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

Montgomery, Miami, Shelby, Logan, Clark, Hardin, and Auglaize Counties, Ohio

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Ohio EPA Technical Report MAS/1995-12-13

Prepared by
State of Ohio Environmental Protection Agency
Division of Surface Water
Environmental Monitoring and Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809
and
Surface Water Section
Southwest District Office
401 East Fifth Street
Dayton, OH 45402-2911

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Errata

Due to the size and complexity of the electronic form of this manuscript, several corruptions developed. As a result, typographic errors identified in three imbedded figures could not be rectified without accruing additional damage to the document. The corrections are as follows:

1) Figure 9. Annual median and 95th percentile conduit flow - Troy WWTP. The design capacity indicated on the figure should be changed from 6.0 MGD to 7.0 MGD,

2) Figure 15. Longitudinal mean concentration of Dissolved Oxygen (D.O.) - Segment II Upper Great Miami River, 1994. The criterion indicated on the figure should read "WWH Average Criterion 5.0 mg/l", and

3) Figure 33. Longitudinal mean concentration of Dissolved Oxygen (D.O.) - Segment II Upper Great Miami River, 1982 - 1994. The criterion indicated on the figure should read "WWH Average Criterion 5.0 mg/l".

NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Qual. Plan. Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale,methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents new publications by Ohio EPA have become available. The following publications should also be consulted as they represent the latest information and analyses used by Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. *in* W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. *in* W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. *in* W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. *in* W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

These documents and this report can be obtained by writing to:

Ohio EPA, Division of Surface Water
Monitoring and Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809
(614) 728-3377

FOREWORD

What is a Biological and Water Quality Survey?
A biological and water quality survey, or “biosurvey”, is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 10-15 different study areas with an aggregate total of 250-300 sampling sites.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.*, NPDES permits, Director’s Orders, the Ohio Water Quality Standards [OAC 3745-1]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] report).

Hierarchy of Indicators
A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. The six “levels” of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental “results” (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.*, rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreational uses. These indicators represent

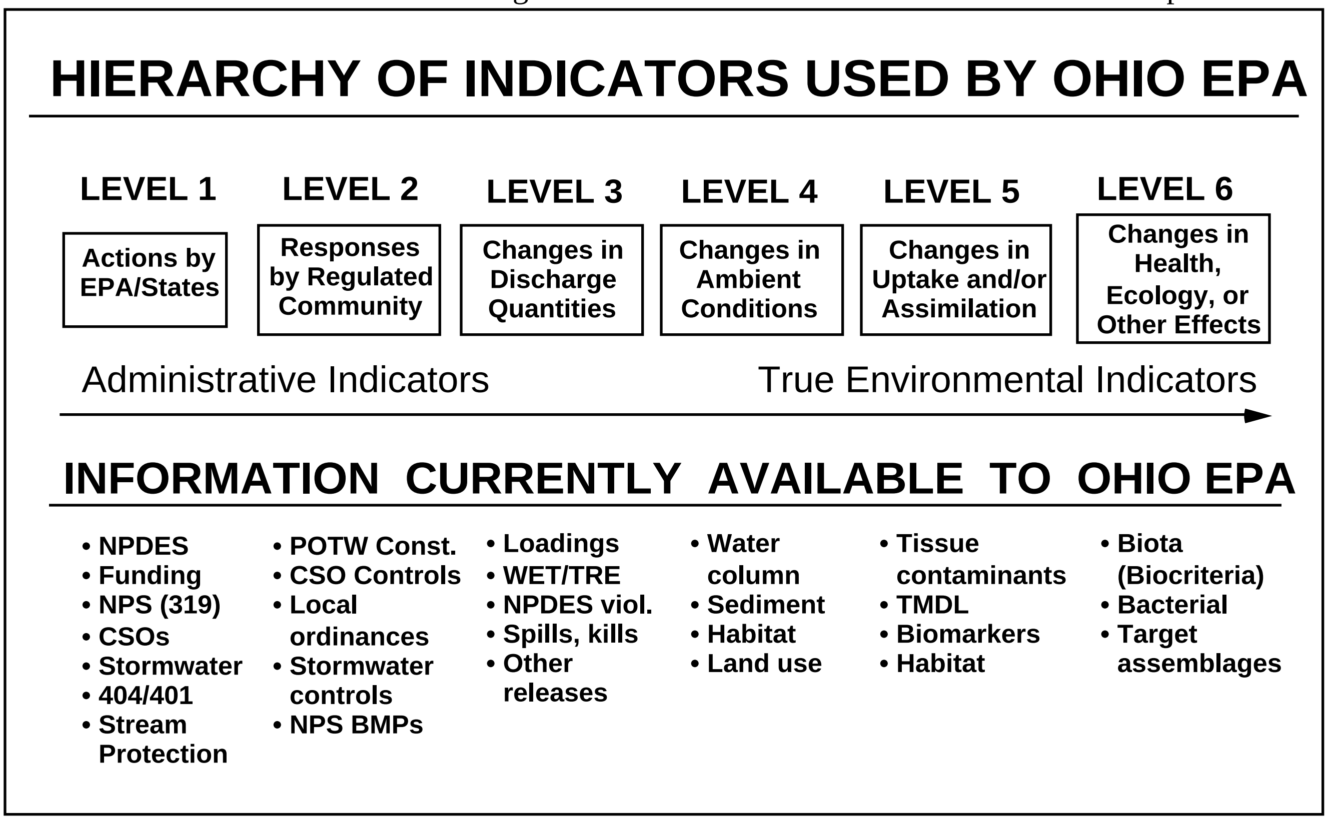

Figure 1. Hierarchy of administrative and environmental indicators used by Ohio EPA for monitoring, assessment, reporting, and evaluating program effectiveness. This is patterned after a model developed by the U.S. EPA, Office of Water.

the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio NPS Assessment, and technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Uses
The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the narrative goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in rivers and streams, the aquatic life use criteria frequently control the resulting protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting aquatic life generally results in water quality suitable for all uses. The five different aquatic life uses currently defined in the Ohio WQS with the general intent of each with respect to the role of biological criteria are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.* Biological criteria are stratified across five ecoregions for the WWH use designation.

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.* Biological criteria for EWH apply uniformly across the state.

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall. No specific biological criteria have been developed for the CWH use although the WWH biocriteria are viewed as attainable for CWH designated streams.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat. Biological criteria for MWH were derived from a separate set of habitat modified reference sites and are stratified across five ecoregions and three major modification types: channelization, run-of-river impoundments, and extensive sedimentation due to non-acidic mine drainage.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 $mi.^2$ drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.*, true ephemeral streams), or other irretrievably altered waterways. No formal biological criteria have been established for the LRW use designation.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.*, fecal coliforms, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health are detailed in other documents.

ACKNOWLEDGEMENTS

The following Ohio EPA staff are acknowledged for their significant contribution to this report.

Study Area Description - Hugh Trimble
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The field work in support of this project would have not been possible without the capable assistance of the following 1994 seasonal field staff: Philip Holt, Robert Holmes, Tony Minamyer, Tim Schmit, and Julie Sulivan.

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(Montgomery, Miami, Shelby, Logan, Clark, Hardin, and Auglaize Counties, Ohio)

State of Ohio Environmental Protection Agency
Division of Surface Water
1800 Watermark Drive
Columbus, Ohio 43215-0166

Introduction

As part of the Five-Year Basin Approach for Monitoring and NPDES (National Pollution Discharge Elimination System) Permit Reissuance, ambient biological, water column chemical, sediment, and bioassay sampling was conducted in the upper Great Miami River mainstem and selected tributaries. The study area included the Great Miami River mainstem from Indian Lake (River Mile [RM] 159.8) to Dayton (RM 85.0), the North Fork Great Miami River, Blackhawk Run, Van Horn Creek, South Fork Great Miami River, Cherokee Mans Run, Bokengehalas Creek, BlueJacket Creek, Possum Run, McKees Creek, Loramie Creek, Spring Creek, Lost Creek, Honey Creek, and one unnamed tributary of the South Fork Great Miami River.

Specific objectives of this evaluation were to:

1) Evaluate the influence of the Indian Lake, Quincy, Sidney, Troy, Piqua, and Miami Concervancy District (MCD) North Regional Wastewater Treatment Plants (WWTPs) on the Great Miami River mainstem,

2) Evaluate the influence of the Piqua Municipal Power Electric Generation Station (MP-EGS) on the Great Miami River mainstem,

3) Evaluate the influence of the Bellefontaine WWTP on Possum Run and Blue Jacket Creek,

4) Evaluate the influence of the New Carlisle WWTP on Honey Creek,

5) Provide a baseline assessment (biological, chemical, and physical) of Loramie Creek and to evaluate the Ft. Loramie, Botkins, and Anna WWTPs,

6) Provide an assessment (biological, chemical, and physical) of Indian Lake tributaries in support of the Indian Lake Watershed Restoration Project,

7) Establish biological monitoring sites on selected tributaries to evaluate nonpoint source (NPS) management activities within the upper Great Miami River watershed, and

8) Evaluate any additional improvements in the biological and water quality conditions since the 1982 biosurvey, evaluate existing use designations, and to expand the Ohio EPA database for long-term trend analysis (*e.g.,* 305[b] reporting).

SUMMARY

Upper Great Miami River Mainstem

Approximately 75 miles of the Great Miami River mainstem were assessed as part of the 1994 survey. The sampling effort included 87 biological, chemical, and physical sampling stations, evaluating the river each from Indian Lake (RM 159.8) to Dayton (RM 85.0). A previous similar survey by Ohio EPA occurred in 1982. The results of the 1994 biological survey showed that for the portion of the upper Great Miami River mainstem between the Quincy dam (RM 143.5) and Dayton (RM 85.0) biological index scores indicated full attainment of the Exceptional Warmwater Habitat (EWH) use designation at most sites (Table 1). This meets a criterion for recommending that a redesignation of this segment to the EWH use designation be made. The impounded segments of the mainstem in Sidney, Piqua, and Troy are recommended to retain the WWH use designation. Based on ambient biological performance, 88.6% (66.3 miles) of the Great Miami River was considered to be in full attainment of the recommended EWH or existing Warmwater Habitat (WWH) aquatic life use designations. The remaining 11.4% (8.5 miles) of the mainstem exhibited partial attainment.

Departures from the applicable biological criteria were limited to five relatively short stream segments (Table 1). A 2.9 mile reach of partial attainment was indicated downstream from the Indian Lake WWTP. The condition of the biota (fish and macroinvertebrates) suggested modest organic and nutrient enrichment. The community response to this disturbance included an increased proportion of tolerant and generalist taxa as well as an increase in the incidence of gross external anomalies on fish. Community index values (IBI, MIwb, ICI) generally indicated nominal departures from the applicable WWH biological criteria, with community performance no worse than fair observed. The decline was attributed to both the influence of moderate enrichment from the Indian Lake WWTP as well as the modified habitat conditions that typified this segment. The effect of modest organic and nutrient loadings from the Indian Lake WWTP were exacerbated by the marginal habitat quality. Lacking the compliment of positive habitat attributes normally associated with a free flowing river (*e.g.*, mixed current velocities, deep pools, well developed riffles and runs, coarse substrates, and wooded riparian corridors), the upper portion of the study area provides a diminished assimilative capacity in comparison with the higher quality habitat common to the mainstem downstream from the Quincy dam.

A relatively brief segment (0.3 miles) of partial attainment (WWH) was observed within the Quincy dam pool. The slight departure from the applicable biological criteria at RM 143.8 (the IBI missed nonsignificant departure by 1 unit) was attributed to the physically simplified habitat typical of run-of-the-river impoundments combined with the secondary effects of upstream habitat and organic enrichment. As such, the ambient biological performance was below the true potential of this reach despite the impounded habitat.

A major recommendation of this report is to redesignate most of the mainstem downstream from the Quincy Dam to the CSX railroad bridge in Dayton from WWH to EWH, based on the strong indications by both the fish and macroinvertebrates that the latter is attainable. Thus references to use attainment status hereafter are based on the recommended use designations. Three segments of partial EWH attainment occurred immediately downstream from the Quincy Dam (0.2 miles), upstream and downstream from Sidney (3.5 miles), and downstream from the MCD N. Regional WWTP (1.6 miles). In each case it was the ICI which barely failed to meet the EWH criterion.

Table 1. Aquatic life use attainment for applicable use designations (existing and recommended) in the Upper Great Miami River study area. Attainment status is based on data collected between June and October, 1994.

River Mile Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI	Attainment Status[b]	Comment
Great Miami River (1994)						
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
158.9(W)/158.3	40	8.6	40	43.0	FULL	dst. Indian Lake
157.3(W)/157.3	32*	8.1[ns]	38	55.0	PARTIAL	dst. Indian Lake WWTP
153.1(B)/153.5	41[ns]	8.1[ns]	30*	47.5	PARTIAL	CR 13
146.3(B)/148.6	39[ns]	8.9	48	46.5	FULL	SR 235
143.8(B)/144.2	37*	8.3[ns]	18[e]	60.0	PARTIAL	Impounded-Quincy Dam
Eastern Corn Belt Plain -WWH/EWH Use Designation (Existing/Recommended)						
143.2(B)/143.4	53	10.7	40*	76.5	FULL/PARTIAL	dst. Impoundment
142.5(B)/142.7	52	9.8	52	70.5	FULL/FULL	dst. Quincy WWTP
138.2(B)/138.5	55	10.0	56	71.0	FULL/FULL	ust. Port Jefferson
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
133.1(B)/133.2	53	9.4	40[e]	60.0	FULL	Impounded-Sidney Dam
Eastern Corn Belt Plain -WWH/EWH Use Designation (Existing/Recommended)						
130.0(B)/130.1	59	10.9	40*	69.0	FULL/PARTIAL	dst. Impoundment
128.6(B,MZ)/128.6	47	10.0	22	--	N/A	Sidney WWTP Mix Zone
127.7(B)/127.5	57	10.7	40*	74.0	FULL/PARTIAL	dst. Sidney WWTP
123.9(B)/123.9	57	10.1	50	61.0	FULL/FULL	Kouther Rd.
117.5(B)/118.5	59	10.4	44	85.5	FULL/FULL	SR 66
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
114.8(B)/114.9	45	9.2	22[e]	46.0	FULL	Impounded-Piqua
114.3(B)[c]/ --	39	8.6	--	47.5	N/A	W Bank-Piqua MP/Impd.
114.3(B)[d]/ --	39	7.9	--	51.5	N/A	E Bank-Piqua WWTP/Imp.
-- /114.27(MZ)	--	--	38	--	N/A	dst. Piqua MP-dst. Dam
-- /114.27(MZ)	--	--	46	--	N/A	dst. Piqua WWTP-dst. Dam
114.1(B)/114.2	50	9.4	46	68.5	FULL	dst. Piqua MP & WWTP
Eastern Corn Belt Plain - WWH/EWH Use Designation (Existing/Recommended)						
112.7(B)/113.5	48	9.1[ns]	52	80.0	FULL/FULL	adj. Main St.
109.9(B)/110.1	57	9.9	54	77.5	FULL/FULL	Eldean Rd.
108.5(B)/ --	57	10.1	-	73.5	(FULL/FULL)	ust. Troy Dam
106.3(B)/106.1	52	10.2	48	55.0	FULL/FULL	SR 41
105.6(B,MZ)/105.6	47	9.9	22	--	N/A	Troy WWTP Mixing Zone
104.7(B)/105.4	55	10.7	50	86.0	FULL/FULL	dst. Troy WWTP
98.7(B)/100.8	57	10.4	52	77.0	FULL/FULL	SR 571

Table 1. continued.

River Mile Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI	Attainment Status[b]	Comment
Great Miami River (1994)						
Eastern Corn Belt Plain - WWH/EWH Use Designation (Existing/Recommended)						
95.9(B)/95.7	57	10.5	52	88.0	FULL/FULL	Ross Rd.
93.8(B)/ --	56	10.1	--	78.0	(FULL/FULL)	Old Vandalia WWTP
91.0(B)/91.1	54	10.5	56	68.0	FULL/FULL	Little York Rd.
87.3(B)/87.7	54	10.2	52	80.5	FULL/FULL	Needmore Rd.
86.6(B,MZ)/86.6	47	9.0	22	--	N/A	MCD N Reg. Mixing Zone
85.0(B)/85.9	56	10.1	38*	72.0	FULL/PARTIAL	dst. MCD N WWTP
Great Miami River (1995)						
Eastern Corn Belt Plain - WWH/EWH Use Designation (Existing/Recommended)						
86.6(B,MZ)/86.6	47	9.3	E	84.5	N/A	MCD N Reg. Mixing Zone
85.0(B)/85.9	54	9.4[ns]	46	82.5	FULL/FULL	dst. MCD N WWTP
North Fork Great Miami River (1994)						
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
11.6(H)/10.7	30*	N/A	MG[ns]	25.0	PARTIAL	Madory Rd.
8.5(H)/8.3	26*	N/A	G	35.5	**NON**	CR 104
4.1(B)/6.3	28*	6.8*	38	56.5	**NON**	SR 117
Blackhawk Run (1994)						
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
0.9(H)/2.3	40	N/A	34[ns]	43.5	FULL	Feikert Rd.-SR 235
Van Horn Creek (1994)						
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
1.3(H)/1.0	27*	N/A	MG[ns]	46.5	**NON**	SR 366
South Fork Great Miami River (1994)						
Eastern Corn Belt Plain - WWH Use Designation (Existing)						
8.0(H)/8.0	41	N/A	54	48.0	FULL	SR 638
5.8(W)/5.8	39[ns]	8.3	52	52.5	FULL	CR 97
1.8(W)/1.8	45	8.0[ns]	E	52.0	FULL	CR 38
***Tributary to S. Fk. Great Miami River** (RM 5.27)*						
Eastern Corn Belt Plain - No Existing /EWH Use Designation (Existing/Recommended)						
3.5(H)/3.4	50	N/A	VG[ns]	44.0	FULL	CR 101
0.4(H)/0.5	56	N/A	E	58.0	FULL	CR 96

Table 1. continued.

River Mile Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI	Attainment Status[b]	Comment
Bokengehalas Creek (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
8.1(W)/8.0	28*	6.1*	G	43.5	PARTIAL	TR 31-ust. Blue Jacket Cr.
4.7(W)/4.7	43	8.4	G	80.0	FULL	TR 209-dst. Blue Jacket Cr.
0.3(W)/0.4	51	9.4	48	54.5	FULL	Mill St.
Blue Jacket Creek (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
6.4(H)/6.4	30*	N/A	P*	45.0	**NON**	TR 216-ust Possum Run
5.5(H)/5.4	37[ns]	N/A	F*	81.0	PARTIAL	CR 11-dst Possum Run
3.1(H)/3.2	33*	N/A	MG[ns]	64.0	PARTIAL	CR 11
0.8(H)/0.6	45	N/A	44	41.0	FULL	TR 31
Possum Run (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
0.7(H)/0.7	32*	N/A	P*	58.0	**NON**	ust. Bellefontaine WWTP
0.4(H)/0.3	41	N/A	F*	74.0	PARTIAL	dst. Bellefontaine WWTP
Loramie Creek (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
36.8(H)/36.8	21*	N/A	P*	35.5	**NON**	ust. Botkins WWTP
35.0(H)/34.9	19*	N/A	18*	42.5	**NON**	dst. Botkins WWTP
30.4(W)/31.7	27*	6.0*	18*	43.0	**NON**	ust. Clay Cr. (Anna WWTP)
29.1(B)/ --	25*	6.9*	--	37.0	N/A[f]	dst. Clay Cr. (Anna WWTP)
28.3(B)/ --	28*	7.3*	--	43.0	N/A[f]	Lake Loramie backwaters
20.8(W)/20.7	30*	8.7	26*	41.0	PARTIAL	ust. Ft. Loramie WWTP
16.6(W)/14.8	23*	5.5*	26*	53.5	**NON**	dst. Ft. Loramie WWTP
7.5(W)/5.8	34*	7.7*	36	71.0	PARTIAL	Lor. Wash./Patterson Rd.
3.7(W)/3.7	48	10.0	48	83.0	FULL	Lehman Rd.
0.5(W)/0.4	50	9.4	52	77.5	FULL	adj. Landman Rd.
Mckees Creek (1994)						
		Eastern Corn Belt Plain - EWH Use Designation (Existing)				
9.5(H)/ --	54	N/A	--	53.5	(FULL)	CR 1
0.7(H)/0.9	54	N/A	52	62.0	FULL	CR 31

Table 1. continued.

River Mile Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI	Attainment Status[b]	Comment
Cherokee Mans Run (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
3.5(H)/3.7	41	N/A	44	69.0	FULL	TR 99
1.8(H)/ --	50	N/A	--	65.0	(FULL)	TR 95
Muchinippi Creek (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
12.5(H)/ --	42	N/A	--	32.0	(FULL)	US 33
7.4(W)/ --	48	8.0ns	--	37.5	(FULL)	Duff Rd.
1.9(W)/ --	28*	6.8*	--	35.0	(**NON**)	Wren Rd.
Spring Creek (1994)						
		Eastern Corn Belt Plain - EWH Use Designation (Existing)				
1.0(W)/1.0	43*	8.1*	VGns	61.0	PARTIAL	Troy Piqua Rd.
Stony Creek (1994)						
		Eastern Corn Belt Plain - WWH Use Designation (Existing)				
3.2(W)/ --	42	<u>5.3</u>*	--	24.5	(**NON**)	TR 30
Lost Creek (1994)						
		Eastern Corn Belt Plain - EWH Use Designation (Existing)				
9.8(W)/9.8	45*	9.0ns	E	87.5	PARTIAL	Troy Urbana Rd.
2.5(W)/2.5	44*	9.0ns	VGns	54.0	(PARTIAL)	SR 202
Honey Creek (1994)						
		Eastern Corn Belt Plain - EWH Use Designation (Existing)				
10.0(W)/10.1	48ns	9.1ns	44ns	70.5	FULL	ust. New Carlisle WWTP
8.0(W)/8.1	48ns	9.2ns	MG*	85.0	PARTIAL	dst. New Carlisle WWTP
3.2(W)/3.2	48ns	9.4	40*	67.5	PARTIAL	Rudy Rd.

* Significant departure from applicable biological criterion (>4 IBI or ICI units, >0.5 MIwb units), poor and very poor results are underlined.
ns Nonsignificant departure from biological criterion (≤4 IBI or ICI units, ≤0.5 MIwb units).
MZ 100 meter mixing zone sample (biological criteria do not apply).
H Headwater site type; W - Wading site type.
B Boat site type.
a Narrative evaluation used in lieu of ICI (E = exceptional; VG = Very Good; G = Good; MG =marginaly good; F = fair; P = poor; VP = very poor).
b Attainment status based on one organism group are parenthetically expressed.
c 100 meter electrofishing zone, sample collected along west river bank opposite the Piqua Municipal Power EGS and upstream from the Piqua WWTP.
d 100 meter electrofishing zone, sample collected along east bank within the influence of Piqua Municipal Power EGS.
e Macroinvertebrate sample collected in impoundments - due to the lack of continuous flow the ICI is not applied in such areas.
f Fish community samples collected within the Lake Loramie backwaters - biological criteia do not apply in such areas.

Table 1. continued.

Ecoregional Biocriteria: Eastern Corn Belt Plain (ECBP)

Index - Site Type	WWH	EWH	MWH[g]
IBI - Headwater/Wading	40	50	24
IBI - Boat	42	48	24
MIwb - Wading	8.3	9.4	5.8
MIwb - Boat	8.5	9.6	5.8
ICI	36	46	22

[g]Modified Warmwater Habitat for channel Modified areas.

While the ICI missed EWH by only 2 units in the Quincy and Sidney segments, the departure was more substantial downstream from the MCD N. Regional WWTP. However, the results of sampling conducted in 1995 as part of the lower Great Miami River survey indicated full EWH attainment downstream from the MCD N. Regional WWTP. No impairment of the existing WWH or recommended EWH aquatic life use designations was observed downstream of the other WWTPs evaluated as part of the 1994 sampling effort. Even within mixing zones fish community performance within these areas of concentrated effluent was consistently exceptional. However, macroinvertebrate community performance within mixing zones was generally fair and the response signatures indicated organic enrichment and at times toxicity, the latter probably due to the effects of chlorine. This was, however, a highly localized phenomenon (limited to the mixing zones) as rapid recovery occurred downstream of each facility. Furthermore, the poorer performance of the macroinvertebrates within the mixing zones does not constitute an impairment of the existing or recommended aquatic life uses as the biocriteria do not apply in these areas.

The results from water column sampling indicated remarkably few water quality criteria exceedences or excursions in the upper Great Miami River mainstem. Dissolved oxygen (D.O.) concentrations well above the WWH and EWH criteria (minimum and average) were observed at nearly every sampling location within the study area. Only three excursions below the WWH average D.O. criterion were recorded and were limited to daytime samples collected downstream from the Indian Lake WWTP in the habitat modified upper portion of the mainstem between RM 151.7 and RM 143.6. Diel sampling revealed six excursions below the WWH minimum D.O. criterion at RM 114.3 in the Piqua dam pool. While these values were below the D.O. water quality criteria, they represented less than 10% of all samples collected over a 69 hour period. Additionally, all of the excursions occurred between midnight (0000 hrs.) and 0600, the time period during which the D.O. regime is controlled by algal respiration. The lower D.O. levels recorded during the early AM hours were also influenced by nutrient loadings from upstream sources, the Piqua WWTP, and thermal loads from the Piqua MP-EGS, all of which was exacerbated by the impounded habitat. The latter two facilities discharge directly to the Piqua dam pool, the EGS recirculating once-through cooling water within the impoundment during periods of low flow. Despite the D.O. excursions observed at RM 114.3 and the direct influence of the Piqua WWTP and Piqua MP-EGS, full attainment of the WWH aquatic life use was observed within the dam pool and downstream. Moreover, community performance within the reach extending downstream of the dam pool was fully consistent with the recommended EWH use designation. No downstream impairments could be attributed to either the Piqua Municipal Power EGS or the Piqua WWTP.

Excluding mixing zone samples, ambient ammonia-nitrogen (NH_3-N) concentrations were generally low and longitudinally stable throughout the upper mainstem. No exceedences of the WWH criteria for unionized ammonia were recorded, with concentrations typically near or at the method detection limits. Levels of NH_3-N above background were observed downstream from the Indian Lake and the Sidney WWTPs. Partial attainment of WWH was observed downstream from the Indian Lake WWTP and partial attainment of the recommended EWH use (the ICI missed EWH by only 2 units) downstream from the Sidney WWTP. The degree to which the biocriteria missed full attainment was proportional to the levels of NH_3-N that were recorded downstream from each WWTP. Stations bracketing other municipal WWTPs in the upper mainstem indicated comparable NH_3-N concentrations upstream and downstream. This was correlated with the extent to which NH_3-N loadings have been reduced at each WWTP.

Mean nitrate+nitrite-N (NO_3+NO_2-N) and total phosphorus concentrations displayed similar longitudinal trends as that observed with NH_3-N, with the exception of a spike downstream of the MCD North Regional WWTP. Nitrate+nitrite-N and total phosphorus concentrations were low, with phosphorus levels remaining well below the 1.0 mg/l WQS guideline. A longitudinal pattern of mean total suspended solids (TSS) was not apparent. The upper portion of the study area (Indian Lake to Quincy dam) and the reach between Piqua and Troy displayed the highest mean TSS concentrations. Five-day biochemical oxygen demand (BOD_5) displayed a general increase longitudinally. The highest BOD_5 was recorded between the Loramie Creek confluence and Troy. With the exception of the reach downstream from the Indian Lake WWTP, all organic and nutrient inputs from municipal entities evaluated were rapidly assimilated by the upper Great Miami River as evidenced by high D.O. levels, low levels of constituents associated with WWTP discharges (ammonia-N, nutrients, BOD_5, TSS), and full attainment of both the existing WWH and recommended EWH use designations.

Pesticide residue concentrations greater than either the chronic aquatic life or human health criteria were recorded at more than 50% of the sampling sites. The residues observed included aldrin, dieldrin, and endosulfan I and II. However, the levels of these pesticides were very low and values above the method detection limit generally constitute exceedences. The determination of true violation for these compounds requires a more intensive sampling effort than that performed for this survey. The occurrence of these environmentally persistent compounds is most likely the result of past agricultural usage within the basin. These pesticides are commonly held on the exchange complex of silts and clays and, as such, their occurrence within the water column is due to the presence of suspended sediment particles in the water samples. No use impairments associated with these pesticides were evident within the study area.

Sediment chemistry samples were collected from 10 locations within the upper Great Miami River study area. Analyses included selected heavy metals, organochlorine pesticides, and semi-volatile and volatile organic compounds. The concentrations were evaluated against the Kelly and Hite (1984) and Persaud et al. (1994) criteria. None of the results indicated excessive chemical contamination of sediments within the mainstem. The site at RM 116.7 (in Piqua) was the only sample where lead, zinc, chromium, and iron concentrations were ranked as either highly or extremely elevated. The source of the contamination was localized and may have been the result of fugitive residue from extensive repair and maintenance activities performed on a nearby bridge. An additional source may have included the recent demolition of a industrial complex near RM 116.7. The contamination appeared highly localized, as metal concentrations within the remainder of the mainstem were near or at background levels (*i.e.,* non-elevated). No use impairments were evident from the level of sediment metal contamination observed.

Other organic chemical residues in sediment were low throughout the study area. Polychlorinated biphenyls (PCBs) were not detected in any sample. Nine pesticides were detected at four of the sampling stations. All values were ranked as non-elevated (Kelly and Hite 1984) or occurred at levels below the low effect level (Persaud *et al.* 1994). Volatile organic compounds were not detected at any sampling station and semi-volatile compounds were detected at only two sampling stations.

Trend Assessment

Positive changes in the performance of the fish and macroinvertebrate communities, ambient concentrations of conventional pollutants, and point source pollutant loadings clearly reflected the effects of improved wastewater treatment at all of the WWTPs that discharge directly to the upper Great Miami River mainstem. With one exception (Quincy), all of the WWTPs evaluated have demonstrated substantial reductions in pollutant loadings since 1988. These actions were initiated largely to comply with water quality-based effluent limits required for compliance with the Ohio WQS and the National Municipal Policy of U.S. EPA.

In 1982, 53.4 % (35.8 miles) of the upper Great Miami River study area was considered to be in full attainment of the existing WWH aquatic life use. Thirty-five percent (23.4 miles) exhibited partial attainment, while the remaining 11.6% (7.8 miles) failed to attain the WWH use. Although ambient biological performance in 1982 indicated significant areas of partial and non-attainment, the magnitude of the departures were not severe. In fact exceptional performance was exhibited at a number of locations by either or both the fish and macroinvertebrates. The 1994 results indicated substantial improvements over 1982, with 88.6% (66.3 miles) in full attainment of existing and *recommended* uses, 11.4% (8.5 miles) in partial attainment, and *no* miles of non-attainment. This constitutes one of the most extensive and significant recoveries witnessed in the 17 year history of the Ohio EPA biological and water quality monitoring program.

In comparison to the 1982 results, nutrients (total phosphorus, NO_3+NO_2-N), NH_3-N, demand parameters, and TSS concentrations were markedly reduced in 1994. Consequently, D.O. concentrations were consistently higher in 1994 throughout most of the study area. The upper portion of the mainstem, between Indian Lake (RM 159.8) and the Quincy Dam (RM 143.4), exhibited the greatest improvements even though use attainment status was partial. In 1982 mean D.O. concentrations were well below the minimum WWH criterion downstream from the Indian Lake WWTP within the reach extending from the WWTP to approximately RM 150.0. The discharge of oxygen demanding wastes by the Indian Lake WWTP substantially exceeded the assimilative capacity of the Great Miami River in 1982.

Ambient biological performance in 1982 appeared reflective of the enriched conditions, particularly downstream of the Indian Lake WWTP. Significant departures from the applicable biological criteria were exhibited by both the benthic macroinvertebrate and fish communities downstream from this facility. The decline in biological performance corresponded with the reach of diminished D.O. concentrations. Although within this segment impairment of the WWH use was still evident in 1994, improvements were clearly evident with the magnitude and severity of degradation significantly reduced. In comparison with the 1982 biosurvey results, additional areas of recovery were identified in 1994. Improved segments included the reach immediately downstream from the Quincy dam, the reach influenced by the Sidney WWTP, and the Piqua dam pool.

Indian Lake Tributaries

The principal drainage network above Indian Lake is comprised of four streams; the North and South Forks of the Great Miami River, Blackhawk Run, and Van Horn Creek. Ambient biological, chemical, and physical data were collected from 24 sites in these tributaries as well as an unnamed tributary to the South Fork in 1994. An aggregate total of 26.7 river miles of the Indian Lake watershed was assessed. Collectively, 13.8 miles (51.7%) supported aquatic assemblages fully consistent with the WWH aquatic life use designation. Partial attainment was evident for 7.2 miles (27.0 %) and the remaining 5.7 miles (21.3%) failed to support the WWH use.

The areas of partial and non-attainment included the North Fork Great Miami River and Van Horn Creek. Departure from the WWH criteria was primarily attributed to marginal and inadequate habitat conditions. The simplified macrohabitats that characterized both streams were due to the effects of direct channel modifications, encroachment of adjacent land use on the riparian zone, and the backwater effect of Indian Lake within the lower reach of the North Fork. These physical factors are typically most detrimental to the fish assemblages, with performance no better than fair observed at any site. In contrast, the macroinvertebrate communities consistently met the minimum WWH ICI criterion with community composition and structure suggesting only modest nutrient enrichment. This community response signature (fair to poor fish community performance and marginally good to good macroinvertebrates) was clearly indicative of the overriding habitat influences.

Water chemistry results did not indicate any nutrient enrichment problems in the Indian Lake tributaries. The concentrations of nutrients were low and similar between streams - no exceedences of the applicable nutrient guidelines was evident. However, violations of the 5.0 mg/l average D.O. criterion were indicated in nearly every tributary, becoming most frequent in the North and South Forks. Violations of the 4.0 mg/l minimum D.O. criterion were limited to the North Fork and Blackhawk Run. The ability of these streams to assimilate modest agricultural nonpoint source nutrient loadings with minimal environmental disturbance was diminished due to the combined effects of degraded habitat and low gradient.

Trend Assessment

Macroinvertebrate data collected in 1982 and 1988 from the North and South Forks, Van Horn Run, and Blackhawk Run represented the only historical biological information available to perform a trend assessment. The performance of the macroinvertebrate community in all of the Indian Lake tributaries has demonstrated a marked improvement since the 1982 and 1988 surveys. Poor performance with index results below the WWH ICI biocriterion was typically encountered. Only the South Fork supported a macroinvertebrate assemblage consistent with the WWH biological criterion during that time period. The degraded conditions were attributed to the combined effects of highly modified macrohabitats, nutrient enrichment from diffuse agricultural nonpoint sources, and drought conditions encountered in 1988.

The results of the 1994 survey indicated a complete recovery of the macroinvertebrates with community performance being fully consistent with the WWH biological criteria in all of the tributaries evaluated. Aquatic life use attainment in 1994, based on both fish and macroinvertebrates, indicated that streams and/or segments which failed to support WWH between 1982 and 1988 improved to full or partial attainment in 1994. The much improved conditions, which were particularly evident in the macroinvertebrate results, occurred after the recent agricultural nonpoint source management efforts of the Indian Lake Watershed Restoration Project.

These efforts were initiated in 1991 and have focused on the implementation of Best Management Practices (BMPs) within the Indian Lake watershed. Specific management activities have included maintenance and expansion of the Conservation Reserve Program (CRP), the installation of filter and buffer strips along the Indian Lake tributaries, restricting access by livestock to the tributaries, and stream bank stabilization. While lingering habitat impacts are still evident in the fish community response, it appears that these restoration efforts were followed by improved chemical, physical, and biological conditions in all of the Indian Lake tributaries.

Loramie Creek

A total of 29.5 miles of the Loramie Creek mainstem was assessed in 1994, excluding the 7.3 mile Lake Loramie dam pool. The sampling effort included 26 biological, habitat, and chemical/physical sampling stations, evaluating the reach from Botkins Rd. (RM 36.8) to Landman Mill Rd. (RM 0.4). Based on ambient biological performance 55.9% (16.5 miles) of the mainstem failed to support the WWH aquatic life use designation (non-attainment). Partial attainment was indicated for 20.7% (6.1 miles) of the mainstem, and the remaining 23.4% (6.9 miles) fully attained the WWH use.

The extensive area of non and partial attainment between RM 36.8 and RM 14.8 reflected the highly impaired stream habitat. Near and instream macrohabitats were degraded throughout most of the upper Loramie Creek, as much of the mainstem has been extensively channelized. The majority of the sites lacked a wooded riparian corridor, or if riparian vegetation was present it was quite limited and composed of grasses and second growth. Encroachment of agricultural land uses on the riparian zone frequently extended to the stream edge. These conditions encourage the rapid delivery of clayey silts and nutrients to the tributaries and mainstem. The modified state of the stream channel is conducive to excessive sedimentation which results in a heavy bedload that reduces depth heterogeneity, increases the embeddedness of the coarser substrates, and limits the function of other instream cover types. Another negative effect is the exacerbation of nutrient enrichment via an interrupted energy base and unlimited sunlight which stimulates nuisance algal growth.

Ambient biological performance ranging from poor to fair was attributed to highly modified macrohabitats and the attendant enrichment effects that are often associated with intensive agricultural land use. No discernable impacts were evident in the response of the biota (fish and benthic macroinvertebrates) from the Botkins, Anna (via Clay Creek), or Ft. Loramie WWTPs. Departure from the applicable biocriteria downstream from these facilities was primarily attributed to the habitat and land use factors described above. While these facilities contribute significant nutrient loadings, no additional impacts above that exerted by the upstream background conditions were evident. The quality of near and instream macrohabitats improved considerably in the lower mainstem between RM 7.5 (Loramie-Washington Rd.) and RM 0.5 (adj. Landman Rd.). Full attainment of the WWH use was indicated for this segment. The biological improvement was correlated with the much improved macrohabitat quality of the lower reach.

Ambient water chemistry indicated enriched conditions within the upper and middle segments of the mainstem, evidenced mainly by lower D.O. concentrations. Daytime and diel sampling indicated 28 violations of the WWH D.O. criteria with values as low as 1.3 mg/l within the reach extending from RM 36.84 to RM 28.9 (SR 29). The greatest D.O. deficit occurred within the upper limits of the Lake Loramie impoundment between RM 30.42 (Harden-Wapakoneta Rd.) and RM 28.9 . Sixty-seven percent of the daytime and 38% of the diel samples collected from this 1.5 mile segment indicated concentrations below the 4.0 mg/l minimum or 5.0 mg/l average WWH

D.O. criterion. The depressed D.O. values appeared to be a result of several factors working in concert. Enriched, channelized, impounded, and stripped of much of the riparian vegetation, the upper portion of Loramie Creek provides optimal conditions for nuisance algal growth and the associated effects on the D.O. regime.

The results from diel and daytime sampling within the lower segment of Loramie Creek, between RM 20.7 (SR 66) and RM 0.41 (adjacent Landman Mill Rd.), clearly indicated improved conditions. Mean D.O. concentrations were well above the WWH criteria. The Ft. Loramie and Minster (via Miami-Erie canal) WWTPs did not appear to inhibit the ability of Loramie Creek to maintain ambient D.O. levels consistent with the WWH use.

Bokengehalas Creek Subbasin
The Bokengehalas Creek subbasin included Bokengehalas Creek, Blue Jacket Creek, and Possum Run. The sampling effort included 23 biological, chemical, and physical sampling stations. A cumulative total of 15.2 miles of the Bokengehalas subbasin was assessed in 1994. Full attainment of the WWH aquatic life use designation was indicated for 73.7% (11.2 miles) of the subbasin. Partial attainment was observed in 21.1% (3.2 miles) while the remaining 5.2% (0.8 miles) failed to support the WWH use (non-attainment).

The partial and non-attainment was not due to the influence of the Bellefontaine WWTP. Ambient biological performance consistently improved downstream of the facility in Possum Run and downstream of the confluence with Blue Jacket Creek. The flow augmentation provided by the WWTP effluent appeared to positively influence the condition of the fish and macroinvertebrates throughout the subbasin. Biological performance consistent with the WWH biocriteria was typically observed downstream from the Bellefontaine WWTP in Possum Run, Blue Jacket Creek, and Bokengehalas Creek. All of the non-attainment was limited to segments upstream of the WWTP influence.

Daytime and diel D.O. monitoring indicated concentrations above the WWH criteria (average and minimum) throughout the Bokengehalas Creek subbasin. Ammonia-N concentrations remained at or near the 0.05 mg/l detection limit at all but one station. Mean concentrations of nitrate+nitrite-N and total phosphorus increased markedly downstream of the Bellefontaine WWTP in Possum Run. A pattern of continued downstream influence was evident for these parameters in Blue Jacket Creek. Despite the nutrient inputs form the Bellefontaine WWTP the loadings were rapidly assimilated as evidenced by D.O. concentrations well above the WWH criteria.

Trend Assessment
In comparison with previous surveys, ambient biological performance within the Bokengehalas Creek subbasin demonstrated a marked improvement in 1994. In 1982, both the macroinvertebrate and fish assemblages exhibited a significant impact in Possum Run and Blue Jacket Creek downstream from the Bellefontaine WWTP. As a result of recent treatment process upgrades, a substantial reduction in pollutant loads contributed by the WWTP to Possum Run, and subsequently Blue Jacket Creek, have occurred since 1987. Near complete biological recovery was indicated within the stream segments influenced by this facility in 1994.

Selected Great Miami River Tributaries
Biological, chemical, and physical data were collected from 29 sampling stations in Cherokee Mans Run, Muchinippi Creek, McKees Creek, Lost Creek, Spring Creek, and Honey Creek. The objectives of the sampling were to evaluate the ambient conditions of these selected tributaries and

to determine the influence of the New Carlisle WWTP on Honey Creek.

Viewed in the aggregate a total of 49.8 miles of selected Great Miami River tributaries were assessed. Based on ambient biological performance 44.0% (21.9 miles) indicated full attainment of the applicable aquatic life use designations (WWH or EWH). Partial attainment was indicated for 43.8% (21.8 miles), and the remaining 12.2% (6.1 miles) failed to support the applicable aquatic life use. The areas of partial attainment included Lost Creek, Honey Creek, and Spring Creek. Non-attainment was limited to the lower reaches of Muchinippi Creek and Stony Creek. The remaining streams or stream segments fully supported the applicable aquatic life use designation.

Partial attainment of the EWH use in Lost Creek was the result of a failure of the fish community to perform at a level consistent with the EWH biological criteria. The macroinvertebrate community consistently met the EWH ICI criterion and was characterized as very good to exceptional. Although, the fish assemblage performed at a good to very good level, this was just below the EWH biocriteria. Low flow conditions, possibly associated with water withdrawal for irrigation, may have contributed to the nominal departures observed in the fish community. Similar biological performance as that encountered in Lost Creek was evident in Spring Creek. Despite communities characterized as good to very good, overall performance was just below the EWH biocriteria.

Use attainment in Stony Creek was based upon the performance of the fish community only. The assemblage exhibited the diversity and functional organization typical of WWH streams of this size and within the ECBP ecoregion as indicated by the IBI score. However, the community failed to support the biomass and structure necessary to meet the WWH MIwb criterion. This resulted in the assignment of the non-attainment status which was attributed to poor macrohabitat quality associated with from recent and past channelization activities.

The area of non-attainment in Muchinippi Creek was limited to the lower reach between RM 4.6 and the mouth. Depauperate macrohabitat quality was observed throughout Muchinippi Creek. The stream is maintained in a permanently modified state to expedite agricultural drainage. Riparian vegetation was virtually nonexistent and consisted of grasses. However, a continuous flow from ground water appeared to positively effect the ability of this modified stream to support a more diverse and organized fish assemblage than would otherwise be expected given the accumulation of modified habitat attributes. The environmentally sensitive, specialized taxa common within the upper part of the mainstem were absent from the lower reach as the ground water influence dissipated with increasing drainage area. As such, the negative effects of nutrient enrichment and habitat modification became more pronounced between RM 4.6 and the mouth.

The New Carlisle WWTP discharges directly to Honey Creek at RM 8.7. Biological and chemical monitoring stations were situated to evaluate the influence of this facility, providing assessment coverage of 10.1 river miles. Based on ambient biological performance, full attainment of the EWH aquatic life use designation was indicated for the 1.4 mile reach extending from RM 10.1 (upstream New Carlisle WWTP) to RM 8.7 (New Carlisle WWTP outfall). Partial attainment was observed downstream from the WWTP to the mouth (8.7 miles). The fish community within this reach consistently performed at a level fully consistent with the EWH biocriteria. Partial attainment was driven by the failure of the macroinvertebrate community to perform at an EWH level. Community performance was characterized as marginally good to good, but lacked the attributes associated with exceptional streams. Immediately downstream of the New Carlisle WWTP the composition of the macroinvertebrate community shifted to a predominance by pollution tolerant taxa, even though environmentally sensitive taxa were still present. This shift suggested an enrichment effect, but no toxic response was indicated. Further downstream improvement was evident, but the recovery was incomplete.

The results from water chemistry sampling indicated four violations of the EWH D.O. minimum criterion at RM 8.08. These occurred within the reach of partial attainment downstream of the New Carlisle WWTP. The remaining stations on Honey Creek indicated ambient D.O. concentrations consistent with the EWH criterion.

Trend Assessment
Benthic macroinvertebrate data collected in 1982 from Cherokee Mans Run, McKees Creek, Spring Creek, and Lost Creek represented the only available information to perform a trend assessment. The results from the 1982 sampling indicated little change in the ambient biological performance within these streams in comparison with the 1994 results.

CONCLUSIONS

Upper Great Miami River (mainstem)

- Significant improvements in aquatic community performance and water quality in the upper Great Miami River mainstem were documented in 1994. The positive trends in these environmental indicators were correlated with treatment upgrades initiated at the major municipal WWTPs discharging to the mainstem.

- Biological performance has so improved throughout the upper Great Miami River that much of the mainstem now meets the criteria for the EWH use designation. The changes observed since 1982 rank as some of the most significant improvements observed for any Ohio river or stream in our 17 years of experience conducting statewide biological surveys. The considerable investment in pollution abatement made by the major municipalities during the 1980s has clearly resulted in meaningful and measurable improvements in the environmental conditions of the upper Great Miami River mainstem.

- Within upper portion of the mainstem (Indian Lake to the Quincy dam), impairment of the WWH use was limited to two segments. Departure from the WWH standard within this reach was associated with previous channel modifications, impoundment, and encroachment of adjacent land uses on the riparian zone. The effects of nutrient and organic enrichment from the Indian Lake WWTP were still exacerbated by the modified physical habitat, despite substantial reductions in pollutant loadings since the mid-1980s. Ambient nutrient concentrations and biochemical oxygen demand were elevated downstream of the WWTP with a corresponding decline in ambient D.O. concentrations. Although impairment was still evident in 1994 downstream from the Indian Lake WWTP, the severity and magnitude were significantly reduced in comparison with previous survey results.

- Within the remaining portion of the study area (Quincy dam to Dayton), no serious impairment of the existing WWH or recommended EWH aquatic use designation was evident downstream of the Quincy, Sidney, Troy, Piqua, MCD North Regional WWTPs, or Piqua Municipal Power EGS. Partial attainment of the recommended EWH use designation occurred in the vicinity of Sidney and was due to the ICI missing attainment by only 2 units. Chemical quality (water column and sediment) within this reach was good to exceptional. Very few exceedences of chemical water quality criteria were recorded and sediment contaminants, if present, typically occurred at or below levels considered to be non-elevated or low effect.

- Fish and macroinvertebrate communities regularly exhibited exceptional performance downstream from the Quincy dam to the lower limits of the study area in Dayton. Both assemblages typically indicated a level of performance that met or easily exceeded the biocriteria for the EWH aquatic life use designation. The high quality environmental conditions evident in 1994 were attributed to both good to exceptional water quality as well as a predominance of high quality macrohabitats.

Indian Lake Tributaries

- Full attainment of the WWH aquatic life use designation was indicated for the South Fork Great Miami River, an unnamed tributary of the South Fork, and Blackhawk Run. Partial and non-attainment was observed in the North Fork Great Miami River and Van Horn Run. Departures from the WWH biological criteria were attributed to inadequate habitat conditions.

- Biological community performance in the Indian Lake tributary network has demonstrated a marked improvement since the 1980s. The results from 1994 indicated substantial recovery of the macroinvertebrates in all of the Indian Lake tributaries; the fish assemblages, however reflected lingering habitat impacts in two of these streams. The improvements followed the implementation of nonpoint source pollution abatement efforts within the watershed.

Loramie Creek

- Pervasive habitat modifications, channelization, siltation, impoundment, and enrichment from agricultural and municipal sources resulted in partial and non-attainment in a majority of the mainstem. Only the lower 4.75 miles of the mainstem supported a community of aquatic organisms fully consistent with the WWH use designation.

- The degraded conditions were the most pronounced within the upper portion of Loramie Creek. Depauperate macrohabitats and enriched conditions resulted in very low ambient D.O. concentrations within this segment; several violations of the WWH minimum and average D.O. criteria were recorded. Biological communities within this reach reflective of poor quality.

- The Botkins WWTP has reduced pollutant loads to Loramie Creek substantially since the mid-1980s. In contrast, the Anna WWTP (via Clay Creek) has consistently increased pollutant loads to Loramie Creek (via Clay Creek) during the same period.

- Chemical water quality was much improved downstream of Lake Loramie. Despite nutrient inputs from the Ft. Loramie WWTP and the Minster WWTP (via the Miami-Erie canal), D.O. concentrations were above the WWH criteria.

Bokengehalas Creek Subbasin

- Full or partial attainment was observed within the stream segments directly influenced by the Bellefontaine WWTP. Moreover, the flow augmentation provided by the Bellefontaine WWTP discharge appeared to positively affect biological performance.

- In comparison with previous assessments, biological performance within the Bokengehalas Creek subbasin has improved considerably. As a result of treatment upgrades, the Bellefontaine WWTP has achieved a substantial reduction in pollutant loadings which are associated with a lessening of the impairment documented in 1982.

Selected Great Miami River Tributaries

- The macroinvertebrate community exhibited a moderate impact downstream from the New Carlisle WWTP. The response suggested moderate organic enrichment, but no toxic effects were indicated. Additional evidence of organic enrichment included several violations of the EWH D.O. minimum criterion downstream from the WWTP.

- Based on ambient biological performance, the areas of partial and non-attainment of the applicable WWH or EWH aquatic life use designations within the remaining selected tributaries evaluated were related to macrohabitat habitat quality. In comparison with the results from previous investigations, biological performance in 1994 indicated little change through time.

RECOMMENDATIONS

Status of Aquatic Life Uses

Several of the streams and rivers evaluated as part of this survey were originally designated for aquatic life uses in the 1978 Ohio WQS. The techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study represents a first use of this type of biological data to evaluate and establish aquatic life use designations. While some of the changes may appear to constitute "downgrades" (*i.e.*, EWH to WWH, WWH to MWH, etc.) or "upgrades" (*i.e.*, LWH to WWH, WWH to EWH etc.), any changes should not be constructed as such because this constitutes the first use of an objective and robust use evaluation system and database. Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations outside of the WWH use prior to basing any permitting actions on the existing, unverified use designations. Thus some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

The following streams or stream segments evaluated in 1994 are recommended to retain their current aquatic life use designation, WWH or EWH. Maintenance of the WWH use applies to the entire length of the river or stream unless otherwise noted.

Great Miami River Mainstem (WWH existing; EWH recommended)
These free-flowing segments of the Great Miami River downstream from Quincy were typically found to contain fish and macroinvertebrate communities which met or exceeded the EWH biocriteria. As such a recommendation to redesignate to the EWH aquatic life use is appropriate for the following segments (the recommended changes apply to the entire length of the river segment unless noted otherwise):

- Quincy dam (RM 143.4) to Pasco Montra Rd. (RM 134.8).

- Sidney WTP dam (RM 130.2) to St. Rt. 66 (116.7).

- Downstream from the Piqua Municipal Power EGS dam (RM 114.0) to the upper limits of the Troy dam pool (RM 108.0).

- Troy dam (RM 106.97) to the CSX RR bridge (RM 84.5) in Dayton.

The aquatic life use attainment status was full for the recommended EWH use designation at all but four of the 19 non-mixing zone sampling locations within the EWH recommended segments. Partial attainment was indicated in the tailwaters of two lowhead dams (Quincy and Sidney) and downstream from the Sidney and MCD North Regional WWTPs (Table 1). The partial attainment status was driven by the performance of the macroinvertebrate community. However, at three locations the macroinvertebrates missed EWH by only two ICI units and at the fourth location downstream from the MCD N. Regional WWTP full attainment of EWH was exhibited in 1995.

Great Miami River Mainstem (WWH existing; WWH recommended)
In recognition of the residual habitat limitations, the following segments of the upper Great Miami River are recommended to retain the existing WWH aquatic life use designation. The WWH segments are limited to the habitat modified reach from Indian Lake to Quincy, and the impounded areas in Sidney, Piqua, and Troy. The specific boundaries for the WWH segments are detailed as follows:

- Indian Lake spillway (RM 159.8) to Quincy Dam (RM 143.4).
- Pasco Montra Rd. near Port Jefferson (RM 134.8) to the Sidney WTP Dam (RM 130.2).
- St. Rt. 66 (RM 116.7) to downstream from the Piqua Dam (RM 114.2).
- Upper limits of the Troy Dam pool (RM 108.0) to the Troy Dam (RM 106.97).

Indian Lake Tributaries (WWH existing; WWH recommended)
North Fork Great Miami River
South Fork Great Miami River
Van Horn Creek
Blackhawk Run

Loramie Creek (WWH existing; WWH recommended)

Bokengehalas Creek Subbasin (WWH existing; WWH recommended)
Bokengehalas Creek
Blue Jacket Creek
Possum Run

Selected Great Miami River Tributaries
Lost Creek (EWH - existing)
Spring Creek (EWH - existing)
McKees Creek (EWH - existing)
Honey Creek (EWH - existing)
Stony Creek (WWH - existing)
Muchinippi Creek (WWH - existing)
Cherokee Mans Run (WWH - existing)

Unnamed tributary to S. Fork Great Miami River (Undesignated; EWH recommended)
Based on ambient biological performance and existing habitat quality the EWH use designation is recommended for an unnamed and undesignated tributary of the South Fork Great Miami River. Full attainment of the EWH biocriteria was indicated at the two sampling sites. As such, the EWH use designation is appropriate for this undesignated stream.

Status of Non-Aquatic Life Uses

Based upon the findings of this study, the Primary Contact Recreational (PCR) use designation should be retained for the stream and river segments evaluated in 1994. Additionally, the PCR recreational use designation is recommended for the unnamed and undesignated tributary to the South Fork Great Miami River evaluated as part of the Indian Lake tributaries survey.

Future Monitoring Needs

A re-evaluation of the areas investigated in 1994 should be conducted in 1999 or 2004 as provided in the Five-Year Basin Monitoring Approach. Streams within the upper Great Miami River basin which were not evaluated in 1994 should receive a higher priority for reassessment in 1999.

The location of the Piqua Municipal Power EGS 801 and 901 monitoring stations should be changed to better reflect ambient river temperatures upstream and downstream of the discharge and intake. The 801 station is presently situated within the Piqua dam pool at the EGS cooling water intake. The thermal effluent is frequently circulated within the dam pool and, as such, water temperature at the intake is not representative of upstream ambient temperature. The juxtaposition of the 801 station within the dam pool limits the utility of this information for compliance monitoring purposes (*i.e.*,the determination of departures from ambient background). The 801 station should be moved upstream of the Piqua Dam pool outside of the influence of the EGS discharge. The 901 temperature values submitted as part of the facilities permit requirements are calculated instream temperatures derived from a heat budget formula which utilizes EGS thermal loadings, upstream river temperature, and river flow. A 901 monitoring station needs to be established downstream from the Piqua dam to monitor actual river temperature within the reach influenced by the EGS thermal plume. The proposed arrangement of monitoring stations will yield temperature data truly reflective of ambient conditions both upstream and downstream of the Piqua Municipal Power EGS.

Other Recommendations

The exceptional environmental quality that now typifies much of the upper Great Miami River are the result of WWTP treatment upgrades, improved water quality, and the predominance of high quality riverine habitats. The importance of the latter two factors (chemical water quality and macrohabitat quality) together cannot be understated. In Ohio, rivers and streams that lack the complement of intact riparian zones and instream habitat typically fail to support biological assemblages fully consistent with the EWH use designation, even if the chemical integrity of the water column is acceptable. The fact that much of the natural riverine riparian and instream habitat of the upper Great Miami River downstream from Quincy has been conserved has allowed for exceptional aquatic community performance once the historical water quality problems were abated. The continued conservation of riparian and instream habitat is a high priority if the exceptional quality of the upper mainstem is to be maintained.

The simplified, more lentic habitats created by run-of-river impoundments clearly exerted a profound influence on ambient biological performance within the upper Great Miami River. Reduced current velocity, increased sediment deposition, increased substrate embeddedness, increased retention time in the water column, and overall habitat simplification are common detrimental effects associated with impoundments created by lowhead dams. In addition to these physical habitat effects, impoundments also alter nutrient cycling (which affects the D.O. and pH regimes) and other water quality constituents such as temperature and sediment chemistry. Dams also impede the free movement of fish, inhibiting not only the upstream dispersal of organisms, but flow dependent species as well (*e.g.*, freshwater mussels, selected sensitive fish and macroinvertebrates). The results from the 1994 survey typically showed biological communities of reduced quality (compared to free-flowing segments) within and sometimes immediately downstream from these impoundments (declines were exhibited mostly by the macroinvertebrates). To promote further improvements in the upper mainstem, the unimpeded dispersal of aquatic organisms, and to encourage the complete biological recovery of these areas, the feasibility of removing some or all of the low head dams on the mainstem should be evaluated.

Measurable environmental improvements have occurred since the implementation of the agricultural nonpoint pollution abatement efforts within the Indian Lake watershed. Every effort should be made to continue and expand the application of BMPs to include riparian and habitat restoration within the watershed. Additionally, these efforts should expanded to other agricultural areas within the upper Great Miami River study area where serious impairment or threats to existing high quality resources have been identified. The Loramie Creek subbasin is a prime candidate for such efforts which should first emphasize habitat restoration. Impairment of the WWH use within the upper mainstem was primarily attributed to the combined effects of degraded habitat conditions, siltation, and nutrient enrichment. By stabilizing the stream banks the recovery of a more natural low flow channel should occur which will in turn limit the delivery, export, and retention of clayey silts and nutrients and promote a more rapid assimilation of nutrient rich agricultural runoff. Given time Loramie Creek should recover the compliment of ecological attributes consistent with the WWH use designation.

STUDY AREA DESCRIPTION

The portion of the Great Miami River that was monitored during the summer of 1994 included the segment from the outlet of Indian Lake (RM 160) to a point below the outfall of the North Regional WWTP in Dayton (RM 85; Figure 2). The River flows in a generally southwesterly direction from Logan County through Shelby, Miami, and Montgomery counties and the drainage area includes portions of Hardin, Auglaize, Champaign, Clark, and Mercer counties. This area encompasses approximately 1150 square miles. The mainstem drops from an elevation of 995 feet to 750 feet for an average gradient of 3.3 ft/mile. Included in the study area were four tributaries to Indian Lake, the North Fork Great Miami River, South Fork Great Miami River, Blackhawk Run, and Van Horn Creek. Other tributaries to the mainstem included Loramie Creek, Honey Creek, Lost Creek, Spring Creek, Stony Creek, McKees Creek, Cherokee Mans Run, Muchinippi Creek, Bokengehalas Creek, Blue Jacket Creek, and Possum Creek. There are 554 miles of streams in the upper Great Miami River watershed. Lakes in the Watershed include Indian Lake (5104 acres), Lake Loramie (825 acres), and Kiser Lake (380 acres). Both Indian Lake and Lake Loramie were constructed in the early 1800s to supply water to the Ohio-Erie canal which parallels much of the mainstem. The Mad River which is a tributary of the Great Miami was also surveyed during 1994 and the results of that survey are addressed in a separate report.

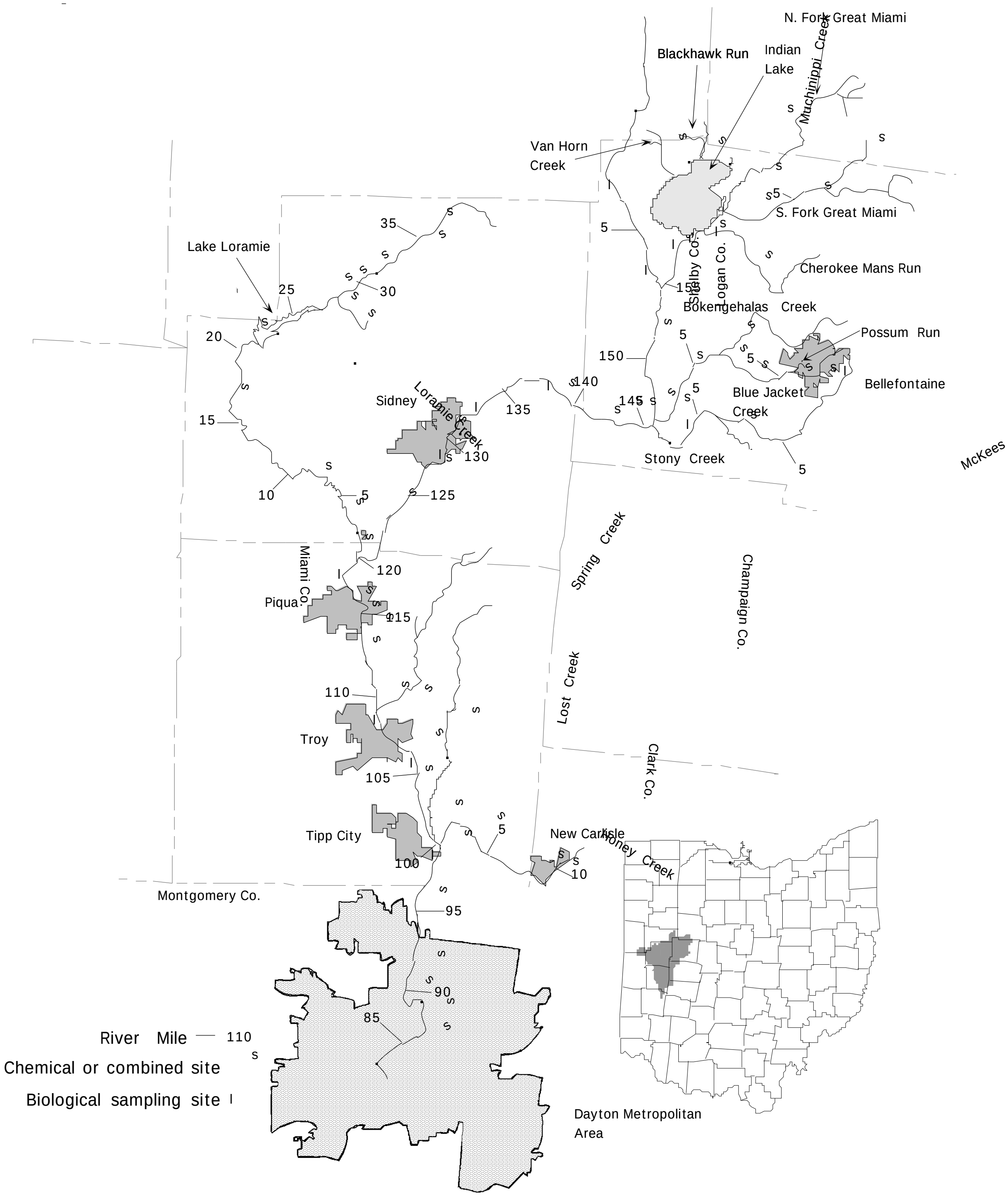


Figure 2 The Upper Great Miami River study area showing principle streams and tributaries, population centers, pollution sources, and water resource monitoring stations

The topography of the upper Great Miami River Basin has been influenced by glaciation 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 ecoregion which is characterized by level to gently sloping land and moderate to low gradient streams. Most of the tributary streams have gradients higher than the mainstem with much of the extra fall occurring on slopes near the river. Almost all of the river is underlain with 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 most cities and villages in the watershed even those located adjacent to the mainstem. Sidney uses a combination of groundwater and surface water while Piqua relies on surface water. In 1989 U.S. EPA designated the Great Miami Buried Valley Aquifer a sole source aquifer which carries a level of protection for the quality of ground water by requiring additional reviews of federal projects above the aquifer. As a result of the higher awareness of the importance of ground water to the region, many communities have initiated wellhead protection programs. There is a direct hydraulic connection between the groundwater and the mainstem. Designated aquatic life uses in the watershed are primarily warmwater habitat (WWH). Honey Creek, Lost Creek, Spring Creek, and McKees Creek were the only EWH designated streams evaluated in 1994. The three lakes in the watershed are designated EWH and state resource water (SRW) due to the presence of state parks at each one. Four streams in the watershed are listed as limited warmwater habitat (LRW) due to industrial discharges and habitat modification and one stream is listed modified warmwater habitat from channelization. All of the streams evaluated as part of the 1994 sampling effort are designated agricultural and industrial water supply, and primary contact recreation. Nonpoint sources of pollution in the watershed reflect the land uses that alter the natural landscape and contribute runoff to the streams. The Ohio Nonpoint Source Assessment (OEPA 1992) documents reported impacts to streams from various categories of nonpoint source pollution (NPS). Agriculture is the largest land use in the watershed and affects the most miles of streams (478 miles) with rowcrop production being reported for 70% of the total agriculture impact. Other sources of NPS reported for this portion of the watershed include: urban runoff (117 miles) from the various cities in the watershed, hydromodification (102 miles) principally channelization, and land disposal (66 miles) mostly attributable to on-site sewage disposal systems.

Erosion from cropland was evaluated against a standard established as the rate at which soil productivity could be maintained, known as the allowable rate. Any erosion above this rate results in a loss of long term productivity for cropland in the watershed (USDA 1989). The Soil Conservation Service determined that this portion of the Great Miami River watershed contained 242,400 acres that were eroding faster that the allowable rate to maintain soil productivity. Of that number, 97,300 acres were eroding at more than twice the allowable rate. The total number of tons eroding above the allowable rate was 1,899,700. The lakes in the watershed reflect the impact of sediment runoff from agricultural lands and construction sites. The Soil Conservation Service conducted a study of sedimentation in Ohio lakes (USDA, 1990) that included all three of the watershed's lakes. Indian Lake had lost 34.7% of its original volume to sedimentation and at the time of the study was losing capacity at a rate of 0.3% of original capacity per year. Similarly Lake Loramie had lost 34.8% of its capacity and was continuing to lose capacity at 0.2% per year. Both lakes have been dredged and recreation users continued to demand dredging to allow boating. As a result of the study and concerns for increasing cost of dredging watershed management projects have been initiated for both lakes. Funding from several sources have been used to promote the use of Best Management Practices (BMPs) to reduce erosion and sediment runoff from crop fields.

Physical stream characteristics, nonpoint pollution sources of the study area, and municipal entities evaluated as part of the 1994 sampling effort are presented in Table 2. A location of all chemical, physical, and biological sampling stations are in Table 3.

Table 2. Stream characteristics and significant identified pollution sources in the Upper Great Miami River study area, 1994.

Stream Name	Length (Miles)	Average Fall (Ft/Mile)	Drainage Area ($Mile^2$)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Great Miami River					
(entire length)	170.3	3.9	5385.3	Agriculture	Indian Lake WWTP
(Study Area)	73.3	3.3	1150.0	Urban Runoff	Quincy WWTP
				Hydromodification	Sidney WWTP
					Piqua WWTP
					Piqua MP-EGS
					Troy WWTP
					MCD North Regional WWTP
South Fork Great Miami River					
	10.2	9.6	53.0	Agriculture Urban Runoff Land Disposal	-
North Fork Great Miami River					
	6.5	8.0	21.6	Agriculture Hydromodification	-
Van Horn Creek					
	0.4	2.5	2.5	Agriculture Urban Runoff Hydromodification	-
Blackhawk Run					
	0.8	2.5	5.16	Agriculture Urban Runoff Hydromodification	-
Loramie Creek					
	36.5	3.3	268.5	Agriculture Hydromodification	Fort Loramie WWTP Botkins WWTP Anna WWTP(Clay Creek)
Honey Creek					
	18.6	19.6	91.6	Agriculture	New Carlisle WWTP
Lost Creek					
	17.4	15.3	59.3	Agriculture Urban Runoff	-

Table 2. continued.

Stream Name	Length (Miles)	Average Fall (Ft/Mile)	Drainage Area (Mile^2)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Spring Creek	12.4	18.0	26.4	Agriculture	-
Stony Creek	9.0	12.2	62.9	Agriculture Hydromodification	-
McKees Creek	10.2	32.4	17.8	-	-
Cherokee Mans Run	10.8	16.5	18.9	-	-
Muchinippi Creek	13.7	3.2	90.6	-	-
Bokengehalas Creek	15.4	20.6	42.64	Agriculture Hydromodification	-
Blue Jacker Creek	7.8	23.8	15.84	Agriculture Urban Runoff Hydromodification	-
Possum Creek	1.52			Agriculture Urban Runoff	Bellefontaine WWTP

Table 3. Sampling locations (water chemistry-C, sediment-S, benthic macroinvertebrate community-B, fish community-F, and continuous monitors-D) within the Upper Great Miami River study area, 1994.

River/Stream River Mile	Sample Type	Latitude/Longitude	Landmark	USGS 7.5' Quad.
Upper Great Miami River				
159.0	(D)	40˚27'51"/83˚53'14"	US 33	Russels Point
159.48	(C,S)	40˚27'55"/83˚52'44"	US 33	Russels Point
158.9	(F)	40˚27'47"/83˚53'15"	ust. Indian Lake WWTP	Russels Point
158.3	(B)	40˚27'19"/83˚53'31"	ust. Indian Lake WWTP	Russels Point
157.3	(F,B)	40˚27'09"/83˚54'25"	dst. Indian Lake WWTP	Russels Point
156.36	(C)	40˚26'10"/83˚54'30"	dst. Indian Lake WWTP	Russels Point
153.5	(B)	40˚24'09"/83˚55'30"	CR 13	Russels Point
153.1	(F)	40˚23'52"/83˚55'41"	CR 13	Russels Point
151.7	(C)	40˚22'43"/83˚55'44"	CR 58	Russels Point
148.6	(B)	40˚20'35"/83˚56'04"	SR 47	DeGraff
146.3	(F)	40˚18'51"/83˚55'39"	SR 235	DeGraff
146.19	(C)	40˚18'46"/83˚55'38"	SR 235	DeGraff
144.2	(B)	40˚18'21"/83˚57'05"	Quincy Dam Pool	DeGraff
143.8	(F)	40˚18'14"/83˚57'30"	Quincy Dam Pool	DeGraff
143.6	(C,S,D)	40˚18'10"/83˚57'42"	Quincy Dam Pool	DeGraff
143.4	(B)	40˚18'08"/83˚57'57"	dst. Quincy Dam-ust. Quincy WWTP	DeGraff
143.2	(F)	40˚18'10"/83˚58'09"	dst. Quincy Dam-ust. Quincy WWTP	DeGraff
143.16	(C)	40˚18'11"/83˚58'10"	dst. Quincy Dam-ust. Quincy WWTP	DeGraff
142.67	(C)	40˚18'29"/83˚58'26"	GT&I R&R Trestle	DeGraff
142.7	(B)	40˚18'29"/83˚58'28"	GT&I R&R Trestle	DeGraff
142.5	(F)	40˚18'30"/83˚58'38"	dst. Quincy WWTP	DeGraff
138.5	(B)	40˚20'00"/83˚02'19"	Baker Rd.	DeGraff
138.39	(C,S)	40˚20'07"/84˚02'07"	Pence Rd.	Port Jefferson
138.2	(F)	40˚20'14"/84˚02'30"	Baker Rd.	Port Jefferson
133.2	(B)	40˚18'45"/84˚06'57"	Staley Cemetery	Port Jefferson
133.1	(F)	40˚18'40"/84˚07'00"	ust. Sidney Boat Club Dam	Port Jefferson
130.1	(B)	40˚17'17"/84˚09'01"	ust. Sidney WWTP	Sidney
130.05	(C,S)	40˚17'13"/84˚09'00"	ust. Sidney WWTP	Sidney
130.0	(F)	40˚17'11"/84˚09'00"	ust. Sidney WWTP	Sidney
128.6	(F,B)	40˚16'10"/84˚09'11"	Sidney WWTP **Mixing Zone**	Sidney
127.7	(F,C)	40˚15'59"/84˚09'55"	dst. Sidney WWTP	Sidney
127.5	(B)	40˚15'57"/84˚10'08"	Vanndermark Rd.	Sidney
123.9	(F,B)	40˚13'27"/84˚10'58"	Kouther Rd.	Piqua East
123.89	(C)	40˚13'26"/84˚12'17"	Kouther Rd.	Piqua East
120.5	(D)	40˚11'16"/84˚13'58"	Lockington Rd.	Piqua East
118.5	(B)	40˚10'25"/84˚15'25"	SR 66	Piqua West
117.5	(F)	40˚09'46"/84˚14'56"	SR 66	Piqua East
117.0	(D)	40˚09'30"/84˚14'38"	SR 66	Piqua East
116.7	(C,S)	40˚09'15"/84˚14'20"	Piqua Sidney Rd.	Piqua East

Table 3. continued.

River/Stream River Mile	Sample Type	Latitude/Longitude	Landmark	USGS 7.5' Quad.
Upper Great Miami River				
114.9	(B)	40˚08'39"/84˚14'18"	ust Piqua MP & WWTP	Piqua East
114.8	(F)	40˚08'27"/84˚14'12"	ust Piqua MP & WWTP	Piqua East
114.54	(C)	40˚08'19"/84˚14'13"	ust Piqua MP & WWTP	Piqua East
114.5	(D)	40˚08'12"/84˚14'12"	ust Piqua MP & WWTP	Piqua East
114.3	(F,D)	40˚08'07"/84˚14'07"	west bank-Piqua MP-EGS	Piqua East
114.3	(F)	40˚08'07"/84˚14'07"	east bank-ust. Piqua WWTP	Piqua East
114.28	(C)	40˚08'01"/84˚14'12"	at Piqua Dam-Piqua MP	Piqua East
114.28	(C)	40˚08'01"/84˚14'12"	at Piqua Dam-Piqua WWTP	Piqua East
114.27	(B)	40˚08'00"/84˚14'10"	dst. Piqua Dam-Piqua MP	Piqua East
114.27	(B)	40˚08'00"/84˚14'10"	dst. Piqua Dam-Piqua WWTP	Piqua East
114.22	(B)	40˚07'58"/84˚14'10"	dst. Piqua Dam	Piqua East
114.16	(C)	40˚07'55"/84˚14'08"	dst. Piqua Dam	Piqua East
114.11	(D)	40˚07'52"/84˚14'07"	dst. Piqua Dam	Piqua East
114.1	(F,D)	40˚07'50"/84˚14'07"	dst. Piqua Dam	Piqua East
113.6	(C,D)	40˚07'25"/84˚14'07"	CR 25-trailer park	Troy
113.5	(BS)	40˚07'16"/84˚14'09"	adj. Main St.	Troy
112.7	(F)	40˚06'39"/84˚14'00"	adj. Main St.	Troy
112.6	(D)	40˚06'35"/84˚13'58"	adj. Main St.	Troy
110.2	(D)	40˚04'46"/84˚13'03"	Eldean Rd.	Troy
110.1	(B)	40˚04'43"/84˚13'02"	Eldean Rd.	Troy
110.07	(C)	40˚04'40"/84˚13'00"	Eldean Rd.	Troy
109.9	(F)	40˚04'32"/84˚12'58"	Eldean Rd.	Troy
108.5	(F)	40˚04'27"/84˚12'43"	ust. Troy Dam	Troy
106.3	(F)	40˚03'02"/84˚11'23"	SR 41	Troy
106.1	(B,C,S)	40˚01'45"/84˚11'12"	SR 41	Troy
105.6	(F,B,D)	40˚01'26"/84˚11'04"	Troy WWTP **Mixing Zone**	Troy
105.4	(B)	40˚01'17"/84˚11'03"	dst. Troy WWTP	Troy
104.7	(F,C)	40˚00'46"/84˚10'58"	adj. SR 202	Troy
100.8	(B)	39˚58'01"/84˚09'58"	Tipp-Elizabeth Rd.	Tipp City
99.1	(C,S)	39˚57'30"/84˚08'25"	SR 571	Tipp City
98.7	(F)	39˚57'12"/84˚08'31"	SR 571	Tipp City
95.9	(F)	39˚55'07"/84˚08'31"	Ross Rd.	Tipp City
95.7	(B)	39˚54'59"/84˚09'50"	Ross Rd.	Tipp City
95.68	(C)	39˚54'57"/84˚09'51"	Ross Rd.	Tipp City
93.8	(F)	39˚53'26"/84˚09'35"	dst. Old Vandalia WWTP	Tipp City
91.14	(C)	39˚51'16"/84˚10'18"	Little York Rd.	Dayton North
91.1	(B)	39˚51'13"/84˚10'19"	Little York Rd.	Dayton North
91.0	(F,S)	39˚51'10"/84˚10'25"	Little York Rd.	Dayton North
88.69	(C)	39˚49'48"/84˚00'02"	Wagoner Ford Rd.	Dayton North
87.7	(B)	39˚49'43"/84˚09'14"	adj. Edgewood-Birch Rd.	Dayton North
87.3	(F,D)	39˚49'22"/84˚09'12"	Needmore Rd.	Dayton North
87.05	(C)	39˚49'13"/84˚09'23"	Needmore Rd.	Dayton North

Table 3. continued.

River/Stream River Mile	Sample Type	Latitude/Longitude	Landmark	USGS 7.5' Quad.
Upper Great Miami River				
86.7	(F)	39˚48'55"/84˚09'20"	Needmore Rd	Dayton North
86.6	(F,B)	39˚48'46"/84˚09'08"	MCD N WWTP **Mixing Zone**	Dayton North
86.13	(C,S)	39˚48'30"/84˚09'04"	adj. SR 202	Dayton North
85.9	(B)	39˚48'20"/84˚09'10"	adj. well field	Dayton North
85.15	(C)	39˚47'56"/84˚09'45"	adj. well field	Dayton North
85.0	(F)	39˚47'53"/84˚09'59"	adj. well field	Dayton North
North Fork Great Miami River				
11.6	(F)	40˚34'03"/83˚46'15"	Madory Rd.	Roundhead
10.7	(B,C)	40˚33'40"/83˚46'37"	Private lane	Roundhead
8.5	(F)	40˚32'25"/83˚46'31"	Schraoer Rd.	Roundhead
8.3	(B)	40˚32'19"/83˚46'39"	CR 104	Roundhead
6.3	(B)	40˚31'24"/83˚48'03"	Dunn Rd.	Roundhead
4.1	(F)	40˚30'44"/83˚49'18"	SR 117	Roundhead
4.02	(C)	40˚30'40"/83˚49'25"	SR 117	Roundhead
Blackhawk Run				
2.3	(B)	40˚32'16"/83˚53'37"	Feikert Rd.	Waynesfield
0.9	(F)	40˚31'19"/83˚53'07"	SR 235	Waynesfield
0.45	(C)	40˚31'18"/83˚53'06"	SR 235	Waynesfield
Van Horn Creek				
1.3	(F)	40˚31'03"/83˚55'35"	SR 366	Waynesfield
1.0	(B)	40˚30'58"/83˚55'37"	SR 366	Waynesfield
0.97	(C)	40˚30'58"/83˚55'36"	SR 366	Waynesfield
South Fork Great Miami River				
8.0	(F,B)	40˚29'43"/83˚44'28"	SR 638	Rushylvania
7.98	(C)	40˚29'44"/83˚44'33"	SR 638	Rushylvania
5.8	(F,B)	40˚29'41"/83˚46'47"	CR 97	Huntsville
5.69	(C)	40˚29'40"/83˚46'43"	CR 97	Huntsville
1.8	(F,B)	40˚28'26"/83˚50'18"	CR 38	Huntsville
1.74	(C)	40˚28'26"/83˚50'27"	CR 38	Huntsville
Tributary to South Fork Great Miami River				
3.5	(F)	40˚28'11"/83˚44'04"	CR 101	Rushylvania
3.4	(B)	40˚28'12"/83˚44'06"	CR 101	Rushylvania
0.5	(B)	40˚29'10"/83˚46'43"	CR 96	Huntsville
0.55	(C)	40˚30'12"/83˚44'36"	CR 96	Huntsville
0.4	(F)	40˚29'18"/83˚46'46"	CR 96	Huntsville

Table 3. continued.

River/Stream River Mile	Sample Type	Latitude/Longitude	Landmark	USGS 7.5' Quad.
Bokengehalas Creek				
8.1	(F)	40˚22'12"/83˚50'51"	TR 31	Bellefontaine
8.0	(B)	40˚22'12"/83˚50'56"	TR 31	Bellefontaine
7.88	(C)	40˚22'12"/83˚50'58"	TR 31	Bellefontaine
4.7	(F,B)	40˚20'53"/83˚53'26"	TR 209	DeGraff
4.61	(C)	40˚20'50"/83˚53'28"	TR 209	DeGraff
0.41	(C)	40˚18'28"/83˚55'12"	Mill St.	DeGraff
0.4	(B,D)	40˚18'26"/83˚55'14"	Mill St.	DeGraff
0.3	(F)	40˚18'25"/83˚55'18"	Mill St.	DeGraff
Blue Jacket Creek				
6.4	(F,B)	40˚20'59"/83˚46'23"	TR 216	Bellefontaine
6.31	(C)	40˚21'01"/83˚46'28"	TR 216	Bellefontaine
5.5	(F)	40˚20'56"/83˚47'15"	CR 11	Bellefontaine
5.4	(B)	40˚20'55"/83˚47'20"	CR 11	Bellefontaine
5.39	(C)	40˚20'55"/83˚47'22"	CR 11	Bellefontaine
3.26	(C)	40˚20'36"/83˚49'24"	CR 11	Bellefontaine
3.2	(B)	40˚20'37"/83˚49'27"	CR 11	Bellefontaine
3.1	(F)	40˚20'42"/83˚49'29"	CR 11	Bellefontaine
0.8	(F)	40˚21'45"/83˚50'58"	TR 31	Bellefontaine
0.72	(C)	40˚21'49"/83˚51'01"	TR 31	Bellefontaine
0.6	(B)	40˚21'50"/83˚51'08"	TR 31	Bellefontaine
Possum Run				
0.93	(C)	40˚21'33"/83˚46'25"	ust. Bellefontaine WWTP	Bellefontaine
0.7	(F,B)	40˚21'22"/83˚46'27"	ust. Bellefontaine WWTP	Bellefontaine
0.4	(F,C)	40˚21'10"/83˚46'41"	dst. Bellefontaine WWTP	Bellefontaine
0.3	(B)	40˚21'08"/83˚46'47"	dst. Bellefontaine WWTP	Bellefontaine
Loramie Creek				
36.84	(C)	40˚28'05"/84˚09'38"	Botkins Rd.	Botkins
36.8	(F,B)	40˚28'04"/84˚09'38"	Botkins Rd.	Botkins
35.0	(F)	40˚27'12"/84˚11'07"	Locktwo Rd.-dst. Botkins WWTP	Botkins
34.96	(C)	40˚27'11"/84˚11'13"	Locktwo Rd.-dst. Botkins WWTP	Botkins
34.9	(B)	40˚27'10"/84˚11'14"	Lock Two Rd.	Botkins
31.7	(B)	40˚25'24"/84˚13'30"	Amsterdam Rd.	Botkins
30.42	(C)	40˚24'54"/84˚14'37"	Harden Wapakoneta Rd.	Botkins
30.4	(F)	40˚25'00"/84˚14'34"	Harden Wapakoneta Rd.	Botkins
29.1	(F)	40˚24'19"/84˚15'49"	SR 29	New Knoxville
28.9	(C,D)	40˚24'16"/84˚16'01"	SR 29	New Knoxville
28.3	(F)	40˚24'03"/84˚16'33"	SR 29	New Knoxville
27.39	(C)	40˚23'39"/84˚17'04"	SR 119	

Table 3. continued.

River/Stream River Mile	Sample Type	Latitude/Longitude	Landmark	USGS 7.5' Quad.
20.8	(F)	40˚21'34"/84˚22'20"	SR 66	Fort Loramie
20.7	(B,C)	40˚21'32"/84˚22'22"	SR 66	Fort Loramie
16.6	(F)	40˚18'29"/84˚23'05"	Cardo Roman Rd.	Osgood
16.51	(C)	40˚18'25"/84˚23'01"	Cardo Roman Rd.	Osgood
14.8	(B)	40˚17'35"/84˚22'21"	SR 66	Fort Loramie
7.67	(C)	40˚15'46"/84˚18'04"	adj. Loramie Washington Rd	Fort Loramie
7.5	(F)	40˚15'42"/84˚17'54"	adj. Loramie Washington Rd.	Fort Loramie
5.8	(B)	40˚15'02"/84˚16'22"	Patterson Rd.	Fort Loramie
3.8	(D)	40˚13'46"/84˚15'22"	Lehman Rd.	Piqua West
3.75	(C)	40˚13'43"/84˚15'23"	Lehman Rd.	Piqua West
3.7	(F,B)	40˚13'40"/84˚15'21"	Lehman Rd.	Piqua West
0.5	(F)	40˚11'42"/84˚14'21"	adj. Landman Mill Rd.	Piqua East
0.41	(C)	40˚11'39"/84˚14'29"	adj. Landman Mill Rd.	Piqua East
0.4	(B)	40˚11'38"/84˚14'30"	adj. Landman Mill Rd.	Piqua East
Cherokee Mans Run				
4.45	(C)	40˚26'21"/83˚49'46"	TR 99	Huntsville
3.7	(B)	40˚26'20"/83˚49'46"	TR 99	Huntsville
3.5	(F)	40˚26'20"/83˚49'44"	TR 99	Huntsville
1.8	(F)	40˚27'51"/83˚51'27"	TR 95	Huntsville
Muchinippi Creek				
12.5	(F)	40˚33'29"/83˚57'33"	US 33	Waynesfield
7.4	(F)	40˚29'57"/83˚58'46"	Duff Rd.	Russels Point
1.9	(F)	40˚25'59"/83˚56'17"	Wren Rd.	Russels Point
McKees Creek				
9.5	(F)	40˚20'03"/83˚44'40"	CR 1	Zanesfield
0.9	(B)	40˚18'36"/83˚50'56"	CR 31	Bellefontaine
0.7	(F)	40˚18'38"/83˚51'09"	CR 31	Bellefontaine
0.52	(C)	40˚18'38"/83˚51'19"	CR 31	Bellefontaine
Spring Creek				
1.2	(B)	40˚04'23"/84˚11'34"	Troy Piqua Rd.	Troy
1.0	(F,B)	40˚04'24"/84˚11'48"	Troy Piqua Rd.	Troy
0.84	(C)	40˚04'21"/84˚11'21"	Troy Piqua Rd.	Troy
Stony Creek				
3.2	(F)	40˚17'48"/83˚53'34"	TR 30	DeGraff

Table 3. continued.

River/Stream River Mile	Sample Type	Latitude/Longitude	Landmark	USGS 7.5' Quad.
Lost Creek				
9.9	(B)	40˚04'46"/84˚07'56"	Troy Urbana Rd.	Troy
9.8	(F,B)	40˚04'43"/84˚07'59"	Troy Urbana Rd.	Troy
9.74	(C)	40˚04'40"/84˚08'02"	Troy Urbana Rd.	Troy
2.6	(C)	39˚59'57"/84˚10'00"	SR 202	Tipp City
2.5	(F,B)	39˚59'51"/84˚07'59"	SR 202	Tipp City
Honey Creek				
10.1	(B)	39˚56'30"/84˚00'57"	ust. New Carlisle WWTP	New Carlisle
10.0	(F)	39˚56'27"/84˚01'02"	ust. New Carlisle WWTP	New Carlisle
9.96	(C)	39˚56'26"/84˚01'02"	ust. New Carlisle WWTP	New Carlisle
9.9	(B)	39˚56'23"/84˚01'02"	New Carlisle WWTP	New Carlisle
8.1	(B)	39˚56'23"/84˚01'02"	dst. New Carlisle WWTP	New Carlisle
8.08	(C)	39˚56'07"/84˚02'27"	dst. New Carlisle WWTP	New Carlisle
8.0	(F)	39˚56'10"/84˚01'02"	dst. New Carlisle WWTP	New Carlisle
3.2	(F,B)	39˚58'08"/84˚06'29"	Rudy Rd.	New Carlisle
3.18	(C)	39˚58'11"/84˚06'32"	Rudy Rd.	New Carlisle

METHODS

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

Determining Use Attainment Status

The attainment status of aquatic life uses (*i.e.*, FULL, PARTIAL, and **NON**) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-17). The biological community performance measures which are used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1994). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981).

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

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1994). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Macroinvertebrate Community Assessment

Macroinvertebrates were sampled quantitatively using multiple-plate, artificial substrate samplers (modified Hester/Dendy) in conjunction with a qualitative assessment of the available natural substrates.

Fish Community Assessment

Fish were sampled using wading or boat method pulsed DC electrofishing gear. The wading method was used at a frequency of one or two samples at each site. The boat method was used at a frequency of two samples at each site.

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1994) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (**Figure 3**). The “magnitude” of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are also expressed as ADV/mile to normalize comparisons between segments and other streams and rivers.

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are the principal arbiter of aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria in the role of principal arbiter within a weight of evidence framework has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991a; Yoder 1994). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and the biological response signatures (Yoder and Rankin 1994) within the biological data itself. Thus the assignment of principal causes and sources of impairment in this report do not represent a true “cause and effect” analysis, but rather represent the association of impairments (based on response indicators) with stressor and exposure indicators whose links with the biosurvey data are based on previous research or experience with analogous situations and impacts. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified. The process is similar to making a medical diagnosis in which a doctor relies on multiple lines of evidence concerning patient health. Such diagnoses are based on previous research which experimentally or statistically linked symptoms and test results to specific diseases or pathologies. Thus a doctor relies on previous experience in interpreting symptoms (*i.e.*, multiple lines from test results) to establish a diagnosis, potential causes and/or sources of the malady, a prognosis, and a strategy for alleviating the symptoms of the disease or condition. As in medical science, where the ultimate arbiter of success is the eventual recovery and the well-being of the patient, the ultimate measure of success in water resource management is restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem “health” compared to human patient “health” (Suter 1993) here we are referring to the process for identifying biological integrity and causes/sources associated with observed impairment, not whether human health and ecosystem health are analogous concepts.

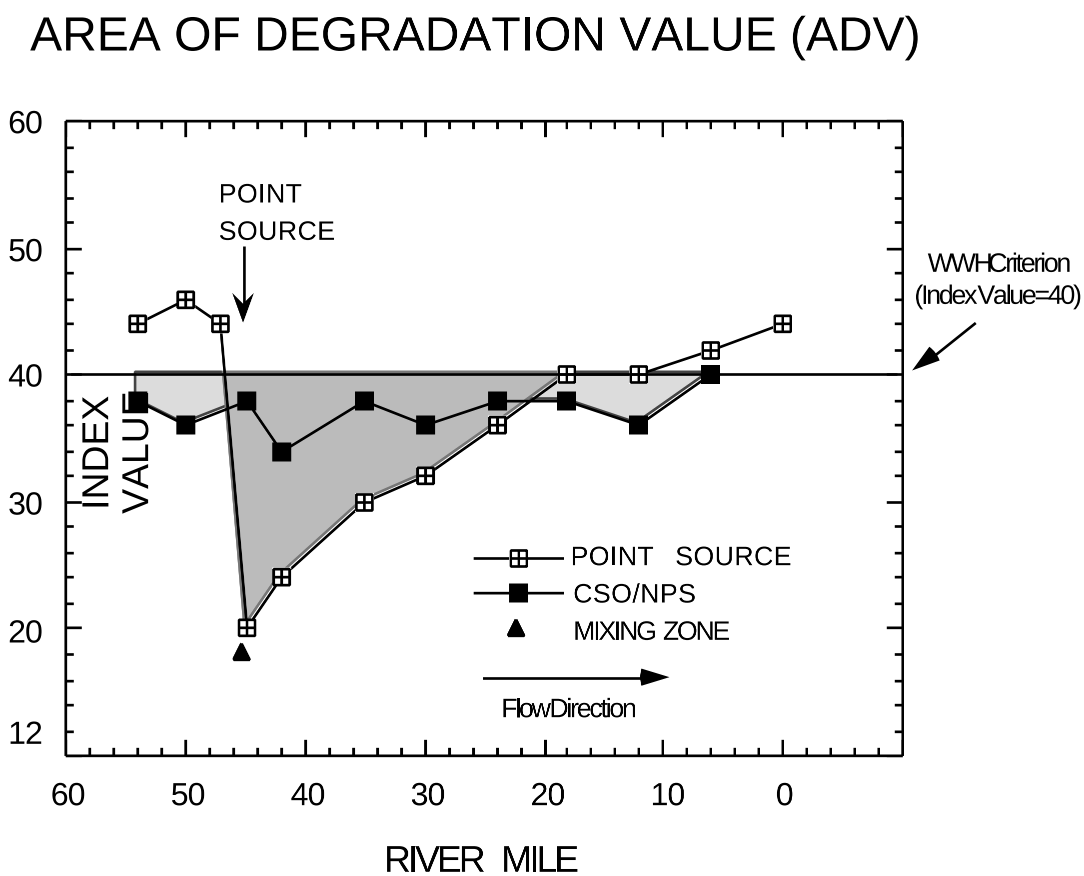


Figure 3 Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

RESULTS and DISCUSSION

Upper Great Miami River(mainstem)

Pollutant Loadings

Monthly effluent loadings are reported to the Ohio EPA by all NPDES (National Pollution Discharge Elimination System) permitted discharging entities. Annual Monthly Operating Report (MOR) data provided the quantity and character of pollutant loadings through the period of record for each entity evaluated within the 1994 Upper Great Miami River study area. Pollutant loading trends analysis typically include: Ammonia-nitrogen (NH_3-N), Five-day Biochemical Oxygen Demand (BOD_5), Carbonaceous Five-day Biochemical Oxygen Demand ($cBOD_5$), Total Suspended Solids (TSS), Nitrate+Nitrite-nitrogen (NO_3+NO_2-N), and Annual Discharge (MGD). Additionally, bioassay results and other relevant compliance information is included. A list of all WWTPs evaluated in the 1994 Upper Great Miami River study area and a brief treatment process history is provided in Table 4.

Indian Lake WWTP

The Indian Lake WWTP discharges directly to the Upper Great Miami River at RM 158.0. The facility was constructed in 1929, with major modifications made in 1967 and 1985. The Indian Lake WWTP is a secondary treatment facility utilizing primary settling, aeration, secondary settling, bar screen, communitor, and chlorination. Current plant design capacity is 4.6 MGD. The collection system consist of 100% separate sewers, with all of the service area sewered. The service population is approximately 5,000 with moderate growth predicted. Two lift stations exist within the collection system, with no bypass or overflow structures. However, an internal plant bypass is activated when inflows exceed 4.7 MGD. A percentage of the inflow is diverted around the aeration and secondary treatment systems, recombining with the main plant flow prior to final effluent discharge. Minor industrial contributors include Belmar Parts and Logan Finishing.

Annual 95th percentile and median conduit flows from the Indian Lake WWTP demonstrated a modest increasing trend through the period of record. Between 1985 and 1994, 95th percentile flows appeared erratic, exceeding the 4.6 MGD design capacity in 1986, 1990, and 1993. The Indian Lake WWTP discharged approximately 1.78 MGD, comprising 9% of the aggregate conduit flow for all major WWTPs discharging directly to the Upper Great Miami River in 1994 (Figure 4 and 5).

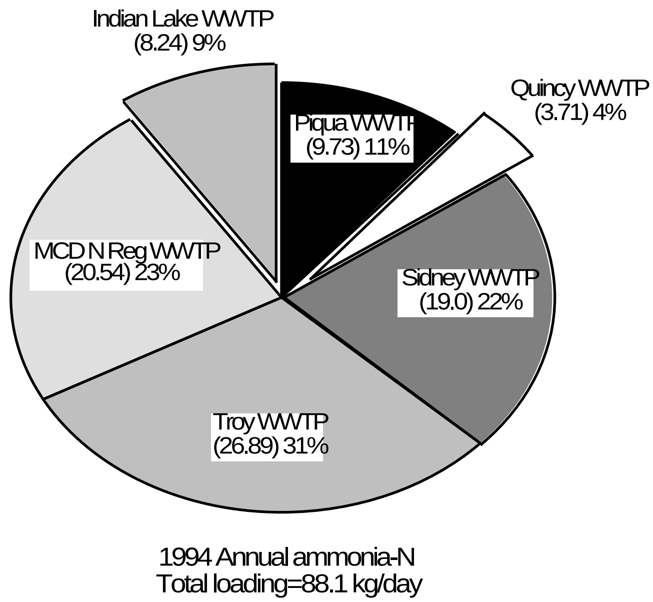
Annual 95th percentile and median ammonia-nitrogen loads were markedly reduced after the 1985 treatment upgrade. Between the period 1979 through 1984 median ammonia-nitrogen loads ranged from 12.9 kg/day to 42.4 kg/day, averaging 32.1 kg/day. Between 1985 and 1994 ammonia-nitrogen loads ranged from 0.142 kg/day to 1.78 kg/day, averaging 0.495 kg/day. The loadings data clearly indicate the Indian Lake WWTP has achieved a significant reduction in ammonia-nitrogen load contributed to the Upper Great Miami River. The Indian Lake WWTP discharged approximately 8.24 kg/day, comprising 9% of the aggregate ammonia-nitrogen load from all major WWTPs discharging directly to the Upper Great Miami River in 1994.

The BOD data available through the period of record is comprised of two parameters, BOD_5 (1976 through 1984) and $cBOD_5$ (1985 through 1994). As observed with ammonia-nitrogen, both BOD and TSS loadings were markedly reduced after the 1985 treatment upgrades. Prior to 1985, annual BOD and TSS loads were erratic with 95th percentile values typically twice that of the medians.

Between 1989 and 1994, the Indian Lake WWTP reported 30 NPDES permit violations. Reported violations were typical constituents of treated domestic wastewater. The majority of recent violations were ammonia-nitrogen.

Table 4. Wastewater treatment process changes in the Upper Great Miami River between 1984 and 1995.

Facility	Receiving Stream	Current Treatment Level	Process Change (Year/Type)
Indian Lake WWTP	Great Miami River	secondary	1985/conventional activated sludge.
Quincy WWTP	Great Miami River	secondary	none
Sidney WWTP	Great Miami River	secondary	1988/contact stabilization, extended aeration.
Troy WWTP	Great Miami River	secondary	1995/flow equalization and grit screening. (ongoing upgrade)
Piqua WWTP	Great Miami River	secondary	1984/activated sludge. 1991/dechlorination, aeration tanks, clarifiers, and new grit & grease removal system.
Vandalia WWTP	Great Miami River	N/A	Abandoned
MCD N. Regional WWTP	Great Miami River	secondary	1988/trickling filters and nitrification towers.
Anna WWTP	Clay Creek-Loramie Creek	secondary	1991/sequencing batch reactor
Botkins WWTP	Loramie Creek	secondary	1989/sequencing batch reactor
Bellefontaine WWTP	Possum Run-Blue Jacket Cr.	secondary	1988/oxidation ditch. 1993/sludge-belt filter press, lime stabilization, and influent splitter to ditches
New Carlisle WWTP	Honey Creek	secondary	1991/biological, rapid sand, filters, towers, and intermediate clarifier.



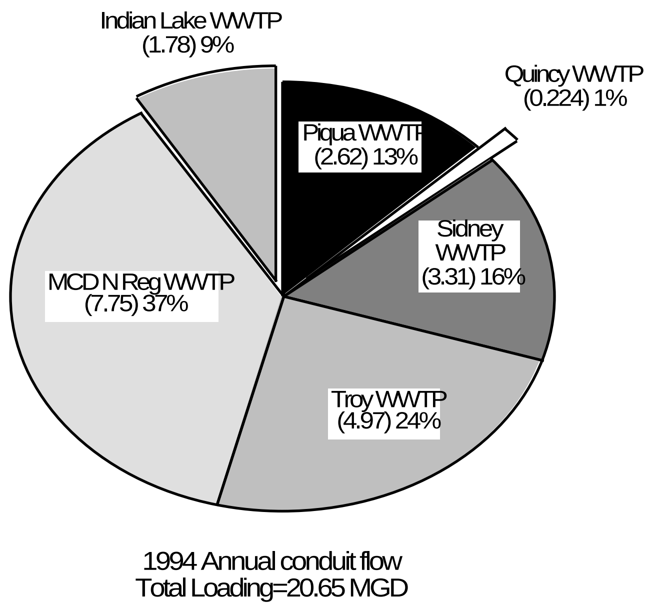


Figure 4 Relative contribution to the aggregate conduit flow (MGD) and ammonia-nitrogen (kg/day) loads from the entities discharging directly to the Upper Great Miami River, 1994.

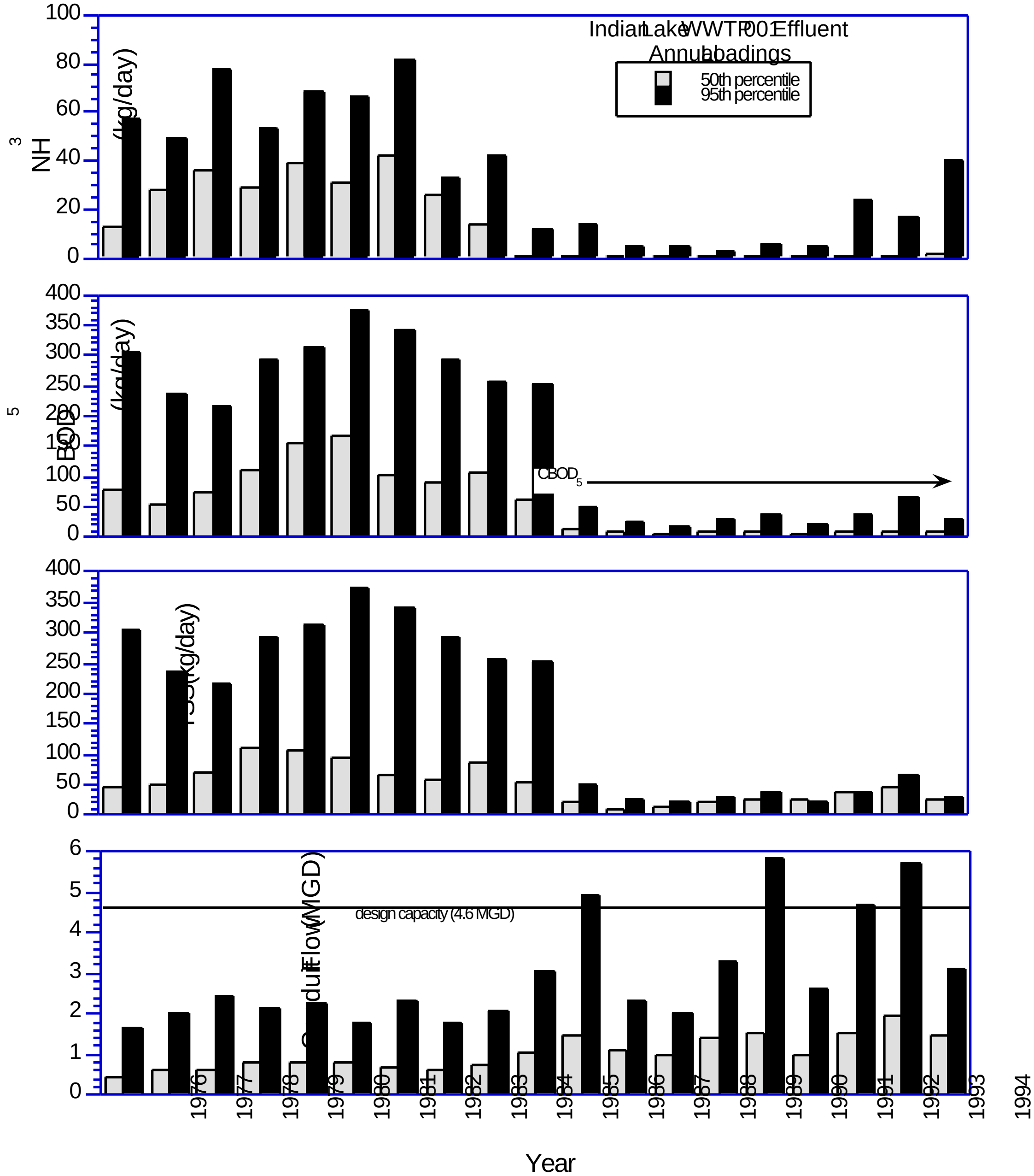


Figure 5 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the Indian Lake WWTP.

Quincy WWTP

The Quincy WWTP discharges directly to the Upper Great Miami River at RM 143.05. Constructed in 1973 the Quincy WWTP is a secondary treatment facility, with a design capacity of 0.19 MGD. The treatment process includes: two aerated lagoons, a settling lagoon, chlorination, and post aeration. The collection system consists of separate sewers, with all of the service area sewered. The service population is approximately 1800 with modest growth expected.

Annual median and 95th percentile conduit flows demonstrated a modest increasing trend through the period of record. Between 1986 and 1994, six years of this nine year period indicated conduit flows (both 50th and 95th percentiles) greater than the 0.19 MGD design capacity. This information suggests that recent inflows to the Quincy WWTP maybe exceeding current plant capacity. The Quincy WWTP currently discharges approximately 0.224 MGD, comprising 1% of the aggregate conduit flow for all major WWTPs discharging directly to the Upper Great Miami River (Figure 4 and 6).

Ammonia-nitrogen loadings data for the typical period of record (1976-present) were far from complete. Only six years of information were available, 1983 and 1990 through 1994. Between 1990 and 1994 peak loads occurred in 1993 and 1992. Both median and 95th percentile values were elevated in these years when compared with earlier plant performance. The striking discrepancies between the 95th percentile and the median in 1993 and 1992 suggest treatment irregularities or plant upsets. Plant performance may have been periodically disrupted by excessive influent loads, evidenced by annual conduit flows greater than plant capacity during this time. The Quincy WWTP currently discharges approximately 3.71 kg/day of ammonia-nitrogen, comprising 4% of the aggregate load from all major WWTPs discharging directly to the Upper Great Miami River.

The BOD data available through the period of record is comprised of two parameters, BOD_5 (1976 through 1989) and $cBOD_5$ (1990 through 1994). Maximum BOD loads occurred during the mid-1980s, and by 1989 median and 95th percentile loads appeared reduced and relatively stable.

Annual median TSS loads displayed a moderate increasing trend between 1983 and 1994. However, annual 95th percentiles were erratic and generally twice the median value. Elevated and erratic 95th percentiles often are indicative of inconsistent plant performance. The pattern of increase observed in annual TSS loads over time appeared similar to that of annual conduit flow, suggesting a possible relationship.

Ninety-six violations of the NPDES permit were reported to the Ohio EPA between 1989 and 1994. The annual number of permit violations ranged from 7 in 1994 to 27 in 1991. All violations were limited to either TSS or $cBOD_5$, with TSS accounting for 73.9%. The pattern of annual violations was roughly correspondent with pattern of annual TSS loads. Additionally, the majority these violations occurred during a period when conduit flows were in excess of plant design capacity. An inflow and infiltration (I/I) analysis may be necessary to better characterize current conditions of the area serviced.

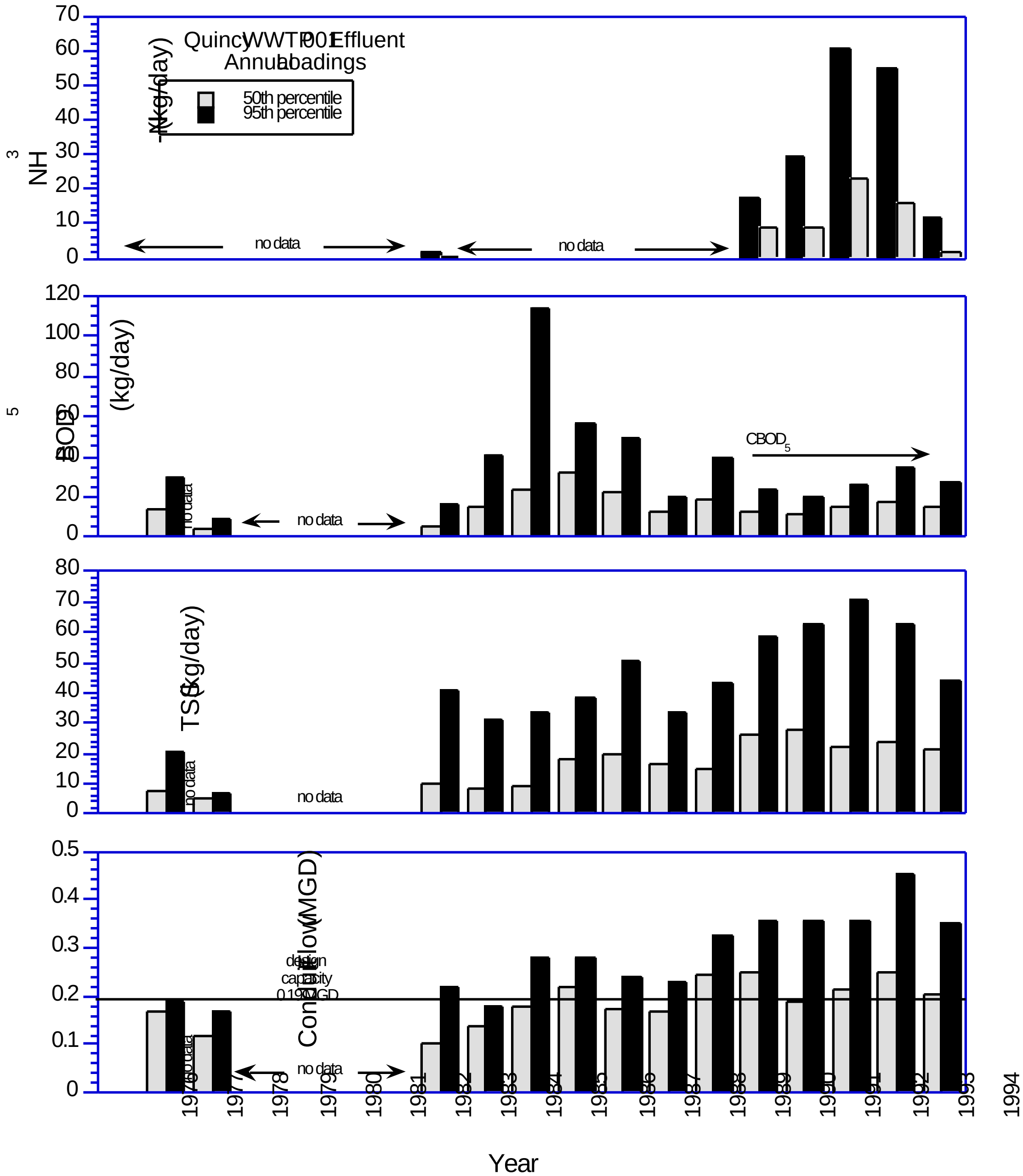


Figure 6 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS) from the Quincy WWTP.

Sidney WWTP

The Sidney WWTP discharges directly to the Upper Great Miami River mainstem at RM 128.68. Constructed in 1955, with plant modifications made in 1968 and 1988 (a major upgrade), the Sidney WWTP is a secondary treatment facility. The treatment process includes: grit chamber, primary settling, conventional aeration, secondary settling, and chlorination. In addition, a 2.0 MG flow equalization basin was added to the system in November, 1993. The collection system is separate with four lift stations. The service area is 100% sewered. Current design capacity is 4.5 MGD.

The service population is approximately 20,000 with moderate growth expected. Significant industrial contributors to the waste stream include: Stolle-Aluminum, Copeland-Compressors, Cargill-Soybean processing, Iron & Aluminum Foundry and a food processor. The city of Sidney has recently expressed interest in expanding plant capacity from the existing 4.5 MGD to 5.75 MGD. The additional capacity may be necessary, in the future, to provide service to village of Port Jefferson and a Honda production facility in the village of Anna.

Annual median conduit flows remained below the 4.5 MGD design capacity and appeared fairly stable through the period of record, though modest increases were noted in 1986, 1989, and 1990. Annual 95th percentile conduit flows, however, were generally in excess of the plant design capacity. Fourteen years (approximately 74%) of the 19 year record indicate 95th percentile conduit flows greater than 4.5 MGD. The Sidney WWTP discharged approximately 3.31 MGD, comprising 16% of the aggregate conduit flow for all major WWTPs discharging directly to the Upper Great Miami River in 1994 (Figure 4 and 7).

Ammonia-nitrogen loadings have been substantially reduced through the period of record. Median and 95th percentile values were elevated and erratic between 1976 and 1981; however, by 1982 loadings (both 50th and 95th percentiles) were markedly reduced. From 1982 to 1994, median ammonia-nitrogen loads demonstrated a decreasing trend, while 95th percentiles loads appeared fairly stable through time. Within this period, a modest increase was observed in 1988 only. This anomalous annual ammonia-nitrogen load may have been a of result of treatment irregularities associated with major plant upgrades initiated in 1988. The Sidney WWTP currently discharges approximately 19.0 kg/day, comprising 22% of the aggregate ammonia-nitrogen load for all major WWTPs discharging directly to the Upper Great Miami River in 1994.

The BOD data available through the period of record is comprised of two parameters, BOD_5 (1976 through 1987) and $cBOD_5$ (1988 through 1994). Annual median BOD loads appeared fairly stable through time. Annual 95th percentiles were elevated and erratic between 1976 and 1984, but markedly reduced after 1984. Annual TSS loads displayed a similar trend as that of BOD, with annual median loads fairly stable through time, and 95th percentile loads elevated and erratic between 1976 and 1985.

Bioassays conducted by Sidney revealed periodic, but significant toxicity to aquatic test organisms. Four out of ten 48-hour acute toxicity tests conducted between January 8, 1993 and January 24, 1994 four tests revealed 100% adverse effects to *Ceriodaphniadubia* and two of these tests also showed adverse effects to fathead minnows *(Pimephalespromelas)*. Only two of the four tests showed significant adverse effects (*i.e.*, >20%) in the mixing zone. All four of the tests revealing significant adverse effects were conducted between January and May 1993. In addition to the acute tests, four chronic 7-day tests were conducted between March 9, 1993 and February 8,

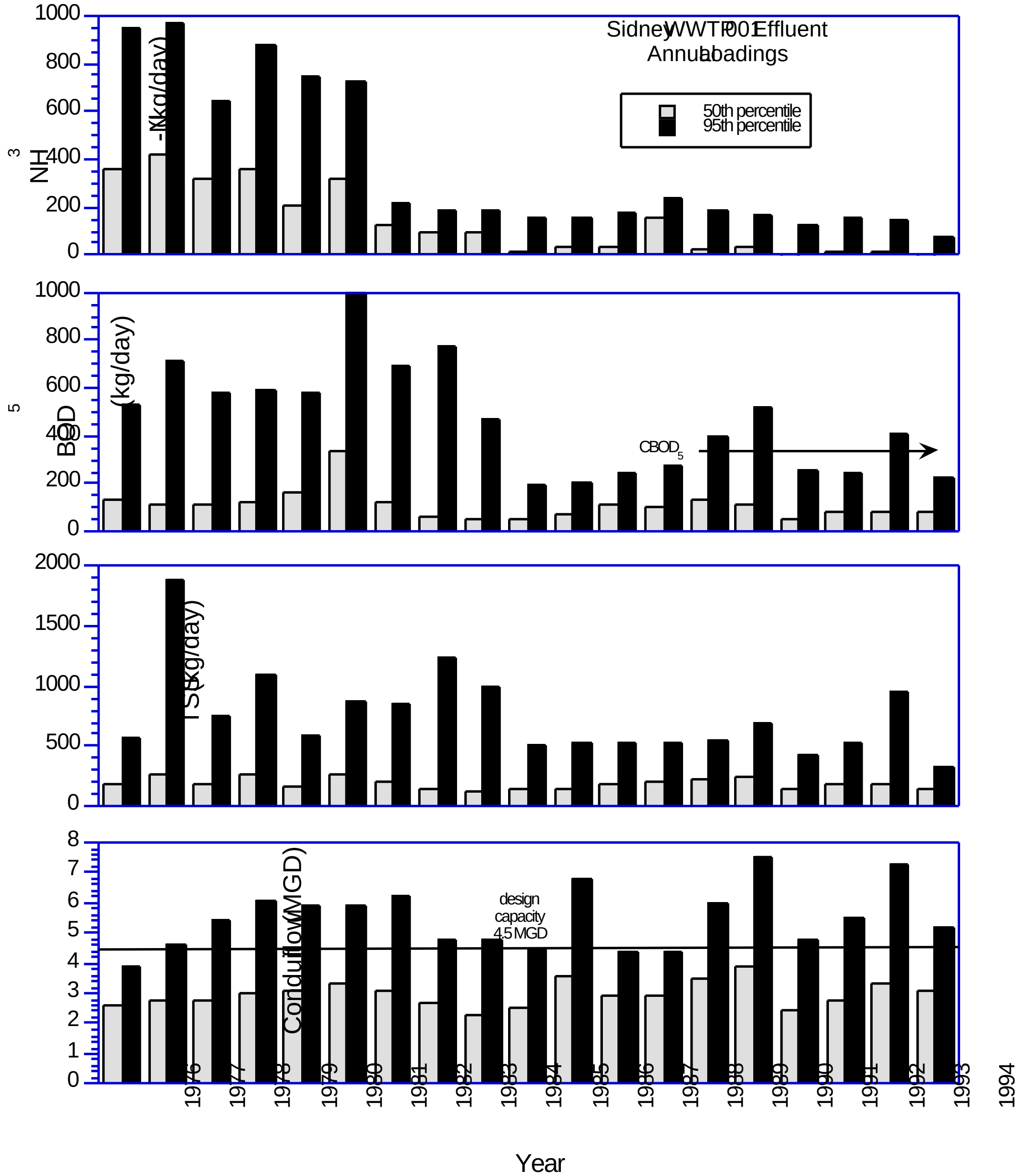


Figure 7 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the Sidney WWTP.

1994. One test revealed impaired reproduction of *C. dubia* in the effluent and two other tests revealed significant mortality to fathead minnows *(P. promelas)*. Acute bioassays conducted by Ohio EPA in November 1993 and January 1994 revealed no significant adverse effects.

Seventy-nine violations were reported between 1989 and 1994. Fecal coliform being the most frequently violated parameter. The majority of the violations were recorded in 1989 and 1990, 22 and 33 respectively. These violations accounted for nearly 70% of all violations from 1989 to 1994. Most parameters reported were typical constituents of domestic wastewater (*e.g.*, ammonia-nitrogen, BOD, and TSS), although in two mercury violations were recorded in 1993.

Piqua WWTP

The Piqua WWTP maintains two direct discharges to the Great Miami River. One discharge is situated immediately upstream of the Piqua dam at RM 114.3, the other is located downstream at RM 114.13. During the 1994 field investigation, only the discharge at RM 114.3 was active. The facility was constructed in 1957, with treatment upgrades made in 1968, 1984, and 1991 (a major upgrade). The Piqua WWTP is a secondary treatment facility consisting of primary settling, activated sludge, secondary settling, chlorination, and post aeration. The current plant design capacity is 4.5 MGD. The collection system consists of separate sewers, with 100% of the service area sewered. The population serviced is approximately 21,000 with moderate growth expected. Significant industrial contributors are Hartzell Fan, Metal Cleaning, and Harzel Prop-Cyanide bath.

Median effluent flows fluctuated between 2.4 MGD and 4.3 MGD with 95th percentile values exceeding the 4.5 MGD design flow several times during the period 1976-1994. No obvious trends were evident for this time period. The Piqua WWTP contributed approximately 13% (2.62 MGD) of the total wastewater volume discharged by five major WWTPs to the Upper Great Miami River mainstem in 1994 (Figure 4 and 8).

A dramatic decline occurred for median and 95th percentile ammonia-nitrogen loadings in 1989. Median values which consistently exceeded 150-200 kg/day prior to 1989 declined to less than 5-10 kg/day afterwards. Ninety-fifth percentile values showed a similar decline to less than 20-30 kg/day during 1992-94. The Piqua WWTP contributed 11% (9.73 kg/day) of the ammonia-nitrogen loading discharged by five major WWTPs to the Upper Great Miami River mainstem in 1994.

The BOD data available through the period of record is comprised of two parameters, BOD_5 (1976 through 1985) and $cBOD_5$ (1986 through 1994). Median and 95th percentile loadings of BOD during the 1976-1994 period show some fluctuations, but demonstrated an overall decline through the period. Annual TSS loads displayed a similar trend as that of BOD.

Bioassays conducted by Piqua between August 19, 1991 and February 8, 1994 revealed significant toxicity to aquatic test organisms in only one of eleven 48-hour acute toxicity tests. The August 1991 test revealed 100% adverse effects to *C. dubia* with no significant adverse effects (*i.e.*, >20%) in the mixing zone. No significant adverse effects to fathead minnows *(P. promelas)* were evident. Acute bioassays conducted by Ohio EPA in November 1993, December 1993, and February 1994 revealed no significant adverse effects.

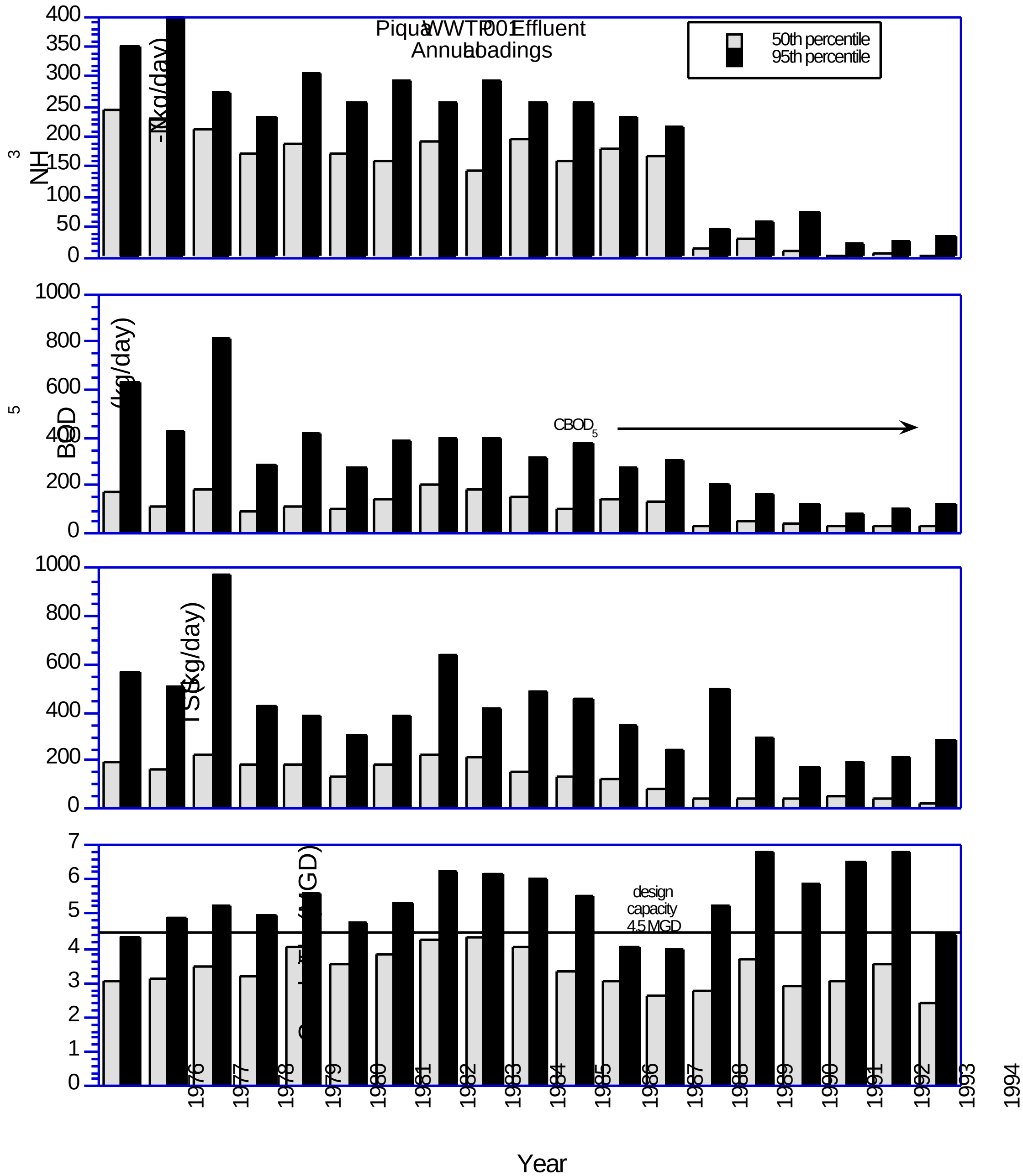


Figure 8 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the Piqua WWTP.

Eighty-nine violations were reported during 1989-94. Heavy metals dominated the NPDES violations from 1989-93. An investigation by the city found solids (digester supernatant) being returned to and collected in the influent wet well as a major source of metals violations. During 1994, the reported number of permit violations were significantly reduced, and appeared more typical of the constituents of treated domestic wastewater (*e.g.*, TSS, residual chlorine, and fecal coliform).

Piqua Municipal Power

The Piqua Municipal Power Plant-Electric Generating Station (Piqua MP-EGS) has a 93 megawatt (MW) capacity and discharges cooling water to the Great Miami River in the vicinity of RM 114.3. The plant maintains four outfalls (001-004) on the west bank, opposite the Piqua WWTP outfall. The facility employs once-through cooling system, with the capacity to withdraw and discharge approximately 68 MGD of water from the mainstem. As such, total withdraw volume has the potential to comprise approximately 4.3 times the $Q_{7,10}$ flow of the mainstem. Because more flow can be required for cooling than is available from the mainstem during the summer-fall low flow period, a portion of the once-through discharge is circulated within the Piqua dam pool. Efforts have recently been made to supplement river flow with the Piqua WWTP discharge, but this comprises only a fraction (approximately 10%) of the volume potentially needed for Piqua MP's once-through cooling system.

The Piqua MP-EGS monitors temperature at the intake (station 801) and reports downstream values (station 901) as part of the NPDES permit requirements. The 801 station has been monitored since 1976, however, downstream values have only been reported since 1994. For the purposes of environmental monitoring and evaluation, the 801 and 901 temperature data provided by Piqua MP-EGS are limited in several ways. First, the EGS 801(upstream) station is situated in the Piqua dam pool at the plant's water intake. The temperature of the water column, at this location, is strongly influenced by the partial recirculation of cooling water from the Piqua MP-EGS within the dam pool itself. As such, the temperatures reported from the 801 station are likely warmer than ambient background levels due to the recirculation of a portion of the thermal discharge. Second, the EGS 901 (downstream) data has only been reported since 1994, precluding a meaningful trend assessment. Last, the EGS 901 temperature data are calculated values, based on river discharge and thermal load, not actual instream measurements.

To better characterize the ambient summer conditions (June 15 - September 16) within the Great Miami River, temperature data collected from the 801 and 901 monitoring stations for the Piqua WWTP were employed. These data augment that provided by Piqua MP-EGS, and represent actual instream temperatures, up and downstream of the power plant. The Piqua WWTP 801 station is located at RM 115.1 (East Main St. Bridge) and the 901 station is 2.7 miles downstream at RM 112.4 (Ferrington Rd.). The 801 and 901 data from Piqua WWTP bracket the Piqua dam pool entirely, providing an opportunity to evaluate ambient river temperatures longitudinally as well as through time. A summary of summer temperature exceedences through the period of record is presented in Table 5

Between 1978 and 1981, during the critical summer period, ambient instream temperatures both up and downstream of the Piqua MP-EGS remained below the summer daily maximum temperature criterion of 29.4 ˚C. A similar pattern was evident in 1982, based on the Piqua WWTP 801 and 901 data; however, within the dam pool, the Piqua MP-EGS 801 (intake) temperature data indicated 13 exceedences of the summer daily maximum limit throughout the month of August (Table 5). These data were clearly reflective of the re-circulation of cooling water within the dam pool, indicating water temperatures at the intake were greater than instream temperatures recorded approximately one mile upstream (Piqua WWTP 801 station). Between 1983 and 1984, only one exceedence of the daily summer maximum temperature was recorded in August 1983, downstream of the Piqua MP-EGS at the Piqua WWTP 901 station. A pattern similar to that observed in 1982 was evident in the 1985 data. Ambient river temperature at the Piqua WWTP 801 and 901 monitoring stations were below the summer daily maximum, although 12 temperature exceedences were reported from the Piqua MP-EGS 801 station. No summer temperature exceedences were recorded at any of the monitoring station in 1986 and 1987.

Table 5. A summary of actual and calculated exceedences of the summer (June 16 - September 15) daily maximum temperature criterion of 29.4 ˚C, and magnitude (expressed as mean temperature of the exceedences) from the Piqua WWTP and Piqua MP-EGS, 801 (upstream) and 901 (downstream) monitoring stations, Upper Great Miami River. Data collected between 1978 and 1994.

Year	Piqua MP-ESG[a] 801 Station RM 114.2 (# of violations/mean temp.)	Piqua MP-EGS[b] 901 Station RM N/A (# of violations/mean temp.)	Piqua WWTP[c] 801 Station RM 115.1 (# of violations/mean temp.)	Piqua WWTP[d] 901 Station RM 112.4 (# of violations/mean temp.)
1978	- / -	- / -	0/0	0/0
1979	- / -	- / -	0/0	0/0
1980	- / -	- / -	0/0	0/0
1981	- / -	- / -	0/0	0/0
1982	13/31.4˚C	- / -	0/0	0/0
1983	- / -	- / -	0/0	1/30.0˚C
1984	0/0	- / -	0/0	0/0
1985	12/31.2˚C	- / -	0/0	0/0
1986	0/0	- / -	0/0	0/0
1987	0/0	- / -	0/0	0/0
1988*	8/31.6˚C	- / -	0/0	3/30.0˚C
1989	0/0	- / -	0/0	0/0
1990	0/0	- / -	0/0	0/0
1991	22/31.3˚C	- / -	0/0	0/0
1992	0/0	- / -	0/0	0/0
1993	0/0	- / -	0/0	0/0
1994	0/0	2/30.1˚C	0/0	0/0

a - Piqua MP-EGS 801 station, located within the Piqua dam pool at the facility's water intake. Exceedences based on actual instream temperature measurements.

b - Piqua MP-EGS 901 Station. Exceedences based on calculated instream value. Temperature data not reported until 1994.

c - Piqua WWTP 801 station, located approximately 1 mile upstream of Piqua dam. Exceedences based on actual instream temperature measurements.

d - Piqua WWTP 901 station, located approximately 2.7 miles downstream of the Piqua dam. Exceedences based on actual instream temperature measurements.

***** - Fish kill attributed to thermal discharge from Piqua MP-EGS occurred in August, 1988 (Ohio DNR 1989).

The temperature data collected at all monitoring stations during the extreme low river flows of 1988 indicated excessive thermal loading from the Piqua MP-EGS during the month of August. Ambient river temperatures upstream of the Piqua dam (Piqua WWTP 801 station) indicated no exceedence of the summer daily maximum. However, eight exceedences of the daily maximum criterion were reported at the Piqua 801 station (within the dam pool), and three exceedences from the Piqua WWTP 901 data (2.7 miles downstream). Additionally, a fish kill was reported by the Ohio DNR downstream of the EGS on August 12. Excessive thermal loads to the mainstem from the EGS resulted in the death of 4,985 fish (Ohio DNR 1989).

No exceedences of the daily maximum summer temperature criterion were reported in 1989, 1990, or 1992. However, June to September 1991, 22 exceedences of the daily maximum criterion were reported from the Piqua MP-EGS 801 station, although no downstream exceedences were reported from the Piqua WWTP 901 station. Two calculated temperature exceedences (Piqua MP-EGS 901 data) were reported during the summer of 1994. All other sampling stations during this time reported instream temperatures below the daily maximum criterion.

The analysis of the temperature data furnished by the Piqua WWTP 801 and 901 monitoring stations, and data from the Piqua MP-EGS 801 station provided a trend assessment of instream summer temperatures of the Great Miami River in the vicinity of the Piqua MP-EGS, between 1978 and 1994. During this 17 year period, the thermal load to the Great Miami River from the EGS was generally within the assimilative capacity of the mainstem. Periods of elevated instream temperature were limited to four years, 1982, 1985, 1988, and 1991, evidenced mainly by plant intake temperatures (EGS 801) in excess of the summer daily maximum criterion. Only during the extreme low river flow of 1988 were temperature exceedences regularly observed within the Piqua dam pool and less frequently further downstream (Piqua WWTP 901 station). The thermal load discharged to the mainstem during the summer of 1988 was clearly in excess of the rivers assimilative capacity, evidenced by a fish kill in August. However, this event represents the only wildlife kill attributed to the Piqua MP-EGS through the period 1982 to 1994.

Excluding summer temperature criteria exceedences, the Piqua MP-EGS reported 39 violations of their NPDES permit between 1989 and 1994. Parameters most frequently violated were temperature(non-summer months), TSS, and pH. Total suspended solids accounted for the majority of the recent violations.

Troy WWTP

The Troy WWTP discharges directly to the Great Miami River at RM 105.6. Constructed in 1937 and upgraded in 1952, 1965, 1975, and 1995 (ongoing), the Troy WWTP is a secondary treatment plant with clarifiers, activated sludge, conventional aeration, chlorination, dechlorination, and land application of sludge. The plant has design capacity of 7.0 MGD. The collection system is separate with seven lift stations. The majority of the service area is sewered. The service population is approximately 19,500 with moderate growth predicted. Significant industrial contributors include: five metal finishers, an electronic component manufacturer, and a food processing facility.

The first phase of a major plant upgrade was initiated in July of 1995. The project will include the addition of a screw pump lift station, a grit removal system, two flow equalization basins, and the elimination of the north interceptor pump station. When complete, the treatment improvements will increase the plant pumping and preliminary treatment capacities.

The Troy WWTP contributed approximately 24% (4.97 MGD) of the total wastewater volume discharged by five major WWTPs to the Upper Great Miami River mainstem in 1994. Median effluent flows fluctuated between 2.7 MGD and 6.0 MGD with 95th percentile values exceeding the 6.0 MGD design flow several times during the period 1976-1994. A slight trend of increasing flow was evident for this period (Figure 4 and 9).

The BOD data available through the period of record is comprised of two parameters, BOD_5 (1976 through 1989) and $cBOD_5$ (1990 through 1994). Median and 95th percentile loadings of BOD_5 during the 1976-1994 period show some fluctuations, but demonstrated an overall decline through the period. The loading amounts were particularly consistent between 1987 and 1994. Median and 95th percentile TSS loads appeared stable through the period of record.

A marked decline occurred for median and 95th percentile ammonia-N loadings through the 1976-1994 period. Median values which exceeded 300 kg/day prior to 1980 declined to less than 15-20 kg/day after 1987. Ninety-fifth percentile values declined through the period from values of 350-550 kg/day to less than 50-100 kg/day during the past five years. However, some variability between median and 95th percentile values was evident. The Troy WWTP contributed 31% (26.8 MGD) of the ammonia-N loading discharged by five major WWTPs to the Upper Great Miami River mainstem in 1994.

Bioassays conducted by Troy between December 1993 and August 1995 revealed no significant toxicity to aquatic test organisms in three 48-hour acute toxicity tests. Acute bioassays conducted by Ohio EPA in July 1988, December 1993, and March 1994 revealed no significant adverse effects.

In August, 1994 the north interceptor pump station discharged approximately 15,000 gallons of raw sewage to the Great Miami River (via an abandoned channel) near SR 41. The discharge was a result of a malfunctioning valve. As part of an ongoing plant upgrade, the north interceptor will be eliminated.

Between 1989 and 1994, 135 NPDES permit violations were reported to Ohio EPA. Heavy metals dominated the violations during the period 1989-91. In 1992 only one violation (pH) was reported and in 1993 no violations were indicated. Seven violations were noted in 1994, but were typical constituents of treated domestic wastewater (*e.g.,* Ammonia-nitrogen and fecal coliform).

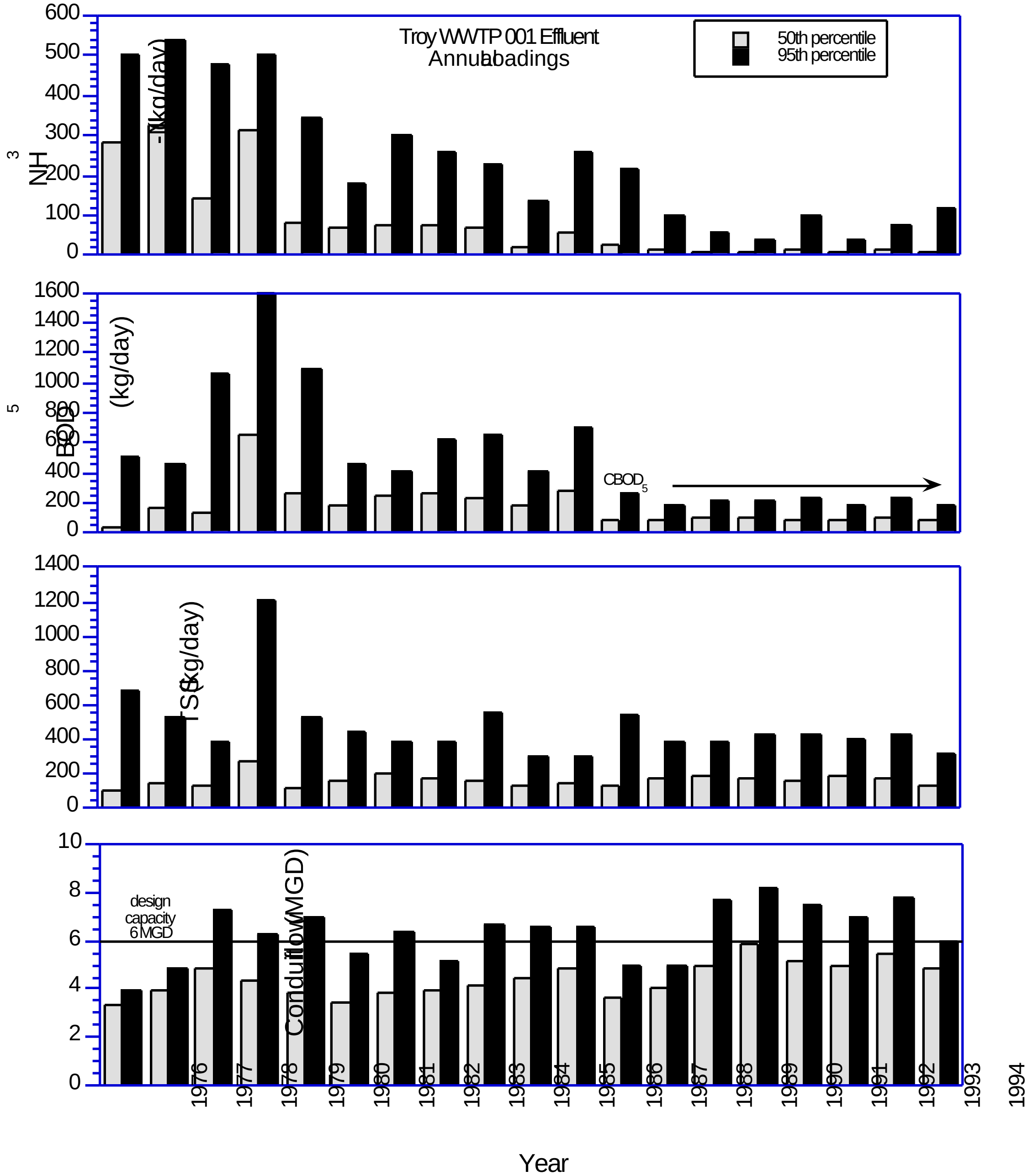


Figure 9 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the Troy WWTP.

MCD N. Regional WWTP

The MCD North Regional WWTP currently discharges directly to the Great Miami River at RM 86.6. Prior to 1988 the MCD N. Regional WWTP discharged further upstream at RM 87.4 (upstream from Needmore Rd.). The facility was constructed in 1985 with a major modification in 1988. The MCD N. Regional WWTP provides secondary treatment, utilizing primary settling, degritting, two stage trickling filters, final settling, chlorination, dechlorination, and land application of sludge. The plant has a design capacity of 11.2 MGD. The collection system consist of 90% separate sewers with the majority of the service area sewered. The service population is 25,000-30,000. Significant industrial contributors include: Cintas Corp, Dayton International Airport (including McCauley Accessory), Delphi Chassis Systems (Inland), Spectro-Physics Laserplane, and Tipp Machine & Tool Inc.

Annual median conduit discharge demonstrated a modest increasing trend through the period of record (1985 through 1994). Median annual discharge during this time was consistently below the current design capacity of 11.2 MGD. However, 95th percentiles for nearly half of the period, were at or in excess of design flow. The MCD N. Regional WWTP contributed 37% (7.75 MGD) of the total conduit discharge of all major WWTPs within the Upper Great Miami River study area in 1994 (Figure 4 and 10).

Loadings of ammonia-nitrogen have been reduced significantly from a median 75.0 kg/day in 1985 to 10.8 kg/day in 1994. Median ammonia-nitrogen loads appeared reduced and fairly stable from 1987 to 1994. However, 95th percentile loads appeared erratic and elevated, with the greatest values occurring between 1985 and 1990. Between 1991 and 1994, 95th percentile loads were reduced and appeared more commensurate with median loads, suggesting more consistent plant performance. The MCD N. Regional WWTP contributed 23% (20.5 kg/day) of the aggregate ammonia-nitrogen load from all of the major WWTPs within the Upper Great Miami River study area in 1994.

The BOD data available through the period of record is comprised of two parameters, BOD_5 (1985 through 1989) and $cBOD_5$ (1990 through 1994). Both the median and 95th percentile loads of BOD demonstrated a general decreasing trend through the period of record. Median annual loadings of TSS appeared fairly stable through the period of record, ranging (approximately) between 90 kg/day and 120 kg/day.

An acute bioassay test conducted by Ohio EPA in January, 1994 indicated no significant adverse effects to either *P. promelas* or *C. dubia* from effluent or receiving water samples. An additional test was conducted by the Ohio EPA in March, 1994. These results indicated only slight effluent toxicity to *P. promelas*. No adverse effects were observed in either test organism from receiving water or mixing zone samples.

Thirty-seven violations were reported during 1989-94. During 1989-90 ammonia dominated the violations. From 1991 through 1994 the number of NPDES violations dropped significantly and were only occasionally reported. A consent order is currently in place addressing the sanitary sewer overflows.

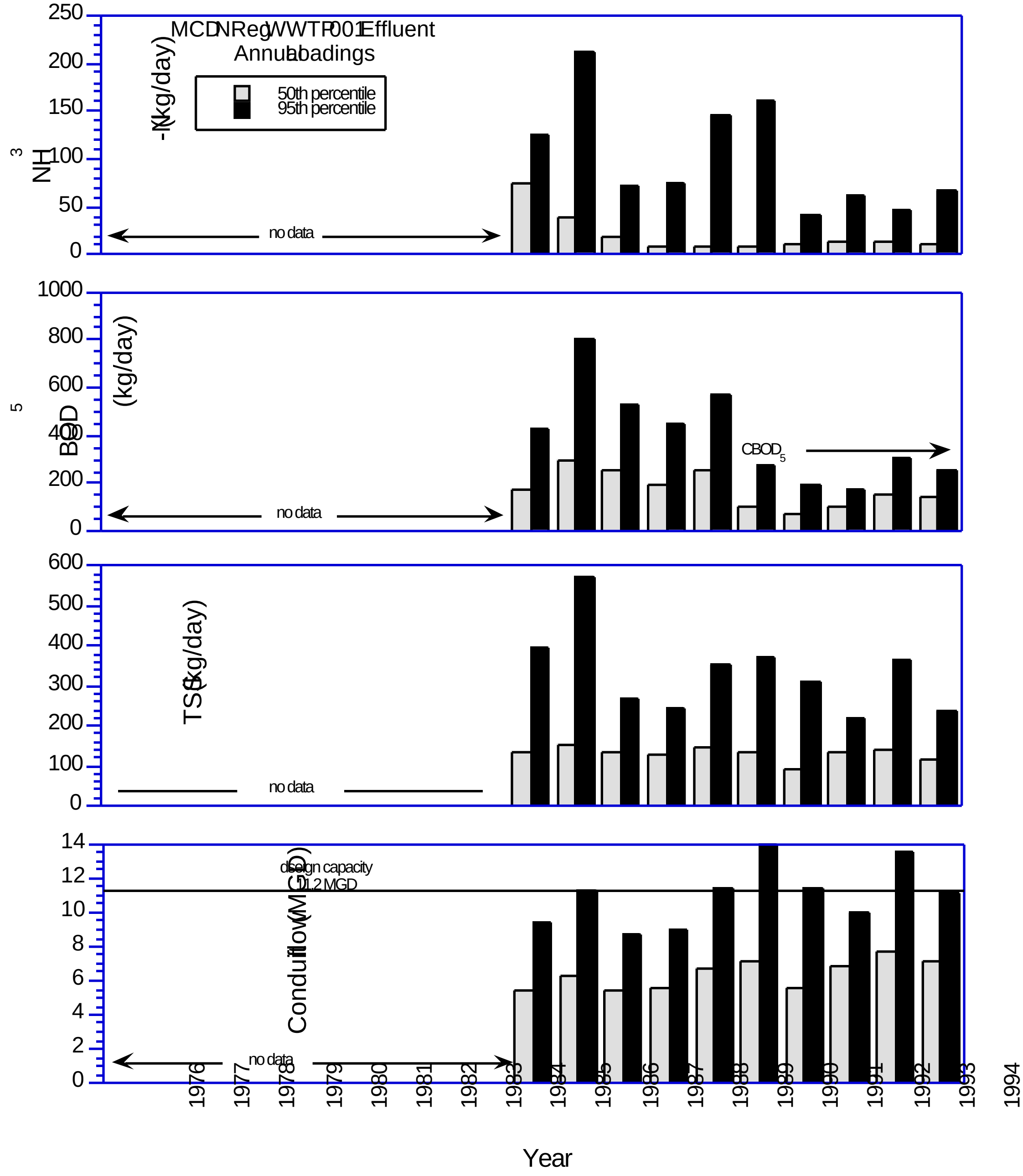


Figure 10 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the MCD North Regional WWTP.

Chemical Water Quality

Segment I: (Indian Lake to Loramie Creek)

Discharge of the Great Miami River, monitored at the USGS gage station in Sidney, indicated river flow well above the critical $Q_7$10 value (21 cfs) throughout the third quarter (May - September) of 1994. Additionally, river discharge was typically above the 80% duration (47 cfs) between May and August. Flows less than the 80% duration were observed only during the month of September. Peak third quarter discharge and duration occurred between late-June and early-July, with flows reaching 1000 cfs (Figure 11).

Six replicate water chemistry sample were collected at 11 station within Segment I of the Upper Great Miami River study area. During each of the six sampling runs, field measurements (dissolved oxygen, temperature, pH, and conductivity) and water samples for laboratory analysis were taken over a two-day period.

Average daytime (10:00-15:00) dissolved oxygen (D.O.) concentrations remained above the 4.0 mg/l WWH minimum water quality criterion at all locations within Segment I. Exceedences of the WWH average D.O. criterion (5.0 mg/l) where limited to three occurrences within the reach extending from Indian Lake WWTP (RM 151.7) to the Quincy dam pool (RM 146.19) (Table 6). Within this segment, D.O. concentrations were generally lower in comparison with the lower portion of Segment I (Figure 12). The depressed D.O. concentration were likely associated with nutrient inputs from Indian Lake WWTP. The effects of immoderate nutrient loadings from this facility were likely exacerbated by the low gradient and physically simplified conditions that characterize the river reach from Indian Lake to the Quincy dam pool. Average D.O. concentrations downstream of the Quincy dam were generally above 9.0 mg/l, well above the WWH standards. The Quincy WWTP and Sidney WWTP appeared to have no negative influence on the capacity of the Great Miami River to maintain more than adequate D.O. levels.

Mean BOD_5 values demonstrated a modest increasing longitudinal trend within Segment I. Fairly distinct nutrient inputs from Indian Lake WWTP were evidenced by an increase in the mean BOD_5 downstream of this facility. Additionally, BOD_5 was markedly increased downstream of the Quincy dam. This observation may have been a result of the export of organic material (*e.g.*, plankton, fine particulate organic matter) from the dam pool, which represents more lentic trophic conditions than that of the free flowing portions of the Great Miami River.

No exceedences of the WWH criteria for unionized ammonia were observed during the 1994 sampling effort within Segment I. Mean ammonia-nitrogen values appeared low and fairly stable throughout the reach, although marked increases were observed downstream of Indian Lake WWTP and the Quincy WWTP. The increase in the mean concentration of ammonia-nitrogen downstream of the Indian Lake WWTP occurred during a period when the this WWTP reported seven violations of their NPDES ammonia-nitrogen limit.

Average concentrations of nitrate+nitrite-nitrogen within Segment I appeared low and longitudinally stable, although marked increases were indicated downstream of the Sidney WWTP and more significantly the Indian Lake WWTP (from 0.5 mg/l to 4.7 mg/l).

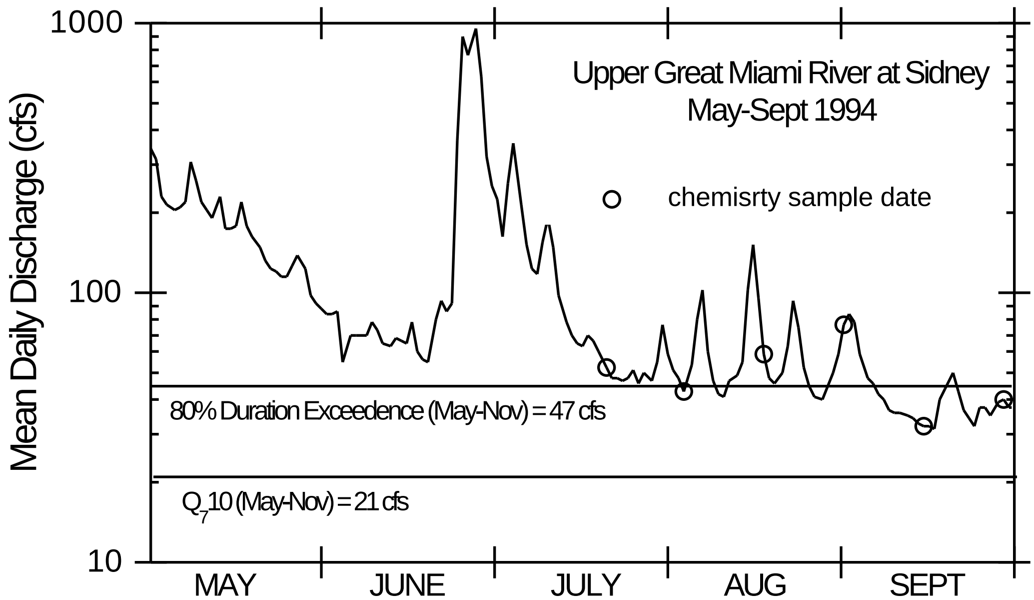


Figure 11 Flow hydrograph for the Great Miami River at Sidney, May through September, 1994 (USGS 1994). Open circles indicate river discharge on the date when water chemistry samples were collected.

Table 6. Exceedences and violations of Ohio EPA water quality standards (OAC 3745-1) for chemical/physical parameters from the Upper Great Miami River study area during 1994 (units are µg/l for metals and organics, and mg/l for all other parameters listed).

Stream Name	River Mile	Parameter (value)
Upper Great Miami River		
	151.70	Dissolved Oxygen (4.2‡) Endosulfan I (0.004*)
	146.19	Dissolved Oxygen (4.4‡)
	143.60	Dissolved Oxygen (4.8‡) Dieldrin (0.002 #) Aldrin (0.004 #) Endosulfan II (0.005*)

Table 6. continued.

Stream Name	River Mile	Parameter (value)
Upper Great Miami River		
	143.16	Endosulfan II (0.004*)
	142.67	Dieldrin (0.004 [#])
	130.05	Endrin (0.003*) Endosulfan II (0.005*)
	127.70	Dieldrin (0.004 [#],0.003 [#]) Endosulfan II (0.007*)
	123.89	Dieldrin (.003 [#], .003 [#]) Endosulfan II (.005*)
	116.70	Dieldrin (0.003 [#], 0.003 [#]) Endosulfan II (0.005*)
	114.54	Endosulfan II (0.004*)
	114.3[a]	D.O. (3.71 [‡‡], 3.57 [‡‡] ,3.97 [‡‡] ,3.69 [‡‡], 3.98 [‡‡], 3.98 [‡‡])
	114.28	Endosulfan II (0.007*) Aldrin (0.009 [#])
	113.60	Aldrin (0.012 [#]) Endrin (0.003)
	104.70	Endosulfan II (0.006*)
	99.10	Endosulfan II (0.005*)
	91.14	Endosulfan II (0.004*)
	87.05	Aldrin (0.008 [#]) Endrin (0.004*)
	86.13	Endosulfan II (0.004*) Endrin (0.006*)

Table 6. continued.

Stream Name	River Mile	Parameter (value)
Loramie Creek		
	36.84	Dissolved oxygen (2.3‡‡, 3.7‡‡)
	34.96	Dissolved oxygen (3.2‡‡)
	30.42	Dissolved oxygen (4.1‡, 4.0‡, 4.5‡, 2.9 ‡‡)
	28.90	Dissolved oxygen (3.2‡‡,1.3‡‡,3.7‡‡,4.4‡) Dissolved oxygen (17 violations ‡‡)[a]
	27.39	Aldrin (0.008 #) Endosulfan II (0.009*, 0.004*) Endrin (0.003*) Dissolved oxygen (3.0 ‡‡)
	16.51	Dissolved oxygen (4.6‡)
	7.67	Aldrin (0.006*) Endosulfan II (0.006*, 0.003*) Endrin (0.004*) Dieldrin (0.005 #, 0.005 #)
Blue Jacket Creek		
	3.26	Endrin (0.003*)
Bokengehalas Creek		
	7.88	Bis (2-Ethylhexyl) Phthalate (10.3*)
South Fork Great Miami River		
	7.98	Dissolved oxygen (4.4‡, 4.8‡, 4.1‡)
Van Horn Creek		
	0.97	Dissolved oxygen (4.9‡)
North Fork Great Miami River		
	10.7	Dissolved oxygen (2.3‡‡, 4.4‡,4.7‡,4.0‡,4.7‡)
	4.02	Endosulfan II (0.005*), Dissolved oxygen (4.0‡, 4.6‡,4.0‡, 4.8‡)

Table 6. continued.

Stream Name	River Mile	Parameter (value)
Blackhawk Run		
	0.45	Dissolved oxygen (3.8‡‡)
Honey Creek		
	8.08	Dissolved oxygen (5.0‡‡‡,3.5‡‡‡,5.5‡‡‡,4.1‡‡‡)
	3.18	Dieldrin (0.002 #)
Lost Creek		
	9.74	Dieldrin (0.002 #)
	2.6	Dissolved oxygen (4.2 ‡‡‡, 2.0 ‡‡‡, 4.0‡‡‡),

a Diel data collected by Datasonde continuous monitors.
* exceedence of numerical criteria for prevention of chronic toxicity (CAC).
# exceedence of numerical criteria for human health 30-day average.
‡ value below the average warmwater habitat dissolved oxygen (D.O.) criterion (5.0 mg/l).
‡‡ violation of the minimum warmwater habitat dissolved oxygen (D.O.) criterion (4.0 mg/l).
‡‡‡ exceedence of the exceptional warmwater habitat minimum dissolved oxygen (D.O.) criterion (6.0 mg/l).

Note: Analyses of fecal coliform and *E. coli* were not performed within the required six hour holding time. As such, the laboratory results were invalidated.

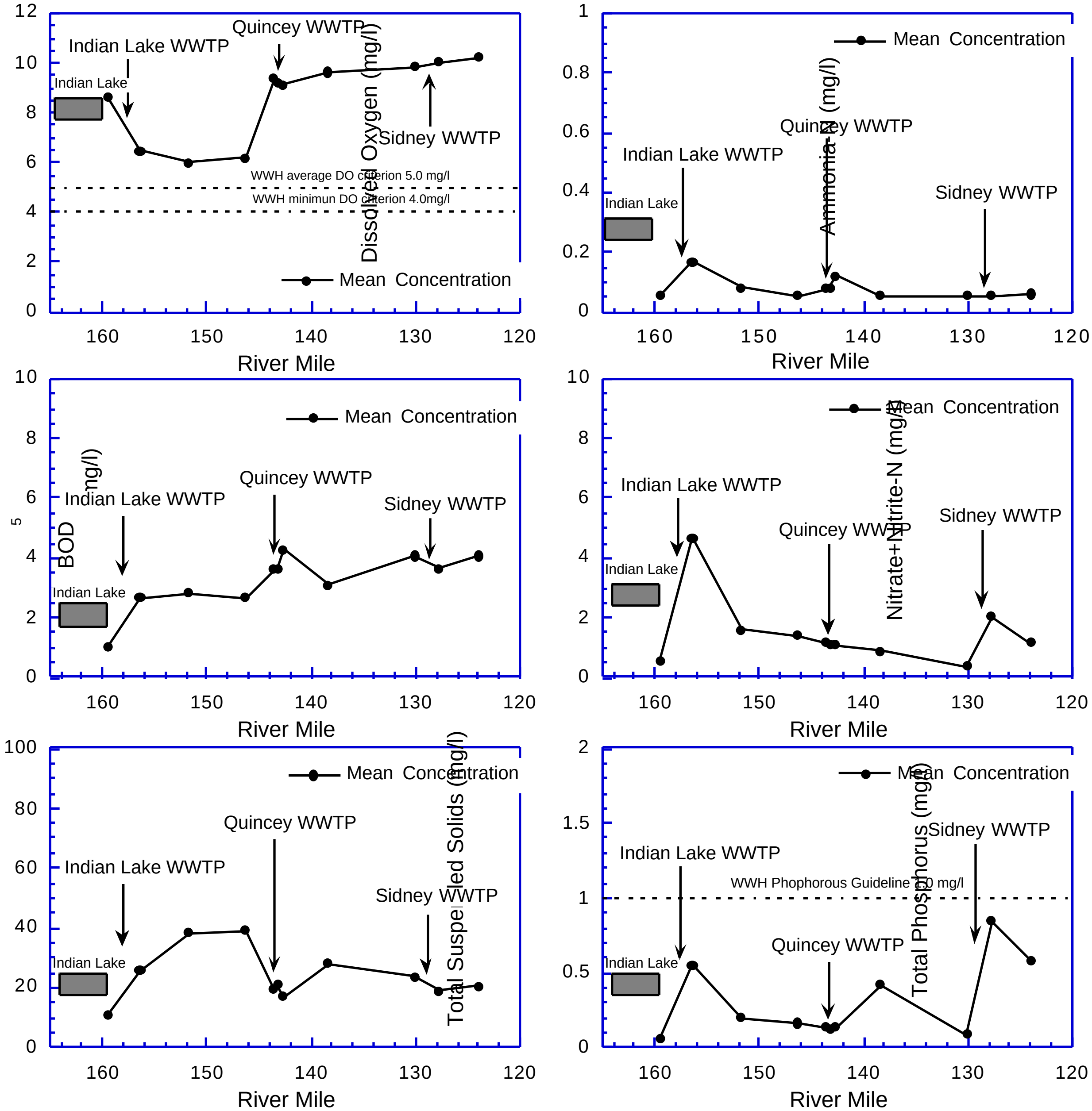


Figure 12 Longitudinal mean concentration of dissolved oxygen, ammonia-nitrogen, nitrate-nitrogen, five-day biochemical oxygen demand, total suspended solids, and total phosphorus from Segment I of the Great Miami River mainstem, 1994.

Average phosphorus values remained below the water quality guideline of 1.0 mg/l throughout Segment I, though mean total phosphorus was elevated in comparison with background conditions, downstream of the Indian Lake WWTP and Sidney WWTP. The greatest mean concentration was observed at RM 127.7 (downstream of the Sidney WWTP).

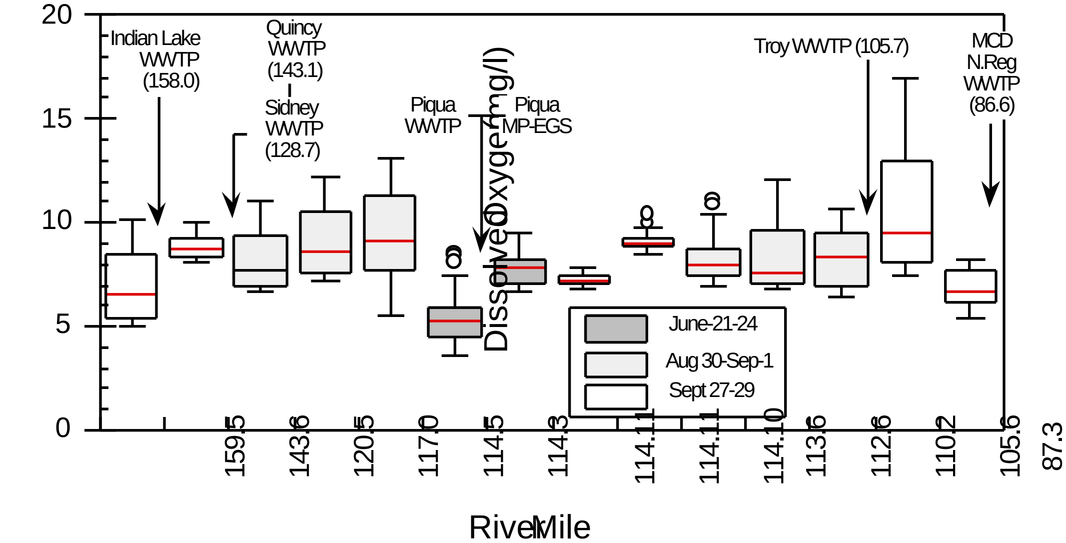
Average TSS values increased throughout the reach extending from the Indian Lake WWTP to the Quincy dam. Mean TSS concentrations appeared reduced within the remaining portion of Segment I, downstream of the Quincy dam. Elevated TSS was not observed downstream of either the Sidney or Quincy WWTPs.

Over half of the sites sampled revealed exceedences of water quality criteria for pesticide residues (Table 6). Pesticide concentrations within the water column, greater than the average human health and chronic toxicity criteria, were limited to three compounds: Dieldrin, Aldrin, and Endosulfan (I and II). No longitudinal or river discharge exceedence pattern was evident. The majority of the exceedences were observed in early August, during a time when river discharge was above 80% duration; however, sampling events during periods of greater river discharge, in late-August, did not indicate any exceedences of the pesticide criteria. The occurrence of these environmentally persistent compounds is most likely related to past agricultural use within the basin. All of these pesticides are commonly held on the exchange complex of silts and clays (Howard 1991). As such, their occurrence within the water column likely reflects the presence of suspended soil particles in the water samples collected.

Datasonde continuous monitors were deployed at three locations within Segment I (RM 159.5, RM 143.6, and RM 120.5). The sampling duration was typically 45 hours, and occurred during September 27-29, and August 30-September 1, 1994.

Diel sampling provided by the continuous monitors indicated that adequate D.O. concentrations, above the WWH standards (average and minimum), were maintained throughout Segment I (Figure 13). The lowest median (6.98 mg/l) and greatest variation were indicated upstream of Indian Lake WWTP (downstream of the Indian Lake dam) at RM 159.5. Diel sampling within the Quincy dam pool (RM 143.6) indicated a higher median (8.75 mg/l) and considerably less variation. Continuous monitoring data collected at RM 120.5 (downstream of the Sidney WWTP), indicated a similar median (8.26 mg/l) but greater variation than that encountered within the Quincy dam pool.

Longitudinal evaluation of the Datasonde information is, unfortunately, confounded to some extent by temporal factors. For example, the data collected at the sampling stations bracketing the Indian Lake WWTP represented early fall conditions (September 27-29), where the data collected at RM 120.5 represented late-summer conditions (August 30-September 1). Each of these data sets appeared representative of different seasonal periods. The seasonal effect was most pronounced in the longitudinal temperature data. Throughout the mainstem, diel sampling conducted in late-September, consistently indicated lower stream temperatures, regardless of the location of the sampling station (Figure 13). As such, caution was applied while making longitudinal comparisons.



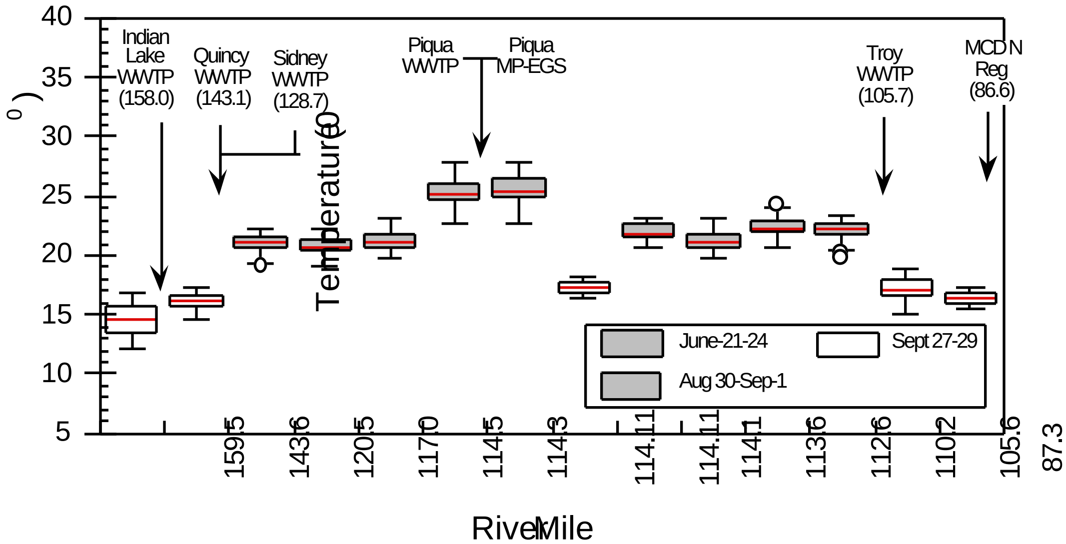


Figure 13 Summarized diurnal dissolved oxygen and temperature data collected with Datasonde continuous monitoring units placed at 14 sampling station within the 1994 Upper Great Miami River study area.

Segment II: (Loramie Creek to downstream MCD N. Regional WWTP)
Discharge of the Great Miami River, monitored at USGS gages in Troy, Dayton and Taylorsville indicated river flows well above the critical $Q_7 10$ values throughout the third quarter (May - September) 1994. Additionally, river discharge was above 80% duration between May and August. Flows less than 80% duration were observed only during the month of September. Peak third-quarter discharge and duration occurred between late-June and early-July, with flows reaching 7000 cfs at the Dayton gage (Figure 14).

Six replicate water chemistry samples were collected at 16 station within Segment II of the Upper Great Miami River study area, between RM 116.7 and RM 85.15. During each of the six sampling runs, field measurements (dissolved oxygen, temperature, pH, and conductivity) and water samples for laboratory analysis were taken over a two-day period.

The average daytime (10:00-15:00) D.O. concentrations remained well-above the WWH criteria (average and minimum) at all locations within Segment II, typically ranging between 9.0-10.0 mg/l (Figure 15). No exceedences of the WWH D.O. criteria were recorded from any water sample collected within Segment II. Marked declines in mean D.O. concentrations were observed within and immediately downstream of the Piqua dam pool (Piqua MP-EGS and Piqua WWTP), and downstream of the Troy WWTP. Despite the declines, adequate D.O. levels were maintained downstream of these facilities.

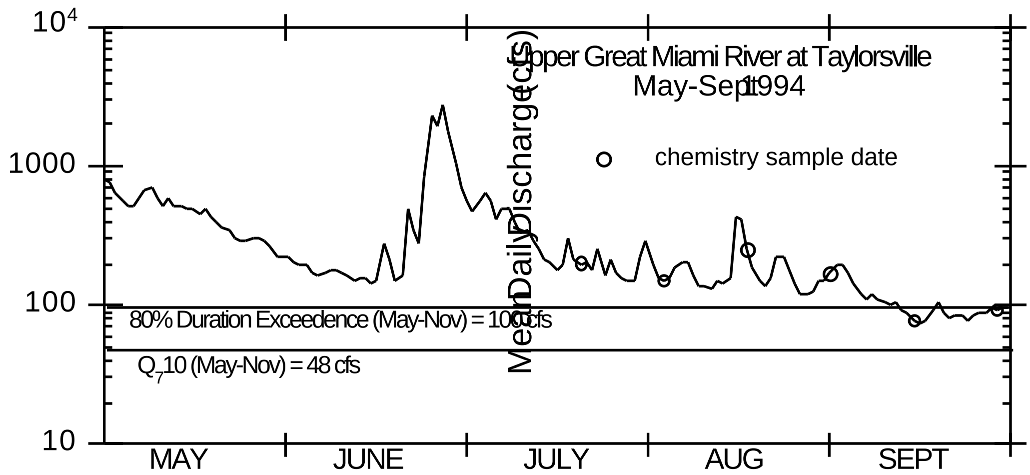
Average BOD_5 values demonstrated a steady increase downstream of the Piqua dam pool (RM 114.28) to Troy (RM 106.1). Mean BOD_5 levels were longitudinally stable and comparable to background conditions downstream of Troy to the lower limits of the study area.

Average ammonia-nitrogen concentrations remained near 0.05 mg/l throughout the study area. No exceedences of the WWH criteria for ammonia-nitrogen were indicated in any of the water samples collected within Segment II.

Average nitrate+nitrite-nitrogen values were near 1.0 mg/l throughout the majority of Segment II. Noted exceptions included, samples collected downstream of the Piqua WWTP and downstream of the MCD North Regional WWTP. Average nitrate+nitrite-nitrogen concentrations were markedly increased within the reaches under the influence of these facilities. The elevated nitrate+nitrite-nitrogen concentrations had little impact on the water quality of the mainstem, and appeared rapidly assimilated.

Average phosphorus values remained well-below the guidance standard of 1.0 mg/l throughout Segment II, with the exception of the station downstream of the Piqua WWTP (RM 114.28). At this location the average value approached 1.4 mg/l. However, this nutrient input appeared rapidly assimilated, evidenced by downstream mean concentrations near background levels and adequate D.O..

Average TSS values increased from 20 mg/l to near 50 mg/l over 5 consecutive sites (RM 123.89 - RM 114.28). Levels remained somewhat elevated throughout the remainder of the reach ranging from 35-50 mg/l. Highest average concentrations were noted in downstream of the Piqua WWTP. During this time, the Piqua WWTP reported NPDES limits violations for TSS, residual chlorine, and fecal coliform.



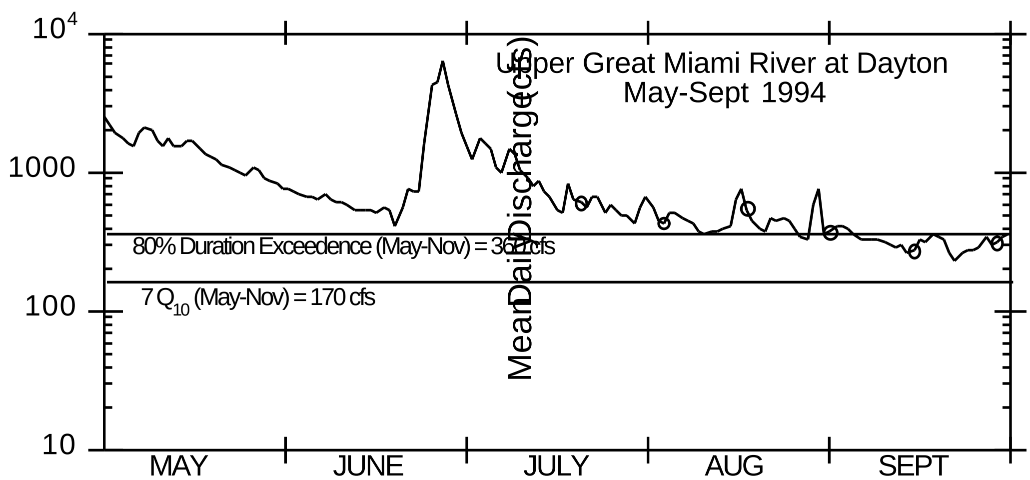


Figure 14 Flow hydrograph for the Great Miami River at Taylorsville and Dayton, May through September, 1994. Open circles indicate river discharge on the dates when water chemistry samples were collected.

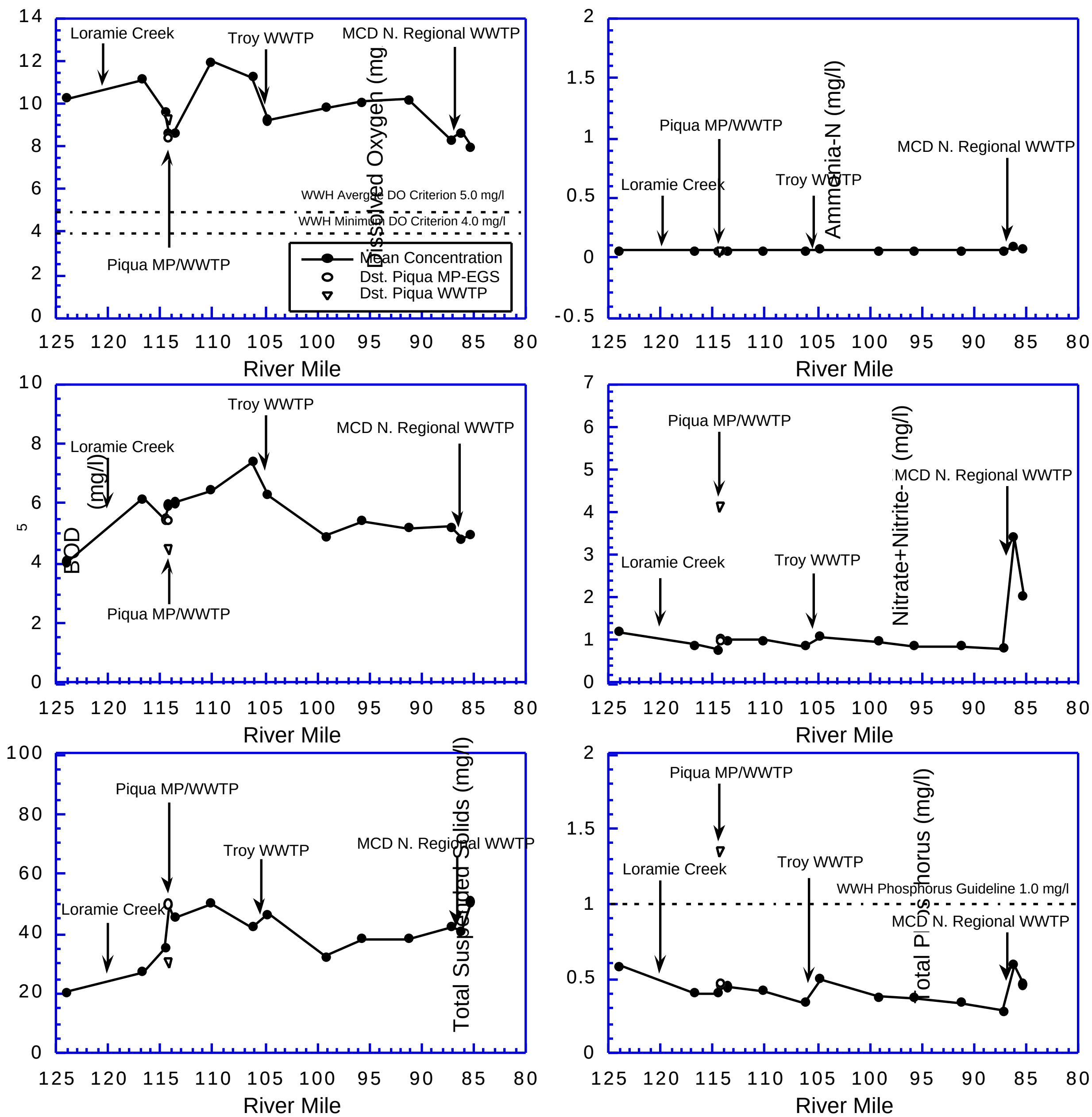


Figure 15 Longitudinal mean concentration of dissolved oxygen, ammonia-nitrogen, nitrate-nitrogen, five-day biochemical oxygen demand, total suspended solids, and total phosphorus from Segment II of the Great Miami River mainstem, 1994.

Over half of the sites sampled revealed exceedences of water quality criteria for pesticide residues (Table 6). Pesticide concentrations within the water column, greater than the average human health and chronic toxicity criteria, were limited to three compounds: Dieldrin, Aldrin, and Endosulfan (I and II). No longitudinal exceedence or river discharge pattern was evident. The majority of the exceedences were observed in early August, during a time when river discharge was above 80% duration; however, sampling events during periods of greater river discharge, in late-August, indicated only one exceedence of the pesticide criteria. The occurrence of these environmentally persistent compounds is most likely related to past agricultural use within the basin. All of these pesticides are commonly held on the exchange complex of silts and clays (Howard 1991). As such, their occurrence within the water column likely reflects the presence of suspended soil particles in the water samples collected.

Datasonde continuous monitors were deployed at 11 locations within Segment II, between RM 117.0 and RM 87.3. The sampling duration was typically 45 hours, and occurred during three distinct periods: August 30-September 1, September 27-29, and June 21-24, 1994.

Diel sampling provided by the continuous monitors indicated that adequate D.O. concentrations, above the WWH standards (average and minimum), were generally maintained throughout Segment II (Figure 13). Only within the Piqua dam pool (RM 114.3) were departures from the WWH standards observed. Between the June 21 and 24, six violations of the 4.0 mg/l WWH minimum D.O. criterion were recorded, with a median value of 5.47 mg/l. The reduced D.O. concentrations within the Piqua dam pool were clearly a result of the impoundment influence, likely exacerbated by thermal and nutrient inputs from the Piqua MP-EGS and the Piqua WWTP respectively. The negative influence of these facilities appeared limited to the dam pool, as adequate D.O. levels were maintained further downstream.

Conductivity (µm/hos), pH (S.U.) and temperature (˚C) values derived from the continuous monitors all remained within the expected range. Exceptions to these observations were limited to conductivity and pH downstream Troy WWTP at RM 104.7. At this location both parameters exhibited elevated readings in comparison with background conditions. The highest median temperatures were recorded within and downstream of the Piqua dam pool (RM 114.3 and RM 114.1) , although instream temperatures did remained below the summer daily maximum criteria of 29.4˚C (Figure 13).

As noted in Segment I, longitudinal evaluation of the Datasonde information from Segment II is, unfortunately confounded by temporal factors. The temperature data collected throughout the mainstem clearly reflects seasonality (Figure 13). Diel sampling in late-June indicated the highest instream values within the entire study area, while the data collected in late-September consistently indicated the lowest instream temperatures. These observation were consistent, regardless of the position of the sampling station on the mainstem. The elevated temperatures recorded within and downstream of the Piqua dam were likely influenced by the thermal discharge from Piqua MP-EGS. However, these data represent the only diel sampling conducted in late-June, and the higher instream temperatures recorded were likely reflective of the of the warmer ambient conditions, typical of mid-summer. Due to the clear seasonality of the data, legitimate longitudinal comparisons are likely precluded. Though diel D.O. data did not reveal as clear a seasonal bias as observed in temperature, similar seasonal factors may have contributed to the results.

Sediment Chemistry

During the summer of 1994 sediment samples were collected from 10 locations on the Upper Great Miami River to assess and characterize the levels of contaminants present in stream sediments. Whenever possible, composite samples of the channel cross-section were collected. Analysis included: selected metals, pesticides residues, and other organic compounds. Base neutral and acid extractables (BNAs) (semi-volatile compounds) were analyzed for 7 of the 10 locations. Volatile organic compounds(VOCs) were analyzed in 5 of 10 locations. The results from sediment analysis were interpreted and characterized by methods provided by Kelley and Hite (1984) and Persaud et al. (1994).

Kelly and Hite (1984) classification system was developed by the Illinois Environmental Protection Agency to evaluate stream sediments by using a mean concentration for each compound from a data base of 94 Illinois background locations. A five tiered classification system was developed based upon the mean plus 1,2,4, and 8, standard deviations. This system addresses relative concentrations and does not directly assess toxicity.

The Persaud et al. (1994) method was developed by the Ontario Ministry of Environment and Energy to objectively rank contaminated sediments. Sediments are classified into three levels of ecotoxic effects based upon the concentration of a contaminant: no effect level, lowest effect level, and severe effect level. Each effect level was derived from bioassay/toxicity testing and/or from ambient data, comparing contaminants with a measure of biological performance. Only the severe effect level was used for heavy metal analysis due to differences in background levels of heavy metals found in Ohio.

Route 25-A in Piqua (RM 116.7) was the most contaminated sediment station within the study area. Iron was found to be in excess of the severe effect level presented by Persaud et al. (1994). Iron at the concentration reported, has been found to affect the health of sediment dwelling organisms. Based upon the Kelly and Hite (1984) classification system lead, zinc, chromium, and iron were ranked as either highly or extremely elevated (Table 7). Possible sources for this contamination, may have been related to fugitive dust released during repairs made on the RT 25-A in the summer of 1994. In addition an old manufacturing complex near the site was demolished in the late summer of 1994. This site could have also contributed fugitive dust to the study area. Regardless, no environmental impact was evident from the sediment contamination at RM 116.7. Additionally, the contamination appeared highly localized, as metal concentration within the remainder of the study area were at or near background levels.

Sediments were scanned for 59 volatile and 93 semivolatile compounds. Volatile organics were not detected in the 5 sediment samples. Three semivolatile compounds were found in 2 of 7 samples (Appendix Table A-2).

Sediments were scanned for 21 pesticide residues and seven PCB congeners. PCBs were not detected at any of the 10 sediment sampling locations. Nine Pesticide residues were detected in 4 of 10 sampling locations. Six of the 9 residues were determined to be below the lowest effect level, and 2 were not rated (Endosulfan II and Heptachlor) (Persaun et al. 1994). Dieldrin was found at a concentration greater than the low effect level (2.65 µg/kg) at RM 86.13 (downstream of the MCD North Regional WWTP) though well below the severe effect concentration. All samples ranked by Kelly and Hite (1984) were considered non-elevated (Appendix Table A-2).

Table 7. Concentrations of heavy metals in sediments of the Upper Great Miami River study area, 1994. Results were evaluated against the Kelly and Hite (1984), Stream Sediment Classification System and the Ontario Aquatic Sediment Quality Guidelines (Persaud et al.1993).

Stream **Landmark River Mile**	**Sediment Concentration (mg/Kg dry weight)** Al	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
Great Miami River										
Indian Lake 159.48	8040	6.74a	0.274a	10.7a	16.1a	17200a	33.3b	20.0	1.61	81.9b
Quincy Dam 143.60	-	4.53a	0.36a	10.8a	17.8 a	13600 a	38.1c	16.4	1.64	81.5b
Quincy WWTP 138.39	9240	4.70a	0.392a	13.6a	18.0a	15800a	37.8b	24.4	1.34	86.2b
Sidney WWTP 130.05	8200	6.32a	0.369a	12.7a	16.4a	13600a	34.1b	21.0	1.14	95.5b
Piqua 25A 116.7	30300	10.4b	1.26c	**48.0d**	69.6c	**46100d**	**139e**	50.0	3.59	**402e**
Piqua Main St. 113.5	-	5.16a	0.567b	17.6b	12.4a	-	41.4c	28.6	0.955	53.8a
Troy Rt 41 106.1	-	4.26a	0.636b	15.1a	13.0a	-	36.1b	23.9	1.16	53.5a
Rt 571 99.1	-	4.99a	0.40a	14.5a	13.0a	23500c	34.2b	24.4	1.13	55.0a
Little York Rd. 91.0	-	5.0a	0.382a	12.0a	11.1a	-	34.9b	25.4	1.22	46.4a
SR 202 86.13	-	8.6b	0.376a	**35.0d**	37.2a	-	54.7c	54.7	1.80	151c

Kelly and Hite Classification System

a - non-elevated
b - slightly elevated
c - elevated
d - highly elevated
e - extremely elevated

Ontario Classification System

bold underlined - above severe effect level

Physical Habitat for Aquatic Life

Segment I (Indian Lake to Loramie Creek)

During the 1994 sampling effort the macrohabitats of the upper portion (Segment I) of the Upper Great Miami River study area were evaluated at 12 sampling stations. Qualitative Habitat Evaluation Index (QHEI) values ranged between 43.0 (downstream from Indian Lake) and 76.5 (upstream of the Quincy WWTP), with a mean reach value of 61.2 (Table 8). A stream segment average QHEI value equal to or greater than 60.0 suggests that near and instream habitats encountered were generally sufficient to support a community of aquatic organisms, at minimum, consistent with the WWH biological criteria (Rankin 1989). However, habitat quality was not homogenous throughout this segment. The condition of physical habitat appeared to improve longitudinally.

Macrohabitats encountered within the reach extending from RM 158.9 (downstream from Indian Lake) to RM 143.8 (Quincy Dam pool) were generally depauperate, characterized by a predominance of moderate influence modified habitat attributes (Table 8). This reach retained much evidence of past channelization, resulting in simplified channel development. Predominant substrates were sand and silts, embedding coarser substrates and limiting the function of additional types of instream cover (*e.g.*, fallen timber, woody debris). The negative influence of these factors is exacerbated by the low gradient of this reach (mean of 0.68 ft/mile), which undoubtedly has limited the rate of natural recovery post modification and creates physical conditions conducive to sediment accretion.

The impoundment formed by the Quincy Dam represented an additional habitat impact. Reduced current velocity, increased sediment deposition, increased embeddedness, and greater physical homogeny are common detrimental effects of impoundments . The simplified, more lentic habitats encountered within the Quincy Dam pool would likely exert a negative influence on the ambient biological potential of this segment.

Macrohabitat quality was markedly improved within the reach extending from RM 143.2 (downstream of the Quincy Dam) to RM 123.9 (upstream of Loramie Creek). Station QHEI values were typically greater than 60.0, reflective of more natural stream conditions. The majority of the stations within this segment contained a fairly diverse array of habitat attributes. The sand and silt substrates common upstream of the Quincy Dam were replaced by coarser glacial boulder, cobble, and gravel. The monotonous channel development, typical of the reach upstream of the Quincy Dam, was replaced by a fairly well developed meandering river course, possessing numerous riffle-run-pool complexes. These positive attributes were likely maintained by the habitat forming fluvial processes associated with an increase in the average gradient (mean of 5.1 ft./mile).

Two lowhead dams in the vicinity of the city of Sidney provided the only impoundment influence downstream of Quincy. One fish sampling station (RM 133.1) was placed within the pool created by a small dam maintained, by the now defunct, Sidney boat club. The sample and subsequent habitat evaluation were conducted a considerable distance upstream of the dam itself, adjacent to Stately Cemetery. Though the area sampled was impounded, it was near the upstream limits of the dam pool. As such, the physical conditions encountered were more reflective of the transition from lotic to lentic habitat, rather than the purely lentic condition encountered in close proximity to the dam itself. The station possessed residual flow, modestly developed meanders, and an abundance of functional instream cover. Though finer substrates predominated, embedding the

Table 8. Qualitative Habitat Evaluation Index (QHEI) matrix showing positive and negative habitat attributes for the Upper Great Miami River study area, 1994.

Key QHEI Components

			Positive Habitat Attributes											Negative Habitat Attributes: High Influence						Moderate Influence														
River Mile	QHEI	Gradient (ft./mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40 cm	Low/No Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse Cover	Max Depth < 40 cm (WD,HW)	**Total H.I. MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover types	Intermittent & Poor Pools	No Fast Current			No Riffle			
14-001) Upper Great Miami River 1994																																		
158.9	43.0	0.7		n				n			n		3						0	s	s			s	s	s		s	s	s	s	9	0.25	2.5
157.3	55.0	0.7	n	n			n	n			n		5						0		s			s				s	s	s	s	6	0.17	1.2
153.1	47.5	0.7						n			n		2	l					1		s			s	s			s	s		s	6	0.67	2.7
146.3	46.5	1.2						n			n		2		l				1	s	s			s	s			s	s		s	7	0.67	3.0
143.8	60.0	0.1	n	n				n		n	n		5						0		s			s	s			s			s	5	0.17	1.0
143.2	76.5	2.8	n	n		n	n	n	n		n		7						0		s								s	s		3	0.13	0.5
142.5	70.5	2.8	n	n			n	n			n		5						0	s	s			s	s			s	s	s		7	0.17	1.3
138.2	71.0	2.0	n	n			n	n			n		5						0	s	s			s				s	s	s		6	0.17	1.2
133.1	60.0	2.0	n	n			n	n			n		5		l				1		s			s	s			s	s		s	6	0.33	1.3
130.0	69.0	12.3	n	n		n	n	n	n		n		7					●	1	s	s				s	s			s	s		6	0.25	1.0
127.7	74.0	5.7	n	n				n			n		4						0					s	s			s	s	s		5	0.20	1.2
123.9	61.0	8.1						n	n		n		3					●	1	s	s		s	s					s	s		6	0.50	2.0
117.5	85.5	2.9	n	n		n	n	n	n	n	n		8								s									s		2	0.11	0.3
114.8	46.0	0.1		n							n			l				●	2	s	s		s	s				s	s		s	7	1.00	3.3
114.3	47.5	0.1		n					n	n	n		4	l				●	2				s	s					s		s	4	0.60	1.4
114.3	51.5	0.1		n						n	n		3	l				●	2				s	s				s			s	4	0.75	1.8
114.1	68.5	4.0	n	n			n	n		n	n		6					●	1	s	s		s	s				s	s		s	7	0.29	1.3
112.7	80.0	4.0	n	n		n	n	n	n	n	n		9						0	s	s		s						s	s		5	0.10	0.6
109.9	77.5	2.3	n	n		n		n	n		n		6					●	1		s		s	s					s	s		5	0.29	1.0
108.5	73.5	2.0	n	n		n		n	n		n		6						0	s	s		s	s					s	s		6	0.14	1.0
106.3	55.0	3.0		n							n		2	l				●	2		s		s	s				s	s	s		6	1.00	3.0
104.7	86.0	3.5	n	n		n	n	n	n		n		7						0		s								s	s		3	0.13	0.5
98.7	77.0	1.8	n	n		n		n	n	n	n		8						0		s			s					s	s		4	0.11	0.6
95.9	88.0	2.7	n	n		n		n	n		n		6						0		s			s					s	s		4	0.14	0.7

Table 8. continued.

Key QHEI Components

Positive Habitat Attributes — **Negative Habitat Attributes** (*High Influence*; *Moderate Influence*)

River Mile	QHEI	Gradient (ft./mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max. Depth > 40 cm	Low/No Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	Low/No Sinuosity	Sparse/No Cover	Max. Depth < 40 cm (WD,HW)	**Total H.I. MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total M.I. MWH Attributes**		
(14-001) Upper Great Miami River 1994																																		
93.8	78.0	2.7	n	n		n		n	n		n		6						0	s	s			s					s	s		5	0.14	0.9
91.0	68.0	2.0		n		n		n	n		n		5		l				1	s	s			s					s	s		5	0.33	1.2
87.3	80.5	6.4	n	n		n	n	n	n		n		7						0	s	s								s	s		4	0.13	0.6
85.0	72.0	6.4		n		n		n	n		n		5							s	s		s	s					s	s		6	0.17	1.2
(14-802) North Fork Great Miami River 1994																																		
11.6	25.0	4.7		n									1	l	l	l	l	l	5		s			s	s			s	s		s	6	3.00	6.0
8.5	35.5	6.3		n				n					2	l	l	l	l	l	5		s			s	s			s	s	s		6	2.00	4.0
4.1	56.5	5.6	n	n				n			n		4			l			1		s			s	s			s	s		s	6	0.40	1.6
(14-803) Blackhawk Run 1994																																		
0.9	43.5	2.6						n			n		2	l	l	l			3		s			s	s			s	s		s	6	1.33	3.3
(14-804) Van Horn Creek 1994																																		
1.3	46.5	9.8		n				n		n			3	l		l	●		3		s			s	s			s	s	s		6	1.00	2.5
(14-800) South Fork Great Miami River 1994																																		
8.0	48.0	11.9		n							n		2			l		●	3	s	s			s	s			s	s	s		7	1.00	3.3
5.8	52.5	6.8						n			n		2		l				1	s	s			s	s			s	s	s		7	0.67	3.0
1.8	62.0	6.8	n	n				n			n		4		l						s			s	s			s	s	s		6	0.40	1.6
(14-805) Unnamed Tributary of the South Fork Great Miami River 1994																																		
3.5	44.0	5.6		n							n		2	l	l			●	3		s			s	s			s	s	s		6	1.33	3.3
0.4	38.0	3.9		n									1	l	l	l	l	l	5		s			s	s			s	s	s		6	3.00	6.0

Table 8. continued.

Key QHEI Components

			Positive Habitat Attributes										**Negative Habitat Attributes**																				
													High Influence						*Moderate Influence*														
River Mile	QHEI	Gradient (ft./mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40 cm	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	Low/No Sinuosity	Sparse/No Cover	Max Depth < 40cm (WD,HW)	**Total H.I. MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	Low/No Riffle Embeddedness		No Riffle			
(14-600) Loramie Creek 1994																																	
36.8	35.5	4.9						■			■	2	●	●	●		●	4	▲	▲			▲	▲			▲	▲	▲		7	1.67	4.0
35.0	42.5	3.1						■			■	2	●	●	●			3	▲	▲			▲	▲			▲	▲	▲		7	1.33	3.7
30.4	43.0	1.0		■				■			■	3	●					1		▲			▲	▲			▲	▲		▲	6	0.50	2.0
29.1	37.0	1.0		■				■			■	3	●	●				2		▲			▲	▲			▲	▲		▲	6	0.75	2.3
28.3	43.0	1.0		■				■			■	3	●	●				2		▲			▲	▲			▲	▲		▲	6	0.75	2.3
20.8	41.0	1.8		■				■			■	3	●					1		▲			▲	▲			▲	▲	▲		6	0.50	2.0
16.6	53.5	2.1		■				■			■	3	●					1		▲			▲	▲			▲	▲		▲	6	0.50	2.0
7.5	71.0	2.3	■	■				■			■	4						0		▲			▲	▲			▲	▲	▲		6	0.20	1.4
3.7	83.0	4.6	■	■		■	■	■	■		■	7						0		▲								▲	▲		3	0.13	0.5
0.5	77.5	8.4	■	■		■	■	■	■		■	7						0		▲								▲	▲		3	0.11	0.4
(14-076) Bokengehalas Creek 1994																																	
8.1	43.5	6.2						■			■	2	●	●		●		3		▲			▲	▲			▲	▲		▲	6	1.33	3.3
4.7	80.0	16.9	■	■		■	■	■	■		■	7		●				1		▲								▲	▲		3	0.25	0.6
0.3	54.5	11.2		■				■	■			3	●	●				2		▲			▲	▲				▲	▲		5	0.60	1.6
(14-077) Blue Jacket Creek 1994																																	
6.4	45.0	31.2		■				■				2			●	●		2	▲	▲			▲	▲	▲		▲	▲	▲	▲	9	1.00	4.0
5.5	81.0	50.0	■	■		■	■	■	■		■	7						0		▲								▲	▲		3	0.13	0.5
3.1	64.0	8.2		■				■			■	3			●			1	▲	▲			▲	▲			▲	▲	▲		7	0.50	2.3
0.8	41.0	12.5		■							■		●		●		●	3		▲			▲	▲	▲		▲	▲	▲		7	1.33	3.7
(14-085) Possum Run 1994																																	
0.7	58.0	55.5		■				■			■	3			●			1	▲	▲			▲	▲			▲	▲	▲		7	0.50	2.3
0.4	74.0	23.8		■		■		■	■		■	5			●			1	▲	▲				▲				▲	▲		5	0.33	1.2

Table 8. continued.

Key QHEI Components

River Mile	QHEI	Gradient (ft./mile)	Positive Habitat Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max. Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	Negative Habitat Attributes, High Influence: Channelized or No Recovery	Silt/Muck Substrates	Low/No Sinuosity	Sparse/No Cover	Max. Depth < 40 cm (WD,HW)	Total H.I. MWH Attributes	Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes		
(14-075) McKees Creek 1994																																		
9.5	53.5	66.6		■			■	■		■	■		5		●	●			2	▲				▲	▲			▲		▲		5	0.50	1.3
0.7	62.0	18.1		■		■	■	■		■	■		6			●			1	▲	▲			▲	▲			▲		▲		6	0.29	1.1
(14-700) Muchinippi Creek 1994																																		
12.5	32.0	4.9									■		1	●	●	●		●	4		▲			▲	▲			▲	▲		▲	6	2.50	5.5
7.4	37.5	3.9		■				■			■		3	●	●			●	3		▲			▲	▲			▲	▲	▲		6	1.00	2.5
1.9	35.0	3.1									■			●	●			●	3		▲			▲	▲			▲	▲		▲	6	2.00	5.0
(14-084) Cherokee Mans Run 1994																																		
3.5	69.0	14.4	■	■		■	■	■			■		6						0		▲		▲					▲	▲	▲		5	0.14	0.9
1.8	65.0	15.3	■	■			■	■			■		5						0		▲			▲				▲	▲	▲		5	0.17	1.0
(14-050) Spring Creek 1994																																		
1.0	61.0	25.0	■	■				■			■		4					●	1					▲	▲			▲	▲	▲		5	0.40	1.4
(14-072) Stony Creek 1994																																		
3.2	24.5	5.2											0	●	●		●	●	4		▲			▲	▲			▲	▲		▲	6	5.00	5.0
(14-048) Lost Creek 1994																																		
9.8	87.5	16.1	■	■		■	■	■		■	■	■	8						0									▲				1	0.11	0.2
2.5	54.0	8.0		■							■							●	1	▲	▲			▲	▲			▲	▲	▲		7	0.67	3.0
(14-043) Honey Creek 1994																																		
10.0	70.5	11.4	■	■				■	■	■	■		6						0	▲			▲	▲				▲	▲			5	0.14	0.9
8.0	85.0	15.2	■	■		■	■	■	■	■	■		8						0				▲					▲	▲			3	0.11	0.4
3.2	67.5	5.2					■	■	■		■		5						0	▲	▲		▲				▲	▲	▲			6	0.17	1.2

natural coarse glacial substrates, areas of relatively clean coarse substrate were maintained. Though by no means optimal, near and instream habitats encounter at RM 133.1 appeared capable of supporting a community consistent with the WWH biological criteria.

Segment II (Loramie Creek to downstream from the MCD N. Reg. WWTP)
During the 1994 sampling effort the macrohabitats of the lower portion (Segment II) of the Upper Great Miami River study area were evaluated at 16 sampling stations. Qualitative Habitat Evaluation Index (QHEI) values ranged between 46.0 (RM 114.8, upstream from the Piqua Dam) and 88.0 (RM 95.9, Ross Rd.), with a mean reach value of 70.9 (Table 8). A stream segment average QHEI value equal to or greater than 60.0 suggests that near and instream habitats encountered were generally sufficient to support , at minimum, a community of aquatic organisms consistent with the WWH biological criteria (Rankin 1989).

The majority of the stations within Segment II contained a diverse array of macrohabitat types commonly associated with natural free flowing riverine systems. The habitat encountered within this segment was characterized by an abundance of coarse glacial substrates, a well developed and sinuous channel, numerous well developed riffle-run-pool complexes, and persistent riparian corridor. These attributes, functioning in concert, provide the requisite physical conditions to support the existing WWH aquatic life use designation.

Areas of diminished habitat quality were limited to segments that were either impounded and/or maintained in a highly channel modified state. Within Segment II, these modified areas comprised only relatively short river reaches flowing through the cities of Piqua, Troy, and Tipp. Though the level of channel modification is extreme within these areas, the vast majority of the Upper Great Miami river is relatively unmodified. Typically, in streams where quality habitat is predominant, relatively short segments of simplified habitat are populated and utilized by emigrant fishes from more productive, physically intact areas (Rankin 1989 and Rankin 1995). As such, many of the short highly modified areas supported an exceptional fish assemblage, comparable to communities encountered in adjacent unmodified reaches.

Additionally, the Miami Concervancy District maintains a retarding basin dam, the Taylorsville Dam, near Vandalia. A retarding basin or flow through dam, impedes or impounds river discharge during periods of high or flood flow only. As a result, the physical integrity of the riverine habitat is preserved, while maintaining adequate flood control. Macrohabitat quality was unimpaired by the Taylorsville Dam.

Biological Assessment: Macroinvertebrate Community

Segment I (Indian Lake to Loramie Creek)

Macroinvertebrate communities were evaluated at 13 stations on the Great Miami River from Indian Lake to the confluence of Loramie Creek (RM 119.89). The Invertebrate Community Index (ICI) ranged from 56 (exceptional) at Baker Road (RM 138.5) to 30 (fair) at CR 13 (RM 153.5) (Table 9, Figure 16). The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT), a measure of the diversity of pollution sensitive taxa, was at Baker Road with 25 taxa.

Macroinvertebrate taxa collected in the Great Miami River that are indicative of high quality streams in Ohio included the caddisflies *Psychomyia flavida* at RMs 143.4 and 130.1, *Protoptila sp.* at RM 138.5, and *Helichopsyche borealis* at four stations between RM 138.5 and RM 85.9. Freshwater mussels (Unionidae) were not commonly encountered during this study except at the station (RM 158.3) upstream from the Indian Lake WWTP. The community at this station included live and fresh-dead specimens of *Anodonta grandis* (giant floater), *Fusconaia flava* (Wabash pigtoe), *Lampsilis radiata luteola* (fat mucket), *Lampsilis ventricosa* (plain pocketbook) and *Quadrula quadrula* (mapleleaf). The only additional unionid species collected as a fresh-dead specimen was *Lasmigona costata* (fluted-shell) at RM 95.7 and RM 91.1. Observation of live unionids in the Great Miami River downstream from about Piqua was precluded by the consistently murky to turbid nature of the water.

The Indian Lake WWTP (RM 157.95) was not significantly impacting the macroinvertebrate community in the Great Miami River. The ICI score declined two points 0.6 mile downstream from the WWTP at SR 235 (ICI=38 at RM 157.3) without any significant shift in community composition. The eight point decline in ICI score at CR 13 (ICI=30 at RM 153.5) was due to the decline of five ICI metrics along with an increase in two. The community was not substantially different from the two upstream stations with the exception of an increase in percent tolerant taxa [mostly midges of the *Polypedilum (P.) fallax* group] to 16.4% (from 5.3% at RM 157.3). Total EPT taxa richness increased to 12 compared to 10 at the two upstream stations. The community response at this station may be due to mild organic enrichment. The macroinvertebrate community improved to the exceptional range by SR 47 (ICI=48 at RM 148.6).

The macroinvertebrate community sampled in the Quincy dam pool (RM 144.2) was performing well below WWH expectations; the ICI score of 18 was within the nonsignificant departure range of the biocriterion for Modified Warmwater Habitat (MWH). The ICI was not designed to evaluate lentic habitats, but based on reference sites from modified habitats, the ICI is expected to achieve a score of 22. The somewhat below expected ICI score may be a response to organic enrichment. The community was predominated by Oligachaeta (aquatic segmented worms) and midges of the genus *Glyptotendipes (Phytotendipes).* The ICI of 40 at the station immediately downstream from the Quincy Dam (RM 143.4) achieved the WWH biocriterion, but the community was structurally indicative of organic enrichment. High numbers of filter feeding hydropsychid caddisflies (increasing to 3276 from 347 at RM 148.6) was an indication of an ample food supply which could be planktonic algae from the dam pool along with other types of suspended organic matter. The midge *Polypedilum (P.) convictum* was also present in high numbers (1826 from 15 at RM 148.6) and oligochaetes continued to be present in relatively high numbers (240 from 568 at RM 144.2). Mayfly diversity and abundance also declined compared to upstream from the dam pool. This community response is fairly typical downstream from a dam pool or lake outlet (Hynes 1970)

Table 9. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Great Miami River study area, 18 July to 17 October 1994.

Quantitative Evaluation

Stream River Mile	Density (/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total EPT[a]	ICI	Evaluation
Great Miami River 1994 (WWH Use Designation)							
158.3	416	43	45	7	10	40	Good
157.3	575	33	45	5	10	38	Good
153.5	255	35	29	8	12	30*	Fair
148.6	388	36	46	14	16	48	Exceptional
144.2	387	33	18	2	4	[18][b]	Fair
143.4	1394	41	51	9	17	40	Good
142.7	747	50	51	12	19	52	Exceptional
138.5	1714	42	70	19	25	56	Exceptional
133.2	1224	34	31	8	16	40	Good
130.1	1489	46	45	13	22	40	Good
128.6	*2062*	*32*	*34*	*7*	*10*	*[22][c]*	*Fair*
127.5	1504	45	34	8	16	40	Good
123.9	1541	37	57	14	17	50	Exceptional
118.5	2080	27	56	13	18	44	Very Good
114.9	533	26	26	7	12	[22][b]	Fair
114.27 E	2612	36	37	11	18	38	Good
114.27 W	1748	40	33	12	21	46	Exceptional
114.22	2740	38	43	15	24	46	Exceptional
113.5	2062	33	59	21	27	52	Exceptional
110.1	1613	36	60	16	21	54	Exceptional
106.1	2689	31	51	17	22	48	Exceptional
105.6	*2327*	*32*	*25*	*7*	*13*	*[22][c]*	*Fair*
105.4	2081	34	36	13	20	50	Exceptional
100.8	1195	41	56	15	21	52	Exceptional
95.7	1968	35	63	16	21	52	Exceptional
91.1	2202	36	59	19	23	56	Exceptional
87.7	2626	39	49	16	22	52	Exceptional
86.6	*1599*	*27*	*21*	*3*	*11*	*[22][c]*	*Fair*
85.9	3023	40	50	14	17	38	Good
N. Fk. Great Miami River (WWH Use Designation)							
10.7	-	-	53	12	-	-	Marginally Good
8.3	-	-	43	14	-	-	Good
6.3	79	31	45	9	11	38	Good

Table 9. continued.

Quantitative Evaluation ***Stream*** River Mile	Density (/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total EPT[a]	ICI	Evaluation
Blackhawk Run (WWH Use Designation)							
2.3	697	40	35	8	10	34[ns]	Marginally Good
Van Horn Creek (WWH Use Designation)							
1.0	385	30	44	9	9	[24][d]	Marginally Good
S. Fk. Great Miami River (WWH Use Designation)							
8.0	598	55	60	15	17	54	Exceptional
5.8	625	48	56	12	16	52	Exceptional
1.8	-	-	69	17	-	-	Exceptional
Trib. to S. Fk. Great Miami River (RM 5.27) (No existing Use Designation)							
3.4	-	-	42	14	-	-	Very Good
0.5	-	-	56	17	-	-	Exceptional
Cherokee Mans Run (WWH Use Designation)							
3.7	906	47	51	11	14	44	Very Good
Bokengehalas Creek (WWH Use Designation							
8.0	-	-	57	13	-	-	Good
4.7	-	-	43	10	-	-	Good
0.4	541	53	51	13	18	48	Exceptional
Blue Jacket Creek (WWH Use Designation)							
6.4	-	-	29	1	-	-	Poor
5.4	-	-	38	5	-	-	Fair
3.2	-	-	46	7	-	-	Marginally Good
0.6	656	41	42	5	6	44	Very Good
Possum Run (WWH Use Designation)							
0.7	-	-	16	1	-	-	Poor
0.3	-	-	26	3	-	-	Low Fair
McKees Creek (EWH Use Designation)							
0.9	294	44	52	11	16	52	Exceptional

Table 9. continued.

Quantitative Evaluation ***Stream*** River Mile	Density (/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total EPT[a]	ICI	Evaluation
Loramie Creek (WWH Use Designation)							
36.8	-	-	24	1	-	-	Poor
34.9	632	37	34	4	4	18*	Fair
31.7	308	33	34	2	4	18*	Fair
20.7	1023	28	38	5	7	26*	Fair
14.8	929	27	38	5	7	26*	Fair
5.8	1733	36	55	15	21	36	Good
3.7	1414	43	45	13	20	48	Exceptional
0.4	1017	46	45	13	16	52	Exceptional
Spring Creek (EWH Use Designation)							
1.2	133	20	43	14	15	[20][d]	Very Good
1.0	-	-	45	14	-	-	Very Good
Lost Creek (EWH Use Designation)							
9.9	398	32	48	15	17	[32][d]	Very Good
9.8	-	-	65	20	-	-	Exceptional
2.5	-	-	55	16	-	-	Very Good
Honey Creek (EWH Use Designation)							
10.1	354	43	50	21	24	44[ns]	Very Good
9.9	-	-	63	20	-	-	Exceptional
8.1	366	40	60	13	16	[30][d]	Marginally Good
3.2	436	53	67	20	25	40*	Good

Table 9. continued.

Qualitative Evaluation ***Stream*** River Mile	No. Qual. Taxa	Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[e]
N. Fk. Great Miami River (WWH Use Designation)					
10.7	53	12	Moderate	Scuds, baetid mayflies,	Marg. Good
8.3	43	14	Mod.-Low	Mayflies	Good
Van Horn Creek (WWH Use Designation)					
1.0	44	9	Mod.-Low	Aquatic sow bugs, midges	Marg. Good
S. Fk. Great Miami River (WWH Use Designation)					
1.8	69	17	Moderate	Hydropsychid caddisflies, baetid mayflies, midges	Exceptional
Trib. to S. Fk. Great Miami River (RM 5.27) (No existing Use Designation)					
3.4	42	14	Mod.-Low	Midges, *Chimarra* caddisflies	Very Good
0.5	56	17	Mod.-Low	Riffle beetles, *Chimarra* caddisflies, baetid mayflies	Exceptional
Bokengehalas Creek (WWH Use Designation)					
8.0	57	13	Mod.-High	Hydropsychid caddisflies, riffle beetles, midges	Good
4.7	43	10	Mod.-Low	Hydropsychid caddisflies, riffle beetles	Good
Blue Jacket Creek (WWH Use Designation)					
6.4	29	1	Low	Flatworms, riffle beetles, midges	Poor
5.4	38	5	Mod.-High	Flatworms, hydropsychid caddisflies, midges	Fair
3.2	46	7	Low	Flatworms, hydropsychid caddisflies, midges	Marg. Good
Possum Run (WWH Use Designation)					
0.7	16	1	Low	None	Poor
0.3	26	3	Moderate	hydropsychid caddisflies, flatworms, midges	Low Fair

Table 9. continued.

Qualitative Evaluation ***Stream*** River Mile	No. Qual. Taxa	Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[e]
Loramie Creek (WWH Use Designation)					
36.8	34	1	Low	None	Poor
Spring Creek (EWH Use Designation					
1.2	43	14	Moderate	Hydropsychid caddisflies	Very Good
1.0	45	14	Moderate	Caddisflies, midges, mayflies	Very Good
Lost Creek (EWH Use Designation)					
9.9	38	15	Moderate	Caddisflies, midges, riffle beetles	Very Good
9.8	65	20	Mod.-Low	Caddisflies, mayflies, riffle beetles	Exceptional
2.5	55	16	Mod.-Low	Caddisflies, mayflies, midges	Very Good
Honey Creek (EWH Use Designation)					
9.9	63	20	Mod.-Low	Caddisflies, mayflies, midges	Exceptional
8.1	60	13	Moderate	Midges, baetid mayflies, flatworms, blackflies	Marg. Good

Ecoregion Biocriteria: Invertebrate community Index (ICI)

	WWH	EWH	MWH
Eastern Corn Belt Plains (ECBP)	36	46	22

[a] EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa richness.

[b] The sample was located in an impoundment.

[c] Mixing zone sampling location.

[d] The quantitative (artificial substrate) sample was affected by slow current speed and the evaluation was based primarily on the qualitative (natural substrate) sampling results.

[e] A qualitative narrative evaluation based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.

* Significant departure from ecoregion biocriterion (>4 ICI units); poor and very poor results are underlined.

[ns] Nonsignificant departure from biocriterion (≤4 ICI units).

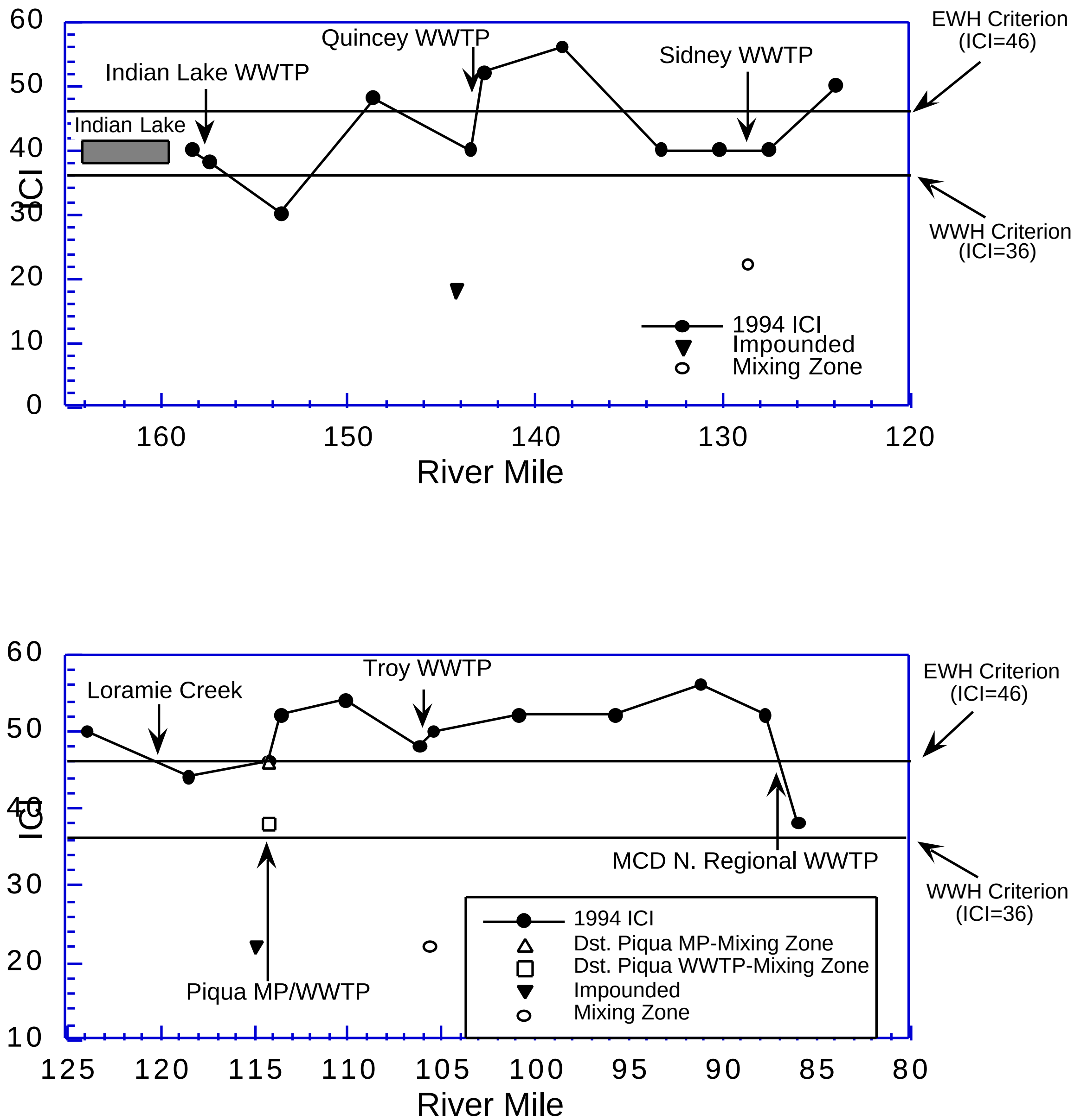


Figure 16 Longitudinal performance of the Invertebrate Community Index (ICI) for Segment I and Segment II of the 1994 Upper Great Miami River study area. The solid lines represent numerical biological criteria in support of the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life use designations, Eastern Corn Belt Plains ecoregion. Both Segment I and II of the Great Miami River are currently designated WWH.

The macroinvertebrate community improved to the exceptional range by the GT&I railroad trestle (ICI=52 at RM 142.7). The Quincy WWTP (RM 143.05) was not having any discernible impact on community performance. The community remained exceptional at Baker Road (ICI=56 at RM 138.5), which had the highest ICI score and highest total EPT taxa richness (25) in this segment, but then declined to the good range at Staley Cemetery (ICI=40 at RM 133.2). Six ICI metrics declined two to four points, but without much increase in percent abundance of tolerant taxa. This general decline in community performance was probably due to the station becoming impounded sometime during the artificial substrate colonization period. The unexpected impoundment was caused by a private individual raising the height of an old lowhead dam located on the premises of the now defunct Sidney Boat Club. Water current speed over the artificial substrates was, however, maintained at the desired minimum level of 0.3 ft./sec. The station at North Street (RM 130.1) demonstrated increased EPT taxa richness (22 from 16 at RM 133.2), however, the ICI stayed at 40 (good) due to a decline in structural metrics caused by high numbers of the midge *Polypedilum (P.) convictum* (1530 from 219 at RM 133.2) and relatively high numbers of oligochaetes (224 from 48 at RM 133.2). The community response at this station may be due to a mild enrichment effect.

The macroinvertebrate community within the Sidney WWTP (RM 128.68) mixing zone was predominated by pollution tolerant oligochaetes and tolerant to intermediate taxa of midges (ICI=22 at RM 128.6). The percent abundance of tolerant organisms increased to 73.8% (from 5.1% at RM 130.1) and the percent abundance of dipterans and non-insects (Metric 8) increased to 95.7% (from 44.5% at RM 130.1). Compositional ICI metrics were less strongly affected with three of the four metrics meeting the expectation for a good community. This community response was indicative of severe organic enrichment within the mixing zone with an, at most, mildly toxic component. The community 1.1 miles downstream from the Sidney WWTP returned to the good range (ICI=40 at RM 127.5). Continued high numbers of the midge *Polypedilum (P.) convictum* (1513) and relatively high numbers of oligochaetes (160) was an indication of continued enrichment. The downstream improvement continued at Kouther Road were the ICI increased to the exceptional range (ICI=50 at RM 123.9).

Segment II (Loramie Creek to downstream MCD N. Reg. WWTP)
Macroinvertebrate communities were evaluated at 16 stations on the Great Miami River from the confluence of Loramie Creek (RM 119.89) to downstream from the MCD North Regional WWTP (RM 86.6). The Invertebrate Community Index (ICI) ranged from 56 (exceptional) at Little York Road (RM 91.1) to 38 (good) downstream from the Piqua WWTP discharge (RM 114.27E) and downstream from the MCD North Regional WWTP discharge (RM 85.9) (Table 9, Figure 16). The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT), a measure of the diversity of pollution sensitive taxa, was located downstream from Piqua, adjacent to CR 15A (RM 113.5) with 27 taxa.

Macroinvertebrate communities in the Great Miami River were very good or exceptional at the free-flowing stations, except for the sites downstream from the Piqua WWTP and the MCD North Regional WWTP. Macroinvertebrate communities within impoundments were not achieving WWH biocriterion expectations, while the majority of the free-flowing stations were achieving exceptional levels. The restricted flow and slack current speed inherent within the impoundments created unsuitable habitats for riverine macroinvertebrate communities. The dams also likely impeded the free movement of fish which serve as the glochidia host for freshwater mussels (Unionidae) and as their dispersal mechanism. Unionids as a whole are declining in diversity and abundance across the country and every effort should be made to promote their recovery.

Therefore, in order for these stretches of the Great Miami River to meet the standards and promote the unimpeded dispersal of aquatic organisms, the feasibility of removing each lowhead dam on the river should be investigated.

The Piqua Municipal Power EGS (RM 114.35, west bank) and the Piqua WWTP (RM 114.35, east bank) discharge to the Piqua Dam pool immediately upstream from the dam (RM 114.3). Macroinvertebrate communities were evaluated immediately downstream from the dam on the east and west sides of the river to evaluate these two dischargers. The major community response to the two dischargers and any enrichment from the reservoir was increased numbers of flatworms, oligochaetes, and non-Tanytarsini midges. The station downstream from the Piqua Municipal Power EGS was the least affected and achieved an exceptional ICI score (ICI=46 at RM 114.27W). The mild enrichment observed at this station my be attributable to the stations close proximity to the reservoir discharge. No thermal discharge was evident from the community response at this station. The station downstream from the Piqua WWTP was more severely affected by enrichment and only achieved a good ICI score (ICI=36 at RM 114.27E). Relatively high numbers of pollution tolerant oligochaetes (640) and the midge *Nanocladiusdistinctus* (115) caused the percent abundance of tolerant organisms (6.2%) (Metric 9) to strongly deviate from the expectation for a good community. This community response was indicative of enrichment without any discernible toxic effect. Mild organic enrichment continued at the station downstream from the two dischargers with continued high numbers of flatworms (1125) and oligochaetes (512). The remainder of the community was, however, mostly unaffected and the ICI scored in the exceptional range (ICI=46 at RM 114.22). The community recovered to upstream conditions with low numbers of oligochaetes (0), flatworms (65), and non-Tanytarsini midges at the station downstream from Piqua adjacent to CR 25A (ICI=52 at RM 113.5).

The Troy WWTP (RM 105.67) was highly impacting the macroinvertebrate community performance in its mixing zone (ICI=22 at RM 105.6). The ICI declined to the fair range due primarily to structural changes in the community. The percent abundance of tolerant organisms (Metric 9) increased to 17.3% (from 0.3% at RM 106.1) and percent abundance of other dipterans and non-insects (Metric 8) increased to 90.9% (from 11.3% at RM 106.1). Mayfly and caddisfly diversity declined somewhat, but only the mayfly taxa richness ICI metric declined below the expected level for a good community. Eighty-nine percent of the hydropsychid caddisflies in the quantitative sample had severely “burned” gills, which was an indication of chlorine toxicity (Simpson 1980). The community response in the Troy WWTP mixing zone was indicative of strong organic enrichment along with mild toxicity, possibly from chlorine. The community recovered to the exceptional range 0.67 mile downstream from the discharge (ICI=50 at RM 105.6).

The MCD North Regional WWTP (RM 86.6) was highly impacting the macroinvertebrate community performance in its mixing zone (ICI=22 at RM 86.6). The ICI declined to the fair range due to structural and compositional changes in the community. The percent abundance of tolerant organisms (Metric 9) increased to 11.4% (from 1.9% at RM 87.7) and percent abundance of other dipterans and non-insects (Metric 8) increased to 89.0% (from 16.2% at RM 87.7). Caddisfly diversity declined somewhat, but the mayfly taxa richness ICI metric declined below the expected level for a good community with only 4 taxa present (from 9 at RM 87.7). Fifteen percent of the hydropsychid caddisflies in the quantitative sample had severely “burned” gills, which was an indication of chlorine toxicity (Simpson 1980). The community response in the MCD North Regional WWTP mixing zone was indicative of strong organic enrichment along with mild toxicity, possibly from chlorine. The community recovered only to the good range 0.7 mile downstream from the discharge (ICI=38 at RM 85.9). Continued high numbers of the midge subgenus *Glyptotendipes (Phytotendipes)* (1015 from 233 at RM 87.7) and oligochaetes (608 from 192 at RM 87.7) was an indication of continued organic enrichment from the WWTP discharge.

Biological Assessment: Fish Community

A total of 28,831 fish, comprising 66 species and 10 hybrids, was collected from the Upper Great Miami River mainstem, between July 21 and August 30, 1994. The sampling effort included 31 sampling stations located between RM 158.9 (Indian Lake) and RM 85.0 (city of Dayton), providing an assessment coverage of 73.9 river miles (118.9 km).

Numerically predominant fish species were: golden redhorse (15.4%), spotfin shiner (13.2%), smallmouth bass (10.1%), northern hog sucker (9.04%), and longear sunfish (4.70%). Species that predominated in terms of biomass included: golden redhorse (34.1%), common carp (27.7%), northern hog sucker (9.09%), smallmouth bass (6.77%), and quillback carpsucker (2.18%).

In terms of numerical abundance, the majority of the species encountered were classified as being moderately intolerant of physical habitat and water quality degradation (*e.g.*, golden redhorse, northern hog sucker, smallmouth bass) (Ohio EPA 1987b). A similar pattern was observed in terms of biomass distribution within the fish assemblage, the majority being concentrated in moderately intolerant species. Though the highly tolerant common carp comprised a considerable proportion of total biomass (27.7%), its position within the community appeared fairly typical in comparison with other medium to large river systems within Ohio. This highly adaptable species is well distributed (Trautman 1981), and commonly occupies a prominent position within the fish assemblages of some of the state's high quality waterways. The abundance of this tolerant species was not indicative of environmental degradation, particularly considering the abundance of environmentally sensitive taxa.

Fish community samples collected between RM 158.9 and RM 157.3 employed the standard wading methodology, while the remaining portion of the study area (RM 153.1 and RM 85.0) was sampled with the standard boat methodology (Ohio EPA 1987b). Community samples collected by wading and boat methods employed both the MIwb and IBI to evaluate the condition of the fish assemblage. Community indices and narrative evaluations ranged between *exceptional* (MIwb=10.9 and IBI=59) at RM 130.0 and *marginallygood-fair* (MIwb=8.1 and IBI=32) at RM 157.3. As a whole, the fish assemblage of the Upper Great Miami River can be characterized as *exceptional* (Table 10).

Taken together, species richness, gross distribution of biomass and numerical abundance within the assemblage, and mean community index values indicate that the fish community supported within the Upper Great Miami River is diverse and abundant, with environmentally sensitive species well represented. These broadly applied community attributes are reflective of good water quality and intact macrohabitats that typify much of the study area.

Table 10. Fish community indices and descriptive statistics based on samples collected by Ohio EPA from the Upper Great Miami River study area, 1980 - 1994.

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (wt./km)	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Upper Great Miami (1994)								
Eastern Corn Belt Plains- WWH Use Designation (Existing)								
158.9(w)	31.0	33	442.5	10.7	43.0	8.6	40	Good
157.3(w)	28.0	33	480.8	99.1	55.0	8.1ns	32*	M.Good-Fair
153.1(B)	21.0	27	322.0	173.8	47.5	8.1ns	41ns	M.Good
146.3(B)	24.5	28	509.0	157.3	46.5	8.9	39ns	Good-M.Good
143.8(B,I)	22.0	25	527.1	196.3	60.0	8.3ns	37*	M.Good-Fair
Eastern Corn Belt Plains- WWH /EWH Use Designation (Existing/Recommended)								
143.2(B)	35.0	44	2096.8	169.9	76.5	10.7	53	Exceptional
142.5(B)	27.5	32	1087.0	185.5	70.5	9.8	52	Exceptional
138.2(B)	32.5	37	1239.0	191.4	71.0	10.0	55	Exceptional
Eastern Corn Belt Plains- WWH Use Designation (Existing)								
133.1(B,I)	28.0	35	1022.0	117.0	60.0	9.4	53	V.Good-Excp.
Eastern Corn Belt Plains- WWH /EWH Use Designation (Existing/Recommended)								
130.0(B)	29.0	31	1489.0	308.1	69.0	10.9	59	Exceptional
128.6(B,MZ)	18.0	24	2550.0	158.6	-	10.0	47	Excp.-V.Good
127.7(B)	33.5	38	1077.0	227.6	74.0	10.7	57	Exceptional
123.9(B)	27.5	31	934.0	223.1	61.0	10.1	57	Exceptional
117.5(B)	29.5	34	1130.7	219.6	85.5	10.4	59	Exceptional
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
114.8(B,I)	20.0	24	741.0	144.8	46.0	9.2	45	V.Good
114.3(B,MZ,a)	11.5	14	715.0	312.5	47.5a	8.6	39	Good-M.Good
114.3(B,MZ,b)	13.0	16	1060.0	212.5	51.5b	7.9	39	Fair-M.Good
114.1(B)	26.0	29	727.0	159.0	68.5	9.4	50	V.Good-Excp.
Eastern Corn Belt Plains- WWH /EWH Use Designation (Recommended/Existing)								
112.7(B)	24.0	27	578.0	140.7	80.0	9.1ns	48	V.Good-Excp.
109.9(B)	26.5	31	1085.0	201.9	77.5	9.9	57	Exceptional
108.5(B)	27.5	30	1402.0	232.7	73.5	10.1	57	Exceptional
106.3(B)	24.0	27	1055.5	130.9	55.0	10.2	52	Exceptional
105.6(B,MZ)	22.0	27	3090.0	238.1	-	9.9	47	Excp.-V.Good
104.7(B)	27.5	30	1407.0	201.7	86.0	10.7	55	Exceptional
98.7(B)	27.0	31	1234.0	211.0	77.0	10.4	57	Exceptional
95.9(B)	28.0	31	1682.0	238.8	88.0	10.5	57	Exceptional
93.8(B)	25.5	29	1205.2	302.5	78.0	10.1	56	Exceptional
91.0(B)	30.5	36	1012.0	185.8	68.0	10.5	54	Exceptional
87.3(B)	27.0	31	1005.0	234.4	80.5	10.2	54	Exceptional
86.6(B,MZ)	14.5	20	2140.0	134.1	-	9.0	47	Good-V.Good
85.0(B)	28.0	34	1216.8	196.2	72.0	10.1	56	Exceptional

Table 10. continued.

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (wt./km)	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Upper Great Miami River (1982)								
	Eastern Corn Belt Plains - WWH Aquatic Life Use Designation (Existing)							
158.5(B)	20.3	31	329.0	135.0	-	7.8*	25*	Fair-Poor
156.8(B)	13.0	24	133.0	40.5	-	5.3*	22*	Poor
155.5(B)	13.0	20	194.0	82.3	-	6.8*	22*	Fair-Poor
151.6(B)	15.7	27	201.0	49.9	-	7.6*	41ns	Fair-M.Good
146.7(B)	17.5	23	134.0	35.9	-	7.9*	39ns	Fair-M.Good
145.5(B)	14.3	24	106.0	30.0	-	6.9*	34*	Fair
143.6(B)	10.3	19	79.0	35.7	-	6.1*	26*	Poor-Fair
142.6(B)	14.0	26	316.0	88.6	-	7.2*	47	Fair-V.Good
138.0(B)	11.3	16	238.0	77.7	-	7.2*	45	Fair-V.Good
133.5(B)	16.0	24	354.0	82.3	-	8.1ns	50	M.Good-Excp.
130.0(B)	25.3	37	270.0	74.2	-	9.0	49	Good-Excp.
128.0(B)	18.3	28	302.0	87.6	-	8.7	47	Good-V.Good
124.2(B)	18.7	27	323.0	56.0	-	8.1ns	37*	Good-Fair
116.9(B)	21.3	30	388.0	80.1	-	8.8	45	Good-V.Good
115.3(B)	13.3	18	201.0	28.2	-	7.4*	38ns	Fair-M.Good
114.7(B)	12.7	19	175.0	56.7	-	6.1*	31*	Poor-Fair
113.8(B)	16.0	21	276.0	117.5	-	7.8*	42	Fair -Good
111.3(B)	18.0	25	423.0	143.6	-	8.1ns	35*	M.Good-Fair
108.5(B)	16.3	26	415.0	91.4	-	8.0ns	49	M.Good-Excp.
107.6(B)	13.7	18	177.0	39.9	-	7.5*	35*	Fair
106.8(B)	20.7	30	344.0	99.4	-	8.7	45	Good-V.Good
104.7(B)	17.0	20	466.0	124.8	-	9.1	48	V.Good-Excp.
100.7(B)	16.3	26	461.0	133.5	-	8.6	42	Good
98.5(B)	21.5	26	425.0	91.2	-	9.2	52	V.Good-Excp.
95.6(B)	21.7	32	492.0	127.7	-	9.1	49	V.Good-Excp.
94.0(B)	18.3	23	512.0	131.9	-	8.5	51	Good-Excp.

Table 10. continued.

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (wt./km)	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
North Fork Great Miami River (1994)								
Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)								
11.6(H)	12.0	14	2108.4	13.7	25.0	N/A	30*	Fair
8.5(H)	14.0	14	1485.0	13.6	35.5	N/A	26*	Poor
4.1(B)	13.6	19	217.3	14.4	56.5	6.8*	28*	Fair-Poor
Blackhawk Run (1994)								
Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)								
0.9(H)	16.0	23	404.3	7.3	43.5	N/A	40	Good
Van Horn Creek (1994)								
Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)								
1.3(H)	12.0	16	1024.5	4.9	46.5	N/A	27*	Poor
South Fork Great Miami River (1994)								
Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)								
8.0(H)	15.5	19	5143.0	32.7	48.0	N/A	41	Good
5.8(W)	25.0	28	1723.5	41.1	52.0	8.3	39[ns]	Good-M.Good
1.8(W)		23	890.3	15.1	62.0	8.0[ns]	45	M.Good-Good
Tributary to South Fork Great Miami River (1994)								
Eastern Corn Belt Plains- EWH Aquatic Life Use Designation (Recommended)								
3.5(H)	13.0	13	2403.0	8.2	44.0	-	50	Exceptional
0.4(H)	19.0	19	3412.5	12.7	38.0	-	56	Exceptional
Bokengehalas Creek (1994)								
Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)								
8.1(W)	16.0	20	961.5	52.1	43.5	6.1*	28*	Fair
4.7(W)	23.5	27	1782.0	47.1	80.0	8.4	43	Good
0.3(W)	26.5	29	930.0	36.0	54.5	9.4	51	Exceptional
Blue Jacket Creek (1994)								
Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)								
6.4(H)	5.0	6	1872.4	5.1	45.0	N/A	30*	Fair
5.5(H)	9.5	11	4005.8	26.1	81.0	N/A	37[ns]	M.Good
3.1(H)	14.0	16	1461.0	73.1	64.0	N/A	33*	Fair
0.8(H)	15.5	18	2260.5	27.7	41.0	N/A	45	Good

Table 10. continued.

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (wt./km)	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Possum Run (1994)								
	Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)							
0.7(H)	5.5	6	3564.0	11.7	58.0	N/A	32*	Fair
0.4(H)	7.5	8	4080.0	22.7	74.0	N/A	41	Good
Loramie Creek (1994)								
	Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)							
36.8(H)	10.5	12	989.3	2.6	35.5	N/A	21*	Poor
35.0(H)	12.5	15	1049.3	7.9	42.5	N/A	19*	Poor
30.4(W)	11.5	15	191.3	16.4	43.0	6.0*	27*	Fair-Poor
29.1(B)	12.0	15	1487.3	75.5	37.0	6.9*	25*	Fair-Poor
28.3(B)	12.3	17	1324.7	147.4	43.0	7.3*	28*	Fair
20.8(W)	21.0	25	1590.0	46.5	41.0	8.7	30*	Good-Fair
16.6(W)	14.0	19	293.3	43.5	53.5	5.5*	23*	Poor
7.5(W)	24.5	29	759.8	61.9	71.0	7.7*	34*	Fair
3.7(W)	32.0	38	1419.8	48.9	83.0	10.0	48	Excp.-V.Good
0.5(W)	24.0	30	945.8	61.9	77.5	9.4	50	Exceptional
McKees Creek (1994)								
	Eastern Corn Belt Plains- EWH Aquatic Life Use Designation (Existing)							
9.5(H)	12.0	12	826.5	5.5	53.5	N/A	54	Exceptional
0.7(H)	17.5	20	924.0	19.7	62.0	N/A	54	Exceptional
Cherokee Mans Run (1994)								
	Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)							
3.5(H)	19.0	19	1006.5	35.6	69.0	N/A	41	Good
1.8(H)	20.0	20	880.5	47.8	65.0	N/A	50	Exceptional
Muchinippi Creek (1994)								
	Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)							
12.5(H)	18.0	18	1964.0	24.7	32.0	N/A	42	Good
7.4(W)	24.0	24	480.0	11.1	37.5	8.0ns	48	M.Good-V.Good
1.9(W)	20.0	20	195.0	20.1	35.0	6.8*	28*	Fair
Spring Creek (1994)								
	Eastern Corn Belt Plains- EWH Aquatic Life Use Designation (Existing)							
1.0(W)	16.5	18	3493.5	8.0	61.0	8.1*	43*	M.Good-Good

Table 10. continued.

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (wt./km)	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Stony Creek (1994)								
	Eastern Corn Belt Plains- WWH Aquatic Life Use Designation (Existing)							
3.2(W)	17.0	17	142.5	35.9	24.5	5.3*	42	Poor-Good
Lost Creek (1994)								
	Eastern Corn Belt Plains- EWH Aquatic Life Use Designation (Existing)							
9.8(W)	19.5	21	1994.3	24.9	87.5	9.0*	45*	Good
2.5(W)	21.0	23	3934.5	12.6	54.0	9.0*	44*	Good
Honey Creek (1994)								
	Eastern Corn Belt Plains- EWH Aquatic Life Use Designation (Existing)							
10.0(W)	20.0	22	3851.3	11.4	70.5	48ns	9.1 ns	V. Good
8.0(W)	23.0	25	2497.5	23.1	85.0	48ns	9.2 ns	V. Good
3.2(W)	28.0	32	2518.5	15.1	67.5	48ns	9.4	V.Good/Excep.

* - Significant departure from applicable criteria (>4 IBI or >0.5 MIwb units), poor or very poor results are underlined.
ns-Nonsignificant departure from biocriteria (≤4 IBI or ≤0.5 MIwb units).
MZ - Mixing zone sample.
W - Wading station.
B - Boat station.
a - West river bank: 100 meter reach within Piqua dam pool, opposite Piqua Municipal Power-upstream Piqua WWTP.
b - East river bank: 100meter reach within Piqua dam pool, under the influence of Piqua Municipal Power.
I - Community sample collected within an impounded river reach.

Ecoregional Biocriteria:

Eastern Corn Belt Plain (ECBP)

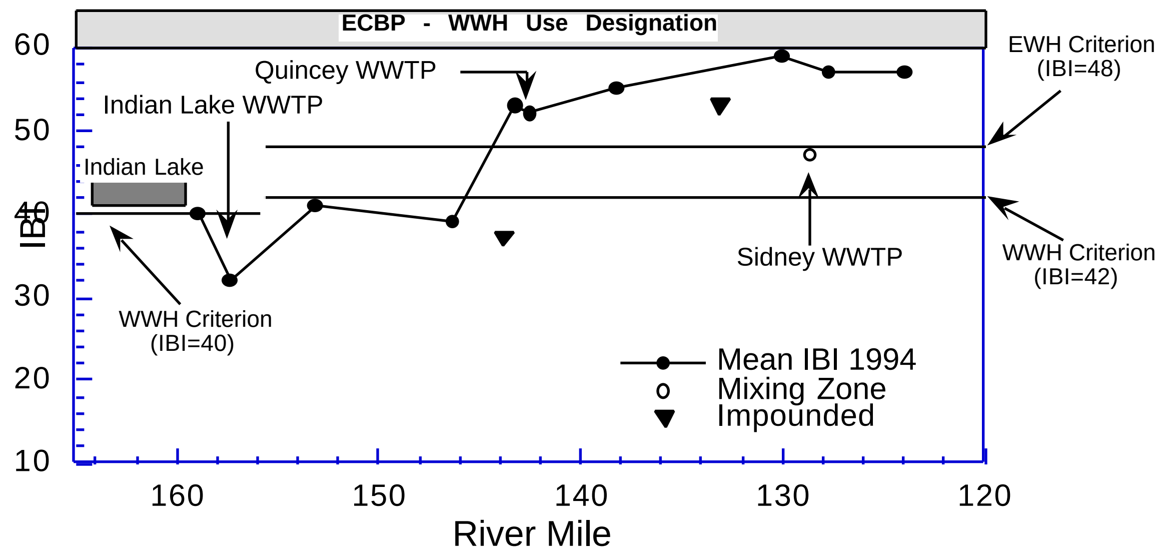
Index - Site Type	WWH	EWH	MWH[c]
IBI - Headwater/Wading	40	50	24
IBI - Boat	42	48	24
MIwb - Wading	8.3	9.4	5.8
MIwb - Boat	8.5	9.6	5.8

c-Modified Warmwater Habitat for channel Modified areas.

Segment I (Indian Lake to Loramie Creek)

The condition of the fish community within the Upper portion of the study area (Segment I) was evaluated at 13 stations, located between RM 158.9 (Indian Lake) and RM 123.9 (upstream of the Loramie Creek confluence). Community indices and narrative evaluations ranged from *exceptional* (MIwb=10.9 and IBI=59) at RM 130.0 to *marginallygood-fair* (MIwb=8.1 and IBI=32) at RM 157.3.

Within the reach extending from RM 158.9 (downstream from Indian Lake) to RM 143.8 (Quincy dam pool) the MIwb indicated a level of community performance consistent with the existing WWH aquatic life use designation (Figure 17 and Table 10). The MIwb did not reveal any significant change in structural evenness within the fish assemblages throughout this segment. However, the IBI indicated significant departure from the WWH criterion at two stations, downstream of the Indian Lake WWTP and within the Quincy dam pool. In comparison with performance upstream (RM 158.9), the IBI was markedly reduced at RM 157.3 (downstream of the Indian Lake WWTP). Reduced IBI performance was primarily driven by shifts in proportional and individual health metrics. The proportion of omnivorous and tolerant species increased, while the proportion of insectivorous and lithophilic species declined. Typically, omnivorous and generalized feeding species predominate in areas where environmental degradation (chemical and/or physical) has disrupted or simplified the food base, favoring these less specialized taxa. The loss or reduction of lithophils can be indicative of habitat impacts, particularly the loss of suitable spawning substrate through sedimentation. The mean percent occurrence of Deformities, Eroded fins, Lesions, Tumors (DELT) anomalies increased significantly from 0.5% upstream (RM 158.9) to 7.2% downstream (RM 157.3). Based upon ecoregional reference conditions, an incidence of DELT anomalies greater than 1.3% (90th percentile) is considered highly elevated (Ohio EPA 1987b). An increase in the occurrence of physical abnormalities has been shown to be a reliable indicator of stream degradation (Leonard and Orth 1986). The changes observed in both the functional organization and health of the fish community were attributed to both the influence of poor physical habitat as well as modest nutrient enrichment from Indian Lake WWTP. Physical conditions within this segment (Indian Lake to Quincy Dam) were generally depauporate. The negative influences of marginal habitat quality were likely exacerbated by moderate nutrient loads from Indian Lake WWTP, resulting in the impact observed at RM 157.3.



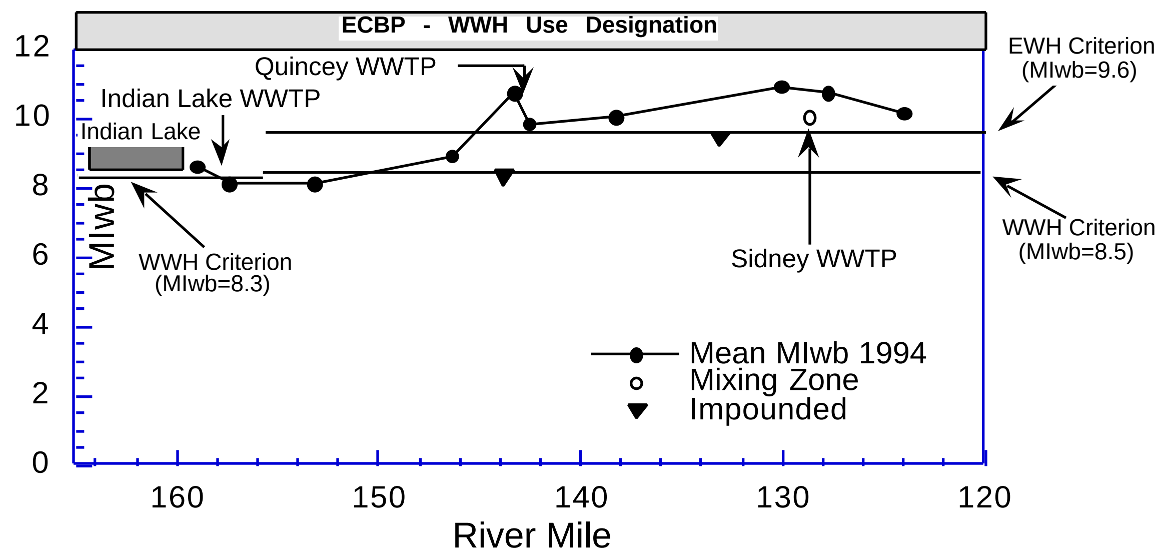


Figure 17 Longitudinal performance of the Index of biotic Integrity (IBI) and the Modified Index of Well-being (MIwb) for Segment I of the Upper Great Miami River. The solid lines represent numerical biological criteria in support of the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life use designations, Eastern Corn Belt Plains ecoregion. Segment I of the Great Miami River is currently designated WWH.

Due to the simplified, more lentic, habitat typical of on-stream impoundments, diminished performance of the IBI within the Quincy dam pool (RM 143.8) was not unexpected. Given the innate habitat limitations of impounded stream segments (*e.g.,* reduced current velocity, increased sediment deposition, increased embeddedness, and greater physical homogeny), the Quincy dam pool did not appear to have the potential to support a fish assemblage consistent with the WWH ecoregional expectations. As such, community performance was deemed commensurate with habitat potential.

Within the remaining portion of Segment I, extending downstream from RM 143.2 (downstream from the Quincy Dam) to RM 123.9 (upstream of Loramie Creek), longitudinal performance of the MIwb and IBI indicated full achievement of existing WWH criteria. Moreover, the level of biological integrity observed within the fish assemblage was fully consistent with the biological criteria established in support of the EWH use designation, criteria reserved for rivers and stream of *exceptional* quality (Figure 17 and Table 10). Though longitudinal performance was reduced within an impounded reach upstream of Sidney, all index values remained within nonsignificant departure of the EWH standard. The fish assemblage within this segment was diverse, well organized, with environmentally sensitive taxa being well represented, fully reflective of macrohabitat potential. The striking improvement observed downstream of the Quincy dam appeared commensurate with the much improved physical habitat observed within this segment. The Quincy and Sidney WWTPs appeared to have little negative effect on fish community performance.

Segment II (Loramie Creek to downstream MCD N. Reg. WWTP)

The condition of the fish community within the lower portion of the study area (Segment II) was evaluated at 18 stations, located between RM 117.5 (adjacent SR 66) and RM 85.0 (downstream of the MCD N. Regional WWTP). Excluding the results derived from mixing zones, community index values and narrative evaluations ranged between *very good-exceptional* (MIwb=9.2 and IBI=48) at RM 114.8 and *exceptional* (MIwb=10.4 and IBI=59) at RM 117.5.

Longitudinal performance of the MIwb and IBI indicated full achievement of the existing WWH biological criteria throughout Segment II. Areas of reduced performance were limited to segments of modified habitat (*e.g.,* impoundments or channelized segments), but community index values in excess of the WWH criteria were maintained. As observed within the lower reach of Segment I, community performance as measured by the MIwb and IBI consistently met the EWH criteria throughout Segment II, indicating that the majority of the Upper Great Miami River study area currently supports an exceptional assemblage of fishes (Figure 18 and Table 10).

The evaluation of the Piqua MP EGS was difficult given the facility's location within the Piqua dam pool. Comparison of longitudinal community performance (upstream and downstream) was confounded, to some extent, by compelling habitat influences. The sampling station located upstream of the facility was situated in the Piqua dam pool at RM 114.8, within a highly channel modified and levied segment maintained by the MCD through the city of Piqua. The Piqua MP EGS possesses a suite of discharges beginning immediately upstream of the Piqua dam itself, eliminating the possibility of a "downstream" station within the dam pool to control for the impoundment influence. To evaluate the ultimate downstream influence of this facility (and the Piqua WWTP), a station was placed downstream of the Piqua dam within the free flowing portion of the Upper Great Miami River at RM 114.1. This arrangement of stations allowed a gross evaluation of downstream effect, but habitat discrepancies between stations precluded an

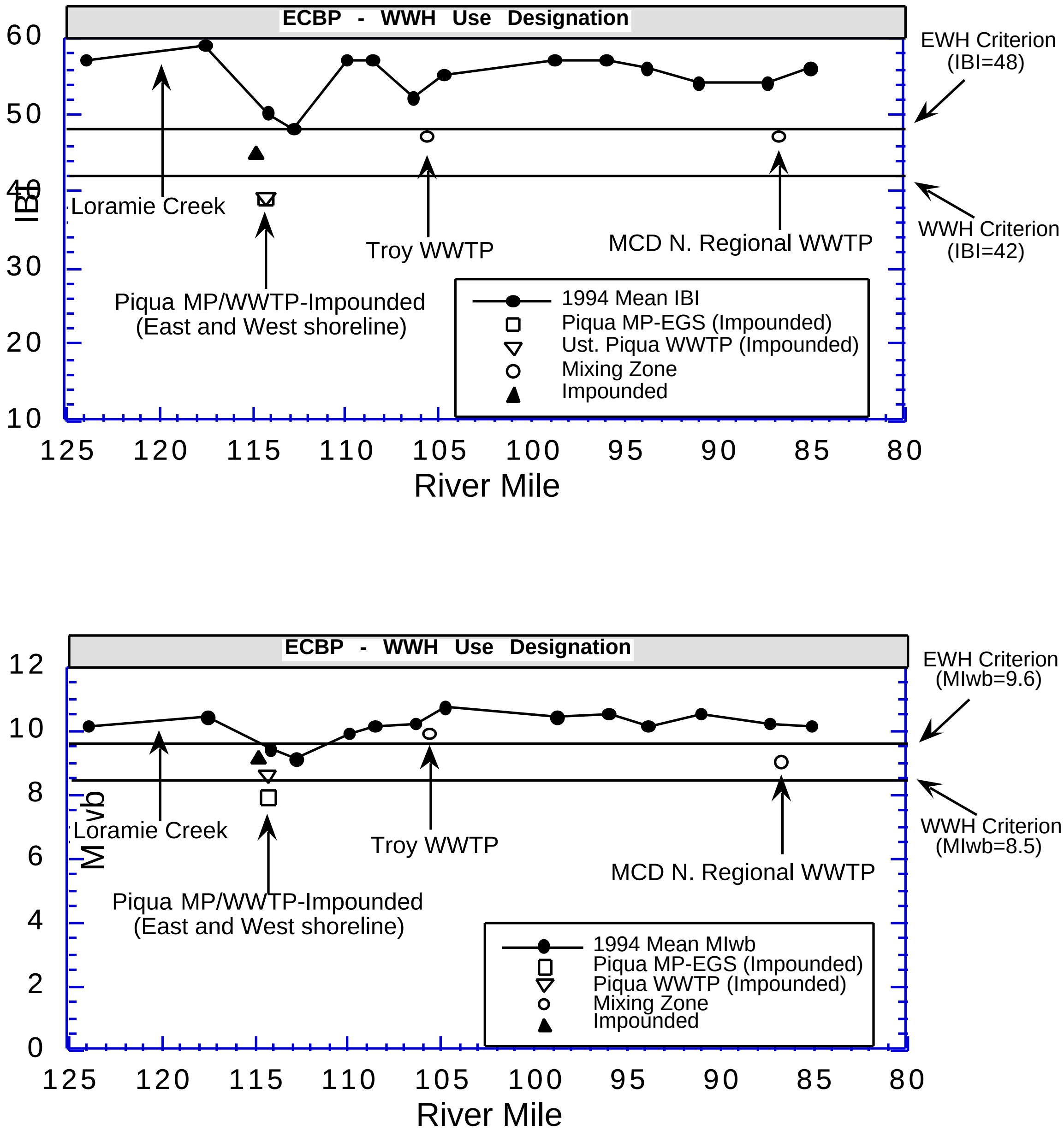


Figure 18 Longitudinal performance of the Index of biotic Integrity (IBI) and the Modified Index of Well-being (MIwb) for Segment II of the Upper Great Miami River. The solid lines represent numerical biological criteria in support of the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life use designations, Eastern Corn Belt Plains ecoregion. Segment II of the Great Miami River is currently designated WWH.

assessment of effect within the dam pool itself. To accommodate this need, a 100-meter sampling station was placed on each river bank (west and east) at RM 114.3. The west bank station extended 100-meter upstream from the Piqua dam, encompassing the numerous discharges from the Piqua MP EGS. The east bank station extended 100 meters immediately upstream of the active Piqua WWTP discharge, nearly parallel with the station on the opposite bank.

The results from the paired stations revealed no significant difference between the community performance from the east and west banks within the dam pool. The IBI values were identical, and the MIwb indicated a greater level of structural evenness within the fish assemblage under the influence of the Piqua MP EGS (west bank) than observed on the east bank (Table 10 and Figure 18). No downstream effect was observed from Piqua MP EGS or Piqua WWTP at RM 114.1. Community performance at this station was characterized as exceptional (MIwb=9.4 and IBI=50).

Assessments of both the Troy and MCD North Regional WWTPs indicated no significant impact downstream of either facility. Modest declines in community performance were observed within the mixing zones; however, index values derived from all samples collected outside the zone of initial mixing indicated an exceptional level of community performance.

Indian Lake Tributaries

Chemical Water Quality

Replicate water column chemistry samples were collected at seven stations within the tributary network of Indian Lake. The direct and indirect tributaries evaluated as part of the 1994 sampling effort included: Van Horn Creek, Blackhawk Run, North Fork Great Miami River, South Fork Great Miami River, and an unnamed tributary of the South Fork Great Miami River.

The results of the field measurements and laboratory analysis did not indicate severe water quality problems. Mean nutrient concentrations (NH_3-N, NO_3+NO_2-N, total phosphorus, and TSS) appeared low, and comparable among all sampling stations. No exceedences of applicable WWH criteria or guidelines were evident (Table 6).

Mean D.O. concentrations were reduced in the North Fork Great Miami River in comparison with other Indian Lake tributaries (Figure 19). Examining individual sampling events, D.O. concentrations below the 5.0 mg/l WWH average criterion were indicated in nearly every tributary, becoming most abundant within the North and South Fork Great Miami River (Table 6). Additionally, violations of the 4.0 mg/l WWH minimum criterion were noted from the North Fork Great Miami River and Blackhawk Run.

One exceedence of the criteria for the prevention of acute toxicity was indicated at RM 4.0 within the North Fork Great Miami River for Endosulfan II (Table 6). The occurrence of this environmentally persistent compound is most likely related to past agricultural use within the basin. Endosulfan II commonly held on the exchange complex of silts and clays (Howard 1991). As such, its occurrence within the water column likely reflects the presence of suspended soil particles in the water samples collected.

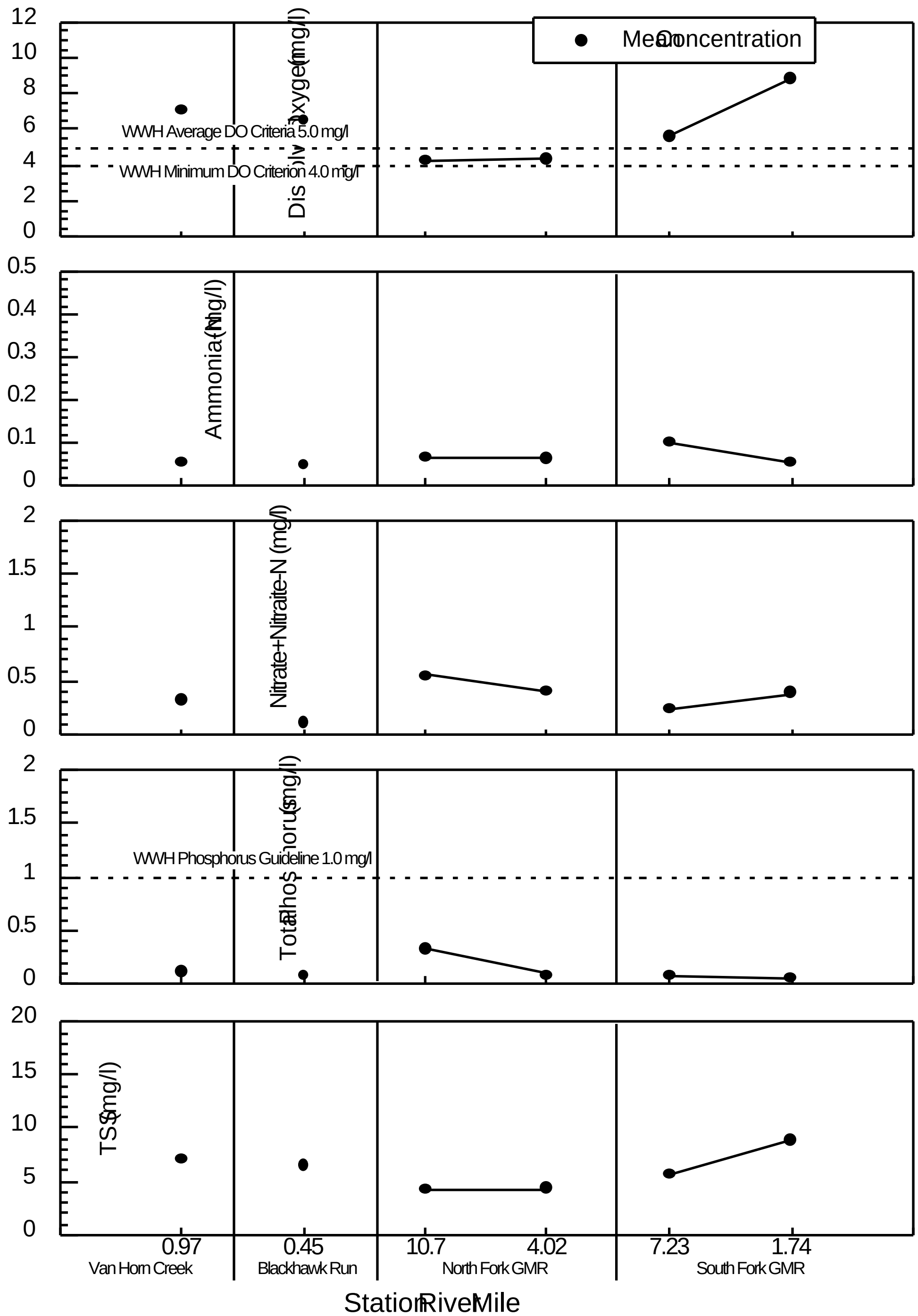


Figure 19 Mean concentrations of dissolved oxygen, ammonia-nitrogen, nitrate+nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) from the Indian Lake tributary network, 1994.

Physical Habitat for Aquatic Life

North Fork Great Miami River

The quality of stream macrohabitats of the North Fork Great Miami River were evaluated at three fish sampling stations. QHEI values increased downstream from a channelized headwater reach (RM 11.6, QHEI=25.0) through an agricultural influenced middle reach (RM 8.5, QHEI=35.5) to a lower backwater reach impounded by Indian Lake (RM 4.1, QHEI=56.5). Overall, a mean QHEI value of 39.0 suggested the macrohabitats of the North Fork Great Miami River were sufficiently impaired to exert a negative influence upon the ambient biological potential (Rankin 1989).

All sites had extensively embedded sand and gravel substrates incorporated with heavy to moderate amounts of silt. Channel development and sinuosity were also poor. Slow current was typical and only the downstream site afforded an appreciable amount of instream cover. In general, the instream channel modifications and pervasive agricultural land use encroachment on the stream margin were considered significant factors in the streams prevalent poor physical habitat conditions.

Blackhawk Run

In evaluating the macrohabitats of Blackhawk Run at one fish sampling site (RM 0.9), a QHEI score of 43.5 was recorded. This channelized Indian Lake backwater stream had poor substrates and exhibited poor development with a moderate amount of instream cover. The prevalent macrohabitats were most conducive to a lentic aquatic community.

Van Horn Creek

Macrohabitats of Van Horn Creek were evaluated at one fish sampling site (RM 1.3) where a QHEI value of 46.5 was determined. Agricultural land use encroachment and channelization have negatively influenced this shallow stream.

South Fork Great Miami River

QHEI scores of 48.0 (RM 8.0), 52.5 (RM 5.8), and 62.0 (RM 1.8) were recorded at three fish sampling sites in the South Fork Great Miami River. The moderate to extensively silt and sand embedded gravel substrates common to all sites were considered particularly limiting. A mean QHEI value of 54.2 for the three sites was also a reflection of low sinuosity, fair to poor development and marginal riparian conditions found at each site. Instream cover varied with a sparse amount at the upstream site and a moderate amount at the downstream location. The middle site (RM 5.8) was contained within a levee.

Tributary to South Fork Great Miami River

Macrohabitats of an unnamed tributary to the South Fork Great Miami River were evaluated at two fish sampling sites; RM 3.5 and 0.4. QHEI values of 44.0 and 38.0 were respectively scored at these sites. Both sites had moderately embedded cobble, gravel, and sand substrates, sparse amounts of instream cover, and displayed the effects of channelization and agricultural land use encroachment. A mean QHEI score of 41.0 was indicative of degraded macrohabitat conditions likely to negatively influence the instream ambient biological potential (Rankin 1989).

Biological Assessment: Benthic Macroinvertebrate Community

North Fork Great Miami River

Macroinvertebrate communities were evaluated at three stations on the North Fork Great Miami River to evaluate the effectiveness of a cattle exclusion project located between RMs 10.7 and 8.3. The upstream station was located upstream from a farmer's lane at RM 10.7. This small stream (run habitat about 3 ft. wide and 2 in. deep) was exhibiting only little recovery from past channelization, and was characterized by a wide trapezoidal cross section, substrates composed primarily of fine gravel, sand, and silt, slow current speed without riffle development; and a herbaceous riparian corridor that was slumping into the stream channel in some areas. Algae and aquatic macrophyte growth was common in this slow moving, open canopied stream and was an indication of nutrient enrichment. Considering the marginal habitat conditions, the macroinvertebrate community at this site was performing quite well and was narratively evaluated as marginally achieving WWH expectations. Twelve taxa of mayflies and caddisflies were qualitatively collected from the natural substrates with scuds and baetid mayflies predominant in the run habitats.

The station located downstream from the cattle exclusion project at CR 104 (RM 8.3) exhibited improved habitat conditions including riffle development and woody riparian corridors. However, low flow conditions continued at this site with run dimensions of approximately two feet wide by four to six inches deep. Mayfly and caddisfly diversity increased to 14 taxa at this site with baetid and heptageniid mayflies predominant in the riffle and run habitats, respectively. The community performance at this station improved into the good range, which may be attributable to improved habitat conditions at this site. Potential threats to the macroinvertebrate community health in this stream were low flow conditions during periods of little precipitation, channel modifications in the form of channelization and the removal of the woody riparian corridor, and sediment runoff from unvegetated ground. All land management practices that would help prevent the detrimental effects from these threats would be beneficial to the community health.

The macroinvertebrate community collected from artificial substrates at the farthest downstream station located at Dunn Road (RM 6.3) achieved the WWH biocriterion with an ICI score of 38. This station had good habitat conditions with riffle-run-pool development and a woody riparian corridor.

Blackhawk Run

Blackhawk Run is a small channelized stream without riffle development or a woody riparian corridor; agricultural row crop is the primary land use above and below the sampling location. The stream banks were severely slumping at the macroinvertebrate collection site at Feikert Road (RM 2.3) due to the absence of a woody riparian to hold them in place. Macroinvertebrate community performance was marginally achieving WWH expectations with an ICI score of 34. However, the community was predominated by midges and non-insects (75%) and was composed of 32.9% tolerant organisms; both were indications of community impairment. The major limitations to community performance at this site were primarily factors related to past channel modifications.

Van Horn Creek

Van Horn Creek is a small channelized stream which was demonstrating limited habitat recovery. Riffle habitat (composed partially of rip rap) was present and a woody riparian corridor was starting to reestablish in limited areas. Nine taxa of mayflies and caddisflies were collected from the natural substrates with aquatic sow bugs and midges predominant in riffle and run habitats. The EPT taxa richness was meeting the expectation for a good community but, due to the predominance of more pollution intermediate forms, the community performance was evaluated as marginally good. The artificial substrates at this site were affected by slow current speed and, therefore, the evaluation was based primarily on the qualitative sample.

South Fork Great Miami River

Macroinvertebrate communities were sampled in the South Fork Great Miami River at SR 638 (RM 8.0), T 97 (RM 5.8), and CR 38 (RM 1.8). ICI scores were indicative of exceptional communities at SR 638 (ICI=54) and T 97 (ICI=52). The unsewered community of Belle Center was not noticeably impacting community performance at T 97. While artificial substrate results were unavailable for the CR 38 site, qualitative sampling of the natural substrates yielded 17 mayfly and caddisfly taxa with hydropsychid caddisflies, baetid mayflies, and midges predominant in riffle and run habitats. The high EPT taxa richness and predominance of mostly pollution intolerant forms characterized the community at this site as exceptional.

Tributary to S. Fk. Great Miami River

This tributary to the South Fork Great Miami River at RM 5.27 is a small, historically channelized stream that was demonstrating substantial habitat recovery at the stations sampled with riffle-run-pool development and localized woody riparian reestablishment. The macroinvertebrate community sampling station at CR 101 (RM 3.4) was located downstream from a bank stabilization project. Fourteen mayfly and caddisfly taxa (42 total taxa) were collected by qualitative methods from the natural substrates with midges and caddisflies of the genus *Chimarra* predominant. The EPT taxa richness was meeting the expectation for an exceptional community but the composition of predominant organisms indicated some level of community imbalance. Green filamentous algae was common at this site which was an indication of enrichment. Community performance at the SR 638 (RM 0.5) sampling station was exceptional with 17 mayfly and caddisfly taxa collected (56 total taxa) with riffle beetles, the caddisfly genus *Chimarra*, and baetid mayflies predominant.

Biological Assessment: Fish Community

North Fork Great Miami River

Twenty nine fish species (3,957 individuals) were collected in the North Fork Great Miami River at three locations in 1994. Sampling occurred twice at Madory Rd. (RM 11.6), once at Schrader Rd. (RM 8.5) and three times at SR 117 (RM 4.1). The headwater IBI narrative ratings of fair (RM 11.6, IBI=30) to poor (RM 8.5, IBI=26) and the boat IBI, MIwb narrative ratings of poor-fair (RM 4.1, IBI=28, MIwb=6.8) were all significant departures from ecoregional expectations for WWH aquatic life use designation.

The fish communities at the upstream sites were similar. Creek chub predominated both sites in number (RM 11.6=40%, RM 8.5=45%) and biomass (RM 11.6=62%, RM 8.5=69%). Bluntnose minnow were second in number (RM 11.6=26%, RM 8.5=24%) comprising eleven percent of the biomass at RM 11.6 and five percent at RM 8.5. Backwater conditions from Indian Lake influenced the fish community at the downstream site which was predominated in number by gizzard shad (35%) and bluegill sunfish (11%) and in biomass by largemouth bass (37%) and carp (33%).

Most IBI metric scores fell in the moderate to poor range in all samples. The relative lack of community structural and functional organization at these sites was most attributed to inadequate macrohabitat conditions (mean reach QHEI=39).

Blackhawk Run

Twenty three fish species (539 individuals) were collected in Blackhawk Run in two samples at RM 0.9, upstream of SR 235. The headwater IBI narrative rating of good (IBI=40) was within the ecoregional expectations for the WWH use designation. The fish community was predominated by lentic species in terms of numerical abundance and biomass, reflective of an impoundment effect from Indian Lake. Despite the absence of a developed lotic assemblage of fishes, the community meet minimum WWH standards.

Van Horn Creek

Sixteen fish species (1366 individuals) were collected in Van Horn Creek in two samples at RM 1.3, upstream of SR 366. The headwater IBI narrative rating of poor (IBI=27) was a significant departure from the ecoregional expectations for the WWH use designation. The fish community was predominated by bluntnose minnow (60% in number, 29% in biomass), creek chub (27% in number, 20% in biomass), and white sucker (5% in number, 26% in biomass). The overwhelming number of tolerant (97%), omnivorous (72%), generalist feeding (27%), and pioneering fishes (84%) yielded typically poor IBI metric scores and were considered reflective of the degraded macrohabitat conditions (QHEI=46.5).

South Fork Great Miami River

Thirty five fish species (8628 individuals) were collected in the South Fork Great Miami River during two sampling passes at three locations in 1994. The headwater IBI narrative rating of good (IBI=41) at SR 638 (RM 8.0) and the wading IBI narrative ratings of marginally good-good (IBI=39, MIwb=8.3) at CR 97 (RM 5.8) and good-marginally good (IBI=39, MIwb=8.3) at CR 38 (RM 1.8, Brickham covered bridge) were all consistent with WWH ecoregional expectations.

Overall, central stoneroller (40% in number, 23% in biomass) and creek chub (21% in number, 16% in biomass) predominated the fish community. Darters were particularly well represented with six species present at all locations. Minimun functional and structural organization was maintained at each station.

Tributary to South Fork Great Miami River

Twenty fish species (3877 individuals) were collected in an unnamed tributary to the South Fork Great Miami River at two locations. Exceptional headwater IBI narrative ratings were recorded at RM 3.5 (IBI=50), upstream of CR 101 and at RM 0.4 (IBI=56), downstream of CR 96. Groundwater flow augmentation may have mitiganted, to some extent, the depauperate macrohabitats. This stream is currently undesignated. Based on the exceptional performance of the fish community, the EWH use designation is recommended.

Loramie Creek

Pollutant Loadings

Botkins WWTP
Constructed in 1965, with a major modification in 1989, the Botkins WWTP is a secondary treatment facility consisting of grit channel, sequencing batch reactor, UV disinfection, aerobic digester and sludge drying beds. The plant has a design capacity of 0.5 MGD and discharges directly to Loramie Creek at RM 35.42. The collection system consist of separate sewers and 100% of the service area is sewered. Population is approximately 1340, with 48% projected growth by the year 2000. One lift station exist with no bypasses or overflows structures. The only industrial contributor is Ramsey-Sais (a food processor). By providing service to Ramsey-Sais, the WWTP has depleted its remaining treatment capacity. The village has requested an expansion from 0.5 MGD to 0.75 MGD.

Annual average conduit flow during the period 1976-1994 increased approximately 30%-50% over the 18 year period. Median flows remained below the design capacity of 0.5 MGD through the period of record. Median loadings of ammonia-nitrogen between 1987 and 1990 averaged near 6.0 kg/day, prior to the 1989 treatment upgrade. After 1989, median ammonia-nitrogen loads substantially reduced, averaging 0.24 kg/day (Figure 20). Median BOD_5 loads reached their peak in the early-1980s, though appeared reduced after the 1989 plant upgrades. As observed with BOD, median TSS loads were the greatest during the early-1980s, demonstrating a marked decline after 1989.

The Botkins WWTP reported 177 violations of its NPDES permit from 1989-94. During 1989 and 1990 the violations were the typical constituents of treated domestic wastewater. From 1991 through 1994 the violations were dominated by metals (copper and mercury).

Anna WWTP
Constructed in 1971, with a major modification in 1989, the Anna WWTP is a secondary treatment facility consisting of batch reactors, chlorination, aerobic sludge digestion, sludge holding, and sludge drying beds. The plant has a design capacity of 0.5 MGD and discharges directly to Clay Creek, which confluences with Loramie Creek at RM 31.11**.** The collection system consist of separate sewers and 100% of the service area is sewered. The service population is approximately 1200 with slow growth expected. Two lift stations exist with no bypasses or overflow structures.

The Anna WWTP is currently being upgraded to an oxidation ditch treatment system. The new design flow will be 0.4 MGD. Additionally, Honda of America engine plant (currently serviced by the Anna WWTP) has submitted plans to redirect their waste stream to the Sidney WWTP

Median annual conduit flow fluctuated during the period 1976-1988. After 1988, median discharge more than doubled, representing a near 80% increase by 1994. Although median values remained below the 0.5 MGD design capacity, 95th percentile annual discharge were consistently near or above the design capacity between 1989 and 1994 (Figure 21).

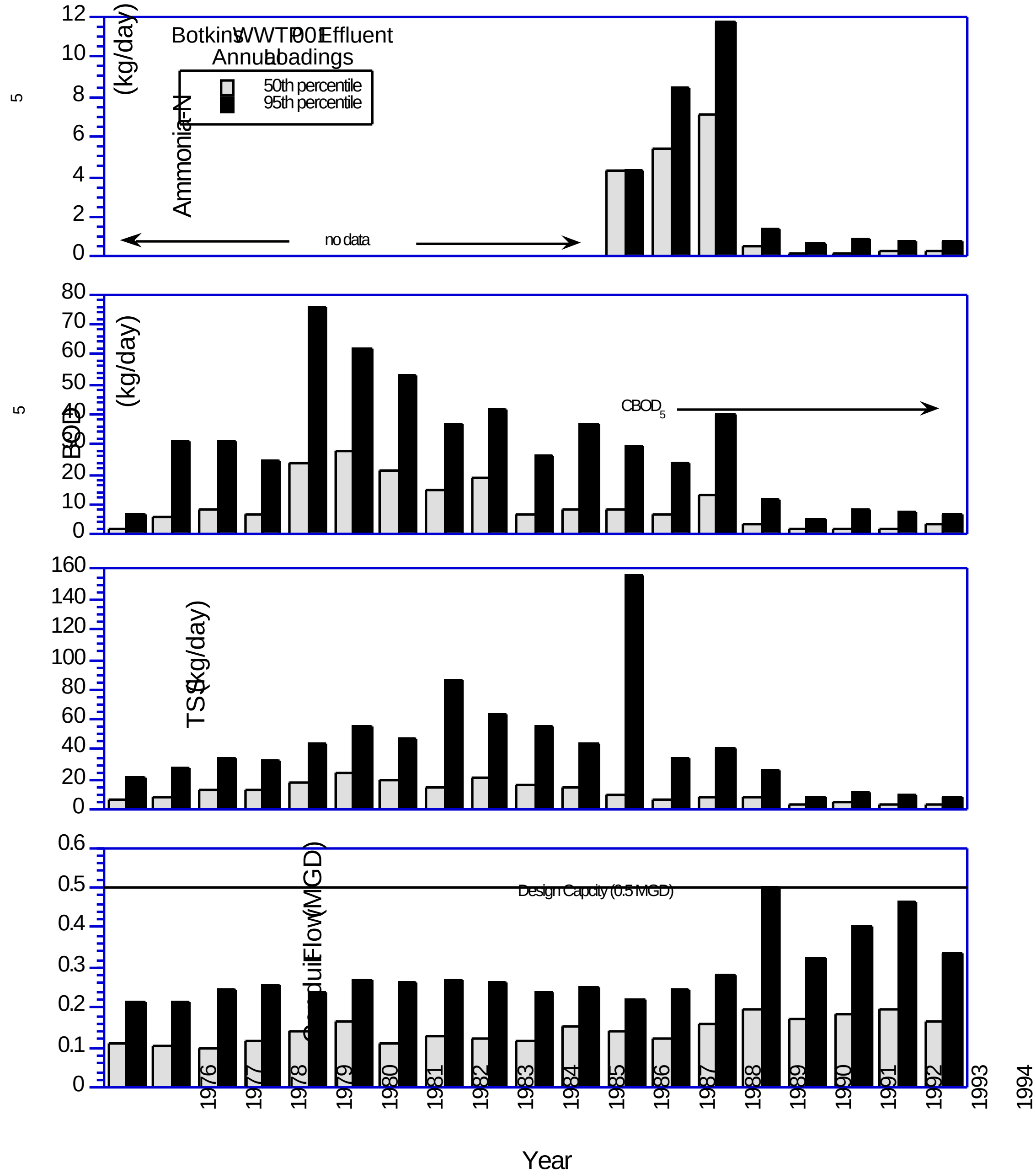


Figure 20 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, biochemical oxygen demand, and total suspended solids from the Botkins WWTP.

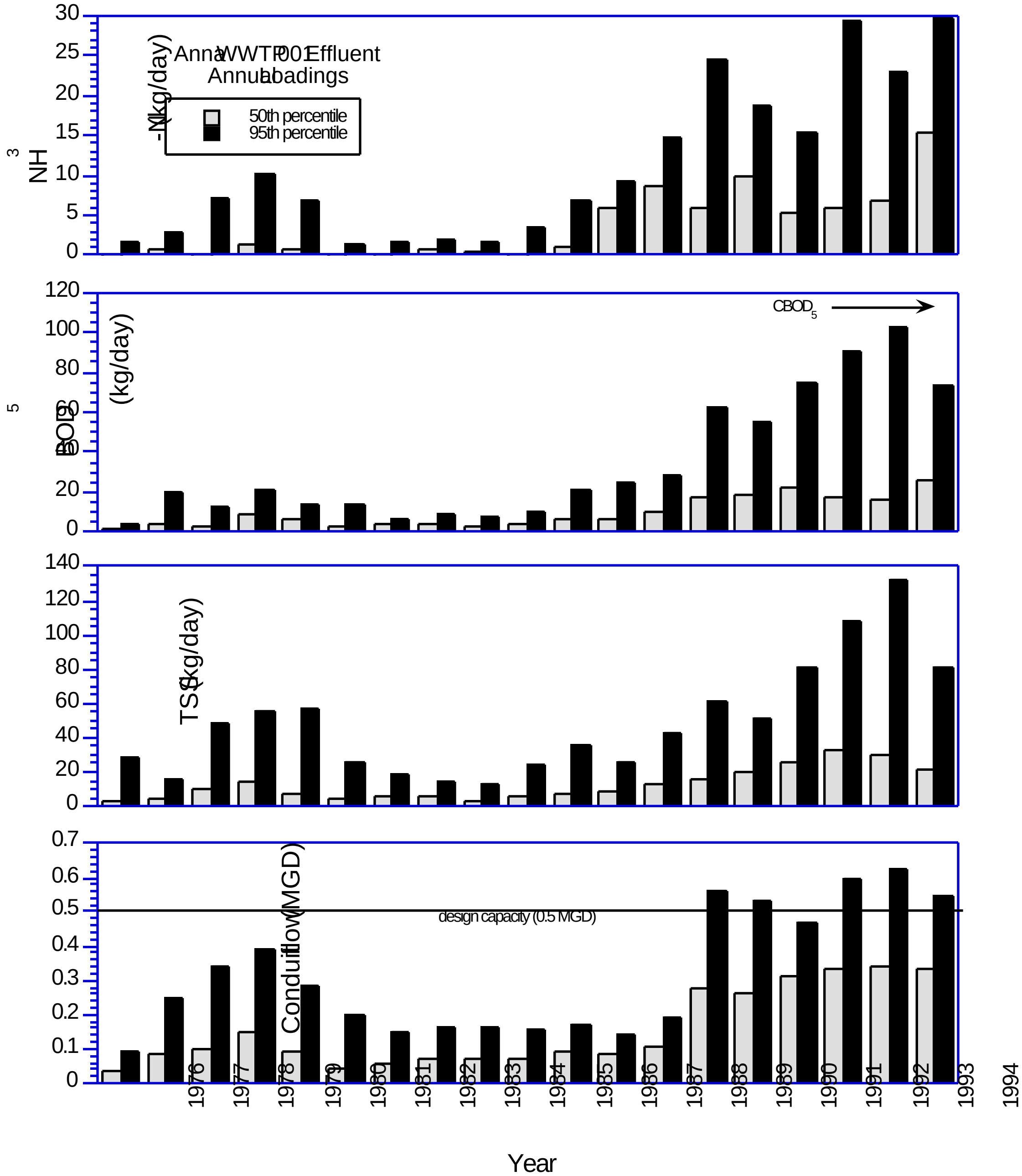


Figure 21 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the Anna WWTP.

Both median and 95th percentile annual loadings of ammonia-nitrogen demonstrated a marked increase between 1986 and 1994. From 1986 to 1991 annual ammonia-nitrogen loads fluctuated greatly. Ammonia-nitrogen loads appeared more stable and reduced between 1991 and 1993. In 1994 ammonia-nitrogen loads reached a peak, with a median of 15.2 kg/day.

Median BOD_5 loads exhibited a gradual increase through the period of record, with the greatest increase observed in 1989. In 1994 BOD_5 rates peaked at approximately 26 kg/day. Median and 95th percentile annual loads of TSS, displayed a pattern similar to that observed with BOD.

The Anna WWTP reported 604 violations of its NPDES permit between 1989 and 1994. Parameters most frequently violated were $cBOD_5$, TSS, fecal coliform and ammonia-nitrogen. The Ohio Department of Natural Resources, Division of Wildlife, reported a wildlife kill in Clay Creek downstream from the Anna WWTP in 1994. Responders indicated that similar stream conditions have been observed since 1992.

Fort Loramie WWTP

The Ft. Loramie WWTP discharges directly to Loramie Creek at RM 19.25. Between 1989 and 1994 this facility reported 112 NPDES permit violations. However, these occurrences were limited to the years 1990, 1992, 1993, and 1994. No violations were indicated for the years 1989 and 1991.

Chemical Water Quality

Discharge of Loramie Creek monitored at the USGS gages at Lockington and Newport, indicated flows near the $Q_7 10$ and 80% duration throughout most of the third quarter (May-September), 1994 (Figure 22). River discharge demonstrated variability from mid-June through late-August. Peak discharge and duration was observed at both stations in late-June, with flows reaching approximately 1200 cfs at the Lockington gage.

Field measurements (dissolved oxygen, conductivity, and pH) and samples collected for laboratory analysis were taken over a two-day period and may account for some of the variability when examining longitudinal concentrations. Replicate water column chemistry samples and instream measurements were collected at 10 stations, located between RM 36.84 (Botkins Rd.- upstream of Botkins WWTP) and RM 0.4 (adjacent Land Mill Rd.).

Dissolved oxygen concentrations below the WWH criteria (minimum and average) were frequently encountered within the stream reach between RM 36.84 and RM 16.51 (Cardo-Roman Rd.). The upper portion of Loramie Creek (upstream of Lake Loramie) clearly exhibited the lowest mean D.O. concentrations, as well as containing the vast majority of D.O. WQ standards exceedences (Figure 23). Violations of the 4.0 mg/l WWH D.O. minimum criterion were observed up and downstream of the Botkins WWTP, and within the backwaters of Lake Loramie, becoming most numerous at RM 28.9 (SR 29) (Table 6). Additionally, several samples within this reach indicated D.O. levels below the 5.0 mg/l average WWH criterion.

Depressed D.O. concentrations observed within the upper reach of Lake Loramie were likely the result of several factors working in concert. The negative effects of nutrient inputs from point and non-point sources were exacerbated by the physically simple, low gradient conditions common within the upper portion of Loramie Creek. Modestly enriched, channelized, impounded, and stripped of its riparian corridor, the upper portion of Loramie Creek provides optimal conditions for excessive algal production (planktonic and other) and the attendant oxygen demand.

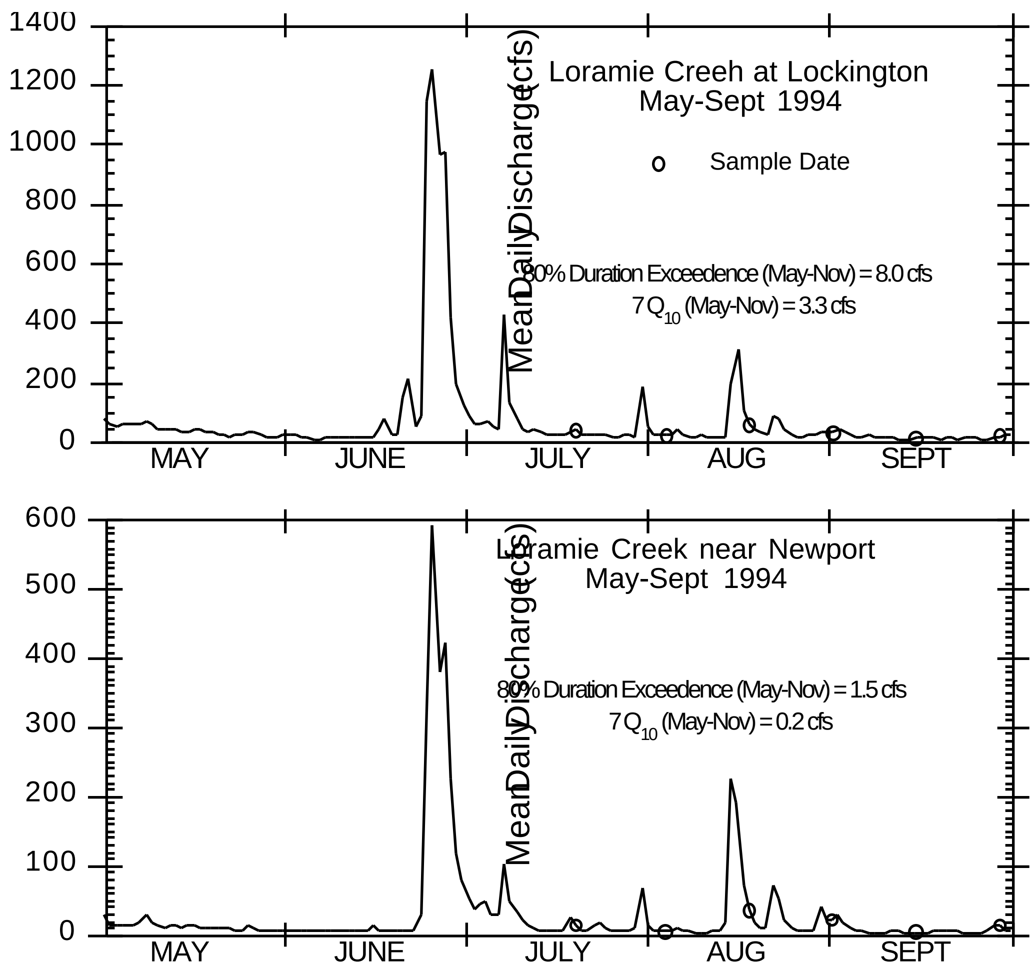


Figure 22 Flow hydrograph for Loramie Creek at Lockington and Newport, May through September, 1994 (USGS 1994). Open circles indicate river discharge on dates when water chemistry samples were collected.

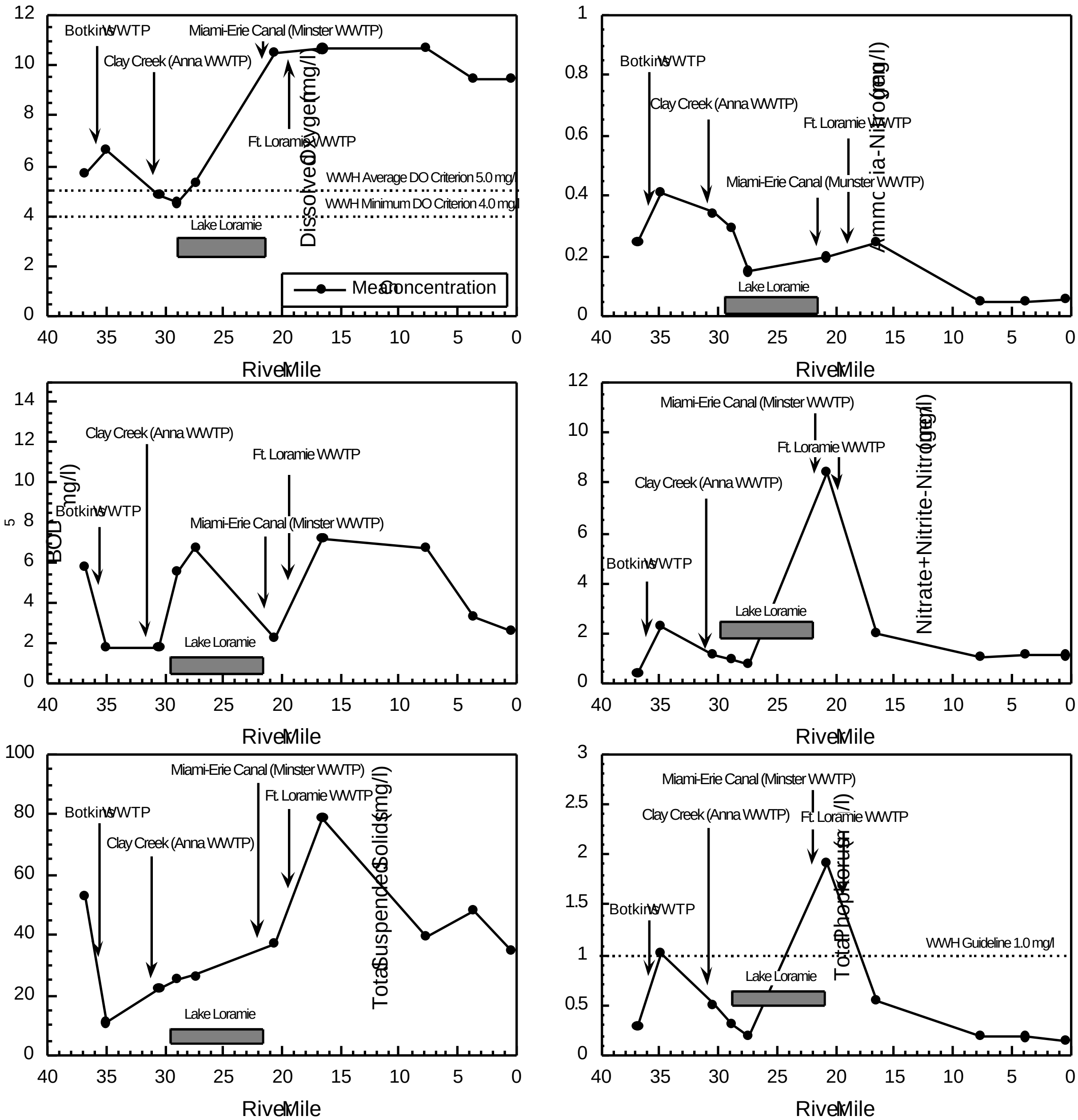


Figure 23 Longitudinal mean concentration of dissolved oxygen, ammonia-nitrogen, nitrate-nitrogen, five-day Biochemical Oxygen demand (BOD_5), total suspended solids, and total phosphorus from Loramie Creek study, 1994.

Downstream of Lake Loramie mean D.O. concentrations were markedly improved, remaining well above the WWH criterion throughout the remainder of the study area. Only one sample (of six), collected at RM 16.51 (downstream of the Fort Loramie WWTP) indicated a D.O. concentration below the 5.0 mg/l average D.O. criterion.

Mean nutrient concentrations did not display a consistent longitudinal pattern, relative to entities evaluated within the Loramie Creek study area. This observation does not exclude these facilities and/or operations from culpability, in terms of their relative contributions to the D.O. problems observed. Rather, the data appeared reflective of compelling background conditions (*e.g.*, adjacent land use practices, channelization, impoundment), that contribute strongly in limiting the ability of the upper portion of Loramie Creek to consistently meet the WWH D.O. criteria.

Mean ammonia-nitrogen concentrations appeared elevated downstream of the Botkins WWTP (RM 34.96 to RM 28.9 (SR 29). Within the remaining portions of the study area, ammonia-nitrogen concentrations appeared comparable and longitudinally stable. No exceedences of the WWH ammonia-nitrogen criteria were observed.

Mean nitrate+nitrite-nitrogen concentrations within the Loramie Creek study area were generally reduced and longitudinally stable. Exceptions to this observation included a modest increase downstream of the Botkins WWTP, and more significantly, a marked increase downstream of Miami-Erie canal, at RM 20.7 (Figure 23). Past Ohio EPA investigations indicated highly enriched conditions within the canal as a result of poorly treated domestic sewage (Ohio EPA 1987). The greatly elevated mean nitrate+nitrite-nitrogen concentration indicated at RM 20.7 was likely reflective of nutrient export to Loramie Creek from the Miami-Erie canal.

Longitudinal mean total phosphorus concentrations depicted a similar trend as that observed with nitrate+nitrite-nitrogen. Mean phosphorus concentration downstream of Botkins WWTP was elevated, near the 1.0 mg/l WWH guideline, while the mean phosphorus concentration downstream of Lake Loramie was nearly twice the WWH guideline (Figure 23). As with nitrate+nitrite-nitrogen, the phosphorus spike recorded downstream of Lake Loramie likely represented nutrient export to Loramie Creek from the Miami-Erie canal.

Mean BOD_5 concentration varied greatly throughout the study area. No clear longitudinal pattern was evident, relative to point source discharges. The greatest mean BOD_5 values were observed upstream of the Botkins WWTP, within the backwaters of Lake Loramie, and downstream of the Ft. Loramie WWTP. The greatest average TSS values were observed upstream of the Botkins WWTP and downstream of the Ft. Loramie WWTP.

Exceedences of the criteria for the prevention of acute toxicity and the human health 30-day average were indicated for several pesticide residues at two stations within the study area (RM 27.39 and RM 7.67) (Table 6). The occurrence of these environmentally persistent compounds within the study area is most likely related to past agricultural use within the basin. All of these organochlorine compounds are commonly held on the exchange complex of silts and clays (Howard 1991). As such, its occurrence within the water column likely reflects the presence of suspended soil particles in the water samples collected.

Datasonde continuous monitors were deployed at two stations within the Loramie Creek study area (RM 28.9 and RM 3.8). Sampling was conducted during the period September 27-29, with a typical duration of 45 hours. The information provided by continuous monitoring data clearly indicated depressed D.O. concentrations upstream of Lake Loramie (Figure 24). Seventeen violations of the 4.0 mg/l minimum WWH criterion were recorded at RM 28.9 (Table 6). The median D.O. concentration at this station was near the WWH minimum standard, with the 75th percentile near the 5.0 mg/l average criterion. Continuous monitoring data collected at RM 3.8 indicated D.O. concentrations well above the WWH criteria (average and minimum).

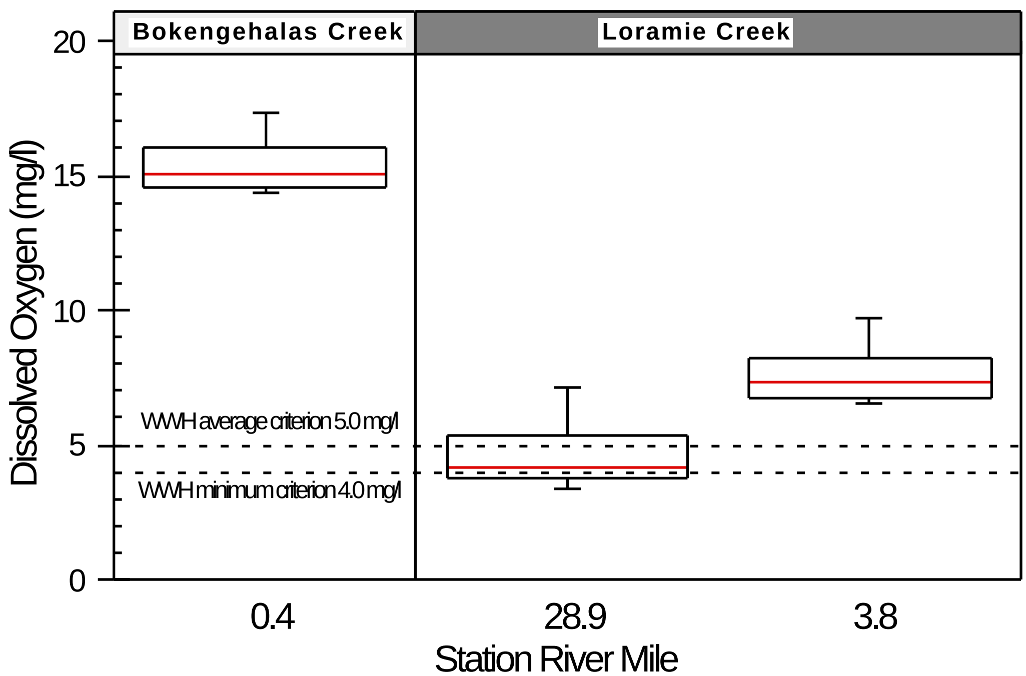


Figure 24 Summarized diurnal dissolved oxygen and temperature data collected with Datasonde continuous monitoring units from Bokengehalas Creek and Loramie Creek, 1994.

Physical Habitat for Aquatic Life

The 1994 Loramie Creek study area extended from the headwaters, upstream of Botkins Rd. (RM 36.8), to RM 0.5, near the confluence with the Great Miami River. The majority of the study area has been extensively channel modified. The Miami Valley Conservancy District maintains Lockington Dam, a flow-thru structure at RM 2.1 and the creek above it to an elevation of 938 feet near Ft. Loramie. The Ohio Division of Parks and Recreation manages Lake Loramie State Park, a 7.3 mile impoundment created by a low head dam located at RM 22.1. Above Lake Loramie the creek serves as the principal drainage way in the agriculturally oriented Dinsmore Township, Shelby County.

In 1994 the quality of the macrohabitats of Loramie Creek were evaluated at ten fish sampling sites. The macrohabitats of the seven upstream sites were noticeably different than those of the three downstream locations. QHEI values for the upstream sites ranged between 35.5 (RM 36.8) and 53.5 (RM 16.6) with a mean reach QHEI score of 42.2. The macrohabitats of the downstream locations scored QHEI values of 71.5 (RM 7.5), 83.0 (RM 3.7) and 77.5 (RM 0.5) with a mean reach QHEI score of 77.2 (Table 11). Essentially, the difference between the two reaches was a reflection of the channel modifications and prevalent agricultural land use typical of the upstream section in contrast to the more natural stream qualities observed downstream.

Gravel and sand substrates predominated Loramie Creek. Scattered boulders and cobbles were present only in the downstream section. Silt, although common to the entire study area, was most plentiful in the extensively embedded upper reach substrates. Moderate amounts of instream cover consisting of good pool conditions and frequent woody debris was universal. However, defined riffles were present only at the three downstream sites. The lack of riffles and associated current variation in the poorly developed channel modified section failed to offer the variation in macrohabitat needed to support aquatic communities consistent with WWH expectations.

Riparian width and floodplain use likewise varied between the two reaches. Upstream, riparian width was typically vary narrow (5-10m) whereas downstream it was moderate (10-50m). Upstream, agricultural land use abutted the stream with forested areas more common downstream.

Overall, the macrohabitats of the upper segment of Loramie Creek were considered very poor. A mean QHEI value of 42.2 for this reach suggested its biological performance would be impaired (Rankin 1989). Despite this, the lower segment macrohabitats were considered very good, indicated by a mean reach QHEI score of 77.2. The probability that this reach would support a biological community comparable to EWH expectations was considered likely (Rankin 1989).

Table 11. Average QHEI scores for two relatively homogenous segments of Loramie Creek based on sampling conducted during July - October, 1994.

Upstream River Mile	Downstream River Mile	River Mile	Sample Location QHEI	Segment Average QHEI
Sample Location: Segment Description				
Segment 1: Botkins Rd. to Cardo Roman Rd.				
36.8	16.6	36.8	35.5	42.2
		35.0	42.5	
		30.4	43.0	
		29.1	37.0	
		28.3	43.0	
		20.8	41.0	
		16.6	53.5	
Segment 2: Loramie Washington Rd. to Landman Mill Rd.				
7.5	0.5	7.5	71.0	77.2
		3.7	83.0	
		0.5	77.5	

Biological Assessment: Benthic Macroinvertebrate Community

Loramie Creek macroinvertebrate communities were sampled at eight stations to evaluate the effects of nonpoint pollution sources and the Ft. Loramie WWTP (Figure 25). Qualitative sampling at the most upstream site (RM 36.8) revealed a poor quality community with 24 total taxa and 1 EPT taxon. The next two stations, both upstream from Lake Loramie, were performing in the fair range (ICI=18 at RM 34.9, ICI=18 at RM 31.7). Communities at all three sites were composed primarily of pollution intermediate (*i.e.,* aquatic sow bugs, *Hydra*, flatworms) and tolerant forms (*i.e.,* aquatic segmented worms, pouch snails) with low EPT taxa richness (ranged from 1 at RM 36.8 to 4 at RMs 34.9 and 31.7). The stream at these sites was channelized with limited woody riparian corridors and contained large amounts of filamentous green algae. Nuisance algae growth is an indication of nutrient enrichment and probably was causing dissolved oxygen depletion from nocturnal algal respiration and decomposition of algal biomass. In order to restore ecological balance to the headwaters of Loramie Creek, modifications to the channel and riparian corridor should cease so that more natural morphology can develop and the woody riparian can become reestablished. Also, the reduction of nutrient loadings from agricultural runoff should be investigated.

Community performance at the first two stations downstream from the Lake Loramie dam (RM 22.1) and bracketing the Ft. Loramie WWTP (RM 19.25) was in the fair range with ICI scores of 26 at both sites (RMs 20.7 and 14.8). The communities continued to be predominated by pollution intermediate forms with only marginal increases in more pollution sensitive forms (total EPT=7 at both sites). The stream channel at these two sites was channelized but was demonstrating some recovery at SR 66 (RM 14.8) with improved riffle development and a narrow woody riparian corridor reestablished on one side. Algal growth was not pervasive at these sites but siltation was noted as a possible limiting factor to community well-being. The Ft. Loramie WWTP was not negatively impacting community performance 4.45 miles downstream from the discharge.

Macroinvertebrate community performance at the three most downstream stations improved to the good range at Patterson Road (ICI=36 at RM 5.8) and into the exceptional range at Lehman Road (ICI=48 at RM 3.7) and Landman Road (ICI=52 at RM 0.4). Mayfly and caddisfly diversity increased to a high of 21 taxa at Patterson Road. Loramie Creek in this lower segment was appeared unchannelized and, at the sites sampled, had intact woody riparian corridors.

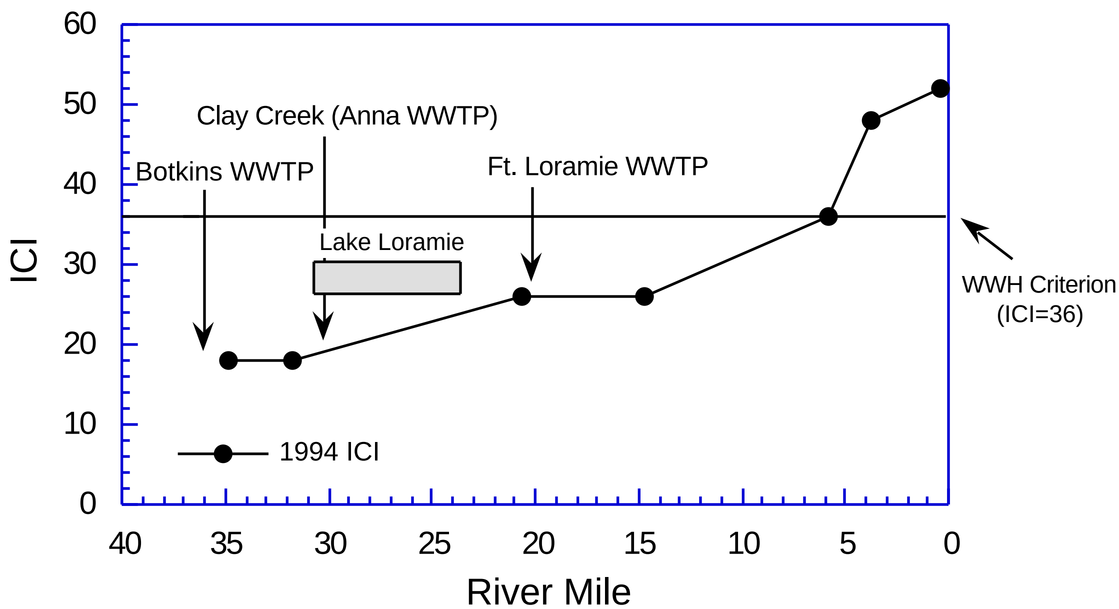


Figure 25 Longitudinal performance of the Invertebrate Community Index (ICI) from the 1994 Loramie Creek study area. The solid line represents numerical biological criteria in support of the current Warmwatrer Habitat (WWH) aquatic life use designation, Eastern Corn Belt Plain ecoregion.

Biological Assessment: Fish Community

Forty eight species and seven hybrid types of fish (13,869 individuals) were collected in Loramie Creek in 1994. Sampling occurred twice at eight wading sites and three times at two boat sites from Botkins Rd (RM 36.8) downstream to a location near the confluence with the Great Miami River (RM 0.5). Overall, the fish assemblage in Loramie Creek was characterized as fair (Table 10). This narrative evaluation was based on fish community indices which ranged from poor (IBI=19 at RM 35.0) to exceptional (IBI=50; MIwb=9.4 at RM 0.5). Including all sites, the mean IBI was 30.5. The mean MIwb for applicable wading and boat sites was 7.7. Ecoregional expectations for the WWH use designation were not met at eight study sites.

A marked difference was observed between the fish communities from sites upstream of RM 16.6 compared to those of the three most downstream sites. Poor IBI narrative ratings were recorded at sites above RM 16.6 (mean IBI=24.7) whereas fair to exceptional ratings qualified downstream locations (mean IBI=44.0). Similarly, macrohabitat conditions, as indicated by QHEI scores, varied between the upstream and downstream reaches. Poor QHEI scores were recorded above RM 16.6 (mean reach QHEI=42.2) while very good values were reflective of the lower stations (mean reach QHEI=77.2). Performance of the fish community, as measured by the IBI, and the quality of near and instream macrohabitats, as measured by the QHEI, displayed a positive and significant correlation (R^2=0.77, $p<0.001$) (Figure 26).

The aggregate fish assemblages of the two reaches were dramatically different. Of the 34 fish species (9,702 individuals) captured in 16 upper reach samples, the numerically most abundant fish were: gizzard shad (48%), bluntnose minnow (10%), and green sunfish (8%). In biomass, the upstream predominant species were: common carp (66%), largemouth bass (7%),and gizzard shad (5%). In 6 downstream samples, 41 fish species (4167 individuals) were collected. Here, greenside darter (13%), green sunfish (12%), and spotfin shiner (10%) were numerically predominant with common carp (30%), northern hogsucker (27%), and golden redhorse (14%) comprising the majority of biomass.

In the composite of upstream samples, no intolerant species, only twelve darter specimens, five individual golden redhorse, and no northern hogsuckers were recorded. The fish community was predominated by omnivorous and pollution tolerant species. Other than the white sucker, simple lithophilic species were essentially absent. The IBI metric value for total species at each site consistently scored in the moderate range. Longitudinal performance of the IBI and the MIwb is presented in Figure 27. Overall, poor macrohabitat conditions resulting from channel modifications and agricultural land use encroachment and subsequent enrichment were considered principal factors behind the poor upstream fish community performance.

Given the compelling nature of the background conditions of Loramie Creek, departure from the WWH biocriteria was not attributed to the influence of Botkins, Anna, or Ft. Loramie WWTPs. Habitat and nonpoint source impacts within basin precluded a meaningful ambient biological assessment of these facilities.

The aggregate fish community from downstream locations included six intolerant and six darter species. Insectivores were predominate and species sensitive to pollution were well represented (43% numerically). Simple lithophils were numerous (42%) indicating improved downstream substrate conditions. The IBI metric score for total species tended toward the high value at each site. Generally, improved macrohabitat qualities in a natural setting were credited for the impressive improvement in downstream fish community performance.

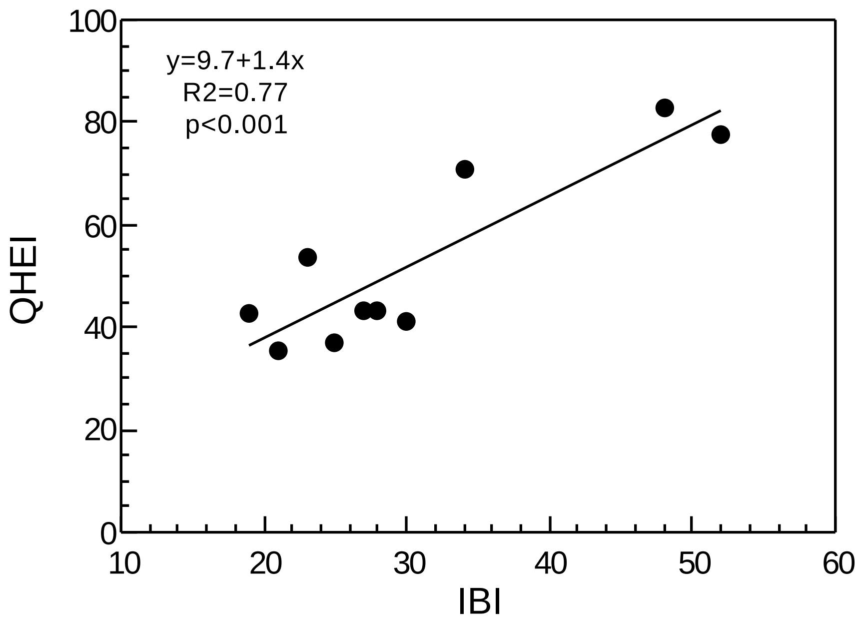
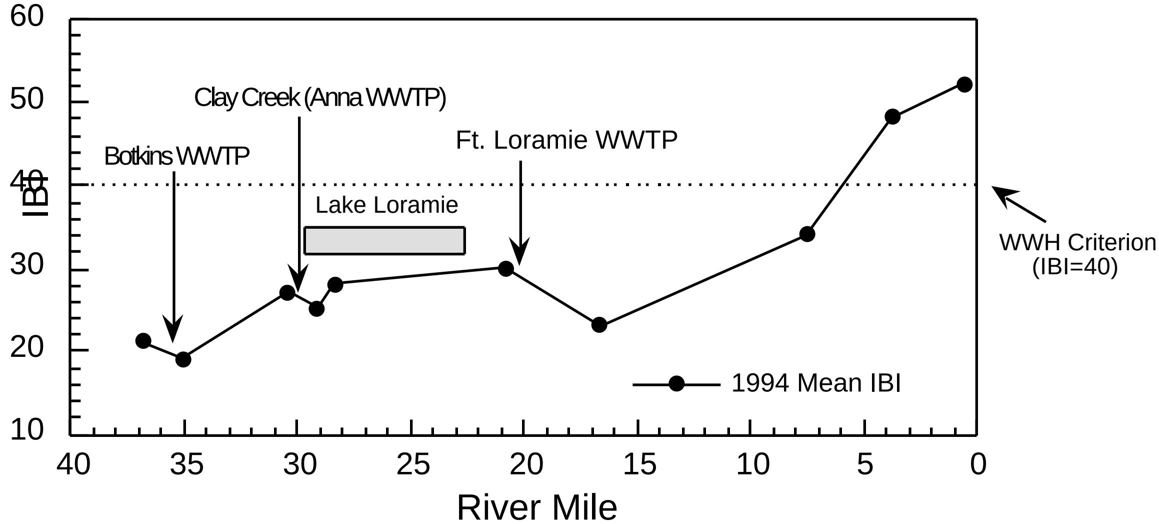


Figure 26 Linear regression between Qualitative Habitat Evaluation Index (QHEI) and Index of Biotic Integrity (IBI) values from the 1994 sampling efforts in Loramie Creek. The analysis suggests a relationship between macrohabitat quality and fish community performance.



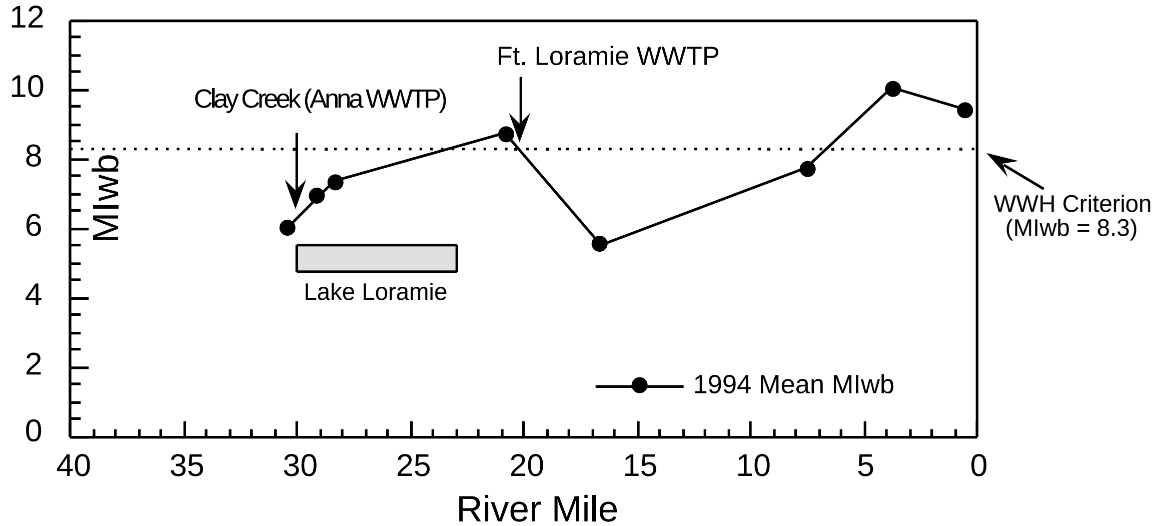


Figure 27 Longitudinal performance of the Index of Biotic Integrity (IBI) and Modified Index of Well-being (MIwb) from the 1994 Loramie Creek study area. The dashed lines represent numerical biological criteria in support of the current Warmwatrer Habitat (WWH) aquatic life use designation, Eastern Corn Belt Plain ecoregion.

Bokengehalas Creek (subbasin)

Pollutant Loadings

Bellefontaine WWTP

Constructed in 1916, with modifications in 1939, 1967, 1988 and 1993-94 the Bellefontaine WWTP is a secondary treatment facility consisting of screening, grit removal, two oxidation ditches, secondary clarifiers chlorination, dechlorination, and sludge holding. The plant has a design capacity of 3.5 MGD and discharges directly to Possum Run. The collection system is separate sewers, with all of the service area sewered. Population is approximately 12,000 with moderate growth expected. Approximately 10,000 linear ft. of replacement sewer lining was installed which has resulted in I/I reduction of approximately 1.0 MGD. Significant industrial contributors include: s Glacier Vandervell (metal finishing), Siemens Energy Automation, AP Technical, and HBD Thermoid.

Annual median conduit flow was typically 2.8 MGD between 1976 and 1994. Ninety-fifth percentile conduit flow throughout the period of record were typically greater than the 3.5 MGD design capacity, while median conduit flow approached design capacity only in 1990. Loadings of ammonia-nitrogen from 1976 to 1986 were typically 17.0 kg/day, with a sharp reduction occurring between 1987 and 1994. Recent plant upgrades have resulted in a near 75% decrease in ammonia-nitrogen loads since 1990. Median BOD_5 decreased by more than 50% in 1987 and continued to decrease through 1994. Annual loadings of TSS through the period of record followed a similar trend as that observed for BOD (Figure 28).

Acute bioassay tests conducted by the Ohio EPA in 1987 and 1988 indicated significant adverse effects to test organisms exposed to effluent and mixing zone samples. Five of ten entity generated bioassay test conducted in 1990 indicated acute toxicity. Additional bioassay test conducted by Ohio EPA in 1993 and 1994 found no adverse effects to test organisms exposed to effluent samples.

Chemical Water Quality

Replicate water column chemistry samples were collected at nine stations within the Bokengehalas subbasin. Specific streams evaluated included: Bokengehalas Creek (three stations), Blue Jacket Creek (four stations), and Possum Run (two stations). The mean longitudinal concentrations of analytes are presented in Figure 29.

Dissolved oxygen concentrations above the WWH criterion (average and minimum) were maintained throughout the Bokengehalas Creek study area. Average ammonia-nitrogen concentrations throughout the study area remained at the 0.05 mg/l detection limit, with the exception of a station on Bokengehalas Creek downstream of Degraff at RM 0.41. No

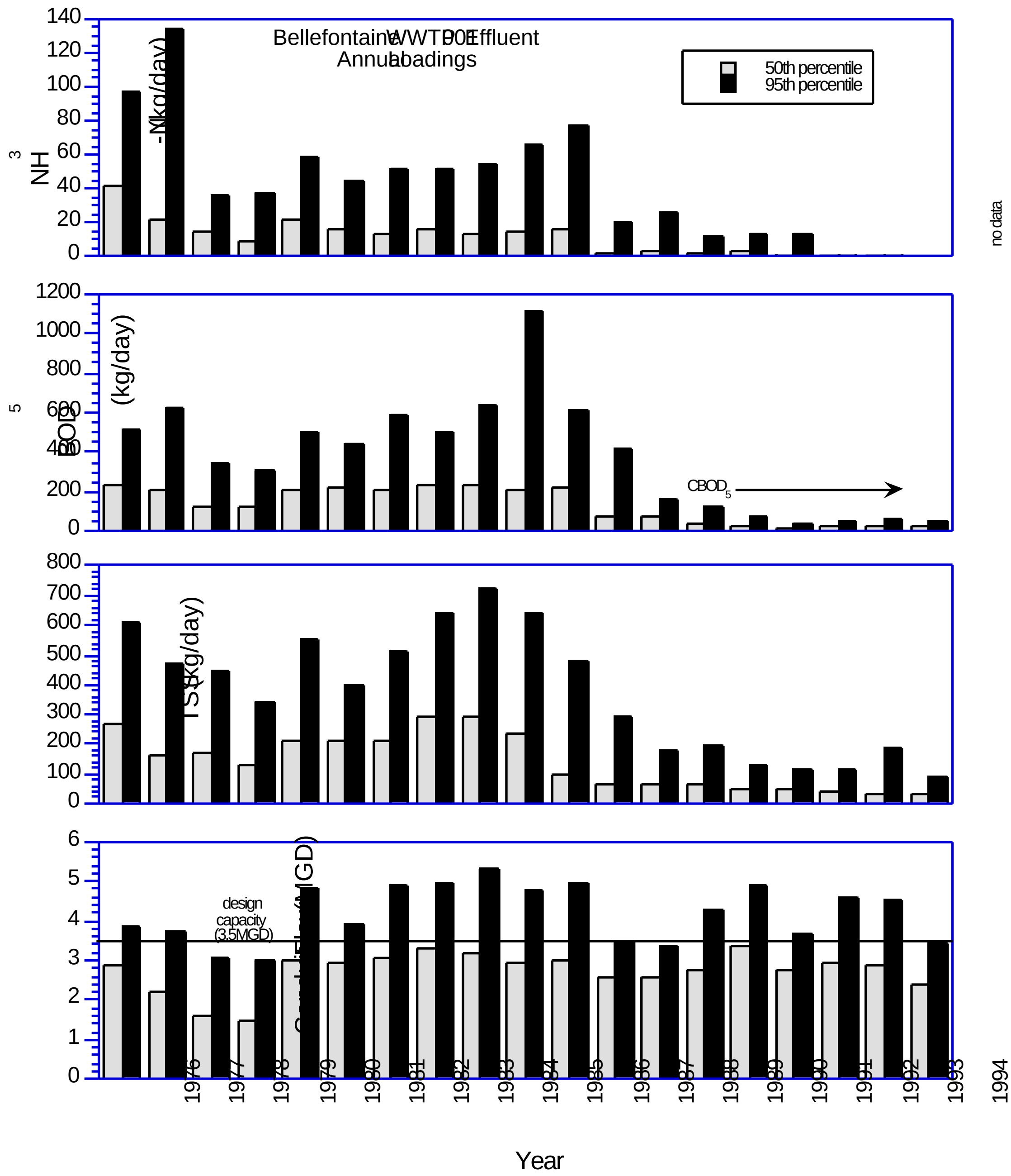


Figure 28 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) from the Bellafontaine WWTP.

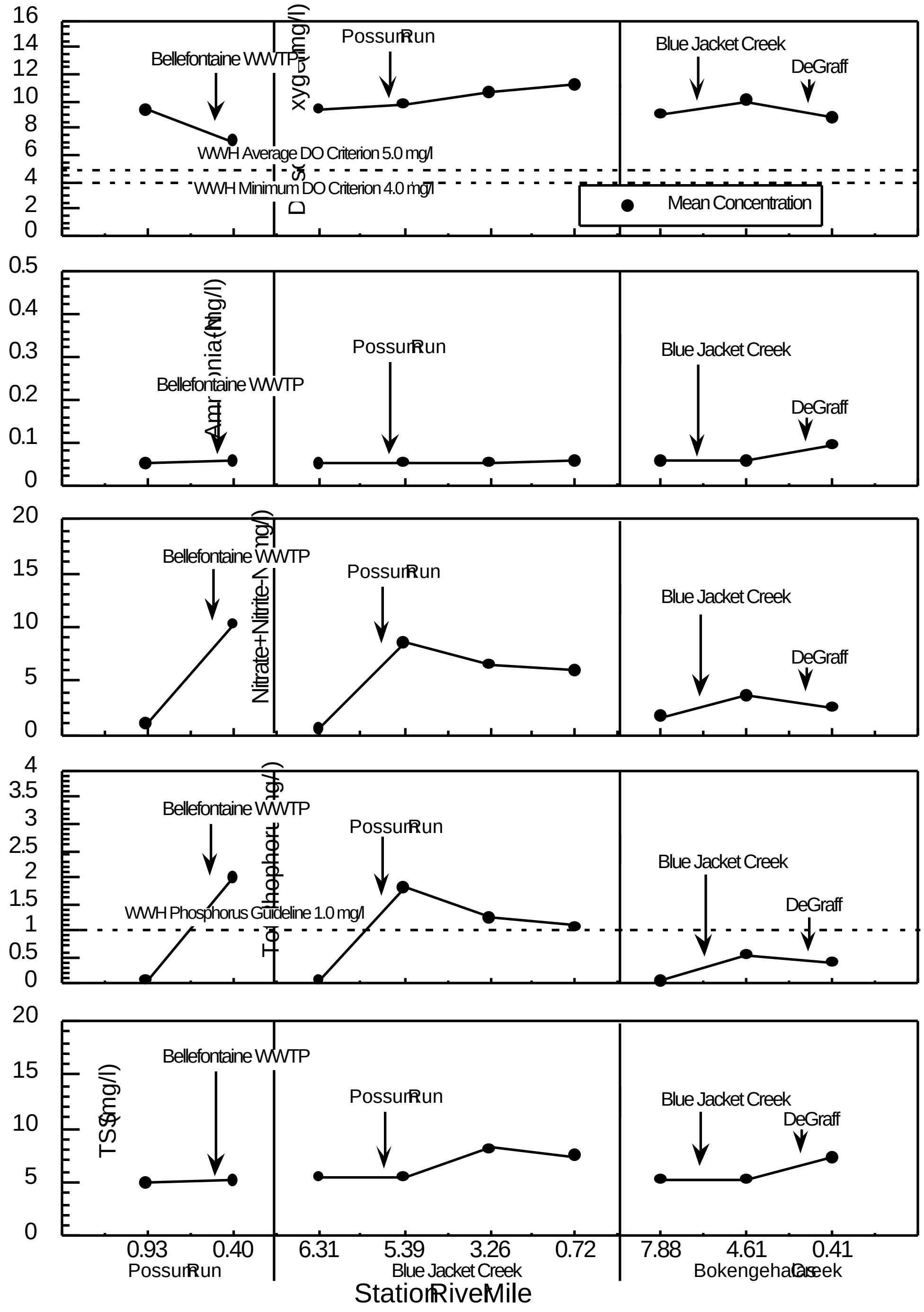


Figure 29 Mean longitudinal concentrations of dissolved oxygen, ammonia-nitrogen, nitrate+nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) from the Bokengehalas subbasin, 1994.

exceedences of the WWH criteria for unionized ammonia were indicated. Average TSS values remained fairly stable throughout the study area, with modest increases observed within the lower portion of Blue Jacket Creek and downstream of DeGraff in Bokengehalas Creek.

Mean concentrations of nitrate+nitrite-nitrogen and total phosphorus demonstrated a marked increase downstream of the Bellefontaine WWTP (Possum Run) and downstream of the confluence of Possum Run with Blue Jacket Creek. Mean concentrations of nitrate+nitrite-nitrogen within Blue Jacket Creek remained elevated for the entire reach downstream of the confluence of Possum Run. A similar pattern, of continued downstream influence, was evident in mean phosphorus concentrations in Blue Jacket Creek. Phosphorus levels downstream of Possum Run remained above the 1.0 mg/l WWH guideline. Elevated nitrate+nitrite-nitrogen and phosphorus levels were not observed in Bokengehalas Creek downstream of the confluence of Blue Jacket Creek.

A single Datasonde was deployed in Bokengehalas Creek at RM 0.4. Sampling was conducted during the period September 27-29, with a duration of approximately 45 hours. The results from the continuous sampling effort indicated D.O. concentrations well above the WWH criterion (Figure 24). Diel conductivity (µm/hos), pH (S.U.), and temperature (˚C) all remained within expected ranges.

Physical Habitat for Aquatic Life

In 1994 nine fish sampling stations were used to evaluate macrohabitat conditions in the Bokengehalas Creek subbasin. Three sites were on the Creek mainstem, one of which was located above the RM 7.0 confluence with Blue Jacket Creek. Four sites were located on Blue Jacket Creek, with one above the RM 5.8 confluence with Possum Run. And, two sites were located on Possum Run, above and below the Bellefontaine WWTP outfall. In general, macrohabitat conditions varied considerably between sites. Although, heavy silt loads and extensively embedded substrates of cobble, gravel and sand tended to predominate all sites. Beyond this, groundwater flow augmentation appeared to influence current velocities at many sites.

For the Bokengehalas Creek sites, QHEI scores of 43.5 (RM 8.1), 80.0 (RM 4.7) and 54.5 (RM 0.3) were recorded. A mean reach QHEI value of 59.3 suggested that the Bokengehalas Creek macrohabitats were less than optimal but probably capable of supporting aquatic organisms consistent with the WWH use designation. Channel modifications at the upper and lower stations were most responsible for the deviation in reach QHEI marks.

QHEI scores ranged between 81.0 (RM 5.5) and 41.0 (RM 0.8) for Blue Jacket Creek locations. A mean reach QHEI score of 57.8 implied that the macrohabitat conditions in Blue Jacket Creek were similar to those of Bokengehalas Creek. Likewise, the upper and lower sites had been channelized resulting in lower QHEI scores at these locations.

The two sites on Possum Run scored QHEI values of 58.0 (RM 0.7) and 74.0 (RM 0.4) with a mean reach value of 66.0. The effects of past channelization and placement of fill along the stream margin had resulted in some channel instability. However a mean reach score of 66.0 was consistent with ecoregional expectations.

For the nine sites evaluated in the Bokengehalas Creek subbasin a mean QHEI score of 60.1 was recorded. Despite numerous instances of channel modification, heavy silt loads and extensively embedded substrates, the overall macrohabitat conditions in the Bokengehalas Creek subbasin were not considered limiting. Instead, macrohabitat conditions at specific sites were found to be inadequate.

Biological Assessment: Benthic Macroinvertebrate Community

Macroinvertebrate communities were evaluated at three stations on Bokengehalas Creek bracketing Blue Jacket Creek and the community of DeGraff. No substantial decline in community performance was evident downstream from either source. Good communities were present at CR 31 (RM 8.0) and T 209 (RM 4.7) with 13 and 10 EPT taxa richness, respectively, and mostly pollution sensitive taxa predominated the natural substrate collections. Quantitative sampling at the station at Mill Street (RM 0.4) achieved an ICI score in the exceptional range (48).

Macroinvertebrate communities were evaluated at four stations on Blue Jacket Creek to evaluate impacts from Possum Run, which receives the Bellefontaine WWTP effluent. The station upstream from Possum Run at Troy Street (RM 6.4) exhibited a poor community with only one EPT taxon and low organism density. The stream at this station was very shallow (pool depth of four inches) which may have been a significant limiting factor. The community downstream from Possum Run (RM 5.4) exhibited improved habitat conditions and community performance. Five EPT taxa were collected with mostly pollution intermediate taxa predominant. A chlorine/septic odor was noted at this station. The community improved only slightly into the marginally good range at CR 11 (RM 3.2) with seven EPT taxa and a continuation of pollution intermediate taxa among the predominant organisms. The station at T 31 (RM 0.6) was sampled with artificial substrates and achieved an ICI score in the very good range (44). Sampling from the natural substrates at this site demonstrated some improvement with mostly pollution sensitive taxa predominant but the EPT taxa richness (5) continued to be below expected levels for a good community. Mayfly taxa richness in particular was noticeably low at all the Blue Jacket Creek sites for unknown reasons.

Macroinvertebrate communities were evaluated at two stations on Possum Run to evaluate any impact from the Bellefontaine WWTP discharge (RM 0.5). The community upstream from the WWTP was very limited with only one EPT taxon and 16 total taxa present in low densities. The poor community performance at this site was probably due to urban and railroad runoff in conjunction with small stream size. Downstream from the WWTP, EPT taxa richness increased to three with pollution intolerant to tolerant taxa predominant. Considering the poor background community performance, the Bellefontaine WWTP was not appearing to have a substantial water quality impact.

Biological Assessment: Fish Community

Thirty seven fish species and five hybrid types of fish (27,002 individuals) were collected in the Bokengehalas subbasin during two sampling passes at nine locations. Sampling sites were situated upstream of the Bellefontaine WWTP downstream to a location near the confluence with the Great Miami River. A primary objective of the 1994 sampling effort was to evaluate the effect of the Bellefontaine WWTP on receiving streams. The Bellefontaine WWTP outfalls to Possum Run at RM 0.5. Possum Run enters Blue Jacket Creek at RM 5.8. Blue Jacket Creek confluences with Bokengehalas Creek at RM 7.0. Bokengehalas Creek joins the Great Miami River at RM 146.0. In evaluating the WWTP, a linear pattern of influence through the stream network was considered (Figure 30).

Headwater IBI metrics were used to evaluate all Possum Run and Blue Jacket Creek sites. Wading metrics were applicable to the Bokengehalas Creek locations. Overall, the performance of the fish communities in the Bokengehalas subbasin was marginally good (mean IBI=38). However, the assemblages located downstream of the WWTP were considered good (mean IBI=41.6) while those removed from its influence were fair (mean IBI=30.0). This difference suggested that flow augmentation from the WWTP positively influenced fish community performance. Futhermore, significant departure from the WWH biocriteria was consistently observed outside of the influence of flow from the WWTP, while performance downstream of the plant at five of six sites was consistent with such expectations.

In general, fish community performance improved in each of the three streams downstream of the confluence with flow from the WWTP and with increasing watershed size. Because the IBI was calibrated along a watershed continuum (*i.e.,* should not improve with drainage size) and flow volume from the WWTP would have diminishing influence downstream, augmentation from groundwater was considered an important factor behind the downstream trend of improved fish community performance. Mottled sculpin, a cold water species requiring permanent flows, was particularly abundant (numerically 28%) in Bokengehalas Creek at RM 8.1 above the Blue Jacket Creek and WWTP flow confluence indicating groundwater flow was likely. Desite this positive factor, overall poor macrohabitat conditions yielded a fair fish community.

The fair performance at the two other sites outside of the WWTP flow on Possum Run (RM 0.7) and Blue Jacket Creek (RM 6.4) was most attributed to extended periods of reduced stream flows, lack of large pools, urban and railroad yard runoff, and marginal physical habitat quality (QHEI scores of 58.0 and 45.0, respectively). The single site downstream of the WWTP which performed below ecoregional expectations was on Blue Jacket Creek at RM 3.1. A mean IBI score of 33 here was influenced by the absence of hornyhead chub in the second sample (caught in the first sample) which affected the minnow and sensitive species metric scores and resulted in a fair IBI score of 30. Although this site had a QHEI score of 64, the macrohabitat conditions were that of a channel recovering from the effects of past modification. As such, some aspects of specific habitat conditions (*i.e.,* poor substrate quality and fair channel morphology) were noticeably deficient in spite of generally acceptable ambient conditions .

Overall, the fish assemblage in the Bokengehalas subbasin was numerically predominated by creek chub (42%), blacknose dace (22%), and central stoneroller (18%). Biomass in the subbasin was predominated by creek chub (32%), common carp (27%), and white sucker (15%). Tolerant species tended to be most well represented. Insectivores comprised a small percent of the fish population at nearly all sites and this metric typically scored low. Scores for most other IBI metrics tended to be moderate or high.

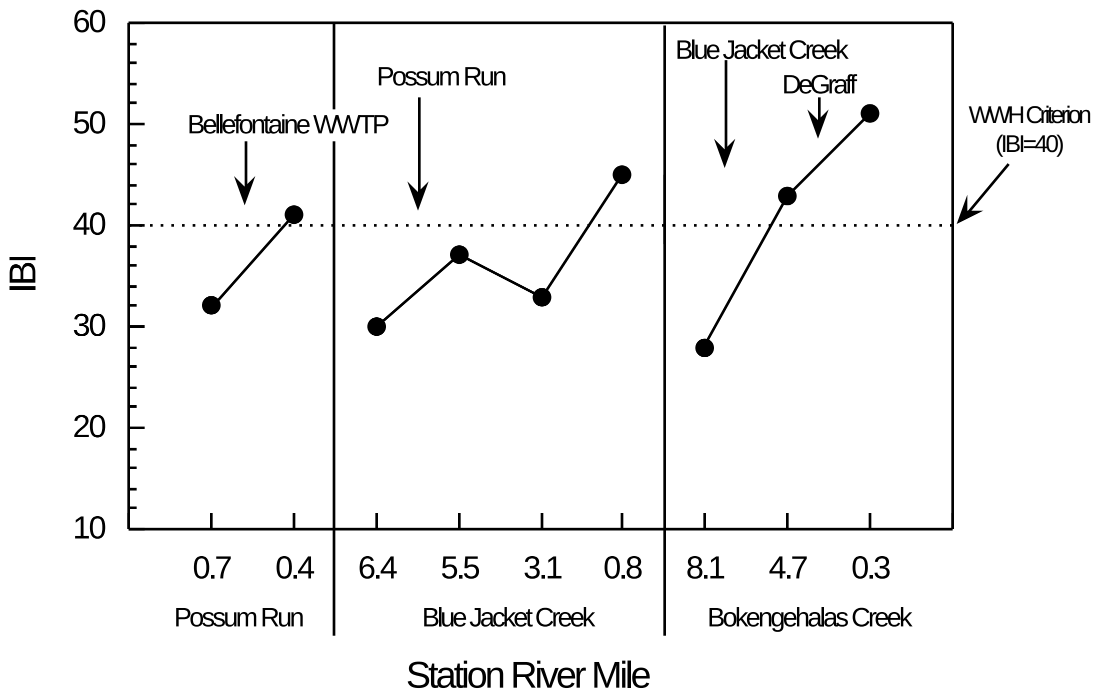


Figure 30 Longitudinal performance of the Index of Biotic Integrity (IBI) within the Bokengehalas subbasin, 1994. The dashed line represents the numeric biological criteria in support of the existing Warmwater Habitat (WWH) aquatic life use designation.

Selected Tributaries

Pollutant Loadings

New Carlisle WWTP

Constructed in 1938, with modifications in 1956, 1981, and 1991, the New Carlisle WWTP is a secondary treatment facility consisting of two primary clarifiers, two biological oxidation towers, RBCs, sludge drying beds, two secondary clarifiers, final clarifier, chlorination, post aeration, and SO_2 dechlorination. The plant has a design capacity of 1.0 MGD and discharges directly to Honey Creek at RM 8.7. The collection system consist of separate sewers, with the majority of the service area sewered. The service population is approximately 6000 with modest growth expected. Two lift stations exist with no bypasses or overflow structures. Significant industrial contributors include only High Tech Castings.

Annual average conduit flow during the period of record exhibited a modest increasing trend, with peak median and 95th percentile discharge occurring in 1984. Annual median loads of ammonia-nitrogen, BOD, and TSS were all markedly reduced after the 1981 treatment upgrade (Figure 31). Erratic ninety-fifth percentile loadings of ammonia-nitrogen, between 1982 and 1989 may have reflected treatment irregularities during that period.

Between 1989 and 1994, 23 NPDES permit violations were reported by the New Carlisle WWTP. Oil and grease, total residual chlorine, and ammonia-nitrogen were the most frequently violated parameters.

Chemical Water Quality

Replicate water column chemistry samples were collected from McKees Creek, Lost Creek, Spring Creek, and Honey Creek at seven sampling stations. Three stations were placed on Honey Creek to evaluate the influence of the New Carlisle WWTP, between RM 9.96 and RM 3.18. Two stations were placed on Lost Creek at RM 9.74 and RM 2.6, and one station was placed near the mouth of Spring Creek and McKees Creek, RM 0.84 and RM 0.52 respectively. Over the course of the survey stream discharge appeared reduced within Lost Creek, reaching near interstitial conditions by early-fall. As such, samples collected from Lost Creek in September were taken from residual pools.

Dissolved oxygen concentration above the 6.0 mg/l EWH minimum D.O. criterion were maintained in McKees Creek and Spring Creek. Three violations of the EWH minimum criterion were indicated at RM 2.6 in Lost Creek, with one value as low as 2.0 mg/l. Four violations of the EWH minimum criteria were observed at downstream of the New Carlisle WWTP at RM 8.08 in Honey Creek, with a value as low as 3.5 mg/l (Table 6). Ohio EPA field staff observed a longitudinal increase in filamentous algae in Honey Creek suggesting modest enrichment.

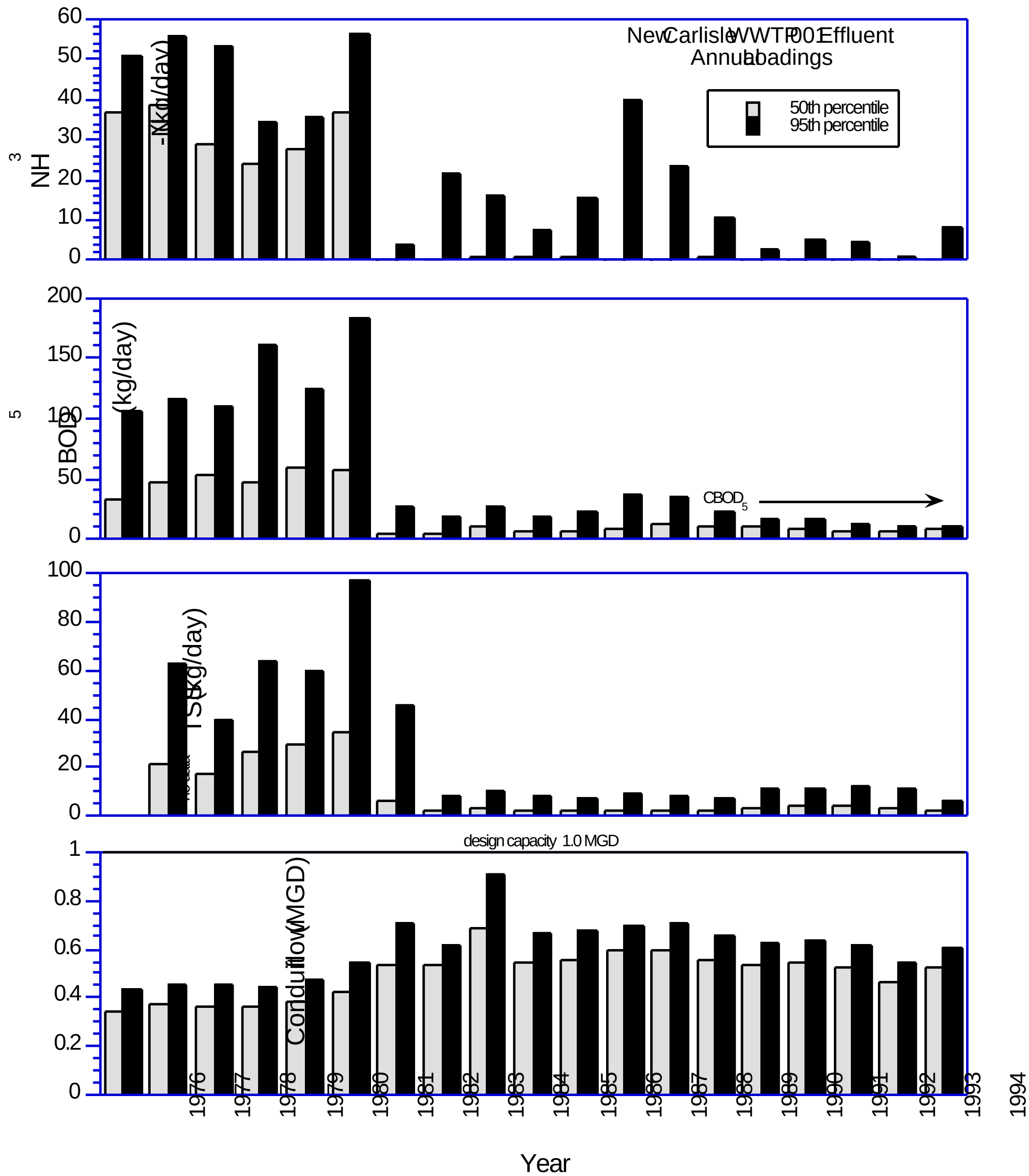


Figure 31 Annual median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of ammonia-nitrogen, biochemical oxygen demand, and total suspended solids from the New Carlisle WWTP.

Ammonia-nitrogen concentrations for all tributaries remained near the detection limit (0.05 mg/l) throughout the tributary survey. No violations of the EWH ammonia-nitrogen criteria were indicated at any station. Average nitrate+nitrite-nitrogen concentrations were low and comparable at five of the seven stations within the tributary study area. Highly elevated nitrate+nitrite-nitrogen levels were observed in Lost Creek at RM 2.6 and in Honey Creek, downstream of the new Carlisle WWTP, at RM 8.08. A mean phosphorus concentration greater than the 1.0 mg/l WWH guideline was observed at one station in Honey Creek at RM 8.08 (downstream of the New Carlisle WWTP). Phosphorus concentrations at remaining stations within the tributary survey were well below the WWH guideline.

Exceedences of the human health 30-day average criteria were indicated within Honey Creek and Lost Creek for Dieldrin (Table 6). The occurrence of this environmentally persistent organochlorine compound is most likely related to past agricultural use within the basins. This pesticide residue is commonly held on the exchange complex of silts and clays (Howard 1991). As such, its occurrence within the water column likely reflects the presence of suspended soil particles in the water samples collected.

Physical Habitat for Aquatic Life

Cherokee Mans Run
Macrohabitat conditions were evaluated at two fish sampling locations on Cherokee Mans Run in 1994. QHEI scores of 69.0 (RM 3.5) and 65.0 (RM 1.8) were recorded. Moderate to heavy amounts of silt was present in the moderate to extensively embedded gravel and sand substrate. A moderate amount of instream cover existed with fair channel development at both sites. A mean reach score of 67.0 suggested that macrohabitat conditions were adequate to support an aquatic community capable of meeting the WWH use designation (Rankin 1989).

Muchinippi Creek
Poor quality macrohabitat conditions were encountered at three fish community evaluation sites on Muchinippi Creek. QHEI scores of 32.0 (RM 12.5), 37.5 (RM 7.4), and 35.0 (RM 1.9) at these sites were reflective of a channelized stream with heavily embedded sand and silt substrates. A sparse amount of instream cover with limited riparian vegetation and agricultural land use encroachment was common to all three sites. A mean reach QHEI score of 34.8 suggested the macrohabitat conditions were sufficiently impaired to exert a negative influence upon the ambient biological potential (Rankin 1989).

Stony Creek
Channelization resulting in poor development, no sinuosity and low stability accompanied by extensively embedded sand and silt substrates and nearly absent instream cover yielded a QHEI score of 24.5 at RM 3.2. This was the lowest QHEI value recorded in the Upper Great Miami River basin in 1994.

McKees Creek
Macrohabitats of McKees Creek, a tributary to Stony Creek, were evaluated at two fish sampling sites; RM 9.5 and 0.7. QHEI values of 53.5 and 62.0 were respectively scored at these sites. Both sites had good variation in substrates, moderate amounts of instream cover and fair development. Agricultural land use encroachment and the effects of past channel modifications negatively affected the mean reach QHEI score of 57.8. Groundwater flow augmentation was

perceived to aid flow velocities and buffer temperature fluctuations providing a positive influence on macrohabitat conditions.

Spring Creek
Macrohabitats of Spring Creek were evaluated at one fish sampling site (RM 1.0) where a QHEI value of 61.0 was determined. Good substrate variation and a moderate amount of instream cover were offset by fair development. The rather wide stream at this location lacked good quality pools. The QHEI score of 61.0 indicated macrohabitats were probably inadequate for the EWH aquatic life use designation (Rankin 1989).

Lost Creek
In evaluating the macrohabitats of Lost Creek at two fish sampling sites, QHEI scores of 87.5 (RM 9.8) and 54.0 (RM 2.5) were recorded. The upstream site had exceptional macrohabitat conditions while the downstream site was influenced by past channel modifications and local water withdrawal for agricultural irrigation. The riparian corridor along Lost Creek was fairly intact. A mean reach QHEI score of 70.8 suggested the ambient macrohabitat conditions were capable of supporting a biological community comparable to EWH expectations (Rankin 1989).

Honey Creek
The macrohabitats of Honey Creek were evaluated at three fish sampling station between located RM 10.0 and RM 3.2. Qualitative Habitat Evaluation Index (QHEI) scores ranged between 85.0 (RM 8.0) and 67.5 (RM 3.2), with a mean reach value of 74.3. A stream segment average QHEI of 74.3 suggests that near and instream habitats encountered were sufficient to support a community of aquatic organisms consistent with the EWH biological criteria (Rankin 1989). Positive habitat attributes encountered throughout the Honey Creek study area included: abundance of functional instream cover, a persistent wooded riparian corridor, coarse glacial substrates, and pooled areas greater than 40 cm in depth (Table 8).

Biological Assessment: Benthic Macroinvertebrate Community

Cherokee Mans Run
Macroinvertebrate community performance in Cherokee Mans Run at T 99 (RM 3.7) was very good with an ICI score of 44. Fourteen unique caddisfly and mayfly taxa were collected using both the artificial and natural substrate methods. Three cool water taxa were collected accounting for 4.9% of the quantitative sample. The cool water taxa were the caddisfly *Hydropsyche (C.) slossonae*, and the midges *Parametriocnemus sp.* and *Paratanytarsus n. sp. 1.* This level of cool water representation, however, did not meet minimal expectations for the CWH aquatic life use designation (≥4 cool water taxa and ≥9% abundance of cool water taxa).

McKees Creek
Macroinvertebrate community performance in McKees Creek at CR 31 (RM 0.9) was exceptional (ICI=52) and included sixteen total mayfly and caddisfly taxa collected from artificial and natural substrates. The community met minimal macroinvertebrate expectations for designation of the CWH aquatic life use with four cool water taxa accounting for 13.8% of the community. The larger natural substrates were coated with travertine [often less accurately referred to as marl (Hynes 1970)], an indication of high calcium carbonate concentrations in the water column.

Spring Creek
Macroinvertebrate community performance in Spring Creek was very good. Fourteen EPT taxa were collected from the natural substrates including the stonefly taxa *Acroneuria evoluta* and *Agnetina capitata* complex.

Lost Creek
Lost Creek supported diverse, high quality macroinvertebrate communities consistent with the EWH aquatic life use designation. EPT taxa richness ranged from 15 at RM 9.9 to 20 at RM 9.8. The stream at SR 202 (RM 2.5) was reduced to interstitial flow, but still maintained a diverse, well balanced community (55 total taxa, 16 EPT taxa).

Honey Creek
Honey Creek upstream from New Carlisle at RM 10.1 supported a diverse, high quality macroinvertebrate community (ICI=44) including 24 total EPT taxa. Community performance downstream from the New Carlisle WWTP (RM 8.72) at SR 571 (RM 8.1) declined into the marginally good range. Community structure shifted to a predominance of pollution intermediate and tolerant forms, but many intolerant forms continued to be present (total EPT=16). This community response indicated enrichment from the WWTP without significant toxicity. Farther downstream at Rudy Road (RM 3.2) the community improved to a level near the upstream condition. The ICI scored in the good range (ICI=40) and the total EPT taxa richness increased to 25. However, the percent abundance of tolerant organisms remained relatively high at 28.5% which was an indication of continued mild enrichment from the WWTP. The New Carlisle WWTP was apparently the principal factor preventing the macroinvertebrate community from achieving EWH expectations downstream from its discharge.

Biological Assessment: Fish Community

Cherokee Mans Run
Twenty one fish species (1,929 individuals) were collected in Cherokee Mans Run at two locations in 1994. Sampling occurred twice downstream of TR 99 (RM 3.5), and once upstream of TR 95 (RM 1.8). The headwater IBI narrative ratings of good (RM 3.5, IBI=41) and exceptional (RM 1.8, IBI=50) were both consistent with ecoregional expectations for the WWH aquatic life use designation at these sites. Mottled sculpin (33%), creek chub (25%), and white sucker (12%) were numerically most abundant in aggregate. Common carp (43%) and white sucker (26%) predominated the aggregate biomass. In general, the fish communities appeared structurally and functionally well balanced.

Muchinippi Creek
Thirty three fish species (1,432 individuals) were collected in Muchinippi Creek in 1994. Sampling occurred once at three sites: RM 12.5, upstream of US 33; RM 7.4, upstream of CR 87; and RM 1.9, upstream of Wren Rd. The headwater IBI narrative rating of good (IBI=42) and the wading rating of very good-marginally good (IBI=48, MIwb=8.0) for the most upstream locations (RM 12.5 and 7.4, respectively) were typical of ecoregional expectations while the downstream site (RM 0.8) with a wading rating of fair (IBI=28, MIwb=6.8) was a significant departure from ecoregional expectations for WWH use designation at these sites.

Overall, striped shiner (51%), bluntnose minnow (10%), and creek chub (8%) were numerically most abundant. In biomass, common carp (31%), striped shiner (23%), white sucker (7%) and channel catfish (7%) were predominant. The upstream fish communities were structurally and functionally well balanced. However, the downstream community appeared to be reflective of the poor quality macrohabitat conditions which were encountered at all three fish evaluation sites (mean reach QHEI score=34.8).

Stony Creek

Seventeen fish species (95 individuals) were collected in Stony Creek in one sample at RM 3.2, upstream of TR 30. The wading IBI narrative rating of good-poor (IBI=42, MIwb=5.3) was within the ecoregional expectations for the WWH use designation. The fish community was predominated by striped shiner (35% in number, 3% in biomass), creek chub (20% in number, 1% in biomass), white sucker (9% in number, 5% in biomass), and common carp (6% in number, 89% in biomass). The poor MIwb score was related to an overall low number of fish in the sample and the marked predominance by the species cited above. The good IBI score was reached in the face of severe habitat degradation (QHEI=24.5). Groundwater flow was perceived to positively influence the fish community performance.

McKees Creek

Twenty three fish species (1,783 individuals) were collected from two sites on McKees Creek, a tributary to Stony Creek. Sampling occurred once at RM 9.5, upstream of CR 1, and twice at RM 0.7, upstream of CR 31. Exceptional headwater IBI scores of 54 were recorded at both sites. Overall, the fish community was predominated numerically by mottled sculpin (33%), striped shiner (17%), central stoneroller (14%), and creek chub (13%). In biomass the predominant species were striped shiner (18%), white sucker (17%), golden redhorse (14%), and creek chub (14%). In general, the fish communities appeared intact and represented a high quality assemblage.

Spring Creek

Eighteen fish species (4,658 individuals) were collected in Spring Creek in two samples at RM 1.0, upstream of Troy-Piqua Rd. The wading narrative rating of good-marginally good (IBI=43, MIwb=8.1) was a significant departure from expectations based on ecoregional standards for the existing EWH aquatic life use designation. Central stoneroller (52% in number, 53% in biomass) and rainbow darter (25% in number, 14% in biomass) predominated the fish community. Poor quality pool habitat seemed to limit fish community performance as no sunfish and few top carnivores were present.

Lost Creek

Twenty four fish species (7,905 individuals) were collected in Lost Creek during two sampling passes at two locations in 1994. Good-very good wading narrative ratings were recorded upstream of Troy-Urbana Rd. (RM 9.8, IBI=45, MIwb=9.0) and downstream of SR 202 (RM 2.5, IBI=44, MIwb=9.0). The fish communities at both sites performed at a level just short of ecoregional expectations for the EWH aquatic life use designation. Both communities were predominated by central stoneroller in number (49%) and biomass (44%). Overall, the assemblages at both sites appeared reflective of the streams potential and no water quality issues were inferred by the performance slightly below expectations.

Honey Creek

A total of 11,823 fish, comprising 34 species, was collected from Honey Creek between August and October, 1994. The sampling effort included three sampling stations located between RM 10.0 (upstream of New Carlisle WWTP) and RM 3.2 (Rudy Rd.), providing an assessment coverage of 6.8 river miles (10.9 km).

Longitudinal performance of the fish community as measured by the IBI and MIwb was uniform (Table 10). Each station indicated a level of performance fully consistent with the EWH aquatic life use designation, with narrative evaluations ranging between very good and exceptional. The fish assemblage within Honey Creek appeared diverse and well organized, with environmentally sensitive taxa well represented. No adverse affect from the New Carlisle WWTP was evident within the fish community.

TREND ASSESSMENT

Upper Great Miami River

Chemical Water Quality: 1982-1994

Historical water column chemistry data from the Upper Great Miami River were employed to perform a long term water quality trend analysis. The most comprehensive data sets available were collected by the Ohio EPA during the summers of 1989 and 1982. The 1989 data included samples collected from three stations between RM 92.6 and RM 85.2, providing assessment coverage for only the lower reach of Segment II of the mainstem. The 1982 data included samples collected between RM 159.2 and RM 92.6, providing nearly identical coverage in comparison with the 1994 sampling effort.

To assess the relative influence of river discharge (primarily non-point influence) on the result of water samples collected from 1982 and 1994, historical river flow data from the USGS monitoring network were used. Within Segment I, mean third quarter river discharge, indicated at the Sidney gage, was approximately 200 cfs greater in 1982, than that recorded in 1994. Within Segment II, mean third quarter discharge, indicated at the Dayton gage, was approximately 700 cfs greater in 1982 than recorded in 1994. The higher river flows recorded in 1982 may have amplified nonpoint source influences on ambient samples collected.

Segment I (Indian Lake to Loramie Creek)

Between 1982 and 1994 chemical water quality of the mainstem was most significantly improved within the upper portion of the study area, from the Indian Lake WWTP to the Quincy Dam. A reduction in mean concentrations of conventional pollutants and an increase D.O. within this segment reflected much improved waste treatment process at Indian Lake WWTP.

In 1982, the Indian Lake WWTP appeared to have a significant and adverse effect upon the water quality of the Great Miami River. Excessive pollutant loads from this facility were evidenced by instream chemical measurements. Mean ammonia-nitrogen concentrations immediately downstream of the Indian Lake WWTP were nearly five times greater than background levels. Furthermore, the ammonia loads were such that, elevated concentrations were maintained several miles downstream to the Quincy dam pool. Mean concentrations of BOD_5 and phosphorus displayed a similar longitudinal trend relative to the Indian Lake WWTP, with mean phosphorus values greater than the 1.0 mg/l WWH guideline observed. The increased oxygen demand associated with excessive nutrient inputs was clearly evident in longitudinal mean D.O. concentrations. A marked reduction of D.O. was indicated immediately downstream of the Indian Lake WWTP, with levels below or near the 4.0 mg/l WWH minimum D.O. criterion recorded several miles downstream (Figure 32).

The results from the 1994 survey indicated significant improvement of the water quality of the Great Miami River within the reach under the influence of the Indian Lake WWTP. Nearly all of the nutrient parameters that were elevated in 1982 have been reduced to background levels. Only nitrate+nitrite-nitrogen concentration were increased in 1994. This observation was likely reflective of improved nitrification at the Indian Lake WWTP. Mean D.O. concentrations were significantly improved, with average values above the WWH criteria (average and minimum) maintained throughout this segment.

Within the remaining portion of Segment I, downstream of the Quincy Dam to the Loramie Creek confluence, no substantial change in chemical water quality were observed in 1994. In comparison with the 1982 results, mean dissolved oxygen appeared moderately improved, while nutrient levels appeared reduced and longitudinally stable.

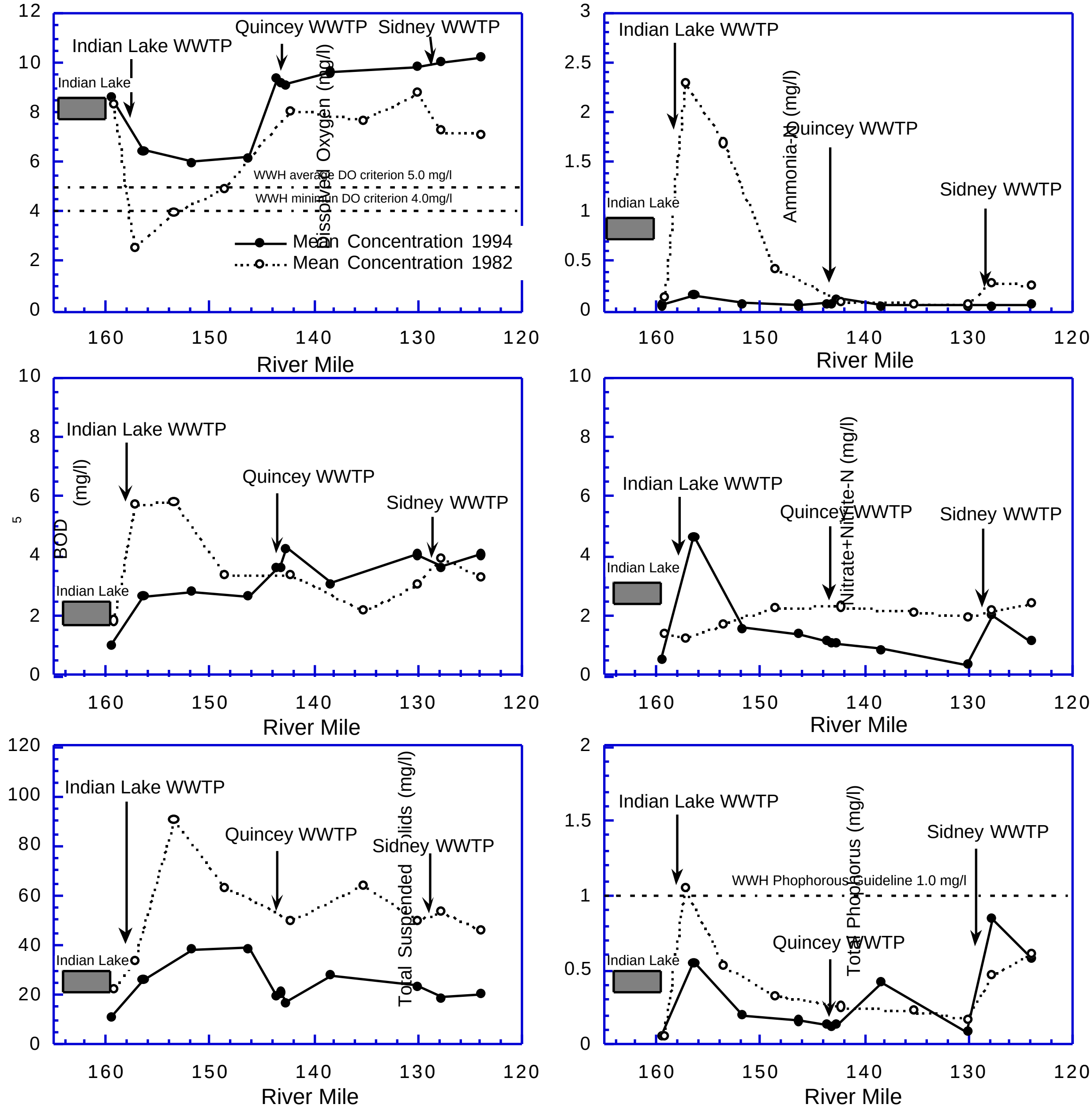


Figure 32 Longitudinal mean concentrations of dissolved oxygen, ammonia-nitrogen, five-day Biochemical Oxygen demand (BOD_5), total suspended solids, and total phosphorus from Segment I of the Great Miami River, 1982 through 1994.

Segment II (Loramie Creek to downstream MCD N. Reg. WWTP)
Between 1982 and 1994 marked improvements in the chemical water quality of the Upper Great Miami River have occurred. An increase in D.O., as well as general reduction of nutrient concentrations within the water column, appeared a result of much improved wastewater treatment provided by the entities discharging to the Upper Great Miami River, Segment II.

In comparison with the data collected in 1982, D.O. was most improved within the reach extending from Loramie Creek to Troy. Although mean D.O. values greater than the WWH criteria (average and minimum) were maintained in 1982, D.O. was markedly reduced downstream of both the Piqua WWTP and Piqua MP-EGS. The results from the 1994 survey indicated an overall increase in the average concentrations, as well as great improvement downstream of these facilities in Piqua (Figure 33). Within the reach extending downstream from Troy to the lower limits of the 1994 study area D.O. concentrations remained stable and comparable between 1982, 1989, and 1994 data sets. Comparing results from the 1982 and 1994 sampling efforts throughout Segment II, D.O. values were on the average 2 mg/l higher in 1994.

Mean nutrient levels within Segment II displayed a decreasing trend through time within the majority of the study area. Mean nitrate+nitrite-nitrogen, total phosphorus, and TSS concentrations were generally reduced throughout Segment II in 1994 when compared historical information (Figure 33). A noted exception to this observation included mean phosphorus concentration downstream of the MCD North regional WWTP, where phosphorus was highly elevated in 1994 in comparison with historical values. However, excluding mixing zones (Piqua WWTP and Piqua MP-EGS), mean phosphorus values remained below the 1.0 mg/l WWH guideline throughout Segment II.

Average ammonia-nitrogen concentrations from the 1982 and 1994 sampling efforts appeared low and stable, longitudinally as well as through time, within the majority of Segment II. Only downstream of the Piqua WWTP were values elevated in 1982. The elevated ammonia-nitrogen levels appeared abated in 1994, with a mean concentration near background levels downstream of the Piqua WWTP. The reduction in ambient concentration of unionized ammonia may have reflected improved treatment process at the Piqua WWTP, or better management of the thermal loads from the Piqua MP-EGS, or both processes working in concert. The ambient concentration of unionized ammonia is pH and temperature dependent. As such, poorly managed thermal loads to the Great Miami River from the Piqua MP-EGS in 1982 could amplify the effects of ammonia loading from the Piqua WWTP on the Great Miami River.

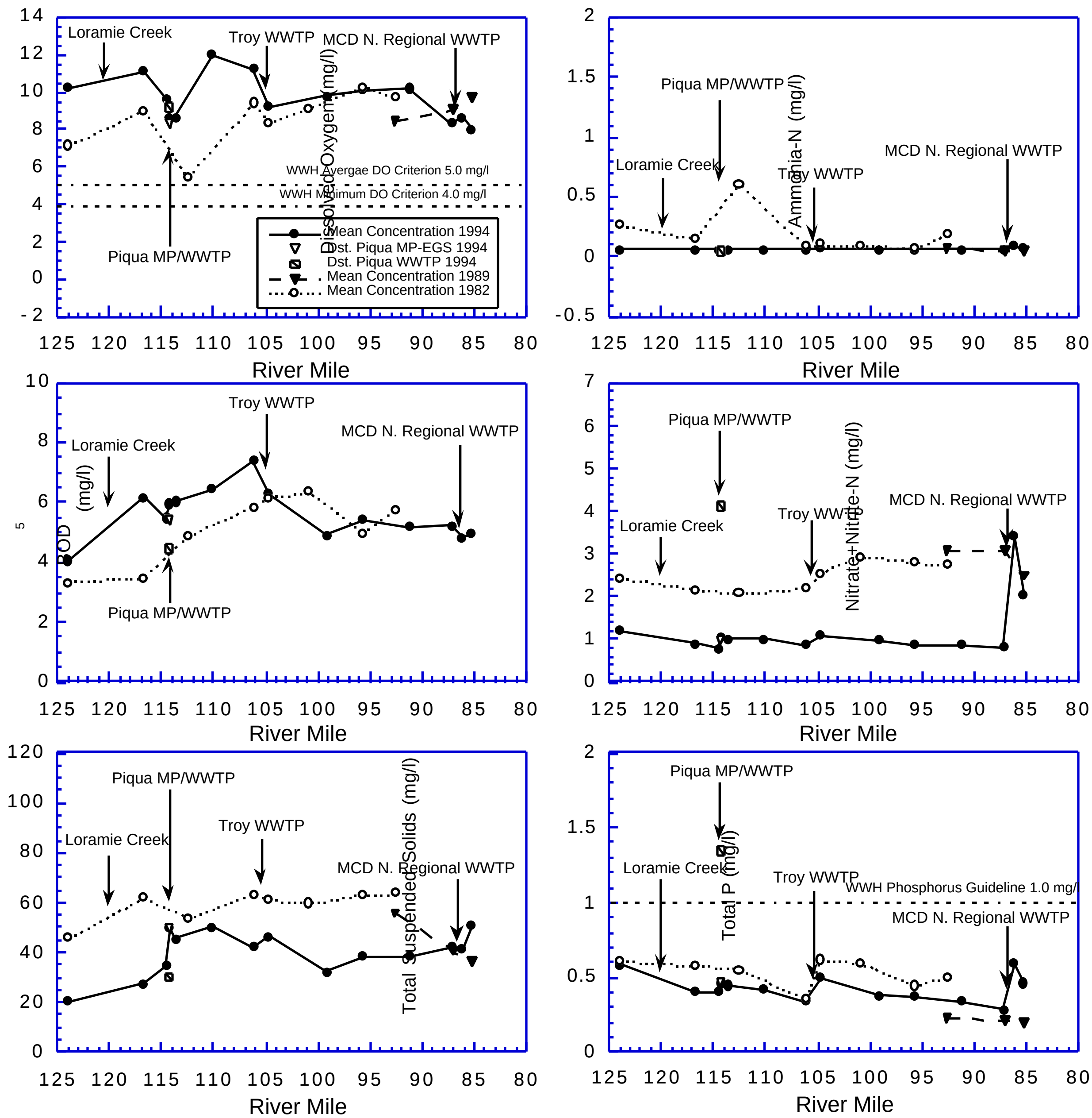


Figure 33 Longitudinal mean concentrations of dissolved oxygen, ammonia-nitrogen, five-day Biochemical Oxygen Demand (BOD_5), total suspended solids, and total phosphorus from Segment II of the Great Miami River, 1982 through 1994.

Benthic Macroinvertebrate Community: 1979-1994

Segment I (Indian Lake to Loramie Creek)
The performance of macroinvertebrate communities in the Great Miami River from Indian Lake to the confluence of Loramie Creek demonstrated overall improvement since the 1982 intensive survey (Ohio EPA 1984). ICI scores in 1994 were achieving a maximum in the mid to high exceptional range (ICI scores from 50 to 56) compared to maximum ICI scores of 46 in 1982 (Figure 34).

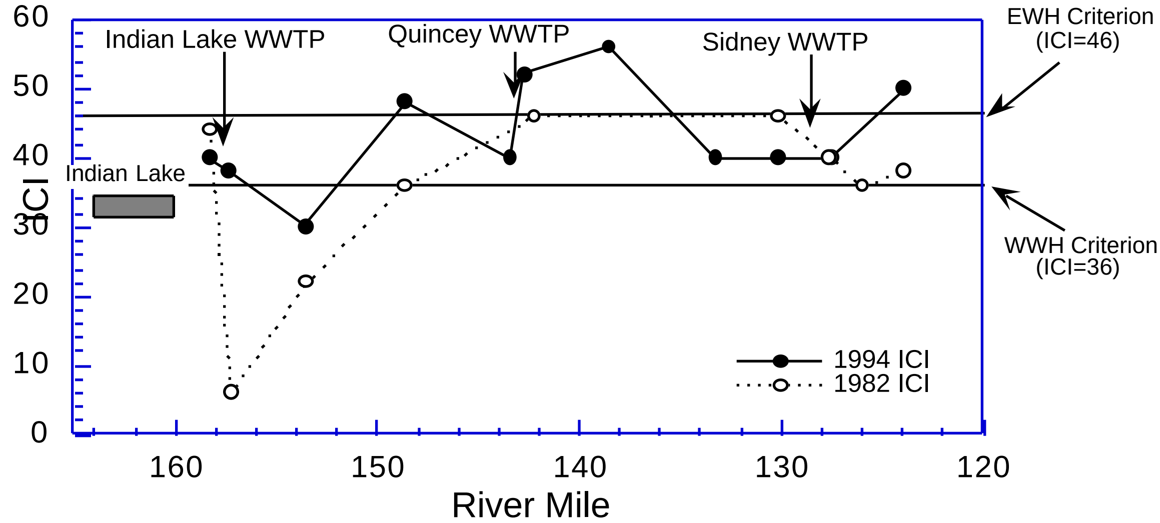
Macroinvertebrate community performance bracketing the Indian Lake WWTP (RM 158.0) continued to demonstrate no detectable impact since the 1985 WWTP upgrades, similar to 1988 sampling results (Ohio EPA 1990). Sampling in 1982 documented severe community impairment downstream from the WWTP (ICI=6 at RM 157.2). However, 1994 results indicated a community decline 4.5 miles downstream from the WWTP which may have been caused by a mild enrichment effect in conjunction with the low gradient nature of the stream in this area. The impairment observed in 1982 extended at least this far downstream.

Macroinvertebrate community response downstream from the Quincy WWTP (RM 143.0) was similar in 1982 with no detectable impact. In fact, ICI scores achieved exceptional levels downstream from Quincy during both years (ICI=46 at RM 142.2 in 1982 and ICI=52 at RM 142.7 in 1994).

In 1982, the macroinvertebrate community performance gradually declined by 10 ICI points downstream from the Sidney WWTP (RM 128.7) due to moderate structural shifts in the community components. The apparent community impairment in 1982 was not evident in 1994, despite a mild enrichment effect, which did not lower the ICI score, detected 1.18 miles downstream from the WWTP.

Segment II (Loramie Creek to downstream from the MCD N. Reg. WWTP)
Macroinvertebrate community performance in the Great Miami River demonstrated a similar trend from Loramie Creek to Little York Road (RM 91.1) compared to the 1982 intensive survey (Ohio EPA 1984) and from Little York Road to the MCD North Regional WWTP compared to the 1980 (Ohio EPA 1982) and 1989 data (Figure 33). ICI scores in 1994 were achieving a maximum in the mid to high exceptional range (ICI from 50 to 56) compared to low to mid exceptional scores (46-50) in 1982, very good scores (42-44) in 1980, and a maximum ICI score in the high exceptional range (56) in 1989.

Community performance declined into the fair range (ICI=28 at RM 114.22) downstream from the Piqua WWTP and Piqua Municipal Power EGS in 1982 compared to an exceptional ICI score (ICI=46) at the same site in 1994. This improvement in community performance indicated improved wastewater treatment by the upstream dischargers. However, the 1994 sample located within the Piqua WWTP mixing zone indicated a community impact typical of organic enrichment (ICI=38 at RM 114.27E). The community performance improved to near upstream levels by RM 113.5 in both years. The Troy WWTP (RM 105.67) was not negatively impacting downstream macroinvertebrate communities in 1982 (ICI=46 at RM 104.7) or 1994 (ICI=50 at RM 105.4).



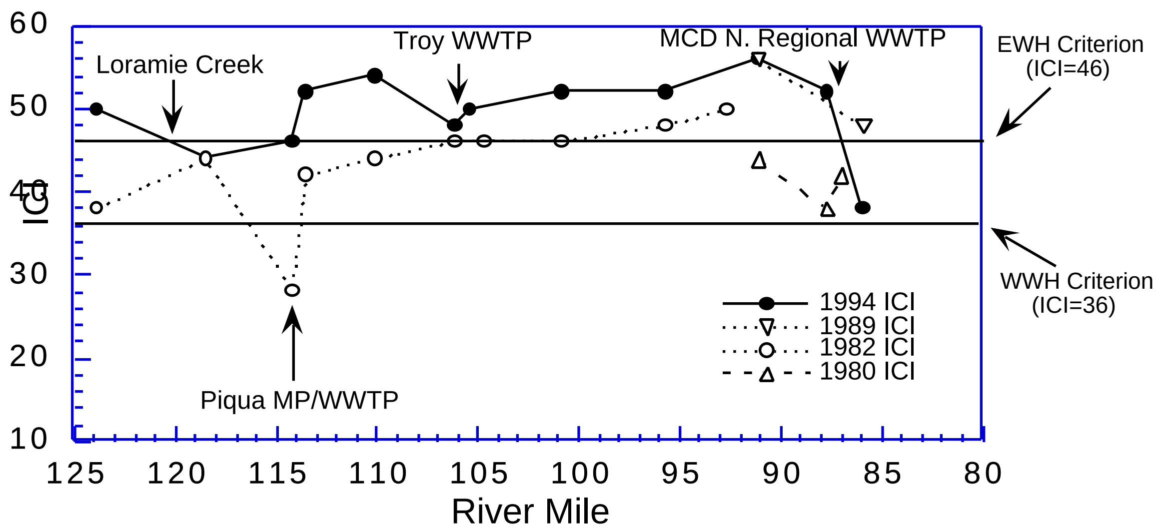


Figure 34 Longitudinal performance of the Invertebrate Community Index (ICI) for Segment I and Segment II of the Upper Great Miami River, 1980 through 1994. The solid lines represent numerical biological criteria in support of the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life use designations, Eastern Corn Belt Plains ecoregion.

Macroinvertebrate community performance downstream from the MCD North Regional WWTP historically has steadily improved over the years from the fair range in 1979 (ICI=26 at RM 87.0) to the very good range (ICI=42 at RM 87.0) in 1980 and then the exceptional range in 1989 (ICI=48 at RM 85.9) and 1993 (ICI=56 at RM 85.9) (Figure 35). 1994 was the first year this station demonstrated a negative impact from the WWTP (ICI=38 at RM 85.9). The MCD North Regional WWTP discharge was located upstream from Needmore Road at RM 87.4 until 1988 when it was moved downstream to RM 86.6. A lowhead dam was constructed at RM 86.8 in 1990 to aid the recharging of the Dayton well field.

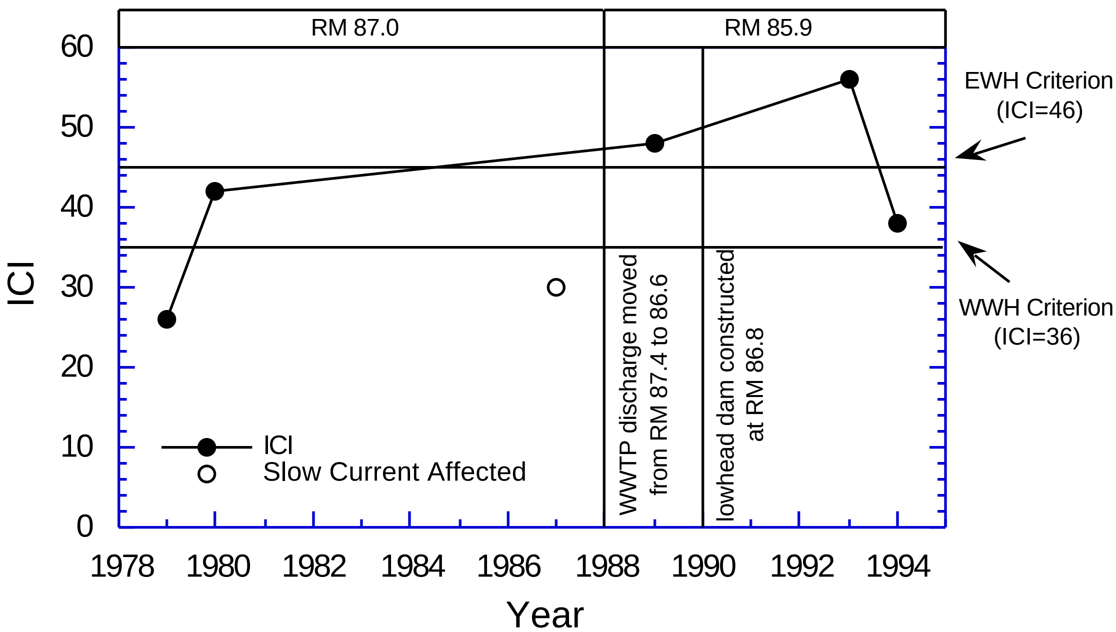


Figure 35 Invertebrate Community Index (ICI) values from the national ambient monitoring station located downstream of the MCD North Regional WWTP, 1979 through 1994.

Biological Assessment: Fish Community 1982-1994

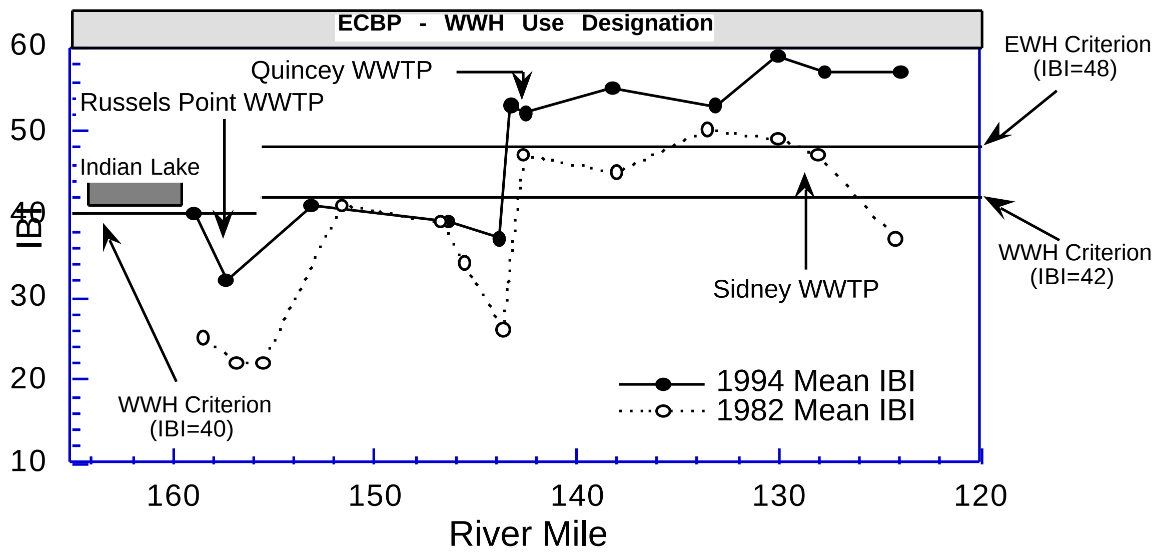
Fish community data was collected from the Upper Great Miami River in 1980, 1982, and 1993. The 1980 survey included three stations, assessing a river reach between RM 91.0 (Little York Rd.) and RM 86.2 (adj SR 202). The 1982 survey was more robust and included 26 stations, from RM 158.5 (upstream of the Indian Lake WWTP) to RM 94.0 (Vandalia WWTP-now abandoned). The 1982 sampling effort provided nearly identical coverage to that of the recent 1994 survey.

Segment I (Indian Lake to Loramie Creek)

Performance of the fish community in 1994 demonstrated striking improvements in comparison with the results from the 1982 survey. Mean species richness, relative abundance and relative weight all markedly increased in 1994. Index values (excluding mixing zones) within Segment I increased by an average of 10.7 points for the IBI (37.2 vs 47.9) and 2.1 points for the MIwb (7.4 vs 9.5). All but two stations in 1994 exhibited substantial improvement in both the MIwb and IBI when compared with the 1982 results (Figure 36 and Table 10).

The results from the 1982 survey found the fish community of Segment I to be, overall, in fair condition. Poor to fair results were indicated within the reach from Indian Lake to the Quincy dam. Severe departure from the WWH standards was most pronounced up and downstream of the Indian Lake WWTP (formerly the Russels Point WWTP), and within the Quincy dam pool itself. Within the reach downstream of the Quincy dam to the confluence with Loramie Creek, community performance was much improved. Index values generally increased with increasing downstream distance from the Quincy dam. No impact was attributed to the Quincy WWTP, however, abrupt departure from the WWH criteria was evident downstream of the Sidney WWTP (Table 10 and Figure 36).

The results from the 1994 survey found nearly all stations within Segment I to be in full agreement with the WWH criteria. Overall performance was characterized as very good to exceptional. Departure from the WWH standards was limited to the reach extending from Indian Lake to the Quincy Dam. Within this segment significant departure of the IBI was observed at two stations, one downstream of the Indian Lake WWTP and the second within the Quincy Dam pool. Despite the diminished performance observed at these two stations, overall conditions within this reach were much improved in 1994. As observed in 1982 community performance generally improved with increasing downstream distance from the Quincy Dam in 1994. However, conditions have so improved that the fish assemblages within the reach from the Quincy dam to Loramie Creek now fully meet the criteria established in support of the EWH aquatic use designation, criteria applied to stream and rivers of the highest quality. No impact was evident downstream of the Quincy or Sidney WWTP in 1994. Community performance downstream of these facilities, even in the Sidney mixing zone, fully achieved the EWH standard. Each station within this segment supported a diverse and well organized assemblage of fishes, consistent with the best ecoregional expectations.



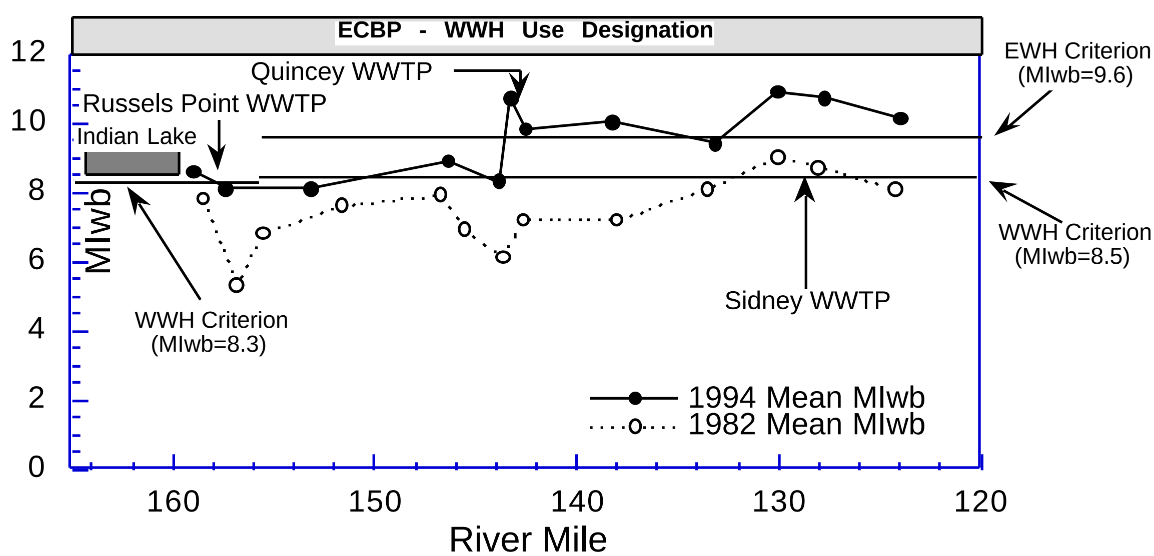
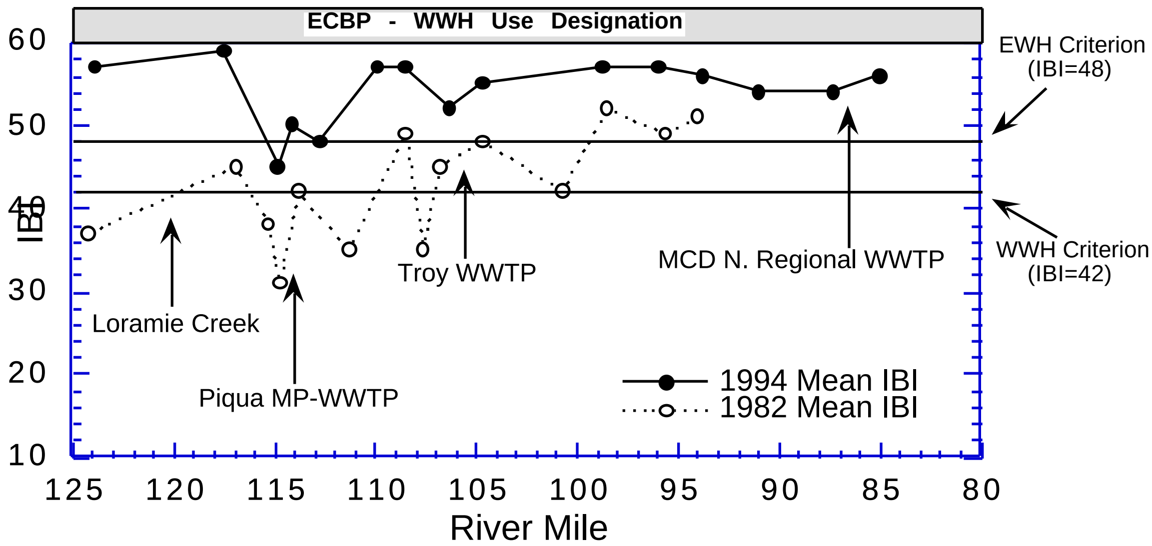


Figure 36 Longitudinal performance of the Index of biotic Integrity (IBI) and the Modified Index of Well-being (MIwb) for Segment I of the Upper Great Miami River, 1982 through 1994. The solid lines represent numerical biological criteria in support of the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life use designations, Eastern Corn Belt Plains ecoregion. Segment I of the Great Miami River is currently designated WWH.

Segment II (Loramie Creek to downstream from the MCD N. Reg. WWTP)
Fish community data collected in 1980 was limited to the extreme lower reach of the 1994 study area. The station placement in 1980 bracketed the former location of the MCD North Regional WWTP. The MCD North Regional WWTP discharge was located at RM 87.4 until 1988 when it was moved downstream to RM 86.6. Results from the 1980 found the fish community in good to fair condition. The MIwb was reduced downstream of the MCD North Regional WWTP (Table 10 and Figure 37).

Results from the 1982 survey found the fish community within Segment II to be, overall, in good to marginally good condition. Significant departure from the WWH biological criteria was limited to five stations within the reach extending from RM 115.3 (upstream from the Piqua dam) to RM 107.6 (Troy dam pool). Performance of the MIwb and/or IBI below the WWH standard was observed within the Piqua dam pool, as well as downstream of Piqua WWTP and PM-EGS. Additionally, diminished performance was noted within the Troy dam pool at RM 107.6. The remaining stations in 1982 (within Segment II) supported a fish assemblage that performed at a level fully consistent with the WWH biological criteria.

Following the trend observed in Segment I, the 1994 fish sampling efforts indicated substantial improvement throughout Segment II in comparison with both the 1980 and 1982 surveys (Figure 37). Results from the 1994 sampling efforts found the fish community within Segment II to be, overall, in exceptional condition. Mean species richness, relative abundance, and relative weight all markedly increased in 1994. Excluding mixing zones and other abbreviated sampling stations (*i.e.,* Piqua dam pool sampling), fish community performance consistently surpassed the WWH standard, fully achieving criteria established for the EWH aquatic life use designation (Table 10). Improvements of this magnitude are unprecedented in the state, and clearly indicate a full and complete recovery from the modest impacts observed in the past. No impact to the fish assemblage was observed downstream of the Piqua WWTP, Piqua Municipal Power-EGS, Troy WWTP, and MCD North Regional WWTP. The fish assemblages downstream of these facilities were diverse, and well organized, representing the best that can be reasonably expected within this ecoregion.



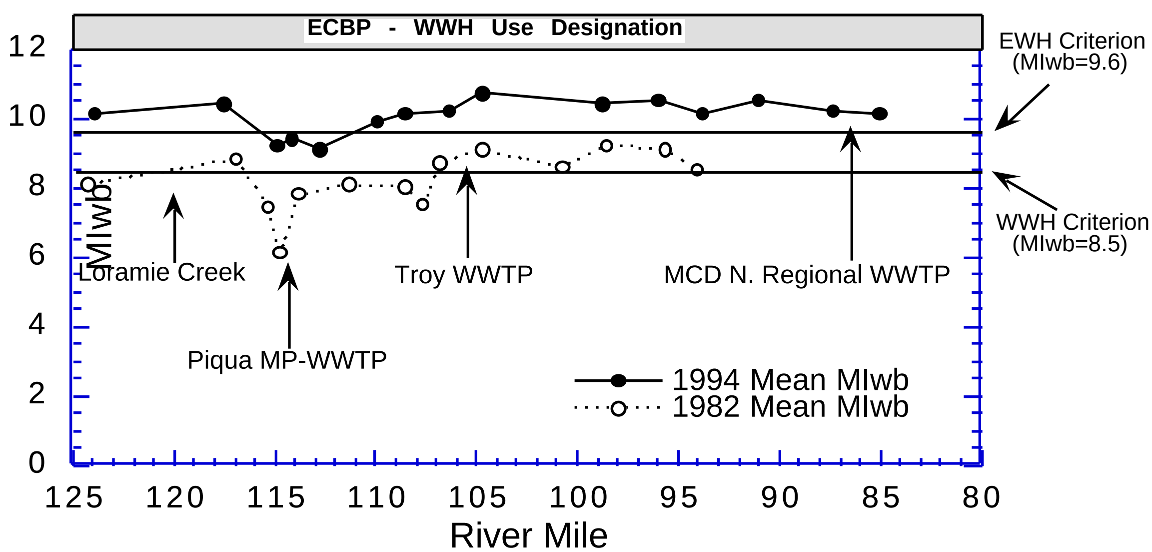


Figure 37 Longitudinal performance of the Index of biotic Integrity (IBI) and the Modified Index of Well-being (MIwb) for Segment II of the Upper Great Miami River, 1982 through 1994. The solid lines represent numerical biological criteria in support of the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life use designations, Eastern Corn Belt Plains ecoregion. Segment II of the Great Miami River is currently designated WWH.

Indian Lake Tributaries

Benthic Macroinvertebrate Community 1982-1994

North Fork Great Miami River

Macroinvertebrate community performance has demonstrated substantial improvement since the 1988 Indian Lake watershed survey when poor (EPT=3; *Physella* snails, beetles, and odonates predominant at RM 10.7) and fair (EPT=5; *Physella* snails, beetles, and odonates predominant at RM 6.3) communities were present (Ohio EPA 1990). The lower community performance in 1988 may have been at least partially due to low flow stress caused by the low precipitation that year.

Blackhawk Run and Van Horn Creek

Macroinvertebrate community performance in Blackhawk Run and Van Horn Creek demonstrated substantial improvement since the 1988 Indian Lake watershed survey (Ohio EPA 1990). Mayfly and caddisfly taxa diversity (EPT) increased to eight taxa in Blackhawk Run (RM 2.3) compared to three in 1988 (RM 2.4) and to nine taxa in Van Horn Creek (RM 1.0) from two in 1988. However, pollution intermediate taxa continued to be represented among the predominant taxa, an indication of continued community stress. Decomposing algal growths and near intermittent stream flows present during the 1988 sampling period were cited as the most significant limiting factors to macroinvertebrate community condition. These factors were not evident during the 1994 field sampling which certainly contributed to the community improvements. The level of community stress noted in 1994 was probably attributable to factors related to past channel modifications and agricultural runoff.

South Fork Great Miami River

The macroinvertebrate community performance in the South Fork Great Miami River during the 1982 (Ohio EPA 1985a) and 1988 (Ohio EPA 1990) intensive surveys demonstrated a slight to moderate decline downstream from the unsewered community of Belle Center. No similar decline was observed during the 1994 survey when macroinvertebrate communities were performing in the exceptional range at all three sampling stations.

Bokengehalas Creek(subbasin)

Benthic Macroinvertebrate Community 1982-1994

Macroinvertebrate community performance in 1994 downstream from the Bellefontaine WWTP in Blue Jacket Creek (RM 5.4) was demonstrated moderate improvement compared to the 1982 intensive survey when community performance was poor (EPT=0; blackflies and midges predominant) and sludge deposits were present in pool habitats (Ohio EPA 1985b). In 1982 the community recovered to the fair range by RM 0.7 (EPT=6; hydropsychid caddisflies and midges predominant). The Bokengehalas Creek community, downstream from the confluence of Blue Jacket Creek, was also performing in the fair range (EPT=6 with hydropsychid caddisflies and riffle beetles predominant at RM 4.6) during 1982. Communities in 1994 were performing in the very good to exceptional range at both of these sites. Possum Run community performance upstream from the Bellefontaine WWTP has remained consistently poor in 1982 and 1994. The community improvements in Blue Jacket Creek and Bokengehalas Creek in 1994 indicated improved waste treatment by the Bellefontaine WWTP.

Fish Community 1982-1994

Fish community data were collected in the Bokengehalas subbasin in 1982 and 1994. Both surveys essentially duplicated the same sampling sites. Longitudinal comparison of recent and past fish community indicated that substantial improvement has occurred in the subbasin downstream of the Bellefontaine WWTP over this 12 year period (Figure 38).

In 1982, cumulative community performance downstream of the Bellefontaine WWTP (*i.e.*, Possum Run, Blue Jacket Creek, and Bokengehalas Creek) was generally characterized as fair (mean IBI=28). The Bellafontaine WWTP effluent appeared to be limiting community performance at that time. By 1987, the previously high levels of ammonia-nitrogen and BOD had been reduced. The improvements in 1994 (mean IBI=42) appeared closely associated with reductions in loading from this facility.

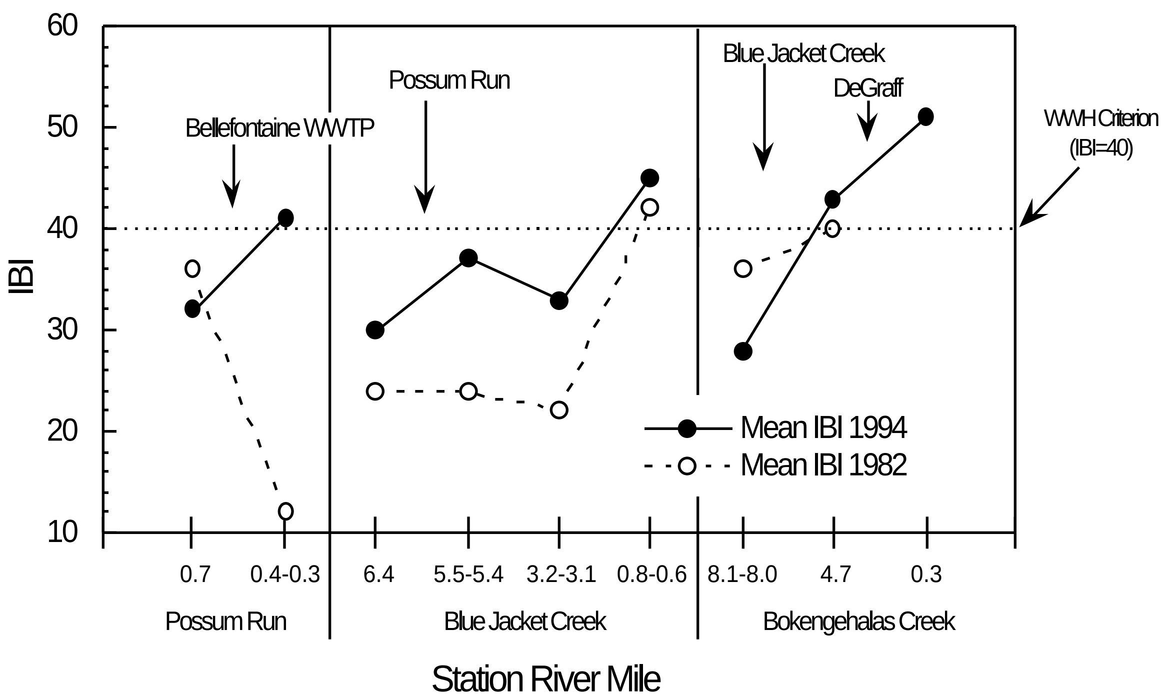


Figure 38 Longitudinal performance of the Index of Biotic Integrity (IBI) within the Bokengehalas subbasin, 1982 through 1994. The dashed line represents the numeric biological criteria in support of the Warmwater Habitat (WWH) aquatic life use designation, Eastern Corn Belt Plains (ECBP) ecoregion.

Selected Tributaries

Benthic Macroinvertebrate Community: 1982-1994

Cherokee Mans Run
The macroinvertebrate community in Cherokee Mans Run in 1994 was performing in the very good range (ICI=44; EPT=11; hydropsychid caddisflies and riffle beetles predominant) at a site (RM 3.7) 1.9 miles upstream from a 1982 qualitative sample that was performing in the good range (EPT=8; hydropsychid caddisflies and midges predominant).

McKees Creek
The McKees Creek macroinvertebrate community was performing at a very good level (EPT=12; mayflies and caddisflies predominant) in 1982 (Ohio EPA 1984); similar to the community conditions observed during the current study.

Spring Creek
The Spring Creek macroinvertebrate community in 1982 was performing at a level comparable to the current study with 14 mayfly and caddisfly taxa collected from the natural substrates at RM 0.9 (Ohio EPA 1984).

Lost Creek
The macroinvertebrate community in Lost Creek was qualitatively evaluated in 1982 at RM 1.5. The 13 mayfly and caddisfly taxa collected was in the expected range for a very good community but was somewhat lower than the 16 EPT taxa collected at RM 2.5 in 1994 with similar methods.

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Fish Community 1982-1994

Fish community data were collected in the Bokengehalas subbasin in 1982 and 1994 at essentially the same sites. Longitudinal comparison of recent and past fish community data indicated substantial improvement has occurred downstream of the Bellefontaine WWTP (Figure 38).

In 1982, fish community performance downstream of the Bellefontaine WWTP (*i.e.*, Possum Run, Blue Jacket Creek, and Bokengehalas Creek) was generally characterized as fair (mean IBI=28). The Bellefontaine WWTP effluent appeared to be significantly limiting community performance in Possum Run and Blue Jacket Creek. By 1987, the previously high levels of ammonia-nitrogen and BOD had been reduced through enhanced waste treatment. In 1994, community performance was much improved, particulaily in Possum Run and Blue Jacket Creek (Figure 37). The specific and overall improvements in 1994 (mean IBI=42) appeared closely associated with reductions in loading from this facility.

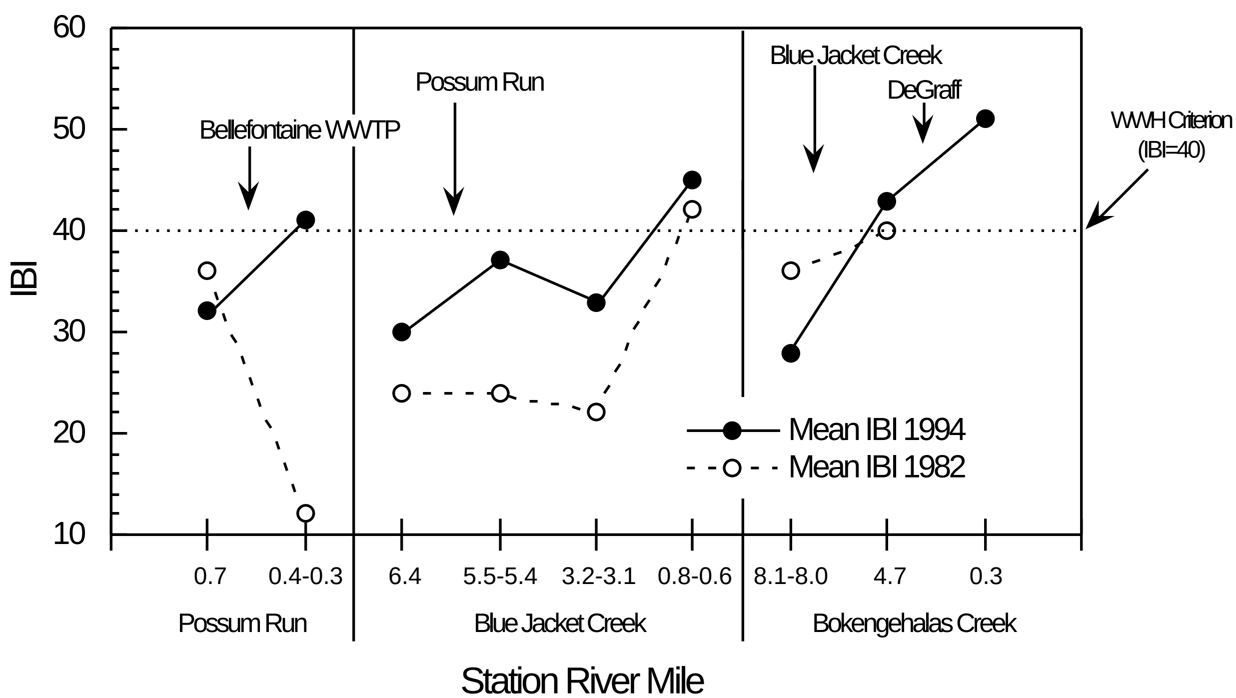

Figure 39 Longitudinal performance of the Index of Biotic Integrity (IBI) within the Bokengehalas subbasin, 1982 through 1994. The dashed line represents the numeric biological criterion in support of the Warmwater Habitat (WWH) aquatic life use designation, Eastern Corn Belt Plains (ECBP) Ecoregion.

Cherokee Mans Run

The macroinvertebrate community in Cherokee Mans Run in 1994 was performing in the very good range (ICI=44; EPT=11; hydropsychid caddisflies and riffle beetles predominant) at a site (RM 3.7) 1.9 miles upstream from a 1982 qualitativ^^^Document Error^^^d@
t^^^^Document Error^^^^@good@
^^^Document Error^^^\!^^^Do^^^Document Error^^^he a^^^Document Error^^^&j^^^Document Error^^^n^^^Document Error^^^X^^^Document Error^^^**Spring Creek**

The Spring Creek macroinvertebrate community in 1982 was performing at a level comparable to the current study with 14 mayfly and caddisfly taxa collected from the natural substrates at RM 0.9 (Ohio EPA 1984).

Lost Creek

The macroinvertebrate community in Lost Creek was qualitatively evaluated in 1982 at RM 1.5. The 13 mayfly and caddisfly taxa collected was in the expected range for a very good community but was somewhat lower than the 16 EPT taxa collected at RM 2.5 in 1994 with similar methods.

Decoy Text

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