State of Ohio
Environmental Protection Agency

Division of Surface Water

Biological and Water Quality Study of the Upper Great Miami River and Selected Tributaries 2008

Auglaize, Mercer, Logan, Shelby, Champaign, and Darke Counties

OHIO EPA Technical Report EAS/2011-1-1

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John R. Kasich, Governor, State of Ohio
Scott J. Nally, Director

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Cover Photo

The South Fork Great Miami River (RM 1.74) upstream from Indian Lake at the Bickham Covered Bridge in Logan County, Ohio.

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Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us/dsw/document_index/psdindx.html) or may be available on CD from:

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INTRODUCTION

As part of the five-year basin approach for NPDES permitting and the TMDL process, an intensive ambient assessment of the upper Great Miami River (GMR) watershed was conducted during the 2008 (and part of 2009) field sampling season. **Figure 1** shows the location of the upper Great Miami River watershed in the state of Ohio. The following subwatersheds, as represented by 10-digit Hydrologic Unit Codes (HUCs), were intensively sampled as part of the study:

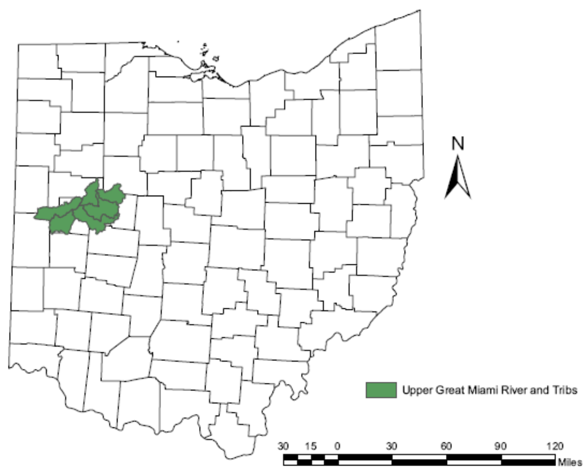


Figure 1. Location of the upper Great Miami River study area in Ohio.

- 0508000101 - Headwaters Great Miami River
- 0508000102 - Muchnippi Creek
- 0508000103 - Bokengehalas Creek-Great Miami River
- 0508000104 - Stony Creek-Great Miami River
- 0508000105 - Headwaters Loramie Creek
- 0508000106 - Turtle Creek-Lower Loramie Creek

The upper Great Miami River and its tributaries were last assessed in 1994. A list of the more recent 2008 sampling stations, including geographical coordinates and the sampling protocols employed at each location, can be found in **Table 1**.

All information collected as part of this survey will support total maximum daily load (TMDL) development for the study areas. The objectives of the TMDL process are to estimate pollutant loads from the various sources within the basin, define or characterize allowable loads to support the various beneficial uses, and to allocate pollutant loads among different pollutant sources through appropriate controls (*e.g.,* NPDES permitting, storm water management, 319 proposals, nonpoint source controls or other abatement strategies). The components of the TMDL process supported by this survey are primarily the identification of impaired waters, verification (and re-designation, if necessary) of beneficial use designations, and causes and sources of use impairment. These data are necessary precursors to the development of effective control or abatement strategies.

As such, the 2008 study of the upper Great Miami River and tributaries was conducted in order to satisfy the following objectives:

1. Monitor and assess the chemical, physical, and biological integrity of the water bodies within the upper Great Miami River study area;

2. Assess habitat influences on stream biotic integrity;

3. Determine recreation water quality;

4. Evaluate the appropriateness of existing beneficial use designations and assign uses to undesignated streams;

5. Characterize any aquatic resource degradation attributable to various land uses, including agriculture and urbanization;

6. Determine any aquatic impacts from known sources and. causal linkages, including point source dischargers and unsewered communities;

7. Assess changes in water quality and biological integrity by comparing the results of this survey with those from the 1994 survey and beyond.

Table 1. Sampling locations in the upper Great Miami River study area, 2008 [(M-macroinvertebrate quantitative sample, m-macroinvertebrate qualitative sample, F-fish sample (2 passes), f- fish sample (1 pass), C - conventional water chemistry, E- Effluent, O-organic water chemistry, P-pathogen, S - sediment, D- Datasonde® monitor)]. Latitude/longitude coordinates are provided in WGS84 datum.

Stream RM	12 Digit WAU*	Sample Type	Lat/Long (DD[#])	Location	USGS Quad
Great Miami River Mainstem					
158.2	03-02	F,M,C,D,P,O,S	40.4556/-83.8953	Upst Indian Lake WWTP	Russells Point
158.05 [a]	03-02	E,O	40.4561/-83.8955	Indian Lake WWTP effluent	Russells Point
157.22	03-02	F,M,C,D,P,O,S	40.4512/-83.9071	SR 235 (Russells Point)	Russells Point
156.36	03-02	D	40.4394/-83.9106	SR 274	Russells Point
153.45	03-06	F,M,C	40.4011/-83.9240	Notestine Rd (CR 13)	Russells Point
146.19	03-06	F,M,C,P,O	40.3128/-83.9272	SR 235 (DeGraff)	DeGraff
143.2	04-06	F,M,C,P,O,S	40.3030/-83.9694	SR 235 (Quincy)	DeGraff
143.1 [b]	04-06	E,O	40.3038/-83.9707	Quincy WWTP effluent	DeGraff
142.5	04-06	F,M,C,D,P,S	40.3082/-83.9742	Dst Quincy WWTP @ rr bridge	DeGraff
138.4	04-06	F,M,C,D	40.3351/-84.0398	Pence/Baker Rd	Port Jefferson
129.99	07-03	F,M,C,D,P,O,S	40.2869/-84.1500	SR 47 (E. North St)	Sidney
North Fork Great Miami River					
10.7	01-01	F,M,C,S	40.5606/-83.7772	farm lane south of Madory Rd	Roundhead
6.31	01-01	F,M,C,D,P,O,S	40.5239/-83.7997	Dunn Rd	Roundhead
South Fork Great Miami River					
8.00	01-02	F,M,C,S	40.4958/-83.7428	SR 638	Rushsylvania

Stream RM	12 Digit WAU*	Sample Type	Lat/Long (DD#)	Location	USGS Quad
7.23	01-02	F,M,C	40.5015/-83.7529	CR 39 (Belle Center)	Roundhead
5.8	01-02	F,M,C	40.4944/-83.7778	CR 97	Huntsville
3.95	01-02	C,F,M,D,S,P,O	40.4839/-83.8071	CR 96	Huntsville
1.74	01-02	F,M,C	40.4744/-83.8404	CR 38, Bickham covered bridge	Huntsville
Tributary to South Fork Great Miami River (7.24) (aka Belle Center Tributary)					
0.55	01-02	F,M,C	40.5035/-83.7435	SR 638	Siver Creek
Liggit Ditch (aka Slow Ditch)					
0.53	01-02	F,M,C,S	40.5038/-83.7677	TR 49	Roundhead
Tributary to South Fork Great Miami River (5.27) (aka New Richland Tributary)					
0.50	01-02	F,M	40.4869/83.7788	CR 96	Huntsville
Van Horn Creek					
0.97	01-03	F,M,C,O,S	40.5163/-83.9268	SR 366	Waynesfield
Muchinippi Creek					
12.98	02-02	F,M,C	40.5607/-83.9525	SR 196	Waynesfield
12.5	02-02	F,M,C,D,P	40.5578/-83.9592	Upst. US 33	Waynesfield
7.4	02-04	F,M,C	40.4988/-83.9792	CR 87	Russells Point
4.76	02-04	F,M,C	40.4683/-83.9572	Myers Rd	Russells Point
2.37	02-04	F,M,C,S	40.4392/-83.9408	SR 274	Russells Point
0.32	02-04	C,D,P,O,S	40.4172/-83.9253	CR 60	Russells Point
Willow Creek					
3.7	02-01	F,M,C,S	40.5414/-84.0302	Dst Wrestle Creek Rd, Dst trib	Uniopolis
0.44	02-01	F,M,C,P	40.5134/-83.9902	Idle Rd	Waynesfield
Little Muchinippi Creek					
6.05	02-03	F,M,C,S	40.4679/-84.0689	Wones Rd	Jackson Center
0.62	02-03	F,M,C, D,P	40.4842/-83.9851	gravel road	Russells Point
Jackson Center Creek					
2.9	02-03	M,C,S	40.4396/-84.0520	SR 274	Jackson Center
1.8	02-03	F,M,C,P,S	40.4540/-84.0449	Lock Two Rd, Dst. Jackson Center WWTP	Jackson Center
Cherokee Mans Run					
7.56	03-01	F,M,C,S	40.4143/-83.8011	SR 117	Huntsville
3.38	03-01	F,M,C,S	40.4513/-83.8352	US 33	Huntsville
Tributary to Great Miami River (157.34)					
0.07	03-02	F,M,C,S	40.4540/-83.9067	Ust. SR 235 nr Russells Point	Russells Point
Rennick Creek					
0.34	03-02	F,M,C	40.4274/-83.9069	SR 235	Russells Point
Brandywine Creek					
0.58	03-06	F,M,C	40.4099/-83.9318	Notestine Rd (upper crossing)	Russells Point
Rum Creek					
8.63	03-03	F,M,C	40.4026/-84.0257	Wildermuth Rd	Jackson Center
6.58	03-03	F,M,C	40.3906/-83.9992	Meranda Rd	Russells Point

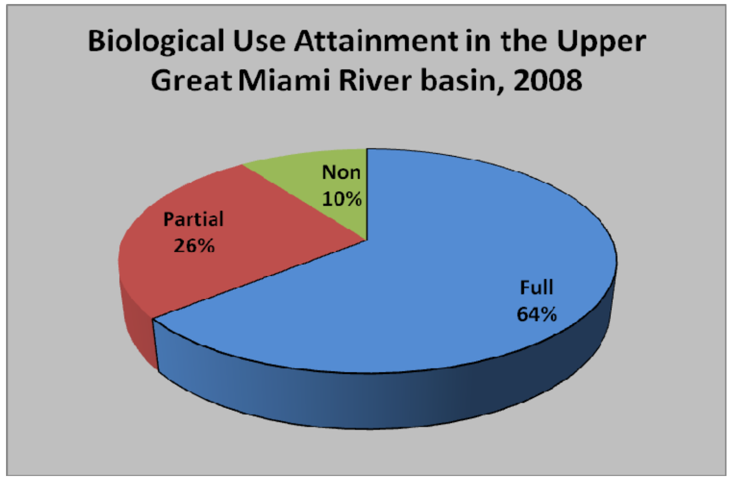
Stream RM	12 Digit WAU*	Sample Type	Lat/Long (DD#)	Location	USGS Quad
0.79	03-03	F,M,C,P	40.3766/-83.9346	CR 58	Russells Point
Bokengehalas Creek					
12.24	03-05	F,M,S	40.3860/-83.8048	CR 13	Huntsville
7.88	03-05	F,M,C,P,S,O	40.3701/-83.8494	TR 31, Upst Blue Jacket Cr	Bellefontaine
4.61	03-05	F,M,C	40.3472/-83.8911	TR 209	DeGraff
1.13	03-05	F,M,C,D,P,O,S	40.3116/-83.9121	Miami St (DeGraff)	DeGraff
Blue Jacket Creek					
6.31	03-04	F,M,C,S	40.3503/-83.7744	Troy St. (TR 216)	Bellefontaine
5.39	03-04	F,M,C,D,P,O,S	40.3484/-83.7891	CR 11 (1st Xing) dst Opossum Run and Bellefontaine WWTP	Bellefontaine
0.72	03-04	F,M,C	40.3635/-83.8502	TR 31	Bellefontaine
Opossum Run					
0.5 [c]	03-04	E,O	40.3532/-83.7773	Bellefontaine WWTP effluent	Bellefontaine
Stony Creek					
2.45	04-03	F,M,C	40.2875/-83.8989	SR 508	DeGraff
1.58	04-03	F,M,C,P,D	40.2908/-83.9100	TR 65A	DeGraff
McKees Creek					
9.5	04-01	F,M,C,S	40.3342/-83.7444	CR 1 (Ludlow Rd)	Zanesfield
5.94	04-01	F,M,C	40.2993/-83.7773	TR 32	Bellefontaine
0.52	04-01	F,M,C,P,S	40.3106/-83.8556	CR 31	Bellefontaine
Lee Creek					
3.35	04-02	F,M,C	40.2683/-83.9267	Friend Rd	DeGraff
Graves Creek					
0.48	04-02	F,M,C,P	40.2736/-83.8932	TR 295	DeGraff
Indian Creek					
0.01	04-04	F,M,C,P	40.3187/-84.0152	@ mouth	Port Jefferson
Plum Creek					
9.00	04-05	F,M,C,S	40.3808/-84.1216	Meranda Rd	Jackson Center
5.22	04-05	F,M,C	40.3460/-84.1634	Fort Loramie-Port Jefferson Rd	Sidney
0.13	04-05	F,M,C,P	40.3095/-84.1329	Canal Feeder Rd	Sidney
Loramie Creek					
36.84	05-01	F,M,C,P,S	40.4681/-84.1606	Botkins Rd	Botkins
34.96	05-01	F,M,C,P,O,S	40.4531/-84.1872	Lock Two Rd dst Botkins WWTP	Botkins
30.42	05-01	F,M,C,D,P,O,S	40.4150/-84.2436	Hardin-Wapakoneta Rd	Botkins
22.1	05-03	F,M,C,P,D,S	40.3575/-84.3583	Dst Loramie Lake dam	Fort Loramie
21.1 [d]	05-03	E,O	40.3620/-84.3691	Lake Loramie WWTP effluent	Fort Loramie
20.7	05-03	F,M,C,D,P,S	40.3591/-84.3739	SR 66	Fort Loramie
18.82	06-02	F,M,C,P,O,S	40.3358/-84.3769	Schlater Rd	Osgood
16.51	06-02	C,D,P,O,S	40.3069/-84.3836	Cardo-Roman Rd	Osgood
14.8	06-02	F,M,C	40.2931/-84.3710	SR 66 (Newport)	Fort Loramie
7.67	06-04	F,M,C	40.2628/-84.3011	Loramie Washington Rd	Fort Loramie

Stream RM	12 Digit WAU*	Sample Type	Lat/Long (DD#)	Location	USGS Quad
1.87	06-04	F,M,C,D,P,O,S	40.2106/-84.2435	Fessler-Buxton Rd	Piqua East
Miami-Erie Canal					
1.8 [e]	05-03	E,O	40.3821/-84.3837	Minster WWTP effluent	New Bremen
0.1	05-03	F,M,C,S,D,P,O	40.3599/-84.3724	near mouth	Fort Loramie
Mile Creek					
9.8	05-02	F,M,C,S	40.3611/-84.5348	Goettemoeller Rd.	North Star
8.74	05-02	F,M,C,S	40.3583/-84.5151	Clune-Stucke Rd	North Star
5.97	05-02	F,M,C,P,S	40.3582/-84.4646	Kremer Rd	Osgood
0.5	05-02	F,M,C,D,P,O,S	40.3492/-84.3869	SR 705	Osgood
Spring Creek					
0.37	05-02	F,M,C,P	40.3488/-84.4155	Baumer-Brandewie Rd	Osgood
Ninemile Creek					
6.38	06-01	F,M,C,S	40.2375/-84.4144	Miller Rd	Versailles
4.18	06-01	F,M,C,P,S	40.2364/-84.3764	Rangeline Rd dst Russia WWTP	Versailles
0.23	06-01	F,M,C,P	40.2542/-84.3286	Roeth Rd	Fort Loramie
Turtle Creek					
8.42	06-03	F,M,C	40.3300/-84.2534	Mason Rd	Fort Loramie
5.66	06-03	F,M,C	40.3009/-84.2551	Russell Rd	Fort Loramie
0.43	06-03	F,M,C,P	40.2358/-84.2483	Stangel Rd	Piqua East

* See **Table 5**.
\# DD = Decimal Degrees

Effluent samples
[a] Indian Lake WWTP effluent discharges to Great Miami River at RM 158.05
[b] Quincy-Degraff WWTP effluent discharges to Great Miami River at RM 143.1
[c] Bellefontaine WWTP effluent discharges to Opossum Run at RM 0.5
[d] Lake Loramie SSD WWTP effluent discharges to Loramie Creek at RM 21.1
[e] Minster WWTP effluent discharges to the Miami-Erie Canal at RM 1.8

EXECUTIVE SUMMARY



Sampling in the upper Great Miami River (GMR) watershed found an abundance of high quality streams in portions of the basin but also significant areas of impairment. Out of a total 78 biological sampling sites, 64% (n=50) were in full attainment of their aquatic life use, 26% were partially impaired (n=20) and 10% were in non-attainment (n=8). Impairment was most often observed in the western half of the basin, particularly in the Loramie Creek sub-watershed and other highly modified stream channels draining extensive agricultural landscapes. Habitat alteration, siltation, and nutrient enrichment associated with channelization and agricultural runoff were the most pervasive impairment factors, accounting for nearly three quarters (73%) of the Causes and Sources listed (**Table 4**). Row crop agricultural runoff may also include manure application to farm fields as portions of the basin (particularly in the western, Loramie Creek watershed) drain some of the highest manure-producing counties in the state (Columbus Dispatch, Oct. 16, 2010). Other sources of aquatic life impairment include waste water treatment systems, impoundments, and toxic spill events. The following sub-sections summarize these additional sources of impairment.

Waste Water Treatment Systems

The upper GMR basin lacks dense population centers and the few scattered municipal waste-water treatment plants (WWTPs) accounted for only 10% of impairments observed. However, the magnitude of impairment associated with point sources was significant, contributing to elevated levels of nutrients and degraded biological communities in stretches of lower Loramie Creek below the Villages of Minster and Fort Loramie (**Figure 2**) and the Great Miami mainstem below Russells Point. Significant impacts in upper Loramie Creek below the Botkins WWTP appeared related to additional

Figure 2. Extensive algal blooms in Loramie Creek associated with excessive nutrients downstream from point and nonpoint source discharges in the Lake Loramie and Mile Creek areas.

pollutants [*i.e.,* total dissolved solids (TDS) and chloride] associated with batch discharges from the local water treatment plant (WTP). The Jackson Center WWTP impacted macroinvertebrates and chemical water quality conditions, over and above the influence of extensive channel modification in Jackson Center Creek (see **Figure 22**).

In response, efforts to reduce phosphorus loadings are recommended for both point and nonpoint sources in the lower Loramie Creek basin. Recently, the Indian Lake (Russells Point) WWTP installed flow equalization to reduce bypass events. The WWTP is also studying feasibility plans to eliminate all illegal, secondary bypasses to the Great Miami River mainstem. At Botkins, operational problems are currently being addressed with increased monitoring of TDS and technical assistance provided by Ohio EPA's Division of Drinking and Ground Waters. The Village of Jackson Center resolved a problem with effluent copper violations by discouraging use of a copper sulfate solution used as a root killer to clear the laterals. The Village also proposed relining nearly 12,000 linear feet of failed and damaged sewer lines in their collection system.

In Bellefontaine, substantial biological improvement and full attainment along the length of Blue Jacket Creek was documented for the first time in over 30 years (**Figure 52, Figure 58**). The combination of long-term reductions in ammonia loadings and improved effluent quality at the Bellefontaine WWTP, coupled with the stream's strong ground water connection and cool, enhanced base flows, were considered the major reasons for improvements. Phosphorus concentrations remain elevated for miles downstream from the WWTP in Blue Jacket and Bokengehalas creeks but potential negative influences appeared largely ameliorated by sufficient ground water recharge and high quality stream habitats associated with local, sub-ecoregional features.

The improving trend below Bellefontaine was initially observed during the 1994 survey following plant upgrades in 1993-94 and the trend continued through 2008. Biological improvement in Blue Jacket Creek *upstream* from Opossum Run and the WWTP was equally dramatic (*i.e.,* from very poor to good quality since 1974 with an upgrade from WWH to CWH recommended). However, specific reasons for the improvement in upstream conditions are unknown.

<u>Pesticide Spills</u>

In one, possibly two, instances, severe biological impacts and wildlife kills resulted from toxic impacts associated with pesticide application. A confirmed kill in upper Bokengehalas Creek on July 30, 2008 (ODNR Report #768) was related to drift from the aerial application of Headline® Fungicide and Mustang Max® insecticide northwest of Bellefontaine. Over 12,000 crayfish were killed in an approximate 4.5 mile stretch of the creek. Biological sampling found severe impacts but at least partial recovery (macroinvertebrate community) within 7 weeks of the incident. Another suspected toxic impact was encountered in the North Fork GMR at Dunn Rd. (RM 6.3). The macroinvertebrates appeared severely impacted in 2008 but no cause or source of impact was apparent. Follow-up sampling conducted in 2009 documented a good quality community and full recovery, an indication of an unknown, pulse type impact the previous year. Given the impacts observed in 2008, efforts should be made to emphasize more land based applications of pesticides to avoid unintended over spraying by aerial application of non-target vegetation and sensitive areas.

Lake Influences

Flow alteration associated with Indian Lake and Lake Loramie negatively influenced biological and water quality conditions in the Great Miami River and Loramie Creek. Below Indian Lake, warm, plankton rich waters pour over the top of the outlet dam and contribute to wide diurnal D.O. fluctuation, elevated stream temperatures, and enriched conditions during the summer. Habitat quality downstream from the dam was already deficient due to past channelization and siltation, apparently originating from lower Cherokee Mans Run. Additionally, slugs of lake water encountered during high flow appeared to scour and destabilize stream banks, contributing to the marginal conditions. While fish community health fell in the exceptional range, the quality was considered unrepresentative of the overall mainstem as the presence of a few lake-supplied species contributed to inflated index scores immediately downstream from the outlet.

Downstream from Lake Loramie, enriched conditions and de-watering of the channel after an extended late summer dry period resulted in substantial changes in stream quality (**Table 4, Figure 3**). The nearest Loramie Creek gage recorded flows near 80% duration for much of August and September (**Figure 24**). The diminished late summer flows also resulted in minimal dilution for two municipal WWTPs in Minster and Fort Loramie that discharge just downstream. Upstream from Lake Loramie, channelization coupled with the backwater conditions created by the Lake Loramie dam contributed to fair fish communities and partial attainment.

Figure 3. Variable flow conditions in Loramie Creek (Station RM 22.1) downstream from Lake Loramie dam. Left photo: Riffle habitat sampled for fish (good quality) on July 17, 2008. Right photo: Similar riffle habitat a few hundred meters downstrem yielded poor quality macroinvertebrates on September 4, 2008.

Sub-ecoregion and Ground Water Influences

Additional analysis of the upper Great Miami basin survey results suggests local geology and natural flow augmentation have significant positive influences on biological performance. Excluding the Great Miami River mainstem, biological communities from 79% of stream sites with enhanced base flows (n=38) met or exceeded WWH expectations (*i.e.,* good quality or better).

The entire upper Great Miami River basin is located within the Eastern Corn Belt Plains (ECBP) ecoregion but the 2008 study area encompasses two[1] distinct sub-ecoregions. The majority is in the **55a, Clayey High Till Plains**, while much of the southeastern and extreme southern drainage is within the **55b**, **Loamy High Till Plains** (see **Figure 48**). State-wide, the **55b** sub-ecoregion is described as “nearly level terrain” (ftp://ftp.epa.gov/wed/ecoregions/in/ohin_front.pdf). However, within the upper Great Miami drainage, the **55b** landscape surrounding Bellefontaine includes the highest elevation point in Ohio (1549 feet above sea level; see **Figure 43**). This region is characterized by high relief, loamy (sandy), well drained soils, and stream habitats often enhanced by the thick, Wisconsinan age deposits of coarse glacial till (rubble and boulders) (USDA 1979). In addition, an abundance of ground water tends to sustain area stream flows, even during periods of extended drought. Because of the higher relief and effective drainage, local farmers and communities are less apt to radically modify stream channels or resort to the extensive field tiling found in other, “flatter” basins in the state. These factors culminate in significantly higher habitat quality in the **55b** landscape compared to the **55a** based on QHEI scores (see **Figure 42**).

Largely as a result of the geologic and geographic influences described above, nearly all biological communities from the **55b** sub-ecoregion tributaries fully met WWH criteria (n=17 sites[2]; **Figure 4**) and often reflected exceptional or cold water habitat potential (**Table 4**). A single site on upper Bokengehalas Creek (RM 7.9) that did not fully attain its designated WWH aquatic life use straddled the sub-ecoregion boundary and was extensively channelized. In addition, the site was impacted by a toxic pesticide spray during the summer of 2008.

In contrast to the **55b**, few **55a** sub-ecoregion sites met such high levels of biological performance. The most typical **55a** sites were channelized (75% of sites) with open canopies and extensively tiled for agricultural drainage. Stream conditions were often characterized as sluggish, silty and nutrient enriched and a majority of sites (57%) did not fully meet WWH aquatic life use criteria. Biological performance typically fell in the fair range within the sub-ecoregion.

The majority of **55a** sites reflected some degree of biological impairment but there were exceptions. For instance, biological performance at 42% of **55a** sites met or exceeded

[1] A small portion of the 55c, Mad River Interlobate sub-ecoregion overlays the extreme SE corner of the upper basin but no sampling was conducted in this area.

[2] Tributary sites only. For this comparison, the larger, Great Miami River mainstem sites were excluded.

WWH expectations, with some falling in the very good to exceptional ranges. Analysis of these "higher quality" **55a sites** found a majority supported fish populations[3] associated with coldwater conditions or enhanced base flow (some of the same populations common to the **55b** sub-ecoregion). Excluding the Great Miami River mainstem, 67% (n=14) of **55a** sites showing signs of enhanced flow were in full attainment of WWH compared to only 26% (n= 8) at sites that did not exhibit a strong ground water signature. Conversely, only 4% (n=1) of enhanced flow sites were in non-attainment of WWH, compared to 45% (n=14) without enhanced flow[4] (**Figure 4**). The **55a** enhanced flow sites were mostly located in the northeastern section of the study area, roughly surrounding Indian Lake to the east, west and south (see **Figure 55**; "55a sites w/high ground water"). Most lay within the Muchinippi Creek and South Fork Great Miami River basins, Rennick Creek and Brandywine Creek.

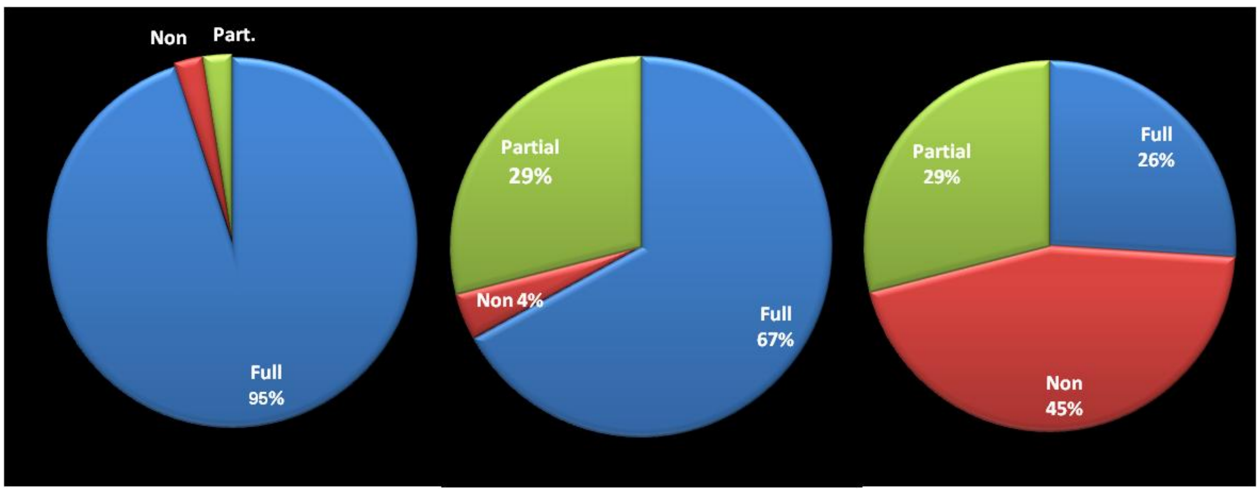


Figure 4. Percentages of **WWH** biological attainment at upper Great Miami River basin tributary sites from sub-ecoregion **55b** (**left chart**), sub-ecoregion **55a** sites "with" groundwater (**middle chart**) and **55a** sites "without" a strong ground water connection (**right chart**), 2008.

Higher biological performance at **55a** sites with enhanced flow was often encountered despite extensive agricultural activity and altered stream channels. In fact, 89% of the sites are listed under county maintenance (**Appendix Table C-2**). Despite these factors, fish communities from the enhanced flow sites often out-performed expectations given the existing habitat quality, particularly from headwater drainages (see **Figure 42)**. The phenomenon was initially observed during the 1994 upper GMR survey (Ohio EPA 1995), and coined the "The Muchinippi Creek Effect" by the Ohio EPA fish assessment unit. The phrase described the "over-reaching" quality of fish community performance in the Muchinippi Creek watershed, a largely modified but fully attaining basin that benefits from sustained ground water flow for much of its length. The

3 Enhanced flow and/or coldwater indicative fish species included mottled sculpin, hornyhead chub, river chub, southern redbelly dace, redside dace, and brook stickleback.

4 The terms "with" or "without" enhanced ground water flows should not be considered absolutes and were not based on extensive or additional physical stream measurements or data. Rather, the presence or absence of enhanced flow was inferred by the composition of the extant biological communities.

presence or absence of this additional flow was an important factor in determining the overall quality of the resource. Expanded site coverage during the 2008 survey (possibly coupled with the additional 14 years of recovery time since 1994) shows the beneficial effects of enhanced flow were not limited to Muchinippi Creek (**Figure 5**).

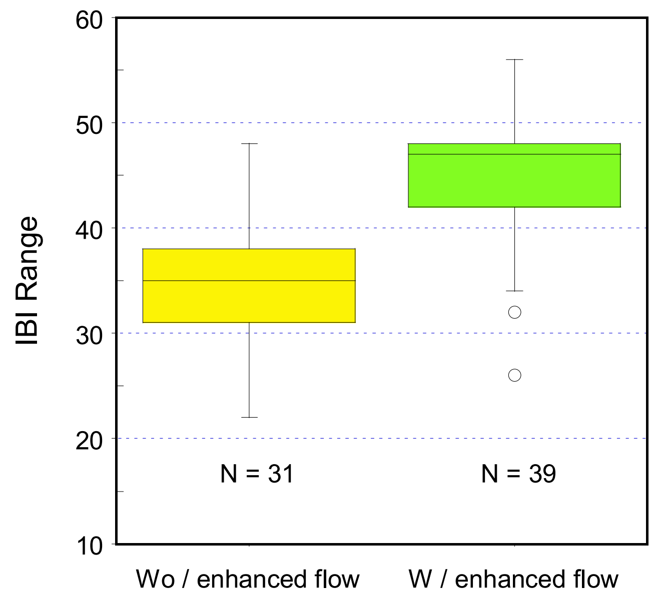


Figure 5. Box and whisker plot of IBI scores from upper GMR basin tributary sites "with" and "without" enhanced ground water flow

Macroinvertebrate performance was also often higher at **55a** sites showing signs of enhanced ground water flow **(55a w/gw)**. However, higher performance was not consistent for all locations. Low quality communities at enhanced flow sites were typically associated with qualitative (*i.e.,* natural substrate) collections from channelized reaches with soft, mucky substrates. Hydric soil deposits concentrated along the local drainages appeared the most likely or pervasive sources of muck. In a few instances, artificial substrate samplers were retrieved from these modified but enhanced flow sites and macroinvertebrates often met WWH expectations (*e.g*., 2008 Liggit Ditch, 1994 Willow Creek). Since the multi-plate samplers tend to compensate for the influence of poor natural substrates, the results are not surprising. It is speculated if both fish *and* quantitative macroinvertebrate collections were available, many of these modified channels with enhanced flow would fully attain WWH.

Water chemistry results also showed variability between sub-ecoregions within the study area. In the **55a**, median phosphorus concentrations at 58% of tributary stations exceeded their respective nutrient target levels (see **Table 10**). In contrast, only 29% of stations in the **55b** exceeded target (proportionally speaking, only half as many as in the **55a**) and all but one were downstream from the Bellefontaine WWTP, the largest municipal discharge in the study area.

When broken down further, into sites with or without enhanced base flow, the differences between sub-ecoregions are more striking. Excluding the Great Miami River mainstem, 81% (n=26) of **55a** sites without ground water flow exceeded the phosphorus target compared to 20% (n=4) at **55a** sites and 29% (n=5) at **55b** sites with additional flow. When stream sites influenced by WWTP discharges are excluded (*i.e.,* only agricultural landscapes are compared), the nutrient target was still exceeded at 74% of sites that did not exhibit an enhanced flow signature compared to 20% and 0% from enhanced flow **55a** and **55b** sites, respectively (**Figure 6**).

Nutrient variation between watersheds could also be attributed to differences in habitat quality (see **Figure 42**) as higher quality and more natural stream habitats have a greater ability to process and assimilate nutrient loadings (Ohio EPA 1999). This phenomenon may hold between the **55a** and **55b** as 76% of **55a** site channels were modified or recovering, compared to only 32% in the **55b**. Coincidentally, Stony Creek was the only **55b** stream listed under county maintenance compared to a minimum, 13 streams in the **55a**. However, while stream modification activity varied across the watershed, agricultural land usage dominated the landscape and was ubiquitous throughout most of the upper Great Miami River survey area (see **Figure 9**; **Figure 11**).

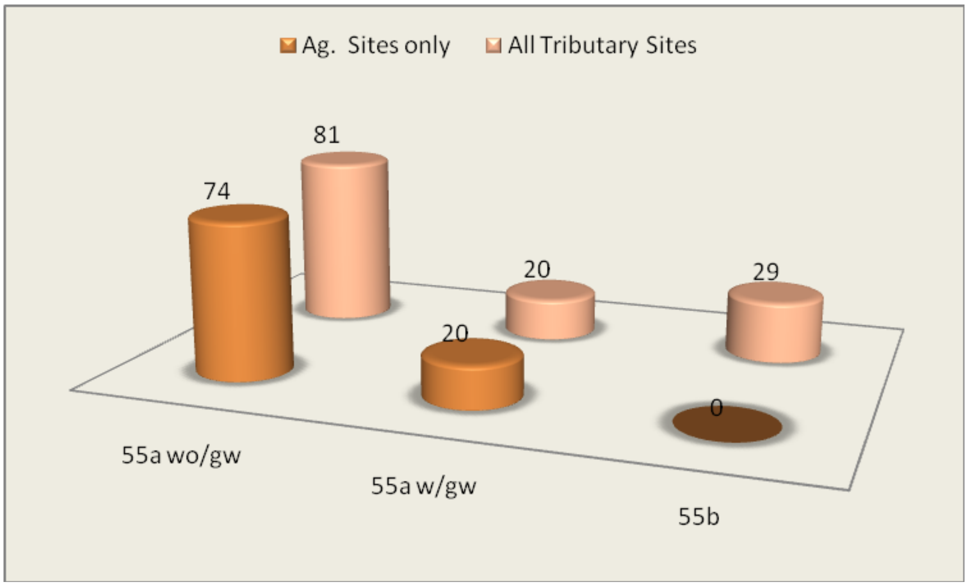


Figure 6. Percentages of tributary sites exceeding regional phosphorus targets in the 55a sub-ecoregion "without" ground water flow ("55a wo/gw"), 55a sub-ecoregion "with" ground water flow ("55a w/gw"), and "55b" sub-ecoregion from 1) all sampling sites (light orange column) and 2) agricultural sites only (dark orange column). Sites downstream from significant WWTP discharges were excluded from the "Ag. Sites Only" row.

Habitat quality does not fully explain the variation in nutrient levels and biological performance among **55a** sub-ecoregion sites. Approximately three quarters of all **55a** channels were modified or recovering and, based on QHEI scores, differences in habitat quality between sites with, or without signs of enhanced flow, were minimal (**Figure 42**). However, biological performance was substantially better and background phosphorus levels were lower in streams characterized by enhanced flow. Results continued to suggest the presence or absence of additional base flow tends to either mitigate or exacerbate water quality impacts within the sub-ecoregion.

Beneficial effects of ground water were apparent throughout most tributaries in the study area. However, differences in chemical and biological performance tended to be most pronounced and consistently demonstrated at the headwater ($\leq$20 mi^2 drainage) level.

Channel Restoration

As a general rule and whenever possible, efforts should be made to restore modified streams within the upper Great Miami River watershed to their natural morphological state. Natural stream channels have a greater capacity to assimilate nutrients and fine sediments by flushing them into adjacent floodplains, help process nutrients into beneficial biomass rather than nuisance algae, improve water quality, create diverse instream habitats, and ultimately (and most important for adjacent landowners) evolve into a stable channel.

Under proposed draft rules under consideration by Ohio EPA and released for interested party review (Ohio EPA draft December 2010), small drainages (*i.e.,* <3.1 mi^2) that are maintained for agricultural drainage would retain or qualify for a less restrictive, modified warmwater habitat (MWH) aquatic life use designation. However, for larger drainages and wherever possible, a goal of reversing previous physical modifications should be pursued (*e.g.,* remove remaining unnecessary dams, move dikes and levees away from stream banks, restore cutoff channels, wetlands, riparian buffers, etc.).

Sub-ecoregions and Channel Management Implications

Biological communities typically benefited from enhanced ground water flow in the upper Great Miami River survey area. However, in several instances, modified streams with sustained flow did not reach full attainment due to the marginal quality of the macroinvertebrate community.

Lower macroinvertebrate performance was most often associated with poor substrate quality. As a general rule, numeric IBI and MIwb fish community scores linked to the QHEI habitat ratings are the most comprehensive assessors of modified stream performance. In contrast, artificial substrates tend to dampen the influence of the natural substrates and qualitative assessments, while insightful, are less rigorous. For these reasons, fish community performance should be given the greatest weight when analyzing attainment in these simple, channelized reaches. Further, candidate stream channel rehabilitation measures should employ a “light touch” or be assigned a lower priority status when addressing these “over-performing” agricultural drainages. Many of these streams were close to full WWH attainment and fish communities often met the WWH benchmark. Compared to most other modified sites, the need for extensive rehabilitation in flow enhanced channels is not as urgent. Simply reducing (or continuing to ignore) on-going channel maintenance efforts allowing channel evolution and natural recovery to take place might be adequate. More intensive remediation should be directed at the most degraded drainages, those requiring greater effort and management to reach their potential.

Sites from the 55a sub-ecoregion that did not exhibit an enhanced flow signature were typically the worst quality streams in the survey. As mentioned previously, most were modified, sluggish, silty and enriched. In these instances, biological communities might benefit from more aggressive channel restoration measures including re-establishment of riparian buffers, installation of secondary overflow channels, over widening of the channel, riffle formation, etc. Attempts to reduce nutrient loading at the source should coincide with any habitat rehabilitation efforts in these drainages.

Recreation Use Quality

Bacteriological impairment was pervasive throughout the upper watershed in Class A and Class B streams (see stream Class definitions on **page 47**). The Primary Contact criterion was exceeded at 73% of sites (*i.e.,* 27 of 37). Row crop agriculture was a suspected source of contamination at all of the impaired sites (100%). Normal row crop agricultural activity may also include manure application to farm fields as portions of the basin (particularly in the western, Loramie Creek watershed) drain some of the highest manure-producing counties in the state (Columbus Dispatch, Oct. 16, 2010). Biosolids from the larger local municipal WWTPs at Russells Point, Bellefontaine, Lake Loramie, and Minster are also spread on area fields near the facilities. Urban runoff was the suspected contaminant source at 37% of the non-attaining sites followed by unsewered communities and on-site septic systems (19%), sanitary sewer overflows and wildlife (11% each). Both feedlots and unrestricted livestock access accounted for 7% of suspected contaminant sources at impaired sites. A deteriorating wastewater collection system in Jackson Center may also have contributed to impairment at one location immediately downstream.

Most violations were related to the geometric mean criterion, as opposed to the single sample maximum criterion. Since much of the sampling was conducted under late summer, low flow conditions, this difference suggests chronic problems with bacteria rather than episodic events related to overflows, bypasses, or runoff events simply attributable to wet weather. Many of the controls recommended to address nutrient enrichment are also recommended to restore the recreation beneficial use in affected areas throughout the upper Great Miami River watershed.

CONCLUSIONS and RECOMMENDATIONS

Upper Great Miami River Basin Summaries

A brief summary of upper Great Miami River basin results at the 10 digit Hydrologic Unit Code (HUC) level can be found below. More detailed 2008 HUC-12 watershed assessment unit attainment statistics, sampling information, and causes and sources of impairment can be found at the Ohio EPA Division of Surface Water web site @:
http://wwwapp.epa.ohio.gov/dsw/ir2010/watershed.php?id=05080001

HUC 05080001 01 (Headwaters Great Miami River)

Biological sampling was conducted at 11 sites within the HUC and 10 (91%) were in full attainment of biological WQS. Only **Van Horn Creek**, a small, historically modified agricultural ditch that drains into Indian Lake was in non-attainment. Macroinvertebrates from the **North Fork Great Miami River (GMR)** at RM 6.3 suggested an unknown, toxic impact in 2008 but follow-up sampling indicated full recovery the following year. Sampling throughout the **South Fork GMR basin** found full attainment of all biological communities and good to exceptional performance. **South Fork GMR** biological communities benefited from enhanced base flows and a strong ground water connection, ameliorating the effects of widespread channelization and unrestricted cattle access. Unfortunately, recent field observations from the spring of 2011 indicate the restored woody riparian buffers near South Fork RMs 8.0 and 7.4 have been removed and the gains in habitat quality and fish community health observed in 2008 may be at risk.

HUC 05080001 03 (Bokengehalas Creek-Great Miami River)

Nineteen sampling sites were located in the HUC including four upper **GMR** mainstem and 15 tributary sites. Mainstem partial attainment was attributed to a variety of sources including past channelization and siltation, plus flow alteration and enrichment influences downstream from the Indian Lake overflow. The addition of organic enrichment loadings from the Indian Lake WWTP in Russells Point coupled with several stream miles of sluggish, mainstem flow may have contributed to low dissolved oxygen (D.O.) levels and far-field impairments well downstream from their source.

Tributary sampling sites in the HUC were about equally split between the 55a and 55b sub-ecoregions. High stream gradients, good to excellent habitat quality and ample ground water recharge in the 55b contributed to consistently full attainment (7 of 8 or 88% of sites). The only site that did not fully attain was extensively channelized and impacted by a toxic, aerial pesticide spray during the 2008 field season. In contrast, 6 of 7 sites (86%) from the 55a sub-ecoregion were in non or partial attainment, related almost entirely to channelization. In this area, performance at enhanced flow sites wasn’t appreciably better than at sites without.

HUC 05080001 02 (Muchinippi Creek)

The Muchinippi Creek basin and some surrounding watersheds were unique compared to other 55a sub-ecoregion streams as much of the basin benefited from enhanced ground water flow. The additional flow tended to ameliorate water quality impacts and compensate for the extensive channelization for agriculture drainage. This was particularly true for fish communities which reflected marginally good to very good quality at 9 of 11 (82%) sites. In contrast, only 5 of 11 macroinvertebrate samples (55%) met WWH expectations. Overall, this resulted in 4 sites in full attainment (36%; all in **Muchinippi Creek**), six sites (55%) in partial attainment and one site (9%) in non-attainment. Lower performance in the macroinvertebrates was commonly related to monotonous habitat and soft, mucky substrates associated with hydric soils. Since fish are normally considered the best indicators of habitat performance, it is recommended that limited effort or resources be devoted to rehabilitating the already adequately performing channels (*e.g.,* **Little Muchinippi Creek** RM 6.05, **Willow Creek,** or the fully attaining, **Muchinippi Creek**).

More severe biological impairments in lower **Little Muchinippi Creek** (RM 0.62) were attributed to nutrient enrichment and channelization. In **Jackson Center Creek**, small stream size, severe channelization and excessive loadings from the Jackson Center WWTP contributed to poor quality macroinvertebrates and partial attainment of the recommended MWH aquatic life use. The lower three miles of **Muchinippi Creek** are sluggish and partially impounded by an abundance of log jams which backed up flow and negatively impacted biological quality.

HUC 05080001 04 (Stony Creek-Great Miami River)

Three upper **GMR** mainstem sites and 11 tributary sites from six different streams were sampled in the HUC. The upper **GMR** was in full attainment of the designated EWH use with the exception of one site (RM 138.8 at Baker Rd.) in partial attainment. Impairment was the result of macroinvertebrate collections from a sluggish, pooled reach and attributed to a relatively minor siltation impact. Tributary sites were all (100%) in full attainment of WWH (**Stony Creek**, **Indian Creek**, **Plum Creek**), CWH (**Lee Creek** and **Graves Creek**), and a dual EWH/CWH aquatic life use (**McKees Creek**). Excepting upper **Plum Creek**, all the high quality tributaries were located in the 55b sub-ecoregion and each tended to benefit from relatively high stream gradients, good to excellent habitat quality, and an ample ground water recharge, common to the sub-ecoregion.

HUC 05080001 05 (Headwaters Loramie Creek)

Only one of eleven sites from the upper Loramie Creek watershed was in full attainment of WWH criteria. The remaining sites were in non or partial attainment of WWH, partial attainment of MWH, or fully met the less protective MWH use. Impairments were associated with channelization and nutrient enrichment from agriculture (**Mile Creek, Spring Creek, Loramie Creek** headwaters), enrichment and late summer flow depletion immediately downstream from Lake Loramie (**Loramie Creek** RM 22.1), and slug-type discharges of TDS and chlorides from the Botkins WTP via the local WWTP (**Loramie Creek** RM 34.96). Extensive, basin wide channelization, poor habitat quality and biological performance in the Mile Creek basin warranted an MWH-C recommendation for agricultural drainage. In **Loramie Creek**, biological communities maintained a marginally good quality in close proximity to two major municipal WWTPs in Minster and Lake Loramie, but chemical and biological quality declined with increased distance downstream (see HUC 01-06, below).

HUC 05080001-06 (Turtle Creek-Loramie Creek)

Seven of eleven biological sampling sites (64%) in the lower Loramie Creek basin were in full attainment of WWH or the existing MWH use in upper **Ninemile Creek**. Non-attainment was limited to upper **Turtle Creek** (RM 8.42), the result of past channelization and nutrient enrichment associated with agriculture. Partial attainment was observed through an approximate 4.5 mile stretch of **Loramie Creek** between Mile Creek and Newport (RM 19.46-14.8). The combination of modified habitat, sluggish flow and excessive nutrients (particularly phosphorus) associated with agriculture and the two major WWTPs in Minster and Lake Loramie were considered the primary causes and sources of impairment.

Aquatic Life Uses Recommendations

Another objective of the upper Great Miami River watershed study was to evaluate the appropriateness of existing beneficial uses and to assign new uses to undesignated or unverified streams. A number of tributary streams evaluated in this study were originally assigned aquatic life use designations in the 1978 and 1985 Ohio Water Quality Standards (WQS). Designations were based largely on best professional judgment as current biological assessment methods and numerical criteria did not exist. As such, aquatic life use designations for eleven 2008 study streams were previously unverified (*i.e.,* **Willow**, **Little Muchinippi**, **Jackson Center**, **Brandywine, Rum, Lee, Graves, Indian, Plum, Mile,** and **Turtle creeks**). Four other evaluated water bodies were undesignated (*i.e.,* not listed in the WQS) and included: **Trib. to Great Miami River (157.34), Rennick Creek, Spring Creek,** and the section of the **Miami-Erie Canal** located in the Minster/Fort Loramie area.

Since adoption of the biological water quality standards, efforts are made to regularly evaluate newly assessed streams during each survey year. The 2008 study, as an objective and robust evaluation of beneficial uses for the aforementioned streams, is precedent setting in comparison to the 1978 and 1985 designations.

Table 2 summarizes assessments associated with the habitat and biological scores garnered at unverified or undesignated streams in 2008. These stream channels ran the gamut from cool, natural and high gradient, to sluggish, severely degraded, and extensively modified for agricultural drainage. Matching the physical diversity of stream sites, biological performance ranged from poor to exceptional, qualities associated with a range of Ohio's tiered aquatic life uses including Modified Warmwater Habitat (MWH), Warmwater Habitat (WWH), Exceptional Warmwater Habitat (EWH), and Coldwater Habitat (CWH). Current and recommended aquatic life, water supply and recreation uses for all the upper Great Miami River basin are outlined in **Table 3**.

The most common characteristic among the unverified or undesignated streams was recent or active channel maintenance for agricultural drainage (13 of 16 streams, or 81%). However, maintenance status was not necessarily the primary factor when evaluating the appropriate use. As discussed in the Executive Summary (**pages 20-25**), comparatively higher biological performance was often encountered in streams with a strong ground water connection, despite channelization. The unique hydrology and enhanced biological performance associated with these modified channels was considered adequate justification for a WWH recommendation.

Each unverified stream in **Table 2** lay near or within the Muchinippi Creek basin. **Muchinippi Creek** is verified (*i.e.,* "+") WWH in the WQS and has channel modifications and enhanced flow characteristics similar to its tributaries. Similarly, the South Fork GMR basin falls within the 55a sub-ecoregion, is listed under active channel maintenance, and supports biological communities reflecting a strong ground water connection. Also, all South Fork basin streams are listed as verified (+) WWH or EWH. Since the unverified streams sampled in 2008 share similar maintenance and hydrologic characteristics to Muchinippi Creek and the South Fork GMR basin, they should also share similar aquatic life use expectations based on physical and geological similarity. For these reasons, WWH+ is recommended for each of the affected streams (*i.e.,* **Willow, Little Muchinippi, Brandywine,** and **Rennick** creeks).

Table 2. Upper Great Miami River basin streams with unverified or unlisted aquatic life uses sampled in 2008. Evaluations are assigned to habitat, fish, and macroinvertebrate communities based on a combination of index scores, stream size, and ecoregion. Raw scores and applicable biocriteria are detailed further in the Aquatic Life Use Attainment Table.

Stream	# of Sites	Size (mi^2)	Habitat Evaluation	Fish Evaluation	Macroinvert. Evaluation	ALU[a] Current	ALU Rec.[b]
Trib. to GMR (157.34)	1	7.6	Very Poor	Fair	Low Fair	--	MWH
Rennick Creek	1	10.3	Fair	Poor	Fair	--	WWH
Brandywine Creek	1	9.02	Fair	Very Good	Fair	WWH	WWH
Rum Creek	3	28.0	Poor-Good	Poor-VGood	Fair-Excellent	WWH	WWH
Willow Creek	2	15.2	Poor	Marg. Good	Fair	WWH	WWH
Little Muchinippi Cr.	2	35.5	Poor-Fair	Fair-Good	Fair-Good	WWH	WWH
Jackson Center Cr.	2	6.86	Poor	Fair-M.Good	Poor	WWH	MWH
Lee Creek	1	22.6	Excellent	Very Good	Excellent	WWH	CWH
Graves Creek	1	11.0	Excellent	Very Good	Good	WWH	CWH
Indian Creek	1	15.9	Excellent	Very Good	Excellent	WWH	WWH
Plum Creek	3	15.9	Fair-Excellent	Good-MGood	Good-MGood	WWH	WWH
Miami and Erie Canal*	1	4.3	Fair	Fair	Good	--	MWH
Mile Creek	4	62.7	VPoor-Poor	Poor-Fair	Poor-High Fair	WWH	MWH
Spring Creek	1	8.8	Poor	Fair	High Fair	--	MWH
Turtle Cr. (RM 9.54-0.0)	3	36.0	Fair-Excellent	Poor-VGood	Fair-Excellent	WWH	WWH

[a] ALU = Aquatic Life Use
[b] Rec. = Recommended

Channel characteristics and biological performance in **Rum Creek** and **Turtle Creek** were variable as some sites were modified and impaired and others were natural and fully attained WWH. However, none of the sampling sites were under sanctioned maintenance and only the extreme upper reach of **Turtle Creek** (upstream from SR 705/RM 9.54) is maintained by the county. Any other modifications were either remnants of historical construction or undertaken by adjacent landowners and are not overseen by Ohio EPA or local governments. Biological communities in both **Rum Creek** and **Turtle Creek** improved in recovering stream channels and fully met WWH at sites with natural, intact stream habitats. The most severe impacts were associated with recent channelization and nutrient enrichment and these areas were restricted to the headwaters of each watershed. For these reasons, a more conservative, WWH designation is recommended for the length of **Rum Creek** and the entire stretch of **Turtle Creek** (from SR 705/RM 9.54 to the mouth) that is not under active maintenance.

The headwaters of **Plum Creek** (station RM 9.0) are channelized and listed under Shelby County maintenance (QHEI = 53). Additional sampling downstream found a recovering channel (QHEI = 62.5 at RM 5.22) and natural stream conditions at the mouth (QHEI = 84.5 at RM 0.13) Biological communities fully met WWH criteria throughout the stream's length. Channelization influences in the headwaters were ameliorated by the presence of adequate gradient, depth, and cover, plus the presence of coarse unembedded substrates and riffle habitats. Despite variable channel maintenance activity, the stream demonstrated WWH potential throughout its length and should be designated as such.

Indian Creek displayed excellent habitat quality and very good to excellent biological performance. The stream easily supports the recommended WWH use.

Lee Creek and **Graves Creek** are located within the 55b sub-ecoregion and reflected the high quality, high gradient, and enhanced flow characteristics typical of streams in the area. In addition to the very good to excellent biological performance, the streams contained coldwater fish and macroinvertebrate populations adequate for the recommended CWH designation.

In contrast to streams discussed above, MWH (Modified Warmwater Habitat) designations are recommended for the following:

Jackson Center Creek	**Miami and Erie Canal**	**Mile Creek**
Spring Creek.	**Trib. to Great Miami River (157.34)**	

Jackson Center Creek is a small agricultural ditch (<8 mi^2) with poor habitat quality (avg. QHEI = 32.25) maintained by Shelby County. Drainages at sampling sites in Jackson Center were even smaller (1.1-3.4 mi^2) and match sizes that would roughly qualify as a maintained agricultural drainage (*i.e.,* <3.1 mi^2) proposed in draft rules under consideration by Ohio EPA and released for interested party review (Ohio EPA draft December 2010).

The **Trib. to GMR (157.34)** was also a small (<8 mi^2), deeply incised agricultural ditch (QHEI=17.5). While the stream is not currently listed under County maintenance, a review of historical topographic maps shows significant alteration as far back as 1961. Existing modifications appear of recent origin so maintenance is apparently undertaken by the local landowner(s). Due to its low gradient (3.7'/mi^2) and the virtual absence of any normal stream attributes (*i.e.,* 1 WWH vs.10 High and Moderate influence MWH attributes), the prospect of rehabilitating the channel to support WWH communities is unlikely. Given the sluggish, marshy characteristics of the drainage further upstream, its ultimate potential may lie in some form of wetland habitat, as opposed to WWH.

The **Miami and Erie Canal** is a man-made ditch, originally built in the 19^{th} Century as a water conveyance to feed the Erie Canal transportation network. Portions of this same canal are located in the Maumee River drainage and are already designated MWH in the Ohio WQS. This report recommendation simply brings the section draining to Loramie Creek into line with existing standards.

Mile Creek and **Spring Creek** are located in the extensively modified and highly agricultural Mile Creek basin, which flows through portions of Darke, Mercer, Shelby and Auglaize Counties. Virtually the entire basin is under ditch maintenance and corresponding habitat quality and biological health fell in the very poor to fair ranges. Physical alteration of stream channels is so pervasive and severe, MWH was considered the most realistic measure of current stream potential.

Other Aquatic Life Use Recommendations

In addition to unverified or undesignated stream uses, adjustments to verified aquatic life use designations are recommended for two 2008 survey streams, **Blue Jacket Creek** and **McKees Creek**. Upper **Blue Jacket Creek**, upstream from the Bellefontaine WWTP on Opossum Run (RM 5.8), demonstrated substantial improvement and CWH potential in the most recent survey. Coldwater conditions were lost downstream from Opossum Run and, given the relatively warm and dominating flow from the Bellefontaine WWTP, expectations of a coldwater fauna in the downstream reach are unrealistic. **McKees Creek** is already designated EWH in the WQS. Biological sampling in 2008 confirmed its high quality with full attainment of EWH. Samples also included coldwater fish and macroinvertebrates populations adequate for a CWH designation. Therefore, both EWH and CWH are recommended for **McKees Creek**.

No other changes are recommended for the remaining 2008 survey streams with verified aquatic life use designations. The upper **Great Miami River** mainstem continued to achieve full or partial attainment in the WWH designated reach from Indian Lake to Quincy, and nearly consistent EWH attainment in the EWH designated reach between Quincy and Sidney. Historical channelization in the WWH reach coupled with sluggish flow, siltation and enrichment, contribute to marginal performance over the approximate 17 mile reach.

Loramie Creek is a verified WWH stream but much of the mainstem is actively or historically modified. Biological communities upstream from Lake Loramie reflected impacts from recent and historic channelization but the stream is not listed under county maintenance. In addition to habitat quality, additional impacts were attributed to a periodically poor effluent quality from the Botkins WWTP and impoundment effects from Lake Loramie downstream. Given this segment's relatively large size (35 mi^2), lack of sanctioned maintenance, impacts attributable to anthropogenic sources, and importance as the main feeder to the recreationally important Lake Loramie, lowering the use is not recommended. In fact, ensuring conditions in Lake Loramie are not degraded by upstream sources should be a priority.

Lower **Loramie Creek** is under Shelby County ditch maintenance for an approximate 14.5 mile stretch from the Lake Loramie dam (RM 22.1) to Loramie-Washington Rd (RM 7.5). Some sections, particularly an approximate four mile stretch downstream from

Mile Creek, had particularly poor habitat quality, slow flow, elevated nutrients, and significant biological and chemical degradation. However, it is recommended the existing WWH use be maintained for the following reasons.

1) Biological and water quality impairments within some of the most degraded reaches of lower Loramie Creek were attributed to excessive nutrient loadings from point and nonpoint sources, not simply habitat alteration. Obvious and controllable water quality impairments should be addressed before resorting to a lowered use.

2) Biological performance at other locations within the maintained reach fully met WWH attainment standards.

3) Lower Loramie Creek's drainage size, ranging from 78 to over 200 mi^2, far exceeds drainages typically associated with the MWH use under proposed, tiered, water conveyance designations for agricultural drainages (Ohio EPA draft December 2010).

In summary, it is recommended that **Rennick, Brandywine, Rum, Willow, Little Muchinippi, Indian, Plum** and **Turtle creeks** receive the WWH aquatic life use. The **Trib. to Great Miami River (157.34), Jackson Center Creek, Mile Creek, Spring Creek,** and **Miami and Erie Canal** are recommended as MWH. **McKees Creek** should receive a CWH designation in addition to its existing EWH designation and the headwaters of **Blue Jacket Creek** should be upgraded from WWH to CWH upstream from RM 5.8 (Opossum Run confluence). **Lee Creek** and **Graves Creek** should also be upgraded from WWH to CWH. All other beneficial uses for streams sampled in the 2008 survey of the upper Great Miami River watershed are considered appropriate and should be retained.

All streams in the study currently designated Primary Contact Recreation should retain their PCR use (Class A for the upper Great Miami River mainstem and Loramie Creek from RM 30.42 to the mouth and Class B for all other streams) along with the Agricultural Water Supply and Industrial Water Supply uses. Formerly unsampled or undesignated streams that were evaluated in the 2008 intensive survey should be classified as PCR Class B, Agricultural Water Supply and Industrial Water Supply (**Table 3**) except for the most upstream site on Jackson Center Creek (Class C).

Raw index scores and applicable biocriteria for every location sampled in the upper Great Miami River watershed in 2008 are included in **Table 4.** Qualitative Habitat Evaluation Index (QHEI) matrix attributes are detailed in **Appendix Table C-1**.

Table 3. Waterbody use designations for the upper Great Miami River basin. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). Designations based on Ohio EPA biological field assessments appear as a plus sign (+). Asterisked (*) designations supplanted by Ohio EPA biological field assessments (+) are displayed to the right of existing markers (*/+). A delta (Δ) indicates a new recommendation based on the findings of this report; a verified use (+) to be removed and replaced by a new recommendation (Δ) is shaded in green. All water bodies with recommended changes are highlighted in yellow.

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	
Great Miami river - CSX RR bridge (RM 84.5) to the Troy dam (RM 107.0)			+						+	+		+		
- at RMs 86.6, 90.3, 118.5 and 130.2			+					+	+	+		+		PWS intakes - Dayton (RMs 86.6 and 90.3), Piqua (RM 118.5), and Sidney (RM 130.2)
- RM 108.0 to downstream of Piqua dam (RM 114.0)			+						+	+		+		
- st. rte. 66 (RM 116.7) to the Sidney water works dam (RM 130.2)			+						+	+		+		
- Pasco-Montra rd. (RM 134.8) to the Quincy dam (RM 143.4)			+						+	+		+		
- all other segments		+							+	+		+		
Loramie creek - Lockington dam (RM 2.1) to the mouth	*	+							+	+		+		
- all other segments		+							+	+		+		
Mill creek		*							*	*		*		
Fox creek		*							*	*		*		
Turtle creek – SR 705 (RM 9.54) to the mouth		*/+							*/+	*/+		*/+		
East Turtle creek		*							*	*		*		
Kiser ditch		*							*	*		*		
all other segments		*							*	*		*		
Ninemile creek - headwaters to county route 14 (RM 4.2)				+					+	+		+		ECBP ecoregion - channel modification
- all other segments		+							+	+		+		
Painter creek		*							*	*		*		
East Painter creek		*							*	*		*		
Mile creek		*		Δ					*/+	*/+		*/+		ECBP ecoregion - channel modification

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	
Miami Erie Canal				Δ					Δ	Δ		Δ		ECBP ecoregion - channel modification
Spring creek				Δ					Δ	Δ		Δ		ECBP ecoregion - channel modification
Honsapple ditch		*							*	*		*		
Keppler ditch		*							*	*		*		
Clay creek (Applegate ditch)				+					*	*		*		ECBP ecoregion - channel modification
Hulls creek (Fridley ditch)		*							*	*		*		
Mill branch		*							*	*		*		
Brush creek		*							*	*		*		
Tawawa creek - at RM 0.14		+						+	+	+		*		PWS intake - Sidney
- all other segments		+							+	+		*		
Mosquito creek		*							*	*		*		
Leatherwood creek		*							*	*		*		
Plum creek		*/+							*/+	*/+		*/+		
Manning run		*							*	*		*		
Line run		*							*	*		*		
Counts run		*							*	*		*		
Turkeyfoot creek		*							*	*		*		
Little Turkeyfoot creek		*							*	*		*		
Indian creek		*/+							*/+	*/+		*/+		
Little Indian creek		*							*	*		*		
Speece & Lovett ditch		*							*	*		*		
Stony creek		+							+	+		+		
Lee creek		*				Δ			*/+	*/+		*/+		
Graves creek		*				Δ			*/+	*/+		*/+		
McKees creek			+			Δ			+	+		+		EWH and CWH
Bokengehalas creek		+							+	+		+		
Bluejacket creek (Headwaters to RM 5.8)		+				Δ			+	+		+		

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	
Bluejacket creek (RM 5.8 to mouth)		+							+	+		+		
Possum run (Bluejacket creek RM 5.8)		+							+	+		+		
Rum creek		*/+							*/+	*/+		*/+		
Hodge ditch		*							*	*		*		
Howell ditch		*							*	*		*		
Shroyer ditch		*							*	*		*		
Indian creek		*							*	*		*		
Brandywine creek		*/+							*/+	*/+		*/+		
Muchinippi creek		+							+	+		+		
Calico creek		*							*	*		*		
Little Muchinippi creek		*/+							*/+	*/+		*/+		
Wolf creek		*							*	*		*		
Baughman ditch		*							*	*		*		
Jackson Center creek		*		Δ					*	*		*		ECBP ecoregion - channel modification
Willow creek		*/+							*/+	*/+		*/+		
Great Miami River trib. (157.34)				Δ					Δ	Δ		Δ		ECBP ecoregion - channel modification
Rennick Creek		Δ							Δ	Δ		Δ		
Cherokee Mans run		+							+	+		+		
South fork Great Miami river		+							+	+		+		
New Richland tributary (South fork R 5.27)			+						+	+		+		
Slow ditch (Liggitt ditch)		+							+	+			+	
Belle Center tributary (South fork R 7.24)		+							+	+			+	
North fork Great Miami river		+							+	+		+		
Blackhawk run		+							+	+		+		
Van Horn creek		+							+	+		+		

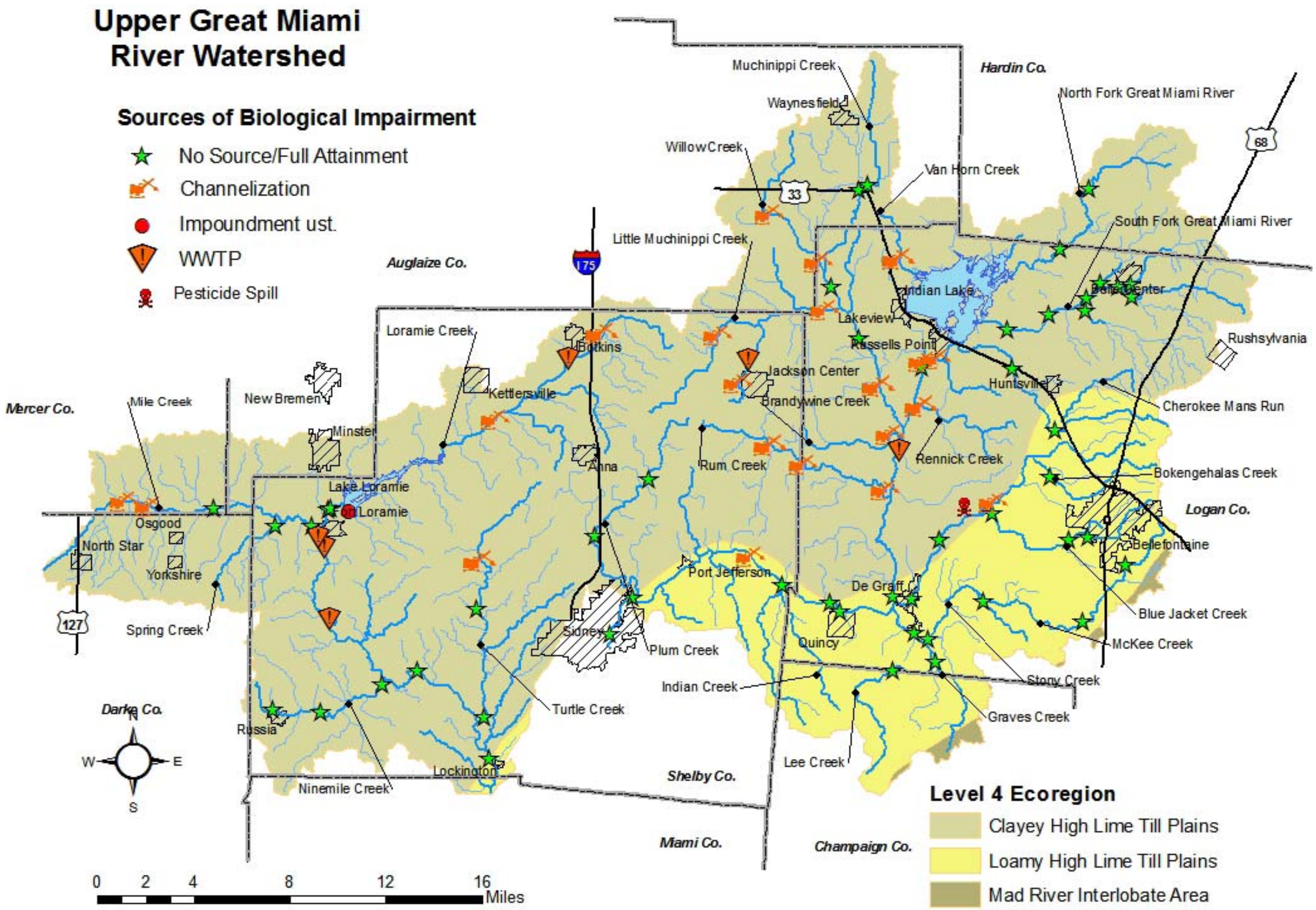


Figure 7. Map of the **Upper Great Miami River** basin showing sampling locations and sources of biological impairment (where applicable). Gray shaded areas represent city and town boundaries. A complete listing of causes and sources of impairment can be found in Table 4.

Table 4. Aquatic life use attainment status at upper Great Miami River basin stations sampled in July-October 2008 and 2009. Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and the streams ability to support a biotic community. Potential Causes and Sources of impairment are listed at sites that did not fully attain their use. All sites are located within the Eastern Cornbelt Plains ecoregion and the 55a and 55b sub-ecoregions. Sampling locations by the 10-digit Hydrologic Unit Code (HUC 10) subwatershed as indicated in green and further stratified at the HUC 12 level (see 12 digit WAU).

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
Biological communities from sub-ecoregion sites shaded in light blue (55b) or orange (55a w/gw) suggest abundant ground water.								
HUC 05080001 03 *Bokengehalas Creek - Great Miami River*								
Great Miami River (14-001)								
WWH Aquatic Life Use (Existing)								
158.90[W] – dst. Cherokee Mans Run and Ind. Lake	02	44	10.4	F*	72.5	PARTIAL	Silt, Habitat Alt., Flow Alt.	Ag.,Channelization, Impoundment ust.
157.22[W] - SR 235 (upper), dst. Indian Lake WWTP	02	48	8.4	36	44.5	FULL		
153.45[B] – Notestine Rd.	06	38[ns]	7.7*	F*	43.5	PARTIAL	Habitat Alt., Silt, Flow Alt., Org. Enrich./DO	Channelization, Ag. Impoundment ust., Major municipal WWTP
146.19[B] – SR 235 (lower)	06	46	8.9	42	76.0	FULL		
HUC 05080001 04 *Stony Creek - Great Miami River*								
EWH Aquatic Life Use (Existing)								
143.20[B] – SR 235 dst. Quincy low-head dam	06	59	9.8	50	79.0	FULL		
142.50[B] – CR 73, dst. Quincy WWTP	06	54	9.8	E	74.5	FULL		
138.39[B] – Baker Rd.	06	56	9.7	38*	73.0	PARTIAL	Silt, Habitat Alt.	Ag., Channelization
HUC 05080001 07 *Tawawa Creek - Great Miami River*								
129.99[B] - E. N. St, Sidney.	03	56	10.2	46	70.0	FULL		

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
HUC 05080001 01 *Headwaters Great Miami River*								
North Fork Great Miami River (14-802)								
WWH Aquatic Life Use (Existing)								
10.7[H] –off Madory Rd.	01	36[ns]	NA	34[ns]	38.5	FULL		
6.31[H] – Dunn Rd. (2008/2009)	01	36[ns]	NA	P*/G	64.0	FULL	Note FULL macroinvertebrate recovery between 2008 / 2009. Exact Cause and Source Unknown.	
South Fork Great Miami River (14-800)								
WWH Aquatic Life Use (Existing)								
8.00[H] – SR 638	02	54	NA	50	76.5	FULL		
7.23[H] – CR 39	02	51	NA	54	76.5	FULL		
5.80[W] – CR 97	02	42	9.2	56	59.0	FULL		
3.95[W] – CR 97 ust. SR 117	02	46	8.9	44	76.0	FULL		
1.74[W] – CR 36	02	46	8.1[ns]	48	83.0	FULL		
Trib. to South Fork Great Miami R. (7.24) aka Belle Center Tributary (14-805)								
WWH Aquatic Life Use (Existing)								
0.55[H] – SR 638	02	50	NA	MG[ns]	44.0	FULL		
Liggit Ditch aka Slow Ditch (14-800-003)								
WWH Aquatic Life Use (Existing)								
0.53[H] – TR 49	02	44	NA	48	27.5	FULL		
Trib. to South Fork Great Miami R. (5.27) aka New Richland Tributary (14-806)								
EWH Aquatic Life Use (Existing)								
0.50[H] – CR 97	02	52	NA	E	65.0	FULL		
Van Horn Creek (14-804)								
WWH Aquatic Life Use (Existing)								
0.97[H] – SR 366	03	34*	NA	F*	60.5	NON	Habitat Alt.	Channelization

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
HUC 05080001 02 *Muchinippi Creek*								
Muchinippi Creek (14-700)								
WWH Aquatic Life Use (Existing)								
12.98[H] – SR 196	02	42	NA	MG[ns]	37.0	FULL		
12.50[H] – US 30	02	36[ns]	NA	MG[ns]	32.0	FULL		
7.40[W] – CR 87	04	48	8.6	50	76.5	FULL		
4.76[W] – Myers Rd.	04	45	8.2	MG[ns]	43.0	FULL		
2.37[W] -SR 274 (sluggish, deep)	04	36[ns]	6.6*	12*	47.0	NON	Alt., Habitat Alt., Silt	Impoundment (log jams), Channelization, Livestock
Willow Creek (14-706)								
WWH Aquatic Life Use (Unverified) / WWH (Recommended)								
3.70[H] – Wrestle Creek Rd.	01	36[ns]	NA	F*	37.0	PARTIAL	Habitat Alt.	Channelization
0.44[H] – Idle Rd.	01	38[ns]	NA	F*	37.5	PARTIAL	Habitat Alt.	Channelization
Little Muchinippi Creek (14-703)								
WWH Aquatic Life Use (Unverified) / WWH (Recommended)								
6.05[H] – Wones Rd.	03	40	NA	F*	41.0	PARTIAL	Habitat Alt.	Channelization
0.62[W] – Myers Rd.	03	34*	7.7*	36	56.0	PARTIAL	Nutrients, Habitat Alt.	Ag, Channelization
Jackson Center Creek (14-705)								
WWH Aquatic Life Use (Unverified) / MWH-C (Recommended)								
2.90[H] – SR 274	03	36	NA	P*	33.5	PARTIAL	Habitat Alt.	Channelization
1.80[H] – Lock 2 Rd. dst. Jackson Center WWTP	03	32	NA	P*	31.0	PARTIAL	Habitat Alt., Silt, Nutrients	Channelization, Ag. Minor municipal WWTP
HUC 05080001 03 *Bokengehalas Creek - Great Miami River*								
Cherokee Mans Run (14-084)								
WWH Aquatic Life Use (Existing)								
7.56[H] – SR 117	01	48	NA	MG[ns]	82.5	FULL		

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
Cherokee Mans Run (continued)								
3.38[H] – US 30	01	48	NA	44	68.0	FULL		
Trib. to Great Miami R. (157.34) (14-001-027)								
Undesignated / MWH-C (Recommended)								
0.07[H] – ust. from SR 235	02	34	NA	LF*	17.5	PARTIAL	Habitat Alt.	Channelization
Rennick Creek (14-001-026)								
Undesignated / WWH (Recommended)								
0.34[H] – SR 235	02	<u>26</u>*	NA	F*	50.0	NON	Habitat Alt.	Channelization
Brandywine Creek (14-083)								
WWH Aquatic Life Use (Unverified) / WWH (Recommended)								
0.58[H]– Notestine Rd.	06	48	NA	F*	46.5	PARTIAL	Habitat Alt.	Channelization
Rum Creek (14-078)								
WWH Aquatic Life Use (Unverified) / WWH (Recommended)								
8.63[H] – Wildermuth Rd.	03	<u>24</u>*	NA	F*	31.5	NON	Habitat Alt.	Channelization
6.58[H] – Miranda Rd.	03	32*	NA	MG[ns]	41.5	PARTIAL	Habitat Alt.	Channelization (old)
0.79[W] – CR 58	03	45	7.5*	46	59.0	PARTIAL	Silt	Channelization upstream
Bokengehalas Creek (14-076)								
WWH Aquatic Life Use (Existing)								
12.24[H] – CR 13, ust spill site	05	46	NA	VG	68.5	FULL		
7.9[W] – T-31, prior to spill	05	38[ns]	6.3*	--	69.0	(PARTIAL)	Silt, Habitat Alt.	Ag., Channelization
7.9[W] – 1 week after spill	05	32*	<u>5.6</u>*	<u>P</u>*	69.0	NON	Other	Pesticide application
7.9 - 4 weeks after spill	05	--	--	42	--	(FULL)		
7.9 - 7 weeks after spill	05	--	--	48	--	(FULL)		
4.61[W] – CR 209 dst. Blue Jacket Creek	05	47	8.6	42	89.0	FULL		

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
Bokengehalas Creek (continued)								
1.13[W] – Miami St. in DeGraff	05	50	8.8	48	88.5	FULL		
Blue Jacket Creek (14-077)								
WWH Aquatic Life Use (Existing) / CWH Headwaters to Opossum Run (Recommended)								
6.3[H] – T-216, ust Bellefontaine WWTP	04	40	NA	36 #	70.0	FULL		
WWH Aquatic Life Use (Existing) / WWH Opossum Run to mouth (Recommended)								
5.5[H] – CR 11, dst. Bellefontaine WWTP	04	44	NA	36 #	84.5	FULL		
0.72[H] – T-31	04	56	NA	40 #	69.5	FULL		
HUC 05080001 04 *Stony Creek - Great Miami River*								
Stony Creek (14-072)								
WWH Aquatic Life Use (Existing)								
2.45[W] – SR 508	03	51	9.6	52	45.0	FULL		
1.58[W] – T-65A	03	48	7.9[ns]	54	51.5	FULL		
McKees Creek (14-075)								
EWH Aquatic Life Use (Existing) EWH/CWH Recommended								
9.5[H] – Ludlow Rd.	01	50	NA	VG	75.0	FULL		
5.94[H] – T-32	01	46	NA	E	72.0	FULL		
0.52[H] – CR 31	01	48	NA	56	88.5	FULL		
Lee Creek (14-073)								
WWH Aquatic Life Use (Unverified) / CWH Aquatic Life Use (Recommended)								
3.35[H] – Friend Rd.	02	48	NA	E	97.5	FULL		
Graves Creek (14-074)								
WWH Aquatic Life Use (Unverified) / CWH Aquatic Life Use (Recommended)								
0.48[H] – T-295	02	48	NA	G	78.0	FULL		

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
Indian Creek (14-069)								
WWH Aquatic Life Use (Unverified) / WWH (Recommended)								
0.01^{H} – at mouth	04	48	NA	E	88.5	FULL		
Plum Creek (14-063)								
WWH Aquatic Life Use (Unverified) / WWH (Recommended)								
9.00^{H} – Miranda Rd.	05	40	NA	MG^{ns}	53.0	FULL		
5.22^{H} – Fort Loramie-Port Jefferson Rd.	05	38^{ns}	NA	G	62.5	FULL		
0.13^{W} – Canal Feeder Rd.	05	38^{ns}	8.3	36	84.5	FULL		
HUC 05080001 *Headwaters Loramie Creek (-05) and Turtle Creek - Loramie Creek (-06)*								
Loramie Creek (14-600)								
WWH Aquatic Life Use (Existing)								
36.84^{H} – Botkins Rd.	05-01	26*	NA	F*	41.0	NON	Habitat Alt., Nutrients	Channelization, Ag.
34.96^{H} – Lock 2 Rd. dst. Botkins WWTP and WTP	05-01	34*	NA	P*	47.5	NON	Nutrients, TDS, Habitat Alt.	Minor municipal WWTP (Botkins), Channelization
30.42^{W} – Hardin-Wapakoneta Rd., ust. Lake Loramie	05-01	30*	7.1*	32^{ns}	39.5	PARTIAL	Silt, Flow Alt. Habitat Alt.	Impoundment downstream Channelization
22.10^{W} - dst. Lake Loramie dam	05-03	43	9.6	P*	71.5	NON	Flow Alt., Nutrients (biological Indicators)	Impoundment upstream
20.7^{W} – SR 66, dst. Minster and Lake Loramie WWTPs	05-03	39^{ns}	8.0^{ns}	34^{ns}	52.0	FULL		
19.3^{W} – dst. Mile Creek	06-02	38^{ns}	8.5	F*	50.5	PARTIAL	Habitat Alt., Phosphorus	Channelization, Municipal WWTPs, Ag.
18.82^{W} – Schlater Rd.	06-02	34*	7.9^{ns}	20*	33.5	PARTIAL	Habitat Alt., Phosphorus	Channelization, Municipal WWTPs, Ag.

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
Loramie Creek (continued)								
14.80[W] – SR 66 at Newport	06-02	37[ns]	9.0	16*	86.0	PARTIAL	Phosphorus	Municipal WWTPs, Ag.
7.5[W] – Loramie-Washington Rd.	06-04	38[ns]	9.3	34[ns]	57.0	FULL		
1.87[W] – Buxton-Fessler Rd.	06-04	53	10.3	42	92.0	FULL		
Miami and Erie Canal (14-600-002)								
Undesignated / MWH-C Aquatic Life Use (Recommended)								
0.1[H] – dst. Minster WWTP	05-03	28	NA	34	48.5	FULL		
Mile Creek (14-609)								
WWH Aquatic Life Use (Unverified) / MWH-C (Recommended)								
9.80[H] – Guettemoeller Rd.	05-02	34	NA	P*	33.5	PARTIAL	Habitat Alt., Nutrients (biological Indicators)	Channelization, Ag.
8.74[H] – Clune Rd.	05-02	26	NA	LF*	28.0	PARTIAL	Habitat Alt., Nutrients (biological Indicators)	Channelization, Ag.
5.97[W] – Kremer Rd.	05-02	30	8.6	22	26.5	FULL		
0.50[W] – SR 705	05-02	35	7.6	HF	38.5	FULL		
Spring Creek (14-609-001)								
Undesignated / MWH-C (Recommended)								
0.37[H] – Baumier-Brandewie Rd.	05-02	32	NA	HF	38.5	FULL		
Ninemile Creek (14-606)								
MWH Aquatic Life Use (Headwaters to RM 4.2 (Existing)								
6.38[H] – Miller Rd.	06-01	28	NA	26	30.5	FULL		
4.18[H] – Rangeline Rd.	06-01	30	NA	28	60.5	FULL		
WWH Aquatic Life Use RM 4.2 to mouth (Existing)								
0.23[W] – Roeth Rd.	06-01	47	9.0	36	80.5	FULL		

River Mile - Location	12 Digit WAU	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status	Cause(s)	Source(s)
Turtle Creek (14-603)								
WWH Aquatic Life Use (Unverified) / WWH SR 705 (RM 9.54) to mouth (Recommended)								
8.42[H] – Mason Rd.	06-03	22*	NA	F*	53.5	NON	Nutrients, Habitat Alt.	Ag., Channelization
5.66[H] – Russel Rd.	06-03	48	NA	MG[ns]	78.5	FULL		
0.43[W] – Stangle Rd.	06-03	47	8.9	E	72.5	FULL		

a - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
b - An evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to current velocities. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
H - Headwaters: sites draining areas ≤ 20 miles^2.
W - Wadable streams: sites draining areas > 20 miles^2.
B - Boat sites (large waters).
ns - Non-significant departure from the biocriteria (≤4 IBI units or ≤0.5 MIwb units).
* - Significant departure from the biocriteria (>4 IBI units or >0.5 MIwb units).
\# - Macroinvertebrate sample collected in 2009

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

MATERIALS and METHODS

All physical, chemical, 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, 2008a, 2008b), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995; Ohio EPA 2006) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in **Table 1**.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (**Table 4**) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI) score, and a sampling location description.

Habitat Assessment

Physical habitat is evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995; Ohio EPA 2006). 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 habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 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 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 whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores averaging greater than 75 frequently reflect habitat conditions able to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Surface water samples were collected, preserved and delivered in appropriate containers to Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature.

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each location using decontaminated stainless steel scoops and excavated using nitrile gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with teflon® lined lids, placed on ice (to maintain 4^{o}C) in a cooler, and shipped to Ohio EPA Division of Environmental Services. Sediment data is reported on a dry weight basis.

Sediment samples were analyzed for total analyte list inorganics (metals), nutrients, volatile organic compounds, semivolatile organic compounds, PCBs, total petroleum hydrocarbons, and cyanide. Specific chemical parameters tested and results are listed in **Appendix B**. Sediment data were evaluated using Ohio Sediment Reference Values (Ohio EPA 2003), along with guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et.al*. 2000). The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed. Concentrations that fall between the TEC and PEC suggest harmful effects may occur.

Recreation Use Assessment

Water quality criteria for determining attainment of the recreation use are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the quantities of bacteria indicators (*Escherichia coli*) present in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are normally 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). 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 feasible. 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 every type of pathogen. 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 the water has received fecal matter from one or multiple sources. Swimming or other recreation-based contact with water having a high *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.

Streams in the upper Great Miami River watershed are designated as primary contact recreation (PCR) and/or secondary contact recreation (SCR) use in OAC Rule 3745-1-24. Water bodies with a designated recreation use of PCR "...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 support, or potentially support, frequent primary contact recreation activities. Streams designated PCR class B support, or potentially support, occasional primary contact recreation activities. Streams designated as PCR class C support, or potentially support, infrequent primary contact recreation activities. Streams designated as SCR use are rarely used for water-based recreation and all but two in the upper Great Miami River watershed study area are designated PCR.

In addition, some waters that are used heavily for swimming can be designated as bathing waters. The geometric mean criterion for bathing waters is ≤126 colony forming units per 100 ml. There are no bathing water designations in the study area.

The *E. coli* criterion that applies to PCR class A streams is a geometric mean of ≤126 colony forming units (cfu)/100 ml. The *E. coli* criterion that applies to PCR class B streams is a geometric mean of ≤161 cfu/100 ml. The criterion that applies to PCR class C streams is a geometric mean of ≤206 cfu/100 ml. The criterion that applies to SCR streams is ≤1,030 cfu/100 ml. The geometric mean is based on two or more samples and is used as the basis for determining the attainment status of the recreation use (**Table 11**).

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates at sampling locations with larger drainage areas and from the natural habitats at all locations. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, and margin). Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b, 2008b).

Fish Community Assessment
Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b, 2008b).

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 used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, 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 1991; 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, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the 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), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

RESULTS and DISCUSSION

Study Area Description

Upper Great Miami River Watershed

The entire Great Miami River watershed drains a total area of 5371 mi^2 (3946 mi^2 in Ohio). The portion of the watershed encompassed in this study includes the upper catchment from Indian Lake (including streams entering the lake) downstream to Sidney (484 mi^2) as well as the adjacent, Loramie Creek subwatershed (265 mi^2). A separate Loramie Creek sub-watershed study area description is located on **page 55**.

The 2008 upper Great Miami River (GMR) study area included six U.S. Geological Survey 10-digit Hydrologic Unit Code (HUC-10) watersheds and 26 HUC-12 Watershed Assessment Units (WAUs) as presented in **Table 5** and covered portions of Hardin, Auglaize, Mercer, Logan, Shelby, Champaign, and Darke counties (**Figure 1, Figure 9, Figure 11**). An additional site on the GMR mainstem in Sidney (RM 129.99) from the 12 digit Watershed Assessment Unit (WAU) 05080001-07-03 was included as the most downstream sampling location in the study area.

The topography of the upper Great Miami River watershed has been influenced by glaciations which left distinctive landforms and thick deposits of silt, sand, and gravel. This portion of the watershed lies entirely within the Eastern Corn Belt Plains (ECBP) ecoregion and is characterized by level to gently sloping land and moderate to low gradient streams. Almost all of the Great Miami River is underlain by a buried valley aquifer composed of highly permeable sands and gravel from past glacial events. The aquifer is the primary source of drinking water for many cities and villages in the watershed. Sidney uses a combination of ground water and surface water. There is a direct hydraulic connection between the ground water and the mainstem.

Within the Eastern Corn Belt Plains ecoregion, the upper GMR basin study area encompasses two[5] distinct sub-ecoregions. The majority is in the 55a, Clayey High Till Plains, while much of the southeastern and extreme southern drainage is within the 55b, Loamy High Till Plains (ftp://ftp.epa.gov/wed/ecoregions/in/ohin_front.pdf).

Streams in the "Loamy, High Lime Till Plains" sub-ecoregion (55b) are often recharged by ground water. Soils in this sub-ecoregion developed from loamy, limy, glacial deposits of Wisconsinan age and typically have better natural drainage than those in the 55a sub-ecoergion. The soils also tend to have less need for sub-surface drainage systems. Habitat (median QHEI = 80) and water quality at headwater sites in this portion of the watershed were largely exceptional with cooler temperatures, stable dissolved oxygen levels, and low concentrations of total suspended solids (TSS), ammonia-N, and total phosphorus.

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[5] A small portion of the 55c, Mad River Interlobate sub-ecoregion overlays the extreme SE corner of the upper basin but no sampling was conducted in this area.

The “Clayey, High Lime Till Plains” sub-ecoregion (55a) is transitional between the 55b and the very low-gradient, poorly drained Maumee Lake Plains (57b) ecoregion to the north. Unlike the 55b, soils are generally poorly drained and require artificial sub-surface drainage systems for agricultural production. Many streams are maintained in a channelized condition without riparian cover; consequently, “exceptional quality fish communities are virtually excluded from the typically turbid, low-gradient streams of the region” (ftp://ftp.epa.gov/wed/ecoregions/in/ohin_front.pdf). However, similar to the 55b, some 55a watersheds in the eastern portion of the upper Great Miami River basin (*e.g.,* Muchinippi Creek, South Fork GMR) benefit from a strong ground water connection (referred to as 55a-GW in this discussion).

Agriculture is the predominant land use within the upper Great Miami River drainage, with cultivated crop and pasture/hay accounting for 70.63% and 7.97% of the total watershed area, respectively. Approximately nine percent (9.18%) of the watershed is developed and 8.87% is forested (**Table 6, Figure 9**). The two large lakes in the watershed are popular state parks and recreational areas; Indian Lake (5104 acres) and Lake Loramie (825 acres) were both originally constructed in the mid 1800s to supply water to the Miami-Erie canal.

The aquatic life use designation in effect for the majority of streams in the upper GMR watershed in 2008 was warmwater habitat (WWH). The GMR mainstem from Quincy dam (RM 143.4) to Pasco-Montra Rd. (RM 134.8) and RM 129.99 were designated exceptional warmwater habitat (EWH) as were the New Richland tributary and McKees Creek. The headwaters of Ninemile Creek to CR 14 (RM 4.2) were designated modified warmwater habitat (MWH) due to channel modification. Recreation use designation for most of the UGMR watershed in 2008 was primary contact recreation (PCR). Exceptions include the Belle Center tributary and Liggit Ditch which were designated secondary contact recreation (SCR). Additionally, the City of Sidney utilizes the main stem and Tawawa Creek (not included in the 2008 study area) as public water supplies.

Communities in the watershed include Russells Point, Lakeview, Belle Center, Huntsville, Waynesfield, Jackson Center, Bellefontaine, Quincy, DeGraff, and Port Jefferson. Additionally, the communities of Botkins, Kettlersville, Fort Loramie, North Star, Yorkshire, Osgood, Anna, Minster, Lockington, Mount Jefferson, and Russia lie in the Loramie Creek subwatershed. There are numerous municipal wastewater treatment plants (WWTPs) in the UGMR study area including 3 major [*i.e.,* > 1 million gallons per day (mgd) discharge] WWTPs in Bellefontaine, Russels Point (Logan Co Indian Lake SSD WWTP), and Minster. Discharge points for these three major facilities and other smaller dischargers are indicated in **Figure 8** and **Figure 10**.

Table 5. The upper Great Miami River watershed survey area broken down by 10 digit Hydrologic Unit Code (HUC) and 12 digit Watershed Assessment Unit (WAU) in 2008.

10-Digit HUC: 05080001-01 Headwaters Great Miami River	
12-digit WAU	Description
05080001-01-01	North Fork Great Miami River
05080001-01-02	South Fork Great Miami River
05080001-01-03	Great Miami River Headwaters to above Cherokee Mans Run [except North and South Fork]
10-Digit HUC: 05080001-02 Muchinippi Creek	
05080001-02-01	Willow Creek
05080001-02-02	Muchinippi Creek Headwaters to Willow Creek
05080001-02-03	Little Muchinippi Creek
05080001-02-04	Muchinippi Creek below Willow Creek to mouth
10-Digit HUC: 05080001-03 Bokengehalas Creek-Great Miami River	
05080001-03-01	Cherokee Mans Run
05080001-03-02	Great Miami River below Cherokee Mans Run to above Muchinippi Creek
05080001-03-03	Rum Creek
05080001-03-04	Blue Jacket Creek
05080001-03-05	Bokengehalas Creek
05080001-03-06	Great Miami R. below Muchinippi Cr to above Bokengehalas Cr [except Rum Cr.]
10-Digit HUC: 05080001-04 Stony Creek-Great Miami River	
05080001-04-01	McKees Creek
05080001-04-02	Lee Creek
05080001-04-03	Stony Creek
05080001-04-04	Indian Creek
05080001-04-05	Plum Creek
05080001-04-06	Great Miami R. below Bokengehalas Cr to above Plum Cr [except Stony and Indian Cr]
10-Digit HUC: 05080001-05 Headwaters Loramie Creek	
05080001-05-01	Loramie Creek headwaters to SR 29 (Upstream Lake Loramie)
05080001-05-02	Mile Creek
05080001-05-03	Loramie Creek below SR 29 to above Mile Creek
10-Digit HUC: 05080001-06 Turtle Creek-Loramie Creek	
05080001-06-01	Ninemile Creek
05080001-06-02	Loramie Creek below Mile Cr to above Ninemile Cr
05080001-06-03	Turtle Creek
05080001-06-04	Loramie Creek below Ninemile Cr to mouth [except Turtle Cr]

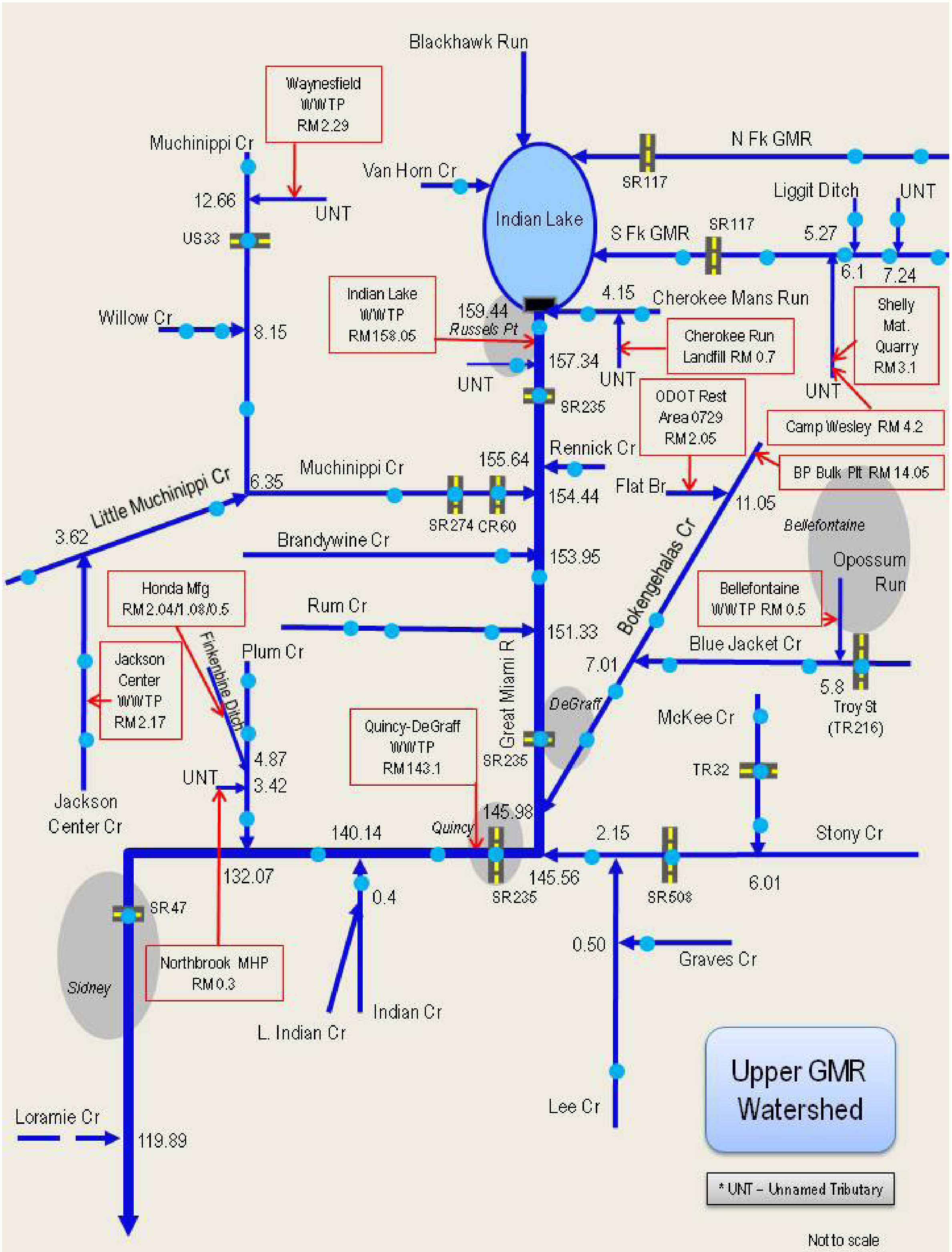


Figure 8. Schematic representation of the upper Great Miami River watershed (excluding the Loramie Creek subwatershed). River miles are indicated for stream confluences and WWTP discharges. Water chemistry sampling locations are indicated by blue circles.

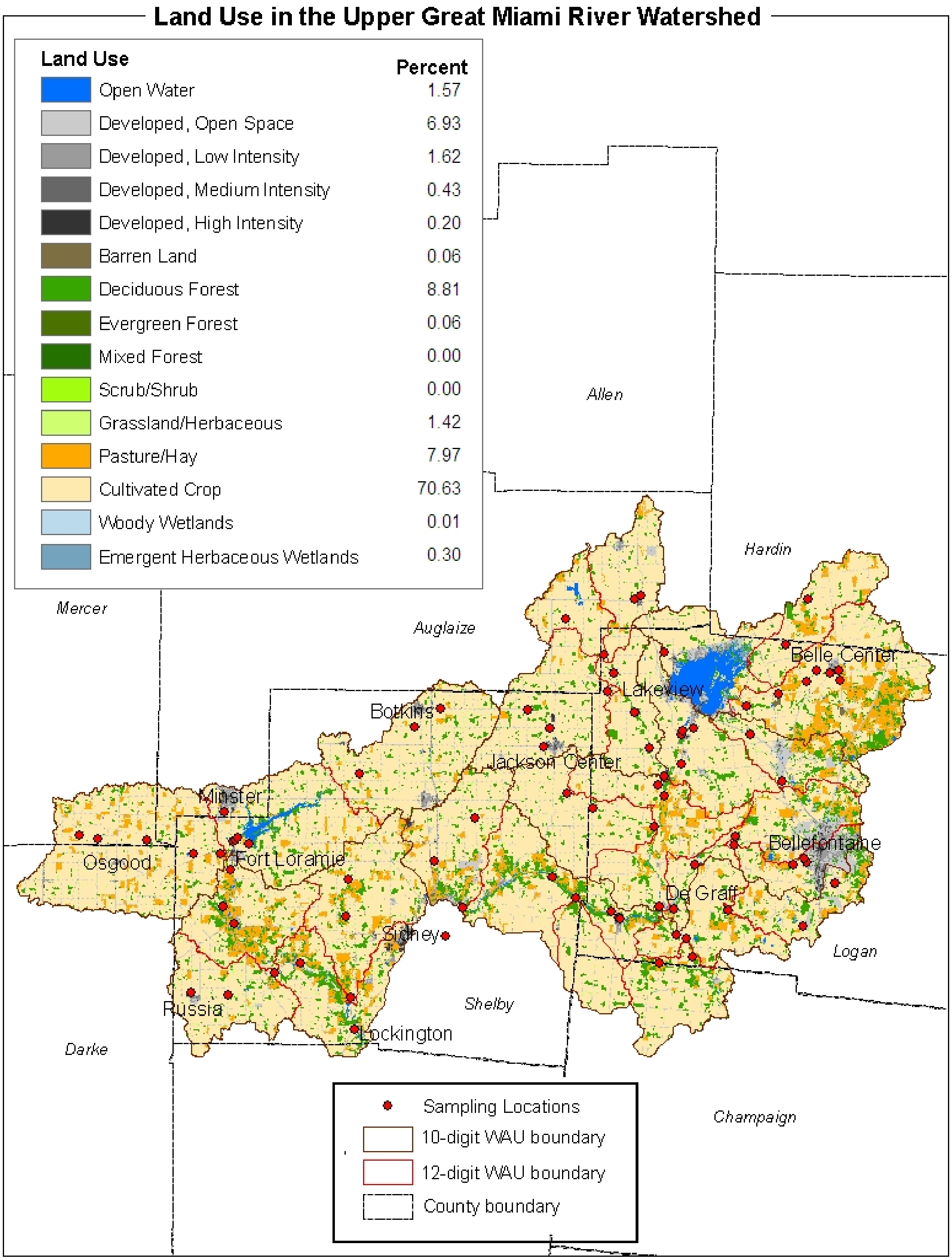
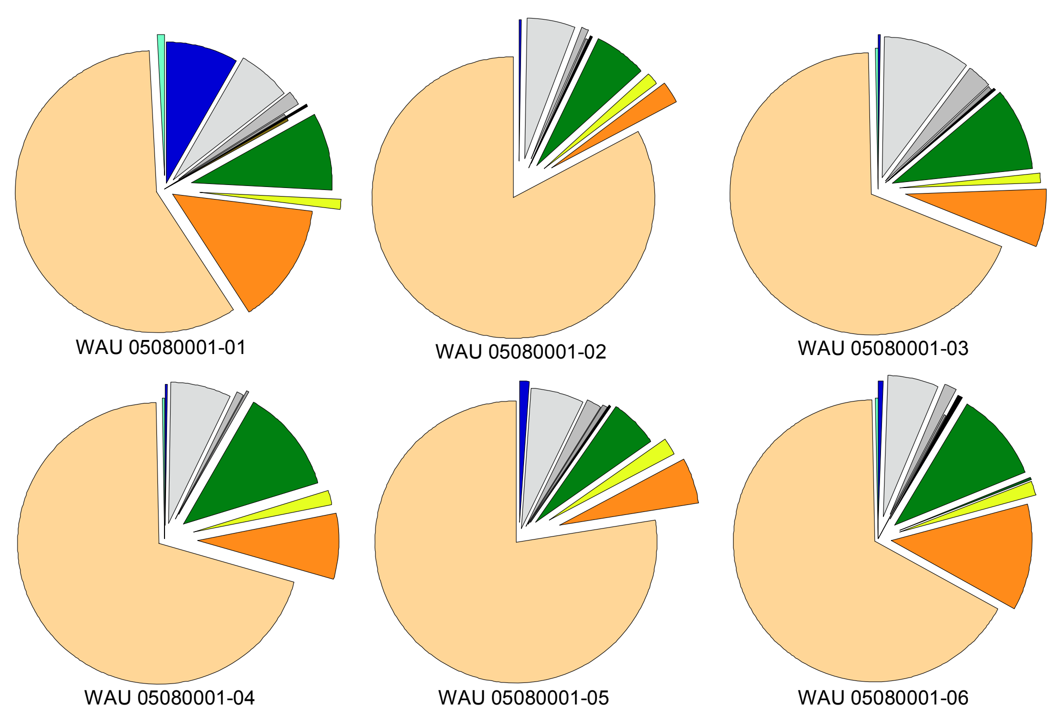


Figure 9. Land use in the upper Great Miami River Watershed (NLCD 2001).

Table 6. Percent land use in the upper Great Miami River watershed (NLCD 2001).

Land Use	Watershed Assessment Unit (WAU 05080001-_ _)					
	01 UGMR Hdwtrs	02 Muchinippi Cr.	03 Bokenge-halas Cr.	04 Stony Cr.	05 Upper Loramie	06 Lower Loramie
Open Water	8.21	0.38	0.28	0.39	1.09	0.47
Developed, Open Space	6.31	5.56	9.99	6.74	6.12	5.84
Developed, Low Intensity	1.65	0.78	2.70	1.00	1.76	1.42
Developed, Medium Intensity	0.35	0.26	0.66	0.21	0.56	0.45
Developed, High Intensity	0.11	0.15	0.28	0.08	0.21	0.34
Barren Land	0.25	0.03	0.05	0.04	0.00	0.04
Deciduous Forest	8.94	6.12	9.38	11.80	5.56	10.40
Evergreen Forest	0.08	0.01	0.04	0.12	0.00	0.10
Mixed Forest	0.00	0.00	0.00	0.00	0.00	0.00
Scrub/Shrub	0.00	0.00	0.00	0.00	0.00	0.00
Grassland/Herbaceous	0.92	1.30	0.93	1.52	1.98	1.74
Pasture/Hay	14.04	2.60	6.92	7.41	5.22	12.32
Cultivated Crop	58.20	82.72	68.52	70.37	77.38	66.62
Woody Wetlands	0.04	0.01	0.01	0.00	0.01	0.00
Emergent Herbaceous Wetlands	0.90	0.07	0.25	0.32	0.11	0.26



Loramie Creek Watershed

Entering the Great Miami River at RM 119.89 south of Lockington, Loramie Creek drains 265 mi^2 (**Figure 10**) and includes two 10-digit HUCs (05080001-05 and 05080001-06) and seven 12-digit WAUs (**Table 5**). Similar to the rest of the upper Great Miami River (UGMR) watershed, the majority of land is in agriculture with cultivated crop and pasture/hay accounting for 72.61% and 8.37%, respectively, of the total watershed area (**Figure 11; Table 6**). Approximately eight percent (8.39%) of the watershed is developed and 7.75% is forested. The Lockington dam (Loramie Creek RM 2.11) is an earthen embankment with two concrete conduits in southern Shelby County near the Village of Lockington. Constructed in 1922 and owned by the Miami Conservancy District (MCD), the dam (6,400 feet long and 69 feet high) is used for flood control. Lake Loramie (825 acres) was originally constructed in 1844 as a storage supply reservoir for the Miami-Erie Canal system and is a popular boating and fishing destination near Fort Loramie.

Tributaries assessed in the watershed include the Miami-Erie Canal, Mile Creek, Spring Creek, Ninemile Creek, and Turtle Creek. The aquatic life use designation in effect for Loramie Creek, Mile Creek, and Turtle Creek in 2008 was WWH. The headwaters of Ninemile Creek to CR 14 (RM 4.2) were designated MWH due to channel modification while Spring Creek and the Miami-Erie Canal were undesignated. While most streams in the watershed have a recreation use designation of PCR Class B, Loramie Creek from RM 30.42 to the mouth has a PCR Class A designation.

Communities in the watershed include Botkins, Kettlersville, Fort Loramie, North Star, Yorkshire, Osgood, Anna, Minster, Lockington, Mount Jefferson, and Russia. While the village of Minster is the only major discharger (> 1.0 MGD), there are numerous smaller municipal and industrial facilities discharging to streams in the Loramie Creek watershed (**Figure 10)**.

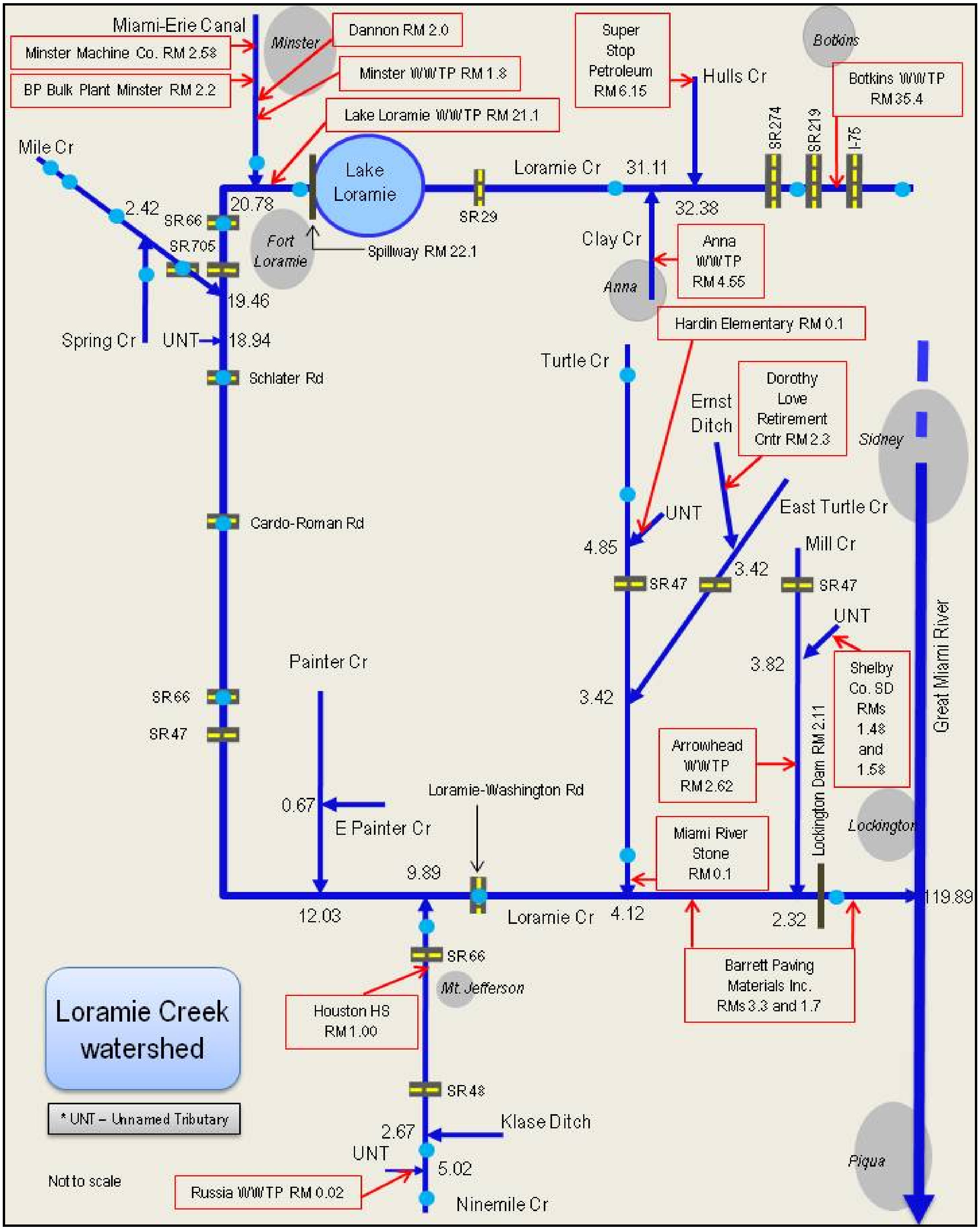


Figure 10. Schematic representation of the Loramie Creek watershed (HUCs 05080001-05 and 06). River miles are indicated for stream confluences and WWTP discharges. Water chemistry sampling locations are indicated by blue circles.

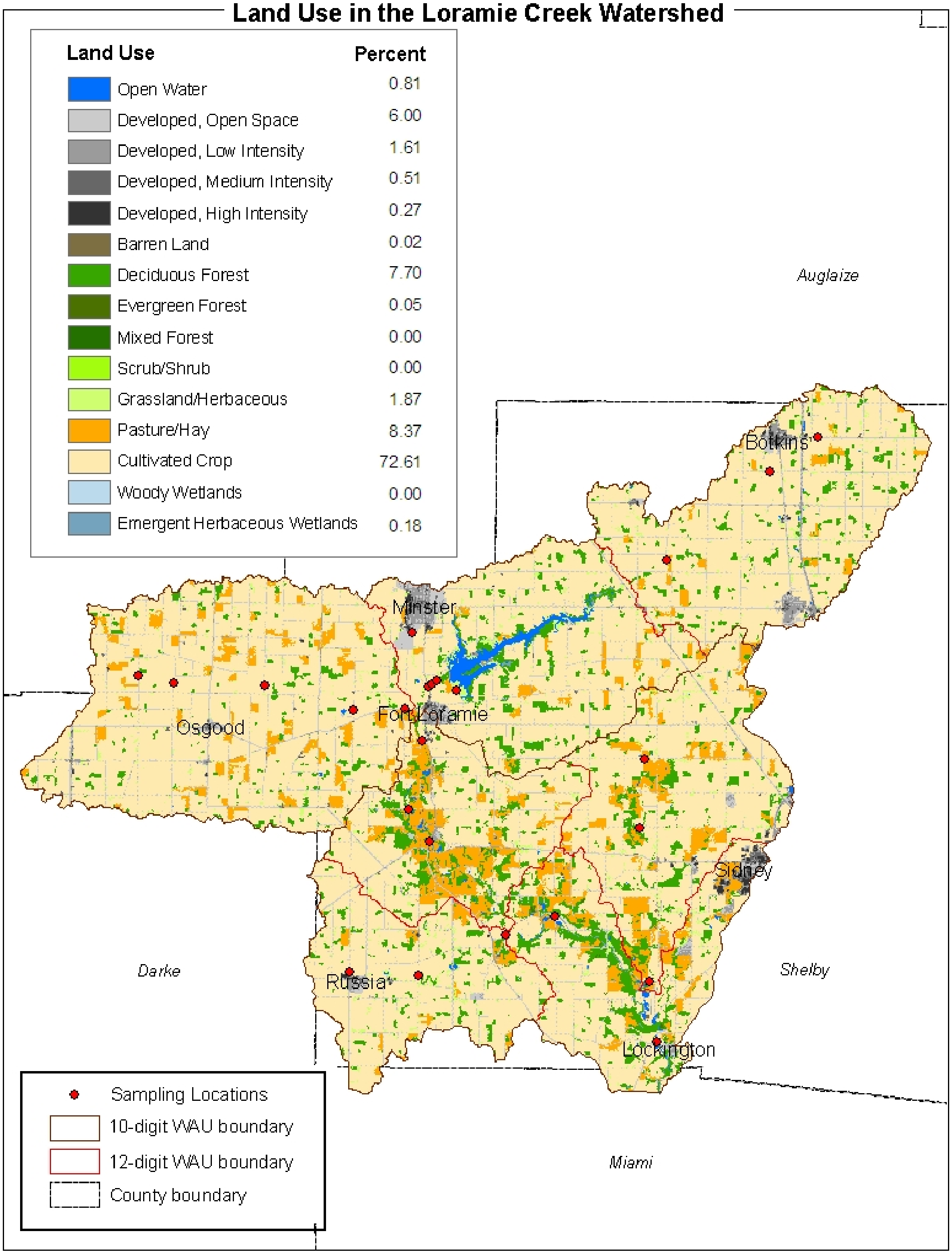


Figure 11. Land Use in the Loramie Creek Watershed (HUCs 05080001-05 and 06) (NLCD 2001).

Point Source Dischargers – NPDES

Upper Great Miami River Watershed

The following discharge list, arranged by 10 digit HUC number, includes summaries and loadings information for selected National Pollutant Discharge Elimination System (NPDES) regulated dischargers in the upper Great Miami River watershed. The receiving stream and its pathway to the Great Miami River (where applicable) is included in *italics* (listed upstream to downstream) following the name of the facility or entity. An alphabetical list of facilities including permit number, discharge location and outfall coordinates are found in **Table 7**.

In addition to the loadings summaries from the discharges, NPDES violations were evaluated using SWIMS (Surface Water Information Management System), primarily from 2003 through a portion of 2008. SWIMS Violations fall within three categories, *Numeric Limit, Reporting Frequency* and *Code* and are defined as follows:

- A **numeric violation** is a violation of a permit limit.
- A **frequency violation** is a failure to monitor the correct number of times for the month.
- **A code violation** is the use of a wrong code or an inappropriate code.

NPDES dischargers within each 10 digit HUC are listed below.

HUC 05080001 01 (Headwaters Great Miami River)

No Permitted Discharges.

HUC 05080001-02 (Muchinippi Creek)

Waynesfield Water Treatment Plant - Tributary to Munchinippi Creek (13.1) RM 3.05

The Village of Waynesfield WTP is located in Auglaize County at Park Drive, Waynesfield. The facility was originally constructed in 1992 and has had no upgrades. Wastewater from treatment of the drinking water passes through settling tanks, through two sand filters and discharges through an 18" tile.

NPDES violations were evaluated from 2003 through a portion of 2008. During the nearly six year period, four *Numeric* violations of TSS and iron occurred in 2005. An approximate five *Frequency* violations for flow rate and iron were documented in 2004.

Table 7. Alphabetical list of upper GMR basin facilities regulated by the National Pollutant Discharge elimination system (NPDES) permit.

Permit #	Type	Facility	Receiving Stream	RM	Lat	Long
1PB00004001	Minor	Anna WWTP	Clay Creek RM 4.55 (aka, Applegate Ditch)	4.55	40.398100	-84.183570
1PG00099001	Minor	Arrowhead WWTP	Mill Creek	2.62	40.246960	-84.234390
1IJ00054001	Minor	Barrett Paving Materials Inc Jones Site	Loramie Creek	1.7	40.206570	-84.243500
1IJ00053001	Minor	Barrett Paving Materials Inc Pence Site	Loramie Creek	3.3	40.224020	-84.250600
1PD00000001	**Major**	**Bellefontaine WWTP**	**Opossum Run [Trib. to BJ Cr. (5.80)]**	**0.5**	**40.353160**	**-83.777300**
1PB00007001	Minor	Botkins WWTP	Loramie Creek	35.4	40.453890	-84.179210
1IN00253001	Minor	BP Bellefontaine Bulk Plant	Bokengehalas Creek	14.05	40.373950	-83.778750
2IN00173001	Minor	BP Amoco Oil Corp Bulk Plant Minster	Miami Erie Canal	2.2	40.388160	-84.383540
1PR00100	Minor	Camp Wesley	Trib. to S. Fk. GMR (5.27)	Nr. 4.2	40.43648	-83.72387
1II00125001-003	Minor	Cherokee Run Landfill (3 upr GMR outfalls)	Trib. to Cherokee Run (4.15)	0.7	40.41757	-83.7231
1IN00058-001	Minor	Dana Glacier Daido America LLC	Nivens Ditch to McKees Cr.	--	40.341111	-83.758611
1IN00058-002	Minor	Dana Glacier Daido America LLC	Storm sewer to Bluejacket Cr. (6.85)	Nr. 0.7	40.340770	-83.758880
2IH00004001	Minor	Dannon Company Inc	Miami Erie Canal	2	40.385590	-84.383400
1PT00039001	Minor	Dorothy Love Retirement Center	Ernst Ditch	2.3	40.318056	-84.207222
1PT00083	Minor	Fairhaven WWTP	Mill Branch	2.4	40.248610	84.200278
1PT00068001	Minor	Hardin Elementary School	Trib. to Turtle Creek (5.85)	0.1	40.291130	-84.245180
1PG00101	Minor	Hickory Dell Estates WWTP	Trib. to Brush Creek (RM 0.28)	--	40.240000	-84.166111
1IN00143001, 006	Minor	Honda of America Mfg Inc (Anna plant)	Finkenbine Ditch [Hdwtrs Plum Cr. trib. (4.87)]	0.5	40.37861	-84.185000
1PT00104001	Minor	Houston HS	Ninemile Creek	1.0	40.246280	-84.334900
1PK00002001	**Major**	**Indian Lake WPCD**	**Great Miami River**	**158.05**	**40.456130**	**-83.895450**
1PB00018001	Minor	Jackson Center WWTP	Jackson Center Creek	2.3	40.447460	-84.047050
1PH00028001	Minor	Lake Loramie SSD	Loramie Creek	21.1	40.361980	-84.36907
1IJ00046001	Minor	Miami River Stone Co - Lehman Rd	Turtle Creek	0.1	40.23311	-84.2527
2GN00007001	Minor	Minster Machine Co	Miami Erie Canal	2.58	40.39362	-84.3835
2PB00036001	**Major**	**Minster WWTP**	**Miami Erie Canal**	**1.8**	**40.382070**	**-84.383710**
1PV00115001	Minor	Northbrook MHP	Trib. to Plum Creek (3.42)	0.3	40.319500	-84.161100
1PP00021001	Minor	ODOT Rest Area 0729	Flat Branch	2.05	40.40368	-83.7895
1PB00036001	Minor	Quincy-DeGraff STP	Great Miami River	143.1	40.303820	-83.970680
1PS00012001	Minor	Russia WWTP	Trib. to Ninemile Creek (5.02)	0.02	40.236920	-84.391830
1PG00021001	Minor	Shelby Co Sew Dist Millcreek Subdiv WWTP	Trib. to Mill Creek (3.82)	1.58	40.268889	-84.206111
1PG00021002	Minor	Shelby Co Sew Dist Millcreek Subdiv WWTP	Trib. to Mill Creek (3.82)	1.48	40.268333	-84.206667
1IJ00019001	Minor	Shelly Materials Inc Belle Center Quarry	Trib. to S. Fk. GMR (5.27)	3.1	40.47371	-83.7394
1PZ00007001	Minor	Super Stop Petroleum Anna OH	Hulls Creek	6.15	40.39529	-84.1562
2PB00022	Minor	Waynesfield WWTP	Trib. to Muchinippi Creek (12.66)	2.29	40.588430	-83.970850
2IY00003	Minor	Waynesfield WTP	Trib. to Muchinippi Creek (13.1)	3.05	40.588333	-83.969444

Waynesfield WWTP – Tributary to Muchinippi Creek (12.66) RM 2.29

The Village of Waynesfield WWTP is located in Auglaize County on Waynesfield Rd./CR 261. The facility was constructed in 1969 and upgraded in 2004 with ultraviolet (UV) disinfection, post aeration and a flow meter. Current design flow is 0.123 MGD. Two inspections by Ohio EPA in 2009 noted the receiving stream was free of solids, odors or color at the outfall and the facility was in generally satisfactory condition. System wide sanitary sewer overflows (SSOs) occur with this facility.

NPDES violations were evaluated from 2004 through a portion of 2009. During the nearly six year period, 162 *Numeric* violations were reported, primarily for $cBOD_5$, TSS, and ammonia-N, during the spring months of April, May, and June. *Frequency* violations were evaluated from 2003 until 2008 and, of the 222 incidents recorded, ninety percent (90%) occurred before 2006. This drop in "violations" resulted almost entirely from a change in reporting procedure and not significant differences in treatment performance or effluent quality.

Jackson Center WWTP - Jackson Center Creek RM 2.3

Jackson Center WWTP is located in Shelby County at 500 Jerry Drive and serves the Village of Jackson Center (est. population= 767) and Plastipak Industries. The facility was built in 1971 and upgraded in 1999 to a design capacity of 0.37 MGD. The treatment works consists of grit removal, comminution, influent pumping, bar screen and tertiary lagoon, oxidation ditch, secondary clarification, chlorination and dechlorination.

The Village of Jackson Center's existing sanitary sewer lines were installed in the 1940s using vitrified clay. The sewers have deteriorated in many locations with failed and leaking joints, structural damage, and cracked pipes. In 2009, the Village received federal stimulus money to slip line a total of 11,989 linear feet of vitrified clay pipe with cured-in-place-piping within their wastewater collection system. This project was completed in the summer of 2010 In addition to 10 manhole covers that were lined to prevent storm water intrusion.

Three lift stations are located in the collection system. The estimated I/I of the facility is 48,000gpd. Since 2004, sludge has been hauled to another facility for disposal.

On March 9, 2005, the Village was issued a Permit to Install (PTI) for a new sludge handling facility consisting of a belt filter press, concrete storage pad, screen auger and two sludge transfer pumps. More recently, the WWTP was issued a PTI for a spiral screw mechanical screen on February 5, 2010.

NPDES violations were evaluated from 2003 through a portion of 2008. *Numeric* violations for copper numbered 61 and were reported for all years, with an increase in frequency toward 2008 (38% of violations occurred from 2007 until 2008). The Village believes a copper sulfate solution sold locally and used to control root growth in sewer lines was the source of elevated copper. After the product was pulled from a local hardware store, the violations declined in 2008 and the trend continued into 2009.

Frequency violations numbered 85 for the same 2003-08 time period, of which 62% were sludge related. Most water violations were associated with pH and nutrients.

Recently, Jackson Center conducted a Water Effect Ratio study of the wastewater treatment plant effluent and receiving stream to address NPDES effluent copper limits. Based on the study results, the Village requested and received a modification to their NPDES permit for an increase in 4x their final effluent limit for copper. Ohio EPA has public noticed their draft NPDES permit with a proposed effective date of March 1, 2011 for the increased copper limit.

HUC 05080001 03 (Bokengehalas Creek-Great Miami River)

Logan Co Indian Lake Sanitary Sewer District (SSD) WWTP - GMR RM 158.14

The Logan County Indian Lake SSD WWTP is located at 1015 Orchard Island Rd. South, in Russells Point. The WWTP serves a population of 14,000 with an average daily design flow of 4.6 MGD. The treatment system consists of an influent pump station, comminutor, bar screen, pre-aeration, grit removal, primary clarifiers, activated sludge aeration, secondary clarification, chlorine contact tank, dechlorination, and step aeration. Prior to installation of flow equalization (EQ) in 2009, flows above 4.6 MGD were bypassed around secondary treatment. Accumulated biosolids associated with the treatment processes are dried and disposed of in an approved landfill.

The Indian Lake WWTP experiences hydraulic surges during storm events. Flows above 4.6 MGD were bypassed around the second treatment system, an action necessary to save secondary solids. These bypasses are in violation of Part III, Item 11, “Unauthorized Discharges” of the sewer districts NPDES permit. As a result, on March 9, 2009 the NPDES permit was modified to include a compliance schedule for elimination of these unauthorized bypasses.

The SSD permit schedule is set-up in two phases. Phase one is designed to eliminate SSOs and direct all flows to the facility. Phase two involves a *No Feasible Alternatives* study to eliminate secondary treatment system bypassing. The phase 1 projects include: new force main and lift station in the slough area, new influent fine screens, conversion of the primary clarifiers to equalization, addition of 1.55 million gallons in three equalization tanks, new UV disinfection, conversion of the anaerobic digesters to aerobic digesters, a new belt press, and the addition of a septage receiving station. Phase 1 projects are scheduled for completion in early 2010 and, when finished, will reduce the need to bypass the secondary treatment system. Phase two planning will involve an evaluation of treatment systems needed to provide complete treatment through the secondary system for all flows entering the treatment plant. A *No Feasible*

Alternatives study will be required as part of any phase two projects that include a secondary bypass. Phase two projects are scheduled for completion in July, 2016.

The WWTP collection system includes 28 lift stations with generator and bypass capabilities and over 300 Grinder pumps. The pumps require constant upkeep and are attended by five maintenance personnel. An automated alarm for system failures stopped functioning in 2008 and is scheduled for replacement. In the meantime, WWTP personnel monitor the system for failures.

In 2008, the USEPA assessed a civil penalty for violations of the Clean Water Act for multiple failures relating to their NPDES permit. Specifically the USEPA cited the district for failure to comply with the Code of Federal Regulations Part 503 sludge disposal rules with regard to documentation of pathogen reduction, vector attraction, and sludge application at agronomic rates. The sewer district has updated their sludge documentation and is currently in compliance with the 503 requirements.

NPDES violations were evaluated from 2003 through a portion of 2008. Over the nearly six year evaluation period, 58 *Numeric Limit* violations were reported for suspended solids (predominately), chlorine and ammonia-N**.** Violations were recorded in all years however, 53% occurred in 2003 and 2008, primarily during September, July and May. No violations were reported in November or December for any year.

Reporting Frequency violations numbered 65 and were recorded from numerous reporting locations (*i.e.,* 001, 581, and 602) in the treatment system. Nearly half were for sludge while the remaining primarily involved fecal coliform, $cBOD_5$, TSS and nutrients; fifty-six percent (56%) of these violations were from outfall 001.

Toxicity testing (*i.e.,* acute bioassays*)* of outfall 001 was conducted in 1999, 2004, 2005 and 2008 and evaluated effluent, upstream, and mixing zone waters. Testing was carried out by Ohio EPA personnel and sample collections were generally unannounced. Acute toxicity was limited to one *C.dubia* test in March of 1999. However, these tests do not address the possibility of chronic toxicity.

Logan Co Indian Lake SSD WWTP Loadings Trends
Third quarter median and peak percentile flows are graphically inconsistent (**Figure 12**) due in part to the absence of EQ, reliance on manual controls, inconsistent inflows related to operating grinder pumps, pump stations, seasonal inhabitants and wet-weather contributions. Percentile variance for ammonia-N and phosphorus displayed no obvious trends, demonstrating difficulty in obtaining consistent flow and constituent concentration. High flows such as seen in 2003 can wash out sludge blankets raising TSS loads and the bacteria needed for nitrification of ammonia-N raising nutrient loads.

Cherokee Run Landfill WWTP – Trib. to Cherokee Run (RM 4.15)

1II00125 **001**, RM 0.7. Final effluent discharge pipe from sedimentation pond located on the north side of the facility. Lat: 40.417570; Long: -83.723056

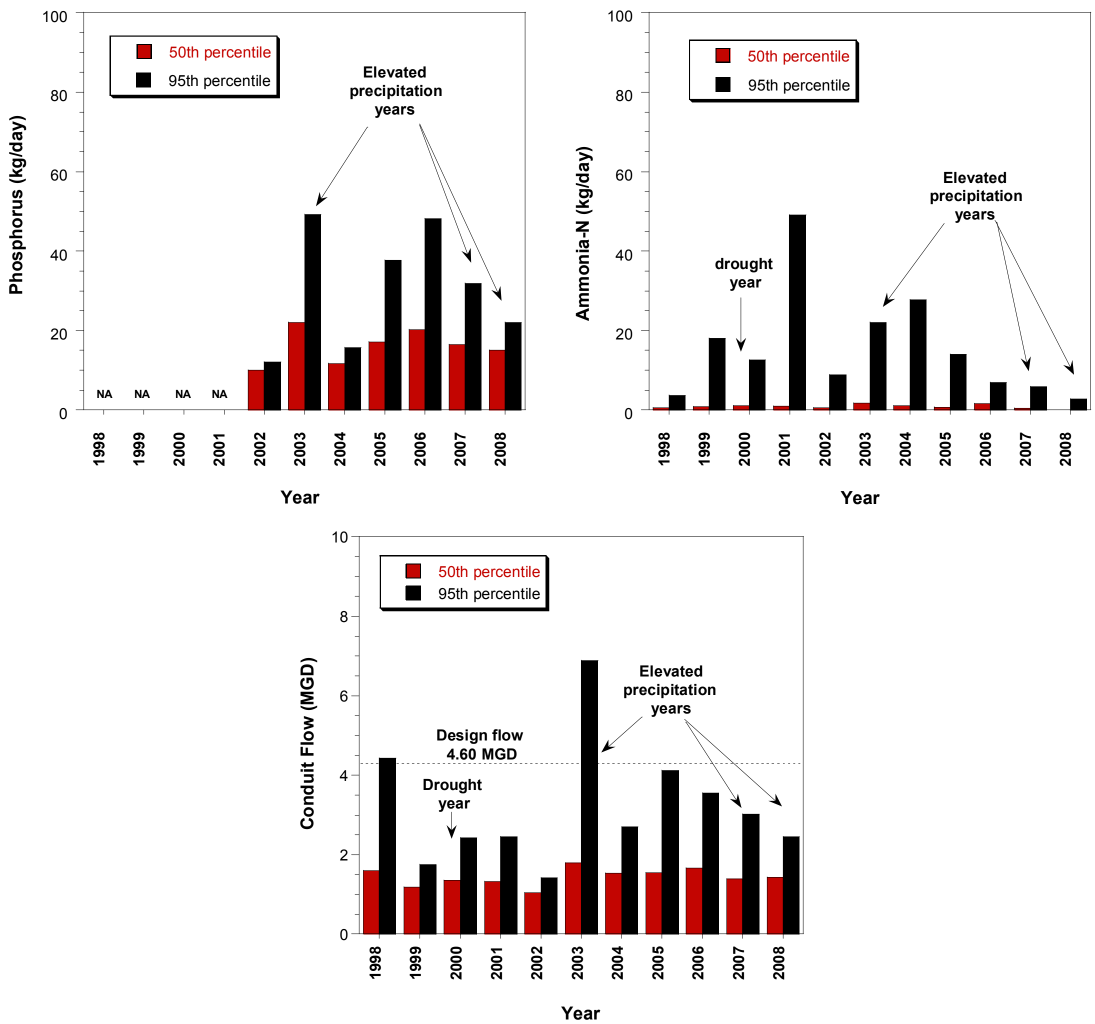


Figure 12. Annual Third-quarter loadings (kg/day) of conduit flow, phosphorus, and ammonia-N at the Logan Co Indian Lake SSD WWTP in the upper Great Miami River study area, 2008.

1II00125 **002**. Final effluent discharge pipe from sedimentation pond located on the west side of the facility. Lat: 40.411860; Long: -83.724470

1II00125 **003**. Final effluent discharge pipe from sedimentation pond located on the south side of the facility. Lat: 40.409740; Long: -83.71977

1II00125 **004**. Discharge located outside the upper GMR watershed.

The Cherokee Run Landfill is located at 2946 State Route 68 North, near Bellefontaine, in Logan County. The solid waste disposal facility and performs bio-remediation of contaminated soils. The treatment unit for each outfall consists of a sediment basin and outfall structures designed for maximum sediment retention and flow control.

Numeric Limit violations were evaluated from 2003 to a portion of 2008. Over the nearly six year period, 125 violations (predominately for TSS) were reported, mostly from outfalls 003, 001 and 002, respectively. Nearly half the violations occurred between 2006 and 2008 and were reported about evenly during each month. Buildup of sediment in the ponds and sampling technique has been stated as the reasons for the violations.

A total of 1,488 *Frequency* violations occurred primarily in 2003 and 2004 for flow rate and color. Daily monitoring was required for both parameters prior to a permit renewal in 2007 and contributed to the large numbers. All four outfalls were under-reported.

Bellefontaine WWTP - Opossum Run (aka, Blue Jacket Cr. Trib @ 5.80) RM 0.5

The Bellefontaine WWTP is located in Logan County at 610 South Troy Rd. In 1985 the system was upgraded to meet secondary treatment standards and designed to treat 3.5 MGD. Expansion to the current design flow of 4.5 MGD occurred in 2010. Following the 2008 survey, treatment plant flows averaged 2.87 MGD between January 2009 and March 2010, with a maximum flow of 6.11 MGD. Treatment works consist of bar screen, grit removal, scum removal, two oxidation ditches, secondary clarification, chlorination and dechlorination. There are 20 separate sanitary lift stations in the collection system and four industrial users. Accumulated biosolids are field applied on approximately 700 acres of farmland surrounding the city. Efforts to minimize I/I are addressed through a series of maintenance projects including; camera work, manhole rehabilitation and projected sewer lining.

In the spring of 2008, NPDES violations at Bellefontaine resulted from excessive rain (seven inches in March) and snowmelt. Later, in June of 2008, a three inch (3") storm event created overflowing manholes on Troy Rd. prior to the wastewater facility and overflowing oxidation ditches and an influent channel onsite. This untreated sewage migrated through the property to storm water basins and fields to Blue Jacket Creek. When the facility returned to below 10.5 MGD it was operating correctly. Also during 2008, a WWTP flow study, I/I maintenance work, and an Ohio EPA Compliance Evaluation Inspection were completed. As part of the Inspection follow-up, a detailed account of maintenance activity was produced by the city in a separate report. In addition, the Troy Rd. overflow has been addressed by a treatment plant head works upgrade and should be completed in 2011.

On October 15, 2009 Permit to Install #710010 was issued to the City of Bellefontaine for a treatment system expansion. The upgrade will include the addition of fine screens, a new secondary effluent channel, one new secondary clarifier, three new sludge pumps, new UV disinfection, and a new effluent flow metering structure. The new design flow will be 4.5 MGD, with a peak design of 15.75 MGD. Construction was initiated in January, 2010. The upgrade is schedule for completion in January, 2011.

Limit violations were evaluated from 2003 through a portion of 2008. Twenty two violations, primarily for $cBOD_5$, TSS and ammonia-N, were reported and most occurred from 2004 until 2007.

Acute bioassay toxicity tests of the Bellefontaine WWTP 001 effluent, mixing zone, and upstream waters were conducted by Ohio EPA in 2004 and 2009. None of the tests had toxic endpoints, although the 2009 test had 10% mortality in the composite effluent. These tests do not address the possibility of chronic toxicity and are generally conducted as unannounced sampling events.

Bellefontaine WWTP Loadings Trends

As with many facilities in the study area, the high precipitation year of 2003 graphically displayed the I/I issues noted for the aging collection systems. However, outside of the extreme precipitation event, 3rd quarter percentile flow variance remained fairly steady over the period of record with the predictability of a newer facility (**Figure 13**).

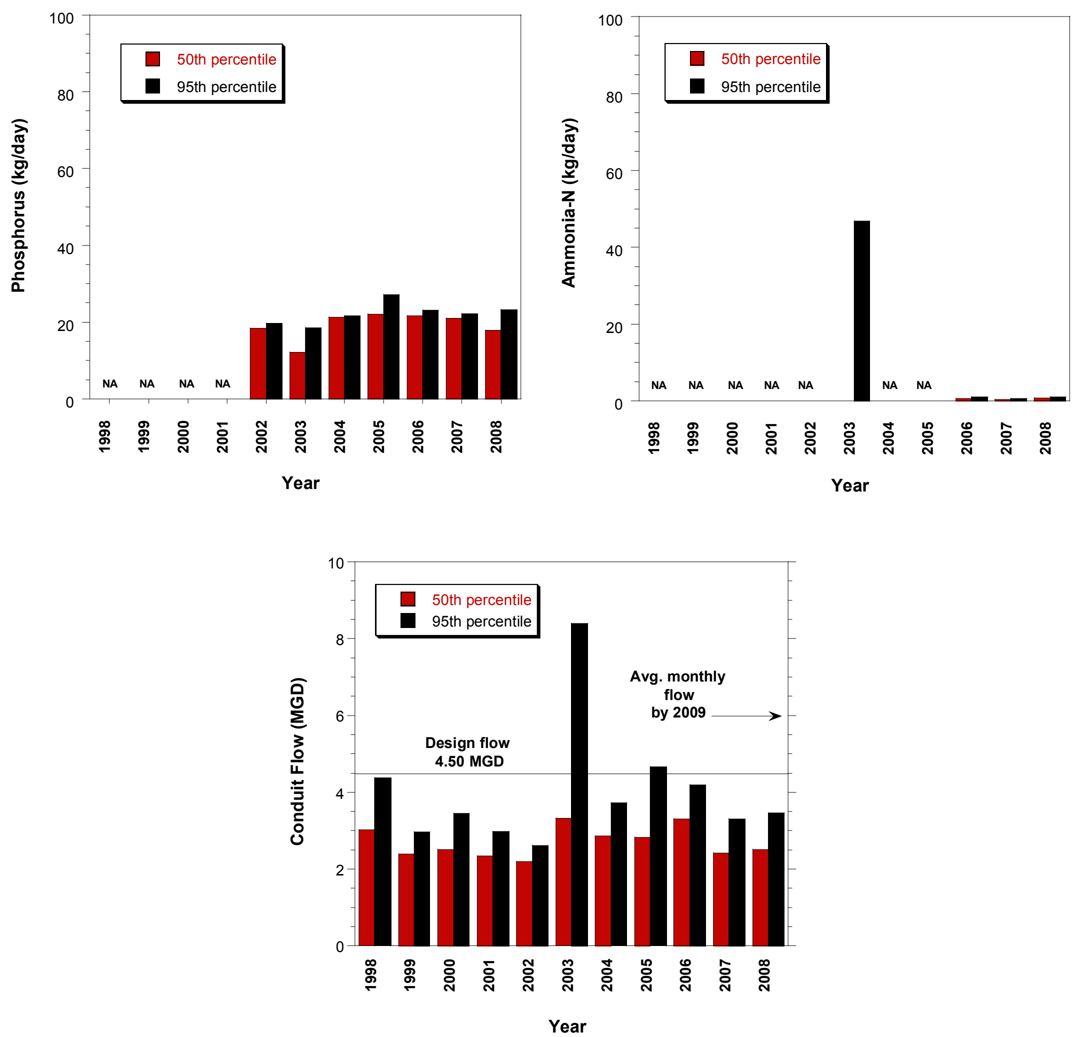


Figure 13. Annual Third-quarter loadings trends (kg/day) for ammonia-N, phosphorus, and conduit flow (mgd) at the Bellefontaine WWTP in the upper Great Miami River study area, 2008.

Percentile variance lessened in predictability from 2005 until 2008 where 2007 showed more uniform flow after the installation of a flow equalization basin. The median percentile remained well under design for the duration of the record indicative of a newer facility with capacity and EQ leveling of incoming flow.

Daido Metal WWTP (aka, Glacier Vandervell, Bellefontaine) –
Storm Sewer to Blue Jacket Creek (6.85) nr. RM 0.7 (Permit #1IN00058-002)
Note: Discharge eliminated June 2009

Daido Metal is located in Logan County at 1215 Greenwood St, in Bellefontaine and manufactured bimetal strip and plated engine bearings. The facility produced a copper and lead powder that was sintered onto a metal strip and rolled to form a bimetal strip. All production was discontinued by June of 2009 and the company will now operate as a distribution facility only. Their NPDES discharge permit was for non-contact cooling water and industrial storm water runoff.

Limit violations were evaluated from 2003 to a portion of 2008. For the nearly six years of data, 12 violations of pH were reported. *Frequency* violations were evaluated from 2003 until 2008 during which, 135 violations for flow rate and pH were reported.

BP Bellefontaine Bulk Plant WWTP - Bokengehalas Creek RM 14.05

The BP Bulk Plant is located in Logan County at 1150 City Rd. 130 in Bellefontaine. The facility is a small, unmanned bulk oil terminal that receives refined petroleum products by transport truck from a BP owned terminal. Unleaded, high sulfur and kerosene fuels are stored in above ground tanks and distributed to consumers by smaller tank trucks. Treatment consists of oil and water separation. All drains capturing spilled material go into an oil/water separator then to a recovery tank. The water fraction discharges to the creek. BP Bellefontaine bulk fuel terminal discontinued operations on 3-15-08.

Numeric Limit violations were evaluated from 2003 to a portion of 2008 with no violations reported.

HUC 05080001 04 (Stony Creek-Great Miami River)

Village of Quincy/Degraff WWTP - Great Miami River RM 143.1

The Quincy WWTP is located in Logan County at 5820 SR 235 North in the Village of Quincy. The treatment system is owned and operated by Quincy but also provides service to the nearby Village of DeGraff. However, each community maintains their own collection systems. The original facility was built in about 1973 with an average design flow of 0.14 MGD and hydraulic capacity of 0.62 MGD. Treatment consisted of a three cell facultative lagoon system, designed to meet secondary treatment standards. An upgrade in 2004 added a new activated sludge, oxidation ditch treatment system designed to meet Best Available Demonstrated Control Technology Limits. The new facility had an average design flow of 0.495 MGD and a peak design of 0.84 MGD. The complete treatment works consist of fine screening, aerated grit removal, two oxidation ditches, two clarifiers, UV disinfection and a cascade post aeration system. As of 2007, the WWTP was operating at 23% below design capacity. During the 2008 survey, Ohio EPA field personnel found the 001 effluent to be generally clear on numerous unannounced sampling visits. The collection system also includes two lift stations in Degraff and one in Quincy; the stations have backup power or alarm systems, but none have both features.

I/I issues contribute to peak flows at the WWTP and system overflows within both villages. SSO's are located within the system and overflows have been reported from the Main St. Lift Station, Poplar St. lift station, and a manhole at 431 South Main St. The manhole has been known to overflow and discharged over 100,000 gallons of raw sewage over a three day period after heavy rains. Some overflows go to yards and some to Bokengehalas Creek. Sewer grouting in the Bokengehalas Creek service area has reduced I/I and the Poplar St. Station was upgraded in 2010, including the addition of standby power. Lift station overflows have been attributed to float and pump failures due to build up of grit, a broken force main and power outages.

Quincy produces a Class B biosolids. Sludge handling facilities include aerobic digesters, wedge wire drying beds, and bio bags. In 2009 the Village contracted with Burch Hydro to land apply 25.88 dry tons of biosolids and was considering land filling a percentage of solids in 2010.

NPDES violations were evaluated from 2003 through a portion of 2008. Over the nearly six year period, 58 *Numeric* violations were reported, primarily for TSS and cBOD5 and primarily during 2003-2004. Treatment system performance and effluent quality improved significantly with the installation of the new treatment plant in 2004. In addition, 33 *Code* violations were reported through 2006, primarily for flow rate during winter months.

Daido Metal Bellefontaine WWTP - Nivens Ditch to McKees Creek
(Permit #1IN00058-001)
Note: Discharge eliminated June 2009

See Daido Metal (aka, Glacier Vandervell)/Blue Jacket Creek discussion, **page 66**.

Honda of America-Anna Plant WWTP-
via Trib. to Plum Creek, aka Finkenbine Ditch (RM 4.87/2.04/1.08/0.5)
001 outfall to Finkenbine Ditch (RM 0.5); 006 outfall to Trib. to Finkenbine Ditch

Honda of America is located in the extreme headwaters of the Plum Creek watershed at 12500 Meranda Road near Anna in Shelby County. The facility began in July, 1985 and manufactures automobile engine components, suspension, and motorcycle components, and assembles engines for Honda automobiles. Honda utilizes ferrous and aluminum castings and ferrous machining in their assembly and support operations. Industrial wastewater treatment is discharged to the South Retention Basin (006) while north area storm water runoff is diverted to the North Retention Basin (001). Industrial wastewater is sent to the Industrial Pretreatment Plant, combined with the pretreatment chemicals effluent, cooling water blow down and storm water runoff, then delivered to the south basin for settling. Sludge from both retention basins is land applied. The onsite Industrial Water Treatment Plant receives industrial water from the cooling towers which is then combined with treatment chemicals and hydrated lime and the lime slurry by-product is then land applied. Dechlorination was added at the facility in 2002.

A file review from 2004 through 2008 found virtually no NPDES violations for the facility. There were no (zero) Limit or Code violations recorded for outfall 001 and only two Frequency violations were detected in 2008. Ohio EPA's primary concerns with the discharges have involved requests for notification prior to emptying of the ponds for maintenance and suggestions regarding periodic dredging of basin sediments.

HUC 05080001 05 (Headwaters Loramie Creek)

Botkins WWTP - Loramie Creek RM 35.42

The Botkins WWTP is located in Shelby County at 17600 CR 25A. The original facility was built in approximately 1989. Current treatment works consist of a bar screen, grit channel, comminution, sequencing batch reactor, rotating drum screen aerobic digestion, sludge drying beds for sludge and UV disinfection. The WWTP serves a population of 1,205 with a design flow of 0.5 mgd and, as of 2007, an estimated ground water infiltration rate of 302,000 gpd (0.302 mgd). Smoke testing and manhole cover liner rehabilitation began in 2007 to help stem the problem. An Ohio EPA lab inspection in 2007 noted a facility lacking documentation, record keeping and some QA/QC procedures.

In addition to one industrial user and three lift stations in the service area, the WWTP also receives regular daily loadings from the Botkins Water Treatment Plant (WTP). The WTP regenerates their water softeners 4 times per day for a total of 15,000 gpd of backwash. They also regenerate their iron filters twice a week with a backwash volume of 35,000 gallons. The water treatment and softener processes use approximately 50 tons of salt per month (Ohio EPA correspondence, 4-29-10). As a result of this information, coupled with detection of chemical and biological impairment in Loramie Creek downstream from the WWTP (**Table 4**), Ohio EPA issued a modified NPDES permit to the WWTP for monitoring of TDS on July 1, 2010. Technical assistance related to WTP operations was provided by the Ohio EPA Divisions of Drinking and Ground Waters.

NPDES violations were evaluated from 2003 through a portion of 2008. During the nearly six year period, 26 *Numeric Limit* violations were reported, primarily for cBOD5, pH and ammonia-N. Nearly half of violations were from 2005 to 2007 with no violations reported in 2008. During the evaluation period, almost 50% of violation occurred during the typically rainy months of May through July.

A total of 276 *Reporting Frequency* violations were documented for the same period from all reporting locations. Ninety-percent (90%) were for outfall 001, 50% of which occurred from 2006 to 2008. The majority was for heavy metals (mostly copper) and occurred in March, June, July and September respectively.

Lake Loramie Special SSD WWTP - Loramie Cr. RM 21.1

The Lake Loramie Special SSD WWTP is located in Shelby County at 3475 Canal Rd. #1 in Minster. Constructed in 1990, the facility currently serves the Lake Loramie Special SSD and the Villages of Ft. Loramie, Kettlersville and McCartysville. The system is a 400,000 gallon per day, Biolac Aeration System that consists of fine screens, equalization basin, biolac aeration, integral clarifier, post aeration polishing lagoon, ultraviolet disinfection and sludge holding lagoon. There are 13 duplex pump stations, 106 grinder pumps and 235 septic tanks tied into the collection system. Average annual flow rate has been reported near 0.3 MGD, for many years. County Commissioners were ordered to install a flow equalization basin at the facility to assist the Village in elimination of SSOs. Upgrades (PTI No. 05-13944) to the wastewater facility were completed by July, 2006 as required by the compliance schedule.

Overflows from the EQ Basin are diverted through a 12" emergency overflow pipe to the effluent line, then blended with the final effluent and disinfected. This overflow is to be used in accordance with the sewer district NPDES permit. The Ft Loramie Pump Station overflow use to flow along SR 66 when inflow was more problematic.

Sludge is land applied to 84 acres of fields adjacent to Lake Loramie WWTP, northeast of the Canal Rd. #1 and SR 66 intersection. This is very low gradient land with low potential for migration or proximity to nearby waters. During an Ohio EPA inspection in 2009, deficiencies were noted in the sludge land application calculations and thereby application rates to nearby fields.

NPDES violations were evaluated from 2003 through a portion of 2008. *Numeric* limit violations numbered 178**,** mostly for ammonia-N and dissolved oxygen (D.O.) in May, June, July and September for all years. Reasons for violations were reported due to weather inflows, mechanical malfunctions, EQ Basin overflows, insufficient staffing and aeration capacity. In addition, 19 *Frequency* violations were documented for the time period comprised of mostly metals and TSS.

Lake Loramie WWTP Loadings Trends

As with many facilities in the study area, the high precipitation year of 2003 graphically displayed the I/I issues noted for the aging collection systems. Percentile flow variance remained fairly steady over the period of record with the predictability of a newer facility (**Figure 14**). Percentile variance lessened in predictability from 2005 until 2008 where 2007 showed more even flow after the installation of an EQ basin. The median percentile remained well under design for the duration of the record indicative of a newer facility with capacity and EQ leveling of incoming flow.

Denitrification was hindered by peak flows reflected in unpredictable ammonia-N loadings, most notably in 2003 and 2008. Otherwise, conversion of ammonia-N to nitrite and nitrate is observed fairly well graphically. Discrepancies between percentiles and loading variance are related to high flows, documented by SSO activity.

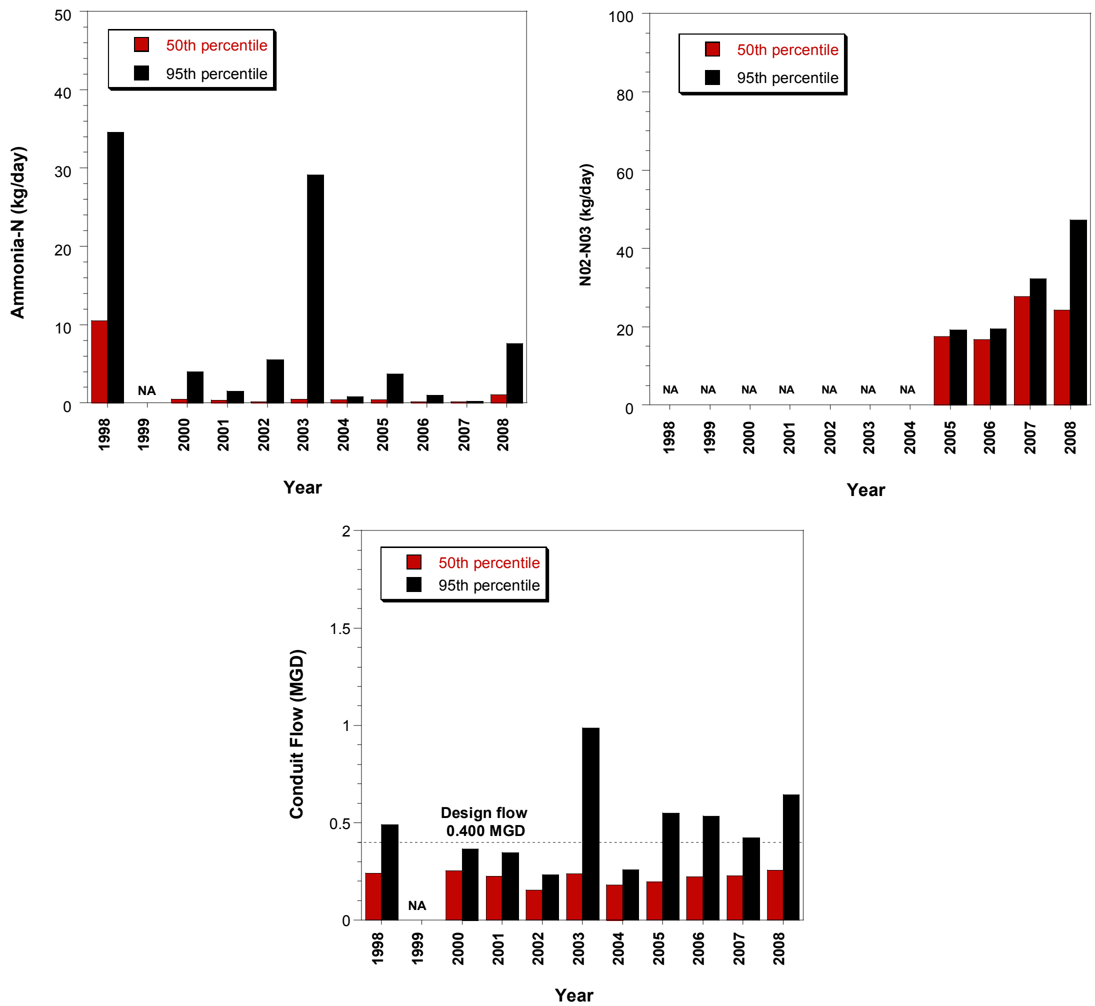


Figure 14. Annual Third-quarter loadings (kg/day) of ammonia-N and nitrate, and conduit flow (mgd) at the Lake Loramie Special Sanitary District WWTP in the upper Great Miami River study area, 2008.

Dannon Co, Inc WWTP - Miami-Erie Canal
(Final storm water effluent collected from First St. storm sewer)

Dannon Company, Inc. is located in Auglaize County at 216 Southgate Drive in Minster. Dannon is a French food-product multinational, based in Paris and produces dairy products used in various foods. The Minster plant is the world's largest producer of yogurt and employs more than 400 people. There has been no formal Ohio EPA enforcement action concerning the treatment plant in the past five years.

Limit Violations of the National Pollutant Discharge Elimination System (NPDES) were evaluated from 2003 to a portion of 2008. During the nearly six year period, five violations of predominately $cBOD_5$ and TSS were reported in 2006.

Minster WWTP - Miami-Erie Canal RM 1.74

The Minster WWTP is located in Auglaize County at 155 W First St. in Minster. The facility was built in 1941 and upgraded in 1992. A storm water equalization basin was added in 1996, UV disinfection in 1998, and a biosolids handling facility in 2001. Treatment works consist of mechanical screens (bar and fine)**,** two extended aeration oxidation ditches, two settling tanks**,** two aerated EQ basins, two flow meters (one for Dannon Co, one for the village) three final clarifiers and UV disinfection. Storm water overflows go to catch basins within the facility and discharge directly to the canal. Local farmers use the Class A biosolids for land application. Ohio EPA field personnel found the effluent to be generally clear during unannounced facility visits.

The Village operates the 1.05 MGD facility to treat both domestic and industrial wastewater flows. The facility has frequently operated above design flow and as a result, a PTI application for expansion was submitted in December of 2010 and is currently under review. Influent flow will continue to increase in the near term due to anticipated expansions at the Dannon facility and in the long term due to anticipated population growth. Currently, the collection system has system wide SSO occurrences.

In 2006, pollutant concentrations were considerably higher than the 5-year averages due to higher flows and frequent upsets at Dannon's pre-treatment facility. The need to upgrade the facility is being driven by the facility's outdated main treatment units which are in need of replacement.

Forty nine NPDES violations were reported during an approximate six year evaluation period from 2003 to 2008, primarily for TSS, $cBOD_5$ and ammonia-N in 2006 and 2007. Most violations were reported in October and February and the least in spring and summer months. *Frequency* violations for chlorine, D.O., flow rate, TSS, pH and bypassing occurred in 2003 and 2004. Nine percent (9%) were sludge related.

Minster was only recently listed as a major discharger (*i.e.,* $\geq$ 1.0 mgd) and that may explain why no bioassay sampling records exist for this facility.

Minster WWTP Loadings Trends

Percentile flow variance was minimal over the period of record (**Figure 15**), although variability was evident following the high precipitation events experienced at many facilities in 2003. Graphically, the benefits to flow regulation are noted in minor percentile variances, most likely due to the facility upgrade in 1992 and addition of flow equalization in 1996.

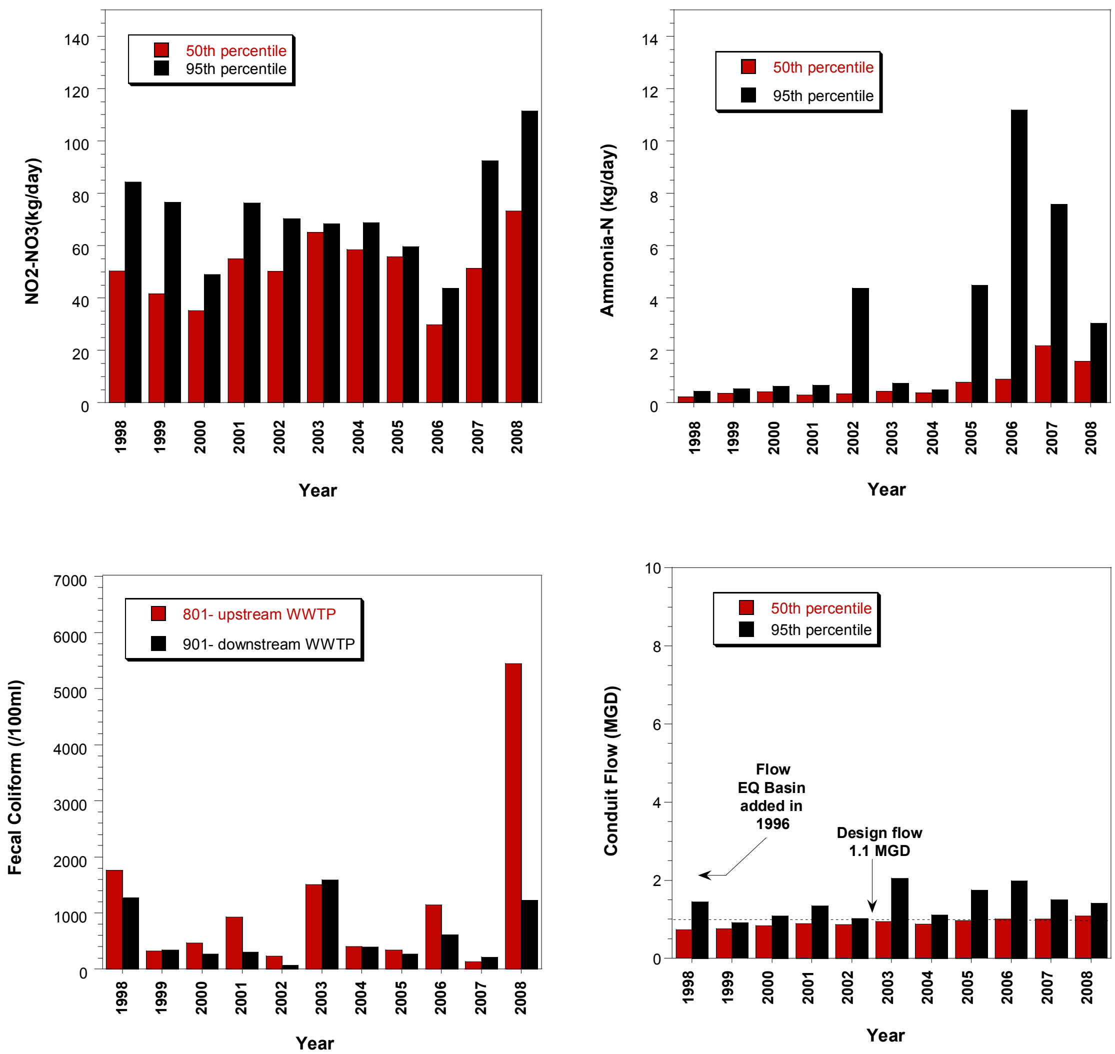


Figure 15. Annual Third-quarter loadings (kg/day) of ammonia-N and nitrate, concentrations of fecal coliform bacteria (CFU/100mL), and conduit flow (mgd) at the Minster WWTP in the upper Great Miami River study area, 2008.

Percentile variances in nutrients (**Figure 15**) mimicked one another during most reporting years. However, exceptions to this trend were encountered from 2006 to 2008, when both ammonia-N and nitrate-nitrite-N percentiles differed sharply, possibly due to inflow dynamics and increases from industry such as Dannon Yogurt. Dannon experienced unpredictable treatment regimes during the same period. The permit violations in 2006 and 2007 for nutrients (see above) and the nutrient load graphs reflect the erratic treatment occurring at the facility during the same period.

Final outfall (001) bracketing of fixed stations 801 and 901, with few exceptions, demonstrated that third-quarter downstream concentrations of ammonia-N were fairly commensurate with upstream values throughout the period of record. Seventy-three percent (73%) of record fecal coliform concentrations upstream from the WWTP exceeded downstream values, pointing to livestock or wildlife fecal loads or possibly unsewered areas. High flows noted in 2003 and 2008 could explain the peaks observed in bacteria concentration upstream of the facility.

BP Amoco Oil Bulk Plant-Minster WWTP - Miami-Erie Canal RM 2.2

The BP Amoco Oil Bulk Plant is located in Auglaize County at 186 South Ohio St., in Minster. The facility is a small, unmanned terminal that receives refined petroleum products by transport truck from a BP owned terminal. Product is stored in above ground tanks and distributed to consumers by smaller tank trucks. Unleaded, high sulfur and kerosene fuels are stored onsite. Treatment consists of oil and water separation. All drains capturing spilled material go into an oil/water separator then to a recovery tank. The water fraction discharges to the Miami-Erie Canal.

Numeric Limit violations were evaluated from 2003 to a portion of 2008. For the nearly six years of data, only one violation for pH occurred. A total of 651 *Reporting Frequency* violations were documented for the same time period from all reporting locations (includes internal). Eighty-five percent (85%) were for flow rate and phosphorus and 56% of those occurred in 2007. Every month had violations with November, January, June and July experiencing 60% of the violations.

HUC 05080001-06 (Turtle Creek-Loramie Creek)

Russia WWTP – Trib. to Ninemile Creek (5.07) RM 0.02
(801-upstream of discharge; 901-not listed)

The Russia WWTP is located in Shelby County at 551 East Main St. in Russia, Ohio. The original facility was built in 1992 as a controlled discharge lagoon treatment system with a design capacity of 0.075 MGD. There are four lift stations with alternating pumps. Lift station #1 is the main lift station, #2 and #3 are for local industry and water treatment plant, and lift station #4 is a private lift station (Francis Manufacturing). The Russia population has increased approximately 25% (600) over the past 20 years. In addition, several commercial and industrial facilities discharge to the collection system; the three largest are Clopay, Superior Aluminum and Francis Manufacturing.

The WWTP consists of a 4-cell facultative lagoon system. There are two aerated lagoons (primary lagoons) for treatment and two stabilization/storage lagoons (secondary lagoon) for settling and storage. On July 3, 2008, Ohio EPA issued a PTI for the installation of the fourth lagoon to increase storage capacity of wastewater from to 90 to 180 days. Construction was completed in October 2008.

Limit violations were evaluated from 2003 to a portion of 2008. One hundred and sixteen violations were reported, primarily for high pH in 2004 through 2006, before declining in 2007 and 2008. Historically, pH violations have been problematic at the facility and can be traced back to at least 1999. The system pH is typically 8.5 to 8.9 and, at one point, grass carp (*Ctenopharyngodon idella*) were stocked in an unsuccessful attempt to control algae and thereby, reduce pH. Other methods that were used in an attempt to control algae (barley straw, ultrasonic waves and alum in conjunction with the aeration) were unsuccessful. Recently, the Village applied for, and received a pH variance during permit renewal. The renewed permit was effective Feb 1, 2010.

Code violations were reported from 2003 to 2008. During the nearly six year period, 29 violations were reported for flow and D.O. Most violations occurred in 2006.

Houston High School WWTP - Ninemile Creek RM 1.0

The Houston High School WWTP is located in Shelby County at 5300 Houston Rd in Houston. On November 19, 2002, Ohio EPA issued a PTI to the high school to replace the existing WWTP. The new WWTP consist of a trash trap, equalization basin, aeration tank, settling tank, slow surface sand filters, chlorination/dechlorination facilities and sludge holding tank with a design flow of 0.10 MGD. Construction of the new WWTP was completed in August 2003. Prior to August 2003, the WWTP consisted of a trash trap, aeration and clarification. The wastewater system serves a student population of approximately 450 people with an annual average daily flow of 0.002 mgd. Sludge is disposed of at a local landfill.

In 2009, the school district decided to relocate Hardin Elementary to the high school property and use the existing WWTP. Based on three years of actual flow data and a student/staff population of 938 for both schools, the existing WWTP was considered sufficient to serve the consolidated campus.

Numeric Limit violations were evaluated from 2003 through 2009 with 24 reported, primarily for pH and chlorine during the winter months. Thirty three percent (35%) occurred from 2007 until 2008, reduced to less than 1% by the end of 2009.

Frequency violations evaluated from 2003 to 2008 numbered 131 and were primarily related to sludge reporting. The number of violations was reduced to four by 2008.

Hickory Dell Estates WWTP - Unnamed tributary to Brush Creek (RM 0.28)

The Hickory Dell Estates WWTP is located in Shelby County at 14212 Charm Hill Dr. in Sidney, Ohio. Upgrades occurred in 2002 increasing the average design flow to 0.02 MGD**.** The average monthly flow in 2008 for a number of months was above design flow of 0.02 MGD (0.04 to 0.09 MGD). The treatment works consist of a trash trap, equalization tanks, aeration tanks, clarifier, dosing chamber, rapid sand filters, ultraviolet disinfection and post aeration. Septage haulers are contracted with and sludge generated at Hickory Dell is taken to the Lake Loramie WWTP. An Ohio EPA Inspection in 2009 noted some bulking solids overflowing the weir and instream below the outfall.

Numeric violations were evaluated from 2003 to a portion of 2008. For the nearly six years of data evaluated, 22 violations were reported, primarily for TSS and $cBOD_5$. Most violations occurred during winter months and 18 percent occurred from 2007 until 2008. Only nine *frequency* violations were documented at the facility with no occurrences in 2008.

Hardin Elementary School WWTP - Trib. to Turtle Creek (RM 4.84) RM 0.1

Hardin Elementary School wastewater treatment works is located at 10207 State Route 47, Sidney, Ohio, in Shelby County. The facility was built in 1989 and upgraded in 1998 to an average design flow of 0.009 MGD. Treatment consists of trash trap, extended aeration, sand filter, chlorination and dechlorination.

NPDES *Numeric Limit* violations were evaluated from 2003 to a portion of 2008. For the nearly six years of data evaluated, 65 violations of predominately ammonia-N, D.O., chlorine and fecal coliform were reported for nearly all months except November. Sixty-percent (60%) of the total violations occurred from 2006 until 2008. Violations for chlorine were reported due to chemical dechlorination inventory depletion and human error.

A total of 225 *Reporting Frequency* violations were documented for flow rate, temperature and D.O. Ten percent (10%) of violations occurred from 2006 to 2007.

A total of 149 *Code* violations were documented for flow rate, odor, color and turbidity all from 2003 until 2005. Most violations occurred in January, April and May.

Since the 2008 survey, plans have been approved to relocate the elementary school to the Houston High School campus on Ninemile Creek and connect to the existing wastewater facility. The discharge to the Turtle Creek tributary will be eliminated.

Fairhaven WWTP - Mill Branch RM 2.24

The Fairhaven WWTP is located in Shelby County at 2901 Fair Rd. in Sidney. The current design flow is 0.013 MGD and treatment consists of bar screen, biolac lagoon, integral clarifier, slow surface sand filters, ultraviolet disinfection, sludge holding lagoon and post aeration. An upgrade in 2006, added a new Air Lift blower, slow sand filters and the addition of UV disinfection. Sludge is currently hauled to Lake Loramie WWTP.

An Ohio EPA inspection in 2007 summarized the effluent as clear and odor free and the receiving stream free of solids both upstream and downstream. It's been reported that no bypasses or overflows exist. Fairhaven has intermittent problems with filamentous bacteria growth causing settling problems and releasing solids to the receiving stream.

Numeric Limit violations were evaluated from 2003 to a portion of 2008. Over the nearly six year period, 46 violations of predominately TSS, $cBOD_5$ and ammonia-N were reported in primarily winter months (70%). Thirteen percent (13%) occurred in 2007, with no reported violations in 2008.

Dorothy Love Retirement Center WWTP - Ernst Ditch to East Turtle Creek (RM 2.3)

Dorothy Love is located at 3003 Cisco Rd., Sidney, Ohio in Shelby County. The original sewage treatment facility was built in 1975 and upgraded in 1990 and 1998 with the addition of an Equalization Basin. Flow design is at 0.104 MGD. The treatment works consists of a trash trap, extended aeration, clarification, fixed media, sand filter, chlorination, dechlorination, post-aeration and a sludge holding tank. In 2007, discussions began on the need for an I/I study. An unannounced inspection in 2008 by Ohio EPA field personnel indicated the final effluent looked to be of good quality.

Numeric Limit violations were evaluated from 2003 to a portion of 2008. For the nearly six years of data, 41 violations of predominately $cBOD_5$, ammonia-N and fecal coliform were reported, of which 63% occurred before 2007. Violations occurred in all seasons but primarily in February, March and May. Violations were reported due to bad UV bulbs, aeration blower motors, snow melt and the ultraviolet system needing cleaned.

Frequency violations were evaluated from 2003 until 2008 and numbered 229, with the most occurring before 2007. These mostly concerned chlorine, TSS, hexavalent chromium and $cBOD_5$ respectively, and were attributed to contract laboratory schedules and missing submission deadlines.

Arrowhead Subdivision WWTP - Mill Creek RM 2.62

The Arrowhead Subdivision WWTP is located in Shelby County on Comanche Dr. in Washington Township, Ohio. The original facility was constructed in approximately 1972 and upgraded in 2002. The treatment facility is designed for 0.07 MGD and flows have been recorded at around 0.043 MGD. The treatment works consist of trash trap, equalization basin, aeration tanks, clarifiers, slow surface sand filters, chlorination/ dechlorination, post aeration and a sludge holding tank.

Collection system I/I can overload the treatment facility although sewer rehabilitation projects have helped to reduce the volume. During an inspection by Ohio EPA in 2005, the wastewater facility was found to be in general compliance with its effluent limits.

Numeric Limit violations were evaluated from 2003 through a portion of 2008. For the nearly six years of data, 53 violations (predominately chlorine, ammonia-N and TSS) were documented. Sixty-two percent (62%) of those violations were reported from 2006 until 2008 and occurred mostly in July and January.

Frequency violations were evaluated from 2003 until 2008 and 91 were documented, primarily for flow rate and water temperature. However, nearly 90% occurred prior to 2006. The greatest numbers of violations were in January and February.

Anna WWTP- Clay Creek RM 4.55 (aka, Applegate ditch)

The Village of Anna WWTP is located in Shelby County at 516 W. Main St in Anna, Ohio. Constructed in 1971 with a major modification in 1989, a new facility was built in 1996 to a design flow of 0.4 MGD. The service population is approximately 1,300. The treatment train consists of an influent pump station, automatic screen/ mechanical bar screen, oxidation ditches, final clarifiers and ultraviolet disinfection. Sludge is not land applied but instead is transported to another NPDES permit holder.

Efforts to minimize I/I included sewer replacement in 2006. In addition, line inspections by camera and other implementations were employed to identify problem areas. An Ohio EPA compliance inspection in 2006 resulted in a satisfactory rating for all areas of the treatment plant.

There were no NPDES *Limit* violations but 73 *Frequency* violations recorded from 2003-2008. Fifty-four (74%) occurred in 2006 and 2007, mostly for Mercury, ammonia-N and TSS during March, November and May respectively. Sixty-four (64) percent of the total violations were sludge related.

Millcreek WWTP (Shelby Co. Sewer Dist. Milcreek subdivision) –
Unnamed tributary to Mill Creek (3.82) at RM 1.58 (001) and RM 1.48 (002)

The Millcreek WWTP is located in Shelby County at Millcreek Rd. and Kuther Rd in Orange Township, Ohio. There are two Millcreek facilities (001 and 002) that discharge less than 200 feet apart to an unnamed tributary of Mill Creek. The treatment works at both consist of a trash trap, equalization basin, aeration tank, clarifier, fixed media clarifier, slow surface sand filter, chlorination/dechlorination, post aeration and a sludge holding tank. Bypassing the sand filters has occurred on occasion during filter cleaning. A PTI was issued by Ohio EPA on May 14, 2003 for an equalization tank.

The Millcreek 001 facility was built in approximately 1968 and was upgraded in 1994 to an average flow design of 0.02 MGD, serving 215 people. Facility 002 discharges an average 0.013 MGD. Director’s Findings and Orders (DFFOs) were issued to Shelby County Commissioners for Arrowhead, Fair Haven, Millcreek, Hickory Dell and Lake Loramie on October 7, 2004 for noncompliance issues.

Both facilities are in disrepair with fractured sand filter beds and a fractured chlorine contact tank. Rather than upgrading, a decision was made in July of 2010 to abandon the facilities and connect to the Sidney WWTP. Sludge is currently hauled to Lake Loramie WWTP from all Shelby County Sewer District facilities.

Numeric violations were evaluated from 2003 through a portion of 2008. Over the nearly six year period, 44 violations were reported, primarily for TSS and $cBOD_5$ during winter months. Fifty-two percent (52%) occurred from 2007 until 2008.

Chemical and Recreation Water Quality

Upper Great Miami River Watershed

Inorganic water chemistry grab samples and field measurements were collected every other week (six times) from June to September at 82 sites in the watershed, including 24 sites in the Loramie Creek subwatershed (**Table 1**). All samples were analyzed for a variety of parameters including nutrients and metals (**Appendix Table A-1**). Additional inorganic sampling was conducted at select sites throughout the year (See Sentinel Site Monitoring Program, **page 104**). Twenty-four (24) sites (including nine in the Loramie Creek subwatershed) were also sampled for organic compounds twice during the summer survey (**Table 12**). Samples from these sites were scanned for 59 volatile organic compounds, 53 semivolatile compounds, 53 pesticide compounds and seven polychlorinated biphenyl (PCB) congeners (**Appendix Table A-2**). Additionally, Datasonde® continuous monitors recorded hourly dissolved oxygen (DO), temperature, pH, and specific conductivity for a 48-hour period at 21 sites in 2008 and at 23 sites in 2009 (**Appendix Tables A-5 - A-7**).

Bacteria samples (*E. coli*) were collected by Ohio EPA in 2008 and 2009. Summarized bacteria results are listed in **Table 11** and the complete datasets are reported in **Appendix Tables A-3 and A-4**. Downloadable bacteria results are also available from the Ohio EPA geographic information systems (GIS) interactive maps at the following link: http://www.epa.ohio.gov/dsw/gis/index.aspx. Thirty-seven (37) locations in the watershed were tested in 2008 for *E. coli* levels four to five times from September 3 through September 11. Additionally, nine locations were tested again in 2009 one to twelve times from June 4 through October 28. Evaluation of *E. coli* results revealed that 26 of the 37 locations sampled in 2008 and five of the nine locations sampled in 2009 failed to attain the applicable geometric mean criterion, indicating an impairment of the recreation use at these locations. Non attainment of the recreation use was most likely related to a variety of possible sources. However, a suspected source of contamination common to all impaired sites was agriculture, the predominant land use in the watershed.

Water chemistry results from daytime grab samples which exceeded State of Ohio Water Quality Standards (WQS) are presented in **Table 9**. Numeric nitrate and total phosphorus criteria for aquatic life protection have not been incorporated into the Ohio WQS. However, Ohio EPA has identified target levels for maintaining biological integrity in rivers (Ohio EPA 1999). An evaluation of ammonia-N, nitrate-nitrite-N, and total phosphorus data compared to these recommended targets is detailed in **Table 10**. (**Note**: Discussions of phosphorus and target level concentrations refer to *total* P.)

Many graphs within the following summaries include dotted lines representing percentile concentrations from least impacted regional reference sites of similar size (Ohio EPA 1999). Statistical data were segregated by ecoregion (ECBP) and further stratified by stream size for these analyses as follows: headwater streams (0-20 mi^2); wadeable streams (> 20-200 mi^2); small rivers (> 200-1000 mi^2) and large rivers (>1000 mi^2).

Great Miami River mainstem

Stream flows in the mainstem and throughout the upper GMR watershed were generally well above normal from May through July reflecting above normal precipitation (**Table 8**). Total rainfall of 16.28 inches was recorded for this three-month period in the West Central region of Ohio, more than 4 inches (4.28 in) above normal for the period (ODNR 2008). June precipitation in the region ranked as the 6th wettest on record (126 years). Conversely, rainfall was below normal in both August and September (total precipitation 3.3 inches) with August ranking as the 7th driest on record.

Great Miami River stream flows from May through September 2008 measured by the USGS gage station at Sidney are presented in **Figure 16** (USGS 2008 and 2000). Virtually all mean daily flows from May through July were well above the 50% (median) duration exceedence flow of 110 cfs with 43% exceeding the 10% duration flow of 599 cfs. The 50% duration flow represents the discharge equaled or exceeded 50% of the time over the period of record. Conversely, 97% of mean daily flows during August and September were less than 50% duration. On specific water chemistry survey sampling days, flows ranged from 46 cfs on September 24 to 3600 cfs on June 26. On bacteria sampling days, flows ranged from 51 cfs on September 3 to 103 cfs on September 9.

Table 8. Precipitation in the West Central region of Ohio May-September, 2008 (ODNR 2008).

Month	**May**	**June**	**July**	**August**	**Sept**
Average rainfall (inches)	4.85	7.29	4.14	1.31	1.99
Departure from Normal*	+0.85	+3.40	+0.03	-1.93	-0.74
% of normal rainfall	121%	187%	101%	40%	73%
PDSI**	**+2.4**	**+3.5**	**+2.2**	**+1.1**	**-0.8**

* Base period 1951 - 2000

** PDSI (Palmer Drought Severity Index)

Above +4 = Extreme Moist Spell	-0.5 to -0.9 = Incipient Drought
3.0 to 3.9 = Very Moist Spell	-1.0 to -1.9 = Mild Drought
2.0 to 2.9 = Unusual Moist Spell	-2.0 to -2.9 = Moderate Drought
1.0 to 1.9 = Moist Spell	-3.0 to -3.9 = Severe Drought
0.5 to 0.9 = Incipient Moist Spell	Below -4.0 = Extreme Drought

Stream quality in the upper reaches of the mainstem (RMs 158.2 - 153.5) was negatively impacted by both Indian Lake and the Indian Lake WWTP. Stations in this reach typically experienced lower daytime grab D.O. levels (overall median saturation 65%) compared to sites downstream (**Figure 17**). Concentrations frequently fell below water quality criteria at RM 153.45 downstream from the Indian Lake WWTP and the confluence of Muchinippi Creek. Hourly continuous monitor measurements recorded from September 3-5 also indicated low D.O. levels at upstream sites with all concentrations measured at SR 274 (RM 156.4) below the average WWH criterion of 5.0 mg/l (**Figure 18**). Field crews frequently noted turbidity in the upper reaches and total suspended solids (TSS) were consistently elevated above target reference values. Periodic high flows over the lake spillway may contribute to bank instability and erosion as well as substrate siltation.

While ammonia-N levels in the mainstem generally remained low, concentrations in the upper reaches were elevated above target reference values. Nitrate-nitrite-N and total phosphorus increased markedly at RM 157.22 (respective medians of 4.20 mg/l and 0.45 mg/l) reflecting the impact of nutrient loading from the Indian Lake WWTP (respective medians of 24.65 mg/l and 2.4 mg/l). Nutrients were assimilated relatively quickly dropping below target reference values again downstream (**Figure 19**). The overall median nitrate-nitrite-N concentration for the eight mainstem sites sampled was 1.57 mg/l while the overall median total phosphorus concentration was 0.114 mg/l.

Copper, lead, and iron concentrations exceeded water quality criteria on June 26 in the upper reaches during exceptionally elevated flows.

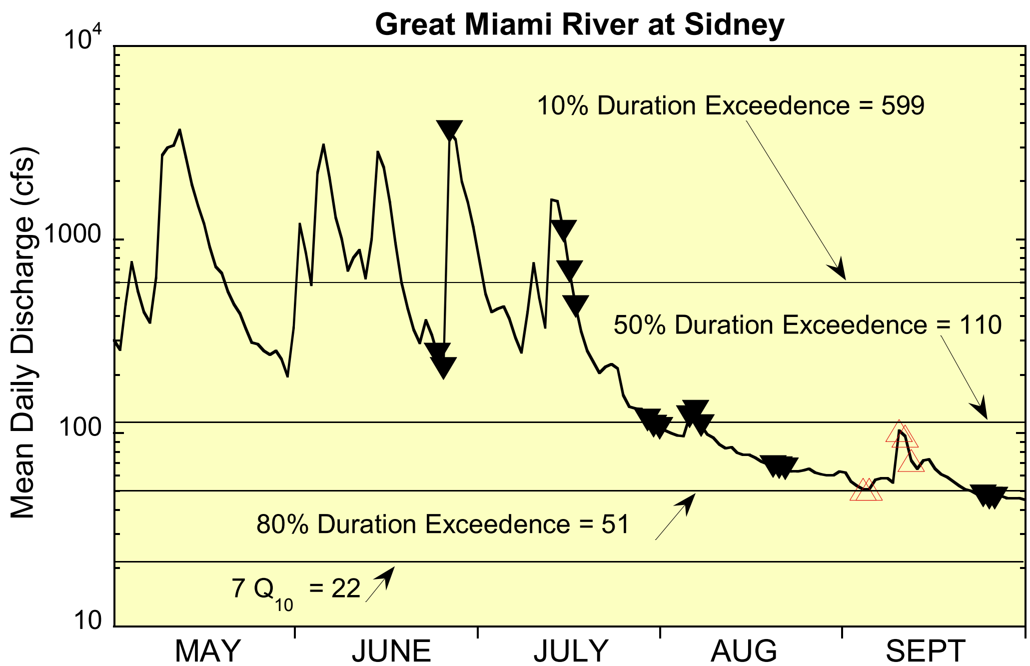


Figure 16. May through September, 2008 flow hydrograph for the Great Miami River at Sidney (USGS station #03261500). Solid triangles indicate river discharge on water chemistry sampling days in the Great Miami River watershed. Open triangles indicate river discharge on bacteriological sampling days. Duration exceedence and $7Q_{10}$ flow lines represent May-Nov period of record 1926-1997.

Five mainstem stream sites were sampled for organic compounds twice during the summer survey (**Table 12**, **Appendix Table A-2**). Fourteen organic compounds were detected, including the plasticizer bis(2-ethylhexyl)phthalate and herbicide atrazine in all samples. Concentrations of the legacy insecticide dieldrin (RM 146.19) and bis(2-ethylhexyl)-phthalate (RM 129.99) exceeded water quality criteria on one occasion. Dieldrin, a highly persistent compound, was banned from agricultural use in 1974 but was still permitted for mothproofing and to fight termite infestations until 1987. The most likely source of the majority of organic contaminants in the mainstem is the application of pesticides or herbicides to cropland.

Mainstem bacteria sampling in 2008 and 2009 indicated the primary contact recreation (PCR) Class A use was not attained at several sites (**Table 11**, **Figure 20**). Possible sources of bacteria include general agricultural and urban runoff, as well as SSOs from the Indian Lake WWTP and wildlife (waterfowl on Indian Lake).

North Fork Great Miami River

The North Fork GMR drains 21.6 mi^2 before entering Indian Lake. Daytime grab D.O. concentrations at two sampling sites near Madory Rd. (RM 10.7) and Dunn Rd. (RM 6.31) were relatively stable with one RM 10.7 value slightly below the WWH average criterion. Additionally, Datasonde® continuous monitoring at RM 6.31 (September 3-5) indicated minimal diurnal variation (**Figure 18**). Ammonia and phosphorus concentrations were low with the majority of values well below reference targets. However, nitrate-nitrite-N levels increased sharply between the Madory Rd. (median 0.12 mg/l) and Dunn Rd. sites (median 2.32 mg/l). Due to its high solubility, nitrate flows easily through agricultural soils to subsurface drains, a major source of nitrates in midwest streams and rivers (http://www.epa.gov/oecaagct/ag101/crop-drainage.html.) Coincidentally, chemical sampling crews regularly observed flow from a field tile immediately upstream from the Dunn Rd. (RM 6.31) sampling bridge.

Organic compounds were also sampled twice at Dunn Rd. (RM 6.31). The herbicides acetochlor, atrazine, and simazine, most likely associated with agriculture, as well as bis(2-ethylhexyl)phthalate (a common plasticizer) were detected in both samples (**Table 12**, **Appendix Table A-2**). Bacteria sampling at Dunn Rd. in both 2008 and 2009 indicated non attainment of the PCR Class B use (**Table 11**, **Figure 20**). Agricultural runoff was the most likely source.

South Fork Great Miami River, Belle Center Tributary, and Liggit Ditch

The South Fork GMR drains 53 mi^2 and flows into Indian Lake in Logan County. Nutrient levels in the South Fork and two of its tributaries (Belle Center Tributary and Liggit Ditch) were low with the majority of ammonia, nitrate-nitrite, and phosphorus concentrations well below reference targets. With the exception of supersaturated D.O. levels in the South Fork headwaters (median 154% at RM 8.0) and Liggitt Ditch (median 149%), daytime grab D.O. concentrations were relatively stable with median saturations approaching 100%. Both the Ligitt Ditch and upper South Fork sites had minimal riparian cover and an open canopy. Such conditions are often conducive to increased light penetration and subsequently, stimulated filamentous algal growth. Excessive algal growth may result in increased daytime D.O. saturation, resulting in acute swings in diurnal D.O. concentrations and ultimately, reduced stream quality.

Acetochlor, atrazine, bis(2-ethylhexyl)phthalate, and metolachlor were detected in at South Fork GMR RM 3.95, the only site sampled for organic compounds in the watershed. Agricultural application of herbicides to cropland is the likely source of these compounds. Additionally, bacteria sampling from the same site indicated the PCR Class B use was not attained in both 2008 and 2009 (**Table 11, Figure 20**). Agriculture and unrestricted cattle access were considered the most likely sources of bacteria.

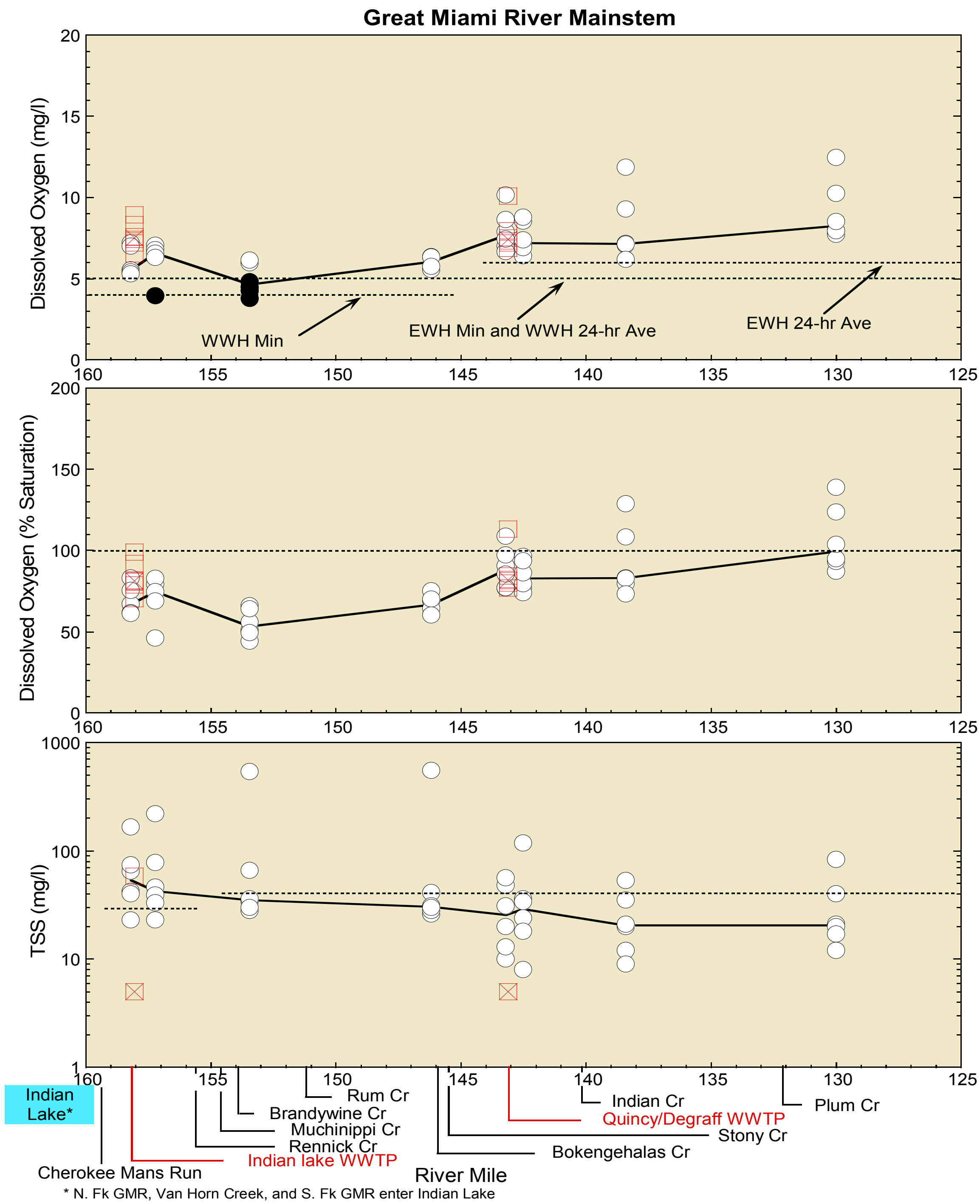


Figure 17. Longitudinal scatter plots of daytime grab dissolved oxygen (D.O.) concentration, D.O. percent saturation, and total suspended solids (TSS) in the mainstem Great Miami River (circles) and two WWTPs (red squares) during 2008. The solid line depicts the median value at each river mile sampled while an "X' depicts the median at the WWTPs. Water quality criteria are shown in the D.O. concentration plot. (Values not meeting criteria are shown as solid circles.) Dashed horizontal lines in the TSS plot represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

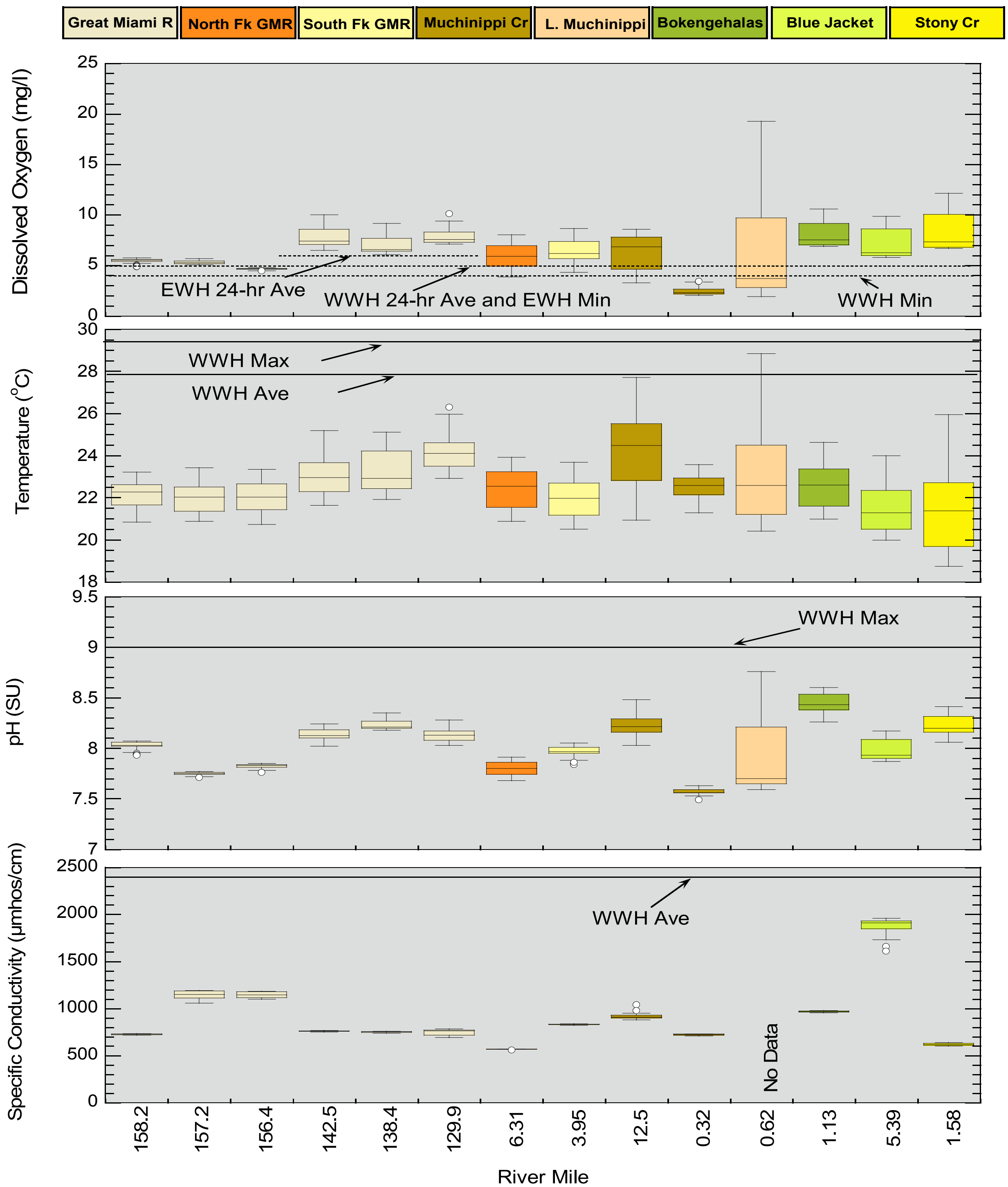


Figure 18. Dissolved oxygen, temperature, pH, and specific conductivity recorded hourly with Datasonde® continuous monitors in the mainstem of the Great Miami River and select tributaries September 3-5, 2008. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Values outside of this range are displayed as individual points.)

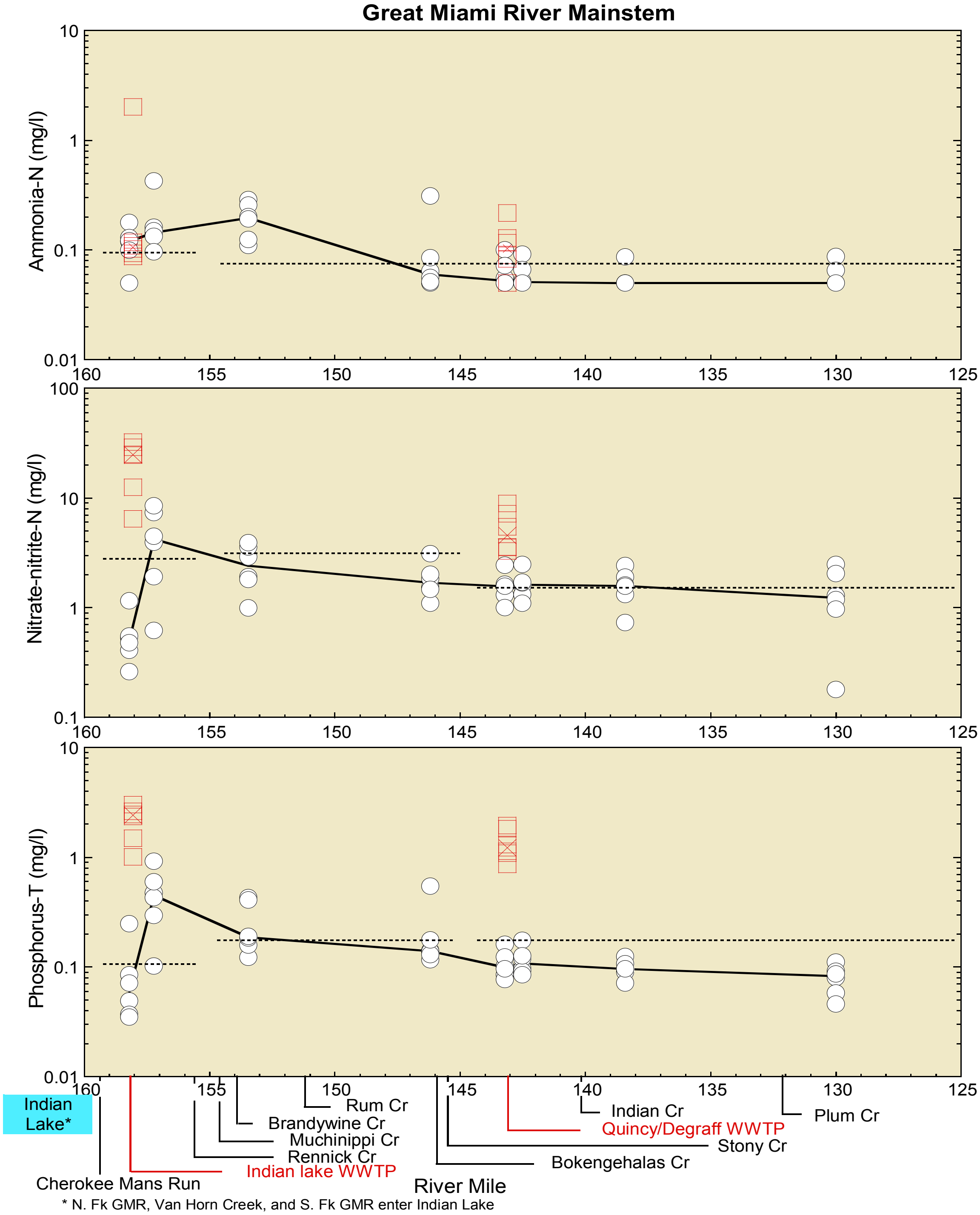


Figure 19. Longitudinal scatter plots of ammonia-N, nitrate-nitrite-N, and total phosphorus in the mainstem Great Miami River (circles) and two WWTPs (squares) during 2008. The solid line depicts the median value at each river mile sampled while an "X' depicts the median at the WWTPs. Dashed horizontal lines represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

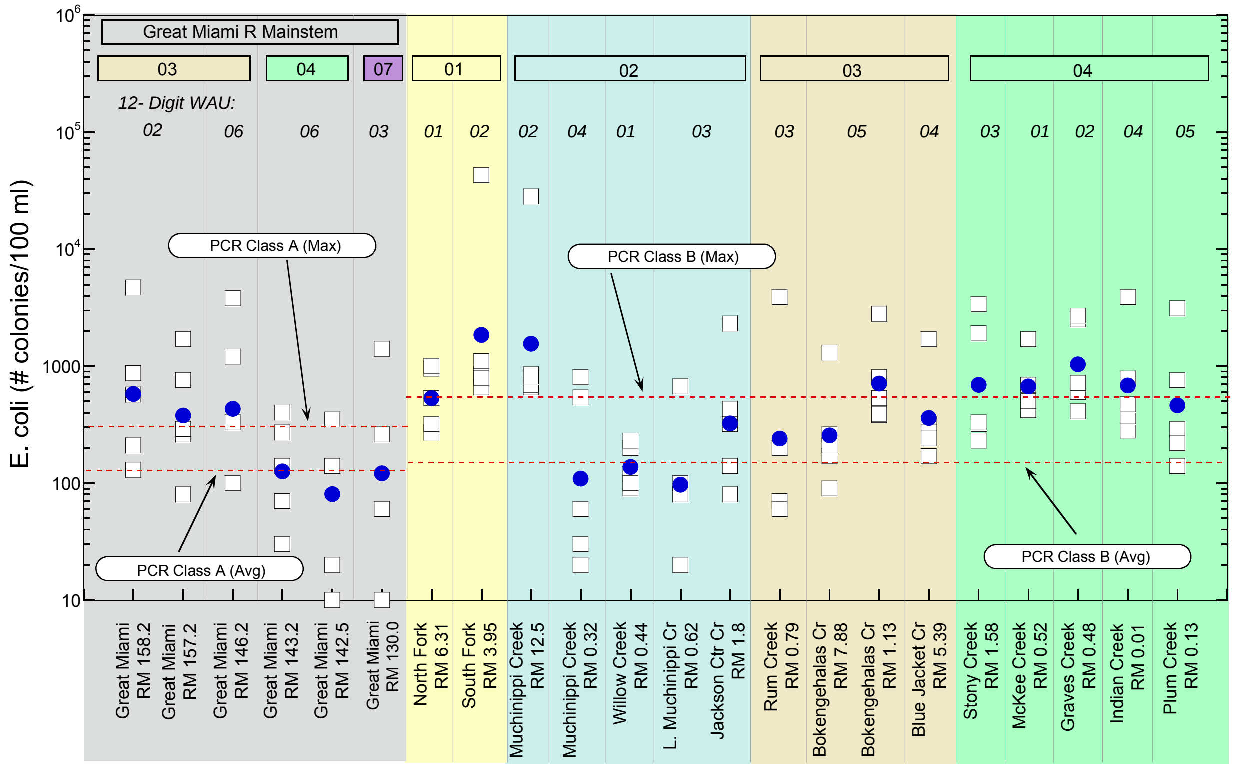


Figure 20, Scatter plots of *E. coli* concentrations in the mainstem of the Great Miami River and select tributaries during the 2008 survey (HUC 05080001-01 to 04 and 07). The 10-digit HUC is provided in the enclosed boxes near the top of the graphic.) Dotted lines represent primary contact recreation (PCR) use water quality criteria. Solid circles represent the geometric mean at each site sampled

<u>Van Horn Creek</u>

One site (RM 0.97) was sampled on Van Horn Creek, a small channelized agricultural ditch draining 2.5 mi^2 which flows directly into Indian Lake. Target reference levels for nutrients were generally met but D.O. concentrations dropped below WWH criteria in late summer as flows diminished. Seven organic compounds were detected including the pesticides and herbicides, acetochlor, atrazine, δ-hexachlorocyclohexane, dieldrin, and metolachlor (likely related to crop application), and plasticizers, bis(2-ethylhexyl)-adipate, bis(2-ethylhexyl)-phthalate. Concentrations of the legacy insecticide dieldrin exceeded water quality criteria on one occasion.

<u>Muchinippi Creek</u>

Muchinippi Creek, a low gradient stream draining 88.4 mi^2, enters the Great Miami River at RM 154.4. All six sites sampled experienced daytime grab D.O. concentrations below WWH water quality criteria (**Table 9, Figure 21**). Additionally, while the majority of hourly D.O. concentrations measured at RM 12.50 from September 3-5 with continuous monitors remained above critical levels (4.0 mg/l), all concentrations recorded downstream at RM 0.32 were less than 4.0 mg/l with a median saturation of only 27.5%[6] (**Figure 18**). The impact of the naturally low stream gradient (average fall 3.2 ft/mi) and the resulting sluggish flow may be exacerbated by the impounded conditions caused by frequent log jams in this stream.

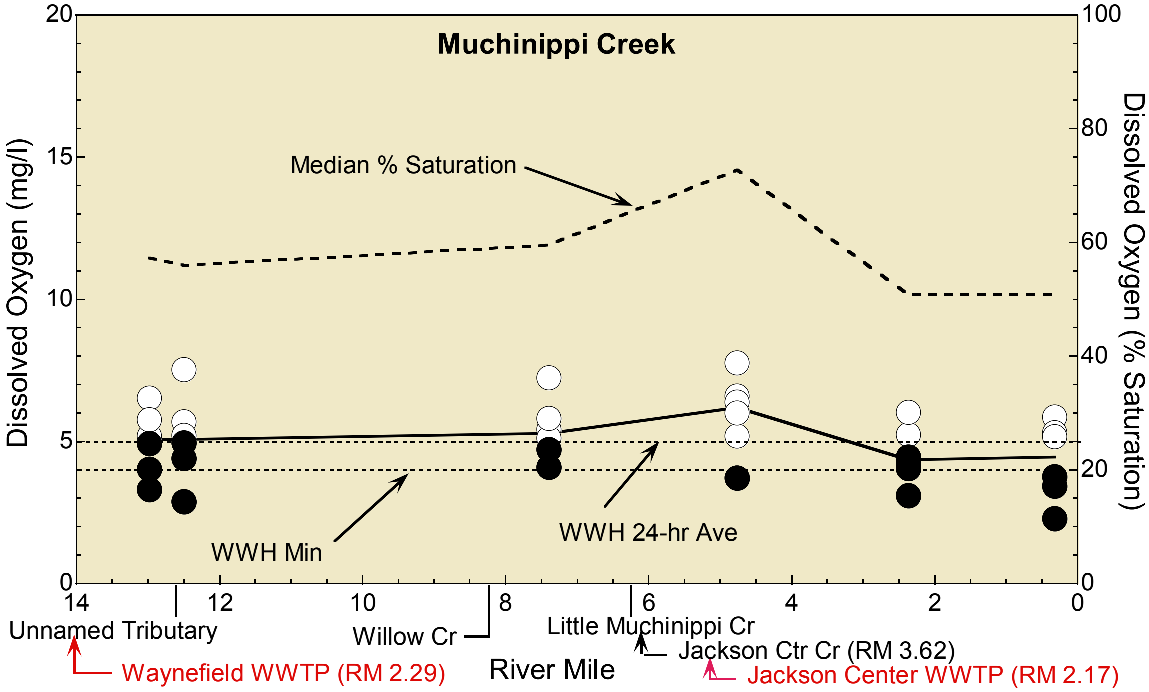


Figure 21. Longitudinal scatter plot of daytime grab dissolved oxygen concentrations and median saturations in Muchinippi Creek during 2008. The solid line depicts the median concentration at each river mile sampled. Water quality criteria are shown as dashed horizontal lines. (Values not meeting criteria are shown as solid circles.)

While ammonia-N concentrations were generally below reference targets, values were elevated in the headwaters at RM 12.98 (median 0.237 mg/l). Ammonia-N concentrations were also elevated above target near the mouth at RM 0.32 (median 0.109 mg/l). Agricultural runoff from cropland (tile drainage) is the most likely source of the elevated ammonia-N. The majority (67%) of phosphorus concentrations were elevated above target with the highest levels measured at RM 12.5 (median 0.341 mg/l) downstream from the Waynesfield WWTP. Phosphorus from fertilizer application to farm fields also contributes to nutrient loading in the watershed. Total suspended solids (TSS) were frequently elevated in the lower reaches (RMs 2.37 and 0.32) and field crews commonly noted turbidity. Soft mucky substrates and eroded stream banks in this lower reach may have contributed to the elevated TSS levels.

Concentrations of iron, copper and lead exceeded water quality criteria at several sites on June 26 during exceptionally elevated flows. Additionally, station RM 0.32 was

[6] A Hydrolab Datasonde® monitor deployed at this site the following year from June 23-25, 2009 also recorded a majority (82%) of DO concentrations below 4.0 mg/l and a median saturation of 46%.

sampled twice for organic compounds and six were detected including acetochlor, atrazine, δ-hexachlorocyclohexane, bis(2-ethylhexyl)phthalate (a plasticizer), metolachlor, and 2,4-Dichlorophenoxyacetic acid (2,4-D). The application of pesticides or herbicides to crops is the most likely source of these compounds.

Bacteria sampling results in Muchinippi Creek were mixed (**Table 11, Figure 20**) with non-attainment of the PCR Class B use in the headwaters at RM 12.50, but full attainment downstream at RM 0.32. Potential sources of bacteria include general agricultural runoff as well as the adjacent, unsewered community of New Hampshire.

Willow Creek

Two sites (RMs 3.7 and 0.44) were sampled in Willow Creek, a channelized agricultural ditch draining 15.2 mi^2 that enters Muchinippi Creek at RM 8.15. Nutrient levels were generally low with most concentrations well below target reference levels. While daytime grab D.O. concentrations dropped below the WWH criterion once at both sites, median saturations were close to 100%. Bacteria sampling at RM 0.44 indicated full attainment of the PCR Class B use designation.

Little Muchinippi Creek

Little Muchinippi Creek drains 35.5 mi^2 before entering Muchinippi Creek at RM 6.35. Daytime grab D.O. concentrations were relatively stable at the two sites sampled (RMs 6.05 and 0.62) with one value minimally below the WWH average criterion at the downstream site. However, Datasonde® monitoring at RM 0.62 recorded the greatest diurnal variability of the survey (**Figure 18**, **Appendix Tables A-5 and A-6**). Hourly D.O. saturations ranged from 23% to 254% with 53% of concentrations below critical levels (<4.0 mg/l). Similarly, hourly pH (SU) ranged from 7.59 to 8.76 and temperatures ranged from 20.4°C to 28.8°C. Supersaturated D.O. concentrations and wide swings in diel D.O. and pH are indicative of nutrient enrichment. Coincidentally, field crews noted excessive filamentous algae at the site late in the survey. While nitrate-nitrite-N concentrations remained generally low, phosphorus concentrations were elevated above target reference levels at both sampling sites and ammonia concentrations were above target at RM 0.62. Elevated nutrient levels most likely resulted from fertilizer application to farm fields and agricultural runoff from cropland.

Concentrations of iron, copper and lead exceeded water quality criteria at the downstream site on June 26 during exceptionally elevated flows. Bacteria samples from RM 0.62 indicated the PCR Class B use was attained (**Table 11**, **Figure 20**).

Jackson Center Creek

Jackson Center Creek, a small channelized ditch draining 6.86 mi^2, receives effluent from the Jackson Center WWTP (RM 2.17) before entering Little Muchinippi Creek at RM 3.62. Sampling sites bracketed the WWTP at RMs 2.9 and 1.8.

Ammonia-N concentrations were generally low but minimally exceeded water quality criteria at RM 1.8 on August 21. Respective median nitrate-nitrite-N and phosphorus concentrations increased from 0.22 mg/l and 0.089 mg/l at RM 2.9 to 11.10 mg/l and 1.053 mg/l at RM 1.8, downstream from the Jackson Center WWTP.

Excessive algal growth at RM 1.8, exacerbated by an open canopy and nutrient loadings from the Jackson Center WWTP (**Figure 22)**, pushed daytime grab D.O. concentrations to the highest levels of any site in the survey (median saturation 232%). Temperatures were also frequently elevated with two values above water quality criteria (**Table 9**).

Figure 22. Jackson Center Creek RM 1.8, 0.5 miles downstream from the Jackson Center WWTP.

Additionally, the PCR Class B use designation was not attained at RM 1.8. Potential sources of bacteria include general agricultural runoff and Jackson Center's deteriorating wastewater collection system. A gray-water discharge from an apparent home septic tank was also observed at RM 2.9 by the macroinvertebrate sampling crew.

<u>Cherokee Mans Run</u>
Cherokee Mans Run drains 17.7 mi^2 and enters the Great Miami River just below Indian Lake at RM 159.44. Water quality as represented by the two sites sampled (RMs 7.56 and 3.38) was good. Ammonia, nitrate-nitrite, phosphorus, and suspended solids concentrations were low with virtually all values well below reference targets. Dissolved oxygen concentrations remained stable with saturations near 100% at both sites.

<u>Tributary to Great Miami River (RM 157.34)</u>
One site (RM 0.07) was sampled on this small channelized agricultural ditch (drainage area 7.6 mi^2). Dissolved oxygen levels were low (median saturation 58%) with concentrations falling below WWH criteria on occasion. Ammonia-N and phosphorus were consistently elevated above target reference values. Additionally, field crews noted turbidity at the site throughout the summer (median total suspended solids 54 mg/l). Water quality was negatively impacted by the totally open canopy, substrates covered in silt or muck, altered channel, and row crops planted at the stream edge.

<u>Rennick Creek</u>
Rennick Creek drains 10.4 mi^2 including the village of Lewistown before entering the Great Miami River at RM 155.64. One site at RM 0.34 was sampled. Daytime grab D.O. concentrations remained stable (median saturation 81%) and target reference levels for nutrients and other parameters were generally met at the site. However, samples collected from a field tile discharging to the creek from the northeast side of SR 235 on July 17 and August 21 indicate ammonia-N concentrations above the target

value (0.618 mg/l and 0.814 mg/l, respectively). The specific source of ammonia remains unknown. Iron concentrations exceeded water quality criteria on June 26 during exceptionally elevated flows.

Brandywine Creek

Brandywine Creek drains 9.0 mi^2 and enters the Great Miami River at RM 153.95. One site (RM 0.58) was sampled in this channelized agricultural ditch during the 2008 survey and nutrient target reference levels were typically met. Copper, lead, and iron concentrations exceeded water quality criteria on June 26 at the site during exceptionally elevated flows.

Rum Creek

Rum Creek drains 28 mi^2 before entering the Great Miami River at RM 151.33. Daytime grab D.O. concentrations dropped below WWH criteria in the headwaters (RM 8.63) on one occasion with overall median saturations at the three sites sampled ranging from 70% at RM 0.79 to 91% at RM 6.58.

While ammonia-N and nitrate-nitrite were generally below reference values at all sites in this agricultural stream, phosphorus and TSS concentrations at RMs 8.63 and 6.58 were elevated above target. Channelization, minimal woody riparian buffer, and silty substrates in this upper reach all contribute to diminished water quality. As in other parts of the upper Great Miami River watershed that experienced the high flows of June 26, copper and lead concentrations exceeded water quality criteria at RM 0.79 and iron exceeded criteria at all three sites.

Bacteria samples collected at RM 0.79 indicate the PCR Class B use was not attained (**Table 11, Figure 20**). Potential sources of bacteria include general agricultural runoff and unrestricted livestock access (horses) in the immediate vicinity.

Bokengehalas Creek

Bokengehalas Creek drains 41.4 mi^2 including the City of Bellefontaine before entering the Great Miami River at RM 145.98 near DeGraff. Stream flows from May through September 2008 as measured by the USGS gage station near DeGraff are presented in **Figure 23** (USGS 2008 and 2000). The median mean daily flow for the three month period May through July (47.5 cfs) exceeded the 10% duration exceedence flow of 46 cfs. The 10% duration exceedence flow represents the discharge which was equaled or exceeded only 10% of the time over the period of record. In contrast, median mean daily flow from August through September (11 cfs) was less than the 50% duration flow of 13 cfs. On specific water chemistry sampling days, mean daily flows ranged from 8.5 cfs on September 24 to 38 cfs on June 25. On bacteria sampling days, mean daily flows ranged from 9.8 cfs on September 4 to 24 cfs on September 9.

Daytime grab D.O. levels were quite stable longitudinally with median saturations at the three sites sampled ranging from 101% at RM 1.13 to 108% at RM 4.61. D.O. concentrations minimally dropped below WWH criteria at RM 7.88 late in the survey on September 24 reflecting diminishing flows. All hourly D.O. concentrations measured at

RM 1.13 from September 3-5, 2008 with a continuous monitor remained well above critical levels (4.0 mg/l) with minimal diurnal variability (**Figure 18**).

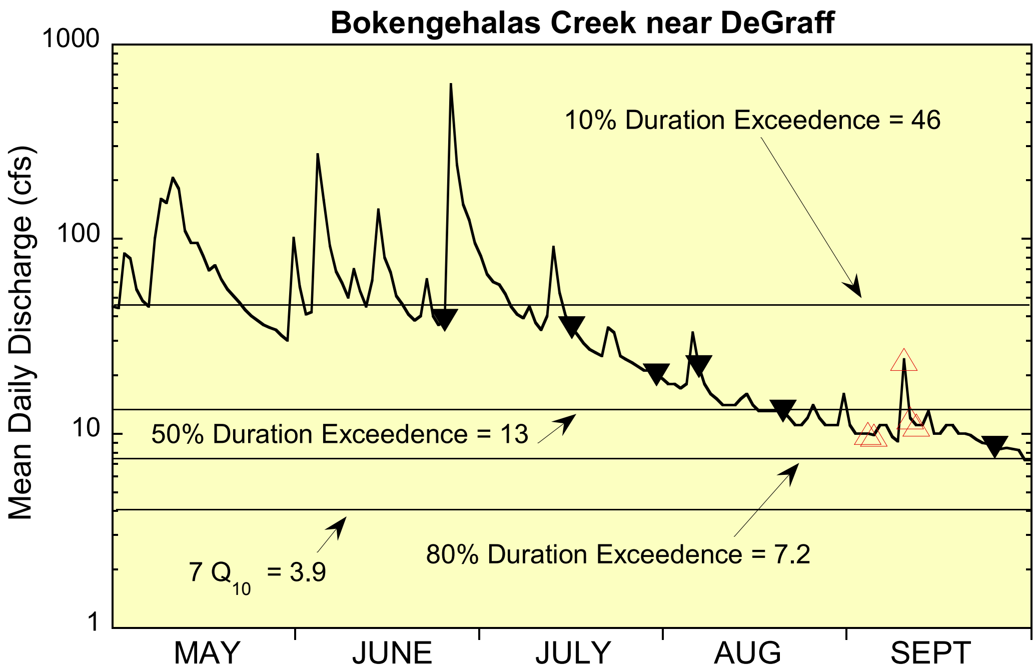


Figure 23. May through September, 2008 flow hydrograph for Bokengehalas Creek near DeGraff (USGS station #03260706). Solid triangles indicate river discharge on water chemistry sampling days in the Bokengehalas Creek watershed. Open triangles indicate river discharge on bacteriological sampling days. (Duration exceedence and $7Q_{10}$ flow lines represent May-Nov period of record 1957-1991.)

Ammonia-N and nitrate-nitrite-N remained low at each of three Bokengehalas Creek sites sampled at RMs 7.88, 4.61, and 1.13. In contrast, phosphorus concentrations downstream from Blue Jacket Creek at RM 4.61 reflected the sustained impact of the Bellefontaine WWTP, located over eight miles upstream (**Figure 8**). Concentrations remained elevated above target reference values downstream to RM 1.13. The median phosphorus concentration at the upstream site (RM 7.88) was 0.011 mg/l compared to 0.186 mg/l downstream from Blue Jacket Creek.

One site (RM 1.13) was sampled for organic compounds twice during the survey. Five compounds were detected including δ-hexachlorocyclohexane, bis(2ethylhexyl)-phthalate, diethylphthalate, metolachlor, and simazine (**Table 12, Appendix Table A-2**). Bis(2ethylhexyl)-phthalate and diethylphthalate are plasticizers. The remaining contaminants originate from pesticide application to cropland in the watershed.

Bokengehalas Creek bacteria sampling in 2008 (RMs 7.88 and 1.13) and 2009 (RM 1.13) indicated the PCR Class B use designation was not attained (**Table 11**, **Figure 20**). Agricultural runoff may have impacted both sites while runoff from the Village of DeGraff was also a potential source of bacteria at the downstream location (RM 1.13).

On July 30, 2008 field crews observed a large number of dead and dying crayfish in Bokengehalas Creek at the upstream sampling location (RM 7.88). The area impacted extended more than four miles upstream from the SR 47 bridge (RM 7.32) to approximately RM 11.8. Further investigation revealed that drift from the aerial application of Headline® Fungicide and Mustang Max® to corn crops adjacent to the stream caused the massive kill (>12,000 crayfish as well as other invertebrates). Headline® Fungicide, manufactured by BASF, contains pyraclostrobin. The active ingredient in Mustang Max®, a pyrethroid insecticide manufactured by FMC Corp/Agri Products, is zeta-cypermethrin. Both chemicals are acutely toxic to aquatic organisms.

Blue Jacket Creek

Blue Jacket Creek drains 14.1 mi^2 and enters Bokengehalas Creek at RM 7.01. Opossum Run, a small tributary, receives the Bellefontaine WWTP discharge at RM 0.5 before entering Blue Jacket Creek at RM 5.80.

Daytime grab D.O. concentrations and saturations in Blue Jacket Creek were relatively stable longitudinally at the three sites sampled. Additionally, continuous monitors placed at RM 5.39 downstream from the Opossum Run confluence in both 2008 (September 3-5) and 2009 (June 23-25) indicated normal diurnal variation (**Figure 18**, **Appendix Tables A-5 - A-7**).

Reflecting the impact of nutrient loading from the Bellefontaine WWTP, nitrate-nitrite-N and phosphorus concentrations spiked downstream from the Opossum Run confluence and remained elevated to the mouth (**Table 10**). The median phosphorus concentration for Blue Jacket Creek samples collected downstream from Opossum Run (RMs 5.39 and 0.72) was 0.832 mg/l compared to a median of 0.014 mg/l at the upstream site (RM 6.31). Phosphorus levels were sustained and delivered into Bokengehalas Creek where concentrations remained well above target reference levels to the mouth.

Blue Jacket Creek (RM 5.39) was sampled twice organic compounds during the survey. Compounds detected included the plasticizer bis(2-ethylhexyl)-phthalate, the persistent insecticide Lindane and its isomer δ-hexachlorocyclohexane, and chloroform, a byproduct of the wastewater disinfection process (**Table 12**, **Appendix Table A-2**). The USEPA gradually began restricting the agricultural use of Lindane in the 1970s due to concerns over its effects on human health and the environment. By 2002, its use was limited to seed treatments and in 2007 these last uses were cancelled.

Bacteria samples from RM 5.39 indicate the PCR Class B use designation was not attained in 2008 (**Table 11**, **Figure 20**). Potential sources of bacteria include general agricultural runoff, and urban runoff from the City of Bellefontaine.

Stony Creek, McKees Creek, Lee Creek, and Graves Creek

Stony Creek drains 62.4 mi^2 and enters the Great Miami River at RM 145.56 south of DeGraff (**Figure 8**). Sampling in this small watershed included two sites on Stony

Creek (RMs 2.45 and 1.58) plus its tributaries McKees Creek (RMs 9.5, 5.94, and 0.52), Lee Creek (RM 3.35), and Graves Creek (RM 0.48).

Daytime grab D.O. levels at the seven sites sampled were remarkably stable with median D.O. saturations ranging from 89% in Lee Creek to 110% in McKees Creek (RM 0.52). One aberrant concentration in McKees Creek at RM 5.94 fell below critical levels (**Table 9**). A continuous monitor deployed in Stony Creek at RM 1.58 (September 3-5) recorded moderate D.O. diurnal variability with all concentrations well above critical levels (**Figure 18**). Notable diurnal temperature variation occurred with hourly temperatures ranging from 18.7°C to 25.9°C.

While nitrate-nitrite-N concentrations in McKees Creek were minimally elevated above the EWH target reference level, nutrient levels throughout the Stony Creek watershed were quite low with concentrations typically well below reference targets (**Table 10**). The overall median nitrate-nitrite-N concentration for the entire Stony Creek watershed was 1.39 mg/l while the median phosphorus concentration was only 0.017 mg/l.

Bacteria sampling at three sites in the watershed (Stony Creek RM 1.58, McKees Creek RM 0.52, and Graves Creek RM 0.48) indicated non-attainment of the PCR Class B use designation (**Table 11, Figure 20**). Potential sources include agricultural runoff and the unsewered community of Springhills in the headwaters of Graves Creek.

<u>Indian Creek</u>

Indian Creek drains 15.9 mi^2 and enters the Great Miami River at RM 140.14. One site near the mouth (RM 0.01) was sampled in this tributary during the 2008 survey. Daytime grab D.O. levels were stable with a median saturation of 98%. Nutrient levels were low with virtually all concentrations well below target reference values. However, bacteria sampling indicated non-attainment of the PCR Class B use designation. Potential sources of bacteria include the unsewered community of Pemberton and general agricultural runoff.

<u>Plum Creek</u>

Plum Creek drains 29 mi^2 before entering the Great Miami River at RM 132.07 northeast of Sidney. Unnamed tributaries in the watershed receive discharges from the Northbrook mobile home park (MHP) and the Honda facility south of Anna (**Figure 8**).

While daytime grab D.O. saturations at downstream sites (RMs 5.22 and 0.13) were typically near 100%, saturations in the headwaters at Meranda Rd (RM 9.00) varied widely from 38% to 165% during the summer. D.O. concentrations at the site dropped below critical levels (< 4.0 mg/l) on one occasion. The stream in this area is an open grassy channel with minimal woody riparian buffer. Nutrient levels throughout Plum Creek were generally low with median phosphorus concentrations at RM 9.00 minimally elevated above target reference levels (**Table 10**). Bacteria sampling at RM 0.13 indicated non-attainment of the PCR Class B use designation (**Table 11, Figure 20**). Potential sources of bacteria include agricultural runoff.

Loramie Creek Watershed

Inorganic water chemistry grab samples were collected at 24 sites in the watershed in 2008, including 10 sites from the mainstem of Loramie Creek (**Table 1**). Nine sites were also sampled for organic compounds twice during the summer survey (**Appendix Tables A-2**). Bacteria samples (*E. coli*) were collected at 15 sites in 2008 and three sites in 2009 (**Table 11**, **Figure 29, Appendix Tables A-3 - A-4**). Additionally, continuous monitors recorded hourly D.O., temperature, pH, and specific conductivity for a 48-hour period at seven sites in 2008 and eleven sites in 2009 (**Figure 25, Figure 26**, **Appendix Tables A-5 - A-7).**

Loramie Creek

Stream flows from May through September 2008 measured at USGS gage stations in Loramie Creek near Newport and Lockington are presented in **Figure 24** (USGS 2008 and 2000). With the exception of late July, mean daily flows in the first three months of the period were well above 50% (median) duration and 32% of flows at both gages exceeded 10% duration. Flows dropped off in August and September with virtually all mean daily flows below median duration and falling near 80% duration at both gages. Duration exceedence flows represent the discharge which was equaled or exceeded that percentage of the time over the period of record. On specific water chemistry sampling days in the Loramie Creek watershed mean daily flows at Newport ranged from 2.2 cfs (September 23) to 504 cfs (July 15). Flows at the Lockington gage ranged from 11 cfs (August 19) to 706 cfs (July 15) on the same dates. On bacteria sampling days the mean daily flow at Newport ranged from 2 cfs (September 3) to 9.4 cfs (September 9) while flows at Lockington ranged from 7.3 cfs to 20 cfs.

Daytime grab D.O. concentrations in Loramie Creek dropped below water quality criteria at several sites in 2008, most notably downstream from the Lake Loramie spillway at RM 22.1 (**Table 9**, **Figure 27**). Flows at the site became progressively lower as the summer progressed (**Figure 3**). Hourly D.O. saturations at RM 22.1 measured with a continuous monitor the following year (July 7-9, 2009) ranged from 1% to 176% with 73% of concentrations below critical levels (< 4.0 mg/l). Datasonde® monitoring in 2009 also documented supersaturated D.O. levels and exceptionally wide swings in diel D.O. at downstream sites in Loramie Creek (**Figure 25**, **Figure 26**). The highest median Datasonde® D.O. saturation was measured at Cardo Roman Rd. (RM 16.51) in both 2008 (133%) and 2009 (278%). Supersaturated D.O. concentrations and wide swings in diel D.O. and pH are indicative of nutrient enrichment.

Regarding nutrients, median ammonia-N concentrations were elevated above target at several sites in the upper reaches of Loramie Creek (RMs 34.93-18.82). Phosphorus concentrations were elevated well above target reference levels throughout Loramie Creek with a median of 0.34 mg/l for all samples upstream from the Miami-Erie Canal, compared to 0.50 mg/l at all sites downstream (**Figure 28**). Concentrations of nitrate-nitrite (median 13.55 mg/l) and total phosphorus (median 5.81 mg/l) spiked at RM 20.7, immediately downstream from the Miami-Erie Canal (Minster WWTP RM 1.8) and the Lake Loramie WWTP (RM 21.1).

Phosphorus loading from nonpoint sources in Mile Creek (confluence RM 19.46) also contributed to the enriched conditions in lower Loramie Creek as nutrient concentrations within this reach were among the highest in the survey (**Table 10**). Field crews often observed extensive algae mats (**Figure 2**) and surface scums (**see photo at right**) in lower Loramie Creek associated with the hypertrophic conditions. Open canopies and elevated water temperatures accentuated the negative impact of heavy nutrient loading from agriculture and municipal wastewater dischargers in the basin (*e.g.,* Lake Loramie, Minster). Total suspended solids also increased downstream from the Mile Creek confluence and remained elevated well above target reference levels for several miles downstream (**Figure 27**).

Loramie Creek @ Cardo-Roman Rd (RM 16.51) July 8, 2008

Specific conductivities and total dissolved solids were also elevated above water quality criteria at several sites in Loramie Creek, typically in the vicinity of wastewater treatment plants. Some of the highest levels in the survey occurred intermittently downstream of the Botkins WWTP at Lock Two Rd (RM 34.96). Exceptionally elevated chloride concentrations were also associated with the same samples (**Appendix Tables A-1**). Detection of these sporadically elevated parameters suggests impairments linked to batch discharges from the local water treatment plant via the Botkins WWTP.

Five Loramie Creek sites were sampled for organic compounds twice during the summer survey (**Table 12**, **Appendix Table A-2**). Among the 12 organic compounds detected, the most frequent were metolachlor, acetochlor and the plasticizer bis(2-ethylhexyl)phthalate. Concentrations of the legacy insecticide dieldrin (RM 30.42) exceeded water quality criteria on one occasion. The application of pesticides to crops is the most likely source of most of these contaminants.

Bacteria sampling in Loramie Creek in 2008 (**Table 11**) indicated the primary contact recreation use was only attained at two of eight sites (RM 36.84 and RM 16.51). Results from additional sampling in 2009 at RM 16.51 and RM 1.87 were mixed with full attainment at RM 16.51 and non-attainment at RM 1.87 (**Figure 29**). Possible sources of bacteria include general agricultural runoff, animal feedlots, sanitary sewer overflows from Minster, and wildlife (*e.g.,* waterfowl on Lake Loramie).

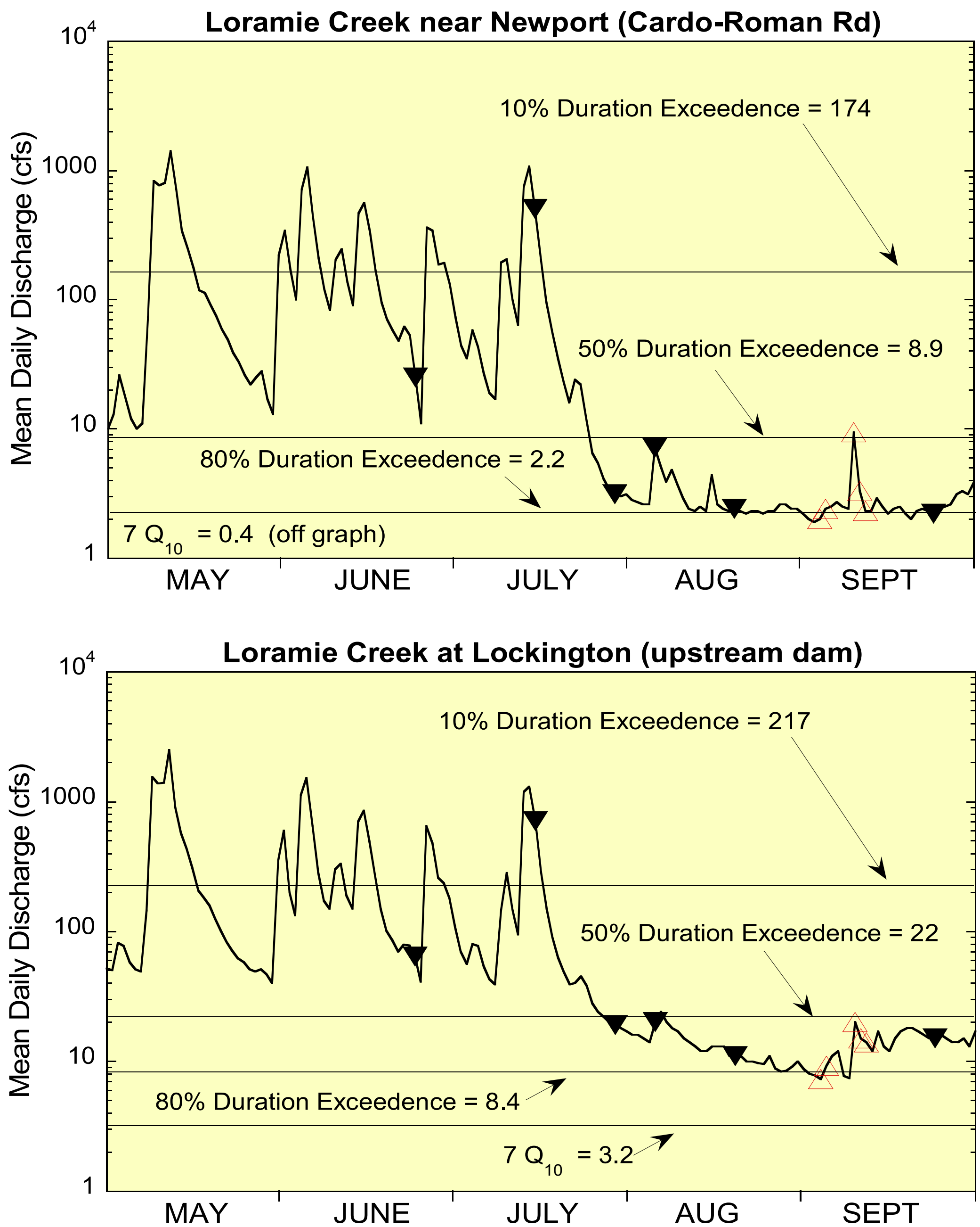


Figure 24. May through September, 2008 flow hydrographs for Loramie Creek near Newport (USGS station #03261950) and Loramie Creek at Lockington (USGS station #03262000). (Duration exceedence and $7Q_{10}$ flow lines represent May-Nov 1964-1997 period of record for Newport gage and 1915-1997 for Lockington gage.) Solid triangles indicate river discharge on water chemistry sampling days in the Loramie Creek watershed. Open triangles indicate river discharge on bacteriological sampling days.

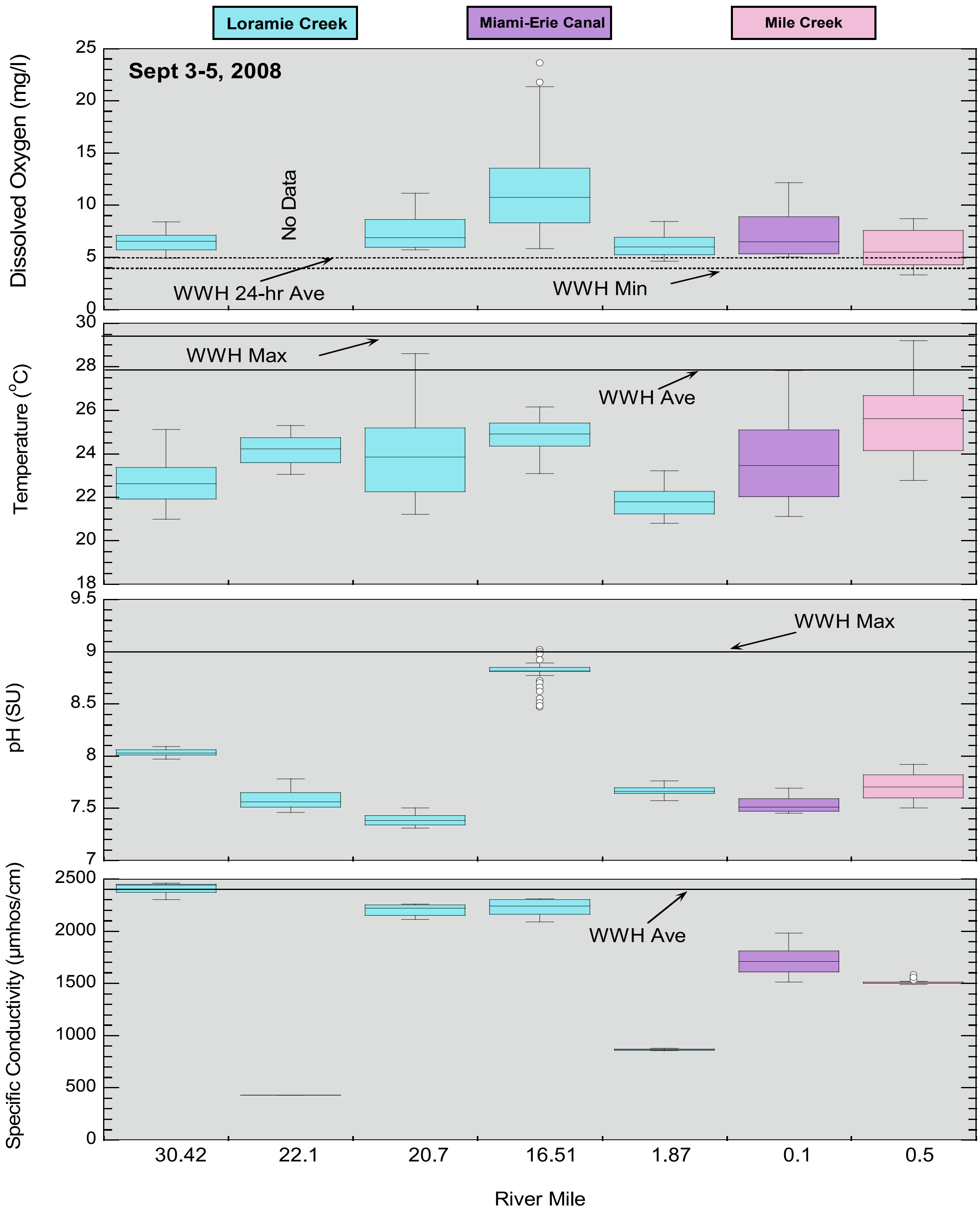


Figure 25. Dissolved oxygen, temperature, pH, and specific conductivity recorded hourly with Datasonde® continuous monitors in Loramie Creek, the Miami-Erie Canal, and Mile Creek September 3-5, 2008. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Values outside of this range are displayed as individual points.)

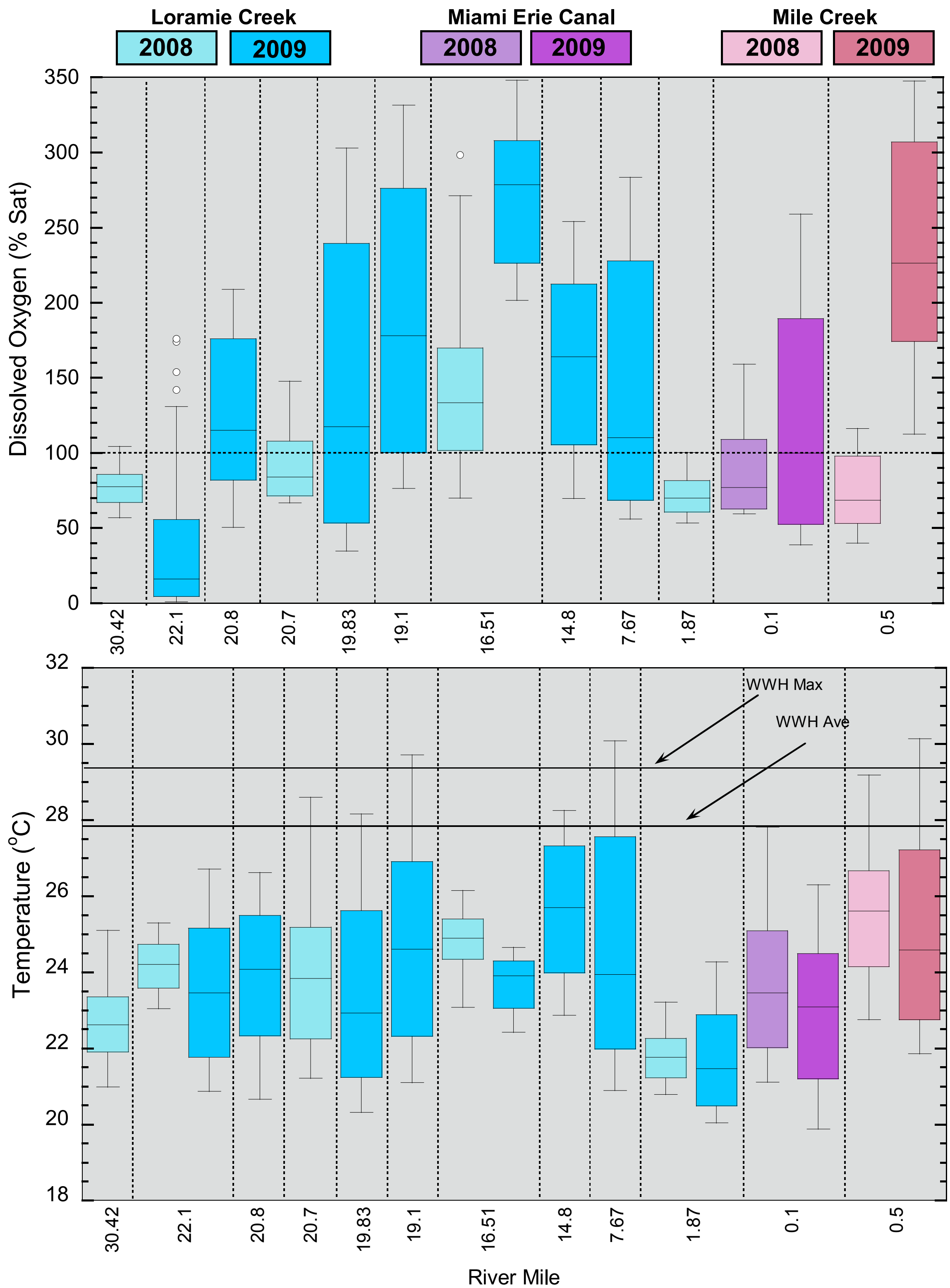


Figure 26. Dissolved oxygen saturation and temperature recorded hourly with Datasonde® continuous monitors in Loramie Creek, the Miami-Erie Canal, and Mile Creek September 3-5, 2008 and July 7-9, 2009.

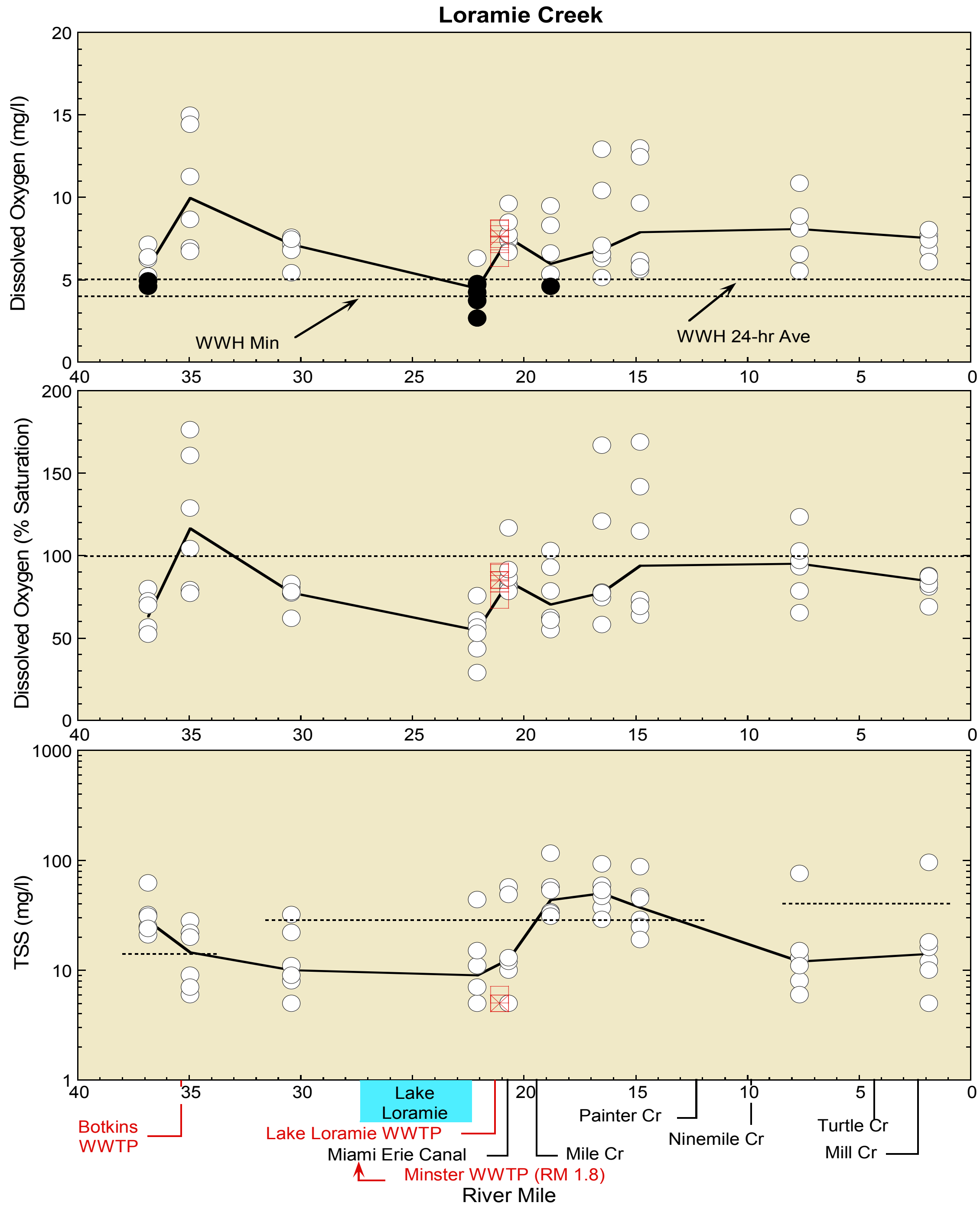


Figure 27. Longitudinal scatter plots of daytime grab dissolved oxygen concentration, D.O. percent saturation, and total suspended solids (TSS) in Loramie Creek (circles) and one WWTP (squares) during 2008. The solid line depicts the median value at each river mile sampled while an "X' depicts the median at the WWTP. Water quality criteria are shown in the D.O. concentration plot. (Values not meeting criteria are shown as solid circles.) Dashed horizontal lines in the TSS plot represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

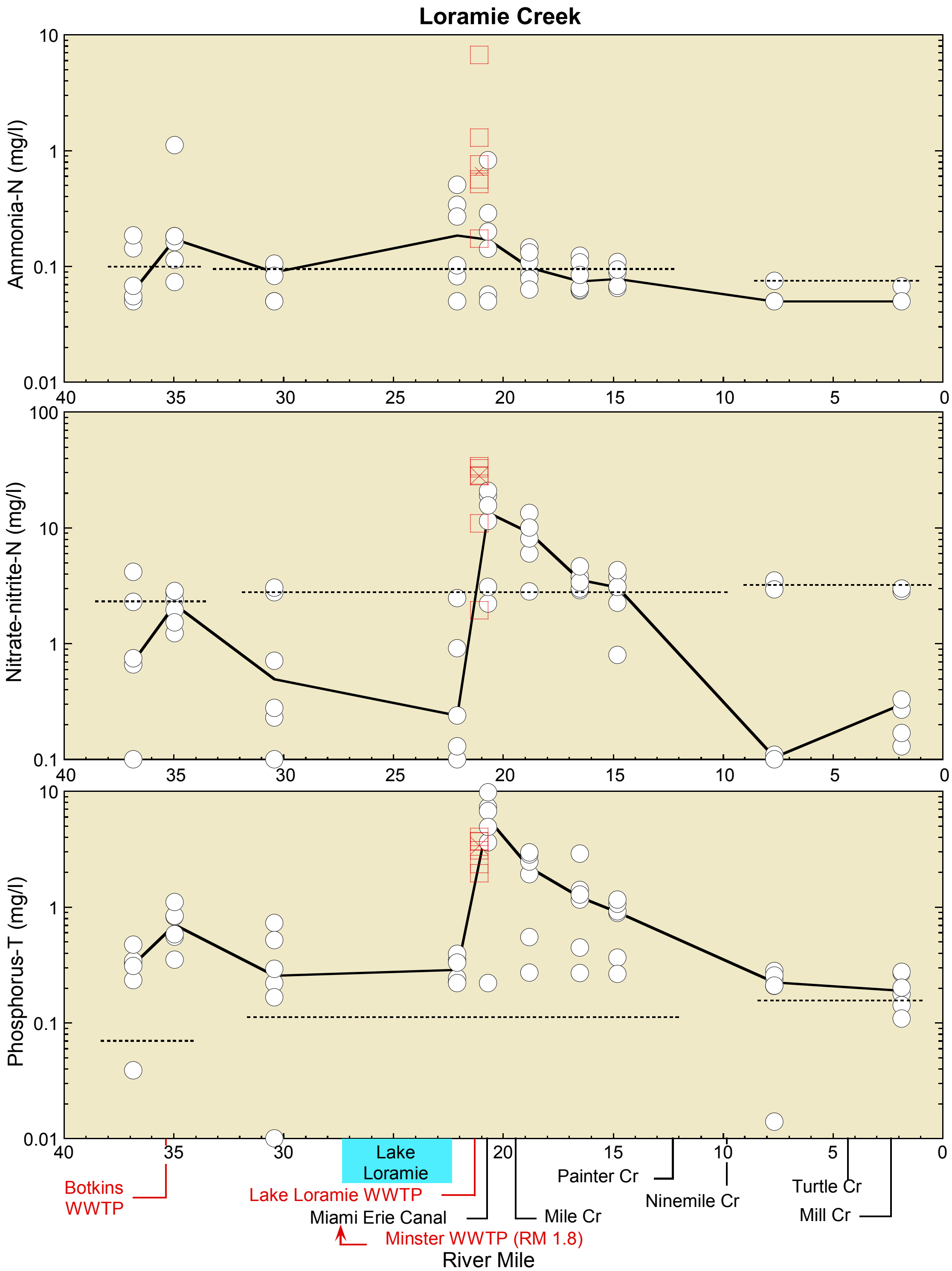


Figure 28. Longitudinal scatter plots of ammonia-N, nitrate-nitrite-N, and total phosphorus in Loramie Creek (circles) and one WWTP (squares) during 2008. The solid line depicts the median value at each river mile sampled while an "X' depicts the median at the WWTP. Dashed horizontal lines represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

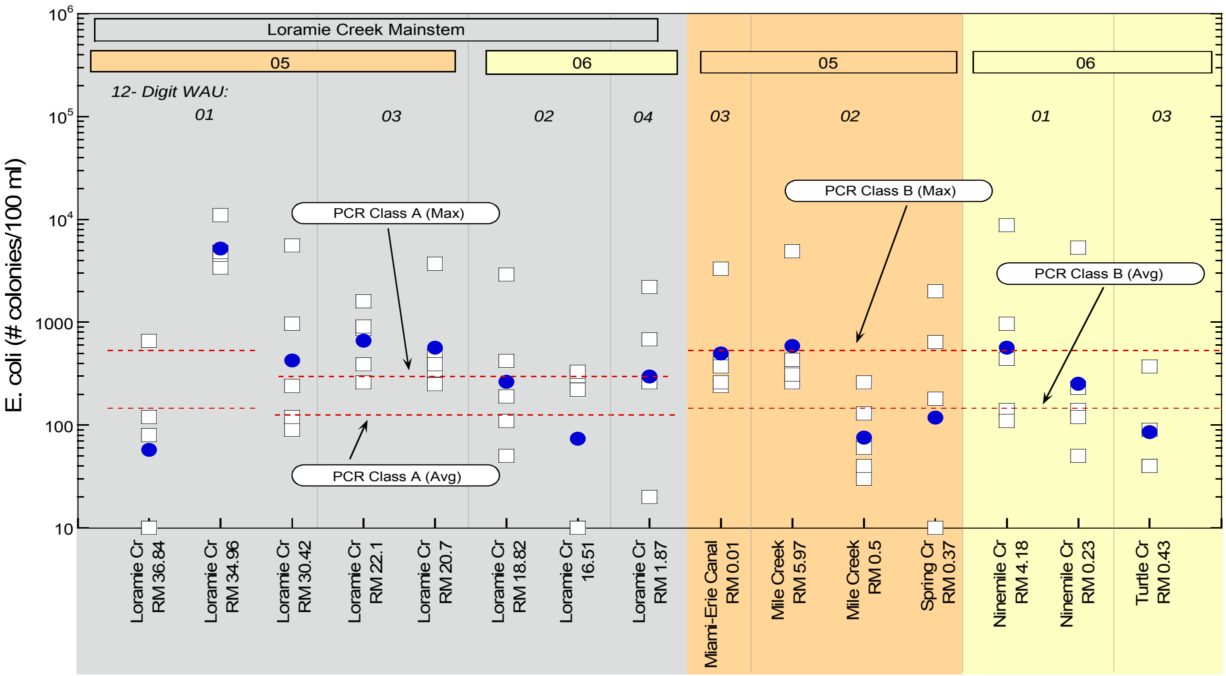


Figure 29. Scatter plots of *E. coli* concentrations in the mainstem of Loramie Creek and select tributaries during the 2008 survey (HUC 05080001-05 and -06). The 10-digit HUC is provided in the enclosed boxes near the top of the graphic. Dotted lines represent primary contact recreation (PCR) use water quality criteria. Solid circles represent the geometric mean at each site sampled.

Miami-Erie Canal

Completed in 1845, the original Miami-Erie Canal connected the Ohio River near Cincinnati with Lake Erie near Toledo and consisted of 301 miles of channel. The canal system had largely ceased to operate by 1906. Today the portion of the Miami-Erie Canal in southern Auglaize and northern Shelby counties drains approximately 4.3 mi^2 and enters Loramie Creek north of Fort Loramie at RM 20.78. It is the receiving stream for several dischargers in Minster including the Minster Machine Company (RM 2.58), BP Oil Company-Minster Bulk Plant (RM 2.2), The Dannon Company (RM 2.0), and the Village of Minster's WWTP (RM 1.8). During the 2008 survey, samples were collected near the mouth of the canal (RM 0.01).

Daytime grab D.O. levels at the mouth were relatively stable in 2008 (median saturation 93%). Continuous monitors placed near the mouth indicated greater diurnal variability in 2009 compared to 2008 (**Figure 26, Appendix Tables A-5 - A-7**) with D.O. saturations ranging from 59% to 159% in 2008 (Sept 3-5) compared to 39% to 259% in 2009 (July 7-9). Conductivity and total dissolved solids exceeded water quality criteria in grab samples on one occasion (**Table 9**). The highest nutrient levels of the survey were measured at the mouth of the Miami-Erie Canal downstream from the Minster WWTP with median nitrate-nitrite-N and total phosphorus concentrations of 14.20 mg/l and 8.10 mg/l, respectively (**Table 10**). The impact of nutrient loading from the Minster WWTP was evident well downstream into Loramie Creek.

Organic compounds detected at the canal mouth include δ-hexachlorocyclohexane, bis(2-ethylhexyl)phthalate, and 2,4-D (**Table 12**, **Appendix Table A-2**). Additionally, bacteria samples indicate the PCR Class B use designation was not attained (**Table 11, Figure 29**). Potential sources of bacteria include general agricultural and urban runoff, and possible sanitary sewer overflows from the Minster collection system.

Mile Creek

Mile Creek, the largest Loramie Creek tributary, is deeply channelized in its entirety (11.8 miles) and drains 62.7 mi^2 before entering Loramie Creek at RM 19.46, south of Fort Loramie. In addition to extensive cropland, the watershed contains numerous animal livestock operations (predominately swine and poultry). Four sites were sampled in 2008 at RMs 9.8, 8.74, 5.97 and 0.5.

Indicative of nutrient enrichment, daytime grab D.O. routinely reached supersaturated levels at the three upstream sites in Mile Creek (**Figure 30**) with medians ranging from 138% (RM 5.97) to 183% (RM 8.74). Daytime grab pH measurements were also elevated in the headwaters, exceeding water quality criteria twice at RM 9.8 (Goettemoeller Rd.). Additionally, total dissolved solids and conductivity were elevated above water quality criteria at both RMs 9.8 and 5.97 on September 23.

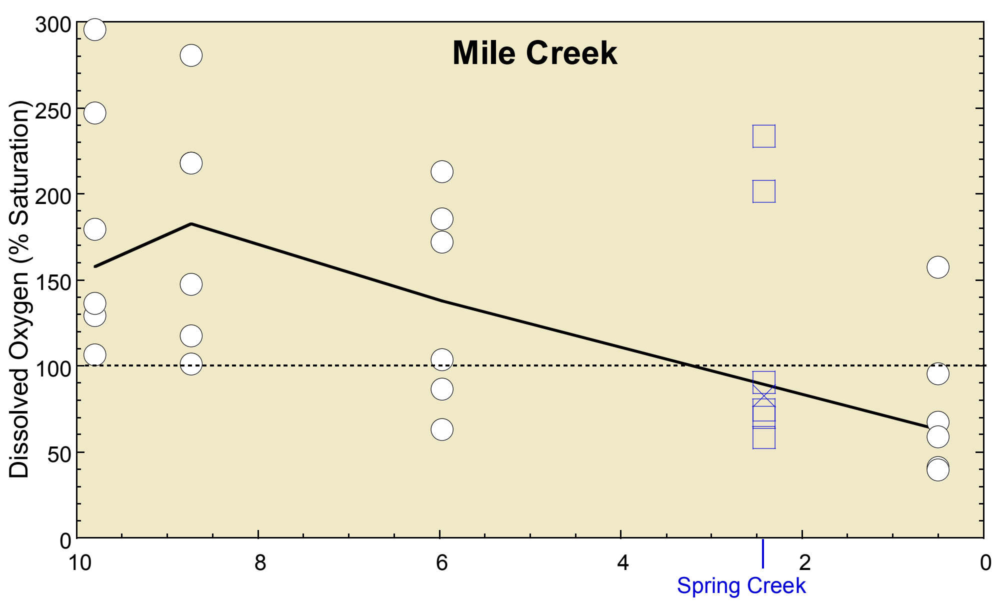


Figure 30. Longitudinal scatter plot of daytime grab dissolved oxygen percent saturation in Mile Creek (circles) and Spring Creek (squares) during 2008. The solid line depicts the median value at each river mile sampled in Mile Creek while an "X' depicts the median in Spring Creek.

Downstream at RM 0.5, daytime grab D.O. concentrations fell below critical levels (<4.0 mg/l) twice during the survey (**Table 9**). A continuous monitor (September 3-5) also measured low levels of D.O. at the site (median saturation 68%). Water temperatures were consistently elevated and exceeded water quality criteria throughout Mile Creek (**Figure 31, Table 9).** Out of all 21 continuous monitors deployed in 2008, the highest median temperature (25.61°C) was measured at Mile Creek RM 0.5 (**Figure 25**).

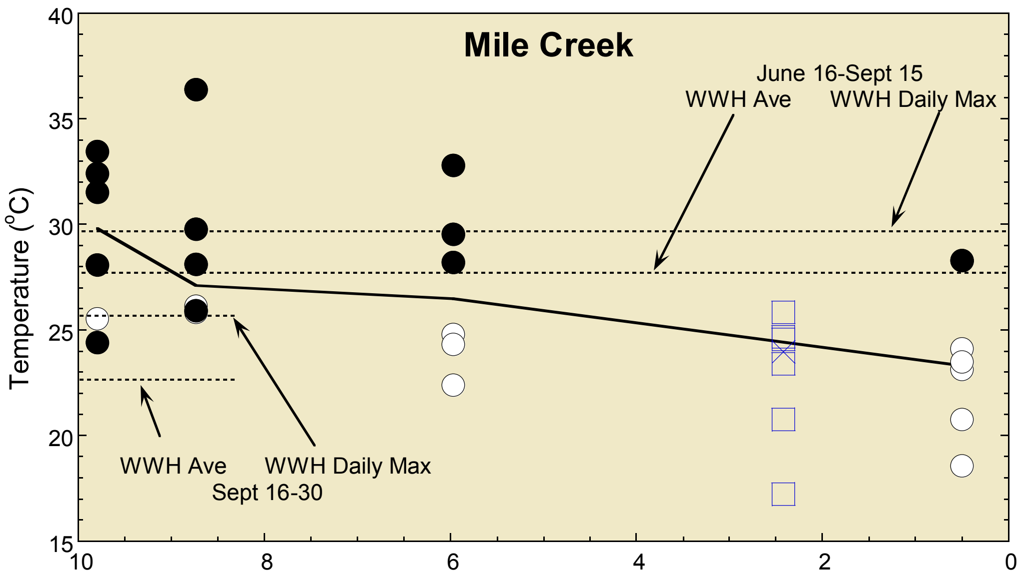


Figure 31. Longitudinal scatter plot of daytime grab temperatures (°C) in Mile Creek (circles) and Spring Creek (squares) during 2008. The solid line depicts the median value at each river mile sampled in Mile Creek while an "X' depicts the median in Spring Creek. Water quality criteria are shown as dashed horizontal lines. (Solid circles are not meeting water quality criteria)

Total suspended solids were frequently elevated above target at the two lower Mile Creek sites (RMs 5.97 and 0.5) compared to upstream (RMs 9.8 and 8.74). Median TSS concentrations increased longitudinally from 10 mg/l to 45 mg/l, respectively.

While ammonia-N was generally below target reference values, concentrations exceeded water quality criteria at RM 5.97 on August 5 (2.13 mg/l). Phosphorus concentrations were consistently elevated above target reference values throughout Mile Creek with medians ranging from 0.295 mg/l at RM 9.8 to 0.528 mg/l at RM 5.97 (**Table 10**). Field crews observed extensive algae in Mile Creek throughout the survey. Open canopies, elevated water temperatures, and minimal woody riparian buffer accentuated the negative impact of nutrient loading from agriculture and the numerous animal feedlots in the watershed.

One site in Mile Creek (RM 0.5) was sampled for organic compounds twice during the summer survey (**Table 12**, **Appendix Table A-2**). Six organic compounds were detected including the pesticides acetochlor, atrazine, metolachlor, α-hexachlorocyclo-hexane, and dieldrin, and the plasticizer bis(2-ethylhexyl)phthalate. Concentrations of dieldrin exceeded water quality criteria on one occasion. As in other areas of the upper

GMR watershed, pesticide application to crops was the likely source of most contaminants.

Bacteria samples were collected at RMs 5.97 and 0.5 in 2008. Results were mixed with non-attainment of the PCR Class B use upstream at RM 5.97 and full attainment at RM 0.5. Possible sources of bacteria include animal feedlots, general agricultural runoff, and the unsewered communities of Osgood, Yorkshire, and North Star.

<u>Spring Creek</u>

Spring Creek, a channelized agricultural ditch, drains 9.1 mi^2 and enters Mile Creek at RM 2.42. Samples were collected at one site (RM 0.37) during the survey. Daytime grab D.O. saturations varied widely from 59% to 234% (**Figure 30**). While ammonia and nitrate-nitrite concentrations were generally low, total phosphorus concentrations were typically elevated above target reference values (median 0.174 mg/l). There were no exceedences of water quality criteria. Bacteria samples collected at the site indicate the PCR Class B use was attained (**Table 11, Figure 29**).

<u>Ninemile Creek</u>

Ninemile Creek drains 26.6 mi^2 and enters Loramie Creek at RM 9.89. A small unnamed tributary receives the discharge from the Russia WWTP at RM 0.02 before entering Ninemile Creek at RM 5.02 and Houston High School discharges at RM 1.00. Three sites were sampled in the tributary at RMs 6.38, 4.18, and 0.23.

Dissolved oxygen saturations in Ninemile Creek were relatively low with medians ranging from 61% (RM 4.18) to 85% (RM 0.23). Daytime grab D.O. concentrations dropped below water quality criteria at RMs 6.38 and 4.18 (**Table 9**) during the latter part of the survey due to stagnant flows. Total suspended solids were consistently elevated at the headwater site at Miller Rd. (RM 6.38) upstream of the Village of Russia (median 65 mg/l). This upstream section of the creek is an extensively channelized agricultural ditch with no woody riparian and a mucky substrate. Nutrients were typically below target reference values at all sites (**Table 10**).

Bacteria samples collected at RMs 4.18 and 0.23 indicate the PCR Class B use designation was not attained (**Table 11, Figure 29**). Potential sources of bacteria include agriculture and urban runoff.

<u>Turtle Creek</u>

Turtle Creek drains 36 mi^2 and enters Loramie Creek at RM 4.12. Several small dischargers in the watershed include Hardin Elementary, Dorothy Love Retirement Center, and Miami River Stone (**Figure 10**). While daytime grab D.O. levels in Turtle Creek were relatively stable longitudinally at the three sites sampled (RMs 8.42, 5.66, and 0.43); concentrations fell below water quality criteria on occasion at the two upstream sites (**Table 9**). No other water quality criteria exceedences were detected.

Ammonia-N concentrations, while generally low, nearly exceeded water quality criteria on June 24 at RM 8.42 (0.543 mg/l) and at RM 5.66 (1.8 mg/l). Nitrate-nitrite-N concentrations were also elevated well above target reference values at these two sites on both June 24 and July 15. Phosphorus concentrations at both upper sites were also elevated above target throughout most of the survey (**Table 10**). This upper reach of Turtle Creek is impacted by nutrient enrichment, siltation and habitat modification associated with agriculture. Bacteria sampling at RM 0.43 indicated the PCR Class B use was attained (**Table 11, Figure 29**).

Sentinel Site Monitoring Program

Typically, Ohio EPA sampling occurs within the critical low flow period of the year during the summer season when the attainment status for biological water quality criteria can be assessed. However, recognizing the impact of non-point pollution sources on streams and the lack of water chemistry data available under varying flow and seasonal conditions, Ohio EPA developed a “sentinel site” approach in an effort to develop data sets over an annual period of varying climatic and flow conditions. In addition to assisting in the analysis of causes and sources of any observed non-attainment, the resulting data set supports water quality modeling efforts for pollutants where total maximum daily loads (TMDLs) may be necessary.

Sentinel site selection is based on several factors including proximity to the watershed boundary, drainage area size (≥ 20 mi^2), and varying land use (urban, agricultural, etc). If possible, locations are selected that have USGS flow stations. Typically, however, bridge to water measurements are taken at each site using a weighted tape in conjunction with periodic in-stream flow measurements in order to develop predictive gage height to stream flow relationships.

Nine sites sampled during the intensive summer survey (June 24 - September 25) in the UGMR watershed were also sampled throughout the year as part of the sentinel site program. Results for select parameters are presented in **Table 13**.

Table 9. Exceedences of Ohio EPA Water Quality Standards (WQS) (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the upper Great Miami River study area during the summer of 2008 (units are µg/l for metals and organics, C° for temperature, SU for pH, µmhos/cm for specific conductivity, and mg/l for all other parameters).

Stream (use designation [b])		**Parameter (value)**
12-digit WAU [a]	**River Mile**	
Great Miami River ***- Quincy dam (RM 143.4) to Pasco-Montra Rd (RM 134.8): (EWH, PCR, AWS, IWS)*** ***- RM 130.2 (EWH, PCR, AWS, IWS, PWS)*** ***-All other segments (WWH, PCR, AWS, IWS)***		
03-02	157.22	Dissolved oxygen (3.96‡‡) Iron-T (7600∞)
03-06	153.45	Dissolved oxygen (4.26‡, 4.83‡, 4.49‡, 3.79‡‡) Iron-T (17300∞) Copper-T (14.3*) Lead-T (12.9*)
03-06	146.19	Iron-T (18300∞) Copper-T (12.8*) Lead-T (12.8*) Dieldrin (0.0021#)
07-03	129.99	bis(2-Ethylhexyl)phthalate (33.1*■)
North Fork Great Miami River (WWH, PCR, AWS, IWS)		
01-01	10.7	Dissolved oxygen (4.51‡)
Van Horn Creek (WWH, PCR, AWS, IWS)		
01-03	0.97	Dissolved oxygen (4.29‡,2.02‡‡) Iron-T (6530∞) Dieldrin (0.0023#)
Muchinippi Creek (WWH, PCR, AWS, IWS)		
02-02	12.98	Dissolved oxygen (4.94‡, 4.02‡,3.32‡‡)
02-02	12.5	Dissolved oxygen (4.95‡, 4.42‡,2.89‡‡) Iron-T (7050∞)
02-04	7.4	Dissolved oxygen (4.72‡ , 4.10‡) Iron-T (8240∞)
02-04	4.76	Dissolved oxygen (3.71‡‡) Iron-T (12600∞)
02-04	2.37	Dissolved oxygen (4.47‡ , 4.25‡ , 4.05‡,3.10‡‡) Iron-T (13300∞) Copper-T (10.4*) Lead-T (8.8*)
02-04	0.32	Dissolved oxygen (3.43‡‡, 3.76‡‡, 2.28‡‡) Iron-T (14500∞) Copper-T (12.9*) Lead-T (11.1*)
Willow Creek (WWH, PCR, AWS, IWS)		

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
02-01	3.7	Dissolved oxygen (4.01‡)
02-01	0.44	Dissolved oxygen (4.01‡) Iron-T (7680∞)
Little Muchinippi Creek (WWH, PCR, AWS, IWS)		
02-03	6.05	Iron-T (6020∞)
02-03	0.62	Dissolved oxygen (4.94‡) Iron-T (14400∞) Copper-T (11.7*) Lead-T (9.8*)
Jackson Center Creek (WWH, PCR, AWS, IWS)		
02-03	1.8	Temperature (23.77*, 29.15*) Ammonia-N (0.107*) Iron-T (6070∞)
Tributary to Great Miami River (RM 157.34) (Undesignated)		
03-02	0.07	Dissolved oxygen (4.62‡ ,4.90‡)
Rennick Creek (Undesignated)		
03-02	0.34	Iron-T (13700∞)
Brandywine Creek (WWH, PCR, AWS, IWS)		
03-06	0.58	Iron-T (8840∞) Copper-T (9.5*) Lead-T (6.9*)
Rum Creek (WWH, PCR, AWS, IWS)		
03-03	8.63	Dissolved oxygen (3.53‡‡) Iron-T (6550∞)
03-03	6.58	Iron-T (9040∞)
03-03	0.79	Iron-T (13000∞) Copper-T (10.8*) Lead-T (9.1*)
Bokengehalas Creek (WWH, PCR, AWS, IWS)		
03-05	7.88	Dissolved Oxygen (4.88‡)
McKees Creek (EWH, PCR, AWS, IWS)		
04-01	5.94	Dissolved oxygen (2.16‡‡)
Plum Creek (WWH, PCR, AWS, IWS)		
04-05	9.00	Dissolved oxygen (3.25‡‡)
Loramie Creek -Lockington dam to the mouth (SRW, WWH, PCR, AWS, IWS) -all other segments (WWH, PCR, AWS, IWS)		
05-01	36.84	Dissolved oxygen (4.59‡ , 4.95‡)
05-01	34.96	Total dissolved solids (1630*, 2160*)

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	
		Specific conductivity (2873*, 3728*) Strontium (25600*)
05-01	30.42	Specific conductivity (2442*) Dieldrin (0.0027$^{\#}$)
05-03	22.1	Dissolved oxygen (4.70‡ , 4.25‡ , 4.77‡, 3.73‡‡,2.68‡‡) Temperature (28.57*, 30.30**)
05-03	20.7	Total dissolved solids (1520*, 1620*) Strontium (27600*)
06-02	18.82	Dissolved oxygen (4.61‡) Total dissolved solids (1610*) Specific conductivity (2429*)
06-02	16.51	Temperature (28.50*)
06-02	14.8	Temperature (28.86*)
Miami-Erie Canal (Undesignated)		
05-03	0.1	Total dissolved solids (1810*) Specific conductivity (2415*) Strontium (25800*)
Mile Creek (WWH, PCR, AWS, IWS)		
05-02	9.8	pH (9.24$^{\Delta}$∊ 9.58$^{\Delta}$Δ Temperature (24.42*, 31.53**, 32.42**, 33.44**, 28.08*) Total dissolved solids (1860*) Specific conductivity (2586*)
05-02	8.74	Temperature (25.91**, 28.10*, 29.78**, 36.38**)
05-02	5.97	Temperature (28.19*, 29.54**, 32.81**) Ammonia-N (2.13*) Total dissolved solids (1880*) Specific conductivity (2950*)
05-02	0.5	Dissolved oxygen (3.52‡‡ , 3.34‡‡) Temperature (28.30*) Dieldrin (0.0044$^{\#}$)
Ninemile Creek ***-Headwaters to CR 14 (RM 4.2) (MWH, PCR, AWS, IWS)*** ***-All other segments (WWH, PCR, AWS, IWS)***		
06-01	6.38	Dissolved oxygen (3.88‡)
06-01	4.18	Dissolved oxygen (0.95‡‡)
Turtle Creek (WWH, PCR, AWS, IWS)		
06-03	8.42	Dissolved oxygen (4.71‡ , 4.69‡)
06-03	5.66	Dissolved oxygen (4.25‡)

a See **Table 1**.

b Use designations:

SRW - State Resource Water

Aquatic Life Habitat	Water Supply	Recreation
MWH - modified warmwater habitat	IWS - industrial water supply	PCR - primary contact

Stream (use designation [b])		Parameter (value)
12-digit WAU [a]	River Mile	

WWH - warmwater habitat
EWH - exceptional warmwater habitat
AWS - agricultural water supply
PWS- public water supply
SCR - secondary contact
BWR -bathing water

Undesignated [WWH criteria apply to ‘undesignated’ surface waters.]

* exceedence of numerical criteria for prevention of chronic toxicity (CAC).
** exceedence of numerical criteria for prevention of acute toxicity (AAC).
*** exceedence of numerical criteria for prevention of lethality (FAV).
∆ exceedence of the pH criteria (6.5-9.0).
exceedence of numerical criteria for the protection of human health (non-drinking-protective of people against adverse exposure to chemicals via eating fish).
■ exceedence of numerical criteria for the protection of human health (drinking water-public water supply).
∞ exceedence of agricultural water supply criterion.
‡ value is below the EWH minimum 24-hour average D.O criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O criterion (4.0 mg/l) as applicable.
‡‡ value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the MWH minimum at any time D.O. criterion (3.0 mg/l) as applicable.

Table 10. Nutrient sampling results in the upper Great Miami River watershed, summer 2008. Values above applicable reference values (targets) are highlighted in yellow.*

Stream RM	12 Digit WAU[a]	DA[b] (mi^2)	Ortho-P (mg/l) Median#	Ammonia-N (mg/l)		Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)	
				Median#	Target*	Median#	Target*	Median#	Target*
Great Miami River (EWH from Quincy dam (RM 143.4) to Pasco-Montra Rd. (RM 134.8) and from RM 116.7 to the Sidney water works dam (RM 130.2); other segments WWH)									
158.2	03-02	122	0.020	0.120	0.096	0.51	2.80	0.060	0.110
158.05[c]	03-02	-	2.570	0.106	-	24.65	-	2.400	-
157.22	03-02	131	0.339	0.145	0.096	4.20	2.80	0.450	0.110
153.45	03-06	246	ns	0.197	0.074	2.41	3.06	0.186	0.170
146.19	03-06	296	ns	0.060	0.074	1.69	3.06	0.140	0.170
143.2	04-06	411	0.058	0.053	0.074	1.57	1.65	0.099	0.170
143.1[d]	04-06	-	1.160	0.103	-	4.52	-	1.215	-
142.5	04-06	412	0.070	0.051	0.074	1.62	1.65	0.108	0.170
138.4	04-06	429	ns	0.050	0.074	1.59	1.65	0.096	0.170
129.99	07-03	541	0.055	0.050	0.074	1.23	1.65	0.083	0.170
North Fork Great Miami River (WWH)									
10.7	01-01	9	0.022	0.050	0.100	0.12	2.24	0.053	0.070
6.31	01-01	14.4	0.019	0.061	0.100	2.32	2.24	0.040	0.070
South Fork Great Miami River (WWH)									
8.00	01-02	12	0.011	0.050	0.100	1.15	2.24	0.016	0.070
7.23	01-02	19.5	ns	0.050	0.100	0.74	2.24	0.025	0.070
5.8	01-02	30	ns	0.050	0.096	0.61	2.80	0.024	0.110
3.95	01-02	47	0.022	0.050	0.096	0.57	2.80	0.035	0.110
1.74	01-02	51	ns	0.050	0.096	0.53	2.80	0.018	0.110
Tributary to South Fork Great Miami River (7.24) (WWH)									
0.55	01-02	7.4	ns	0.050	0.100	0.27	2.24	0.031	0.070
Liggit Ditch (WWH)									
0.53	01-02	6.5	0.015	0.050	0.100	0.14	2.24	0.019	0.070
Van Horn Creek (WWH)									
0.97	01-03	3	ns	0.056	0.100	0.10	2.24	0.049	0.070
Muchinippi Creek (WWH)									
12.98	02-02	6.8	ns	0.237	0.100	0.64	2.24	0.153	0.070
12.5	02-02	16	ns	0.073	0.100	0.23	2.24	0.341	0.070
7.4	02-04	36	ns	0.073	0.096	0.26	2.80	0.091	0.110
4.76	02-04	77	ns	0.058	0.096	0.49	2.80	0.102	0.110
2.37	02-04	85	ns	0.088	0.096	0.47	2.80	0.124	0.110
0.32	02-04	88	0.121	0.109	0.096	0.53	2.80	0.149	0.110
Willow Creek (WWH)									
3.7	02-01	8.1	0.010	0.056	0.100	0.30	2.24	0.024	0.070
0.44	02-01	15.1	ns	0.050	0.100	0.29	2.24	0.033	0.070
Little Muchinippi Creek (WWH)									
6.05	02-03	9.3	0.062	0.056	0.100	0.42	2.24	0.115	0.070
0.62	02-03	35.2	ns	0.140	0.096	0.96	2.80	0.139	0.110
Jackson Center Creek (WWH)									
2.9	02-03	1.1	0.041	0.058	0.100	0.22	2.24	0.089	0.070
1.8	02-03	3	1.185	0.065	0.100	11.10	2.24	1.053	0.070
Cherokee Mans Run (WWH)									
7.56	03-01	8.5	0.010	0.050	0.100	1.50	2.24	0.012	0.070
3.38	03-01	14.6	ns	0.050	0.100	0.80	2.24	0.016	0.070
Tributary to Great Miami River (157.34) (undesignated-WWH apply)									

Stream RM	12 Digit WAU[a]	DA[b] (mi^2)	Ortho-P (mg/l) Median#	Ammonia-N (mg/l)		Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)	
				Median#	Target*	Median#	Target*	Median#	Target*
0.07	03-02	7.6	0.011	0.165	0.100	0.14	2.24	0.096	0.070
Rennick Creek (undesignated-WWH apply)									
0.34	03-02	10.3	ns	0.080	0.100	0.72	2.24	0.048	0.070
Brandywine Creek (WWH)									
0.58	03-06	8.8	ns	0.062	0.100	0.10	2.24	0.049	0.070
Rum Creek (WWH)									
8.63	03-03	8.2	0.049	0.066	0.100	0.78	2.24	0.104	0.070
6.58	03-03	15.3	ns	0.051	0.100	1.40	2.24	0.103	0.070
0.79	03-03	27.2	ns	0.065	0.096	0.14	2.80	0.066	0.110
Bokengehalas Creek (WWH)									
7.88	03-05	21	ns	0.050	0.096	1.92	2.80	0.011	0.110
4.61	03-05	36.3	ns	0.050	0.096	2.64	2.80	0.221	0.110
1.13	03-05	41	0.164	0.050	0.096	2.46	2.80	0.173	0.110
Blue Jacket Creek (WWH)									
6.31	03-04	3	0.010	0.050	0.100	1.00	2.24	0.014	0.070
5.39	03-04	7.8	1.160	0.050	0.100	7.05	2.24	1.125	0.070
0.72	03-04	13.7	ns	0.050	0.100	3.25	2.24	0.432	0.070
Opossum Run (WWH)									
0.5 [e]	03-04	-	1.900	0.058	-	10.10	-	1.950	-
Stony Creek (WWH)									
2.45	04-03	35.4	ns	0.050	0.096	1.17	2.80	0.015	0.110
1.58	04-03	59.1	ns	0.050	0.096	1.38	2.80	0.018	0.110
McKees Creek (EWH)									
9.5	04-01	3	ns	0.050	0.100	1.52	0.98	0.011	0.050
5.94	04-01	8.7	ns	0.050	0.100	1.32	0.98	0.015	0.050
0.52	04-01	17.7	ns	0.050	0.100	1.39	0.98	0.012	0.050
Lee Creek (WWH)									
3.35	04-02	9.5	ns	0.050	0.100	0.89	2.24	0.032	0.070
Graves Creek (WWH)									
0.48	04-02	10.9	ns	0.050	0.100	2.14	*2.24*	0.018	0.070
Indian Creek (WWH)									
0.01	04-04	15.9	ns	0.050	0.100	1.40	2.24	0.023	0.070
Plum Creek (WWH)									
9	04-05	7.8	0.047	0.050	0.100	0.10	2.24	0.073	0.070
5.22	04-05	14.7	ns	0.050	0.100	0.10	2.24	0.045	0.070
0.13	04-05	29	ns	0.050	0.096	0.62	2.80	0.037	0.110
Loramie Creek (WWH)									
36.84	05-01	6.8	0.226	0.062	0.100	0.71	2.24	0.320	0.070
34.96	05-01	15.7	0.626	0.172	0.100	2.19	2.24	0.704	0.070
30.42	05-01	35	ns	0.090	0.096	0.50	2.80	0.256	0.110
22.1	05-03	78	0.206	0.186	0.096	0.24	2.80	0.288	0.110
21.1 [f]	05-03	-	3.460	0.661	-	28.15	-	3.375	-
20.7	05-03	82	4.135	0.171	0.096	13.55	2.80	5.810	0.110
18.82	06-02	148	ns	0.098	0.096	9.11	2.80	2.190	0.110
16.51	06-02	152	1.050	0.075	0.096	3.57	2.80	1.220	0.110
14.8	06-02	158	ns	0.078	0.096	3.08	2.80	0.903	0.110
7.67	06-04	205	ns	0.050	0.074	0.11	3.06	0.225	0.170
1.87	06-04	257	0.131	0.050	0.074	0.30	3.06	0.189	0.170
Miami-Erie Canal (undesignated-WWH apply)									
1.8 [g]	05-03	-	6.380	0.257	-	18.85	-	12.600	-

Stream RM	12 Digit WAU[a]	DA[b] (mi^2)	Ortho-P (mg/l) Median#	Ammonia-N (mg/l)		Nitrate-nitrite-N (mg/l)		Phosphorus-T (mg/l)	
				Median#	Target*	Median#	Target*	Median#	Target*
0.1	05-03	4.3	ns	0.151	0.100	14.20	2.24	8.100	0.070
Mile Creek (WWH)									
9.8	05-02	9.7	1.407	0.058	0.100	0.19	2.24	0.295	0.070
8.74	05-02	18.5	0.206	0.061	0.100	0.41	2.24	0.311	0.070
5.97	05-02	34.7	0.349	0.083	0.096	0.94	2.80	0.528	0.110
0.5	05-02	62.3	0.117	0.050	0.096	0.13	2.80	0.309	0.110
Spring Creek (undesignated-WWH apply)									
0.37	05-02	8.8	ns	0.050	0.100	0.11	2.24	0.174	0.070
Ninemile Creek (Headwaters to RM 4.2 - MWH, other segments WWH)									
6.38	06-01	3	ns	0.085	0.100	0.78	3.11	0.073	0.580
4.18	06-01	11.5	ns	0.077	0.100	0.54	3.11	0.088	0.580
0.23	06-01	26.6	ns	0.054	0.096	0.27	2.80	0.063	0.110
Turtle Creek (WWH)									
8.42	06-03	8.4	ns	0.050	0.100	0.10	2.24	0.196	0.070
5.66	06-03	17.3	ns	0.063	0.100	0.11	2.24	0.132	0.070
0.43	06-03	35.9	ns	0.050	0.096	1.21	2.80	0.018	0.110

\# Data medians from summer sampling June- September 2008.

[a] See **Table 1**.
[b] Drainage area

* Target values per *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams –* Tables 1 and 2, Appendix Tables 1 and 2 (Ohio EPA Technical Bulletin MAS/1999-1-1).

Ecoregion Eastern Corn Belt (ECBP)	Headwater (0-20mi^2)			Wadeable (≥20-200 mi^2)		Small River (≥200-1000 mi^2)		Large River (>1000 mi^2)	
	MWH	**WWH**	**EWH**	**WWH**	**EWH**	**WWH**	**EWH**	**WWH**	**EWH**
NO_3-NO_2-N (mg/l)	**3.11**	**2.24**	**0.98**	**2.80**	**0.84**	**3.06**	**1.65**	**4.14**	**3.08**
Phosphorus-T (mg/l)	**0.58**	**0.07**	**0.05**	**0.11**	**0.08**	**0.17**	**0.17**	**0.41**	**0.46**
NH_3-N (mg/l) (90th%tile)	**0.1**			**0.096**		**0.074**		**0.299**	

Effluent samples

[c] Indian Lake WWTP effluent discharges to Great Miami River at RM 158.05
[d] Quincy-Degraff WWTP effluent discharges to Great Miami River at RM 143.1
[e] Bellefontaine WWTP effluent discharges to Opossum Run at RM 0.5
[f] Lake Loramie WWTP effluent discharges to Loramie Creek at RM 21.1
[g] Minster WWTP effluent discharges to the Miami-Erie Canal at RM 1.8

ns no sample

Table 11. Ohio EPA bacteriological (*E. coli*) sampling results in the Upper Great Miami River study area during 2008 and 2009. All values are expressed as colony forming units (cfu) or most probable number (MPN) per 100 ml of water. Values above criteria are highlighted in red. *

Stream RM	12- Digit WAU [a]	Location	Year	Samples (#)	*E. coli* Geometric Mean	*E. coli* Max Value	Attainment Status	Suspected Sources of Bacteria [b]
***Great Miami River** - PCR-Class A*								
158.2	03-02	Upstream Indian Lake WWTP	2008	5	**576**	**4700**	**NON**	G,H, J
157.2	03-02	SR 235 (Russells Point)	2008	5	**379**	**1700**	**NON**	F,G,H
			2009	1	-	579	N/A	
146.2	03-06	SR 235 (DeGraff)	2008	5	**432**	**3800**	**NON**	H
143.2	04-06	SR 235 (Quincy)	2008	5	126	**400**	FULL	
142.5	04-06	Dst Quincy WWTP, adj CR 73 (RR bridge)	2008	5	81	**350**	FULL	
130.0	07-03	SR 47 (E North St) (Sidney)	2008	4	122	**1400**	FULL	
			2009	12	**239**	**2420**	**NON**	G,H
***North Fork Great Miami River** - PCR Class B*								
6.31	01-01	Dunn Rd.	2008	5	**534**	**1000**	**NON**	H
			2009	2	**380**	**1990**	**NON**	H
***South Fork Great Miami River**- PCR Class B*								
3.95	01-02	CR 96 (Dst Belle Center)	2008	5	**1838**	**43000**	**NON**	B,H
			2009	2	**1348**	**1730**	**NON**	B,H
***Muchinippi Creek** – PCR Class B*								
12.5	02-02	Upstream US 33	2008	5	**1544**	**28000**	**NON**	D,G, H
0.32	02-04	CR 60 (East of Bloom Center)	2008	5	109	**800**	FULL	
			2009	1	-	178	N/A	
***Willow Creek** – PCR Class B*								
0.44	02-01	Idle Rd.	2008	5	138	230	FULL	
***Little Muchinippi Creek** - PCR Class B*								
0.62	02-03	gravel road near mouth	2008	5	97	**670**	FULL	
***Jackson Center Creek -** PCR Class B*								
1.8	02-03	Lock Two Rd, Dst Jackson Center WWTP	2008	5	**324**	**2300**	**NON**	A,C[1],H
***Rum Creek -** PCR Class B*								
0.79	03-03	CR 58	2008	4	**239**	**3900**	**NON**	B,H
***Bokengehalas Creek** - PCR Class B*								
7.88	03-05	TR 31, Upst Blue Jacket Creek	2008	5	**255**	**1300**	**NON**	H
1.13	03-05	Miami St (DeGraff)	2008	5	**706**	**2800**	**NON**	G,H

Stream RM	12- Digit WAU [a]	Location	Year	Samples (#)	*E. coli*		Attainment Status	Suspected Sources of Bacteria [b]
					Geometric Mean	Max Value		
			2009	2	**668**	**687**	**NON**	G,H
Blue Jacket Creek *- PCR Class B*								
5.39	03-04	CR 11, Dst Bellefontaine WWTP	2008	5	**359**	**1700**	**NON**	G,H
Stony Creek *- PCR Class B*								
1.58	04-03	TR 65A	2008	5	**690**	**3400**	**NON**	H
McKees Creek *- PCR Class B*								
0.52	04-01	CR 31	2008	5	**670**	**1700**	**NON**	H
Graves Creek *- PCR Class B*								
0.48	04-02	TR 295	2008	5	**1036**	**2700**	**NON**	D,H
Indian Creek *- PCR Class B*								
0.01	04-04	@ mouth	2008	5	**683**	**3900**	**NON**	D,H
Plum Creek *- PCR Class B*								
0.13	04-05	Canal Feeder Rd.	2008	5	**462**	**3100**	**NON**	H
Loramie Creek *- PCR Class B upstream Hardin Wapakoneta Rd. (RM 30.42), PCR Class A from RM 30.42 to mouth*								
36.84	05-01	Botkins Rd.	2008	5	58	**660**	FULL	
34.96	05-01	Lock Two Rd. (Dst Botkins WWTP)	2008	5	**5221**	**11000**	**NON**	H
30.42	05-01	Hardin-Wapakoneta Rd.	2008	5	**426**	**5600**	**NON**	H
22.1	05-03	Dst Loramie Lake Dam	2008	5	**662**	**1600**	**NON**	H,J
20.7	05-03	SR 66, Dst Lake Loramie WWTP	2008	5	**565**	**3700**	**NON**	F,G,H
18.82	06-02	Schlater Rd.	2008	5	**264**	**2900**	**NON**	H,I
16.51	06-02	Cardo-Roman Rd.	2008	5	74	**330**	FULL	
			2009	10	124	**2920**	FULL	
1.87	06-04	Fessler-Buxton Rd.	2008	4	**297**	**2200**	**NON**	H
			2009	10	**144**	**1410**	**NON**	H,J
Miami Erie Canal *- PCR Class B*								
0.01	05-03	@ mouth	2008	5	**497**	**3300**	**NON**	F,G,H
Mile Creek *- PCR Class B*								
5.97	05-02	Kremer Rd.	2008	5	**587**	**4900**	**NON**	D,H,I
0.5	05-02	SR 705	2008	5	75	260	FULL	
			2009	1	-	1050	N/A	
Spring Creek *- PCR Class B*								
0.37	05-02	Baumer-Brandewie Rd.	2008	5	118	**2000**	FULL	
Ninemile Creek *- PCR Class B*								

Stream RM	12- Digit WAU [a]	Location	Year	Samples (#)	*E. coli*		Attainment Status	Suspected Sources of Bacteria [b]
					Geometric Mean	Max Value		
4.18	06-01	Range Line Rd. (Dst Russia WWTP)	2008	5	**566**	**8800**	**NON**	G,H
0.23	06-01	Roeth Rd.	2008	5	**252**	**5300**	**NON**	G,H
Turtle Creek *- PCR Class B*								
0.43	06-03	Stangel Rd.	2008	4	85	370	FULL	

* Samples were collected from September 3 - 11, 2008 and from June 4 - October 28, 2009. Attainment status is based on the seasonal (May 1-October 31) geometric mean. The status cannot be determined at locations where fewer than two samples were collected during the recreation season (Ohio Administrative Code 3745-1-07).

Subcategory	Seasonal geometric mean (cfu)
Bathing Water	126
Class A primary contact recreation	126
Class B primary contact recreation	161
Class C primary contact recreation	206
Secondary contact recreation	1030

a See Table 5.

b **Suspected Sources of Bacteria:**

A - Home sewage treatment systems
B - Livestock access to stream
C - Wastewater treatment plant
[1-] deteriorating collection system
D - Unsewered community
E - Combined sewer overflow (CSOs)
F - Sanitary sewer overflows (SSOs)
G - Urban runoff (city, village, etc.)
H - Agricultural runoff
I - Animal Feedlot Operation
J - Wildlife (geese, etc)
K - Unknown

Table 12. Frequency of organic compounds detected in stream water samples in the upper Great Miami River watershed during 2008 (HUC 05080001). (Number of water quality criteria exceedences / Number of detections).[1]

Watershed Assessment Unit (12-Digit WAU) [a]	**Upper GMR mainstem**	**Upper Great Miami River watershed**						**Loramie Creek watershed**					**TOTAL**
		01-01	**01-02**	**01-03**	**02-04**	**03-04**	**03-05**	**05-01**	**05-02**	**05-03**	**06-02**	**06-04**	
Number of sites/samples	5/10	1/2	1/2	1/2	1/2	1/2	1/2	2/4	1/2	1/2	2/4	1/2	**18/36**
Acetochlor*	*/7	*/2	*/1	*/1	*/2	-	-	*/2	*/1	-	*/4	*/3	***/23**
Atrazine*	*/10	*/2	*/2	*/2	*/2	-	-	*/4	*/2	-	*/1	-	***/25**
α-Hexachlorocyclohexane	0/3	-	-	-	-	-	-	0/1	0/1	-	0/3	0/1	**0/9**
δ-Hexachlorocyclohexane*	*/5	-	-	*/1	*/1	*/1	*/1	*/2	-	*/1	*/2	*/1	***/15**
γ-Hexachlorocyclohexane (Lindane)	-	-	-	-	-	0/1	-	-	-	-	0/1	-	**0/2**
bis(2-Ethylhexyl)adipate*	-	-	-	*/1	-	-	-	-	-	-	-	-	***/1**
bis(2-Ethylhexyl)phthalate	1/10	0/2	0/2	0/2	0/2	0/2	0/2	0/3	0/2	0/2	0/3	0/2	**1/34**
Chloroform	0/1	-	-	-	-	0/2	-	-	-	-	-	-	**0/3**
Dieldrin	1/1	-	-	1/1	-	-	-	1/1	1/1	-	-	-	**4/4**
Diethylphthalate	0/1	-	-	-	-	-	0/1	-	-	-	-	-	**0/2**
Endosulfan I	-	-	-	-	-	-	-	-	-	-	0/1	-	**0/1**
Glyphosate*	-	-	-	-	-	-	-	0/1	-	-	-	-	**0/1**
Metolachlor*	*/6	-	*/1	*/2	*/2	-	*/1	*/4	*/1	-	*/3	*/2	***/22**
Pentachlorophenol	-	-	-	-	-	-	-	0/1	-	-	0/1	-	**0/2**
Simazine	0/4	0/2	-	-	-	-	0/1	-	-	-	-	-	**0/7**
Toluene	0/1	-	-	-	-	-	-	-	-	-	-	-	**0/1**
o-Xylene	0/1	-	-	-	-	-	-	-	-	-	-	-	**0/1**
Total m&p-xylenes	0/1	-	-	-	-	-	-	-	-	-	-	-	**0/1**
2,4-D*	*/2	-	-	-	*/1	-	-	*/1	-	*/1	-	-	***/5**
TOTAL	**2/53**	**0/8**	**0/6**	**1/10**	**0/10**	**0/6**	**0/6**	**1/20**	**1/8**	**0/4**	**0/19**	**0/9**	**5/159**

[1] Excluding wastewater treatment plant (WWTP) samples. * No applicable water quality criteria available for parameter.
[a] See **Table 1**.

Table 13. Sampling results for select parameters at nine sentinel sites in the upper Great Miami River watershed (January 10 - December 18, 2008). Values above applicable reference (target) values are highlighted in yellow [c,d].

Date	Bridge to water dist. (ft) [a]	Mean Daily Flow (cfs) [a]	NH_3-N (mg/l)	Nitrate-nitrite-N (mg/l)	Ortho-P (mg/l) [b]	Phos-T (mg/l)	TSS (mg/l)
Great Miami River @ Russells Point @ SR 235 (RM 157.2)							
03/11/08	13.65	-	<0.050	1.88	ns	0.096	40
04/01/08	-	-	<0.050	1.04	ns	0.038	30
05/20/08	17.135	-	<0.050	1.47	0.018	0.053	26
06/26/08	12.51	-	0.425	1.91	0.105	0.294	220
07/02/08	-	-	0.071	1.51	0.012	0.099	73
07/17/08	17.67	-	0.140	0.62	0.011	0.102	78
07/31/08	19.8	-	0.160	3.94	0.339	0.473	46
08/07/08	19.85	-	0.149	4.45	0.399	0.426	39
08/21/08	20.07	-	0.133	7.35	0.570	0.597	33
09/04/08	-	-	0.121	9.43	0.750	0.801	31
09/25/08	20.05	-	0.096	8.49	ns	0.918	23
10/16/08	19.70	-	0.057	8.95	ns	0.712	27
12/18/08	19.55	-	0.072	5.48	0.315	0.407	<5
Great Miami River @ Sidney @ SR 47 (RM 129.9)							
03/11/08	-	1430	<0.050	2.58	ns	0.093	23
04/01/08	-	1050	<0.050	2.72	ns	0.059	21
05/20/08	-	537	<0.050	2.89	ns	0.041	11
06/25/08	-	215	0.087	2.47	0.060	0.111	83
07/08/08	-	260	<0.050	1.73	0.043	0.099	30
07/16/08	-	680	0.065	2.05	0.049	0.091	40
07/30/08	-	108	<0.050	1.28	0.063	0.080	21
08/06/08	-	129	<0.050	1.18	0.064	0.086	20
08/20/08	-	66	<0.050	0.97	0.044	0.058	17
09/04/08	-	51	<0.050	0.98	0.071	0.084	17
09/24/08	-	46	<0.050	0.18	0.016	0.046	12
10/16/08	-	53	<0.050	0.58	ns	0.058	9
12/18/08	-	77	<0.050	4.81	0.046	0.099	<5
North Fork Great Miami River @ Dunn Rd. (RM 6.31)							
01/10/08	8.72	-	0.051	3.08	ns	0.362	31
03/11/08	9.75	-	<0.050	3.51	ns	0.076	10
04/01/08	-	-	<0.050	3.79	ns	0.049	11
05/20/08	10.42	-	<0.050	4.62	0.031	0.044	9
06/25/08	10.81	-	<0.050	4.13	0.017	0.022	<5
07/02/08	-	-	<0.050	6.55	0.034	0.038	13
07/16/08	10.68	-	0.137	4.52	0.072	0.068	<5
07/30/08	10.94	-	0.058	1.75	0.020	0.046	<5
08/06/08	10.87	-	<0.050	0.27	0.039	0.057	5
08/20/08	11.05	-	0.063	2.88	<0.010	0.017	18
09/04/08	-	-	0.124	0.14	0.014	0.033	<5

Date	Bridge to water dist. (ft) [a]	Mean Daily Flow (cfs) [a]	NH_3-N (mg/l)	Nitrate-nitrite-N (mg/l)	Ortho-P (mg/l) [b]	Phos-T (mg/l)	TSS (mg/l)
09/24/08	11.08	-	0.073	0.63	0.014	0.033	17
10/16/08	11.06	-	<0.050	<0.10	ns	0.068	34
12/18/08	10.89	-	<0.050	16.0	0.040	0.082	<5
South Fork Great Miami River @ CR 96 (RM 3.95)							
04/01/08	-	-	<0.050	1.94	ns	0.031	11
05/20/08	15.085	-	<0.050	2.07	0.011	0.020	<5
06/25/08	15.42	-	<0.050	1.15	0.016	0.024	<5
07/02/08	-	-	<0.050	1.96	0.032	0.046	13
07/16/08	15.23	-	<0.050	1.75	0.043	0.060	7
07/30/08	15.59	-	<0.050	0.56	0.021	0.031	<5
08/06/08	15.64	-	0.085	0.58	0.036	0.060	<5
08/20/08	15.78	-	<0.050	0.29	0.014	0.025	<5
09/04/08	-	-	<0.050	0.23	0.024	0.037	ns
09/24/08	15.78	-	<0.050	0.12	0.022	0.039	6
10/16/08	15.74	4.015	<0.050	<0.10	ns	0.078	<5
12/18/08	15.73	-	ns	ns	0.016	ns	<5
Muchinippi Creek @ CR 60 (RM 0.32)							
03/11/08	9.29	-	0.060	3.72	ns	0.105	23
04/01/08	-	-	<0.050	3.66	ns	0.085	21
05/20/08	12.395	-	<0.050	4.73	0.045	0.072	10
06/26/08	7.07	-	0.357	4.60	0.178	0.504	440
07/08/08	14.14	32.866	0.055	1.97	0.062	0.093	40
07/17/08	13.2	-	0.070	2.15	0.058	0.088	31
07/31/08	15.03	-	0.105	0.30	0.104	0.141	15
08/07/08	15.09	-	0.119	0.76	0.113	0.137	17
08/21/08	15.46	-	0.113	0.14	0.128	0.157	16
09/04/08	-	-	0.092	<0.10	0.192	0.258	9
09/25/08	-	-	0.052	<0.10	0.167	0.258	19
10/16/08	14.74	-	<0.050	<0.10	ns	0.287	7
12/18/08	14.83	-	0.098	5.13	0.067	0.108	<5
Bokengehalas Creek @ Miami St (DeGraff) RM (1.13)							
01/10/08	-	241	0.138	3.50	ns	0.208	60
03/11/08	-	70	0.086	2.58	ns	0.059	12
04/01/08	-	104	<0.050	1.98	ns	0.033	6
05/20/08	-	55	<0.050	2.79	0.084	0.109	10
06/25/08	-	38	<0.050	2.67	0.148	0.147	6
07/02/08	-	66	<0.050	2.16	0.092	0.126	17
07/16/08	-	35	<0.050	2.32	0.109	0.116	<5
07/30/08	-	20	0.050	2.44	0.157	0.163	5
08/06/08	-	22	<0.050	2.07	0.171	0.188	<5
08/20/08	-	13	<0.050	2.47	0.183	0.183	<5
09/04/08	-	9.8	<0.050	2.40	0.243	0.255	<5
09/24/08	-	8.5	<0.050	2.79	0.253	0.248	<5
10/16/08	-	na	<0.050	1.76	ns	0.240	<5

Date	Bridge to water dist. (ft) [a]	Mean Daily Flow (cfs) [a]	NH_3-N (mg/l)	Nitrate-nitrite-N (mg/l)	Ortho-P (mg/l) [b]	Phos-T (mg/l)	TSS (mg/l)
12/18/08	-	na	0.050	2.75	0.311	0.391	<5
Loramie Creek @ Cardo-Roman Rd. (RM 16.51)							
03/11/08	-	309	0.314	6.66	ns	0.332	34
04/02/08	-	211	0.206	5.33	ns	0.330	109
05/20/08	-	75	<0.050	7.97	ns	0.517	36
06/24/08	-	25	0.123	3.75	0.341	0.448	37
07/08/08	-	17	<0.050	1.60	0.513	0.610	89
07/15/08	-	504	0.108	2.90	0.166	0.269	93
07/29/08	-	3.1	0.062	3.00	1.05	2.88	47
08/05/08	-	7.1	0.063	3.79	1.05	1.16	59
08/19/08	-	2.4	0.065	3.39	1.22	1.40	53
09/04/08	-	2.4	0.079	3.88	0.419	0.664	45
09/23/08	-	2.2	0.084	4.65	1.13	1.28	29
10/16/08	-	13	0.148	7.67	ns	1.86	46
12/18/08	-	3.9	0.129	16.7	0.933	1.34	19
Loramie Creek @ Fessler-Buxton Rd (RM 1.87)							
01/10/08	-	4410	0.186	6.33	ns	0.644	106
03/11/08	-	479	0.084	4.36	ns	0.245	23
04/02/08	-	355	0.115	4.78	ns	0.255	41
05/20/08	-	125	<0.050	5.64	ns	0.204	17
06/24/08	-	64	<0.050	2.85	0.182	0.268	12
07/15/08	-	706	0.067	2.99	0.149	0.276	96
07/29/08	-	19	<0.050	0.13	0.128	0.177	16
08/05/08	-	20	<0.050	0.27	0.131	0.201	18
08/19/08	-	11	<0.050	0.17	0.100	0.142	10
09/04/08	-	9.2	<0.050	0.17	0.133	0.177	8
09/23/08	-	15	<0.050	0.33	ns	0.109	<5
10/16/08	-	na	<0.050	0.12	ns	0.125	6
12/18/08	-	na	0.139	7.02	0.191	0.329	<5
Mile Creek @ SR 705 (RM 0.5)							
03/11/08	-	-	0.427	9.06	ns	0.282	46
04/02/08	-	-	0.163	9.32	ns	0.208	15
05/20/08	19.54	-	<0.050	10.7	ns	0.133	29
06/24/08	23.2	-	<0.050	6.49	0.080	0.064	50
07/08/08	20.35	3.908	<0.050	1.61	0.014	0.131	20
07/15/08	16.53	-	0.365	7.38	0.418	0.412	15
07/29/08	20.59	-	<0.050	0.15	0.076	0.310	62
08/05/08	20.38	-	0.207	<0.10	0.209	0.389	60
08/19/08	20.665	-	<0.050	<0.10	0.154	0.307	45
09/04/08	-	-	0.062	<0.10	0.101	0.176	24
09/23/08	20.55	-	<0.050	<0.10	0.067	0.102	<5
10/16/08	20.49	-	<0.050	0.53	ns	0.123	22
12/18/08	20.53	-	1.49	9.08	0.191	0.406	12

Date	Bridge to water dist. (ft) [a]	Mean Daily Flow (cfs) [a]	NH_3-N (mg/l)	Nitrate-nitrite-N (mg/l)	Ortho-P (mg/l) [b]	Phos-T (mg/l)	TSS (mg/l)

ns no sample
na not available
[a] USGS flow measurements
Great Miami River @ SR 47 in Sidney - USGS Station No. 03261500
Loramie Creek @ Cardo Roman Rd. - USGS Station No. 03261950
Loramie Creek @ Fessler Buxton Rd. - USGS Station No. 03262000
Bokengehalas Creek @ Miami St in DeGraff - USGS Station No. 03260706
For the remaining sites, the relative flows are inversely related to bridge to water measurements (i.e. the greater the bridge to water measurement, the lower the flow and vice-versa).
[b] There are no applicable reference (target) values for orthophosphate.
[c] Target values per *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* – Tables 1 and 2, Appendix Tables 1 and 2 (Ohio EPA Technical Bulletin MAS/1999-1-1).

Ecoregion Eastern Corn Belt (ECBP)	Headwater (0-$20 mi^2$)			Wadeable (≥ 20-$200 mi^2$)		Small River (≥ 200-$1000 mi^2$)		Large River ($>1000 mi^2$)	
	MWH	WWH	EWH	WWH	EWH	WWH	EWH	WWH	EWH
NO_3-NO_2-N (mg/l)	3.11	2.24	0.98	2.80	0.84	3.06	1.65	4.14	3.08
Phosphorus-T (mg/l)	0.58	0.07	0.05	0.11	0.08	0.17	0.17	0.41	0.46
NH_3-N (mg/l) (90^{th}%tile)	0.1			0.096		0.074		0.299	
TSS (mg/l) (75^{th} %ile)	14			29		41		46	

[d] Exceedences of Ohio EPA water quality criteria (OAC 3745-1) that are not already included in Table 9 are presented below

Site	Date	Parameter (Value)
GMR @ Russells Point @ SR 235 (RM 157.2)	10/16/08	Dissolved oxygen (4.57‡)
North Fork GMR @ Dunn Rd. (RM 6.31)	01/10/08	Iron (6520∞)
South Fork GMR @ CR 96 (RM 3.95)	10/16/08	Dissolved oxygen (3.58‡‡)
Muchinippi Creek @ CR 60 (RM 0.32)	10/16/08	Dissolved oxygen (3.21‡‡)
Loramie Creek @ Cardo-Roman Rd. (RM 16.51)	04/02/08	Iron (5700∞)
	07/08/08	pH (9.32Δ) Temperature (27.85*)
Loramie Creek @ Fessler-Buxton Rd. (RM 1.87)	01/10/08	Iron (15400∞) Copper-T (16*)
Mile Creek @ SR 705 (RM 0.5)	07/08/08	Temperature (28.13*)

* exceedence of numerical criteria for prevention of chronic toxicity (CAC).
Δ exceedence of the pH criteria (6.5-9.0).
∞ exceedence of agricultural water supply criterion.
‡ value is below the EWH minimum 24-hour average D.O criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O criterion (4.0 mg/l) as applicable.
‡‡ value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the MWH minimum at any time D.O. criterion (3.0 mg/l) as applicable.

Water Chemistry and Sub-ecoregional Differences

Hydrologic and geographic differences within the UGMR watershed may partially explain variable stream water quality, especially for smaller drainage areas. Locations, QHEIs, and select water chemistry results for headwater sites (drainage ≤ 20 mi^2) in the ECBP sub-ecoregions are presented in **Figure 32** and **Figure 33**.

Streams in the “Loamy, High Lime Till Plains” sub-ecoregion (55b) are recharged by ground water. Soils in this sub-ecoregion have better natural drainage and tend to have less need for sub-surface drainage systems. Habitat (median QHEI = 80) and water quality at headwater sites in this portion of the watershed were exceptional with cooler temperatures, stable D.O. levels, and low concentrations of TSS, ammonia-N, and total phosphorus.

Conversely, soils in the “Clayey, High Lime Till Plains” sub-ecoregion (55a) are generally poorly drained and require artificial sub-surface drainage systems for agricultural production. Many streams are maintained in a channelized condition without riparian cover. However, similar to sub-ecoregion 55b, some areas in the eastern portion of the 55a sub-ecoregion are also subject to high ground water (referred to as 55a-GW in this discussion). While overall habitat quality at headwater sites was similar in both the 55a and 55a-GW areas of the sub-ecoregion (QHEI medians near 40), the enhanced flow provided by ground water recharge may have contributed to higher quality waters at 55a-GW sites. Median temperatures were marginally higher at 55a-GW headwater sites (21.95°C) compared to other sites in sub-ecoregion 55a (21.27°C). However, perhaps tempered by the influx of cooler ground water, sites with enhanced flows experienced much less variability in temperature (range 6.1°C) compared to the rest of sub-ecoregion 55a sites (range 11.2°C). Higher D.O. saturations (median 97%) were also measured at 55a-GW sites compared to other sites in sub-ecoregion 55a (median 76%). Additionally, total phosphorus concentrations and TSS were much lower at sites with ground water recharge.

The above analysis was limited to headwater sampling sites since the smaller watersheds tend to reflect the most direct connection to the surrounding land use and local hydrology. Biological and water quality trends related to enhanced flow were also considered most demonstrable in the smaller drainages. Still, when somewhat larger, wading sites (20-200 mi^2) are included, similar trends among selected chemical parameters were still evident (*e.g.,* phosphorus; see **Figure 6**). Therefore, as a general rule and absent excessive point source loadings, chemical water quality conditions in upper Great Miami River basin tributaries were enhanced in areas with a strong ground water connection.

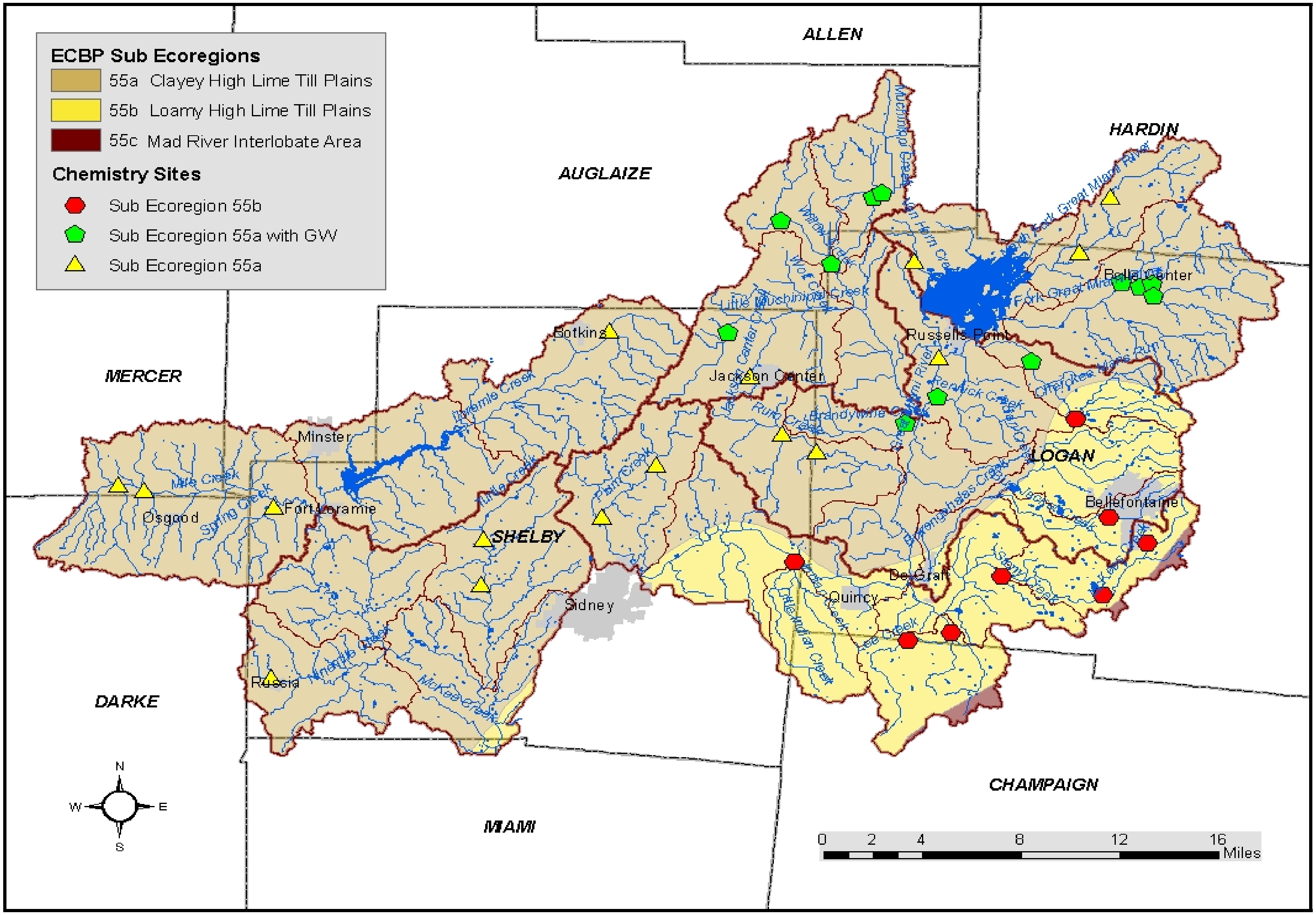


Figure 32. Sub-ecoregions in the Eastern Corn Belt Plains (ECBP) and chemistry locations with drainage areas ≤ 20 mi^2 (excluding sites directly influenced by WWTP discharges.

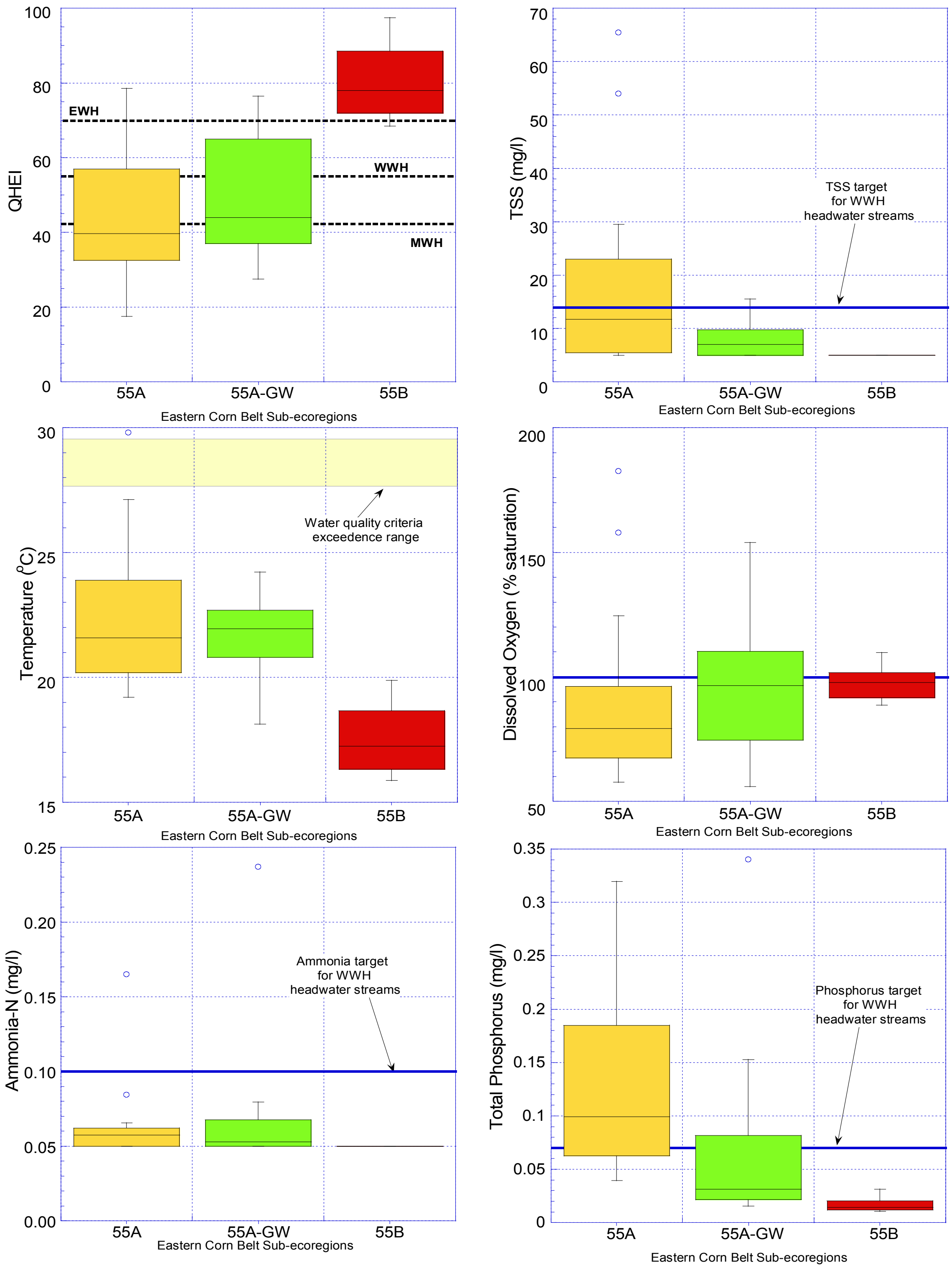


Figure 33. Boxplots of QHEI, total suspended solids, temperature, dissolved oxygen saturation, ammonia-N, and total phosphorus at headwater sites (drainage ≤ 20 mi^2) by sub-ecoregion in the Upper Great Miami River watershed (excludes sites directly influenced by wastewater discharges).

Chemical Water Quality Changes

Upper Great Miami River Watershed

Great Miami River mainstem

Ohio EPA last conducted an intensive biological and water quality study of the upper Great Miami River watershed in 1994 (Ohio EPA 1995). May through September stream flows for 2008 and 1994 as measured by the USGS gage station at Sidney are compared in **Figure 34** and **Table 14.** Much higher flows were measured in 2008 compared to 1994. On water chemistry sampling days in the watershed, 2008 flows ranged from 46 to 3600 cfs (median 113 cfs) compared to 1994 flows of 32 to 108 cfs (median 60 cfs). During the May through September period, sixty percent (60%) of 2008 mean daily flows were above the historical median (110 cfs) compared to only 32% for 1994.

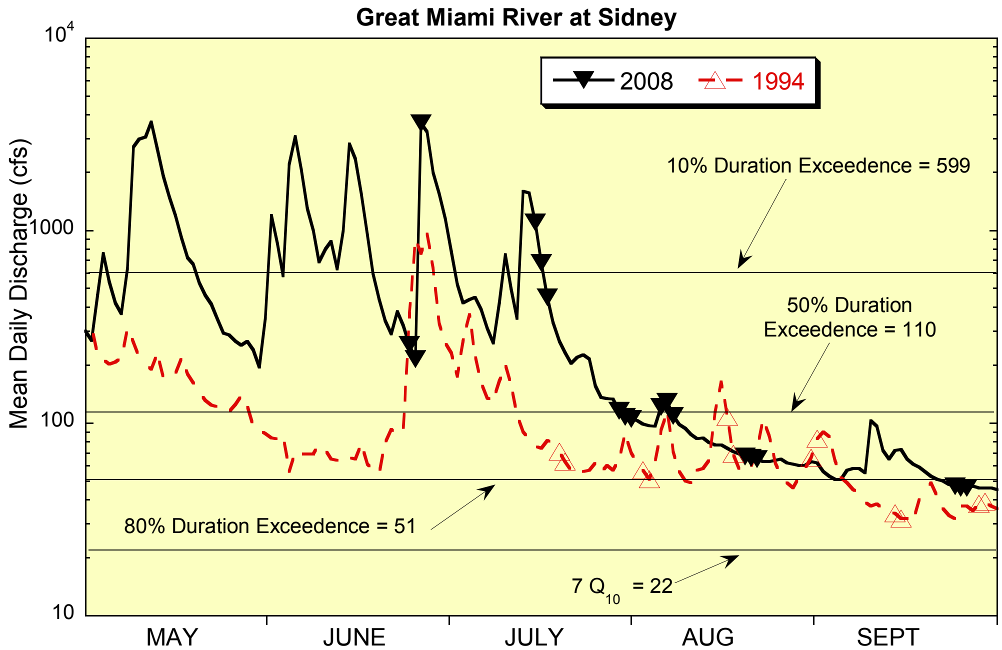


Figure 34. May through September, 2008 and 1994 flow hydrograph for the Great Miami River at Sidney (USGS station #03261500). Markers indicate river discharge on water chemistry sampling days for each year. (Duration exceedence and $7Q_{10}$ flow lines represent May-Nov period of record 1926-1997.

A comparison of Great Miami River mainstem 2008 and 1994 water chemistry data for select parameters is presented in **Figure 35**. Water samples were collected at eight sites in this reach of the mainstem during the 2008 survey compared to nine sites in the 1994 survey. (The 1994 study included the mainstem from Russells Point (RM 159.48) to north Dayton (RM 85.0); for comparison to 2008 data only sites from Russells Point to Sidney (RM 129.99) are represented in the graphs and discussion below.)

Dissolved oxygen concentrations (daytime grabs) were somewhat higher in 1994 compared to 2008; medians in 2008 ranged from 4.7 mg/l to 8.2 mg/l compared to 6.1 mg/l to 10.2 mg/l in 1994. Longitudinally, the pattern was similar in both years with lower D.O. levels in the upper reaches compared to higher concentrations at downstream sites.

Table 14. Median daily discharge flows (cfs) by month at gages in the upper Great Miami River watershed in 2008 and 1994.

	GMR @ Sidney (#03261500)		**Bokengehalas Cr near DeGraff** (#03260706)		**Loramie Cr near Newport** (#03261950)		**Loramie Cr @ Lockington** (#03262000)	
Month	**2008**	**1994**	**2008**	**1994**	**2008**	**1994**	**2008**	**1994**
May	462	179	55	25	49	9	83	35
June	975	78	60	14	170	4	218	23
July	333	81	35	9	35	13	56	29
August	74	62	14	8	2	7	12	24
Sept	54	38	10	6	2	3	15	15
May-Sept	253	74	33	10	16	6	47	24

Nutrient levels and patterns were similar in both years. While ammonia-N levels at most sites in the mainstem were low with medians approaching the minimum detection limit (MDL) of 0.05 mg/l, higher concentrations occurred in the upper reaches downstream from the Indian Lake WWTP in both survey years. Nitrate-nitrite-N and total phosphorus also increased markedly downstream from the Indian Lake WWTP with medians well above target reference levels both years. For the most part nitrate-nitrite-N levels in the mainstem were little changed with an overall median of 1.57 mg/l in 2008 compared to 1.16 mg/l in 1994. Total phosphorus levels were also comparable with an overall median of 0.114 mg/l in 2008 compared to 0.14 mg/l in 1994.

North Fork Great Miami River

Water samples were collected at two sites in the North Fork Great Miami River in 2008 (RMs 10.7 and 6.31) and in 1994 (RMs 10.7 and 4.0). Virtually all daytime grab D.O. concentrations measured in this tributary fell below the WWH 5.0 mg/l average criterion in 1994. Higher flows in 2008 may have contributed to higher D.O. levels in this low gradient agricultural stream.

Ammonia-N concentrations were well below target reference levels throughout the North Fork in both years. Nitrate-nitrite-N and total phosphorus were also generally low with respective overall medians of 0.27 mg/l and 0.07 mg/l in 1994 compared to 1.19 mg/l and 0.049 mg/l in 2008.

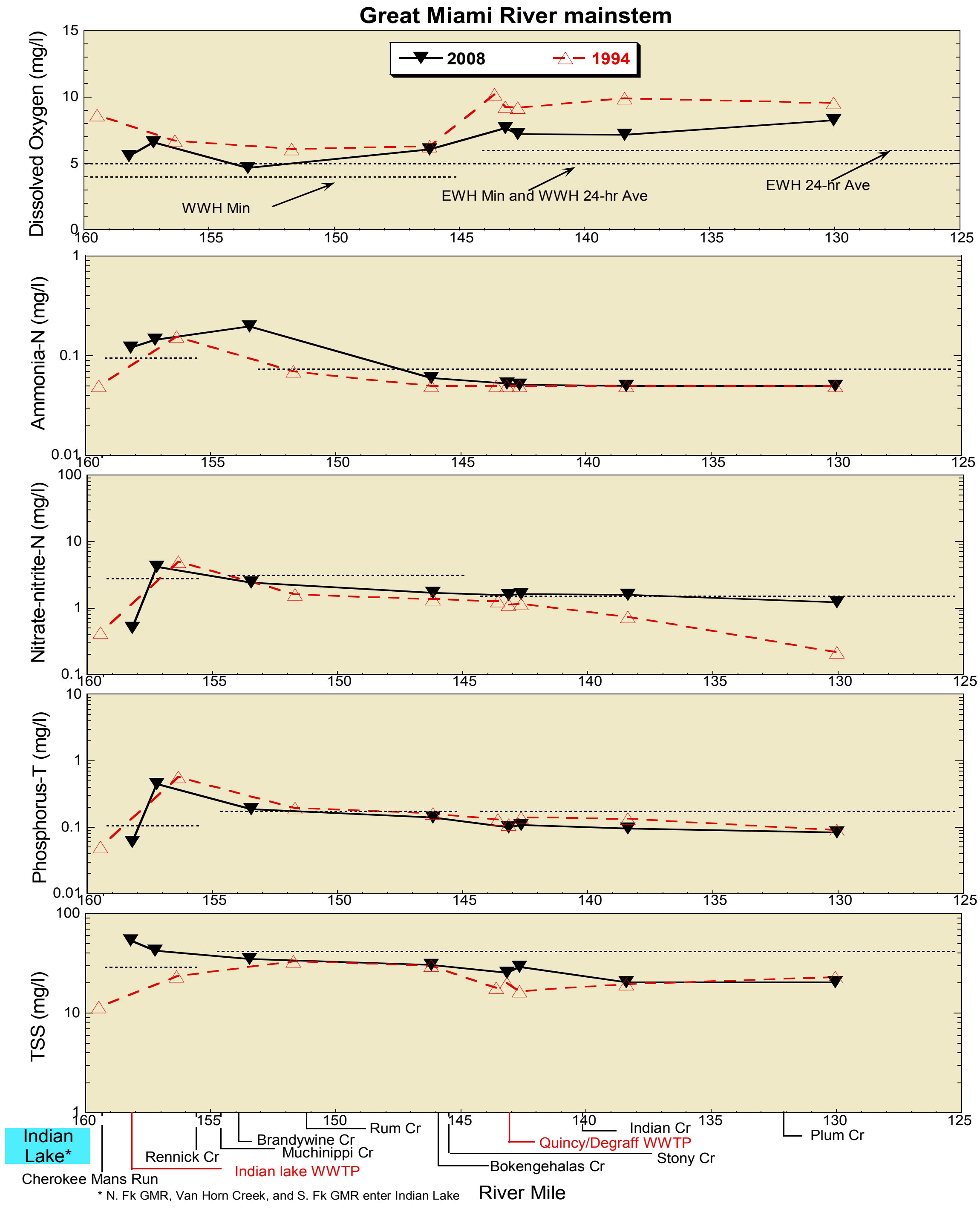


Figure 35. Longitudinal plots of median concentrations of dissolved oxygen, ammonia-N, nitrate-nitrite-N, total phosphorus, and total suspended solids in the upper Great Miami River (2008 and 1994). Water quality criteria are shown in the D.O. plot. Dashed horizontal lines represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

South Fork Great Miami River and Belle Center Tributary

The South Fork GMR was sampled at two sites in 1994 (RMs 8.0 and 1.74) compared to five sites in 2008. The Belle Center tributary was sampled at RM 0.55 in both surveys. Similar to the North Fork GMR, most daytime grab D.O. concentrations measured at the headwater site (RM 8.0) fell below the WWH 5.0 mg/l average criterion in 1994. There were no exceedences of D.O. water quality criteria in 2008.

Nutrients and suspended solids typically fell well below target reference levels in both surveys. Overall nitrate-nitrite-N concentrations were somewhat higher in 2008 (median 0.605 mg/l) compared to 1994 (0.15 mg/l) while total phosphorus levels in 2008 (median 0.024 mg/l) were lower than 1994 (median 0.06 mg/l).

Van Horn Creek

Van Horn Creek was sampled at RM 0.97 in 2008 and 1994. Median D.O. concentrations were minimally higher in 1994 (6.65 mg/l) compared to 2008 (5.85 mg/l). While one concentration minimally fell below WWH criteria in 1994, several readings dropped below criteria in 2008 due to diminishing flows. Nutrient and TSS concentrations generally fell below target reference levels in 2008 but median phosphorus (0.12 mg/l) and TSS (46 mg/l) were above target in 1994.

Bokengehalas Creek and Blue Jacket Creek

May through September stream flows for 2008 and 1994 from the Bokengehalas Creek gage in DeGraff are compared in **Figure 36** and **Table 14.** Flows were significantly higher in 2008; on specific sampling dates, 2008 flows ranged from 8.5 to 38 cfs (median 21 cfs) compared to 1994 flows of 5.7 to 8.9 cfs (median 7 cfs). During the period, seventy-six percent (76%) of 2008 mean daily flows were above the historical median (13 cfs) compared to 38% for 1994.

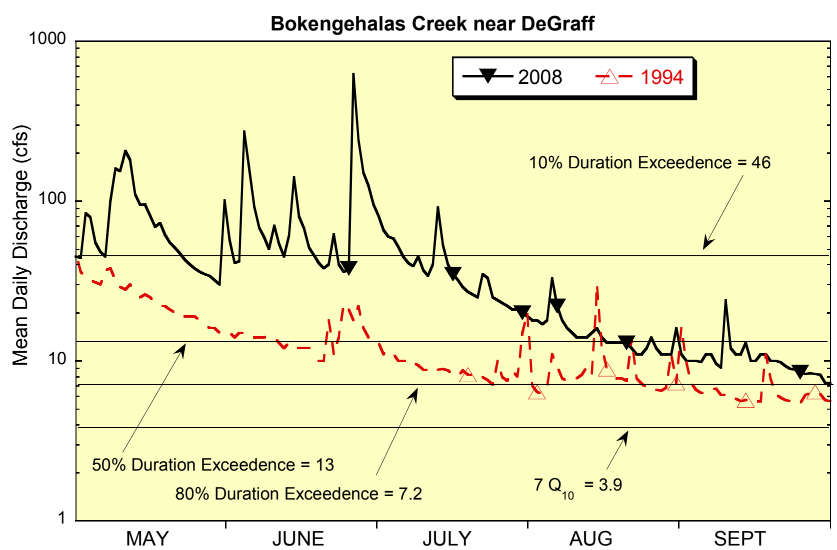


Figure 36. May through September, 2008 and 1994 flow hydrograph for Bokengehalas Creek near DeGraff (USGS gage #03260706). Markers indicate water chemistry sample dates for each year. (Duration exceedence and $7Q_{10}$ flow lines represent May-Nov period of record 1957-1991.)

Water samples from 2008 and 1994 indicate little change in water quality between surveys (**Figure 37**). Sampling was conducted at three sites (RMs 7.88, 4.61 and 0.41) in Bokengehalas Creek and four sites (RMs 6.31, 5.39, 3.26, and 0.72) in Blue Jacket Creek in 1994. Longitudinally, median 2008 concentrations for D.O., ammonia-N, nitrate-nitrite-N, total phosphorus, and TSS mirrored 1994 levels in both Bokengehalas Creek and Blue Jacket Creek.

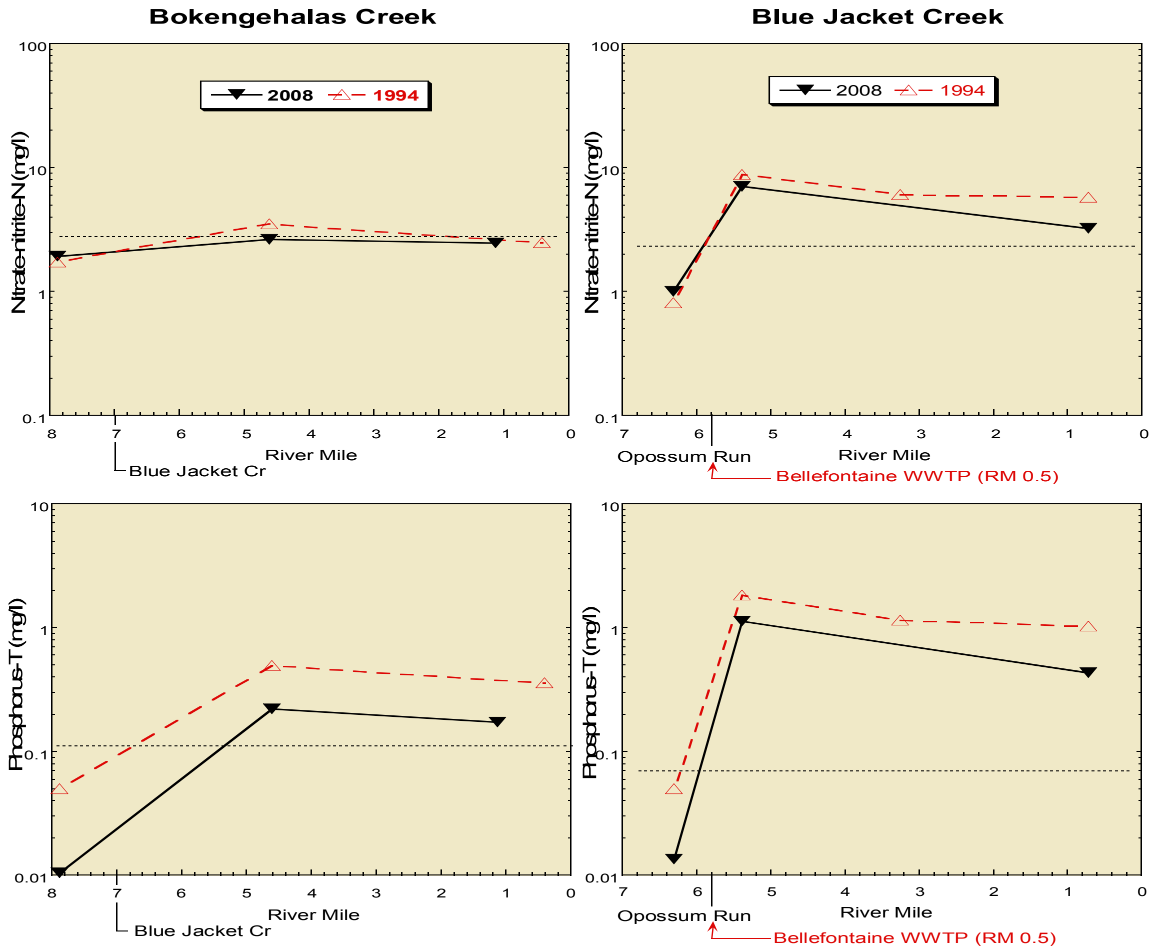


Figure 37. Longitudinal plots of median concentrations of nitrate-nitrite-N and total phosphorus in Bokengehalas Creek and Blue Jacket Creek (2008 and 1994). Dashed horizontal lines represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Dissolved oxygen remained stable with median saturations near 100% at most sites. Ammonia-N and TSS were low throughout the watershed with all concentrations less than target reference values and the majority of concentrations less than minimum detection limits (0.05 mg/l and 5 mg/l, respectively) in both survey years.

While levels were somewhat lower in 2008, nutrient loading from the Bellefontaine WWTP (discharge to Opossum Run RM 0.5) was evident in both years (**Figure 37**). Concentrations of both nitrate-nitrite-N and phosphorus increased in Blue Jacket Creek downstream from Opossum Run and remained well above target reference values to the mouth. Elevated phosphorus levels were sustained through Blue Jacket Creek and remained above target for the length of Bokengehalas Creek downstream.

Loramie Creek Watershed

Loramie Creek

May through September stream flows for 2008 and 1994 as measured by the two USGS gage stations in Loramie Creek near Newport and Lockington are compared in **Figure 38** and **Table 14**. While flows in the Loramie Creek watershed were typically significantly higher in 2008 compared to 1994 from May through July, flows in August and September were generally higher in 1994 relative to 2008. On specific water chemistry sampling days in 2008 mean daily flows at Newport ranged from 2.2 cfs to 504 cfs (median 5.1 cfs) compared to 1994 flows of 2.1 cfs to 70 cfs (median 13 cfs). Mean daily flows on water chemistry sampling days in 2008 downstream at the Lockington gage ranged from 11 cfs to 706 cfs (median 20 cfs) compared to 1994 flows ranging from 7 cfs to 103 cfs (median 25 cfs). At the Newport gage during the May through September period, fifty-six percent (56%) of 2008 mean daily flows were above the historical median (8.9 cfs) compared to 39% for 1994. For the same five-month period at the Lockington gage fifty-eight percent (58%) of 2008 mean daily flows were above the historical median (22 cfs) compared to 56% for 1994.

A comparison of Loramie Creek 2008 and 1994 water chemistry data for select parameters is presented in **Figure 39**. Water samples were collected at ten sites in each survey with six sites common to both surveys. Conditions in Loramie Creek are little changed since the 1994 survey. Pervasive habitat modification, channelization, siltation, and enrichment from both agricultural and municipal sources continue to negatively impact this stream, especially in the upper and middle segments.

Excessive algal production and the resulting oxygen demand (daytime grab D.O. levels below WWH criteria, wide diel swings, etc.) were observed in the upper and middle reaches of Loramie Creek during both surveys. This segment of Loramie Creek also experienced elevated ammonia-N concentrations with medians frequently above target reference values. While concentrations of nitrate-nitrite-N and total phosphorus increased somewhat downstream from the Botkins WWTP discharge (RM 35.4), significant increases were noted downstream from the Miami-Erie Canal (Minster WWTP discharge RM 1.8) in both years. The overall median total phosphorus concentration in Loramie Creek increased from 0.28 mg/l in 1994 to 0.35 mg/l in 2008. Total suspended solids increased downstream from the Mile Creek confluence in both surveys.

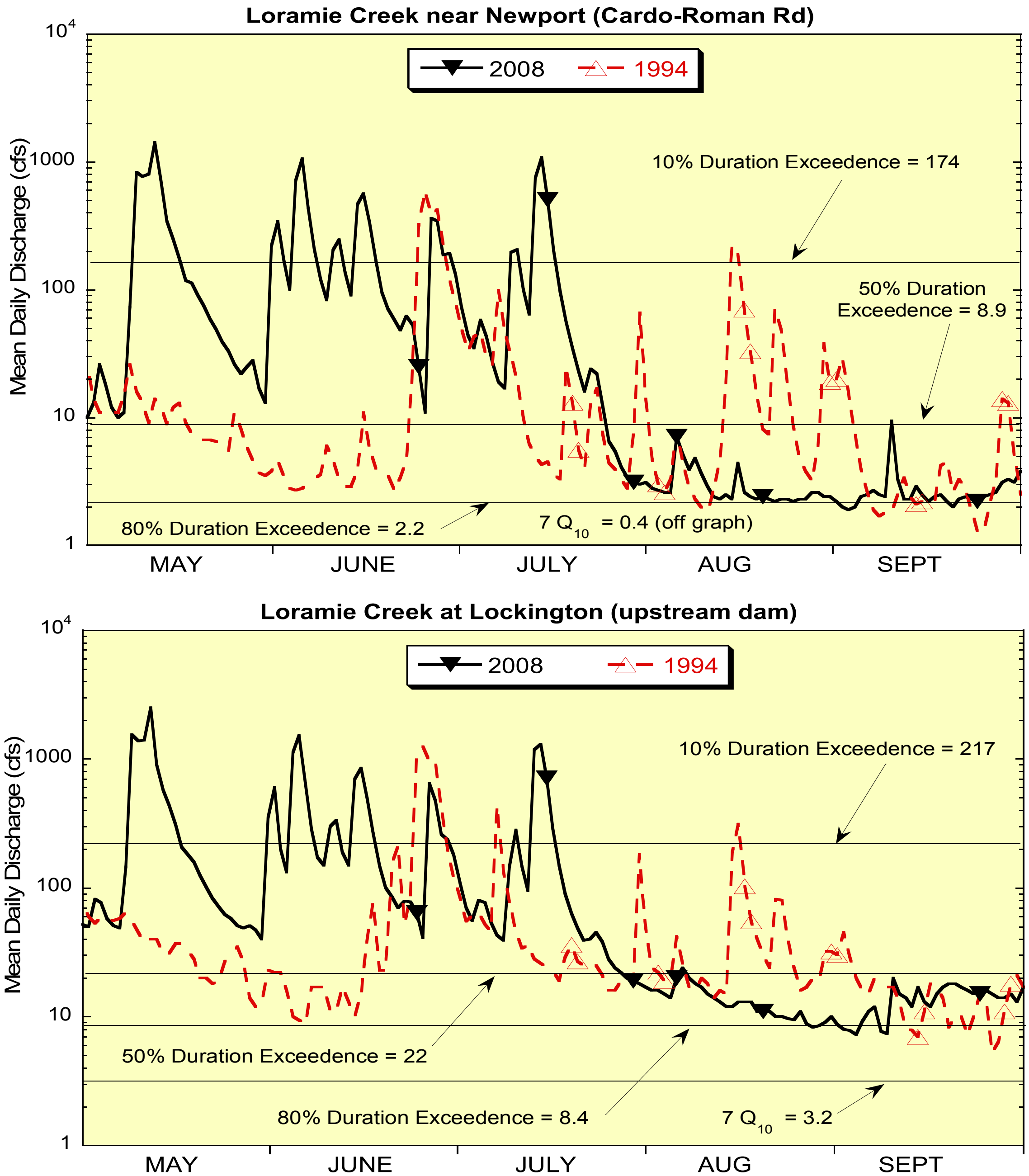


Figure 38. May through September, 2008 and 1994 flow hydrographs for Loramie Creek near Newport (USGS station #03261950) and Loramie Creek at Lockington (USGS station #03262000). Markers indicate river discharge on water chemistry sampling days in the Loramie Creek watershed for each year. (Duration exceedence and $7Q_{10}$ flow lines represent May-Nov 1964-1997 period of record for Newport gage and 1915-1997 for Lockington gage.)

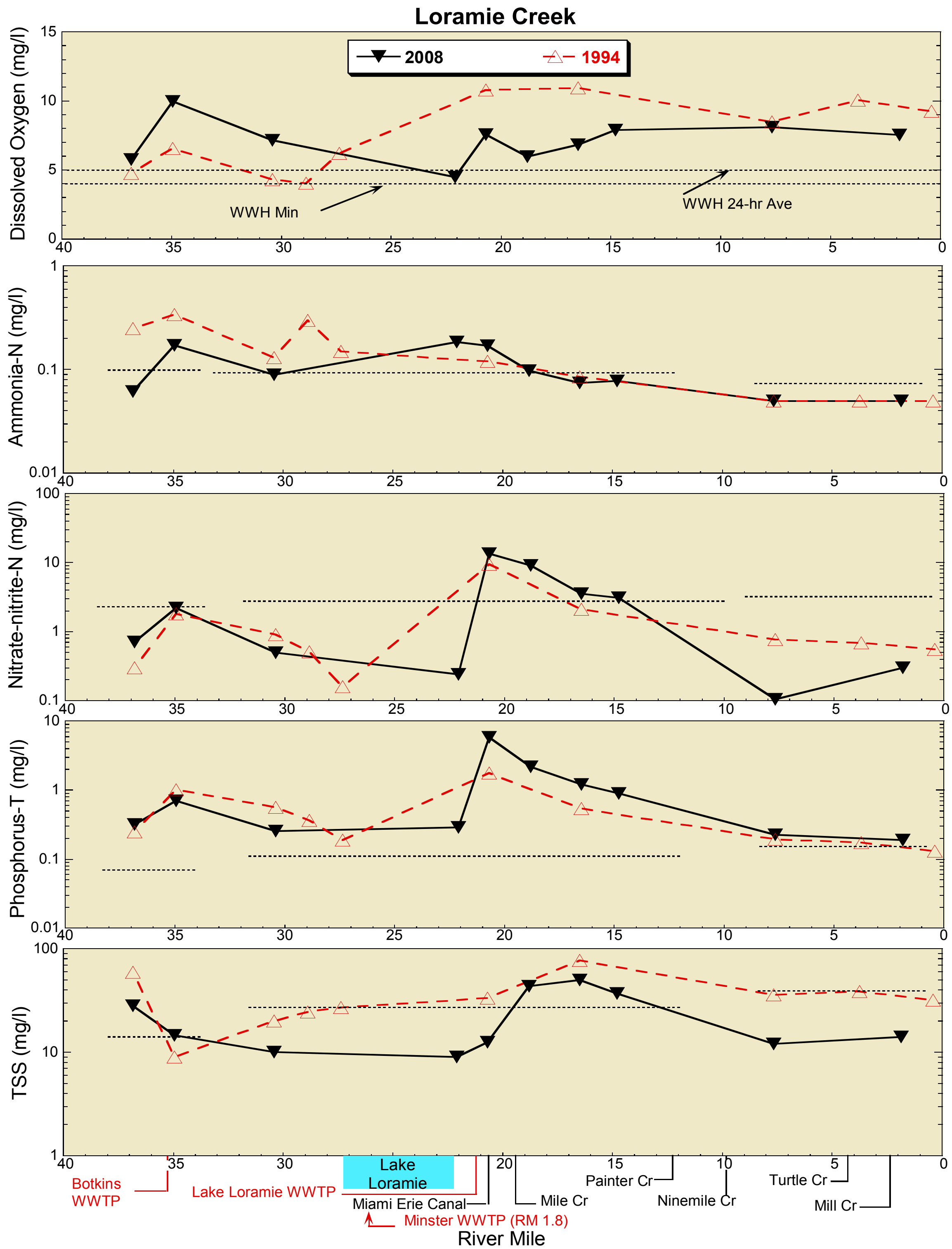


Figure 39. Longitudinal plots of median concentrations of dissolved oxygen (D.O.), ammonia-N, nitrate-nitrite-N, total phosphorus and total suspended solids (TSS) in Loramie Creek in 2008 and 1994. Water quality criteria are shown in the D.O. plot. Dashed horizontal lines in other plots represent applicable reference values from sites of similar size in the Eastern Corn Belt Plains (ECBP).

Chemical Sediment Quality

Upper Great Miami River Watershed

A total of 43 sediment samples were collected from the upper Great Miami River watershed survey area. Five samples were collected on the mainstem and 38 samples were collected among 18 tributaries. The higher numbers of tributary samples were collected in order to match water column dissolved phosphorus sites. Sediment metals and nutrients are listed in **Appendix Table B1- B8**. Sediment organics are listed in **Appendix Table B-9**.

Sediment collection involves looking for freshly deposited sediment in the stream bed with a bias toward fine grained material (<60 microns, silt, clay, muck). The goal for an acceptable sample is a minimum of 30% fine grain material (Ohio EPA, 2001). Depositional zones on both sides of the stream channel are sampled to obtain a composite representing that segment of the stream. Samples are collected with a stainless steel scoop and composited in a stainless steel bucket. The samples are placed in the appropriate containers and placed in a cooler at 4° C.

Sediment data were evaluated using Ohio Sediment Reference Values (Ohio EPA 2003), along with guidelines established in MacDonald *et.al*. 2000. The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed. Concentrations that fell between the TEC and PEC suggest harmful effects may occur. Sediment metals detected between the MacDonald TEC and PEC, but beneath the Ohio SRV, defer to the Ohio SRV. This scenario applies to arsenic, cadmium, copper and nickel. Sediment metals exceeding the MacDonald PEC (*i.e.,* adverse effects likely to occur) are referenced in Appendix Tables. Sediment nutrients (*i.e.*, ammonia, phosphorus and TOC %) were evaluated using the Ontario guidelines (Persaud et al. 1993). Those values exceeding the Severe Effect Level (*i.e.,* levels at which pronounced effects to sediment dwelling community can be expected) are discussed in the text.

Biological evaluations were conducted at 41 of the 43 sediment sites. Sixty-three percent (26/41) of the sediment sites fully met the designated aquatic life use biological criteria. Fifty percent (13) of the full attainment sites were found to be free of organic contamination and had levels of metals and nutrients below the Ohio SRV, the MacDonald sediment guidelines and the Ontario nutrient guidelines.

More significant was that seven of the most contaminated sediment sites documented in the survey [GMR RM 143.2, South Fork GMR RM 3.95, Bokengehalas Creek RM 1.13, Blue Jacket Creek RM 5.39, Cherokee Mans Run RM 3.5 and McKees Creek (RMs 9.5 and 0.52)] were collected at locations in full attainment of the applicable EWH or WWH biological criteria. Four of the seven sites (GMR RM 143.2, South Fork GMR RM 3.95, Cherokee Mans Run RM 3.5, and McKees Creek RM 9.5) had only small pockets of sediment in an otherwise sandy/ gravely substrate. Three of the seven sites (McKees

Creek RM 0.52, Blue Jacket Creek RM 5.39 and Bokengehalas Creek RM 1.13) were from silty/mucky substrates. However, biological communities at each of the three sites were influenced by ground water flow and the Bokengehalas Creek contamination at RM 1.13 was found downstream from the biological sampling site.

Five sediment samples were collected from sites in non-attainment of the designated aquatic life use. Muchinippi Creek RM 2.37 and Loramie Creek RM 22.1 were free of organic contamination and had levels of metals and nutrients below the Ohio SRV, MacDonald, and Ontario sediment guidelines. Two sites (Loramie Creek RMs 36.84 and 34.96) reflected minimal sediment contamination from the wood preservatives pentachlorophenol and 3&4 methylphenol. Van Horn Creek sediments revealed metal contamination with arsenic levels exceeding the Ohio SRV and MacDonald TEC and manganese concentrations over the Ohio SRV. Biological impairment was noted at all sites but impacts appeared the result of causes other than sediment toxicity.

Ten sediment sites were in partial aquatic life use attainment and 9 of those were due to impaired macroinvertebrate communities. Five of the ten partial attainment sites (three MWH-C and two WWH) were free of organic contamination with levels of metals and nutrients below the Ohio SRV, MacDonald, and Ontario guidelines. Departure from the biological criteria did not appear related to sediment contamination.

Great Miami River RM 158.2 WAU 05080001-03-02

(Biological Attainment: Partial) (WWH)

The most upstream sediment site on the mainstem is at RM 158.2, just upstream from the Indian Lake WWTP outfall (RM 158.05). This site is 1.52 miles downstream from the spillway (RM 159.72) and 1.24 miles downstream from the mouth of Cherokee Mans Run (RM 159.44). No sediment metals were found above Ohio EPA or MacDonald guidelines and no sediment organics were detected. However, sediment ammonia (140 mg/kg) exceeded the Ontario Open Water Disposal guideline. This low gradient and historically modified segment flows through hydric soils and may be influenced by bypasses from the Indian Lake WWTP, lake sediment flowing over the dam and/or agricultural influences. The substrate had moderate embeddedness of sandy soil with a 28% portion of fine grained sample material, slightly below the goal of 30%.

Great Miami River RM 157.22 WAU 05080001-03-02

(Biological Attainment: Full) (WWH)

This site is located one mile downstream from the Indian Lake WWTP outfall. No metals or nutrients exceeded sediment guidelines and no organic compounds were detected. Sediment particle size was 35% fine grained material.

Great Miami River RM 143.2 WAU 05080001-04-06

(Biological Attainment: Full) (EWH)

Sediments were sampled upstream and downstream from the State Route 235 bridge, immediately downstream from the Quincy dam (RM 143.4). Sediment copper (317 mg/kg) exceeded the Ohio SRV (34 mg/kg) and the MacDonald PEC (149 mg/kg), levels at which adverse effects usually or always occur. Sediment organics analysis detected fluoranthene (0.80 mg/kg) and pyrene (0.70 mg/kg) over the MacDonald TEC, levels at which adverse effects may occur.

Sediment ammonia (1900 mg/kg) at RM 143.2 exceeded the Ontario open water disposal sediment guidelines. A drainage swale (river left, looking downstream) drains the town of Quincy near one of the sediment sampling locations. The Quincy Dam can act as a settling basin to slow water velocity and allow the finer particles to settle out during low flow. During higher flow the scouring action of the river can transport these stored particles downstream.

The Quincy-Degraff WWTP collection system has numerous SSOs which discharge throughout both cities and drain into the Great Miami River upstream from the sampling locations. Failed septic systems upstream from the dam may be another source of contamination.

Great Miami River RM 142.5 WAU 05080001-04-06

(Biological Attainment: Full) (EWH)

Downstream from the Quincy-Degraff WWTP outfall are a series of limestone trestles that span the Great Miami River valley from the old Grand Trunk Railway. The substrate was cobble, coarse and fine sand allowing only 5% fine grained material to be collected in the sample. Owing to the lack of fine sediment, no metals or nutrient exceeded sediment guidelines. No organic compounds were detected.

Great Miami River RM 129.99 WAU 05080001-07-06

(Biological Attainment: Full) (EWH)

The most downstream mainstem sediment site was located at the SR 47 bridge in Sidney. The substrate was cobble with coarse sand and some urban debris and the sample was only 24% fine grained material. No metals or nutrients exceeded sediment guidelines and no organic compounds were detected.

Upper Great Miami River Tributaries

South Fork Great Miami River RM 8.00 WAU 05080001-01-02

(Biological Attainment: Full) (WWH)

A sediment sample taken from pockets of silt and muck had 44% fine grained material. No organic compounds were detected but the metal strontium (499 mg/kg) exceeded the Ohio SRV (390 mg/kg). Strontium is commonly found in outwash sand and gravel deposits and is considered to be naturally occurring. All other nutrient and metal concentrations were below Ontario and MacDonald sediment guidelines.

South Fork Great Miami River RM 3.95 WAU 05080001-01-02

(Biological Attainment: Full) (WWH)

Sediment ammonia (510 mg/kg) was detected above the Ontario Open Water Disposal sediment guidelines but no organic compounds were detected. All other metals and nutrients were below sediment guidelines. Particle size of 26% fine grained material was below the 30% goal.

Ligitt Ditch RM 0.53 WAU 05080001-01-02
(Biological Attainment: Full) (WWH)
All nutrient and metal concentrations were below sediment guidelines in Ligitt Ditch and no organic compounds were detected. Particle size of 23% fine grained material was below the 30% goal.

North Fork Great Miami River RM 10.7 WAU 05080001-01-01
(Biological Attainment: Full) (WWH)
This site had moderate embeddedness and a particle size of 47% fine grained material. All nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected.

North Fork Great Miami River RM 6.31 WAU 05080001-01-01
[Biological Attainment: 2008, Non (ICI=Poor) / 2009, Full (ICI=Good)] (WWH)
Like the North Fork GMR upstream, all nutrient and metal concentrations were below sediment guidelines at RM 6.31 and no organic compounds were detected. The entire sample (100%) was comprised of fine grained material.

Macroinvertebrate sampling from this site reflected poor quality and possible impacts from an unknown toxicant. Re-sampling documented full recovery in 2009 and was considered confirmation of a severe but short term impact the previous year. While 2008 sediment samples revealed no evidence of contamination, it should be noted that similar sampling conducted in Bokengehalas Creek immediately following a documented pesticide kill, also found no related compounds in the sediments.

Van Horn Creek RM 0.97 WAU 05080001-01-03
(Biological Attainment: Non) (WWH)
This site is located north of Indian Lake on Highway 366. The channelized stream flows between two homes and open farmland. Clay brown sediment, similar to surrounding farm soil was collected from pockets along the stream margins. Sediment arsenic (24.8 mg/kg) was above the Ohio SRV and the MacDonald TEC (*i.e.*, adverse effects may occur) while sediment manganese (2810 mg/kg) was above the Ohio SRV. Sediment arsenic may be a legacy compound associated with brush control activities along the stream banks, while sediment manganese is a naturally occurring element. No organic compounds were detected in the sediments. By August the flow was down to a trickle and almost dry by September. Fine grained material comprised 35% of the sample.

Muchinippi Creek RM 2.37 WAU 05080001-02-02
(Biological Attainment: Non) (WWH)
Located in a wooded wetland separated by SR 274, this site had a significant amount of soft sandy sediment with gravel deposits. Sediment was taken from the base of root wads and mostly river right sampling locations. Fine grained material composed only 27% of the sample taken. No metal or nutrient concentrations exceeded sediment guidelines and no organic compounds were detected.

Muchinippi Creek RM 0.32 WAU 05080001-02-04
(Not biologically evaluated) (WWH)
The lower reach of Muchinippi Creek flows through a mixture of wooded riparian and open farmland. Organic analysis detected the herbicide methoxychlor (11.6 µg/kg) but there are no guidelines to evaluate this compound. Sediment ammonia was 100 mg/kg, just at the Ontario sediment guideline for open water disposal. No metals were detected above the Ohio and MacDonald guidelines. Fine grained material comprised 35% of the sample.

Little Muchinippi Creek RM 6.05 WAU 05080001-02-03
(Biological Attainment: Partial) (WWH)
Soft mucky sediment resulted in a sample of 100% fine grained material. However, no metals or nutrients exceeded sediment guidelines and no organic compounds were detected.

Jackson Center Creek RM 2.9 WAU 05080001-02-03
(Biological Attainment: Partial) (MWH-C recommended)
The PAHs, flouranthene (1.23 mg/kg) and pyrene (0.99 mg/kg) were detected at concentrations exceeding the MacDonald TEC. The plasticizer, bis(2-ethylhexyl)-phthalate (0.83 mg/kg), is a common sediment contaminant used in flexible vinyl products and a suspected endrocrine disrupter. However, there is no sediment toxicity guideline for this compound. Nutrient and metals concentrations were below Ohio SRV, MacDonald, and Ontario sediment guidelines. The sample was composed entirely (100%) of fine grained material..

Jackson Center Creek RM 1.8 WAU 05080001-02-03
(Biological Attainment: Partial) (MWH-C recommended)
Sediment results were similar to collections upstream with the PAH flouranthene (0.74 mg/kg) detected at concentrations above the MacDonald TEC. Bis(2-ethylhexyl)-phthalate (0.98 mg/kg) was also detected but there is no associated sediment guideline for the compound. Nutrient and metal concentrations were all below sediment guidelines. Fine grained material comprised 44% of the sample.

Willow Creek RM 3.7 WAU 05080001-02-01
(Biological Attainment: Partial) (WWH)
Located north of Indian Lake in an extensive agricultural landscape, Willow Creek sampling was conducted upstream from the Wrestle Creek Road bridge. A large farming operation is located on the northern side of the creek. Thick grey/black pudding-like muck composed most of the stream bed and fine grained material accounted for 45% of the sample. Sediment ammonia was 140 mg/kg, exceeding the Ontario open water disposal sediment guideline. Metal concentrations were below sediment guidelines and no organic compounds were detected.

It is theorized elevated sediment ammonia could have resulted from granular nitrate fertilizer, spilled on hard surfaces at upstream Ag. operations, and washed into the stream. Entrained in the thick, hydric muck substrates of Willow Creek, the NO3 would reduce to NH3 under anoxic conditions. Livestock were an unlikely source as none were observed in the area and large animal operations were mostly confined to the western part of the watershed.

Tributary to Great Miami River (157.34) RM 0.07 WAU 05080001-03-02
(Biological Attainment: Partial) (MWH-C recommended)
All nutrient and metal sediment concentrations were below Ohio EPA, Ontario and MacDonald sediment guidelines. No organic compounds were detected in the sediments. Fine grained material comprised 41% of the sample.

Bokengehalas Creek RM 12.24 WAU 05080001-03-05
(Biological Attainment: Full) (WWH)
The PAH flouranthene (0.67 mg/kg) was the only organic compound detected but concentrations exceeded the MacDonald TEC. The metal magnesium was detected at 56500 mg/kg, exceeding the Ohio SRV. No nutrients were detected above the MacDonald or Ontario sediment guidelines. The sediment particle size of 22% fine grained material fell below the 30% goal.

Bokengehalas Creek RM 7.88 WAU 05080001-03-05
(*Biological Attainment: Partial 1 wk prior to spill: Non 1 wk after spill) (WWH)*
Upper Bokengehalas Creek is historically modified and flows through farm fields with little riparian cover. Brown sediment was deposited over sand along much of the sampling area. At TR 31, a farm field ditch discharged directly to the creek resulting in heavy soil deposition in the stream bed.

On July 29th 2008, this section of the creek experienced a significant wildlife kill (ODNR Wildlife Report #768) following aerial application of the fungicide Headline® and insecticide Mustang Max® to adjacent farm fields. The spray affected an approximate 4.5 mile stream reach from upstream Flat Run to Blue Jacket Creek, just east of Bellefontaine (~ RMs 6.5-11). ODNR reported over 12,000 crayfish killed in the reach and Ohio EPA sampling found poor quality fish and macroinvertebrates immediately following the incident.

Fine grained material comprised 48% of the sediment sample from RM 7.88. Ammonia concentrations equaled the Ontario open water disposal sediment guideline (100 mg/kg) while arsenic (19.9 mg/kg) and strontium (559 mg/kg) exceeded their respective Ohio SRVs. Despite the aerial spray upstream, no organic compounds were detected at RM 7.88, approximately 3 miles downstream from the spill source.

Bokengehalas Creek RM 1.13 WAU 05080001-03-05
(Biological Attainment: Full) (WWH)
Sediment was collected downstream from the Miami St. Bridge in Degraff. The mixture of tan colored muck and fine sand was collected from an inner bend, opposite a large grain elevator and agricultural storage facility (Champion Landmark, Inc.). Ammonia concentrations (370 mg/kg) exceeded the Ontario open water disposal sediment

guideline while lead (51.8 mg/kg) surpassed the Ohio SRV. Fine grained material comprised 50% of the sample.

In addition to ammonia and lead, ten PAH compounds were detected, including five in concentrations above the MacDonald PEC (**Appendix Table B-9**). Fluoranthene concentrations (1.62 mg/kg) surpassed the MacDonald TEC while benzo(b)flouranthene (2.04 mg/kg) and benzo(g,h,i)perylene (1.40 mg/kg) were detected but have no corresponding toxicity guidelines.

Recently, it was discovered this sampling locaton was also near the source of an August 28, 2008 wildlife kill on Bokengehalas Creek (ODNR Wildlife Report #771). The spill emanated from a catch basin on the Champion Landmark property and the affected reach extended 0.75 mi. downstream, nearly to the confluence with the Great Miami River. While the catch basin was the source, the specific party responsible for the discharge remains unknown. Exceptional quality biological communities found in lower Bokengehalas Creek were collected *upstream* from this affected area.

Blue Jacket Creek RM 6.31 WAU 05080001-03-04
(*Biological Attainment: Full) (CWH recommeded)*
This site is upstream of Opossum Run and the Bellefontaine WWTP but downstream from the Bellefontaine urban area and the Daido Metal USA storm water pond. No organic compounds were detected in sediments. Nutrient and metals concentrations were all below Ohio EPA, MacDonald, and Ontario sediment guidelines. Fine grained material made up 50% of the sediment material.

Blue Jacket Creek RM 5.39 WAU 05080001-03-04
(*Biological Attainment: Full) (WWH)*
Station RM 5.39 was the most contaminated sediment site in the upper GMR survey. The second most contaminated was nearby in McKees Creek (RM 9.5). The Bluejacket Creek location is downstream from Opossum Run and the Bellefontaine WWTP. An old unregulated landfill is located in the vicinity of Opossum Run and an old coal gasification facility is in the immediate area. Fine grained material was found in 100% of the sediment sample.

Ten PAH compounds related to coal tars were detected in sediment for a total of 22.38 mg/kg, including benz(a)anthracene (2.19 mg/kg), benzo(a)pyrene (2.11 mg/kg), chrysene (2.26 mg/kg), phenanthrene (1.80 mg/kg) and pyrene (3.61 mg/kg) which were found over the MacDonald PEC. Benzo(b)flouranthene (2.04 mg/kg), benzo(g,h,i)perylene (1.49 mg/kg), benzo(k)fluoranthene (1.44 mg/kg), and indeno-(1,2,3-cd)pyrene (1.57 mg.kg) were detected but the parameters have no guidelines to evaluate toxicity.

Five legacy pesticides were detected including two, 4,4'-DDD (8.7 µg/kg) and dieldrin (8.9 µg/kg), above the MacDonald TEC. 4,4-DDD is a breakdown product of DDT which was banned from use in 1973. Dieldrin was banned from use in 1987. In addition, isomers of the 1988 banned pesticide chlordane (gamma-chlordane, 21.0 µg/kg and alpha-chlordane, 18.5 µg/kg) exceeded the MacDonald PEC. Mirex was also detected at 26.0 µg/kg but no sediment toxicity values are available. The insecticide has been banned since 1978 but was used extensively in pesticidal formulations to control the imported fire ant (Solenopsis invicta), and as a flame retardant in electronic components, plastics, and fabrics.

Polychlorinated biphenyl (PCB) cogners (PCB-1242 and PCB-1254) were detected in sediment for a total of 375.1 µg/kg. The total PCB concentrations exceeded the MacDonald TEC.

Six sediment metals were found over the Ohio SRV including magnesium (36,800 mg/kg), copper (112 mg/kg), mercury (0.288 mg/kg), nickel (84.1mg/kg), lead (720 mg/kg), and zinc (177 mg/kg). In addition, nickel and lead concentrations exceeded the MacDonald PEC.

Cherokee Mans Run RM 7.56 WAU 05080001-03-01
(*Biological Attainment: Full) (WWH)*
The sample from this upper site on Cherokee Mans Run was composed of 45% fine grained material. No metals or nutrients exceeded sediment guidelines and no organic compounds were detected.

Cherokee Mans Run RM 3.5 WAU 05080001-03-01
(*Biological Attainment: Full) (WWH)*
Sampling from this location detected the four PAHs [benz(a) anthracene (0.56 mg/kg), fluoranthene (1.30 mg/kg), phenanthrene (1.47 mg/kg) and pyrene (0.97 mg/kg)] and 4,4'-DDT, a legacy pesticide, exceeding the MacDonald PEC (adverse effects usually occur). No metals or nutrients exceeded sediment guidelines. Sediment particle size was only 13% fine grained material, well below the 30% sediment goal.

Plum Creek RM 9.0 WAU 05080001-04-05
(*Biological Attainment: Full) (WWH)*
No nutrient or metal parameters exceeded sediment guidelines in Plum Creek except for magnesium (36,800 mg/kg), which exceeded the Ohio SRV. No organic compounds were detected. Sediment particle size was 40% fine grained material.

McKees Creek RM 9.5 WAU 05080001-04-01
(*Biological Attainment: Full) (EWH/CWH recommended)*
Sediment analysis documented concentrations of six metals [arsenic (20.5 mg/kg), cadmium (0.956 mg/kg), copper (87.3 mg/kg), manganese (938 mg/kg), lead (73.2 mg/kg), and zinc (196 mg/kg)] exceeding the Ohio SRV and three (lead, copper, and zinc) exceeding the MacDonald PEC. In addition, ammonia (170 mg/kg), exceeded the Ontario open water sediment disposal guideline and Total Organic Carbon (TOC) concentrations were 11% over the Ontario Severe Effect Level guideline. Fine grained material comprised 33% of the sample.

The suspected source of the metals is a neighborhood detention pond draining to McKees Creek at RM 9.5. The detention pond likely received aerial deposition of metals from the Daido Metal USA facility (formerly Detroit Aluminum and Brass) on 1215 Greenwood St. In 1987, an Ohio EPA Division of Emergency and Remedial Response (DERR) clean up was required at the facility due to high levels of lead covering the neighborhood. Soils were removed in the neighborhood due to airborne deposition of metals.

Sediment organic analysis documented nine different PAH compounds totaling 45.68 mg/kg, in excess of the MacDonald PEC. PAH's found over their specific MacDonald PEC included benz(a)anthracene (3.33 mg/kg), benzo(a)pyrene (3.65 mg/kg), chrysene (4.62 mg/kg), fluoranthene (10.1 mg/kg), phenanthrene (5.69 mg/kg) and pyrene (7.91 mg/kg). No other organic compounds were detected.

McKees Creek RM 0.52 WAU 05080001-04-01
(*Biological Attainment: Full) (EWH/CWH recommended)*
No metal or organic contamination was found in sediments taken near the confluence with Bokengehalas Creek. Sediment ammonia was 2,000 mg/kg, just at the Ontario open water sediment disposal guideline. Livestock operations in the area may be the source of ammonia. The sample was composed entirely (100%) of fine grained material.

Loramie Creek Basin

Loramie Creek RM 38.84 WAU 05080001-05-01
(Biological Attainment: Non) (WWH)
Located in an extensive agricultural landscape, no metals exceeded Ohio EPA or MacDonald sediment guidelines at the site. Pentachlorophenol (1.71 mg/kg), a wood preservative, was detected but the compound has no associated toxicity evaluation guideline. Fine grained material comprised 44% of the sample.

Loramie Creek RM 34.96 WAU 05080001-05-03
(Biological Attainment: Non) (WWH)
Strontium (853 mg/kg) exceeded the Ohio SRV but no other metals or nutrients were exceeded sediment guidelines. A wood preservative, 3&4 methylphenol, was detected but the compound has no associated toxicity evaluation guideline. Fine grained material comprised 30% of the sample.

Loramie Creek RM 30.42 WAU 05080001-05-01
(Biological Attainment: Partial) (WWH)
No metal, nutrient or organic chemical parameters were found above Ohio EPA, MacDonald, or Ontario sediment guidelines. Sediment from this site had 11% fine grained material, well below the goal of 30%.

Loramie Creek RM 22.1 WAU 05080001-05-01
(Biological Attainment: Non) (WWH)

Located immediately downstream from the Lake Loramie dam, all nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected. One hundred percent of the sample was fine grained material.

Loramie Creek RM 20.7 WAU 05080001-05-03
(Biological Attainment: Full) (WWH)
The Loramie Creek RM 20.7 site was located immediately downstream from the Miami-Erie Canal (Village of Minster, Minster WWTP) and the Lake Loramie WWTP. The sediment sample was mostly sand and gravel with only 9% fine grained material. Despite the relatively coarse sediments, phosphorus concentrations (2260 mg/kg) and strontium (738 mg/kg) exceeded the Ontario and Ohio SRV guidelines, respectively. The only organic compound detected was 3&4 methylphenol (0.74 mg/kg), a wood preservative with no sediment guidelines.

Loramie Creek RM 18.82 WAU 05080001-06-02
(Biological Attainment: Partial) (WWH)
Sediment strontium was detected at 444 mg/kg, exceeding the Ohio SRV. All nutrients were below Ontario and MacDonald guidelines and no organic compounds were detected. Fine grained material comprised 28% of the sample, slightly below the 30% goal.

Loramie Creek RM 16.51 WAU 05080001-06-02
(No Biological Analysis) (*WWH*)
All nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected. Sediment particle size was 23% fine grained material, below the 30% goal.

Loramie Creek RM 1.87 WAU 05080001-06-04
(Biological Attainment: Full) (WWH)
All nutrient and metal sediment concentrations were below Ohio EPA, Ontario and MacDonald sediment guidelines. No organic compounds were detected. Sediment particle size was 7% fine grained material, well below the 30% goal.

Miami-Erie Canal RM 0.1 WAU 05080001-05-03
(Biological Attainment: Full) (MWH-C recommended)
The entire canal sediment sample was composed of fine grained material (< 60 microns). While no organic compounds were detected, cadmium (0.919 mg/kg) and manganese (1020 mg/l) exceeded the Ohio SRV and ammonia (340 mg/kg) exceeded Ontario Open Water disposal guidelines.

Mile Creek RM 9.8 WAU 05080001-05-02
(Biological Attainment: Partial) (MWH-C recommended)
The upper reaches of Mile Creek are extensively modified and drain an agricultural landscape. However, all nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected. The sample was comprised of 36% fine grained material.

Mile Creek RM 8.74 WAU 05080001-05-02
(Biological Attainment: Partial) (MWH-C recommended)
All nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected. The sample was comprised of 44% fine grained material.

Mile Creek RM 5.97 WAU 05080001-05-02
(Biological Attainment: Full) (MWH-C recommended)
No nutrient or organic chemical parameters were found above Ohio EPA, MacDonald, or Ontario sediment guidelines. Sediment iron (55,400 mg/kg) exceeded the Ohio SRV. Sediment particle size was 100% fine grained material.

Mile Creek RM 0.5 WAU 05080001-05-02
(Biological Attainment: Full) (MWH-C recommended)
All nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected. Sediment particle size was made up of 44% fine grained material.

Ninemile Creek RM 6.38 WAU 05080001-06-01
(Biological Attainment: Full) (MWH)
All nutrient and metal concentrations were below sediment guidelines and no organic compounds were detected. The entire sediment sample (100%) was made up of fine grained material.

Ninemile Creek RM 4.18 WAU 05080001-06-01
(Biological Attainment: Full) (MWH)
All nutrient and metal concentrations were below sediment guidelines. The wood preservatives 3&4 methylphenol (0.70 mg/kg) and pentachlorophenol (1.32 mg/kg) were detected but there are no associated sediment guidelines for these compounds. Sediment particle size of 22% fine grained material was below the 30% goal.

Stream Habitat Conditions

Upper Great Miami River Watershed

Stream habitat was evaluated at 78 upper Great Miami River (GMR) basin fish sites. Good to excellent habitat was found at 37 sites (47%) including Cherokee Mans Run, Blue Jacket, Bokengehalas, McKees, Lee, Graves, and Indian creeks, and a majority of the South Fork GMR and upper GMR mainstems (**Table 15**). The average QHEI score for the upper GMR was 67.0, reflecting good habitat quality. Mainstem sites were predominated by high quality bottom substrates, including cobble, gravel, boulder, and sand at 5 of the 7 sites (**Table 15**). However, two sites scored poorly (QHEI = 44.5 and 43.5 at RMs 157.22 and 153.45, respectively), the result of poor substrate quality dominated by silt (**Appendix Table C-1**). These were the second and third sites downstream from Indian Lake where the channelized river segment widens and slows down, thus settling out miles of transported silt and sediment runoff into one section.

Fair to poor habitat was noted at 36 (46%) stream sampling sites (**Table 15**), including all of Jackson Center, Rum, Stony, and Willow creeks, and most of Muchinnippi and Loramie creeks. Habitat at these streams was characterized by silty substrates, little to no woody riparian buffers, and habitat alteration (channelization) (**Appendix Table C-1**). In addition, four sites (5%) were characterized by very poor habitat quality, including two sites on Mile Creek (RM 8.7 and RM 6.0), Liggit Ditch, and a tributary to the upper Great Miami River at RM 157.34. Stream channels at these locations were channelized with substrates covered in silt or muck and row crops planted near the edges of their steeply leveed banks (see **Figure 41**). At Mile Creek RM 6.0, erosion from ATV traffic was also apparent along the river right stream bank and in the stream channel.

Figure 40. Nuisance algae blooms typical of streams with poor and very poor habitat (*e.g.,* Mile Creek RM 9.8, above).

In addition, much of Mile Creek and the GMR Tributary at RM 157.34 appeared to have flashy flow regimes, likely having sustained flow only during and immediately following storm events. Both streams were within the 55a sub-ecoregion and there was no apparent ground water connection to sustain base flows or buffer temperatures. These otherwise stagnant channels lacked sufficient canopy cover and were easily heated, creating nuisance algae blooms and severe diurnal dissolved oxygen swings (**Figure 40**). In contrast, Liggit Ditch was within the 55a subregion but had sustained ground water flows (**Figure 41**). Despite extensive channelization, the enhanced flows contributed to good quality fish communities commensurate with WWH standards.

Figure 41. The four upper GMR basin modified stream sites pictured above had very poor habitat for aquatic life. Mile Creek is under Shelby/Mercer County maintenance and recommended MWH. Liggit Ditch is also under county maintenance, but a strong ground water connection contributed to good quality fish and full WWH attainment. The Tributary to GMR @ RM 157.34 was historically modified and is currently maintained by private landowner(s) resulting in very poor habitat quality (QHEI=17.5) with little prospects for recovery. Therefore, MWH was recommended.

Table 15. Summarized results of QHEI scores for the upper Great Miami River study area, 2008.

Stream/Location	Sub-ecoregion[a]	RM	D.A.(mi.^{2})[b]	QHEI
Excellent				
Great Miami River, dst. Quincy Dam @ SR 235	55b	143.2	411.0[B]	79.0
Great Miami River @ SR 235	55b	146.2	296.0[W]	76.0
South Fork Great Miami River @ CR 38	55a ^GW	1.7	51.0[W]	83.0
South Fork Great Miami River @ SR 638	55a ^GW	8.0	11.6[H]	76.5
South Fork Great Miami River @ CR 39	55a ^GW	7.2	19.5[H]	76.5
South Fork Great Miami River @ CR 96	55a ^GW	4.0	47.0[W]	76.0
Muchinnippi Creek @ CR 87	55a ^GW	7.4	36.0[W]	76.5
Ninemile Creek	55a	0.2	26.6[W]	80.5
Plum Creek	55b	0.1	29.0[W]	84.5
Turtle Creek	55a	5.7	17.3[H]	78.5
Loramie Creek	55b	1.9	257.0[W]	92.0
Loramie Creek	55a	14.8	157.0[W]	86.0
Cherokee Mans Run @ SR 117	55b	7.6	8.5[H]	82.5
Blue Jacket Creek	55b	5.5	3.9[H]	84.5
Blue Jacket Creek	55b	6.3	2.9[H]	70.0
Bokengehalas Creek	55b	4.6	36.3[W]	89.0
Bokengehalas Creek	55b	1.1	40.3[W]	88.5
McKees Creek	55b	0.5	17.6[H]	88.5
McKees Creek	55b	9.5	3.0[H]	75.0
McKees Creek	55b	5.9	8.7[H]	72.0
Graves Creek	55b	0.5	10.9[H]	78.0
Lee Creek	55b	3.4	9.5[H]	97.5
Indian Creek	55b	0.0	15.9[H]	88.5
Good				
Great Miami River dst. Quincy WWTP, adj. CR 73	55b	142.5	412.0[B]	74.5
GMR. dst. Cher. Manns Run, ust. Ind. Lake WWTP	55a	158.9	122.0 [W]	72.5
Great Miami River ust. Port Jefferson @ Baker Rd.	55b	138.4	429.0[B]	73.0
Great Miami River @ SR 47 (E N St.) in Sidney	55b	130.0	541.0[B]	70.0
Van Horn Creek @ SR 366	55a	1.0	3.0 [H]	60.5
North Fork Great Miami River @ Dunn Rd..	55a	6.3	14.4 [H]	64.0
Trib. to S. Fk. GMR (5.27) aka New Richland Trib.	55a ^GW	0.5	11.4[H]	65.0
Ninemile Creek	55a	4.2	11.5 [H]	60.5
Turtle Creek	55a ^GW	0.4	35.9[W]	72.5
Plum Creek	55a	5.2	14.7[H]	62.5
Loramie Creek	55a	22.1	77.7[W]	71.5
Cherokee Mans Run @ US 33	55a ^GW	3.4	14.6[H]	68.0
Blue Jacket Creek	55b	0.7	13.6[H]	69.5
Bokengehalas Creek @ TR 31	55b	7.9	20.7[W]	69.0
Bokengehalas Creek ust. Spill	55b	12.2	4.8[H]	68.5
Fair				
Miami and Erie Canal @ mouth	55a	0.1	4.3[H]	48.5
South Fork Great Miami River @ CR 97	55a ^GW	5.8	30.0[W]	59.0
Trib. to S. Fk. GMR (7.24) aka Belle Center Trib.	55a ^GW	0.6	7.2[H]	44.0
Little Muchinnippi Creek nr. mouth	55a ^GW	0.6	35.2[W]	56.0
Muchinnippi Creek @ SR 274	55a	2.4	85.0[W]	47.0

Stream/Location	Sub-ecoregion[a]	RM	D.A.(mi.^{2})[b]	QHEI
Turtle Creek	55a	8.4	8.4[H]	53.5
Plum Creek	55a	9.0	7.8[H]	53.0
Loramie Creek	55a	7.5	205.0[W]	57.0
Loramie Creek	55a	20.7	82.0[W]	52.0
Loramie Creek	55a	19.3	147.0[W]	50.5
Loramie Creek	55a	35.0	15.9[H]	47.5
Rennick Creek @ SR 235	55a ^GW	0.3	10.3[H]	50.0
Brandywine Creek, @ Notestine Rd.	55a ^GW	0.6	8.8[H]	46.5
Rum Creek @ CR 58	55a ^GW	0.8	27.2[W]	59.0
Stony Creek	55b	1.6	59.1[W]	51.5
Stony Creek	55b	2.5	35.4[W]	45.0
Poor				
Great Miami River, @ SR 235	55a	157.2	131.0[W]	44.5
Great Miami River, @ CR 13	55a	153.5	247.0[W]	43.5
North Fork Great Miami R. dst. Madory Rd.	55a	10.7	9.0[H]	38.5
Willow Creek, @ Idle Rd.	55a ^GW	0.4	15.1[H]	37.5
Willow Creek, @ Wrestle Cr Rd.	55a ^GW	3.7	7.6[H]	37.0
Jackson Center Cr. ust. SR 274 & Jackson Center	55a	2.9	1.1[H]	33.5
Jackson Center Cr. @ Lock Two Rd	55a	1.8	3.0[H]	31.0
Little Muchinnippi Creek @ Wones Rd.	55a ^GW	6.1	9.3[H]	41.0
Muchinnippi Creek, @ Myers Rd.	55a ^GW	4.8	77.0[W]	43.0
Muchinnippi Creek,	55a ^GW	13.0	6.8[H]	37.0
Muchinnippi Creek, ust. US 33	55a ^GW	12.5	16.0[H]	32.0
Spring Creek	55a	0.4	8.8[H]	38.5
Mile Creek	55a	0.5	62.3[W]	38.5
Mile Creek	55a	9.8	9.7[H]	33.5
Ninemile Creek	55a	6.4	3.0[H]	30.5
Loramie Creek	55a	36.8	6.8[H]	41.0
Loramie Creek	55a	30.4	35.0[W]	39.5
Loramie Creek	55a	18.8	148.0[W]	33.5
Rum Creek, @ Meranda Rd.	55a	6.6	15.3[H]	41.5
Rum Creek, @ Wildermuth Rd.	55a	8.6	8.2[H]	31.5
Very Poor				
Liggit Ditch, @ TR 49	55a ^GW	0.5	6.5[H]	27.5
Mile Creek	55a	8.7	18.5[H]	28.0
Mile Creek	55a	6.0	34.7[W]	26.5
Trib. to Great Miami River (157.34) @ mouth	55a	0.1	7.6[H]	17.5

General narrative ranges assigned to QHEI scores.			
Narrative Rating		QHEI Range	
		Hdwtrs (≤20 sq mi)	Larger Streams
Excellent		≥70	≥75
Good		55 to 69	60 to 74
Fair		43 to 54	45 to 59
Poor		30 to 42	30 to 44
Very Poor		<30	<30

[a] **Sub-ecoregion** =(**55a**) - Clayey High Lime Till Plains, (**55b**) - Loamy High Lime Till Plains, (**55a^GW**) **-** Clayey High Lime Till Plains with enhanced ground water flow signature.
[b] **H** = headwater sampling method. **W** = wading sampling method. **B** = boat sampling method

Stream Habitat Sub-ecoregion Discussion

Significant differences were found in QHEI scores between the 55a (Clayey High Lime Till Plains) and 55b (Loamy, High Lime Till Plains) sub-ecoregions (**Figure 7**). The greatest differences were found among the headwater stream sites (< 20 mi^2) but the trend also held, to a lesser degree, at wading (> 20 mi^2) sites (**Figure 42)**. Exceptional habitat scores dominated the 55b while fair to poor scores were the average in the 55a (**Table 15**). Wading site habitat scores were good to exceptional in the 55b and exceptional to poor for the 55a, with the greatest similarities found among sites which scored within the acceptable WWH range (**Figure 42**).

As shown previously, separation of habitat scores between sub-ecoregions was also apparent in the upper Great Miami River mainstem (**Figure 44**). Each of the five sites located within the 55b sub-ecoregion scored in the excellent QHEI range. In contrast, most 55a mainstem sampling locations (between Indian Lake and the Quincy lowhead dam impoundment) were sluggish, silty and historically modified with QHEIs in the fair and poor ranges. The difference in habitat quality between the mainstem reaches was obvious. However, at the level of analysis for this report, precise cause and effect relationships between geographic or geologic variation, historic trends in channel maintenance activity, and mainstem habitat quality are uncertain.

Further examination of the 55a and 55b sub-ecoregions also showed significant differences in elevation among the sample sites (**Figure 43**). Greater elevation and stream channel slope combined with better natural drainage in the 55b sub-ecoregion yielded a greater natural capacity to buffer against anthropogenic disturbances. In contrast, streams in the 55a sub-ecoregion have a lesser natural capacity to drain and filter out pollutants and handle disturbances. An exception to this pattern was found in streams having a high ground water connection like Muchinnippi Creek (see **Figure 47**). The high ground water recharge helped alleviate the effects of nonpoint source pollutants (*e.g.,* algae blooms creating large D.O swings). These ameliorating effects were often observed, despite the presence of degraded stream habitat, poorly drained soils, and low stream gradients characteristic of the 55a sub-ecoregion.

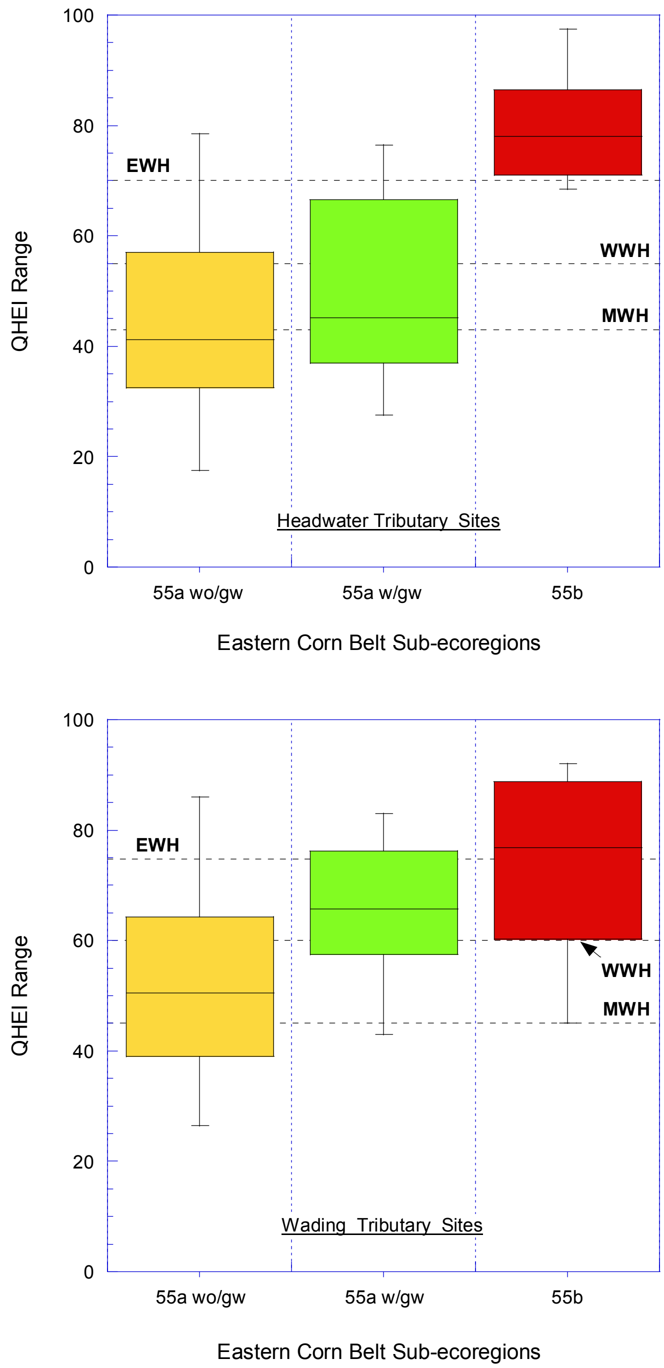


Figure 42. QHEI scores plotted by 55a, 55a with high ground water, and 55b sub-ecoregion categories for headwater (top) and wading (bottom) sites in the upper Great Miami River watershed, 2008.

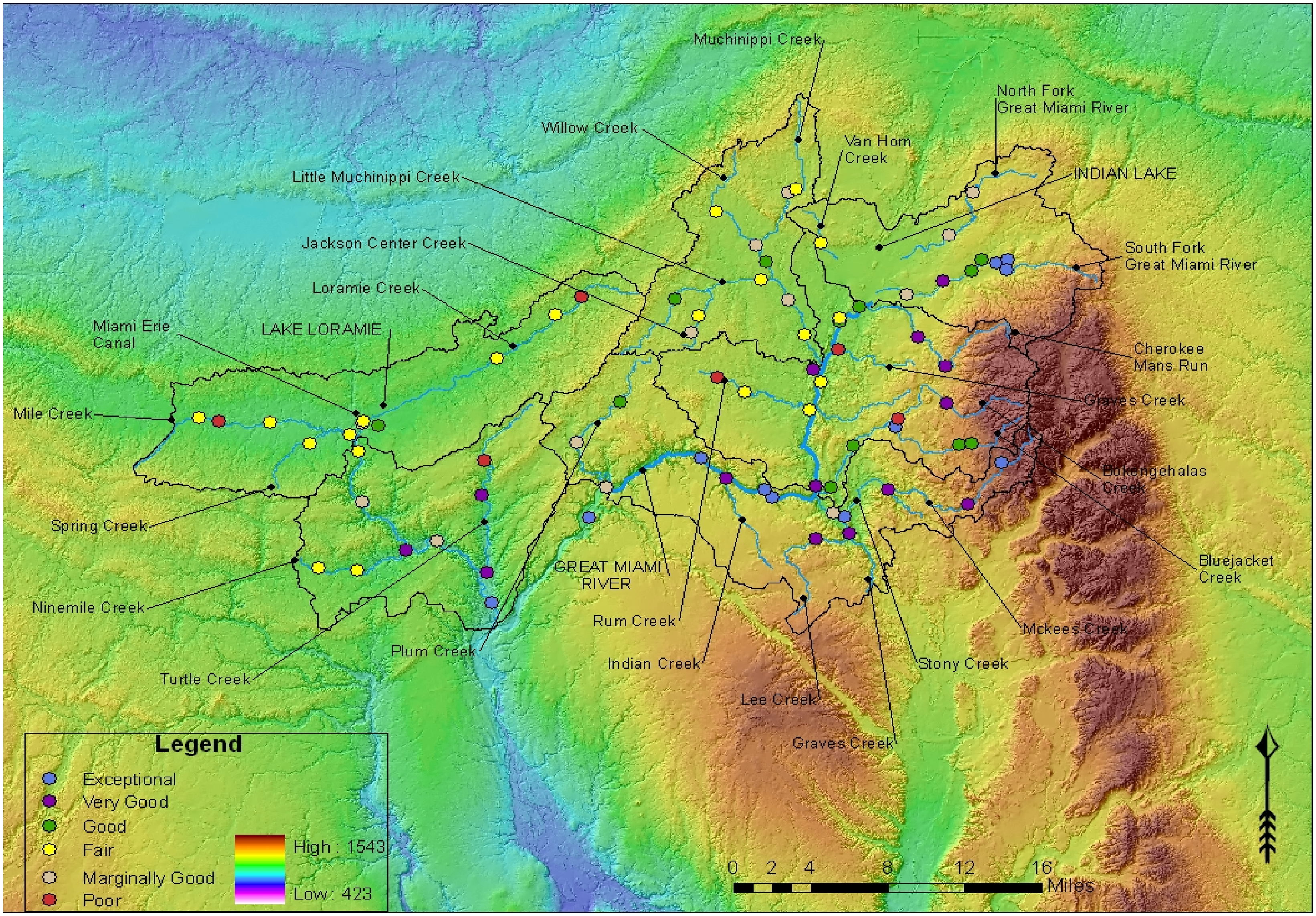


Figure 43. Upper GMR basin 2008, narrative fish sampling results overlaying a portion of the Ohio 10 meter digital elevation map (DEM) with hillshade.

Stream Habitat Trends (1994-2008)

Upper Great Miami River

Stream habitat quality in the upper GMR mainstem displayed one significant change from 1994 to 2008 (**Figure 44**). Habitat improved from fair to very good downstream from the Indian Lake dam (RM 158.9). Habitat in this reach is slowly recovering from channelization as the river forms a more heterogeneous channel consisting of riffle, run, and pool morphological characteristics. However, habitat quality slightly decreased at two mainstem sites downstream at SR 235 and Notestine Rd. (RM 157.2 and RM 153.5). This historically modified section of the river is very wide and slow and the substrates are covered in silt and fine sediment. It appears that as the upstream channel erodes and becomes more stable, the silt and sediment is being deposited downstream in reaches near RM's 157.0 and 153.5.

Beginning upstream from the Quincy low-head dam impoundment (RM 146.2) and extending downstream to Sidney (RM 130.0), habitat quality in the Great Miami River habitat improved from fair to very good. This stretch of the upper mainstem is located entirely within the 55b sub-ecoregion and characterized by more natural, unmodified channels, particularly within the EWH designated reach downstream from the Quincy dam. This lower, 55b section is clearly more stable, showing little to no change in habitat in 14 years, as evidenced by the nearly identical QHEI scores (**Figure 44**).

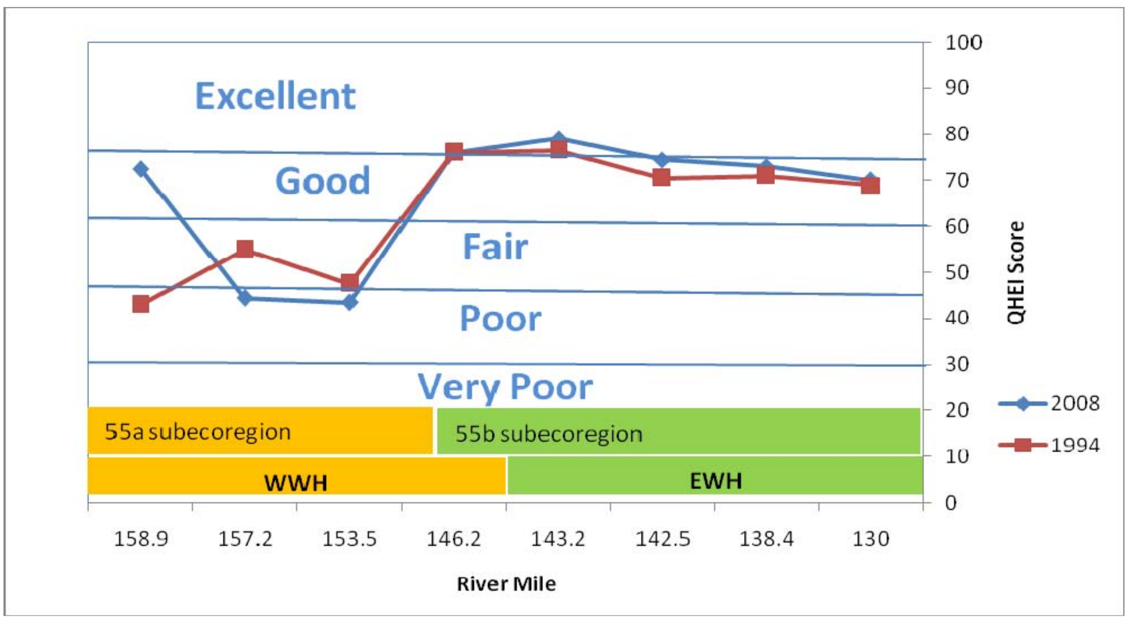


Figure 44. QHEI trends from similar sampling locations in the upper Great Miami River mainstem outlined by sub-ecoregion, narrative habitat quality, and aquatic life use designations (1994 and 2008).

Upper Great Miami River basin Tributaries

Comparisons between historical habitat scores from upper GMR tributaries and 2008 scores showed overall improvements in three of six streams sampled (**Figure 45**).

Bokengehalas Creek, McKees Creek, and the South Fork GMR all displayed significant improvements in habitats. In contrast, Blue Jacket, Loramie, and Muchinnippi creeks showed only modest improvement since 1994.

Regarding the improved tributaries, recovery from channelization and silt reduction in McKees Creek yielded higher QHEI scores at both river miles 9.5 and 0.6 (**Figure 45**). Based on field sheet notations, Bokengehalas Creek habitat at Township Rd. 31 (RM 8.0) shifted from “channelized” to “recovering” between 1994 and 2008; improved substrate conditions and less silt were found downstream at Township Rd. 209 (RM 4.6) during the same period. The South Fork GMR showed similar improvements, ranging from recovery from channelization in the headwaters (RM 8.0) and middle reaches (RM 5.8) to improved substrates and less siltation near the most downstream site at RM 1.8. Unfortunately, recent field observations from the spring of 2011 indicate the restored woody riparian buffers near South Fork RMs 8.0 and 7.4 have been removed and the gains in habitat quality and fish community health observed in 2008 may be at risk.

Blue Jacket Creek, Loramie Creek, and Muchinnippi Creek stations showed less change in habitat quality. In Blue Jacket Creek, recovery from channelization was limited to the headwater site (RM 6.3), upstream from Opossum Run and the Bellefontaine WWTP. No significant improvement was observed downstream, near RM 5.5, and a large difference in QHEIs at TR 31 (RM 0.72) was related to differences in sampling reaches (*i.e.,* upstream and downstream from the bridge), not differences in quality between surveys (**Figure 45**).

In Loramie Creek, the only notable change in habitat quality between surveys was at SR 66 (RM 20.8), between the Miami-Erie Canal and Mile Creek. The stream was showing signs of recovery, forming a more stable channel within the boundaries of its leveed banks in 2008. Habitat quality in the Muchinnippi Creek headwaters (*i.e.,* U.S. Route 33 at RM 12.5) was identical during both 1994 and 2008 surveys (QHEIs = 32). The headwaters are petitioned under the Auglaize County ditch maintenance laws and were in a channelized condition during each year. Like the differences observed in lower Blue Jacket Creek, differences in QHEI scores at Muchinnippi Creek RM 7.4 were related to sampling zone variation (*i.e.,* upstream and downstream from the bridge), not a significant change in habitat quality (**Figure 45**).

To remedy observed habitat problems, efforts should be made to restore modified streams to their natural morphological state. Natural stream channels have a greater capacity to assimilate nutrients and fine sediments by flushing them into adjacent floodplains, help process nutrients into beneficial biomass rather than nuisance algae, improve water quality, create diverse instream habitats, and ultimately (and most important for adjacent landowners) evolve into a stable channel. Many current causes and sources of stress within the watershed could be reduced or eliminated by allowing altered stream channels and riparian vegetation to recover naturally. As a goal and wherever possible, previous physical modifications should be undone (*e.g.*, remove remaining dams, restore cutoff channels, restore wetlands, move dikes and levees away from stream banks).

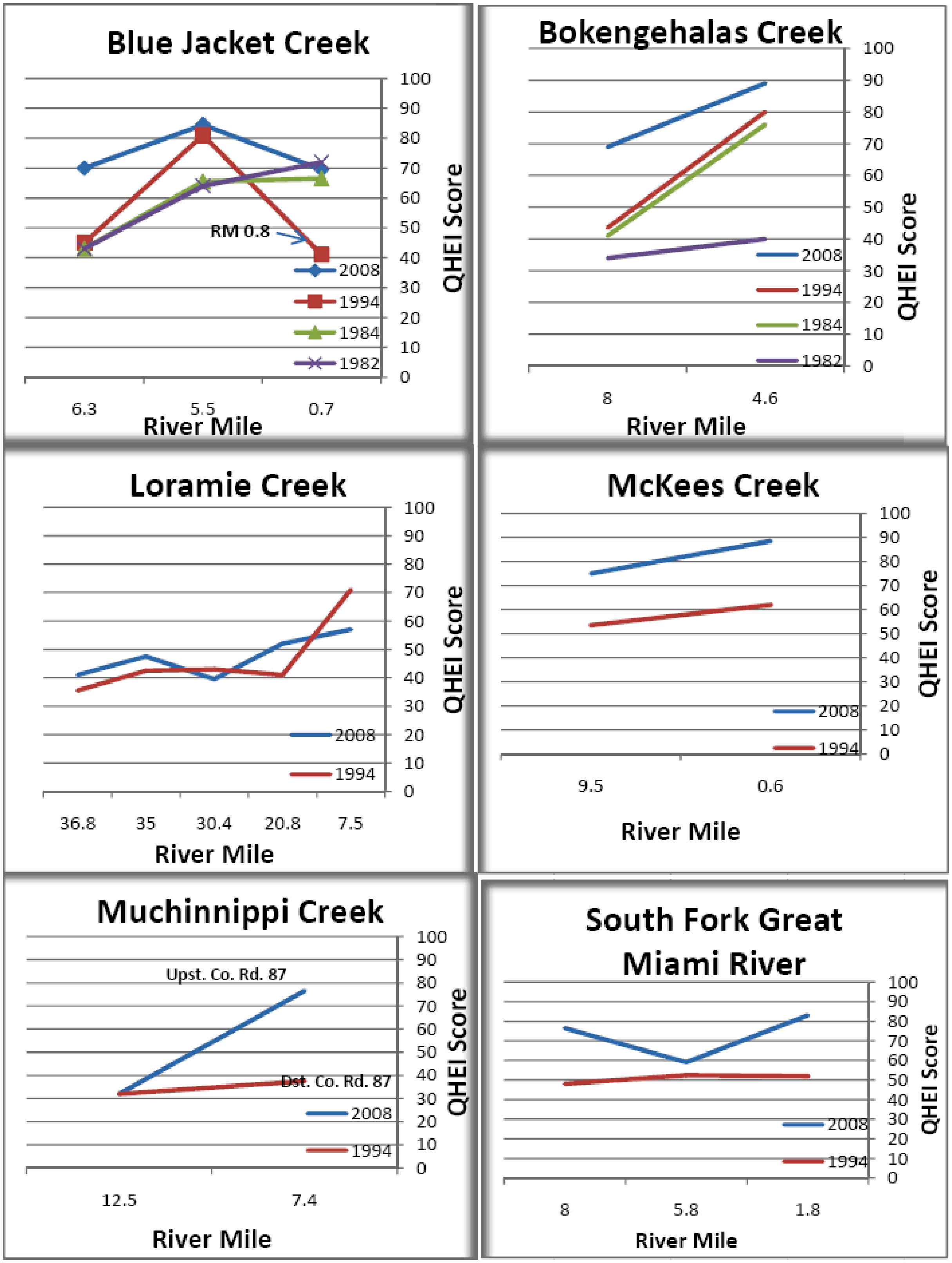


Figure 45. Upper Great Miami River tributaries historical QHEI score comparisons, 1982-2008.

Fish Community

Upper Great Miami River Watershed

Fish sampling was conducted at 78 sites during the upper GMR watershed study, 2008. Sixty-five of the fish sites attained respective designated aquatic life uses. The average IBI score on the mainstem of the upper Great Miami River was 50 while tributary sites scored an average IBI of 43. Fish collection data, sorted by narrative quality and based on IBI and MIwb scores, is summarized in **Table 16**. IBI metric scores for headwater, wading and boat method sample sites are detailed in **Appendix D**. Relative numbers of fish species collected per location are presented in **Appendix E**. Sampling locations were evaluated using the appropriate WWH, MWH, CWH or EWH biocriteria. Biological attainment status and associated IBI and MIwb scores are presented in **Table 4**.

Fish Communities Fully Meeting Biocriteria

Watershed: 83%
Great Miami River: 88%
Tributaries: 82%

The Great Miami River watershed sites sampled during 2008 achieved the applicable fish biocriterion at 65 of the 78 sites evaluated (83%). Five sites were partially achieving the biocriterion (8%) and eight sites did not meet standards, representing 10% of the total watershed sites.

Upper Great Miami River mainstem

The Great Miami River is designated WWH from its source at the Indian Lake dam (RM 159.7) to the Quincy dam at RM 143.4. An EWH designated reach extends over 50 miles downstream from Quincy dam to the CSX RR bridge at RM 84.5 near Troy (excluding dam pools in Sidney, Piqua, and Troy). The fish community was in full attainment at seven of the eight sites that were sampled between RM 158.90 and RM 129.99. The Great Miami River at Notestine Rd. (RM 153.45) was the only site that partially met WWH criteria due to habitat impairment (channelization) and organic enrichment downstream from the Indian Lake WWTP (**Table 4**). Therefore, 12.21 miles of the Great Miami River fully achieved WWH biocriteria and 0.5 miles partially met. Fish communities from the lower 13.21 miles of the upper Great Miami River fully achieved the designated EWH aquatic life use.

The descriptive narrative fish community evaluations provided in **Table 16** allow for the comparison of fish communities from site to site. The upper Great Miami River mainstem scored in the exceptional category at the four downstream EWH designated sites while three of four sites within the upper, WWH reach were very good to marginally good. Only the GMR mainstem at Notestine Road (RM 153.45) in the fair range.

Eight tributary sites also scored within the exceptional category, and thirty-eight of the tributaries met the designated aquatic life use of WWH or CWH (**Table 16, Table 4**). Sites that scored within the good and marginally good categories would meet the minimum WWH biocriterion for fish.

Upper Great Miami River Tributaries

Fish communities at thirteen Great Miami River tributary stations did not meet (n=7) or only partially met (n=6) the applicable biocriteria associated with their aquatic life use designations (**Table 4, Table 16**). The most common cause of impairment among eleven of the thirteen sites was habitat alteration (*i.e.,* channelization). The modified channels often exacerbated other, associated forms of pollution including excessive nutrient loadings (primarily phosphorus) from nonpoint sources and siltation. In addition, municipal waste treatment discharges contributed to impairments at two modified channel sites on Loramie Creek at RMs 35.0 (downstream from Botkins) and 18.82 (downstream from Minster and the Lake Loramie SSD), respectively.

Fish community impairments at remaining upper GMR tributary sites were not directly related to habitat alteration associated with agriculture. For example, Rum Creek (RM 0.79) at County Rd. 58 had largely recovered from historic channelization (QHEI=59.0). However, excessive silt exported from erosion and runoff via the modified channel upstream resulted in the fish only partially meeting WWH criteria. Loramie Creek (RM 30.42) at Hardin-Wapakoneta Rd. was channelized but also essentially a backwater area of Lake Loramie, consisting mainly of pool/glide habitats covered in silt. As a result, the fish community was more indicative of a lake ecosystem, lacking darter and intolerant species typically associated with riffle and run habitats (**Appendix D**).

A toxic impact from aerial pesticide spray occurred in Bokengehalas Creek on July 30, 2008, northwest of Bellefontaine (ODNR spill #768). The spray impacted macroinvertebrate populations particularly hard with over 12,000 crayfish killed in an approximate 4.5 mile reach. The Ohio EPA wading site at TR 31 (RM 7.9), requiring two sample passes for assessment of the fish community, was located within the affected spill area. These circumstances resulted in collections both immediately before and after the incident. The first sampling event on 7/16/08 occurred several weeks before the spray and received an IBI score of 38 (marginally good) with a MIwb of 6.3 (fair). One week after the spill on 8/04/2008, no dead fish were observed but a sharp, post-spray decline in fish community performance was detected. The IBI score was 32 (fair) and the MIwb score (5.6) was in the poor range (**Table 4, Table 16**). The first sampling pass yielded 18 fish species and one sensitive species, the rosyface shiner. Post-spray sampling found only 14 total species and sensitive varieties were absent (**Appendix E**).

Fish community performance in Mile Creek fell almost entirely in the fair to poor ranges but met the recommended MWH aquatic life use designation. However, despite demonstrating adequate community level quality, individual specimens from Mile Creek at Kremer Rd. (RM 5.97) were in very poor physical health. Many had parasites and a gold fish, *Carassius auratus,* had a spinal deformity. An emaciated channel catfish, *Ichtalurus punctatus,* suffered the greatest amount of DELT's and was presumably subjected to the poor water quality conditions much longer than the rest of the community (**Figure 46**). The presence of these multiple DELTs (*i.e.,* focal discoloration, raised lesions on the mandible, and eroded barbells) were indicative of chronic sublethal stress.

Figure 46. Pictured above is an emaciated channel catfish caught in Mile Creek (RM 5.97) at Kremer Rd. which was suffering chronic sub-lethal stress from poor water quality. This was apparent from the multiple DELT's: focal discoloration, raised lesions on the mandible, and eroded barbells**.**

Table 16. Fish community status for stations sampled in the upper Great Miami River basin based on data collected in 2008. The Index of Biotic Integrity (IBI) and Modified Index of well being (MIwb) scores are based on fish community performance. Narrative evaluations (Exceptional, Very Good, etc.) were based upon the corresponding IBI and MIwb relative to the drainage area, ecoregion, and assigned aquatic life use. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the stream habitat to support a biotic community.

Stream/Location	Sub-ecoregion	River Mile	Drain.[a] (mi.^{2})	Species (Total)	Relative Number	Rel. Wt (Kg)	IBI	MIwb[b]	QHEI
Exceptional									
Great Miami River dst. Quincy Dam @ SR 235	55b	143.2	411.0[B]	29	727.0	134	59	9.8	79.0
Great Miami River dst. Quincy WWTP, adj. CR 73	55b	142.5	412.0[B]	24	657.0	189	54	9.8	74.5
Great Miami River ust. Port Jefferson @ Baker Rd.	55b	138.4	429.0[B]	31	663.0	111	56	9.7	73.0
Great Miami River @ SR 47 (E N St.) in Sidney	55b	130.0	541.0[B]	29	678.0	147	56	10.2	70.0
South Fork Great Miami River, @ SR 638	55a^GW	8.0	11.6[H]	22	1484.0	NA	54	NA	76.5
South Fork Great Miami River, @ CR 39	55a^GW	7.2	19.5[H]	22	1981.5	24.87	51	NA	76.5
Trib. to S. Fk. Great Miami R. (5.27) New Richland Trib.	55a ^GW	0.5	11.4[H]	21	2818.0	NA	52	NA	65.0
Trib. to S. Fk. GMR (7.24) aka, Belle Center Trib. @ SR 638	55a ^GW	0.6	7.2[H]	16	828.0	NA	50	NA	44.0
Loramie Creek	55b	1.9	257.0[W]	37	1060.5	78.45	53	10.3	92.0
Blue Jacket Creek	55b	0.7	13.6[H]	20	2350.0	NA	56	NA	69.5
McKees Creek	55b	9.5	3.0[H]	9	860.0	NA	50	NA	75.0
Stony Creek	55b	2.5	35.4[W]	31	1415.3	15.14	51	9.6	45.0
Very Good									
Great Miami River, SR 235	55b	146.2	296.0[B]	33	401.0	95	46	8.9	76.0
South Fork Great Miami River @ CR 96	55a ^GW	4.0	47.0[W]	23	1625.3	14.48	46	8.9	76.0
Ninemile Creek	55a	0.2	26.6[W]	27	870.8	35.16	47	9	80.5
Turtle Creek	55a	5.7	17.3[H]	21	936.0	NA	48	NA	78.5
Turtle Creek	55a ^GW	0.4	35.9[W]	27	632.3	17.88	47	8.9	72.5
Cherokee Mans Run @ SR 117	55b	7.6	8.5[H]	13	594.0	NA	48	NA	82.5
Cherokee Mans Run @ US 33	55a ^GW	3.4	14.6[H]	16	1786.0	NA	48	NA	68.0
Brandywine Creek @ Notestine Rd.	55a ^GW	0.6	8.8[H]	24	1502.3	NA	48	NA	46.5
Bokengehalas Creek	55b	12.2	4.8[H]	9	1436.0	NA	46	NA	68.5
McKees Creek	55b	5.9	8.7[H]	15	770.0	NA	46	NA	72.0
McKees Creek	55b	0.5	17.6[H]	11	614.0	NA	48	NA	88.5
Graves Creek	55b	0.5	10.9[H]	15	718.0	NA	48	NA	78.0

Stream/Location	Sub-ecoregion	River Mile	Drain.[a] ($mi.^2$)	Species (Total)	Relative Number	Rel. Wt (Kg)	IBI	MIwb[b]	QHEI
Lee Creek	55b	3.4	9.5[H]	13	942.0	NA	48	NA	97.5
Indian Creek	55b	0.0	15.9[H]	20	1566.0	NA	48	NA	88.5
Good									
Great Miami River dst. Cher. Manns Run, ust. Ind. Lake WWTP	55a	158.9	122.0[W]	36	1736.0	236	44	10.4	72.5
Great Miami River @ SR 235	55a	157.2	131.0[W]	33	352.0	77	48	8.4	44.5
Liggit Ditch @ TR 49	55a ^GW	0.5	6.5[H]	17	2010.0	NA	44	NA	27.5
South Fork Great Miami River @ CR 97	55a ^GW	5.8	30.0[W]	27	1752.8	22.09	42	9.2	59.0
Little Muchinnippi Creek @ Wones Rd.	55a ^GW	6.1	9.3[H]	17	5500.0	NA	40	NA	41.0
Muchinnippi Creek	55a ^GW	13.0	6.8[H]	18	1032.0	NA	42	NA	37.0
Muchinnippi Creek @ CR 87	55a ^GW	7.4	36.0[W]	25	1228.0	24.05	48	8.6	76.5
Plum Creek	55a	9.0	7.8[H]	19	8684.0	56	40	NA	53.0
Loramie Creek	55a	22.1	77.7[W]	31	1269.0	132.65	43	9.6	71.5
Blue Jacket Creek	55b	6.3	2.9[H]	8	742.0	NA	40	NA	70.0
Blue Jacket Creek	55b	5.5	3.9[H]	9	2158.0	NA	44	NA	84.5
Bokengehalas Creek	55b	4.6	36.3[W]	26	740.0	26.9	47	8.6	89.0
Bokengehalas Creek	55b	1.1	40.3[W]	26	513.8	21.44	50	8.8	88.5
Marginally Good									
N. Fk. Great Miami River @ farm lane dst. Madory Rd.	55a	10.7	9.0[H]	18	1974.0	NA	36[ns]	NA	38.5
N. Fk. Great Miami River @ Dunn Rd.	55a	6.3	14.4[H]	16	2402.0	NA	36[ns]	NA	64.0
S. Fk. Great Miami River @ CR 38	55a ^GW	1.7	51.0[W]	25	749.3	20.91	46	8.1[ns]	83.0
Willow Creek @ Idle Rd.	55a ^GW	0.4	15.1[H]	15	1080.0	NA	38[ns]	NA	37.5
Jackson Center Creek ust. SR 274 & Jackson Center	55a	2.9	1.1[H]	9	208.0	NA	36	NA	33.5
Muchinnippi Creek ust. US 33	55a ^GW	12.5	16.0[H]	15	476.0	NA	36[ns]	NA	32.0
Muchinnippi Creek @ Myers Rd.	55a ^GW	4.8	77.0[W]	29	1340.3	12.32	45	8.2	43.0
Plum Creek	55a	5.2	14.7[H]	20	6488.0	NA	38[ns]	NA	62.5
Plum Creek	55b	0.1	29.0[W]	28	1358.0	6.4	38[ns]	8.3	84.5
Loramie Creek	55a	20.7	82.0[W]	23	862.5	53.47	39[ns]	8	52.0
Loramie Creek	55a	19.3	147.0[W]	19	612.0	22.38	38[ns]	8.5	50.5
Loramie Creek	55a	14.8	157.0[W]	30	1828.5	49.28	37[ns]	9.1	86.0
Loramie Creek	55a	7.5	205.0[W]	26	776.3	61.53	38[ns]	9.3	57.0
Stony Creek	55b	1.6	59.1[W]	27	181.5	30.62	48	7.9[ns]	51.5

Stream/Location	Sub-ecoregion	River Mile	Drain.[a] (mi.2)	Species (Total)	Relative Number	Rel. Wt (Kg)	IBI	MIwb[b]	QHEI
Fair									
Great Miami River @ CR 13 (Notestine Rd.)	55a	153.5	247.0[B]	22	243.0	91	38	7.7*	43.5
Miami and Erie Canal @ mouth	55a	0.1	4.3[H]	8	580.0	NA	28	NA	48.5
Van Horn Creek @ SR 366	55a	1.0	3.0[H]	16	1448.0	NA	34*	NA	60.5
Willow Creek, Dst. Wrestle Cr Rd. & dst. Trib.	55a ^GW	3.7	7.6[H]	11	370.0	NA	36[ns]	NA	37.0
Jackson Center Cr. @ Lock Two Rd, dst. Jck. Ctr. WWTP	55a	1.8	3.0[H]	9	543.0	NA	32	NA	31.0
Little Muchinnippi Cr. @ gravel Rd. near mouth	55a ^GW	0.6	35.2[W]	22	2298.0	10.15	34*	7.7*	56.0
Muchinnippi Creek @ SR 274	55a	2.4	85.0[W]	22	184.5	63.92	36[ns]	6.6*	47.0
Spring Creek	55a	0.4	8.8[H]	17	3580.0	NA	32	NA	38.5
Mile Creek	55a	9.8	9.7[H]	7	694.0	NA	34	NA	33.5
Mile Creek	55a	6.0	34.7[W]	22	2739.0	62.32	30	8.6	26.5
Mile Creek	55a	0.5	62.3[W]	25	1113.8	20.98	35	7.6	38.5
Ninemile Creek	55a	6.4	3.0[H]	6	344.0	NA	28	NA	30.5
Ninemile Creek	55a	4.2	11.5[H]	13	258.0	NA	30	NA	60.5
Loramie Creek	55a	35.0	15.9[H]	14	416.0	NA	34*	NA	47.5
Loramie Creek	55a	30.4	35.0[W]	15	579.8	40.53	30*	7.1*	39.5
Loramie Creek	55a	18.8	148.0[W]	22	352.0	40.48	34*	7.9[ns]	33.5
Trib. to Great Miami R. (157.34) via path off SR 235	55a	0.1	7.6[H]	21	1761.0	NA	34	NA	17.5
Rum Creek, @ Meranda Rd.	55a	6.6	15.3[H]	14	804.0	NA	32*	NA	41.5
Rum Creek, @ CR 58	55a ^GW	0.8	27.2[W]	22	606.0	14.38	45	7.6*	59.0
Bokengehalas Creek (Pre Spill), @ TR 31	55b	7.9	20.7[W]	18	504.0	7.85	38[ns]	6.3*	69.0
Poor									
Mile Creek	55a	8.7	18.5[W]	15	1800.0	NA	26	NA	28.0
Turtle Creek	55a	8.4	8.4[H]	14	424.0	NA	22*	NA	53.5
Loramie Creek	55a	36.8	6.8[H]	12	904.0	NA	26*	NA	41.0
Rennick Creek @ SR 235	55a ^GW	0.3	10.3[H]	12	148.0	NA	26*	NA	50.0
Rum Creek @ Wildermuth Rd.	55a	8.6	8.2[H]	11	627.7	NA	24*	NA	31.5
Bokengehalas Creek (Post Spill)	55b	7.9	20.7[W]	14	524.0	9.31	32*	5.6*	69.0

[a] - Letters in superscript refer to fish site type and associated biocriteria as indicated in the table below. B=boat, W=wading, and H=headwater.
[b] - MIwb is not applicable to headwater streams ≤ 20 mi2.

Stream/Location	Sub-ecoregion	River Mile	Drain.[a] (mi.[2])	Species (Total)	Relative Number	Rel. Wt (Kg)	IBI	MIwb[b]	QHEI

Sub-ecoregion = (55a) - Clayey High Lime Till Plains, (55b) - Loamy High Lime Till Plains, (55a^GW) – Clayey High Lime Till Plains with high ground water, (Boat) – Large drainage – sub-ecoregion criteria not comparable to habitat/ground water phenomena in smaller drainages.

Biological Criteria for Eastern Corn Belt Plains Ecoregion

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

Fish Community Sub-ecoregion Discussion

Several distinct patterns among habitat characteristics and biological community performance were found between sub-ecoregions within the upper Great Miami River study area. For example, better fish community performance was found in tributary sites within the Loamy High Lime Till Plains (55b) sub-ecoregion compared to streams in the Clayey High Lime Till Plains (55a) sub-ecoregion (**Figure 48**). Each 55b collection included fish populations associated with cold water conditions including mottled sculpin, southern redbelly dace, redside dace, and brook stickleback (Ohio EPA 1987b) or yielded species suggesting a strong groundwater connection and abundant base flow, [*i.e.,* pollution intolerant hornyhead and river chubs (Trautman 1981, Ohio EPA file data)]. The combination of cool flow, good water quality, and intact physical habitats routinely encountered in the 55b resulted in consistently high fish community performance (**Figure 48**). In most instances, 55b performance was also higher than in the adjacent, 55a sub-ecoregion.

While fish community performance was comparatively lower in the 55a, additional analysis revealed a unique subset of 55a sites linked by a strong ground water connection. These enhanced flow sites demonstrated almost consistently higher quality than found in 55a sites lacking sustained flow (**Figure 49**). The higher performing 55a sites were characterized by some of the same cold water or enhanced flow indicator species found in the 55b, particularly mottled sculpin (South Fork GMR basin, Cherokee Mans Run, Rennick and Brandywine creeks), hornyhead chub and river chub (Muchinippi Creek basin, lower Rum Creek). In most instances, this subset of 55a sites also demonstrated levels of performance over and above expectations associated with existing physical habitat quality, as portrayed by the QHEI. This general trend was observed throughout the upper watershed but tended to be strongest within headwater (<20 mi.^{2}) sites (**Figure 49**). Statewide, the presence of additional base flows are recognized as a positive stream attribute that may temper the negative effects of less than prime quality habitat (Ohio EPA file data).

Figure 47. Muchinnippi Creek, RM 12.5, is located within the 55a sub-ecoregion and benefits from high ground water flow which tempers the chemical and biological impacts commonly associated with the poor physical habitat in channelized streams.

The best example of an upper GMR watershed displaying the combination of degraded (*i.e.*, modified) stream habitats, enhanced base flow and comparatively high fish community performance was Muchinnippi Creek (**Figure 47**). Excluding the very small and WWTP influenced

Jackson Center Creek, habitat quality was in the fair to very poor ranges at eight of nine sites sampled (**Table 15**). However, fish performance was in the good and marginally good ranges at all but two sites; fair quality communities were encountered in one highly enriched section of lower Little Muchinippi Creek (RM 0.62) and the lowest reaches of the mainstem at RM 2.4 (**Table 16**). Besides being the largest drainage sampled, the lower stretch of Muchinippi Creek was sluggish, silty, and impounded by log jams.

The phenomena of marginal habitat and over-performing fish communities in the upper GMR was first observed in the Muchinippi Creek mainstem during the 1994 fish survey and coined “the Muchinippi effect” by field staff. These enhanced flow conditions, particularly at the headwater level, appeared to positively affect the ability of the modified stream to support a more diverse and organized fish assemblage than expected, given the accumulation of modified habitat attributes (Ohio EPA 1995).

IBI and QHEI scores delineated by sub-ecoregion for all sampling sites (plus the upper Great Miami River mainstem) are shown in **Figure 50**. Throughout the upper GMR watershed and taken as a whole, fish community performance (*i.e.,* IBI score) was strongly linked to gross sub-ecoregional features. Absent one site that was extensively modified and impacted by a toxic spill, all 55b sites met or exceeded WWH or EWH expectations. In contrast, nearly all 55a sites that lacked a strong groundwater connection performed below WWH levels (additional influences such as WWTP discharges, nutrients, channelization, etc., may have also contributed to impairments). Exceptions to this trend were mostly from natural stream channels and larger drainages near unique physical features (**Figure 50**). These exceptions included abnormally high performance near the tailwaters of two large impoundments, Indian Lake and Lake Loramie, and an unmodified section of lower Ninemile Creek, atypical of most other sampling sites in the region. The addition of lake related species at tailwater sites was a localized phenomenon that tended to inflate IBI scores.

Fish community performance at 55a sites with enhanced base flows tended to fall between the two extremes of the 55b and 55a lacking groundwater. However, the majority still met or exceeded minimum WWH expectations. Regardless of base flow, nearly all 55a sites were exposed to historic or active channel maintenance for agricultural drainage. The 55a sites with enhanced flow tended to ameliorate the negative influences associated with these activities and commensurate fish community performance was often higher.

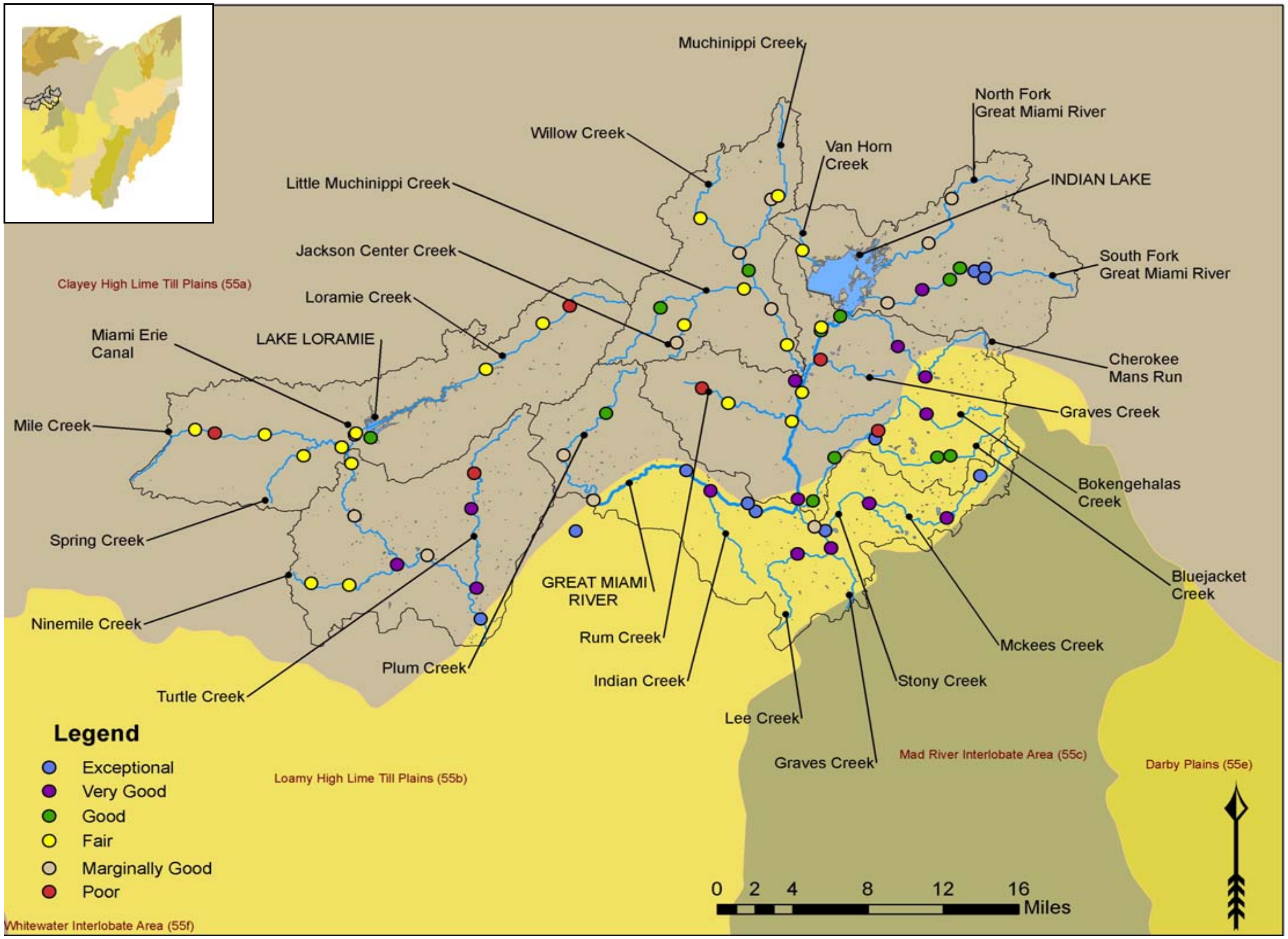


Figure 48. Upper Great Miami River watershed narrative fish community performance displayed over the geologic sub-ecoregion map.

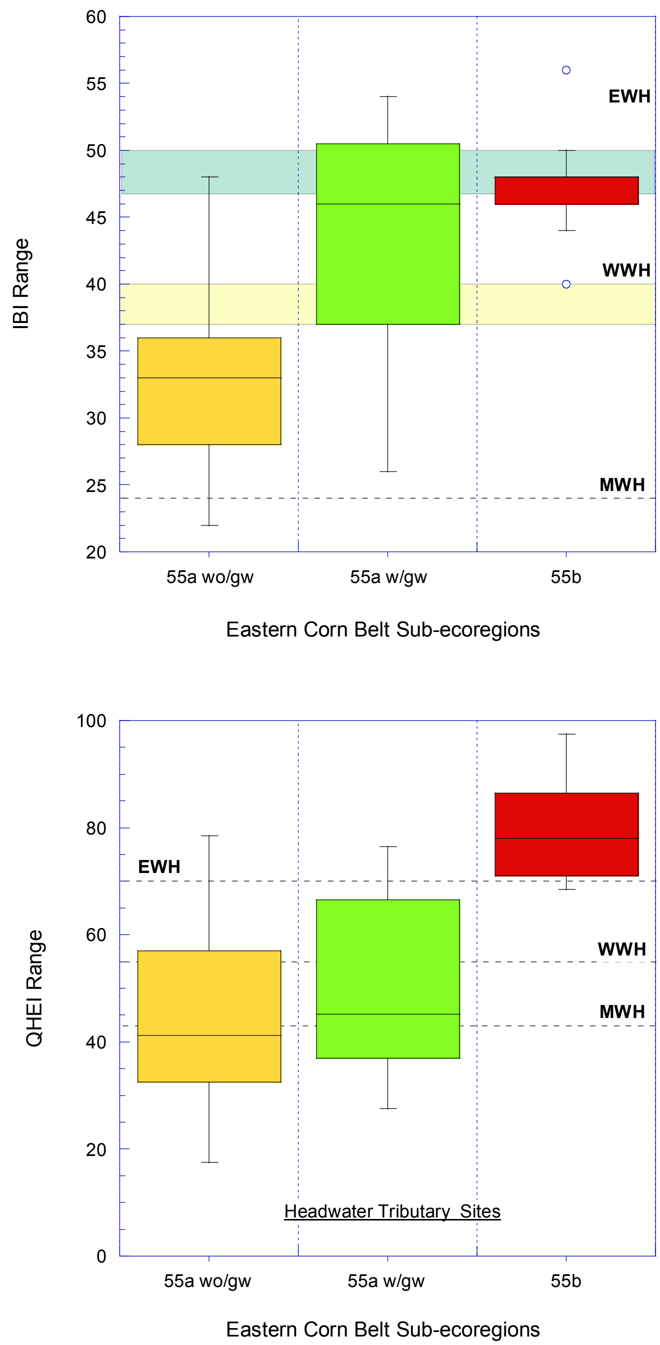


Figure 49. IBI and QHEI scores from selected groups of headwater fish sites within three varying sub-ecoregional areas of the upper Great Miami River basin, 2008. The divisions include 55a sub-ecoregion sites without ground water (left), a subset of 55a sites with enhanced ground water recharge (middle), and the 55b sub-ecoregion (right). All sites are located within the Eastern Corn Belt Plains ecoregion.

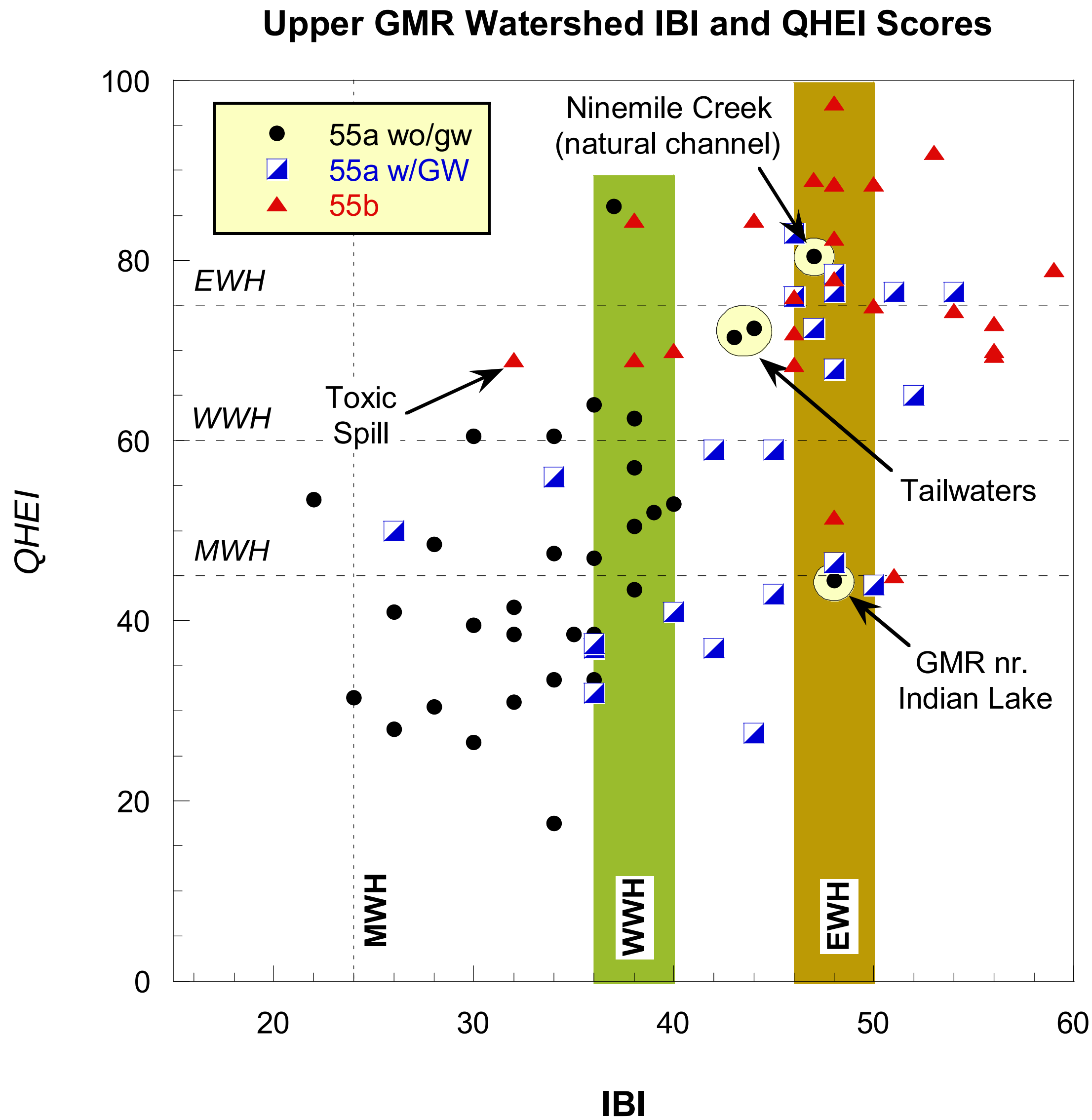


Figure 50. Scatter plot of all upper Great Miami River basin fish sites plotted by QHEI and IBI score from sites within the 55a without enhanced ground water flow (wo/GW), 55a with enhanced ground water flow (w/GW), and 55b sub-ecoregions.

Fish Community Trends

Upper Great Miami River mainstem

Mainstem fish community performance in 2008 was similar to results from 1994 with three noteworthy variations in trends. The first occurred at RM 157.2, immediately downstream from the Indian Lake WWTP, the second four miles downstream at RM 153.5 (Notestine Rd.), and the third, at RM 143.2, immediately downstream from the Quincy dam. At RM 157.2, improvements in 2008 continued the positive trend first observed between the 1982 and 1994 surveys (**Figure 51**). Following a major facility upgrade at Indian Lake in 1985, IBI scores increased from the poor in 1982 (22) to fair in 1994 (32). This positive trend continued from 1994-2008 as the IBI improved from fair (32) to excellent (48), fully meeting WWH biocriteria. Besides noted differences in IBI performance, the physical health of individual fish also improved. In 1994, 7.2% of the fish had DELT anomalies but only 0.4% of fish showed physical health ailments in 2008. DELT anomalies have been historically linked with degraded or poor water quality conditions (Ohio EPA 1987b) and the physical changes in the fish suggest improved water quality conditions over time.

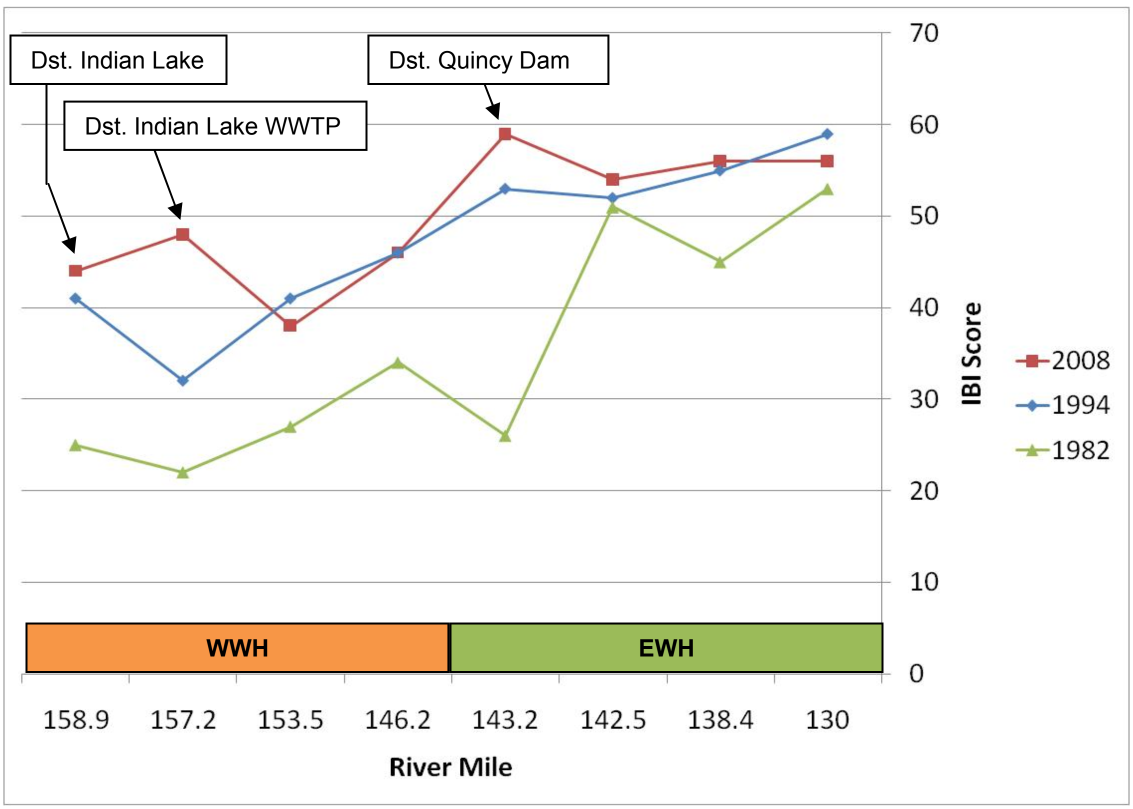


Figure 51. Upper Great Miami River mainstem IBI trends from 1982-2008.

However, by next site downstream at Notestine Rd. (RM 153.45) IBI performance from both 1994 and 2008 fell in the marginally good range and the 2008 MIwb score of 7.8 (not plotted) dropped slightly below WWH expectations. The combined influences of channelization, the upstream wastewater collection system, and upstream impoundment appear to result in a trend of marginal fish performance through this sluggish reach (**Table 4**). Downstream from the Quincy low-head dam at RM 143.20 the fish community performance was exceptional during both the 1994 and 2008 surveys, but the IBI score did increase significantly from 53 (1994) to 59 (2008).

Upper Great Miami River Tributaries

Seventeen sites on six upper Great Miami River tributaries were historically sampled prior to 2008. Linear comparisons of the historical IBI scores and the 2008 IBI scores are plotted in **Figure 52**. Four of the six tributaries displayed overall improvements over historical IBI scores and fish community performance. Two tributaries, McKees Creek and Muchinnippi Creek, showed decreases in IBI scores at two sites each.

Loramie Creek showed large improvements in IBI score at RM's 35.0 and 20.7 with both sites increasing by ten or more points (**Figure 52**). Blue Jacket Creek also showed significant improvements in fish community performance at each of the three sites sampled. The most downstream site at TR 31 (RM 0.72) showed the largest improvement, increasing from an IBI of 45 (good) to 56 (exceptional). In addition to far-field improvements downstream from the Bellefontaine WWTP, slight differences in the 2008 sampling location and correspondingly better habitat quality (see **page 147**) may have contributed to the enhanced fish performance. The South Fork GMR was another tributary to show significant improvement in fish community performance and IBI score. At the most upstream headwater site at SR 638 (RM 8.0) the IBI score increased from 41 (WWH) to 54 (EWH standards). The South Fork GMR was another tributary to show significant improvement in fish community performance and IBI score. At the most upstream headwater site at SR 638 (RM 8.0) the IBI score increased from 41 (WWH) to 54 (EWH standards). The improvement in fish performance followed a corresponding improvement in habitat quality, as the stream channel recovered from historic modification **Figure 45**. Unfortunately, recent field observations from the spring of 2011 indicate the restored woody riparian buffers near South Fork RMs 8.0 and 7.4 have been removed and the gains in habitat quality and fish community health observed in 2008 may be at risk.

Fish community performance and IBI scores decreased at two sites in both McKees Creek and Muchinnippi Creek between surveys but each fully met criteria for their respective aquatic life us designations (**Figure 52**). In 1994 the most upstream and downstream sites on McKees Creek (RMs 9.5 and 0.5) had exceptional fish communities with IBI values of 54. Sampling in 2008 yielded lower IBI scores of 50 and 48, respectively, but both met EWH criteria (**Table 4**). However, 2008 species richness at McKees Creek RM 0.5 (11) was almost half the 20 species found in 1994 (**Appendix E**). Muchinnippi Creek sites at County Rd. 87 (RM 7.4) and US Route 33 (RM 12.5) had lower IBI scores in 2008 compared to 1994 but maintained full WWH attainment. The two point decrease in IBI at RM 7.4 was negligible but at RM 12.5, the IBI score dropped from 42 (good) to 36 (marginally good) and three fewer total species were caught in 2008 (**Appendix D**).

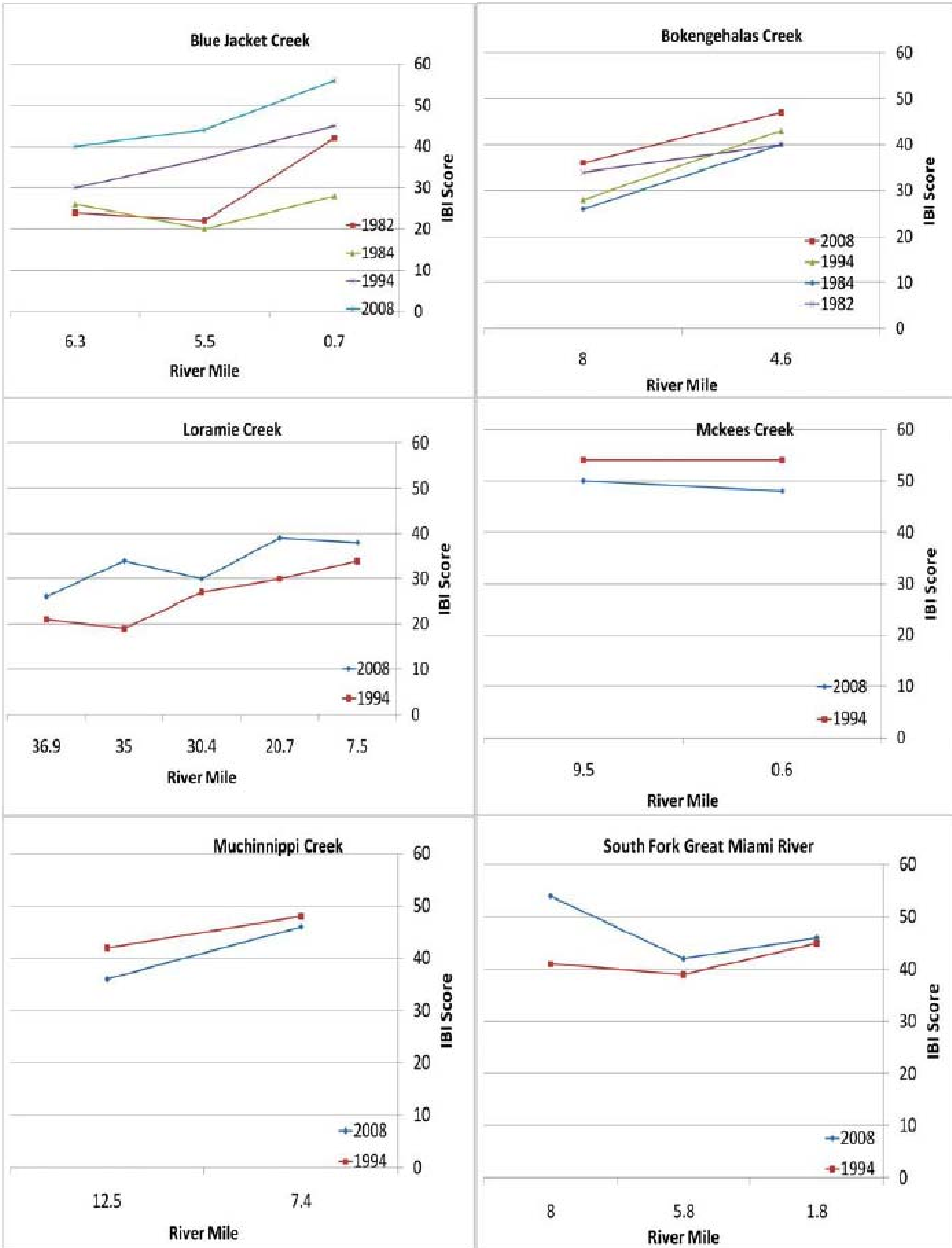


Figure 52. Upper Great Miami tributary IBI trends at similar sampling locations listed by tributary and river mile, 1982-2008.

Macroinvertebrate Community

Upper Great Miami River Watershed

As part of the upper Great Miami River basin sampling effort, macroinvertebrates were collected from 76 sampling sites throughout the basin during the summers of 2008 and 2009. Sampling effort included 39 quantitative (artificial substrate) sites and 37 qualitative (dipnet/hand picking) sites. A summary of the macroinvertebrate collection data, sorted by narrative quality is presented in (**Table 17**). Invertebrate Community Index (ICI) scores and metric scores for each quantitative sample can be found in **Appendix F**. A summary of the data and lists and numbers of macroinvertebrate taxa collected from each survey site are found in **Appendix G**.

Upper Great Miami River mainstem

Macroinvertebrates

Fully Meeting Biocriteria

Watershed: 70%
Upper Great Miami River: 63%
Tributaries: 71%

The upper Great Miami River mainstem was sampled at 8 locations from its source at Indian Lake, to Sidney, Ohio (Station RMs 158.9-129.99). The upper mainstem originates as overflow from Indian Lake, which receives drainage from the North and South Forks of the Great Miami and the local watershed upstream. From Indian Lake to the Quincy low-head dam, much of the river channel is historically modified and designated WWH for an approximate 17 mile stretch. Downstream from the Quincy Dam at RM 143.2, the remaining 13 stream miles are mostly natural, free-flowing, and designated EWH. The Logan Co Indian Lake SSD (aka, Russells Point) WWTP is the only major municipal discharge (*i.e.,* >1 mgd) and is located a short distance downstream from Indian Lake at RM 158.0. The minor (*i.e.,* <1 mgd), Quincy WWTP at RM 143.1 was the only other significant mainstem point source discharge in the survey.

In the WWH designated reach, upper Great Miami River macroinvertebrates were of marginal quality, ranging from fair to good, before reaching the very good range upstream from Quincy (ICI = 42 at RM 146.19). Based on qualitative collections (artificial substrate samplers were lost), benthic communities reflected fair quality immediately downstream from the Indian Lake overflow and Cherokee Mans Run at RM 158.9. The modified channel was wide, shallow, and heavily silted with ubiquitous, soft sand substrates. The low density and low diversity community was predominated by pollution facultative (*i.e.,* somewhat tolerant) populations of net-spinning caddisflies (genus *Cheumatopsyche*) and midges, typically associated with siltation and nutrient enrichment. Besides the warm, enriched flow that pours over the Indian Lake dam, Cherokee Mans Run appeared to introduce a significant sediment load to the historically modified channel.

Immediately downstream from the Indian Lake WWTP at RM 157.22, artificial substrates were successfully retrieved and the modest ICI score (36) fell in the low good range. However, despite attaining, the community continued to be predominated by facultative, net-spinning caddisflies and the quality of natural substrate collections [26 total taxa; only 2 Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa] was lower than found upstream (**Table 17**). Macroinvertebrates met WWH criteria but still reflected excessive sedimentation and enriched conditions.

Four miles further downstream at RM 153.4, samplers were again lost and qualitative sampling indicated fair quality, mostly the result of sluggish, silty habitat and past channelization. Lack of re-aeration in the long channelized stretch extending downstream from Russells Point may have exacerbated nutrient and dissolved oxygen problems in the reach. The river channel remained sluggish for an additional seven miles downstream but siltation appeared to lessen and macroinvertebrate performance gradually improved. In addition to an increase in ICI score (42) at RM 146.19, increases in pollution sensitive and EPT taxa reflected water quality improvement well downstream from Russells Point and prior to the Quincy low-head dam impoundment.

Macroinvertebrate quality improved in the EWH designated reach between Quincy and Sidney, falling in the very good to exceptional ranges at nearly all sites. One exception was a channelized stretch at Baker Rd., RM 138.39 where the ICI of 38 was only in the good range. Other mainstem sites in this stretch were swift and firm bottomed and included strong riffle habitats. However, the Baker Rd. site was sluggish and silty and the resultant macroinvertebrate performance was not up to EWH standards. Current velocities were technically adequate for a valid ICI score (*i.e.*, slightly greater than 0.3'/sec.) but samplers were heavily silted. The community included a lower percentage of mayflies and higher percentage of tolerant taxa than acceptable for an exceptional stream. Natural substrates were also quite silty but numbers of EPT (15) and sensitive taxa (21) were in line with collections at other EWH sites in the reach. The overall results, based on both quantitative and qualitative collections, suggest the impairment at Baker Rd. was fairly localized and not particularly severe.

<u>Upper Great Miami River Basin Tributaries</u>

Excluding the Great Miami mainstem, 73 macroinvertebrate samples were collected from 29 streams in upper basin tributaries (**Table 17**). Sites were routinely sampled once during the summer of 2008. However, Bokengehalas Creek RM 7.9 was sampled on three occasions to monitor trends following a wildlife kill from aerial pesticide spraying. In addition, the North Fork GMR RM 2.0 was re-sampled in 2009 after 2008 collections suggested an unknown toxic impact. In Blue Jacket Creek, the presence of a major WWTP, a complex urban landscape, and use attainability issues resulted in a decision to replace 2008 qualitative data with artificial substrate collections in 2009. In each instance, the most recent sampling was used to determine use attainment.

Tributary samples largely attained WWH expectations as 46 samples (63%) were in the exceptional to marginally good ranges. In contrast, 27 samples (37%) were in the fair to poor ranges. Besides higher ICI scores (when sampled quantitatively) the higher quality sites tended to have a greater richness of total, EPT and pollution sensitive taxa, a predominance of sensitive, or sensitive and facultative populations, and correspondingly low numbers of tolerant forms.

Causes and Sources of Impairment

Analysis of tributary results found differences in macroinvertebrate performance were often associated with differences in habitat and watershed characteristics, including stream channel quality, stream flow, land use, and ecoregional features (**Table 17**, **Figure 53**). For instance, all "natural" [7] stream channel sites yielded communities that met or exceeded WWH criteria. In contrast, channelized stream sites were evenly split between attaining and non-attaining performance (27% of all sites, respectively). Modified stream sites were often characterized by open canopies, a lack or woody riparian borders, fine substrates of silt, sand or muck, poor riffle development, low channel sinuosity, and homogenous pool and glide habitats.

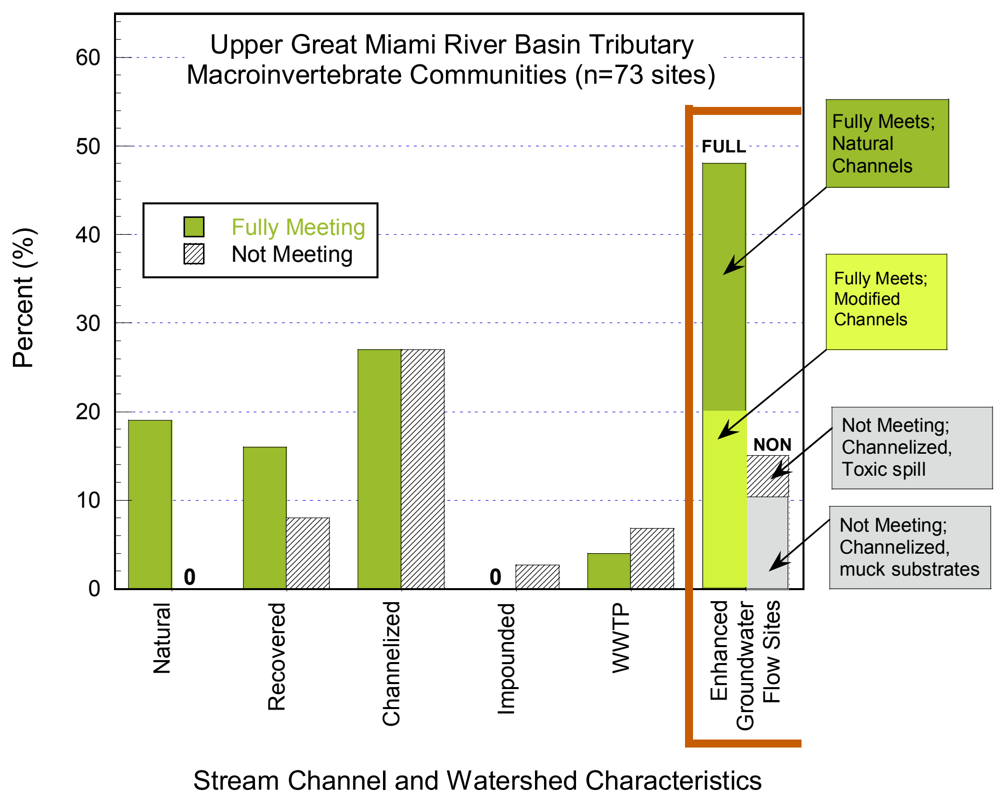


Figure 53. Upper Great Miami River basin macroinvertebrate results plotted as the percentages of sites fully meeting or not meeting WWH performance levels at sites exposed to different habitat and water quality variables. Separate columns on the far right show the subset of the sites with enhanced ground water flow. Channel morphology descriptions were based on macroinvertebrate field crew observations.

[7] Based on macroinvertebrate field crew observations, natural steam channels were free-flowing and unmodified with little to no indication of past channelization activity.

In addition, macroinvertebrate performance was consistently better at sites identified as having cool or sustained base flows, often despite the presence of stream modifications (**Figure 53**). On the rare occasions these sites performed below WWH expectations, impacts were related primarily to poor quality, muck substrates (see **page 171**) and a toxic spill related to pesticide spray.

Broken down by stream river miles (**Figure 54**), habitat alteration associated with channelization for agriculture was considered the primary source of impairment to the macroinvertebrates, followed by silt and nutrients associated with agriculture or municipal WWTPs (enrichment).

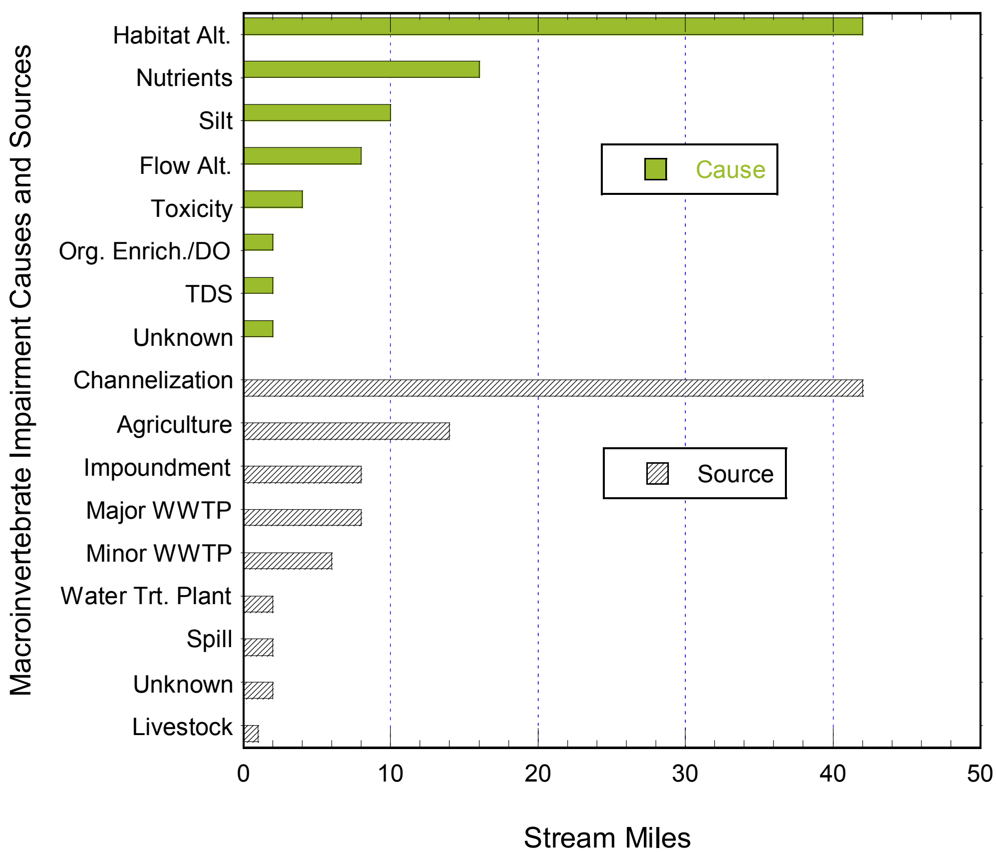


Figure 54. Suspected Causes and Sources of Impairment (in miles) affecting macroinvertebrate communities from the upper Great Miami River basin study area, 2008-2009.

Macroinvertebrate Community Sub-ecoregion Discussion

Further inspection of the macroinvertebrate results found highest quality tributary sites were often associated with the presence of sustained ground water flow[8]. These

[8] Sites with enhanced base flows were identified based on the presence of coldwater fish and macroinvertebrate populations or collections of select fish species typically associated with high ground water recharge; see ***Fish Community Sub-ecoregion Discussion*** on Page 159.

features were most evident in the eastern half of the watershed, particularly the southeastern portion of the watershed between Bellefontaine and DeGraff. Excluding the large, Great Miami River mainstem, tributary sites within this area often reflected coldwater habitat or EWH potential as macroinvertebrate performance benefited from enhanced, ground water intrusion. Major drainages in this region include the Bokengehalas and Stony Creek basins, containing Blue Jacket, McKees, Graves, and Lee Creeks (HUC #s 05080001 03 and 04). When overlain on a sub-ecoregion map, these subwatersheds closely mirror the extreme northwestern portion of the Eastern Corn Belt Plain 55b (loamy, high lime, till plains) sub-ecoregion (**Figure 55**).

<u>55b Sub-ecoregion</u>
The 55b sub-ecoregion is characterized by high relief, well drained, loamy, calcerous tills and abundant ground water. Over 75% of macroinvertebrate sites within the region were in the very good and exceptional ranges. The only site that scored below WWH standards (Bokengehalas Creek RM 7.9) was sampled immediately following a wildlife kill involving a toxic aerial pesticide spray. In addition to higher quality among the sub-ecoregion tributary sites, 50% also yielded 3 or more coldwater macroinvertebrates, indicative of abundant, cool ground water intrusion. Remaining 55b sites that fell in the good or marginally good ranges appeared at least modestly influenced by nearby pollution sources including septic tank drainage (Cherokee Mans RM 7.56), Bellefontaine urban runoff and the Bellefontaine WWTP (Blue Jacket Creek RMs 6.31-0.72), and bank erosion (Graves Creek).

<u>55a Sub-ecoregion sites with enhanced ground water (w/GW) flow</u>
Enhanced ground water flow also had a positive effect on macroinvertebrate performance at some 55a sub-ecoregion sites (**Figure 55**). Median performance at 55a sites with enhanced flow fell in the marginally good (headwater sites) to excellent (wading sites) ranges, levels similar to the 55b and almost consistently higher than 55a sites that lacked a strong groundwater signature (**Figure 56**). Like the 55b sub-ecoregion, comparatively higher numbers of pollution sensitive and EPT taxa were routinely encountered at the 55a with groundwater sites. Those few sites with low macroinvertebrate performance (*i.e.,* fair quality), shared a common pattern of channelized stream habitat combined with substrates of fine muck. Hydric soils associated with drained, former wetland and marshy areas were a suspected source of muck in the affected streams and all were within or adjacent to the Muchinippi Creek watershed, including Willow, Rennick, Brandywine, and Little Muchinippi creeks. Average numbers of EPT (5) and sensitive taxa (6) from these sites were also lower compared to other enhanced flow sites in the sub-ecoregion (14 and 15, respectively).

<u>55a Sub-ecoregion sites without enhanced ground water (wo/GW) flow</u>
The remaining 27 sites from the **55a** sub-ecoregion lacked the sustained ground water flow that characterized much of the eastern and southern halves of the study area. Most sites were located in the central and western portions of the watershed, including the 265 mi^2 Loramie Creek basin, large portions of Rum Creek and Plum Creek, the lower three miles of Muchinippi Creek, and two Indian Lake tributaries, Van Horn Creek and the North Fork of the Great Miami River. *(continued on page 174)*

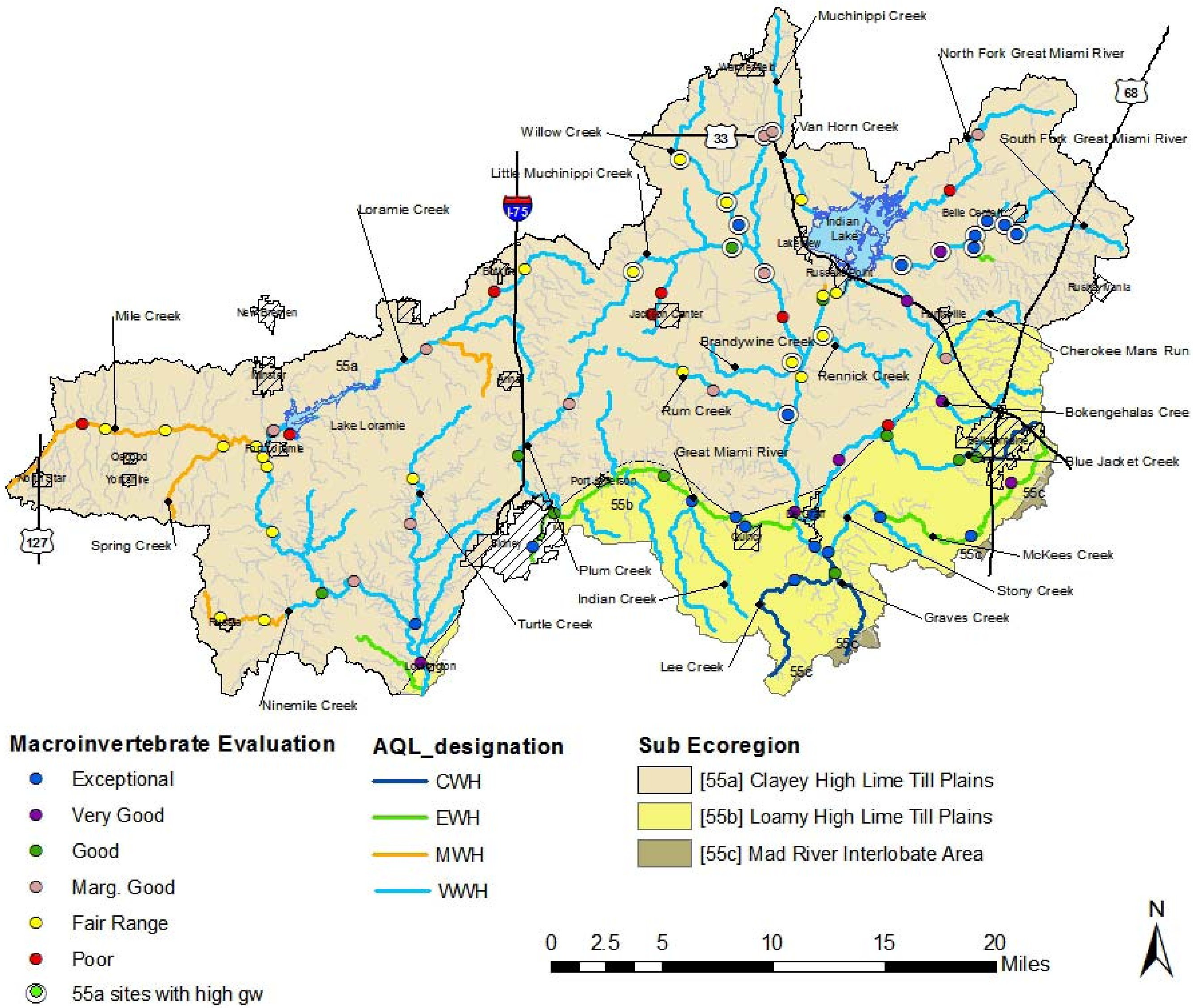


Figure 55. Narrative evaluations of macroinvertebrate community health in the upper Great Miami River basin, 2008-2009.

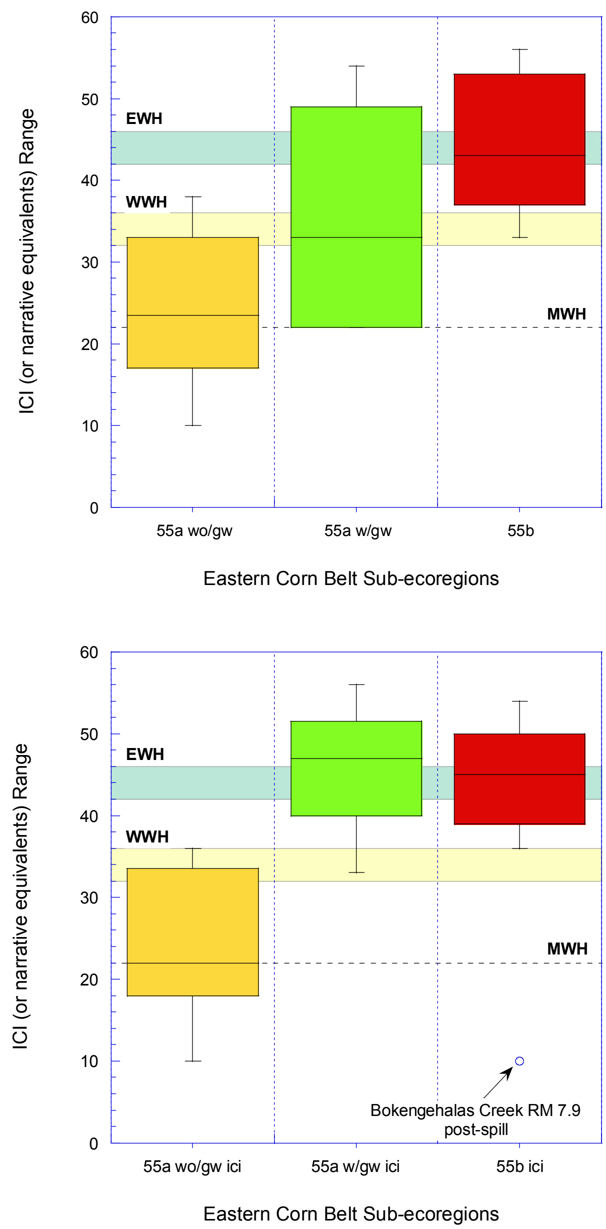


Figure 56. Box and whisker plot of macroinvertebrate evaluations within three varying sub-ecoregional areas of the upper Great Miami River basin, 2008. The divisions include 55a sub-ecoregion sites without ground water (left), a subset of 55a sites with enhanced ground water recharge (middle), and the 55b sub-ecoregion (right). All sites are located within the Eastern Corn Belt Plains ecoregion..

<u>55a Sub-ecoregion sites without enhanced ground water (wo/GW) flow</u> *(continued)*

Note: As the majority of macroinvertebrate impairment in the upper Great Miami survey area were restricted to 55a sites *without* enhanced ground water flows, the impaired stream reaches are discussed in detail below.

Van Horne Creek

Van Horn Creek is a small (2.8 mi^2), mostly modified agricultural drainage that discharges to Indian Lake. The fair quality community at station RM 0.97 included a handful of facultative EPT taxa (5) and only 5 pollution sensitive varieties.

North Fork Great Miami River

The upper reaches of the North Fork were channelized and enriched at RM 10.3 but macroinvertebrates marginally attained WWH (ICI = 34). Habitat quality improved downstream at RM 6.31 as the stream channel recovered from past channelization activity. However, macroinvertebrate populations were very difficult to find and the poor quality, low density community (18 total taxa/3 EPT taxa) suggested a possible toxic or slug type impact. In contrast, follow-up sampling conducted at the same site the following summer found a good quality community with 51 total and 11 EPT taxa (**Table 17**). Unlike the 2008 collections, 2009 conditions were considered fairly typical of a small, recovered stream channel situated in an extensive agricultural landscape. Collections were considered confirmation of an unidentified toxic or slug type impact the previous year. Toxic impacts were encountered in nearby Bokengehalas Creek during 2008 and attributed to aerial pesticide spraying.

Rum Creek and Plum Creek

The upper reaches of these upper GMR tributaries were located in the 55a sub-ecoregion. Both channels transitioned from channelized, to recovering; to natural over the approximate 9 mile sample reach between headwaters and mouth. The upper Plum Creek channel was actively maintained by Shelby County. Upper Rum Creek was also extensively modified but work was apparently conducted by local land owners and not the local (Logan) county. Natural channel sites near the mouths of both tributaries reflected enhanced ground water flow and supported good (Plum Creek) to exceptional (Rum Creek) quality macroinvertebrates (see 55a w/GW discussion **page 171**).

Upper Rum Creek ranged from fair to marginally good at RMs 8.63 and 6.58 while upper Plum Creek performance ranged from marginally good (RM 9.0) to good (RM 5.22). Plum Creek RM 9.0 was one of the few modified sites in the survey that lacked significant ground water intrusion but still met minimum WWH standards. Despite extensive modification, stream gradient was relatively high (5.95/ft. mile) and the stream bottom was firm with occasional riffle/run habitats and deposits of coarse substrates. In contrast, most other channelized sites from the 55a sub-ecoregion had fine substrates, sluggish flow, and riffle habitats that were either absent or of poor quality.

Lower Muchinippi Creek

While the upper Muchinippi Creek watershed drainages tended to benefit from enhanced base flows, the lower three miles of the mainstream did not demonstrate a strong groundwater signature. Macroinvertebrates were poor (ICI = 12) at RM 2.7, as the negative influences of modified habitat and muck substrates were exacerbated by sluggish flow and impoundment from abundant log jams in this lower reach.

Jackson Center Creek
Qualitative sampling from two stations bracketing the Jackson Center WWTP (RM 2.3) revealed poor quality macroinvertebrates at both locations (**Table 17**). The very small stream was extensively channelized for agricultural drainage and choked with filamentous algae and fine silt downstream from the WWTP (**Figure 22**). Macroinvertebrates reflected highly enriched conditions and potentially severe diurnal DO swings at the downstream site. A few facultative mayfly and caddisfly taxa were found and the collections were not indicative of severe toxicity. However, the collection of 21 pollution tolerant taxa (the most in the entire Great Miami survey) did suggest significant water quality impairment. The massive load of fine silt that filled the channel was an additional, potential source of impact.

Loramie Creek Watershed

Macroinvertebrate sampling was conducted at 22 locations in the Loramie Creek basin including ten sites on the Loramie Creek mainstem, five sites in the Mile Creek basin, one site at the mouth of the Miami-Erie Canal, and three sites each on Ninemile Creek and Turtle Creek (**Table 1**). Community health typically reflected the pervasive influences of nutrient enrichment, siltation and habitat modification associated with agriculture, coupled with the additional enrichment influences from municipal WWTPs and Lake Loramie. Sixty-eight percent of sites (n=15) were in the poor to fair ranges and only one site, located near the mouth of Turtle Creek, reached exceptional quality (**Table 17**; **Figure 55**).

Loramie Creek
In the headwaters of Loramie Creek upstream from Lake Loramie, macroinvertebrate communities bracketing the Botkins WWTP declined from Fair at RM 36.84 to Poor at 34.96, 0.46 miles downstream from the discharge. In addition to a highly enriched appearance (as evidenced by the very high densities of blackflies and flatworms) the nearly complete absence of EPT taxa suggested additional impacts. Chemical sampling later revealed intermittent but extremely high levels of dissolved solids and conductivity at the same location. Further investigation of the WWTP operational procedures found the local Water Treatment Plant delivered high levels of chlorides and dissolved solids via filter back-flushing to the wastewater plant on a regular basis. This influent was considered the likely source of biological and chemical impacts detected downstream. Macroinvertebrates marginally recovered and reached a marginally good condition downstream at RM 30.42, immediately prior to the Lake Loramie impoundment.

Downstream from the Lake Loramie dam at RM 22.1, late summer flows were reduced to a trickle (**Figure 3**) and macroinvertebrates reflected fair quality and highly enriched conditions. The water was warm, green and murky and the community was predominated by dense populations of enrichment tolerant flatworms, aquatic worms, hemoglobin-utilizing (red) midges and the facultative, square-gill mayfly genus, *Caenis*.

Downstream at SR 66 (RM 20.7), communities continued to appear enriched but maintained a marginally good quality (ICI = 34) immediately downstream from the Lake Loramie WWTP and Minster WWTP (via the Miami-Erie Canal). While habitat was historically channelized, the effluent dominated flow was relatively clear and the over-widened channel had a modest gradient, firm bottom, and moderate riffle run development.

Beginning downstream from Mile Creek at RM 19.5 and extending several miles downstream, the channel became increasingly incised, deep and sluggish. Substrates were predominantly silt and muck, and the water column became increasingly murky, green and brown. The water surface was often covered with a pervasive layer of scummy algae and foam that extended for miles downstream (see **Figure 2** and **Figure 40**). Macroinvertebrate performance in this reach also declined, remaining below WWH standards (*i.e.,* fair range) for approximately five miles (RMs 19.3-14.8). Habitat quality improved at RM 14.8 as stream gradient increased and deposits of coarse till and limestone formed bars and riffle habitats. The extensive, intact levee construction that lined the creek for miles downstream from Fort Loramie was also reduced at the downstream site. However, even coarse substrates at RM 14.8 were caked with a thick, congealed layer of solids and algae and macorinvertebrate communities continued to reflect highly enriched conditions.

Over the remaining 14.8 river miles of Loramie Creek, macroinvertebrate communities gradually improved to the good (ICI = 38 at RM 7.5) and very good ranges (ICI = 42) near the mouth at RM 1.87. Improvements corresponded with increasing improvement in habitat quality, increased stream gradient, a clearing of the water column, and lessening of channel maintenance activity. However, the channel is still defined as under maintenance as far downstream as RM 7.5.

Mile Creek and Spring Creek

Mile Creek and its tributary, Spring Creek, are extensively channelized for agricultural drainage. Macroinvertebrate collections from five sampling locations ranged from poor to fair, with marginal attainment of the recommended, MWH designation in the lower reaches of Mile Creek and at the mouth of Spring Creek. None of the sites met the existing but unverified, WWH designation.

Miami-Erie Canal

Macrionvertebrates from the canal were in the marginally good range (ICI = 34) and fully met the recommended MWH designation. An abundance of effluent dominated, clear flow provided adequate depth and current for the artificial substrate collections and the moderately enriched community was predominated by facultative midges and filter-feeding varieties. The near absence of mayflies may be related to elevated TDS and conductance levels revealed in chemical sampling.

Ninemile Creek

The headwaters of Ninemile Creek are extensively channelized but macroinvertebrates marginally met the existing MWH aquatic life use designation (ICI=26 at RM 6.38). At RM 4.18, no obvious indications of impact from the Russia WWTP could be detected (ICI=28), given the over-riding influence of habitat modifications upstream. Near the mouth at RM 0.23, the stream channel was natural and habitat conditions improved substantially. Benthic communities reached a good quality (ICI = 36) in the WWH designated segment, prior to the confluence with Loramie Creek.

Turtle Creek

Historically modified and highly enriched at RM 8.43, macroinvertebrates reflected fair quality in the upper reaches of the creek. Communities gradually improved with increased distance downstream at RMs 5.66 (marginally good) and RM 0.43 (exceptional). Improvement in communities coincided with the shift from modified to natural stream channels and a lessening of enrichment effects at the downstream sites.

Table 17. A summary of macroinvertebrate collection information, field observations, and narrative evaluations from the upper Great Miami River basin in 2008 and 2009. Great Miami River mainstem sites are shaded in gray. Tributary sites from the Eastern Corn Belt Plains **55b** sub-ecoregion are shaded in light blue while **55a** sub-ecoregion sites with enhanced ground water flow are shaded in tan. **55a** sites **without enhanced ground water** flow are unshaded.

River	RM	Drain. Area	Qual Total	Qual EPT*	Qual Intol.#	Density[a]	ICI[b]	Channel Morphology	Predominant Populations (Tolerance Ratings*)
Exceptional									
Great Miami River	143.20	405.0	53	17	22	2328	50	Natural	Net-spinning caddisflies, midges (F,I), minnow mayflies (F)
Great Miami River	142.50	406.0	53	18	21	Mod	--	Natural	Midges (F,I), minnow mayflies (F)
Great Miami River	129.99	541.0	61	21	26	5842	46	Channelized	Net-spinning caddisflies (F,I), tanytarsini midges (I)
South Fk. Great Miami R.	8.00	11.6	41	15	12	626	50	Chan./Recovered	Net-spinning caddisflies, midges (F,I)
South Fk. Great Miami R.	7.23	19.5	62	17	23	457	54	Chan./Recovered	Minnow mayflies (F), snailcase caddisflies (I)
South Fk. Great Miami R.	5.80	29.6	49	16	19	633	56	Natural	Net-spinning caddisflies, midges (F,I)
South Fk. Great Miami R.	1.74	51.0	51	18	18	521	48	Natural	Net-spinning caddisflies, midges (F,I), minnow mayflies (F)
Liggitt Ditch	0.53	6.5	33	11	7	235	48	Channelized	Damselflies (F, T), flatheaded mayflies (F)
New Richland Trib.	0.49	11.4	63	16	21	Low	--	Natural	Net-spinning caddis. (F,I), minnow mayflies, riffle beetles (F)
Muchinippi Creek	7.40	36.0	47	13	13	499	50	Channelized	Flatworms, minnow mayflies (F)
Rum Creek	0.79	27.2	47	13	18	148	46	Chan./Recovered	Minnow mayflies, net-spinning caddisflies (F)
Bokengehalas Creek	7.90	20.7	49	10	14	736	48	Channelized	Midges (variable tolerance), water mites (F)
Bokengehalas Creek	1.13	40.3	52	17	23	627	48	Chan./Recovered	Minnow mayflies (F)
Stony Creek	2.45	35.4	69	22	25	459	52	Channelized	Blackflies (F), minnow mayflies (F,I)
Stony Creek	1.58	59.1	68	18	26	1768	54	Channelized	Blackflies (F)
McKees Creek	5.94	8.7	61	23	32	High	--	Chan./Recovered	Minnow mayflies, net-spinning caddisflies (F,I, coldwater),
McKees Creek	0.52	17.7	48	17	25	1137	56	Natural	Minnow mayflies, net-spinning caddisflies (F,I, coldwater),
Lee Creek	3.35	9.5	56	20	22	High	--	Chan./Recovered	Blackflies (F), minnow mayflies (F,I, coldwater)
Indian Creek	0.01	15.9	56	18	21	Mod	--	Natural	Minnow mayflies, flathead mayflies (F,I)
Turtle Creek	0.43	35.9	57	18	24	197	--	Natural	Mayflies, caddisflies (F,I)
Very Good									
Great Miami River	146.19	296.0	36	10	11	315	42	Channelized	Midges, riffle beetles (F,I)
South Fk. Great Miami R.	3.95	47.0	62	19	17	1087	44	Chan./Recovered	Net-spinning caddisflies (F,I), blackflies (F)
Cherokee Mans Run	3.38	14.6	54	15	16	520	44	Natural	Minnow mayflies, blackflies (F)
Bokengehalas Creek	12.24	4.8	62	15	19	Mod	--	Channelized	Net-spinning caddisflies, baetids, midges (F,I)

River	RM	Drain. Area	Qual Total	Qual EPT*	Qual Intol.#	Density[a]	ICI[b]	Channel Morphology	Predominant Populations (Tolerance Ratings*)
Bokengehalas Creek	7.90	20.7	75	13	20	703	42	Channelized	Minnow mayflies, midges (T,F)
Bokengehalas Creek	4.61	36.3	52	13	21	1217	42	Natural	Minnow mayflies, midges (I)
McKees Creek	9.50	3.0	45	13	20	Mod	--	Natural	Minnow mayflies, (F,I, coldwater), blackflies (F)
Loramie Creek	1.87	257.0	61	14	20	1338	42	Natural	Net-spinning caddisflies (F,I); minnow mayflies (F)
Good									
Great Miami River	157.22	1534	26	2	5	803	36	Chan./Recovered	Midges, blackflies, net-spinning caddisflies (F)
Great Miami River	138.39	429.0	51	15	22	1567	38	Channelized	Midges (F,I)
N. Fk. Great Miami R. (2009)	6.31	14.4	51	11	13	High	--	Chan./Recovered	Minnow mayflies, blackflies (F)
Little Muchinippi Creek	0.62	35.2	49	7	7	1751	36	Channelized	Flatworms, minnow mayflies (F)
Blue Jacket Creek (2009)	6.31	2.9	42	8	11	419	36	Channelized	Net-spinning caddisflies (I); blackflies, flatworms (F)
Blue Jacket Creek (2009)	5.50	3.9	37	5	7	591	36	Channelized	Net-spinning caddisflies (I); flatworms, midges (F)
Blue Jacket Creek (2009)	0.72	13.6	49	11	10	289	40	Channelized	Minnow mayflies, net-spinning caddisflies, midges (F,I)
Graves Creek	0.48	10.9	47	13	18	Mod	--	Channelized	Minnow mayflies (F,I, coldwater)
Plum Creek	5.22	14.7	49	14	11	High	--	Chan./Recovered	Flatworms, riffle beetles (F), snailcase caddisflies (I)
Plum Creek	0.13	29.0	54	14	19	116	36	Natural	Midges (I), minnow mayflies (F), net-spinning caddis. (F,I)
Ninemile Creek	0.23	26.6	50	11	17	461	36	Natural	Minnow mayflies, flatworms (F)
Marginally Good									
North Fk. Great Miami R.	10.70	9.0	48	12	5	80	34	Channelized	Flatworms (F), snails (tolerant)
Belle Center Trib.	0.55	7.2	46	10	10	Low	--	Channelized	Minnow mayflies, blackflies, midges (F)
Muchinippi Creek	12.98	6.8	41	11	7	Mod	--	Channelized	Minnow mayflies, blackflies, snails, fingernail clams (F)
Muchinippi Creek	12.50	16.0	44	8	8	Mod	--	Channelized	Flatworms, minnow mayflies (F)
Muchinippi Creek	4.76	77.0	42	8	9	253	--	Chan./Recovered	Flat-headed mayflies (F), red midges (variable tolerance)
Cherokee Mans Run	7.56	8.5	38	10	11	High	--	Natural	Blackflies (F)
Rum Creek	6.58	15.3	41	9	8	Mod	--	Chan./Recovered	Net-spinning caddis. (F,I), minnow mayflies (F), midges (I)
Plum Creek	9.00	7.8	44	10	5	High	--	Channelized	Flatworms, isopods, fingernail clams (F), midges (sens.)
Loramie Creek	30.42	35.0	36	3	4	890	32	Chan./Recovered	Midges (variable tolerance)
Loramie Creek	20.70	82.0	42	5	6	2830	34	Channelized	Flatworms (F), midges (F,I)
Loramie Creek	7.50	205.0	47	15	16	1074	34	Channelized	Minnow mayflies (F)
Miami-Erie Canal	0.10	4.3	35	5	5	937	34	Channelized	Blackflies, net-spinning caddisflies, midges (F)
Turtle Creek	5.66	17.3	36	9	9	Mod	--	Natural	Net-spinning caddisflies, minnow mayflies (F)

River	RM	Drain. Area	Qual Total	Qual EPT*	Qual Intol.#	Density[a]	ICI[b]	Channel Morphology	Predominant Populations (Tolerance Ratings*)
High Fair									
Loramie Creek	19.30	147.0	36	5	5	Mod	--	Channelized	Midges, Caenis (F), water boatmen (T)
Mile Creek	5.97	34.7	25	2	1	105	22	Channelized	Water boatmen, beetles (T)
Mile Creek	0.50	62.3	39	5	4	1514	--	Channelized	Water boatmen (T), midges (I-T)
Spring Creek	0.37	8.8	35	6	5	High	--	Channelized	Flatworms (F)
Ninemile Creek	6.38	3.0	26	1	0	55	26	Channelized	Beetles, physid snails (T)
Ninemile Creek	4.18	11.5	46	8	9	176	28	Chan/Recovered	Flatworms, isopods (F), damselflies (tolerant)
Fair									
Great Miami River	158.90	118.0	41	6	8	Low	--	Channelized	Midges, net-spinning caddisflies (F)
Great Miami River	153.45	247.0	29	7	5	Low	--	Channelized	Midges, flat-headed mayflies (F)
Van Horn Creek	0.97	2.8	38	5	5	Mod	--	Channelized	Minnow mayflies, blackflies, flatworms (F)
Little Muchinippi Creek	6.05	9.3	48	5	8	Mod	--	Channelized	Midges (variable tolerance), water mites (F)
Willow Creek	3.70	8.1	38	4	3	Mod	--	Channelized	Midges (variable tolerance), biting midges (F)
Willow Creek	0.44	15.1	34	4	3	Mod	--	Channelized	Midges (variable tolerance), blackflies (F)
Rennick Creek	0.34	10.3	42	5	9	Low	--	Channelized	Midges (variable tolerance), isopods (F)
Brandywine Creek	0.58	8.8	46	4	5	Low	--	Channelized	Midges (F,T)
Rum Creek	8.63	8.2	28	4	3	Low	--	Channelized	Midges (T)
Loramie Creek	36.84	6.8	35	6	3	Low	--	Channelized	Net-spinning caddisflies (F), minnow mayflies, midges (F,T)
Turtle Creek	8.42	8.4	44	5	3	High	--	Chan./Recovered	Flatworms, net-spinning caddisflies, isopods, (F)
Low Fair									
Trib. to GMR (RM 157.34)	0.07	7.6	32	4	4	Low	--	Channelized	Midges, water boatmen (T)
Loramie Creek	18.82	148.0	28	4	3	1320	20	Channelized	Midges (F,T); squaregill mayflies (F)
Loramie Creek	14.80	157.0	54	9	8	2401	16	Chan./Recovered	Flatworms, midges (F)
Mile Creek	8.74	18.5	27	5	3	High	--	Channelized	Flatworms, beetles (T), squaregill mayflies (F)
Poor									
N. Fk. Great Miami R. (2008)	6.31	14.4	18	3	2	Low	--	Chan/Recovered	Riffle beetles (F) in 2008.
Muchinippi Creek	2.37	85.0	31	4	5	23	12	Impounded	Burrowing mayflies, midges
Jackson Center Creek	2.90	1.1	47	3	2	Low	--	Channelized	Midges (variable tolerance)
Jackson Center Creek	1.80	3.4	47	4	5	High	--	Channelized	Flatworms, isopods (F); physid snails (T)

River	RM	Drain. Area	Qual Total	Qual EPT*	Qual Intol.#	Density[a]	ICI[b]	Channel Morphology	Predominant Populations (Tolerance Ratings*)
Bokengehalas Creek (spill)	7.90	20.7	33	4	11	Low	--	Channelized	Midges (F,T)
Loramie Creek	34.96	15.9	29	1	3	High	--	Chan./Recovered	Flatworms (F), midges (F,T)
Loramie Creek	22.10	77.7	29	3	2	High	--	Chan./Recovered	Flatworms (F)
Mile Creek	9.80	9.7	18	1	1	High	--	Channelized	Flatworms (F), beetles (T)

***** - Qual. EPT = Number of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa found during qualitative sampling.

- Qual. Intol. = Intolerant (*i.e.,* pollution sensitive) taxa found during qualitative sampling and are those listed on the Ohio EPA macroinvertebrate taxa list as being either Moderately Intolerant (MI) or Intolerant (I).

a – Numerical densities refer to numbers of organisms per square foot from the artificial substrate samplers (where available). Narrative descriptions (*e.g.,* high, low, moderate) refer to field observations and estimates of relative density for benthic populations from natural substrates.

b – Invertebrate Community Index. ICI not available for sampling locations with drainage area <20mi^2 (excluding reference sites), and are indicated by n/a. Dashed lines (--) indicate sites where quantitative data were not available due to vandalism, dessication, or some other disturbance of Hester Dendy artificial substrates (HDs).

c – Predominant taxa are those observed on natural substrates. Please refer to **Appendix Table G** for predominant (numerically dominant) taxa on artificial substrates. Tolerance categories for taxa groups are parenthetically expressed: VT=Very Tolerant, T= Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant).

Macroinvertebrate Community Trends

Upper Great Miami River mainstem

Mainstem macroinvertebrates trend analysis for 2008 was confounded by loss of artificial substrate samplers and marginal current velocities over samplers at several locations (**Figure 57**). Where samplers were lost, an ICI score based on the qualitative narrative evaluation at the affected sites was substituted.

Outside of the grossly polluted conditions encountered below the Indian Lake (Russells Point) WWTP in 1982, survey results from 1994 and 2008 reflected improved communities and similar longitudinal trends. A 2008 decline upstream from the WWTP was most likely related to the condition of the natural substrate community (artificial substrates were lost) than a significant change in the quality of the Indian Lake overflow. All surveys show fair quality in the sluggish, modified reach that extends for miles downstream from Russells Point and gradual improvement prior to the Quincy low-head dam Impoundment. Sampling between Quincy and Sidney in the EWH designated reach shows minimum EWH criteria were met or exceeded during almost all surveys with the major exception of the 2008 sample from Baker Rd. (RM 138.8). As mentioned previously, this decline was considered primarily a function of localized silt deposition and not significant changes in water quality.

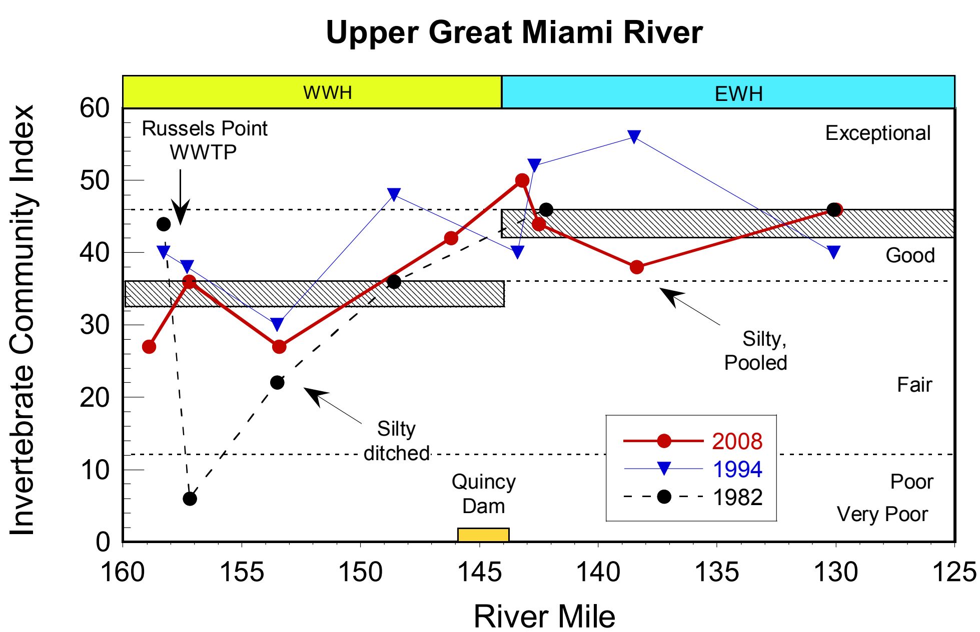


Figure 57. Macroinvertebrate trends in the upper Great Miami River from Indian Lake to Sidney, 1982-2008. An equivalent ICI score based on the qualitative sampling narrative evaluation was substituted at sites where artificial substrate data were unavailable.

Blue Jacket Creek

A 1994 survey of Blue Jacket Creek found substantial far-field improvements downstream from Opossum Run and the Bellefontaine WWTP and major improving trend when compared to the grossly polluted conditions encountered in 1974 and 1982 (**Figure 58**). However, each survey indicated poor quality conditions in Bellefontaine *upstream* from the WWTP and continued impairment (fair range in 1994) in Blue Jacket Creek for several miles downstream from the discharge.

2008 results reflect additional, near-field improvement downstream from the WWTP and, for the first time, good quality communities (ICI = 36) were found *upstream* from Opossum Run. For the first time in nearly 35 years of monitoring, 2008 Blue Jacket Creek macroinvertebrates attain WQS throughout its length. In addition, collections upstream from Opossum Run found coldwater indicator taxa richness (≥ 4) adequate to warrant a CWH recommendation. Downstream from Opossum Run, summer stream flows were so dominated by the warm WWTP effluent, an extension of the CWH designation downstream was considered impractical. Riparian removal and channelization in the lower reaches of Blue Jacket Creek were additional factors contributing to elimination of coldwater varieties.

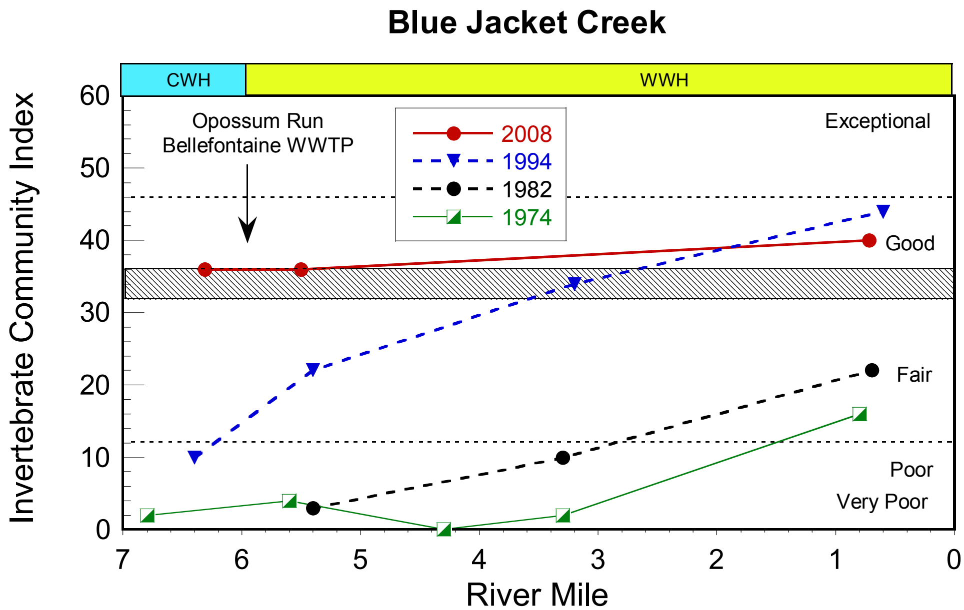


Figure 58. Macroinvertebrate trends in Blue Jacket Creek, 1974-2008. An equivalent ICI score based on the qualitative sampling narrative evaluation was substituted at sites where artificial substrate data were unavailable.

Bokengehalas Creek

Since 1994, macroinvertebrate performance in Bokengehalas Creek has consistently fallen in the good to exceptional ranges. In 2008, this trend was interrupted following a toxic wildlife kill near RM 7.9 related to an aerial pesticide application (**Figure 59**). Qualitative sampling conducted a few days after the incident found poor quality conditions, the absence of most populations and numerous dead or dying crayfish and larval insect specimens. Artificial substrates were re-deployed following the incident and it appeared the community was largely recovered about four weeks (ICI=42) to six weeks (ICI=48) later.

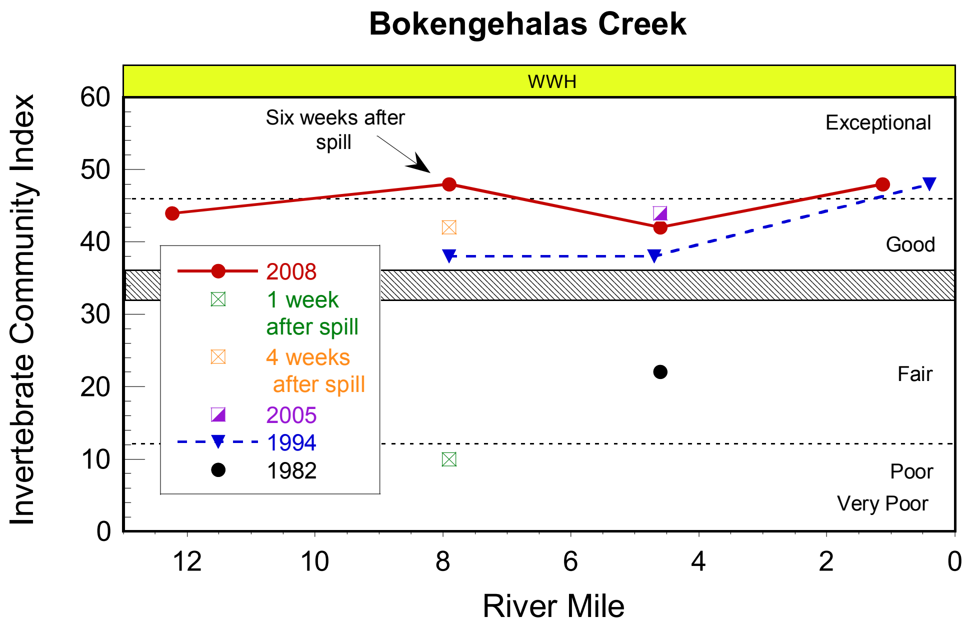


Figure 59. Macroinvertebrate trends in Bokengehalas Creek, 1982-2008. 2008 sampling includes additional quantitative and qualitative sampling efforts conducted at RM 7.9 to evaluate a toxic wildlife kill associated with aerial pesticide application. An equivalent ICI score based on the qualitative sampling narrative evaluation was substituted at sites where artificial substrate data were unavailable.

McKees Creek

Macroinvertebrates have been sampled from the lower mile of McKees Creek on three occasions from 1982 to 2008. ICI scores were consistently in the exceptional range in 2008 and 1994 (56 and 52, respectively) while 1982 qualitative collections were “very good”. In addition to consistently exceptional performance, the more recent surveys have also revealed the presence of coldwater macroinvertebrate taxa adequate for a CWH designation.

South Fork Great Miami River

Macroinvertebrates have been collected on 13 occasions from an approximate seven mile reach of the South Fork from New Richland to Indian Lake (**Figure 60**). Communities have consistently fallen in the very good and exceptional ranges with little indication of any significant water quality problems. Potential impacts from unrestricted cattle access and channel maintenance along the mainstem appear ameliorated by an abundance of ground water flow.

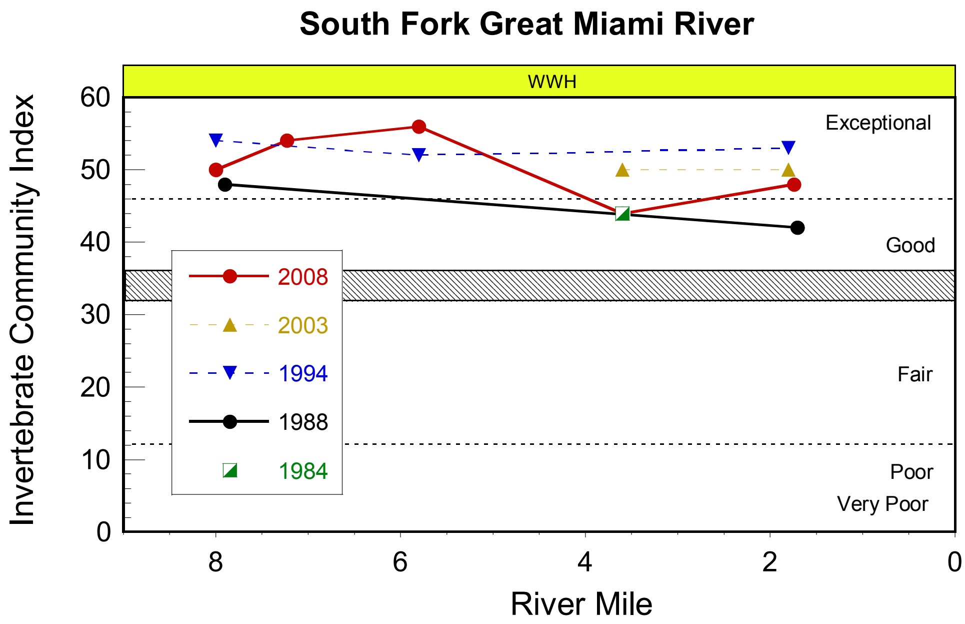


Figure 60. Macroinvertebrate trends in the South Fork Great Miami River, 1984-2008. An equivalent ICI score based on the qualitative sampling narrative evaluation was substituted at sites where artificial substrate data were unavailable.

Loramie Creek

Compared to a 1994 survey of Loramie Creek, headwater communities continued to reflect fair to poor quality upstream and downstream from the Botkins WWTP in 2008 (**Figure 61**). Poor quality in 1994 was related to stream intermittence at the most upstream site while poor communities in 2008 were encountered downstream from the Botkins WWTP. Unlike 1994 collections, the most recent survey shows communities improved and reached minimum warmwater standards prior to entering Lake Loramie.

Downstream from Lake Loramie, 2008 sampling indicated severe, late summer dewatering impacts immediately downstream from the lake overflow (corresponding 1994 sampling was not conducted). Additional flow provided by the Lake Loramie and Minster (via the Miami-Erie Canal) WWTPs and adequate habitat quality contributed to a short reach of improved conditions immediately downstream in 2008. However, both 1994 and 2008 surveys revealed several miles of impaired, fair quality communities with increased distance downstream (**Figure 61**). Declines in quality coincided with long stretches of extensively modified habitat, persistent elevated nutrient levels from point and nonpoint sources and declining D.O. levels.

Sluggish current velocities over 2008 artificial substrates between Mile Creek and the mouth may have also contributed to less than optimal ICI scores in the lower 19 mile stream reach. However, in each instance, other measures of community health (*e.g.,* sensitive, EPT and tolerant taxa richness, field observations) tended to mirror the condition of the artificial substrate community. Also, Loramie Creek samplers from all sites between RMs 18.1 and the mouth were collected from slow or non-detectable current and the trend of decline and recovery downstream from the Mile Creek, Fort Loramie and Minster areas was still apparent. For these reasons, longitudinal ICI scoring trends were considered reflective of the general stream quality conditions throughout the reach.

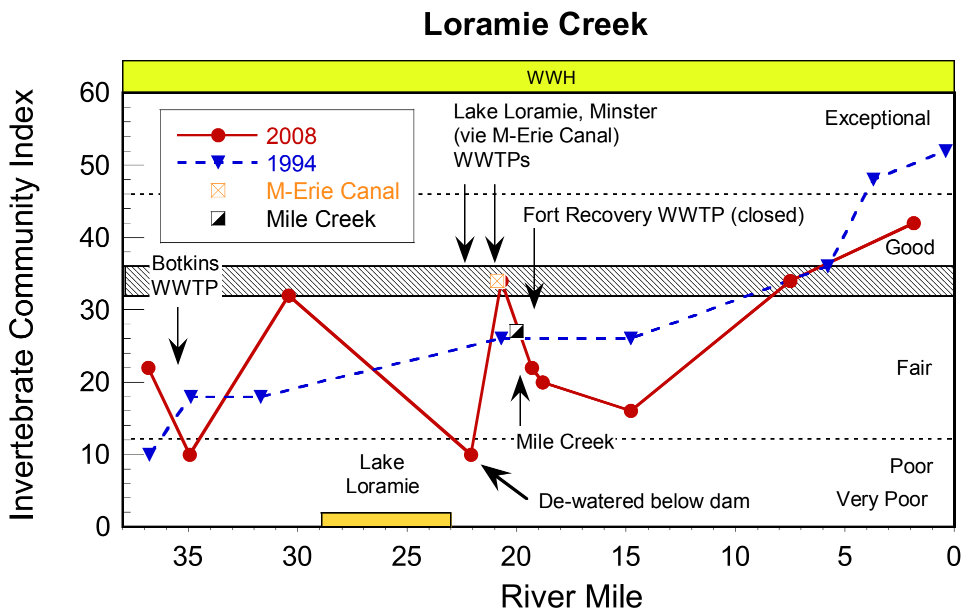


Figure 61. Macroinvertebrate trends in Loramie Creek, 1994-2008. An equivalent ICI score based on the qualitative sampling narrative evaluation was substituted at sites where artificial substrate data were unavailable.

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