 1970) and upgraded in 1988 and 1991, the Sycamore Creek WWTP is a secondary treatment plant with rapid sand filters and chlorination. The construction of dechlorination facilities was scheduled for completion in August 1994. The collection system is separate with 70% of the service area sewered (population is 30,000). The plant has a design capacity of 6.0 MGD and discharges to Sycamore Creek near the mouth. Industrial contributions amount to only 1% of the inflow. There are three lift stations each with bypasses and one with an overflow. A Consent Order has been issued to address the sanitary sewer overflows, mercury exceedences, and the extension of service to unsewered areas.

- Average annual conduit flow during 1983-1993 varied from 5.530 to 7.510 MGD. Since 1984, the average annual flow has exceeded the design capacity of 6.0 MGD.

- Ammonia-N loadings (median values) increased during 1979-1989 from 95 to 175 kg/day and 95th percentile values followed a similar pattern (Figure 16). Loading reductions in 1989 and 1991 illustrates the improvement in effluent quality brought about by the 1988 and 1991 facility upgrades.

- BOD_5 loadings were also significantly reduced subsequent to the 1988 and 1991 plant upgrades.

- Total suspended solids loadings (median and 95th percentile values) fluctuated significantly during 1979-1990 indicating considerable variability in effluent quality. Similar to ammonia-N and BOD_5, total suspended solids loadings decreased markedly during 1991-1993 due to the plant upgrades.

- Bioassay tests showed the following: no acute toxicity was evident to *Ceriodaphnia dubia* except in the mixing zone (100% mortality) in March 1990; no acute toxicity was evident in April 1990;

no acute toxicity was evident in the effluent, but acute toxicity was observed in Sycamore Creek in April 1990; test results submitted by Hamilton Co. revealed four of seven test failures.

Little Miami River - Totes, Inc.

- Totes, Inc. manufactures latex boots utilizing various processes (i.e., latex dips, mold cleaning, mixing/curing and compounding). Production is on a 24 hour shift, five days/week, 52 weeks/year. Wastewater volume is approximated at 0.029 MGD and consists of non-contact cooling water, second-stage chlorination, wash treatment tank, and stormwater. The treatment processes consists of activated sludge, settling, sand filters, and chlorination.

East Fork Little Miami River - Batavia WWTP

- Constructed in 1955, the Batavia WWTP is a secondary treatment plant consisting of secondary settling, activated sludge, anaerobic digesters, and chlorination. The collection system is separate with three lift stations and no reported overflows or bypasses. The WWTP discharges to the East Fork Little Miami River with a design capacity of 0.24 MGD. The population served is 1,700 and stagnant growth is predicted. Industrial contributions are minor and include Cincinnati Chemical Processing (chemical manufacturer).

- Inflow/infiltration is a problem resulting in overflows during storm events and plant overloads. Problems also occur with the sludge digesters which periodically are inoperable.

- Average annual conduit flow during 1984-1987 increased (excepting 1986) from 0.193 to 1.680 MGD. Conduit flow increased incrementally during 1988-1992, but then declined to 0.332 MGD. Average flows during 1989-1993 (0.264-0.608 MGD) exceeded the design capacity of 0.24 MGD.

- Annual ammonia-N loadings (median values) during 1979-1988 varied, but remained below 10 kg/day (Figure 19). Annual nitrate-N loadings (median values) declined in 1980 and 1981, but increased steadily until 1991 and remained at the 1980 levels in 1992 and 1993.

- Annual total suspended solids loadings (median values) generally increased during 1982-1988. TSS loadings from 1989-1993, however, declined to levels below those observed over the previous 10 years. Significant departures between median and 95th percentile values occurred reflecting inconsistent treatment efficiency.

East Fork Little Miami River - Clermont County Middle East Fork Regional WWTP

- Constructed in 1973 and a major modification in 1981, the Middle East Fork Regional WWTP is a secondary treatment plant with secondary clarification, anaerobic digestion, and chlorination. A phase II upgrade (*i.e.*, new clarifiers) is also in progress (70% complete). The collection system is separate with 50% of the service area sewered. There are 11 lift stations with three bypasses and a moderate inflow/infiltration problem. The population served is 10,031 and the design capacity of the current upgrade is 7.0 MGD. Industries contribute 15% of the inflow with the most significant input from Ford Transmission followed by Sun Chemical, U.S. Precision Lens, and two poultry processors.

- Average annual conduit flows ranged from 1.730 to 2.100 MGD in 1983-1987, averaged 2.400 MGD from 1988-1992, and was 2.190 MGD in 1993. The reported flow data indicates the WWTP is operating well below design capacity.

- Ammonia-N loadings (median values) fluctuated during 1979-1993 with the highest loading years occurring during 1984-1986 (Figure 17). Differences between the median and 95th percentiles were considerable particularly from 1987-1993. Loadings were lowest during 1989-1992 and remained near 7.0 kg/day in 1993.

East Fork Little Miami River - Clermont County Lower East Fork WWTP

- Constructed in 1979 and upgrade in 1992 (RBC trains and flow equalization were added), the Lower East Fork WWTP is a tertiary treatment plant with rapid sand filters, secondary clarifiers, aerobic digestion, and chlorination. Disinfection by ultraviolet light is being evaluated as an alternative to chlorination. Occasional nuisance odors from the sludge holding and digestion tanks continue to be a problem and the use of ferric chloride is being investigated. The collection system is separate and contains 29 lift stations, 11 with bypasses (several are active) and five with overflows. A number of overflows impact the Shayler Creek subbasin, some of which is due to vandalism and debris which blocks flow within the collection system. The service area is 60% sewered and serves a population of 39,449 (population equivalent of 50,000). Rapid growth, however, is predicted for the area. The plant has a design capacity of 7.0 MGD, discharges to the East Fork Little Miami River, and receives and industrial input of 2.1 %.

- Infiltration/inflow is excessive and high flows to the plant are a problem. Some of this is a result of instream inceptor sewer alignments in which the harsh conditions result in structural failures and stream water enters the sewer.

- Average annual conduit flow decreased by more than one MGD (4.710-6.060 MGD) during 1983-1988, but increased during 1989-1991(average = 4.25 MGD). The annual average flow for the 10 year period were below the design capacity of 7.0 MGD.

- Annual ammonia-N loadings (median values) demonstrated a steady reduction from 1980 through 1985, but increased to the highest levels during 1986-1991. Loadings declined markedly, however, following the WWTP upgrade in 1992- 1993.

- Bioassay tests showed the following: only slight acute toxicity was evident to fathead minnows and no toxicity was evident for *Ceriodaphnia dubia* in February 1993 and acute toxicity was evident in the effluent in April 1993 with 100% mortality to *Ceriodaphnia dubia.*

East Fork Little Miami River - Milford WWTP

- Constructed in 1961 and upgraded in 1989 (new plant), the Milford WWTP is a secondary treatment plant consisting of two oxidation ditches, sludge press, sludge drying beds, post-aeration, and chlorination/dechlorination. The facility discharges to the East Fork Little Miami River and receives no industrial wastewater. The collection system contains two combined sewer overflows at Mill and Main Streets (outfall 002) and upstream U.S. Rt. 50 (outfall 003). Recent discharges for these two CSOs are listed in Table A-2c. The WWTP design capacity is 0.750 MGD. Administrative Orders (AO) were issued by U.S. EPA in 1987 requiring Milford to attain compliance with their NPDES permit.

- Average annual conduit flow increased by nearly 46% during 1983-1993 (0.472-0.687 MGD), but remained below the design capacity of 0.750 MGD.

- Annual BOD_5 loadings (median values) demonstrated variability during 1979-1987 with values ranging from 58 to 70 kg/day (Figure 18). Steady reductions in BOD_5/$CBOD_5$ values from 43 to 5.44 kg/day occurred during 1988-1993. Differences between median and 95th percentile values demonstrate variability in effluent quality and treatment efficiency.

- Annual ammonia-N loadings (median values) demonstrated variability during 1979-1987 with significant reductions in ammonia-N loadings occurring from 1988-1993. Loadings for 50th and 95th percentile varied mostly from 1984-1986 and 1989.

- Annual total suspended solids loadings (50th percentile) fluctuated considerably with no discernable trends from 1979-1988. Substantial reductions occurred during 1989-1993 (except in 1991). Differences between median and 95th percentile values demonstrate variability in effluent quality and treatment efficiency.

Conduit Flow (001 Outfall)

- The amount of treated, wastewater effluent discharged to the Little Miami River increased between 1983 and 1993 as the result of the upgraded larger capacity WWTPs. The cumulative total average annual flow (001 conduit outfall) for five (5) WWTPs increased 60% from 7.545 MGD in 1983 to 12.134 MGD in 1993 (Figure 20). Two of the five entities accounted for most of the increase (*i.e.*, increased flow from the Greene Co. Sugar Creek and Lebanon WWTPs were 1.83 and 2.479 MGD, respectively).

- During 1993, the total cumulative third quarter effluent flow to the watershed from 24 dischargers was 50.5 MGD with it divided relatively equally between the upper and lower halves of the watershed (Figure 21). From July 1 - September 30, 1993, nine (9) WWTPs discharged a total of 22.74 MGD to the upper half and 15 entities discharged 27.8 MGD of effluent to the lower watershed (Figures 22-23).

Ammonia-N Loadings

- The 1993 annual total average ammonia-N loading from 19 dischargers to the Little Miami River watershed was 183.75 kg/day (Figure 24). The largest contributor was the Greene County Sugar Creek WWTP (33.5%) followed by the Clermont County Middle East Fork WWTP (8.5%), Lebanon WWTP (7.8%), and Montgomery County Eastern Regional WWTP (7.5%). Due primarily to increased nitrification at the facilities during the warmer months, the total third quarter (July 1 - September 30, 1993) average ammonia-N loading decreased to 113.78 kg/day (Figure 25). The largest contributors during those months were the Greene County Sugar Creek WWTP (28.3%) and Montgomery County Eastern Regional WWTP (17.5%) followed by the Lebanon WWTP (9.1%), Cedarville WWTP (7.4%), and Clermont County Lower East Fork WWTP (6.9%).

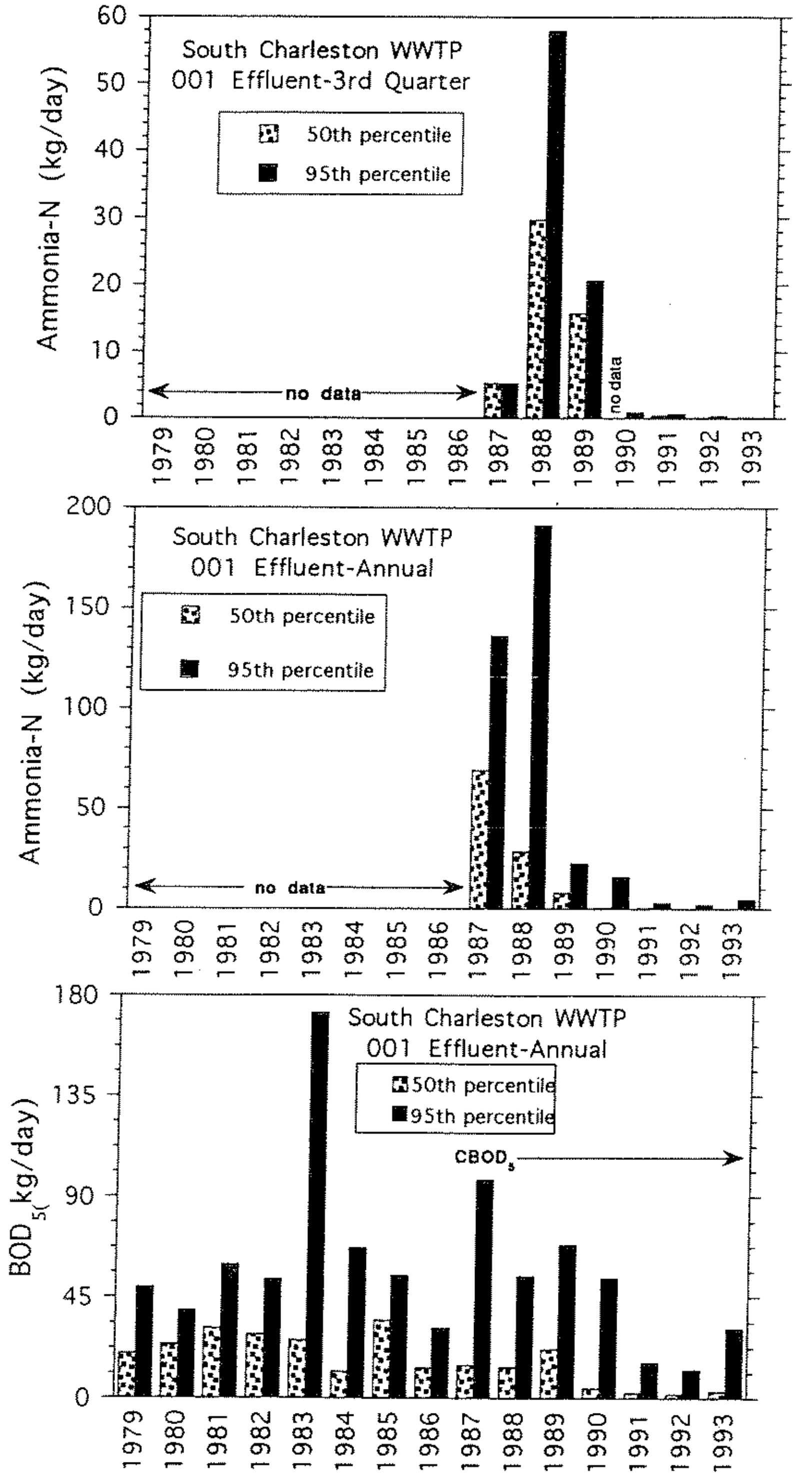

Figure 5. Median and 95th percentile loadings (kg/day) of ammonia-N (third quarter and annual) and BOD_5 (annual) from the South Charleston WWTP (001 outfall).

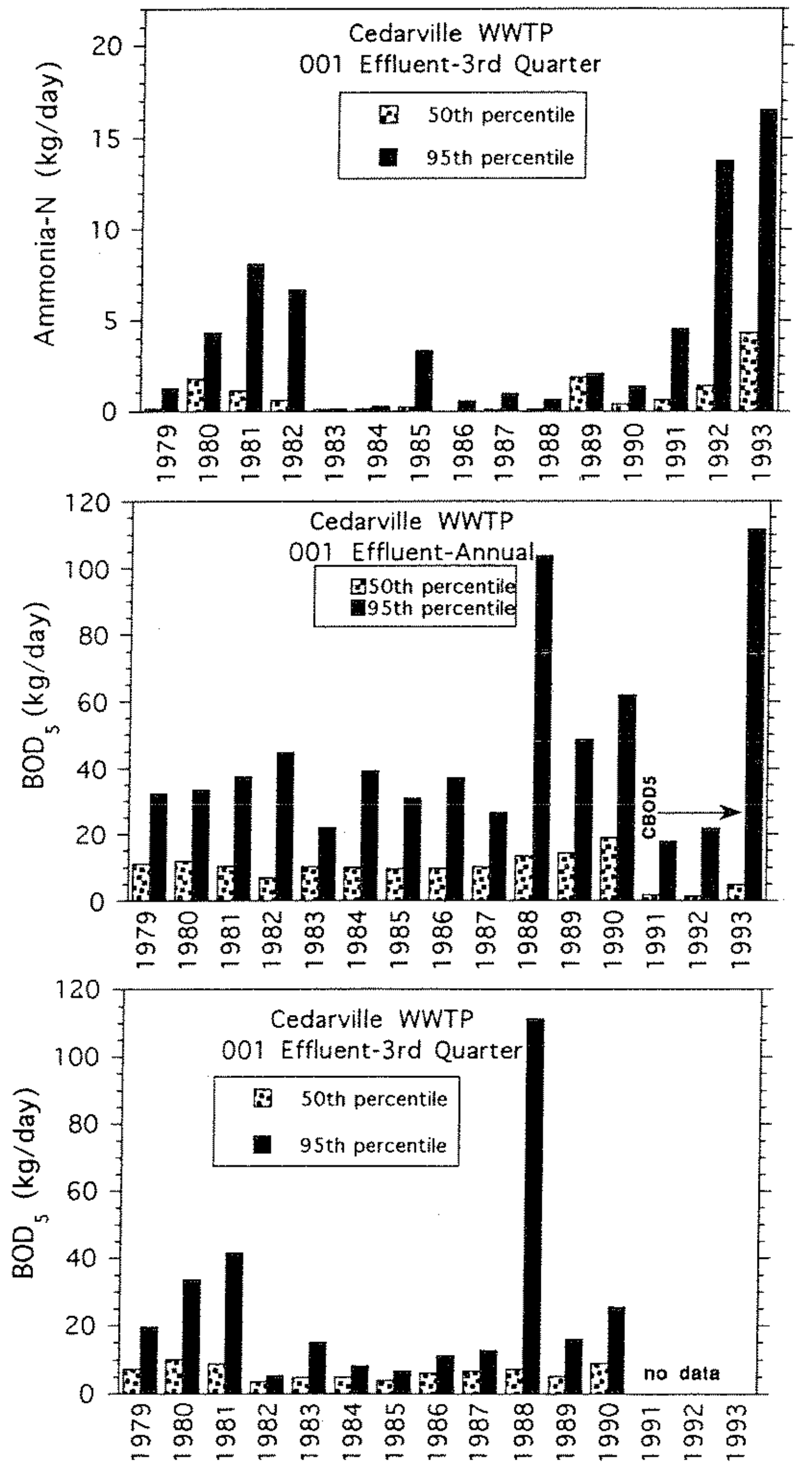

Figure 6. Median and 95th percentile annual loadings (kg/day) of ammonia-N (third quarter) and BOD_5 (third quarter and annual) from the Cedarville WWTP (001 outfall).

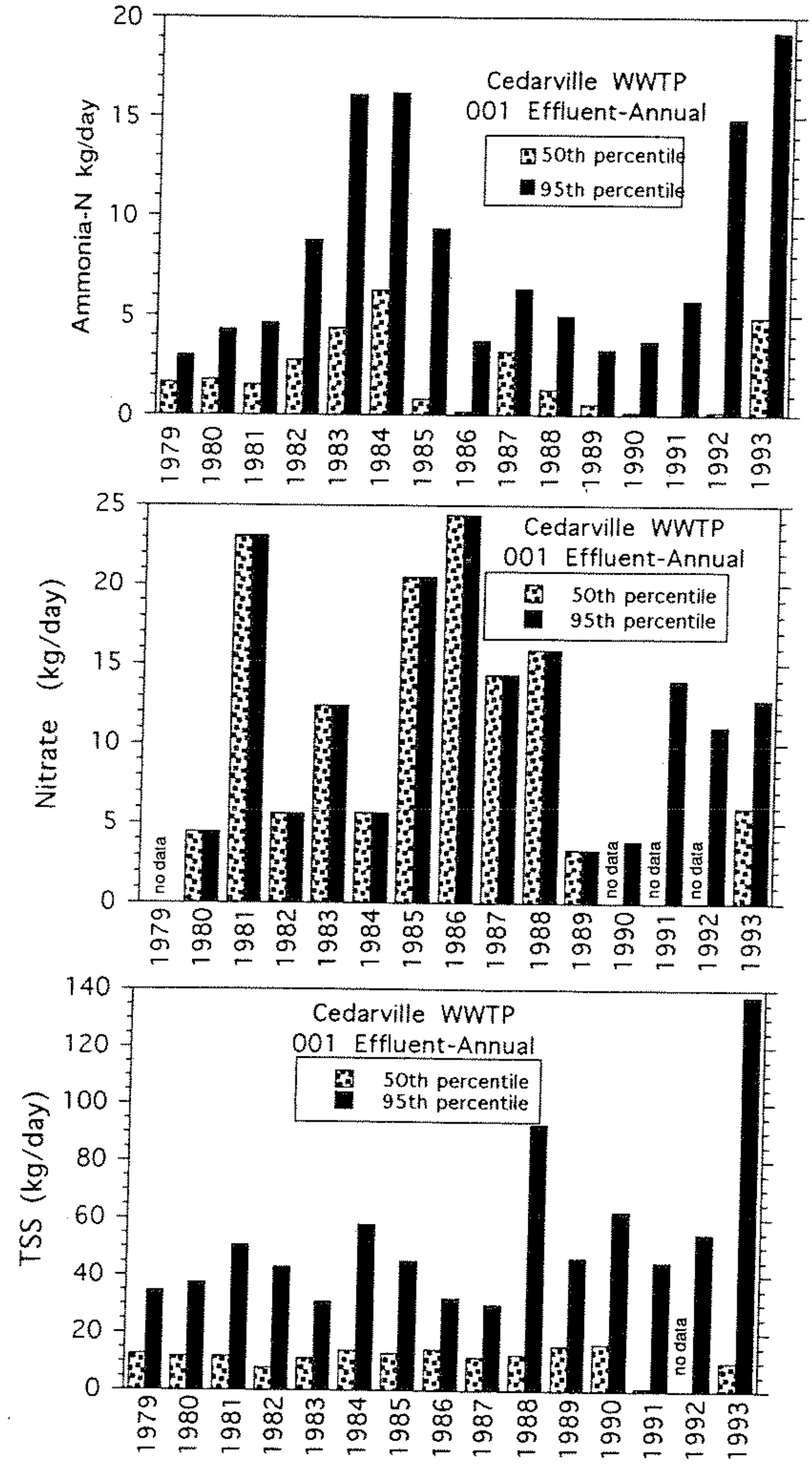

Figure 7. Median and 95th percentile annual loadings (kg/day) of ammonia-N, nitrate, and total suspended solids (TSS) from the Cedarville WWTP (001 outfall).

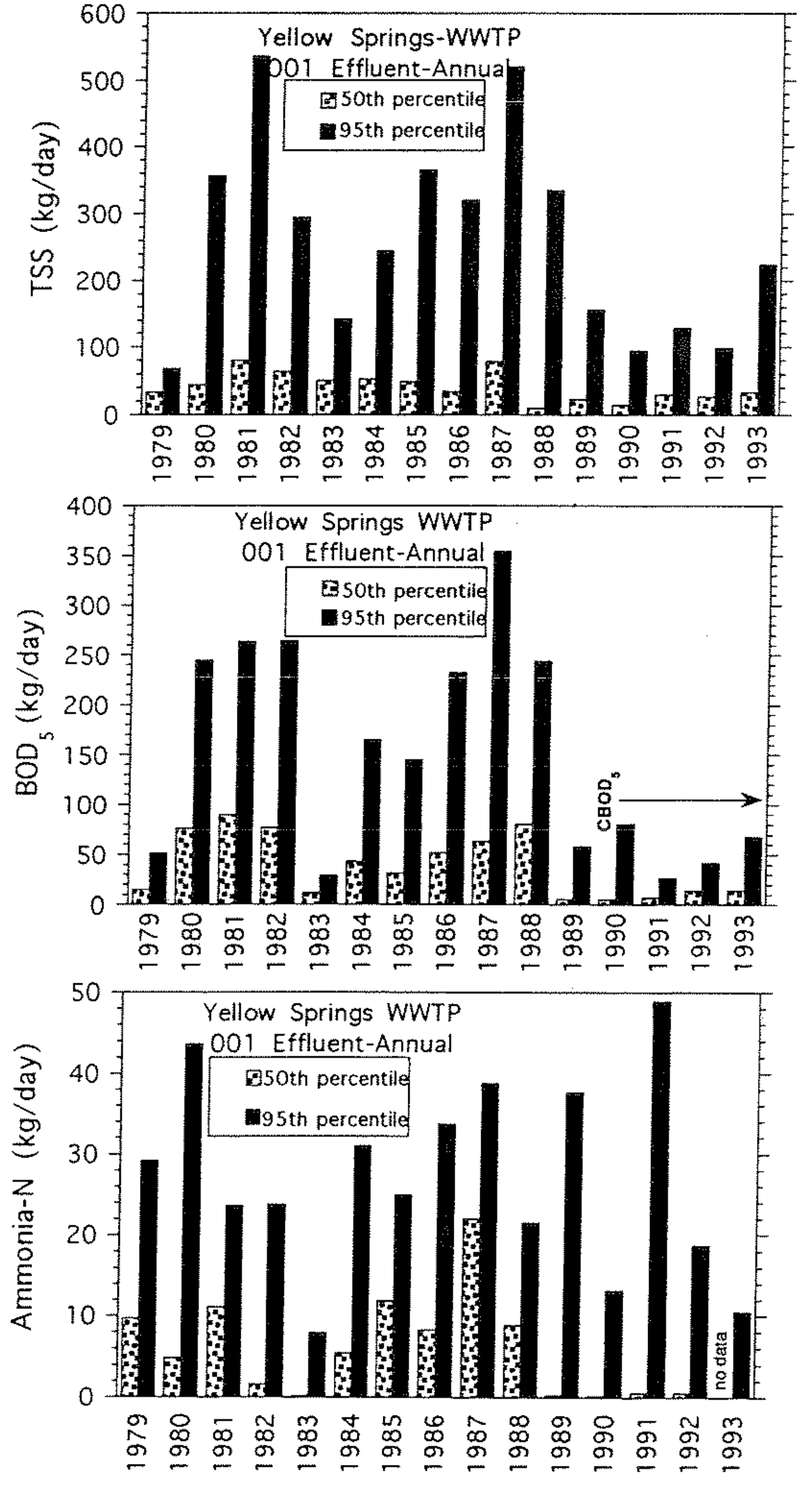

Figure 8. Median and 95th percentile annual loadings (kg/day) of total suspended solids (TSS), BOD_5, and ammonia-N from the Yellow Springs WWTP (001 outfall).

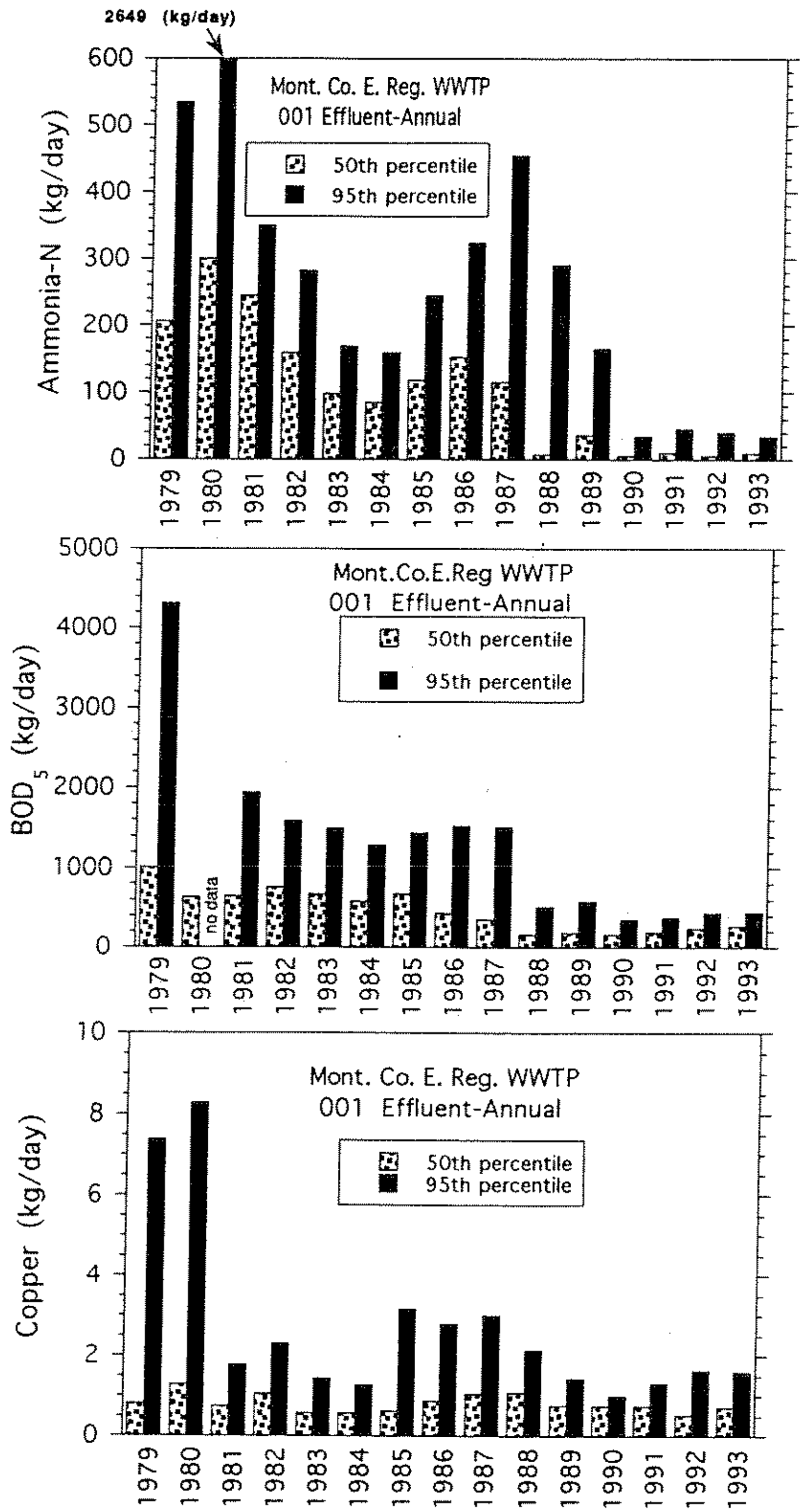

Figure 9. Median and 95th percentile annual loadings (kg/day) of ammonia-N, BOD_5, and copper from the Montgomery Co. E. Regional WWTP (001 outfall).

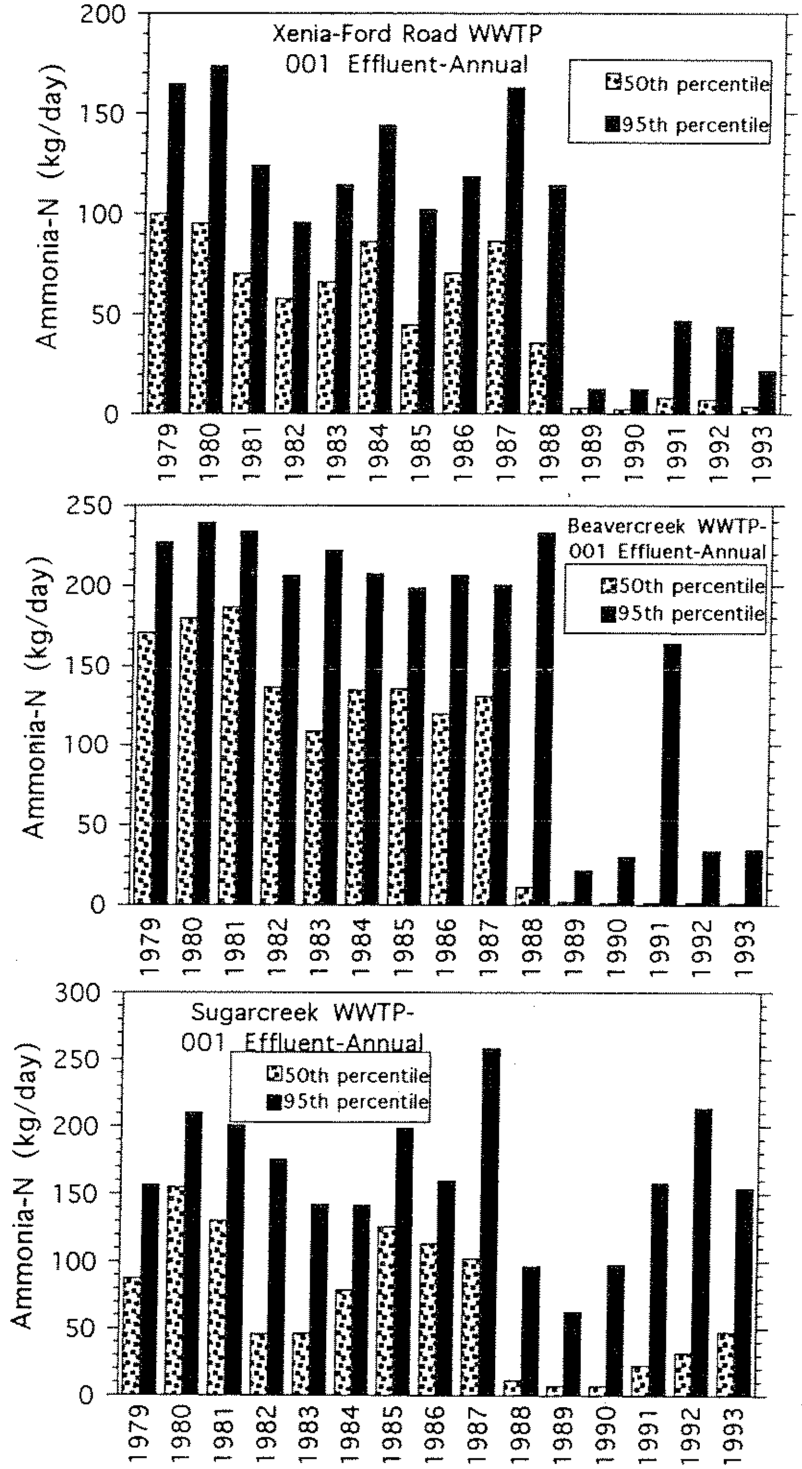

Figure 10. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Xenia-Ford Rd., Greene Co. Beaver Creek, and Greene Co. Sugar Creek WWTPs (001 outfall).

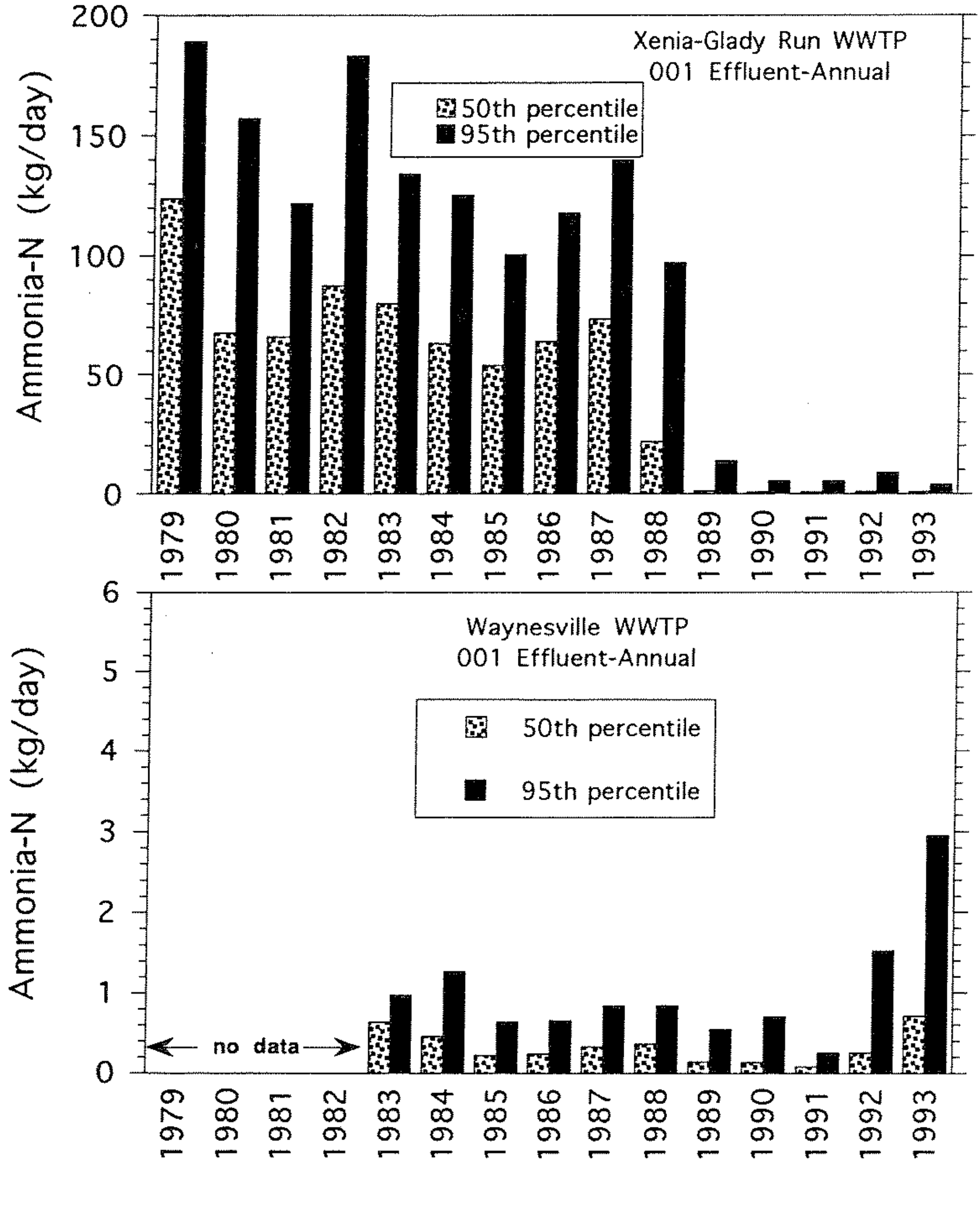

Figure 11. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Xenia-Glady Run and Waynesville WWTPs (001 outfall).

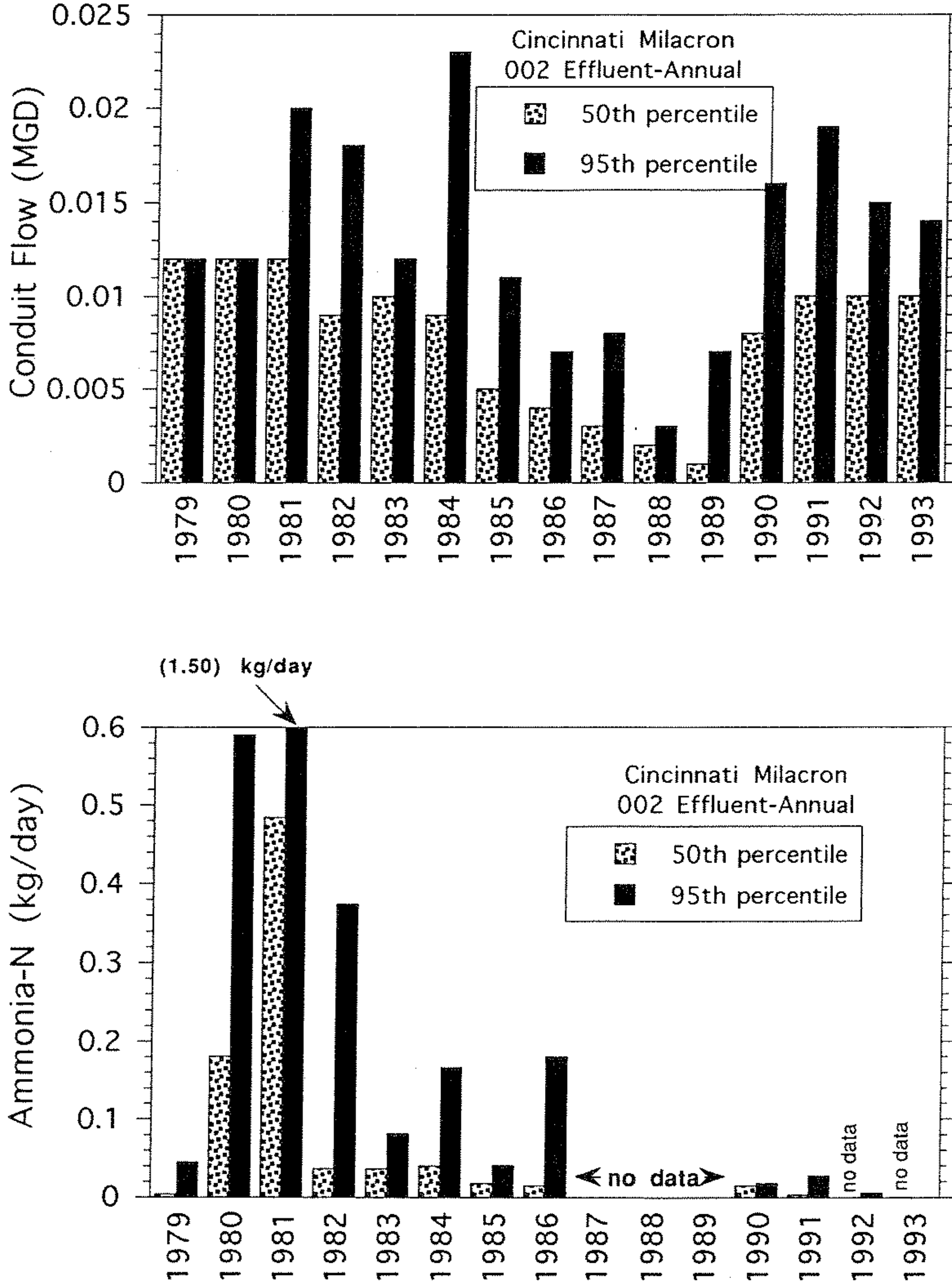

Figure 12. Median and 95th percentile annual loadings of flow (MGD) and ammonia-N (kg/day) from Cincinnati Milacron (002 outfall).

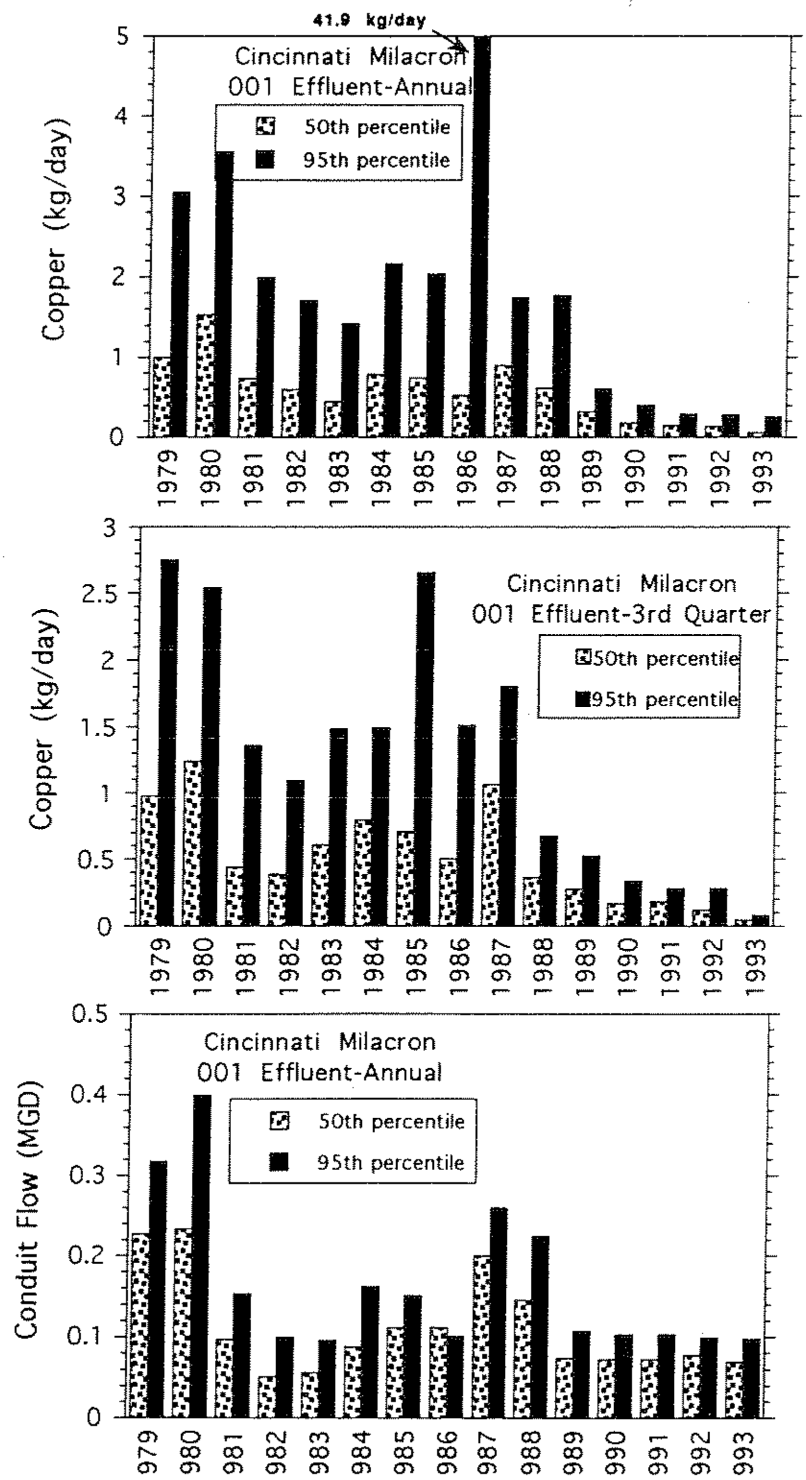

Figure 13. Median and 95th percentile annual loadings of total copper (kg/day, annual and third quarter) and conduit flow (MGD) for Cincinnati Milacron (outfall 001).

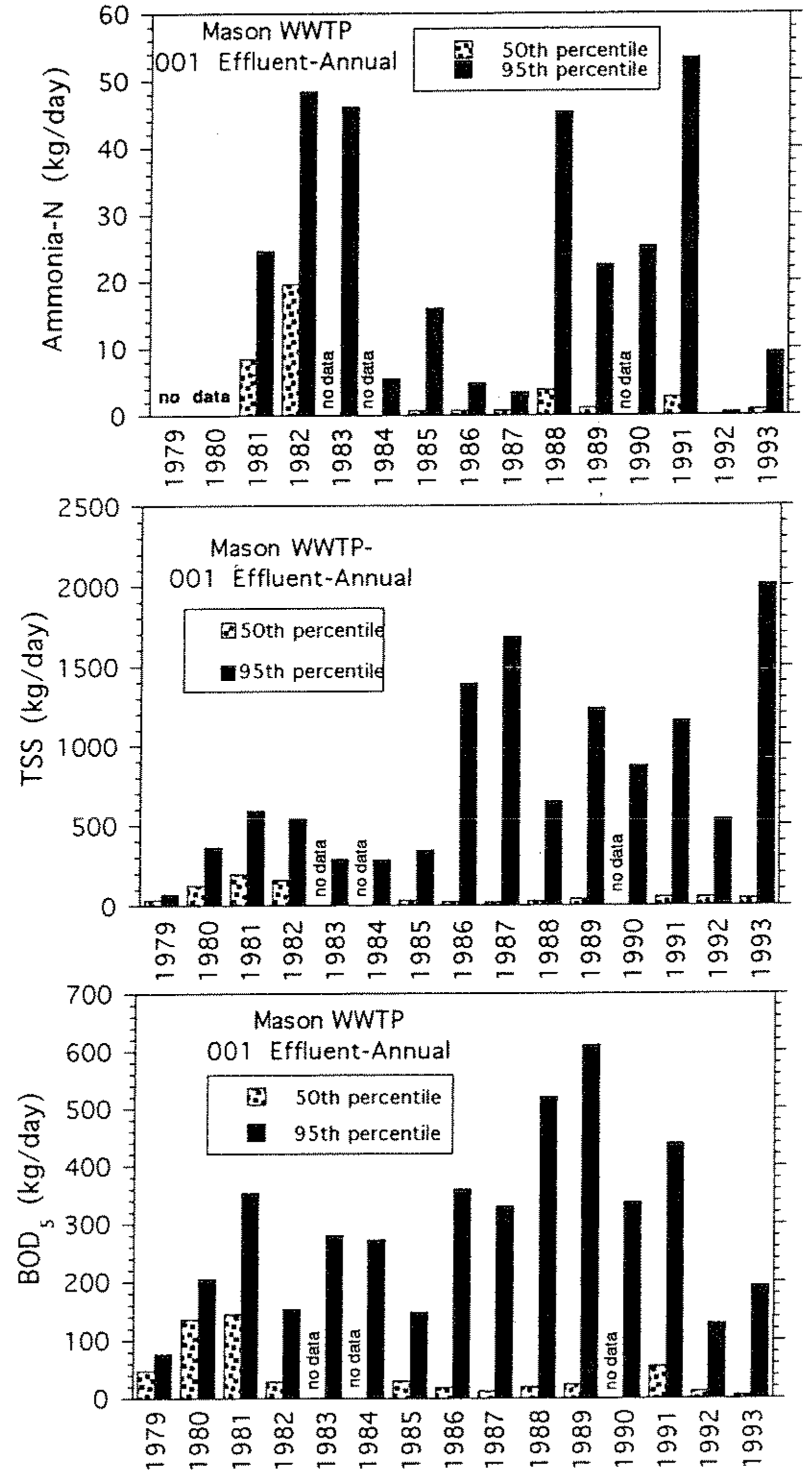

Figure 14. Median and 95th percentile annual loadings (kg/day) of ammonia-N, total suspended solids (TSS), and BOD_5 from the Mason WWTP (outfall 001).

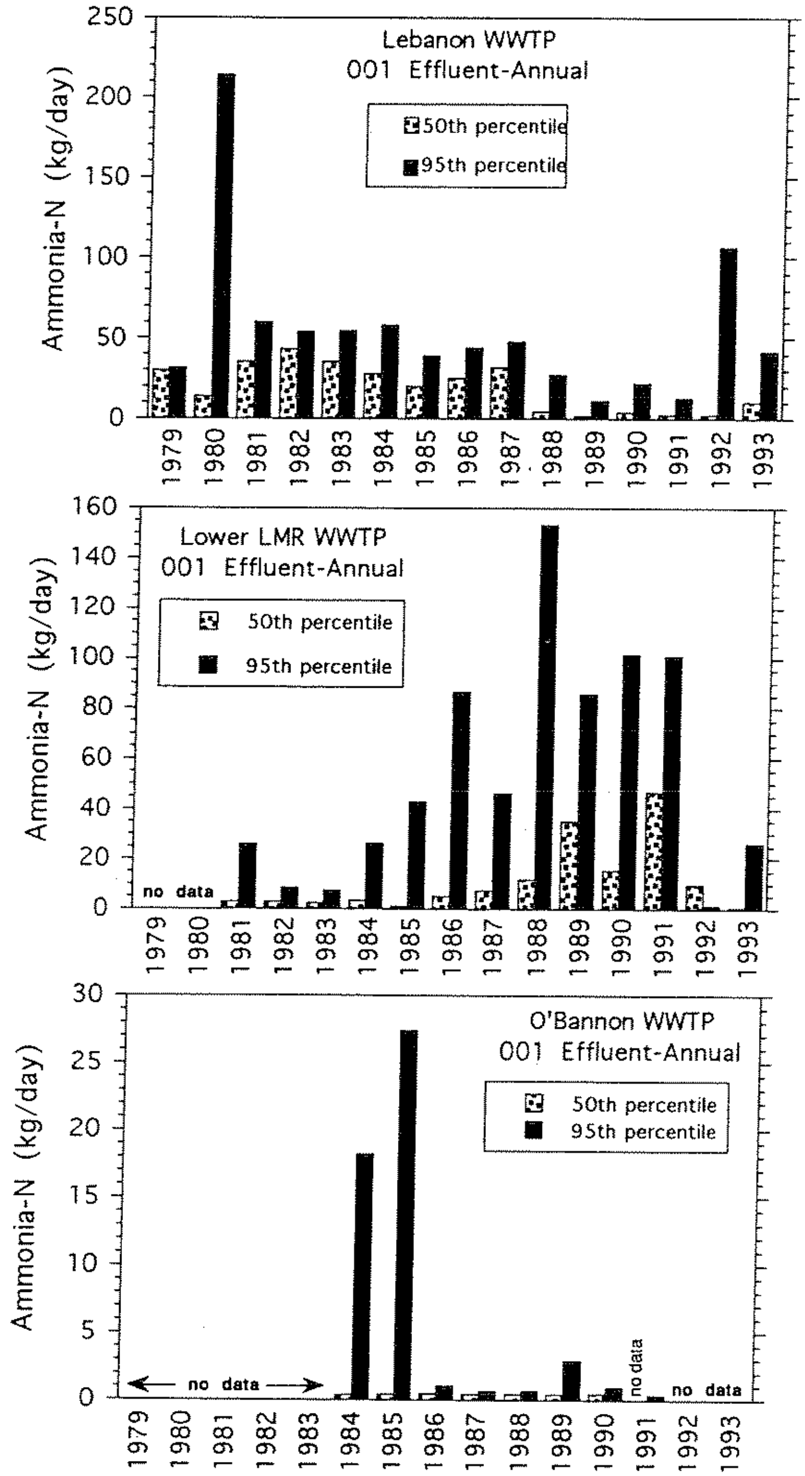

Figure 15. Median and 95th percentile annual loadings (kg/day) of ammonia-N from the Lebanon, Warren Co. Lower LMR, and O'Bannon WWTPs (001 outfall).