Biological and Water Quality Study of the Mahoning River Basin

Ashtabula, Columbiana, Portage, Mahoning, Stark, and Trumbull Counties (Ohio)
Lawrence and Mercer Counties (Pennsylvania)

OEPA Technical Report MAS/1995-12-14

May 1, 1996

Volume I

State of Ohio Environmental Protection Agency
Division of Surface Water
Monitoring and Assessment Section
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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. Section, 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 Quality 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
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(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 1A 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 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 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

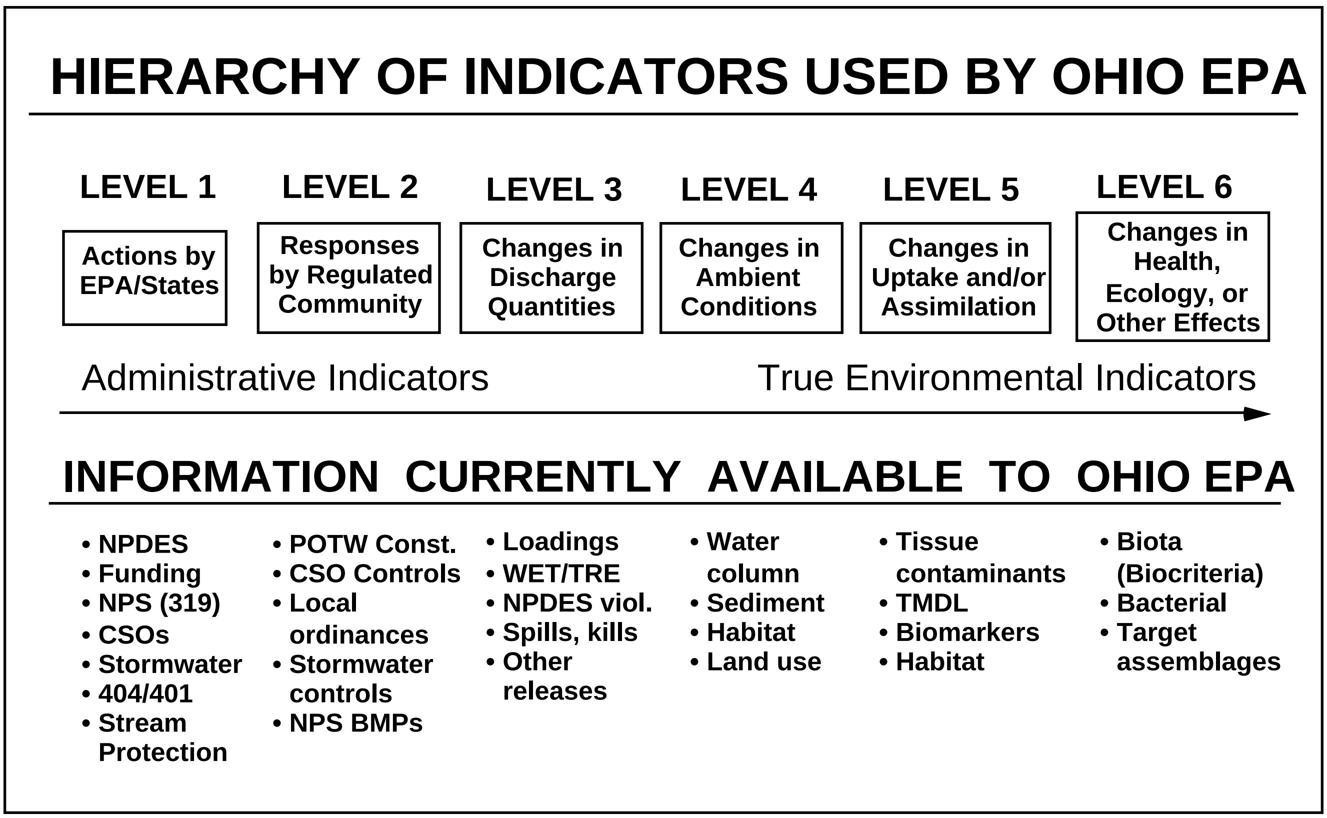

Figure 1A. Hierarchy of administrative and environmental indicators used by Ohio EPA for monitoring, assessment, reporting, and evaluating program effectiveness. This is patterned after a model developed by the U.S. EPA, Office of Water.

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 Nonpoint Source Assessment, and other 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 biolocal 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 persons are acknowledged for their significant contributions to this report.

Report Coordinator, Introduction, and Summary - Marty Knapp
Methods - Chris Yoder
Study Area - Mark Bergman and Rich McClay
Pollutant Loadings - Bob Davic, Ken Frase, Dave Stroud, and Steve Tuckerman
Sediment Quality - Bob Davic, Ken Frase, Dave Stroud, and Steve Tuckerman
Water Chemistry and Chemical Trend Assessment - Bob Davic, Ken Frase, Dave Stroud, and Steve Tuckerman
Physical Habitat - Randall E. Sanders
Macroinvertebrate Assemblages - Marty Knapp
Fish Assemblages - Randall E. Sanders
Programming and Data Management - Edward T. Rankin, Dennis Mishne, and Charlie Staudt
Reviewers - Chris O. Yoder, Marc A. Smith, Jeff DeShon,

This evaluation and report would not have been possible without the assistance of the study team and numerous full and part time staff in the field and offices. The chemistry analyses (laboratory) were conducted by the Ohio EPA, Division of Environmental Services. Datasonde results were provided by the Water Quality Modeling Unit. The Ohio EPA thanks all the individuals and agencies who participated in the volunteer monitoring program. The Ohio EPA also thanks and acknowledges the property owners who permitted access to the sampling locations throughout the study area. .

Biological and Water Quality Study of the Mahoning River Basin

Ashtabula, Columbiana, Portage, Mahoning, Stark, and Trumbull Counties (Ohio)
Lawrence and Mercer Counties (Pennsylvania)

State of Ohio Environmental Protection Agency
Division of Surface Water
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INTRODUCTION

The Mahoning River basin study area includes the Mahoning River (18-001) mainstem, the Beaver River (18-100) mainstem between New Castle, PA and Beaver Falls, PA, the Shenango River (18-500) mainstem in and downstream from New Castle, PA, Little Yankee Creek (18-504), Yankee Creek (18-506), Pymatuning Creek (18-550), and other selected tributaries of the Mahoning River mainstem.

The Mahoning River is 108.3 miles long and, downstream from Leavittsburg, has historically been one of the most polluted of any stream or river in Ohio. The Mahoning River watershed occupies 1,133 square miles of land area, the Yankee Creek watershed occupies 46 square miles, and the Pymatuning Creek watershed occupies 175 square miles.

As part of Ohio EPA's Five-year Basin Approach for Monitoring and National Pollutant Discharge Elimination System (NPDES) permitting, chemical, physical, and biological sampling was conducted in the Mahoning River basin study area during the summer and early fall of 1994. The principal objectives of this study were to:

1) determine the extent to which uses designated in the Ohio Water Quality Standards (WQS) are or are not attained (*i.e.,* determine use attainment status);

2) evaluate existing use designations and recommend any changes which may be needed;

3) identify causes and sources associated with any non-attainment or partial attainment of uses designated in the Ohio WQS;

4) provide information for the development of Water Quality Permit Support Documents (WQPSDs) in support of NPDES permit reissuance for selected point sources; and,

5) assess and characterize changes (trends) in biological performance and chemical/physical water quality since previous surveys (*i.e.,* 1980 and 1983) and subsequent upgrades by major municipal and industrial wastewater treatment facilities.

Similar to the previous surveys of 1980, 1983, and 1986, standardized methods were used throughout the study area to collect quantitative and qualitative biological, chemical, and physical data. During the 1994 survey, a total of 42 sampling sites on the Mahoning River mainstem, 25 sites located on Mahoning River tributaries, 3 Beaver River and 2 Shenango River sites, 10 sites in the Yankee Creek subbasin, and 10 sites in the Pymatuning subbasin (Table 1) were sampled. Seventeen (17) point source discharges were directly evaluated which included analyses of pollutant loading trends based on monthly operating reports (MORs), NPDES permit violations, combined sewer overflows (CSO), whole effluent toxicity tests, and other relevant information (*e.g.,* spills, overflows, bypasses, unauthorized releases of pollutants, Ohio Division of Wildlife fish kill reports, and other biological data) indicative of potential environmental impacts was also reviewed and summarized.

The findings of this report may factor into regulatory or other actions taken by the Ohio EPA (*e.g.*, NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1]), and may be incorporated into the State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] report).

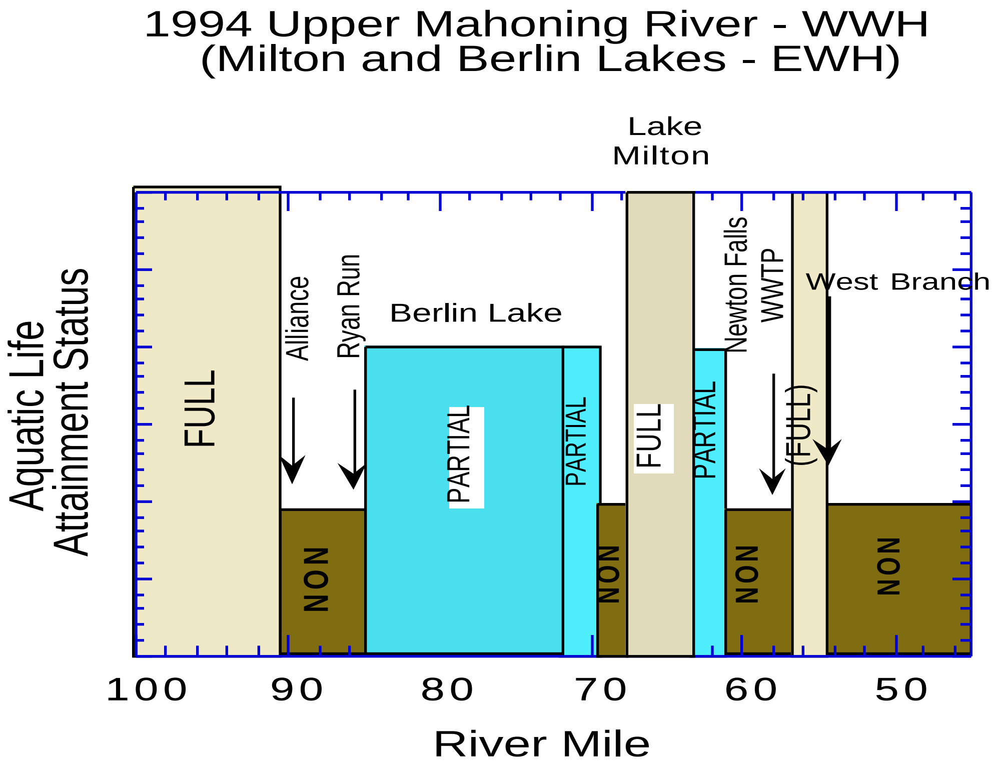
SUMMARY

Aquatic Life Use Attainment

The status of aquatic life use attainment for all sites sampled in the Mahoning River basin study area is provided in Table 1 and segments of full, partial, and non-attainment are summarized in Figure 1B. The approach used by Ohio EPA to determine use attainment status is explained in the METHODS section. The following discussion of aquatic life use attainment status is organized by major river segment or tributary aggregation.

Upper Mahoning River Mainstem
Within the upper mainstem from King Road (RM 100.6) upstream from Alliance to the Leavittsburg dam (RM 45.6) only the two upstream most stations were in full attainment of the existing Warmwater Habitat (WWH) aquatic life use, with both the fish and macroinvertebrate community indices (IBI, MIwb, and ICI) meeting the biological criteria. One station below the Newton Falls dam exhibited full attainment, but this was based on only one organism group (macroinvertebrates). Two stations exhibited partial attainment and nine stations exhibited non-attainment of the WWH biocriteria. Within the free-flowing sections of the upper mainstem, macroinvertebrate communities met the ICI biocriterion for the WWH use at all except two locations in Alliance. The resulting partial attainment was therefore due to the failure of the fish community to meet the WWH biocriteria at three locations. Both organism groups failed to attain the WWH criteria in Alliance at Webb Road, and within the impounded sections of the mainstem. This segment contains two large reservoirs (Berlin Lake and Lake Milton) and four low-head dams (Sebring, Alliance, Newton Falls, and Leavittsburg), which result in a significant physical alteration of the free-flowing riverine habitat.

Lower Mahoning River Mainstem
Of the 45.5 river miles evaluated in the lower Mahoning River mainstem, a total of 0.3 miles (2 sites) were in full attainment of the existing WWH use designation, 5.8 miles (3 sites) in partial attainment, and 39.4 miles (23 sites) in non-attainment. The macroinvertebrate communities met the WWH ICI biocriterion from downstream of the Leavittsburg dam (RM 45.5) to upstream from the Dickey Run storm sewer (RM 39.1) in Warren. The partial and non-attainment in this segment was due to the failure of the fish community to meet the WWH biocriteria for the IBI and/or MIwb. The partial attainment in the downtown area of Warren at RM 38.8/38.2 was due to both the fish and macroinvertebrate indices not meeting the WWH biocriteria. All sites in the Mahoning River mainstem downstream from Warren Consolidated Industries (WCI) and the Warren WWTP (RM 35.4) to the confluence with the Beaver River exhibited non-attainment.



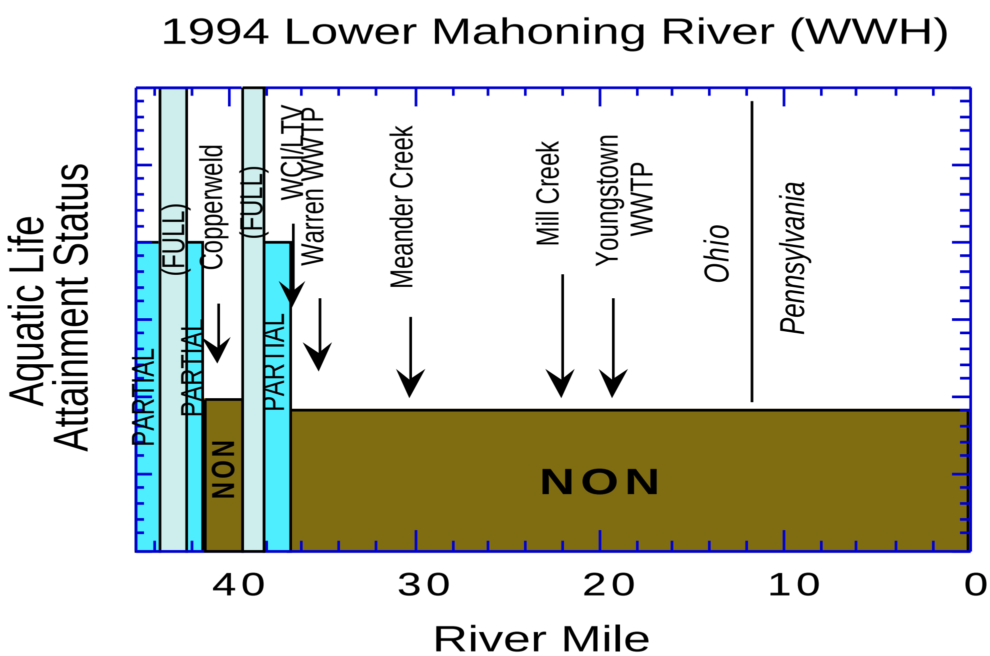


Figure 1B. Longitudinal summary of the attainment status in the upper half (top graph) and lower half (bottom graph) of the Mahoning River during 1994.

Table 1. Aquatic life use attainment status based on the existing Warmwater Habitat (WWH) use designation for rivers and streams in the Mahoning River basin study area based on sampling conducted during July-October 1994.

RIVER MILE Fish/Inverts.	IBI	Mod. Iwb	ICI[a]	QHEI[b]	WWH Attain- ment Status[c]	Comments
Mahoning River						
			Erie-Ontario Lake Plain - WWH Use Designation (Existing)			
100.6/100.6	51	NA	42	74.5	FULL	King Road
93.3**R**/92.6**R**	36[ns]	8.2	36	61.0	FULL	Knox School Rd., Hartley Rd.
89.4/ --	23*	6.7*	--	61.0	[**NON**]	Lake Park Rd.
85.5/85.2	28*	6.2*	16*	42.5	**NON**	Webb Ave.
85.0/84.8	36[ns]	8.5	4*	72.5	**NON**	Gas Hill Drive
70.3/70.7	27*	9.1	32[ns]	67.5	PARTIAL	Dst. Berlin Lake
69.4/69.3	29*	7.8*	18*	55.0	**NON**	Bedell Rd. at Shillings Mill
63.6/62.7	33*	7.5*	36	75.0	PARTIAL	Dst. L. Milton & M. Co. LM
57.8/59.1	26*	7.7*	20*	48.5	**NON**	Dst. Kale Cr., ust Newton Falls
56.8[I]/ -	27*	6.7*	--	40.5	[**NON**]	Dst. Newton Falls WWTP, upst.dam
-- /56.5	--	--	42	-	[FULL]	Dst. Newton Falls and dam
54.8/54.7	22*	7.3*	32[ns]	60.5	**NON**	Dst. West Branch
47.5[I]/47.3[I]	25*	6.8*	24[d]	43.0	**NON**	Ust. Eagle Creek, Nelson Moser Rd.
45.7[I]/ -	30*	7.3*	--	40.5	[**NON**]	Ust. dam at Leavittsburg (impounded)
45.5/45.5	26*	6.9*	38	47.0	PARTIAL	Dst. Leavittsburg dam
44.3/ -	37[ns]	9.2	--	65.5	[FULL]	Upstream 422, dst. 2nd dam
43.3/43.3	28*	8.5[ns]	34	65.5	PARTIAL	SR 422 (ust. health advisory)
40.6/41.1	25*	7.9*	30[ns]	60.0	**NON**	Dst. Copperweld Steel, ust Red Run
39.4[I]/ --	25*	7.2*	--	46.5	[**NON**]	Packard Park, ust Summit dam
-- /39.1	--	--	34	-	[FULL]	Dst. Summit dam, ust Thomas
39.06/39.06	*27*	*7.7*	*16*	*75.0*	*NA[e]*	*Thomas Steel mixing zone*
38.8/38.2	34*	8.3[ns]	26*	80.5	PARTIAL	Perkins Park, dst. Thom. Steel
35.4/35.4	25*	6.5*	6*	65.0	**NON**	Dst. W. C. I., ust. Warren WWTP
35.25/35.25	*37*	*8.3*	*4*	*76.0*	*NA[e]*	*Warren WWTP mixing zone*
35.0/35.1	22*	6.0*	4*	68.5	**NON**	Dst. Warren WWTP
32.2/33.2	27*	5.4*	8*	63.5	**NON**	Dst. West Pk Rd. (dst. RMI)
30.0[I]/30.2	25*	6.0*	10*	56.0	**NON**	Ust. Belmont Ave., dst. Meander Cr.
29.0[I]/29.1[I]	22*	4.4*	6[d]	48.0	**NON**	Dst. Oh. Ed. EGS, ust. Niles WWTP
28.5[I]/28.7[I]	21*	4.9*	6[d]	42.5	**NON**	Dst. Niles WWTP, ust. McDon. Stl.
26.2/25.3	24*	7.1*	P*	75.5	**NON**	Dst. Lib. St. Dam, ust. L. Squaw Cr.
25.1/25.1	23*	5.8*	12*	78.5	**NON**	Dst. L. Squaw Cr. (Girard WWTP)
23.0[I]/21.7	18*	4.4*	14*	44.0	**NON**	Dst. Div. St., Ust. Mill Cr.
21.1[I]/21.6	19*	4.2*	18*	57.5	**NON**	West Ave., dst. Mill Creek

Table 1. (continued)

RIVER MILE Fish/Inverts.	IBI	Mod. Iwb	ICI[a]	QHEI[b]	WWH Attain-ment Status[c]	Comments
***Mahoning River** (continued)*						
20.4/ --	20*	5.3*	--	76.0	[**NON**]	Dst. Marshall Street
19.4/19.4	*19*	*4.9*	*10*	*79.0*	*NA[e]*	*Youngstown WWTP mixing zone*
19.2/19.3	17*	3.8*	10*	65.5	**NON**	Dst. Youngstown WWTP
16.3[I]/ --	16*	4.2*	--	47.5	[**NON**]	LTV/Campbell Rd., ust. Camp. Dam
-- /15.8	--	--	10*	--	[**NON**]	LTV/Campbell Rd., dst. Camp. dam
15.6/15.5	18*	4.5*	6*	73.5	**NON**	SR 616 (dst. Camp. WWTP)
12.5/12.4	18*	7.8*	8*	81.0	**NON**	Dst. Dam, ust. Lowellville WWTP
12.0/11.5	21*	6.2*	10*	78.5	**NON**	OH/PA line, dst. Lowellville WWTP
7.1/6.7	22*	5.8*	8*	77.0	**NON**	0.4 mi. ust. US Rt. 224 in PA
3.1/ --	21*	5.6*	--	83.0	[**NON**]	Dst. Brewster Rd. in PA
1.1/1.4	23*	6.2*	10*	79.0	**NON**	Dst. SR 108, ust. N. Castle WWTP
0.2/0.4	26*	7.1*	16*	79.5	**NON**	Old SR 18, dst. New Castle WWTP
West Branch Mahoning River						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.4/0.4	40	6.3*	34	67.0	PARTIAL	First bridge ust. mouth
Eagle Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
-- /6.6	--	--	44	--	[FULL]	Free-flowing site
0.8/ --	23*	7.2*	--	51.5	[**NON**]	Near mouth, impounded
Silver Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.8**R**/0.9	44	NA	G	79.0	FULL	Trib. to Eagle Creek
Mosquito Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
1.0/0.6	21*	5.1*	30[ns]	45.0	**NON**	Ust. mouth
Meander Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
3.0/ --	26*	5.8*	--	44.0	[**NON**]	Dst. Reservoir
2.3/2.0	28*	7.4*	22*	44.0	**NON**	Ust. M. Cr. WWTP
1.7/1.6	20*	3.3*	4*	84.5	**NON**	Dst. Meander Cr. WWTP mix. zone
0.1/0.7	21*	2.7*	8*	41.5	**NON**	Ust. mouth

Table 1. (continued)

RIVER MILE Fish/Inverts.	IBI	Mod. Iwb	ICI[a]	QHEI[b]	WWH Attain-ment Status[c]	Comments
Mill Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
11.0/11.2	17*	3.4*	28*	37.0	**NON**	Western Reserve Rd.
9.7/9.7	16*	2.9*	30[ns]	44.0	**NON**	Ust. Mah. Co. Boardman WWTP
9.5/9.5	15*	1.5*	14*	59.0	**NON**	Dst. Mah. Co. Boardman WWTP
7.7/7.8	16*	1.5*	12*	38.5	**NON**	SR 224
5.7/5.4	18*	4.0*	24*	60.5	**NON**	Shields Rd./ust. Shields Rd.
2.6/2.7	18*	4.5*	40	71.5	**NON**	Dst. Newport Lake at USGS gage
1.9/ --	20*	4.0*	--	53.0	[**NON**]	
1.5/1.6	24*	4.7*	38	73.0	**NON**	Ust. Slippery Rock Bridge
0.8/ --	27*	4.8*	--	67.0	[**NON**]	Lake Glacier
0.3/0.1	31*	4.1*	24*	46.5	**NON**	Near mouth
Bears Den Run						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.1/0.1	20*	NA	F*	67.0	**NON**	W. Glacier Dr., ust mouth (CSOs)
Ax Factory Run						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.1/0.1	30*	NA	F*	69.5	**NON**	W. Cohasset Dr., ust. mouth (CSOs)
Anderson Run						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.2/0.2	20*	NA	F*	63.5	**NON**	West Newport Dr. (SSO?)
Indian Run						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.1/0.3	24*	NA	MG[ns]	65.0	**NON**	US Rt. 224 (eliminated SSOs)
Dry Run						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.6/0.6	28*	NA	G	61.5	PARTIAL	Ust. Gladstone bridge
Yellow Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
1.0/1.0	22*	5.3*	G	64.5	**NON**	Ust. Catherine Street

Table 1. (continued)

RIVER MILE Fish/Inverts.	IBI	Mod. Iwb	ICI[a]	QHEI[b]	WWH Attain- ment Status[c]	Comments
Beaver River						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
20.1/20.1	30*	6.6*	38	79.5	PARTIAL	Dst. Shaw Island, ust. N.C. EGS
18.0/18.0	27*	6.7*	38	76.0	PARTIAL	Dst. SR 168, dst.. N.C. EGS
15.3/15.3	26*	7.2*	38	74.0	PARTIAL	SR 288
Shenango River						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
2.7/-	42	8.8	--	80.5	[FULL]	Dst. Neshannock Cr. & RR Xing
0.7/1.0	37[ns]	8.3[ns]	36	84.5	FULL	Dst. Cherry St., ust. mouth
Yankee Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
8.8/ --	33*	5.5*	--	46.0	**NON**	1st bridge dst.. SR 305, SR 7
-- /6.5	--	--	E	-	[FULL]	1st bridge dst.. SR 305, SR 7
0.6/1.2	28*	7.0*	G	65.0	PARTIAL	Addison Rd. ust. Brookfield WWTP
0.3/0.3	37[ns]	6.8*	VP*	57.5	**NON**	Dst. Brookfield WWTP
Little Yankee Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
9.5**R**/9.6	35[ns]	NA	52	80.5	FULL	Steward Road
4.6/4.9	25*	4.0*	30[ns]	66.0	**NON**	Ust. Hubbard WWTP
4.4/4.4	26*	6.7*	26*	80.0	**NON**	Dst.. Hubbard WWTP
2.0/1.6	28*	7.5*	38	76.0	PARTIAL	Fox North Road
0.4/ --	24*	6.9*	--	--	[**NON**]	Ust. Bedford Road
0.3/0.2	30*	6.3*	28*	54.0	**NON**	Dst. Bedford Road
Little Deer Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
0.5**R**	35*	NA	20*		**NON**	Ust. mouth
Pymatuning Creek						
	Erie-Ontario Lake Plain - WWH Use Designation (Existing)					
30.5/ --	34*	NA	--	54.0	[**NON**]	U.S. Route 6 (<20 sq. mi.)
-- /29.1	--	--	34	--	[FULL]	Mann Rd. (watershed < 20 sq. mi.)
24.7/ --	23*	4.4*	--	45.5	[**NON**]	U.S. Route 322
-- /22.7**R**	--	--	36	--	[FULL]	Underwood Rd
17.6/17.8	25*	5.6*	8*	55.0	**NON**	State Route 87

Table 1. (continued)

RIVER MILE Fish/Inverts.	IBI	Mod. Iwb	ICI[a]	QHEI[b]	WWH Attain-ment Status[c]	Comments
Pymatuning Creek *(continued)*						
17.1/17.3	28*	5.9*	4*	64.0	**NON**	Downstream Kraft Dairy
16.1/16.1	26*	5.3*	8*	68.0	**NON**	Upstream Kinsman
15.7/15.8	23*	4.8*	14*	67.5	**NON**	Dst. Kinsman & Storm Sewer #2
15.0/15.2	32*	6.2*	22*	82.0	**NON**	South of Kinsman near SR 7
8.6/8.4	25*	4.9*	4*	62.0	**NON**	SR 88
2.2/ --	33*	6.5*	--	54.5	[**NON**]	Brockway Sharon Rd. (PA Line)
Sugar Creek						
Erie-Ontario Lake Plain - WWH Use Designation (Existing)						
1.0/1.0	37[ns]	NA	MG[ns]	65.5	FULL	Burnett Road

* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
[a] The narrative evaluation using the qualitative sample (E-exceptional, G-good, MG-marginally good, F-fair, P-poor, VP-very poor) is based on best professional judgment utilizing sample attributes such as taxa richness, EPT taxa richness, and community composition and is used in lieu of the ICI when artificial substrate data are not available.
[b] All Qualitative Habitat Evaluation Index (QHEI) values are based on the most recent version (Rankin 1989).
[c] Use attainment status based on one organism group is parenthetically expressed.
[d] Macroinvertebrate site located in an impounded habitat - literal interpretation of the ICI may not apply.
[I] Samping site located in an impounded habitat.
[e] *N/A:* biocriteria do not apply within mixing zones.
R - Regional reference site.
N/A - not applicable.

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)

INDEX - Site Type	WWH	EWH	MWH[f]
IBI - Headwaters	40	50	24/NA
IBI - Wading	38	50	24/NA
IBI - Boat	40	48	24/30
Mod. Iwb - Wading	7.9	9.4	6.2/NA
Mod. Iwb - Boat	8.7	9.6	5.8/6.6
ICI	34	46	NA

[f] - Modified Warmwater Habitat for channelized/impounded habitats.

Mahoning River Tributaries
Sampling results in Mahoning River mainstem tributaries showed only 2 of the 25 tributary locations in full attainment of the WWH use (Eagle Creek [RM 6.6] and Silver Creek [RM 0.8/0.9]). Two locations exhibited partial attainment (W. Br. Mahoning River [RM 0.4] and Dry Run [RM 0.6]), and the remaining 21 exhibited non-attainment (Mosquito Creek [RM 1.0/0.6], all sites in lower Meander Creek, all sites in Mill Creek and tributaries, and Yellow Creek [RM 1.0]).

Beaver and Shenango Rivers
Both Shenango River sites in Pennsylvania exhibited full attainment of the Ohio WWH aquatic life use biocriteria. The three Beaver River sites in Pennyslvania exhibited partial attainment due to the failure of the fish community to meet the Ohio WWH biocriteria. The macroinvertebrate community met the Ohio WWH biocriterion at all of the Shenango and Beaver River sites.

Yankee Creek and Little Deer Creek
Full attainment of the existing WWH use designation was exhibited at only one site, SR 305 (RM 6.5), in Yankee Creek and was based on data for macroinvertebrates only. Fish sampling further upstream at RM 8.8 revealed a failure to attain the WWH biocriteria which resulted in non-attainment. The site immediately upstream from the Brookfield WWTP exhibited partial attainment (due to fair fish community performance) and the site downstream exhibited non-attainment. Both fish and macroinvertebrate indices failed to meet the WWH biocriteria in Little Deer Creek.

Little Yankee Creek
The only site in Little Yankee Creek to exhibit full attainment of the WWH use was the upstream most site at Steward Road (RM 9.5/9.6). Severe non-attainment was evident both upstream (RM 4.6/4.9) and downstream (RM 4.4) from the Hubbard WWTP. The site at Fox North Road (RM 2.0/1.6) exhibited partial attainment and the remaining two downstream sites exhibited non-attainment.

Pymatuning Creek and Sugar Creek
The only sites in Pymatuning Creek in full attainment were located in the upper mainstem under free flowing conditions based on data for macroinvertebrates only (RMs 29.1 and 22.7). The remaining nine mainstem sites exhibited non-attainment. The fish community failed to meet the WWH biocriteria at any sites in the mainstem of Pymatuning Creek, whereas the macroinvertebrate community met the WWH biocriterion at only the two most upstream sites. Pymatuning Creek consists of a very low gradient, wetlands type stream habitat which influenced the sampling results. The results from one site in Sugar Creek exhibited full attainment of the WWH use.

Biological Community Performance

Macroinvertebrate Community
Macroinvertebrate community performance met or exceeded the applicable Invertebrate Community Index (ICI) biocriterion at 10 of 31 (32%) Mahoning River mainstem sites (excluding mixing zones and impoundments), 10 of 21 (48%) Mahoning River tributary locations, all four Beaver River and Shenango River sites, 5 of 9 (56%) Yankee Creek subbasin sites, and 3 of 9 (33%) sites in the Pymatuning Creek subbasin. ICI scores or qualitative evaluations were indicative of exceptional to very good quality at five locations in the Mahoning River (RMs 100.6 and 56.5), Eagle Creek (RM 6.6), Yankee Creek (RM 6.5), and Little Yankee Creek (RM 9.6). Fair or poor quality macroinvertebrate assemblages, however, predominated the lower Mahoning River mainstem from Warren (RM 35.1) to the mouth, lower Meander Creek, Mill Creek downstream from the Boardman WWTP to SR 224 (RM 7.8), three Mill Creek tributaries (Bears Den Run, Ax Factory Run, Anderson Run), Yankee Creek at the mouth, Little Yankee Creek downstream from the Hubbard WWTP, and Pymatuning Creek downstream from SR 87 (RM 17.8 to 8.4).

Fish Community

Fish community performance met or exceeded the applicable Index of Biotic Integrity (IBI) and Modified Index of Well-Being (Miwb) biocriteria at 10% (4 of 40) and 15% (6 of 39) of the sites (excluding mixing zones and impoundments), respectively, in the Mahoning River mainstem and 8% (2 of 24) and 0% (0 of 18) of the sites, respectively, in Mahoning River tributaries, 40% (2 of 5) of the sites for both indices in the Beaver and Shenango Rivers, 20% (2 of 10) and 0% (0 of 8) of the sites, respectively, in the Yankee Creek subbasin, none of the Pymatuning River subbasin sites except for Sugar Creek (IBI only). Fish assemblages were indicative of exceptional to very good quality at only one site, the headwaters of the Mahoning River (RM 100.6). Fair or poor quality assemblages, however, predominated at the majority (74 of 87) of the sampling sites (85%). In the lower Mahoning River mainstem at least one fish community index represented poor or very poor performance at 19 of the 20 sites downstream from Warren. Only the site at the mouth (RM 0.2) indicated marginally fair quality.

Although significant improvements in water quality (*i.e.*, water column chemistry) have occurred in the lower Mahoning River mainstem since the grossly polluted conditions of the 1940s through 1970s, biological recovery was far from complete in 1994. Although some of the biological indicators have shown incremental improvements since 1980, overall community performance was consistently poor between Warren and the mouth. Furthermore, the response signatures in the biological data were indicative of toxicity in this segment. Evidence of this included very low biological index scores, elevated numbers of fish with external anomalies (*i.e.*, DELT anomalies), predominance by highly tolerant species, an absence of pollution sensitive species (*e.g.*, no EPT taxa between Warren and Niles, no tanytarsini midges between Warren and the mouth), and highly elevated biochemical markers in fish. Bottom sediment quality in the lower Mahoning River mainstem in 1994 was very poor with concentrations of heavy metals, PCBs, and PAHs at extremely elevated levels which have the potential to cause severe effects on the aquatic fauna. Thus many of the remaining problems in the mainstem are the result of past and on-going discharges of toxic substances, particularly those associated with steel making. Significant loadings of organic waste have and continue to be discharged principally from municipal wastewater treatment plants (WWTP) and sewer overflows (CSOs and SSOs), but adverse effects were generally overshadowed by those associated with the contaminated sediments.

The Mahoning River tributaries were generally impacted by organic wastes from WWTPs and to a lesser extent CSOs. The most extensive problems occurred in Mill Creek both upstream and downstream from the Boardman WWTP where fish community performance was poor and very poor. Similarly poor conditions were observed in Meander Creek. Community performance was somewhat better in the other major branches of the Mahoning River basin study area (Yankee Creek and Pymatuning Creek subbasins), but problems were observed both upstream and downstream from WWTPs and unsewered areas.

Mahoning River: Impact Types Matrix

Biological community performance in the Mahoning River mainstem was evaluated further by examining specific responses of key compoents of the community data and comparing these with response and stressor indicators. Community performance generally declines as the mainstem flows downstream through the urban and industrial sections from Warren to Youngstown. A narrative matrix (Figure 1C) was constructed summarizing selected environmental stressors (*i.e.*, cumulative load, spills, CSOs/SSOs, number of dams/pools, and concentrations of urban/industrial land use), exposures (*i.e.*, sediment and fish tissue contamination levels, toxicity), and response indicators (*i.e.*, fish and macroinvertebrate indices, habitat quality). Designated aquatic life use attainment status was also included as part of the matrix. The shading darkens as the departure from reference widens. While some ratings were necessarily general or based on relative comparisons, they show that observed reductions in response indicators coincide with increased exposure and the increasing prescence of external stressors from both point and nonpoint sources.

The greatest declines in the biological community metrics were noted in segments within and downstream from Warren WCI/LTV to the state line, and coincided with high to very high stressor and exposure indicator levels. The poor rating of the response indicators (fish and macroinvertebrate indices) and exposure indicators extended downstream into Pennsylvania, despite generally low stressor levels from the state line to the mouth.

Physical Habitat for Aquatic Life

Mahoning River
The construction of numerous large reservoirs and low-head dams on the Mahoning River has significantly altered the natural riverine habitat and created an alternating series of free-flowing and impounded segments throughout mainstem. Mean Qualitative Habitat Evaluation Index (QHEI) scores in relatively homogenous segments comprised of free-flowing sites were distinctly higher than for impounded segments. The mean QHEI for the free-flowing segments was 70.6 (range 60.5-78.8) compared to a mean of 47.4 (range 42.5-55.0) for predominantly impounded segments.

Between Alliance and the low-head dam in Leavittsburg, the mainstem changes from a small headwaters stream to a small river. Two large reservoirs, Berlin Lake and Lake Milton, impound approximately 20 river miles of the upper mainstem between RM 84.0 and 64.0. Downstream from Levittsburg to the mouth the mainstem becomes a moderately sized river. The longest segment of free-flowing habitat and the highest QHEI scores is located between Lowellville and the mouth (RM 12.5 to 0.2). The numerous low-head dam impoundments in the lower mainstem have the potential to limit attainment of the existing WWH aquatic life use designation. Physical habitat and flow in the mainstem is also affected by the two mainstem reservoirs and other reservoirs located on several tributaries. Water is released from many of these reservoirs in order to provide minimum base flows in the lower mainstem for industrial, public water supply, and water quality purposes.

Meander Creek
The quality of physical habitat in Meander Creek improves downstream from the Mahoning Co. Meander Creek WWTP. The QHEI score increased from 44.0 at both sampling locations upstream from the WWTP (RMs 3.0 and 2.3) to 84.5 in the free-flowing segment downstream from the WWTP. The quality of habitat declined near the mouth due to the impounding effect of the Liberty Street dam located on the Mahoning River. The WWTP effluent was the principal source of downstream flow as water is removed upstream for public water supply purposes.

Mill Creek and Tributaries (Bears Den Run, Ax Factory Run, Anderson Run, and Indian Run)
Mill Creek contained relatively poor quality physical habitat at the upstream sampling locations and was affected at three of the five downstream sites by small impoundments. Mill Creek had a very low gradient at the upstream most site (RM 11.0) and appeared to have been previously channelized. QHEI scores between RMs 11.0 and 6.2 ranged from 37.0 to 60.5. Most of the lower 10 miles of Mill Creek is located within the Mill Creek Park District which provides for forested riparian corridors and protection from riparian encroachment.

QHEI scores for the four Mill Creek tributaries were higher than most sites in Mill Creek and ranged from 63.5 to 69.5. All four streams contained free-flowing habitat comprised of pools, riffles, and runs. Bears Den Run and Ax Factory Run were the most similar with high gradients and coarse substrates predominated by boulders (as slabs), cobble, and gravel. Anderson Run and Indian Run had lower gradients with finer substrates predominated by fine gravel, sand, or silt.

SEGMENT	DES. USE	RESPONSE INDICATORS				EXPOSURE INDICATORS						STRESSORS				
	Attain-ment Status	QHEI	IBI	MIwb	ICI	Water Column Chem.	Sediment Contam.	Toxicity	% DELTS	Fish tissue (PCB)	Bio-marker	# Dams/ Pools	Urban - Industrial Land Use	Cumu-lative Load	SPILLS	CSOs SSOs
Mahoning River																
Headwaters to Alliance	FULL	68	MG-E	G	G-VG	Bacteria	Low	Low	Low	Low	-	Low	Low	Low	Low	None
Alliance	**NON**	**59**	**P***- MG	**P***- VG	**P*- F***	Bacteria	**High**	**Very High**	Mod	-	-	Mod.	**High**	Mod	**High**	Mod
Berlin Lk to Leavittsburg	PAR-TIAL	**54**	**P*- F***	**F***- VG	**F***- G	Bacteria	Low	Low	Mod	Low	Mod	**V.High**	Low-Mod	Mod	Mod	Mod
Leavitt dam to downtown Warren	PAR-TIAL	61	**P***- MG	**F***- VG	**F***- G	Bacteria	**V. High**	Mod- **High**	Mod	**High**	Mod	Mod.	Mod- **High**	Mod	Mod	Mod
WCI/LTV to Liberty Dam	**NON**	**57**	**P*- F***	**P*- F***	**P***	Temp. D.O.	**V.High**	**Very High**	**High**	**High**	**High**	**High**	**Very High**	**High**	**High**	**High**
Liberty Dam to State Line	**NON**	68	**P***- MG	**P*- F***	**P*- F***	Bacteria Lead	**V. High**	**Very High**	**Very High**	**High**	**High**	**High**	**High**	**High**	**High**	**V.High**
State Line to mouth	**NON**	80	**P***	**P*- F***	**P*- F***	Bacteria	**V. High**	**Very High**	**High**	-	-	Low	Low	**High**	Low	Low

Figure 1C. A matrix of summarized information from environmental response indicators, measurements of pollutant exposure levels, and potential pollutant stressors in segments of the Mahoning River mainstem. Toxicity evaluations were generally based on historical bioassay results and/or in-stream biological responses.

Beaver River
Similar to the lower reaches of the Mahoning River downstream from Lowellville, the Beaver River contained diverse, free-flowing physical habitats with QHEI scores indicative of good to exceptional quality habitat (QHEI range: 74.0-79.5). The most diverse physical habitat extended from the origin (confluence of the Mahoning and Shenango Rivers) to the Penn Power - New Castle Electric Generating Station which was characterized by deep pools, well defined riffle-run complexes, an abundance of woody debris, braided channels, vegetated shoals and islands, and shallow backwaters.

Shenango River
The Shenango River also contained diverse, free-flowing habitats indicative of exceptional quality at both sampling locations (QHEIs of 80.5 and 84.5). The stream channel had good to exceptional development, little or no bank erosion, deep pools, well defined riffle-run complexes, fast current, a high number of different cover types, dense patches of water-willow, and substrates predominated by a mixture of boulders, cobble, and gravel.

Yankee Creek and Little Yankee Creek
Habitat quality in Yankee Creek ranged from fair to good with QHEI scores ranging from 46.0 to 65.0. The stream channel contained substrates predominated by fine materials (*i.e.,* sand, silt, and hardpan) with no riffles and intermittent or sluggish flow. Little Yankee Creek contained relatively good quality habitat at the free-flowing sites between RM 9.5 and 2.0 (QHEI range: 66.0-80.5), but offered only marginal quality near the mouth (RM 0.3) due to impoundment by a low-head dam on the Shenango River. Predominant substrate types changed from a mixture of sand, gravel, cobble, boulder, and bedrock in the free-flowing section to silt and hardpan at RM 0.3. Two sites contained no riffle or run habitat (RMs 4.4 and 0.2).

Pymatuning Creek
Pymatuning Creek is a naturally low gradient wetland stream (1.7 ft/mi. average gradient) surrounded by a dense, wooded riparian wetland. Notable exceptions to this were at RM 24.7 (upstream SR 322) where the stream was flanked by open pasture and at RM 0.2 (upstream Brockway-Sharon Rd.) where a low-head dam created an impoundment. Sand substrates were generally predominant. The amount of instream cover was moderate to extensive with deep pools (>70 cm) at all sites. Channel development was typically poor to fair (no riffle-run habitats) and only one site (RM 15.0) exhibited functional riffles. QHEI scores ranged from 82.0 (RM 15.0) to 45.5 (RM 24.7).

Chemical Water Quality

Upper Mahoning River Mainstem
Only three of 13 stations sampled in the upper Mahoning River showed exceedences of Warmwater Habitat (WWH) criteria for chemical/physical parameters (excluding total iron) and Primary Contact Recreation (PCR) criteria for fecal bacteria. Exceedences of the PCR fecal coliform bacteria criterion were observed at RM 93.2, RM 83.3, and RM 47.3, and one violation of the WWH dissolved oxygen (D.O.) criterion occurred at RM 93.2. Exceedences of the total iron criterion were detected in 75% of the samples collected in the upper Mahoning River, which is a common occurrence in Ohio streams. The only stations with an average (n=5) total iron concentration less than 1000 ug/l were the most upstream site at RM 100.5 and upstream from the Leavittsburg dam at RM 45.7.

Lower Mahoning River Mainstem
Fecal coliform bacteria counts exceeded the PCR criterion at eight of 14 locations in the lower mainstem with a significant trend toward increased fecal coliform counts downstream from Mill Creek and within Youngstown. The only exceedences of heavy metals criteria in the lower mainstem were

for total lead at RM 19.3 and RM 15.5. Potential sources of the fecal coliform bacteria and lead exceedences included unsewered areas, dry weather CSOs, sanitary sewer overflows (SSOs), permitted discharges, and illegal discharges.

Datasonde continuous monitor data showed one violation of the D.O. criteria at RM 30.8 upstream from the confluences of Mosquito Creek and Meander Creek. Organics were sampled at only two stations in the lower mainstem and showed human health criteria exceedences for aldrin (RM 45.5) and naphthalene (RM 12.4). Iron exceeded the WWH criterion in 127 of 130 (98%) non-mixing zone samples in the lower mainstem.

There was a significant increase in the water temperature of the Mahoning River downstream from the Ohio Edison - Niles EGS discharge at RM 29.1. Average stream temperature increased by approximately 5C. Exceedences of the daily average temperature criterion were recorded at five stations from RM 29.1 to RM 23.4.

Mahoning River Tributaries
The only exceedences of Warmwater Habitat (WWH) criteria for chemical/physical parameters in the West Branch Mahoning River, Eagle Creek, and Silver Creek were for iron in a few samples. Grab water samples collected at three stations upstream and downstream from the Meander Creek WWTP indicated significant problems with chemical water quality. Violations of the minimum D.O. criterion were recorded downstream from the Meander Creek WWTP (RM 1.8 and RM 0.8). One total lead value of 21 ug/l was recorded at RM 1.8.

The chemical quality of Mill Creek was severely impacted by the Boardman WWTP. Ammonia-N concentrations exceeded the WWH criteria at RMs 9.5, 7.8 and 5.4. Only one of 11 D.O. Samples (9%) collected upstream from the Boardman WWTP was below 5.0 mg/l compared to 14 of 18 samples (78%) from RM 9.5 to RM 5.4. Other water quality criteria exceedences included total iron (23% of all samples), low pH at RM 0.8, and total lead at RM 5.4 and RM 0.8. Two tributaries showed D.O. violations (Anderson Run and Indian Run) and one for total lead (Anderson Run). Anderson Run, Ax Factory Run, and Indian Run all showed exceedences of the iron criterion.

Yankee Creek and Little Yankee Creek
D.O. violations were observed in two samples at Yankee Creek (RM 11.3) and one sample in Little Deer Creek (RM 0.4). On one sampling date there was an exceedence of the copper criterion in Yankee Creek (RM 0.3) downstream from the Brookfield WWTP.

Pymatuning Creek
There were numerous violations of the WWH D.O. criteria at all sites sampled from RM 17.78 (SR 87) to RM 1.94. This section of the Pymatuning Creek is a naturally low gradient, swamp stream which likely accounts for the low D.O. values. All stations showed exceedences of the iron criterion. Elevated fecal coliform and *E. coli* bacteria counts were documented in seven of 12 (58%) samples in Pymatuning Creek downstream from Kinsman. *E. Coli* counts (400/100 ml at RM 15.9 and 350/100 ml at RM 15.85) and fecal coliform counts (4000/100 ml at RM 15.87; 2500/100 ml at RM 15.85 and 2300/100 ml at RM 15.80) exceeded the PCR criteria. *E. coli* (600/100 ml at RM 16.1; 4700, 2700, 860/100 ml at RM 15.87; 5500, 12000, 2400/100 ml at RM 15.8; 1200, 7200, 900/100 ml at RM 15.80 and 1900/100 ml at RM 15.20) and fecal coliform (6400 at RM 15.87; 7600 at RM 15.85 and 9100 at RM 15.80) counts also exceeded the Secondary Contact Recreation (SCR) criteria.

Volunteer Monitoring Data

Lower Mahoning River
Chemical water quality data was also collected by volunteers at five Mahoning River sites, and in Mosquito Creek, Meander Creek, Mill Creek, and Crab Creek during 1993 and 1994 (see Appendix). The results documented elevated concentrations of copper, lead, and zinc in Crab Creek between October 1993 and April 1994, which led to the discovery of a malfunctioning siphon dam. Data collected in the Mahoning River at Lowellville showed that the Pennsylvania lead criterion (7 ug/l) was exceeded in 19 of 53 samples from May 1993 to December 1994. The highest concentrations of lead collected by the volunteer monitoring program between 1993 and 1994 occurred at the mouths of Mill Creek (70 and 89 ug/l) and Crab Creek (64 and 88 ug/l).

Chemical Sediment Quality

The chemical quality of bottom sediment was based on two classification schemes. The Kelly and Hite (1984) classification ranks sediment concentrations from low concentrations (non-elevated) measured at relatively unimpacted areas to higher concentrations (*e.g.,* slightly, highly, or extremely elevated). The Ontario guidelines (Persuad 1994) are based on the chronic, long term effects of contaminants on benthic organisms and ranks sediment quality at no effect, lowest effect, and severe effect levels.

Upper Mahoning River Mainstem
Sediment sampling results for heavy metals from six sites in the upper mainstem showed only one site, Webb Road in Alliance (RM 85.0), with highly and/or extremely elevated concentrations (chromium, lead, and zinc). This was also the only one of the three sites sampled for organic contaminants in the upper mainstem where PCBs (highly elevated), pesticides (elevated), and PAHs were detected. Although concentrations of these parameters were relatively high at the Webb Rd. site, none of the concentrations were above the Ontario guidelines severe effect level nor were these at the same levels detected in the very heavily impacted lower mainstem.

Lower Mahoning River Mainstem
The lower Mahoning River showed relatively good sediment quality between Leavitsburg and Warren (RM 45.5 to RM 43.3). Concentrations of heavy metals were first detected at extremely elevated levels at RM 41.5 (chromium and iron) downstream from Copperweld Steel, at RM 40.2 (zinc) downstream from Red Run, and at RM 38.9 (lead) downstream from the Dickey Run stormsewer (Thomas Steel). Extremely elevated levels of these four parameters continued to be observed at all sediment sampling locations in the lower mainstem to the mouth. Arsenic, copper, and cadmium were also found at highly elevated or extremely elevated levels at most of the sites from RM 38.9 to the mouth. Chromium and iron were detected at severe effect levels at all sites from RM 41.50 to the mouth. Zinc was detected at severe effect levels at eight of the 13 sediment sites from RM 35.5 (downstream from Warren WCI/LTV). Arsenic was detected above the severe effect level at RMs 35.5 and 21.7.

Polychlorinate biphenyls (PCBs) were below detection in lower Mahoning River sediments from RM 45.5 (Leavittsburg dam) to RM 40.2 (Packard Park), but were found at highly to extremely elevated levels at 10 of 13 sites from Perkins Park in Warren (RM 38.9) to the mouth. At one site (RM 35.4) PCB 1260 was detected at the Ontario severe effect level. Many of the PCB sediment concentrations observed in 1994 were greater than the Ontario lowest effect level. Pesticides were detected at most stations in the lower mainstem (except at RM 43.3 and RM 35.4) and at highly or extremely elevated levels at RMs 35.5, 21.7, and 16.4.

Polycyclic aromatic hydrocarbon (PAH) compounds were below detection at the two upstream sites (RM 45.5 and RM 41.5) in the lower mainstem, but were detected in all 15 of the sediment sampling stations downstream from Red Run (RM 40.2) to the mouth at concentrations greater than the Ontario lowest effect level. Three peaks for total PAHs were collected at RMs 35.5, 16.4, and 11.5, confirming the prescence of elevated PAH levels in areas of current or past coking operations. Although none of the PAH concentrations collected in 1994 exceeded the Ontario severe effect level, sediment samples were not located at the point of discharge of the present or past coking operations unlike the sediment samples collected during previous studies.

Mainstem Tributaries and Other Subbasins
Highly elevated levels of chromium, lead, and zinc were found in Meander Creek downstream from the Meander Creek WWTP. In the Mill Creek subbasin, Ax Factory Run had the highest sediment concentration of arsenic (highly elevated) and iron (highly elevated), Bears Den Run the highest concentration of chromium (highly elevated), and Mill Creek at RM 11.3 the highest concentration of zinc (highly elevated). Nickel in Mill Creek (RM 11.3) and iron in Ax Factory Run and Bears Den Run exceeded the Ontario severe effect level. Beaver River (RM 14.8) sediment concentrations were lower than those found at the mouth of the Mahoning River, but concentrations of arsenic, chromium, iron, lead, and zinc were highly or extremely elevated. Sediment sampling for heavy metals in the Yankee Creek, Little Yankee Creek, and Pymatuning Creek basins showed generally good sediment quality.

Fish Tissue Contaminants

PCBs were not detected in any of the nine fish tissue samples collected upstream from Warren (RMs 70.3, 44.3, and 40.6), but were detected downstream in all 18 samples collected between Perkins Park (RM 38.8) and Lowellville (RM 12.5). Slightly elevated concentrations (>50 and ≤300 ug/kg) of PCBs were detected in one largemouth bass sample, one black crappie sample, two of three white crappie samples, and one of six walleye samples. Elevated PCB concentrations (>300 and ≤1000 ug/kg) were detected in one of four smallmouth bass samples, one carp filet sample, one muskellunge sample, and three of six walleye samples. Highly elevated PCB concentrations (>1000 and ≤5000 ug/kg) were detected in all three whole body carp samples and two of three channel catfish skin-off filet samples. One of three channel catfish samples had extremely elevated PCB concentrations (>5000 ug/kg). A channel catfish collected at RM 38.8 had the highest PCB concentration (8648 ug/kg) reported in the survey.

Pesticides were below detection in 14 fish tissue samples from RM 70.3 to RM 35.4, but were detected in six of 13 samples in the from the Warren WWTP (RM 35.0) to Lowellville (RM 12.5). A total of eight pesticides and their derivatives were detected, but most (DDT/DDE, dieldrin, chlordane, and nonachlor) were detected in three whole body composite samples of common carp. None of the pesticides were detected at concentrations greater than FDA Action Levels.

Mercury was detected in all 27 fish tissue samples collected in the Mahoning River in 1994, ranging from 0.0399 ug/g to 0.346 ug/g, all of which are below the FDA Action Level of 1.0 ug/g. The highest concentrations of lead (six detections) and the only detections of cadmium were from three whole body composite samples of common carp.

Biomarker Contaminants

A total of 106 common carp from 10 locations and 14 white suckers from three locations in the Mahoning River mainstem were analyzed for ethoxyresorufin-o-deethlylase (EROD) activity, bile metabolites, blood chemistry, and glutathione. Median EROD values for all sites for common carp were above the reference value except for the two upstream most sites tested (RM 58.7 and 43.3). Sites located between the Warren WWTP (RM 35.4) and Mill Creek (RM 21.1) had significantly higher EROD values than the two upstream sites. Increased EROD activity in this segment is likely due to: 1) the presence of EROD inducing chemicals such as PAHs and halogenated hydrocarbons (*e.g.*, PCBs); 2) other agents suppressing EROD activity in the lower segment from Campbell (RM 16.3) to Lowellville (RM 12.0); and/or 3) the increase in ambient temperature observed at RM 29.1 in Niles.

Naphthalene-type (NAPH-type) and benzo(a)pyrene-type (B[a]P-type) metabolite values for common carp showed an increase from upstream to downstream. Significantly higher levels of these metabolites were found at RMs 16.3, 15.6, and 12.0 (and at RM 29.0 for NAPH-type only) than at the upstream sites (RMs 57.8 and 43.3). Some fish sampled from all sites exceeded both NAPH-type and B(a)P-type metabolite reference values. The elevated presence of these bile metabolites indicated that PAHs are bioavailable.

Blood urea nitrogen (BUN) values for common carp showed a decrease from upstream to downstream. BUN values at RMs 57.8, RM 43.3, and RM 29.0 were higher than the downstream sites between RM 21.1 and RM 12.9. In March 1996, Ohio EPA personnel discovered an unsewered area in the Hilltop locale near McDonald in Trumbull County. Raw sewage from an estimated 600-800 homes was entering the Mahoning River without any treatment (not even septic tanks) between the Ohio Edison-Niles EGS and the Niles WWTP (RM 30.0 to RM 28.7). The presence of untreated sewage was associated with the highest BUN value measured at RM 29.0 immediately downstream from this previously undocumented discharge.

The common carp biomarker samples at RM 29.0 yielded the highest median and/or mean values of BUN and EROD, and the second highest NAPH-type metabolite. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool (Liberty Street Dam). The most significant water sampling result at RM 29.1 was a substantial increase in temperature (average increase of 5C, range 2-8C) compared to the station just upstream (RM 30.0) which was attributed to the thermal discharge from the Ohio Edison-Niles EGS.

Analysis of Historical Trends

Upper Mahoning River Mainstem

No large scale biological or chemical water quality surveys of the upper Mahoning River mainstem have been conducted by the Ohio EPA prior to 1994. Biological and chemical sampling was conducted at RM 93.3/92.6 in 1983 and 1984 as part of the Stream Regionalization Project and again in 1994. There was no significant difference in chemical water quality or comparable biological community quality (full attainment) between these time periods. Chemical data at Webb Road (RM 85.5) indicated improvements in D.O. and ammonia-N concentrations between a 1974-75 and the 1994 survey.

Lower Mahoning River Mainstem

Historically, the lower Mahoning River has been severely impacted by untreated and poorly treated industrial and municipal WWTP discharges. Since the 1950s, significant reductions in the volume of wastewater, total suspended solids, oil and grease, total iron, and total phenolics have occurred. These reductions occurred mostly as a result of the partial or complete shutdown of major steel making facilities. The 1980 Ohio EPA survey of the lower Mahoning River mainstem was conducted at a time when most of the steel making facilities were already well into the process of being closed. During the period 1988-89 most of the municipal WWTPs attained secondary or better levels of wastewater treatment. The 1994 chemical data showed improvements to instream concentrations of ammonia-N and D.O. related to these improvements.

Unlike what has been observed in most other Ohio rivers and streams, the 1994 survey results showed only slight improvements in WWH aquatic life use attainment status during the past 14 years. The number of miles exhibiting poor or very poor condition has remained unchanged (38.2 miles in both 1980 and 1994). Although fish assemblages remain severely impacted at many locations, incremental improvements in IBI and MIwb values were paralleled by an increased number, weight, and species of fish collected in 1994. Overall changes in species composition represented a positive change from an exclusive occurrence of highly tolerant species to the inclusion of moderately tolerant and intermediate species. The only macroinvertebrate station sampled by the Ohio EPA in the lower Mahoning River prior to the 1994 survey was RM 12.4 at Lowellville. The ICI scores increased from 0 in 1979 and 1982, to 8 in 1994, a change from very poor to poor condition.

Chemical data collected at the Lowellville fixed monitoring station (RM 12.5) from the early 1970s to the present indicated significant improvements in D.O. and ammonia-N concentrations since the early 1980s, due to the WWTP upgrades of 1988-89. As a result of reduced industrial point source loadings in the early 1980s, both cyanide and phenolic compounds are no longer detected in the water column at the Lowellville station (excepting the resuspension of contaminated sediments during high flow). Ohio EPA survey results also showed reductions of chromium, nickel, and zinc between 1980 and 1994. However, concentrations of total lead at the Lowellville station showed little change from 1980 to 1994 (all values in the 7 to 10 ug/l range). Levels of fecal bacteria at the Lowellville station have consistently remained well above the Primary Contact Recreation (PCR) fecal coliform bacteria criteria during the past 20 years.

Sediment chemistry data showed little or no indication that Mahoning River sediments were less contaminated in 1994 than in previous years. Copper, chromium, iron, lead, and zinc were found at potentially toxic concentrations in 1994 and at comparable levels to that found during 1975-1986. Summed PAH concentrations were about the same in 1986 (77.7 mg/kg) and 1994 (83.3 mg/kg) at a comparable location near Lowellville (RM 13.2). These long term data for heavy metals and PAH compounds indicates that, contrary to the conclusions of Havens and Emerson (1976), long term flushing and bacterial decomposition of the bottom sediment has not resulted in significant improvements in the quality of lower Mahoning River sediments.

PCB concentrations in fish tissue were also at comparable levels in 1986 and 1994. Four whole body samples of carp collected in 1986 between RM 30.4 and RM 12.8 contained 2400, 2700, 2600, and 4200 ug/kg of total PCBs, compared to three whole body samples of carp collected in 1994 between RM 35.0 and RM 12.5 which contained 1720, 3100, and 3400 ug/kg of total PCBs.

Mill Creek

Between 1982 and 1994, macroinvertebrate and fish community indices improved only slightly downstream from the Boardman WWTP. Although macroinvertebrate community performance showed a significant improvement in the lower reach of Mill Creek (ICI increased from 0 in 1983 to 40 in 1994 at RM 2.6/2.7), fish community performance remained in the fair and poor ranges. The miles in non-attainment remained at 11.3 and the miles in the poor or very poor biological performance range decreased only slightly from 10.6 to 9.9. Chemical/physical parameters in 1994 revealed continued exceedences and violations of ammonia-N and D.O. criteria immedately downstream (within 2 mles) from the Boardman WWTP with an oxygen sag in both years at approximately RM 7.8. The 1982 results showed a six mile segment below the WWTP with low D.O. and high ammonia-N concentrations.

Yankee Creek /Little Yankee Creek
Fish community perfomance upstream from the Brookfield WWTP was similar in 1984 and 1994, but was improved downstream from the WWTP in 1994. This was in contrast to the macroinvertebrates which improved from fair in 1984 to good in 1994 upstream from the Brookfield WWTP, but was poor downstream during both years. The result has been a change in use attainment status at the upstream site (RM 0.6/1.2) to partial while the downstream site remained in non-attainment of the WWH aquatic life use. The 1984 survey showed degraded conditions downstream from the Brookfield WWTP due to organic enrichment, elevated ammonia-N and TKN concentrations, and low D.O. levels. Although chemistry data from the 1994 survey showed lower ammonia and higher D.O. concentrations, there were higher levels of COD, TDS, total phosphorus, zinc, and nitrate+nitrite-N (average of 0.32 mg/l upstream to 3.68 ug/l downstream) in Yankee Creek downstream from the Brookfield WWTP.

Fish and macroinvertebrate assemblages in Little Yankee Creek improved markedly downstream from the Hubbard WWTP from 1984 to 1994. In 1984, there was no site between the Hubbard WWTP and the mouth where the macroinvertebrate community performance met ecoregional expectations and fish community peformance was mostly in the poor range. In 1994, at RM 1.6 the ICI was 38 which exceeded the ecoregion criterion and fish community peformance was mostly in the fair range below the WWTP. The 1984 survey showed degraded conditions below the Hubbard WWTP due to organic enrichment, elevated ammonia-N and total kjeldahl nitrogen (TKN) concentrations, and low D.O.. levels. Chemical/physical parameters from 1994 showed much improved water quality conditions below the WWTP with lower ammonia-N concentrations and higher D.O. concentrations. However, the 1994 survey also showed higher levels of copper, TKN, nitrite+nitrate-N, total phosphorus, and zinc downstream from the Hubbard WWTP when compared to upstream concentrations.

Pymatuning Creek
Little historical biological or chemical/physical water quality data has been collected by Ohio EPA in Pymatuning Creek. The majority of sampling prior to the 1994 survey occurred in 1983-1984 for the Stream Regionalization Project project. There was no change in the use attainment status at the two Pymatuning Creek sites sampled in 1983 and 1994. IBI scores at U.S. Rt. 6 (RM 24.3/24.7) declined between 1983 (IBI = 31, MIwb = 5.2) and 1994 (IBI = 23, MIwb = 4.4) and exhibited non-attainment in both years. While the comparatively unique habitat of Pymatuning Creek (swampy, low gradient) is responsible for the non-attainment, the decline in IBI and ICI values potentially indicates water quality problems. ICI scores exceeded ecoregional expectations at Underwood Rd. (RM 22.7) in both years, but declined from an ICI of 42 (1983) to 36 (1994). There was no significant change in ambient chemical water quality in Pymatuning Creek between 1983 and 1994.

Point Source Discharge Summaries

The following are general summaries of information about major point source dicharges which were evaluated during the 1994 survey, arranged in order from upstream to downstream. These summaries may also provide the basis for the section 1 part of Water Quality Permit Support Documents (WQPSDs).

Alliance WWTP (Beech Creek RM 0.35, Mahoning River RM 82.03)
The city of Alliance WWTP discharges to an impounded portion of Beech Creek within the Berlin Reservoir. The discharge location corresponds to RM 0.35 of Beech Creek, which joins the Mahoning River at RM 82.03. The station upstream from Berlin Reservoir at RM 85.0/84.8 was in non-attainment of the WWH usedesignation due to the poor performance of the macroinvertebrate community (the fish indices met the biocriteria). The next downstream station was below the Berlin Reservoir in the tailwaters at RM 70.3/70.7 which was in partial attainment of WWH. Bioassays

conducted by the Ohio EPA on the Alliance WWTP effluent showed no significant toxicity to either of two test organisms in July 1987, October 1993, and June 1994 effluent samples.

Analysis of monthly operating report (MOR) data submitted by Alliance indicates a significant reduction in BOD_5, total suspended solids, and oil and grease loadings after 1984. These loadings reductions coincide with WWTP process improvements completed by 1984. NPDES permit violations reported from 1989 to 1994 include pH, oil and grease, cadmium, nickel, mercury, zinc, chlorine, and total suspended solids. Ohio EPA Emergency Response Records from 1989 to 1994 contained two reported spills at the Alliance WWTP. The WWTP also reported spills of oil and diesel fuel totaling 140 gallons between 1991 and 1992.

Hamlin Holdings, Inc./CSC Industries, Inc./Copperweld Steel (RM 41.83)
The CSC Industries/Copperweld Steel plant has been in operation since 1939. The facility manufactures steel bars which can be hot rolled, thermal treated, and/or cold drawn. Processes include melting with electric furnaces, annealing, hardening, tempering, quenching, cold and hot rolling, and cold finishing. Copperweld filed for Chapter 11 bankruptcy protection on November 22, 1993. The company emerged from bankruptcy as CSC Ltd. with a trust fund established to close acid lagoons. In October 1995 the company name changed to Hamlin Holdings, Inc. New treatment facilities were constructed in late 1992. Treated process wastewater is discharged from outfall 005 (formerly outfall 002). Outfall 005 is an onshore discharge at river mile (RM) 41.83 with a shore hugging plume. Although there is no diffuser, mixing with the mainstem flow is rapid and complete as the plume enters a riffle-run habitat. Outfall 003 discharges pump house intake strainer backwash and outfall 004 discharges pump house intake traveling screen backwash. Process water treatment includes neutralization, sedimentation, oil and grease skimming, and wastewater recycle. Domestic sewage is treated by a small extended aeration plant with trickling filter and chlorination. Sewage is discharged to the final sedimentation lagoon and contributes to outfall 005 flow.

Monthly operating report (MOR) data from 1990 through 1994 for outfall 005 showed NPDES permit violations for lead, oil and grease, pH, and total suspended solids (TSS). Ambient water chemistry data from the 1994 survey showed higher levels of lead in the Mahoning River downstream from Copperweld Steel at RM 41.5 compared to upstream at RM 43.3. The first significant impact on sediment quality from heavy metals was found in the mainstem downstream from Copperweld Steel. From RM 43.3 (ust. Copperweld) to RM 41.5 (downstream) sediment concentrations increased by an order of magnitude for copper (from non-elevated to highly elevated), chromium (from highly to extremely elevated), iron (from highly to extremely elevated) , and nickel. Using the Ontario severe effects levels as guidelines, RM 41.5 was the first site in the Mahoning River that exceeded this guideline (chromium, iron, and nickel). One potential source of the heavy metals at Copperweld Steel is the historic landfilling of electric arc furnace dust. Baghouse dust from the melt shop has also been landfilled on site and is regulated as a hazardous waste under RCRA. Old waste acid neutralization lagoons are located near the Mahoning River, and the property also has an old solid waste landfill. In June 1995, Ohio EPA personnel from the Division of Emergency and Remedial Response collected six sediment samples along Copperweld Steel property. In addition to being analyzed for heavy metals and PCBs, sediment bioassay tests were conducted. These tests did not reveal any significant toxicity associated with sediments. Ohio EPA spill records from 1978 to 1994 listed five reported incidents at Copperweld Steel and included low pH water (1983), waste acid (1985 and 1990), and fuel oil (1983 and 1984).

A 1987 U.S. EPA bioassay on the 005 outfall resulted in a 1.0 TU_a and 2.8 TU_c. These results were well below the allowable effluent toxicity (AET) values of 20 TU_a and 68 TU_c. An Ohio EPA bioassay conducted in 1988 showed no significant toxicity to either test organism. No further bioassays have been conducted on this entity.

Biological index values for the fish and macroinvertebrate communities decreased (-3 IBI, -0.6 MIwb, and -4 ICI units) from upstream Copperweld Steel at RM 43.3 to downstream at RM 40.6/41.1 changing the attainment status for the Warmwater Habitat (WWH) use designation from partial to non-attainment due primarily to the IBI scoring in the poor range (Table 1). The Macroinvertebrate community performance met the WWH criteria at RM 45.5 and 43.3 where the ICI scored 38 and 34, respectively. These communities had the highest numbers of combined mayfly and caddisfly taxa (14) and total taxa (41) collected on the artificial substrates of all sites sampled in the lower Mahoning River mainstem. Caddisflies were predominant (38.2%) at RM 45.5 compared to mayflies (42.0%) at RM 43.3. Downstream from Copperweld Steel at RM 41.1 the ICI score declined to 30 (marginally good). While the density and proportions of mayflies and caddisflies on the artificial substrates were similar, the numbers of mayfly and caddisfly taxa were lower.

Compared to the results obtained from previous surveys in the 1980s, the 1994 results indicate some detectable improvements in the overall performance of the biological communities. Use attainment status improved from non-attainment in 1980 to either partial or full attainment in 1994 from the Leavittsburg dam (RM 45.5) to upstream from Copperweld Steel (RM 43.3). Although the two sites downstream (RM 40.6/41.1 and 39.4) from Copperweld Steel were in non-attainment in 1994, fish numbers and biomass increased since 1980 and the ICI score at RM 41.1 was in the non-significant departure range for meeting ecoregional expectations.

Thomas Steel Strip Corporation (Dickey Run Stormsewer RM 1.2, Mahoning River RM 39.17)
Thomas Steel Strip produces cold reduced steel strip some of which is electroplated with nickel, copper, brass, or a nickel-zinc alloy. Processes include pickling, cold rolling, annealing, temper rolling, slitting, and electroplating. Wastewater treatment includes oxidation of cyanide waste with sodium hypochlorite and caustic soda, chromium destruction with sulfur dioxide and sulfuric acid, neutralization of acid, settling of solids, and oil skimmers. Spent rolling solution is treated with polymers to break oil emulsions. Outfall 001 discharges to the Dickey Run storm sewer at approximately RM 1.2 which, in turn, empties into the Mahoning River at RM 39.06. There are no other known or permitted discharges to the storm sewer.

Monthly operating report (MOR) data from 1990 to 1994 indicates NPDES permit violations for cyanide, lead, oil and grease, and total suspended solids (TSS). Effluent compliance sample data collected by Ohio EPA between 1989 and 1994 indicates consistently elevated levels of copper, nickel, and zinc. On the most recent sample in July, 1994 ammonia-N was recorded at 6.34 mg/l and free cyanide at 26 ug/l. A dissolved metals sample on the same day indicated 38 ug/l dissolved copper, 42 ug/l dissolved nickel, and 25 ug/l dissolved zinc. The same sample had the following levels of total metals for these chemicals respectively; 122 ug/l total copper, 235 ug/l total nickel, 241 ug/l total zinc. Naphthalene was detected at 2.5 ug/l in the effluent sampled for the October 1993 Ohio EPA bioassay. Sediment concentrations from the 1994 survey showed increases in copper, chromium, iron, lead, and PCBs downstream from the Dicky Run storm sewer at RM 38.9 when compared to an upstream sample collected at RM 40.2. Of these copper showed the most obvious increase changing from the slightly elevated range at RM 40.2 to highly elevated at RM 38.9. A known source of PCBs in the Warren area (Standard Transformer Co.) is on the DERR master sites list. During the 1994 survey the discharge from the Dickey Run storm sewer and mixing zone ranged in color from gray to brown and oil sheens were also observed on the surface. Ohio EPA emergency response records from 1978 to 1988 contained three reported spills at Thomas Steel Strip. No spills from the facility were reported between 1989 and 1993.

Results from two 1989 bioassays conducted by Ohio EPA showed toxicity to *Ceriodaphnia* of 2.9 TU_a and 6.7 TU_a. An October 1993 Ohio EPA bioassay resulted in a 1.3 TU_a to both *Ceriodaphnia* and fathead minnows, and a July 1994 Ohio EPA bioassay resulted in a 1.8 TU_a to *Ceriodaphnia*. The entity conducted bioassays using *Ceriodaphnia*in 1991, 1993, and 1994. Four of seven tests in 1991 showed toxicity ranging from 3.1 TU_a to greater than 10.0 TU_a. Three of 12 tests from 1993 and 1994 resulted in 1.4, 3.4, and 4.0 TU_a, respectively. A calculated AET of 18.9 TU_a based on instantaneous dilution with the Mahoning River does not apply, because the discharge from the Dicky Run storm sewer does not mix rapidly with the Mahoning River. Ohio EPA field crews observed that the plume from the Dicky Run storm sewer hugs the bank as it enters the Mahoning River. In lieu of rapid mixing, AETs of 0.3 TU_a and 1.0 TU_c apply. These bioassay results demonstrate the potential of this discharge to exert deleterious acute effects on aquatic organisms within the discharge plume. Although there is a zone of acute toxicity, this situation may be preferrable over the use of a diffuser to abate toxicity. At present, fish avoid this shore hugging plume since it does not extend across the river. If a diffuser were utilized, the effect from toxicity could extend for the entire width of the river.

Aquatic life use attainment status in the mainstem Mahoning River upstream and downstream from Thomas Steel Strip ranged from partial to non-attainment due to influence of multiple causes and sources (Table 1). At RM 39.1, approximately 50 meters upstream from the Dickey Run storm sewer, and about 150 meters downstream from the Summit Street dam the macroinvertebrates indicated good community performance (ICI = 34). Caddisflies and mayflies predominated the artificial substrate sample which met minimum ecoregional expectations. As the Thomas Steel effluent enters the Mahoning River (RM 39.06) via the Dickey Run storm sewer mixing is slow as the plume tends to hug the bank. The predominant macroinvertebrate taxa collected in the mixing zone of the Dickey Run storm sewer with the Mahoning River were the toxic tolerant taxon *Cricotopus bicinctus* along with oligochaetes (ICI = 16). The macroinvertebrate data reinforced the bioassay results showing that the slow mixing characteristics of the discharge creates an acutely toxic zone along the right bank of the Mahoning River. The upstream fish sampling site (RM 39.4) was in the impoundment formed by the Summit Street dam. The IBI (25) and MIwb (7.2) indices, as expected, were well below minimum ecoregional expectations due to a combined effect of point sources and the impounded habitat. In the mixing zone of the Dickey Run storm sewer the fish community indices performed at about the same level (IBI = 27; MIwb = 7.7) despite much improved habitat.

Use attainment status was partial at the first downstream site which was also influenced by CSOs from Warren. The performance of the macroinvertebrate community was lower than upstream as the ICI (26) failed to meet minimum ecoregional expectations. The principal reason for this was a decline in the density of caddisflies and an increase in the numbers of other dipterans and non-insects. The response of the macroinvertebrate community at this site was different from the mixing zone in that the toxic response signatures were greatly reduced. The fish community exhibited mixed results as the IBI (34) failed to meet the minimum ecoregional biocriteria, but was improved from results obtained just upstream in previous years. Any further downstream influence from Thomas Steel Strip was not discernable downstream from 35.4 as more severe impacts from other sources occurred (Table 1).

Compared to the results obtained from previous surveys the 1994 results indicate some detectable improvements in the performance of the biological communities. Use attainment status immediately downstream from Thomas Steel Strip and upstream from the impacts of WCI and the Warren WWTP improved from non-attainment in 1980 to partial in 1994. Biological index scores also improved moving from the very poor/poor range in 1980 to fair in 1994.

WCI Steel Inc. (Mahoning River RMs 37.15 to 35.86)

WCI Steel is a manufacturer of flat rolled sheet and coiled steel with discharges to the Mahoning River mainstem between river mile (RM) 37.0 and 35.9. WCI Steel purchased the steel mill from LTV Corp. in late 1988. LTV retained ownership of the coke plant including outfall 014. The facility is an integrated steel mill including blast furnace, basic oxygen furnace, slab mill, rolling mills, galvanizing line, terne line, silicon line, and acid cleaning. Process wastewater for outfall 013 is treated at a central wastewater treatment facility which includes clarification, flocculation, coagulation, and neutralization. The treatment process for outfall 008 includes settling basins, recycle lagoon, coagulation, and oil skimming and for outfall 010 includes settling basins, coagulation, and oil skimming.

The largest outfall in terms of flow and loadings is outfall 013, with an average daily flow of approximately 35 MGD. Outfall 008 is the next largest, with an average flow between 1993 and 1994 of approximately 7.0 MGD, and outfall 007 is the third largest at approximately 2.0 MGD. Loadings of total suspended solids and oil and grease from outfalls 013 and 008 have remained relatively constant between 1990 and 1994.

Monthly operating reports (MOR) indicated NPDES permit violations for all nine outfalls between 1990 and 1994 and included the following parameters: ammonia, oil and grease, zinc, copper, cyanide, and lead. Some of the metals violations may be due to contaminated Mahoning River intake water. The WCI intake is located downstream of all of the discharges except outfall 013. Chemistry data from the 1994 survey shows higher levels of iron, nitrate+nitrite, and zinc in the Mahoning River downstream from the WCI discharges at RM 35.4 compared to upstream results at RM 38.2 on the same sampling days.

Sediment chemistry data from 1994 shows substantial increases in the concentrations of arsenic, copper, cadmium, chromium, iron, lead, zinc, total PCBs, and total PAHs downstream from WCI (RM 35.5 and 35.4) compared to upstream (RM 37.4). Ohio EPA spills records from 1978 to 1988 contained 28 reported incidents related to WCI. The 1990 Water Quality Based Effluent Limit (WQBEL) report recommended that plans to minimize and contain spills be developed. The Ohio EPA spills records from 1989 to 1994 contained 23 reported incidents related to WCI.

In addition to process wastewater outfalls there are approximateley 14 storm water outfalls to the Mahoning River. During a permit renewal compliance inspection in November 1995, Ohio EPA NEDO personnel observed an oily discharge from a pipe in the WCI area. The discharge was estimated at 200 gpm, with an oil sheen, lime, and a pH of 12.0 S.U. and was subsequently identified as WCI storm water outfall 064. The headwaters of this storm sewer receives non-contact cooling water from BOC Gases Co. (previously known as Airco). The storm water outfalls in the WCI/LTV area may be a significant source of pollution and should be addressed in the upcoming permit.

During the 1994 survey, Ohio EPA personnel noted bank areas along WCI area where slag was leaching into the river. Also noted, were wetland areas filled with slag leachate between the banks of the river and the slag piles. This area has a high potential of slag leachate entering the Mahoning River during elevated runoff and flow events. In September 1994, samples of slag leachate that was flowing into the Mahoning River from two areas along the left bank where WCI historically landfilled slag showed elevated pH (11.9 S.U.) and conductivity values (ranging from 2000 to 4500 umhos/cm). Strontium (963 to 3190 ug/l) and barium (222 ug/l) were also elevated.

WCI is the largest source of oil and grease loadings to the Mahoning River. The macroinvertebrate sampling crew observed oil at most sites on the mainstem downstream from Warren to the Ohio-Pennsylvania state line. Although an oil sheen on the water along with oil deposits on rocks were observed upstream in the Dickey Run storm sewer mixing zone (RM 39.06), oil was not observed at the next downstream site (RM 38.2) which was upstream from WCI. Downstream from WCI, oil deposits in the margin habitat or on the water surface were observed at sampling sites from RM 35.4 to RM 28.7. Downstream from the Liberty Street dam oil was observed at the macroinvertebrate stations from RM 25.3 to 15.5, but not in the quantities observed upstream between RM 35.4 and RM 28.7. No oil was observed at the macroinvertebrate sampling sites between the state line and the mouth.

Entity bioassay data collected between August 1990 and June 1991 showed significant acute toxicity (30-53% mortality) to *Ceriodaphnia* (one of six tests) and fathead minnows (two of six tests) in outfall 008 effluent, and to fathead minnows (one of six tests) in outfall 013 effluent. The ambient upstream control used for these bioassays also showed significant toxicity (30-63% mortality) to fathead minnows in the October and December 1990 tests. A 1992 biomonitoring review of this data by Ohio EPA concluded that these outfalls did not have a chronic toxicity problem. There was significant toxicity to fish in the upstream sample on the October and December 1990 bioassays. Bioassays conducted by Ohio EPA personnel in July and October 1994 showed no significant toxicity to fish and *Ceriodaphnia* in outfalls 008 and 013, but did show some toxicity to *Ceriodaphnia* in in the outfall 013 upstream control in the October sample. Outfalls 008 and 013 contained levels of the PAH naphthalene ranging from 0.8 to 2.4 ug/l on both bioassay sampling dates. The WCI water intake is located downstream from all outfalls except 013.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites. An exception was that the highest BUN value occurred at RM 29.0. Elevated BUN values occur in waters with high ammonia and/or organic nitrogen levels, where ammonia is a component of toxic sediments, or as a result of gill and kidney disfunction

Between the Leavittsburg dam and downtown Warren the aquatic life use attainment status for WWH was a mix of full and partial attainment with only one segment of extended non-attainment from RM 41.1 to RM 39.4 (Table 1). At least one biological index (IBI, MIwb, or ICI) met or was in non-significant departure of ecoregion expectations, except for the impounded site at Packard Park (RM 39.4). The entire segment of the Mahoning River downstream from WCI (35.4) to the mouth (RM 0.1) was in non-attainment of the WWH biocriteria, and nearly all of the biological index values (IBI, Miwb, or ICI) reflected poor or very poor community performance. While there are other sources of pollution in the lower mainstem that contribute to the extensive and severe non-attainment in the lower mainstem (RM 35.4 to RM 0.1), the beginning of this reach is adjacent to and downstream from WCI. The character of the biological communities in this reach was markedly different from that observed upstream. The fish and macroinvertebrate indices declined by 9 IBI, 1.8 MIwb, and 20 ICI units from immediately upstream (RM 38.8/38.2) in downtown Warren to the site downstream (RM 35.4) from the WCI dischargers. The six sites (RMs 35.4, 35.1, 33.2, 30.2, 29.1, and 28.7) between WCI and the Liberty Street Dam contained no mayfly/caddisfly/stonefly (EPT taxa) or tanytansini midges on the quantitative samples nor on the natural substrates. These sites were located in pool/slow run habitats without good riffle development and while the habitat conditions were less than ideal, this alone does not account for the absence of EPT or tanytarsini midge taxa. Similar habitat conditions existed upstream at RM 43.3 where EPT taxa and tanytarsini midges accounted for 63% of the organisms in the quantitative samples and five EPT taxa were collected in the qualitative sample, for an ICI value of 34 which meets ecoregional expectations. The relative number of smallmouth bass declined markedly from upstream (RM 38.8) to downstream from the WCI discharges. The incidence of external anomalies on fish (DELT anomalies) increased from 3.0% to 11.5% from RM 38.8 to RM 35.4, and remained between 10.7% to 11.5% at the next four sites from RM 35.4 to RM 30.0. The combination of deficiencies in community structure and organization, predominance of poor and very poor biological index scores, and extremely elevated DELT anomalies is a response to acutely toxic conditions in the mainstem.

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community in the segment immediately downstream from WCI (RM 35.4 to RM 30.0). Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 33% for the IBI in the segment dowtream from WCI (RM 35.4) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

LTV Steel Corp., Inc./Warren Coke Plant (Mahoning River RM 35.68)
The LTV Steel Warren coke plant produces coke, tar, light oil, and ammonia sulfate from burning coal. All process water is sent to the city of Warren WWTP following pretreatment. Outfall 014 is limited to non-contact cooling water, groundwater, and stormwater runoff. The discharge from outfall 014 is to an unnamed tributary which empties into the Mahoning River at RM 35.68 on the right bank, just downstream the final outfall from WCI which enters on the opposite bank. The unnamed tributary downstream from the 014 discharge has been impounded and an oil boom is maintained to capture oil prior to the Mahoning River. Average annual flows ranged from 2-4 MGD from 1984 to 1994. Ammonia-N, total suspended solids, and oil and grease loadings have declined from 1988 to 1994 when compared to pre-1988 levels. The permit information form (PIF) for LTV indicated that outfall 014 is now tied into the Warren sanitary sewer system (date unknown).

Monthly operating report (MOR) data for the LTV Warren coke plant indicates NPDES permit violations for ammonia-N, BOD5, oil and grease, and pH between 1990 and 1994. Ambient water chemistry data from 1994 shows higher levels of iron, nitrate+nitrite (NO2+NO3-N), and zinc in the Mahoning River downstream from WCI and LTV (RM 35.4) compared to upstream (RM 38.2) on the same sampling days. Naphthalene (6.7 ug/l) and benzene (60 ug/l) were detected in the effluent during bioassay testing. This was the highest level of naphthalene detected among the Mahoning River discharges during Ohio EPA bioassay sampling from 1988 to 1994. Ohio EPA sediment data from 1994 shows dramatic increases in the concentrations of arsenic, copper, cadmium, chromium, iron, lead, zinc, total PCBs, and total PAHs from upstream from WCI and LTV (RM 37.4) to downstream (RM 35.5 and 35.4). Ohio EPA spill records from 1989 to 1994 contained 27 reported incidents related to the LTV facility. Ohio EPA bioassays conducted in November 1993 and May 1994 showed marginal toxicity in the 014 effluent. The 1993 upstream sample also exhibited toxicity.

A sediment sample collected from the coke plant tributary which received the outfall 014 discharge by U.S. EPA in April 1986 had a total PAH concentration of 101,720 mg/kg. Sediment samples in the Mahoning River just upstream from the coke plant tributary showed a total PAH level of 3.06 mg/kg and a sample just downstream had 262.9 mg/kg of total PAHs. This data documented the coke plant tributary as a source of PAH loading to the Mahoning River.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites. An exception was that the highest BUN value occurred at RM 29.0. Elevated BUN values occur in waters with high ammonia and/or organic nitrogen levels, where ammonia is a component of toxic sediments, or as a result of gill and kidney disfunction

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While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community in the segment immediately downstream from WCI (RM 35.4 to RM 30.0). Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 33% for the IBI in the segment dowtream from WCI and LTV (RM 35.4) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

City of Warren WWTP (Mahoning River RM 35.25)
The Warren WWTP has a 16.0 MGD design flow and was last upgraded to advanced secondary treatment in February 1988. Treatment processes include grit removal, detritus settling tanks, extended aeration activated sludge, primary and final settling tanks, chlorination, and post aeration with the discharge to the mainstem at river mile (RM) 35.25. The sewage system is about 20 percent combined with CSOs and separate sewer bypasses. The Warren sewage system has a history of problems with sanitary sewer overflows (SSOs). In 1991 and 1992 the city removed 10 SSOs (#'s

21-31), and between 1993 and 1995 removed 4 other SSOs.

A significant reduction in discharged loadings of BOD_5 and total suspended solids occurred after the 1988 upgrade. The upgrades to the major municipal WWTPs along the mainstem have resulted in significant improvements in instream concentrations of ammonia-N and dissolved oxygen (D.O.) in the lower Mahoning River as evidenced by data collected in 1994.

Monthly operating report (MOR) data from 1990 through 1994 indicates NPDES permit violations for dissolved oxygen, copper, free cyanide, and zinc. Based on 1994 annual mean loading values the Warren WWTP comprised 21.2% of the volume, 2.9% of the ammonia-N, and 15.8% of the $cBOD_5$ discharged by six major WWTPs to the lower mainstem. Ambient water chemistry data from the 1994 survey shows higher levels of total dissolved solids (TDS), nitrate+nitrite (NO_2+NO_3-N), and phosphorus in the Mahoning River downstream from the Warren WWTP (RM 35.1) compared to upstream (RM 35.4) on the same sampling days. Concentrations of phosphorus and NO_2+NO_3-N remained low in the Mahoning River from RM 45.5 to 36.4, but showed two stepwise increases, first below the Warren WWTP (RM 35.25) and next below the Youngstown WWTP (RM 19.43). Both NO_2+NO_3-N and total phosphorus concentrations were well above background levels at the Ohio-Pennsylvania state line and remained so to the confluence with the Shenango River at New Castle, Pennsylvania.

Ohio EPA bioassays conducted in January 1992, October 1993, and August 1994 showed no significant toxicity of the Warren WWTP effluents to either of two test organisms. There was marginal mortality in the upstream samples in two of these bioassays. Total residual chlorine was measured at 0.42 and 0.31 mg/l in the 1994 bioassays.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River.

Biological sampling in the mainstem upstream (RM 35.4) and downstream (RM 35.0/35.1) from the Warren WWTP indicated non-attainment of the WWH use (Table 1). All of the biological indices were in the poor range of community performance. Results from the mixing zone showed a poor performance for the macroinvertebrates, but fair results for the fish community. The character of the biological communities in this reach of the mainstem was markedly different from that observed upstream from WCI and Warren. The combination of deficiencies in community structure and organization, predominance of poor and very poor biological index scores, and extremely elevated anomalies fish (DELT anomalies) is a response to acutely toxic conditions in the mainstem.

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community in the segment immediately downstream from WCI (RM 35.4 to RM 30.0). Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 33% for the IBI in the segment dowtream from WCI (RM 35.4) to the mouth (RM 1.1).

Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

RMI-Niles (Mahoning River RM 33.63)
RMI-Niles is a manufacturer of titanium alloy in slabs, billets, and sheets and has one discharge to the Mahoning River at river mile (RM) 33.63. Wastewater includes non-contact cooling, process water, sanitary wastewater, and stormwater. Sanitary wastewater is treated in two extended aeration plants, one of which has chlorination. Pickled wastewater is pH adjusted. Final treatment consists of all wastewater entering two settling ponds with an oil skimmer before final discharge to the Mahoning River. Average effluent flow is 0.5 MGD.

Monthly operating report (MOR) data indicates a long history of NPDES permit violations for numerous parameters between 1989 and 1994 as follows: total suspended solids, pH, oil and grease, BOD_5, fluoride, titanium, aluminum, and fecal coliform bacteria. Loadings of total suspended solids, oil and grease, and titanium from 1986 through 1994 have remained relatively constant, but flows have gradually declined since 1989. Bioassays have either not been conducted on this entity or data was not available at the time of this writing. Ohio EPA spill records indicate six incidents associated with RMI-Niles between 1990 and 1994 including various substances such as PCB contaminated waste, oil, hydrofluoric acid, and “wastewater”. RMI has been experiencing problems with oil in their discharge to the Mahoning River. This was not obvious at the point of discharge to the river because of turbulent mixing. However, there was a noticeable oil sheen in the Mahoning River during an inspection by Ohio EPA personnel in 1993.

The macroinvertebrate sampling crew observed oil at most sites on the mainstem downstream from Warren to the Ohio-Pennsylvania state line in 1994. Although an oil sheen on the water along with oil deposits on rocks were observed upstream in the Dickey Run storm sewer mixing zone (RM 39.06), oil was not observed at the next downstream site (RM 38.2) which was upstream from the area of WCI. Downstream from this area, oil deposits in the margin habitat or on the water surface were observed at sampling sites from RM 35.4 to RM 28.7. Downstream from the Liberty Street dam oil was observed at the macroinvertebrate stations from RM 25.3 to 15.5, but not in the quantities observed upstream between RM 35.4 and RM 28.7. No oil was observed at the macroinvertebrate sampling sites between the state line and the mouth.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River.

Biological sampling in the Mahoning River upstream (RM 35.0/35.1) from RMI-Niles showed non-attainment of WWH criteria with all biological indices in the poor range (Table 1). Upstream sources of pollution associated with the extensive non-attainment include the cumulative loading of municipal and industrial dischargers, industrial spills, and very poor sediment quality. Downstream (RM 32.2/33.2) from the RMI-Niles the biological indices were essentially the same.

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community in the segment immediately downstream from WCI (RM 35.4 to RM 30.0). Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by nearly 50% for the MIwb and 30% for the IBI. Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

Meander Creek WWTP (Meander Creek Rm 1.98, Mahoning River RM 30.27)
The Mahoning County Meander Creek WWTP discharges to Meander Creek at river mile (RM) 1.98.The Meander Creek WWTP is owned and operated by the Mahoning County Board of Commissioners. The plant was built in 1976 with treatment processes for pre-chlorination, grit removal, pure oxygen activated sludge, two stage, clarification, rapid sand filtration, and ozone disinfection. Its design has a separate sewage system and the ability to remove phosphorus. Due to ongoing permit violations at the Meander Creek WWTP, Mahoning County was referred to the Attorney General's Office and a consent order was signed in January 1994 requiring the county to hire class IV certified operators, submit MOR and bioassays on time, develop a plan to monitor mercury, and to develop a laboratory QA/QC program. Approximately three miles of Meander Creek were sampled during June-October 1994 as part of the above referenced study. One site at the mouth was sampled as part of the 1980 Mahoning River survey.

Meander Creek is a small to medium size tributary (85.8 mi.^{2} drainage area) of the Mahoning River (RM 30.27). The stream is impounded throughout much of its length by the Meander Creek Reservoir (a 2010 acre water supply for the city of Youngstown) located approximately one mile upstream from the Meander Creek WWTP discharge and a small low-head dam located immediately upstream. Meander Creek becomes free flowing at the discharge, but is impounded again near the mouth by the effect of the Liberty Street dam pool on the Mahoning River. A water treatment plant (WTP) operated by the Mahoning Valley Sanitary District (MVSD) is located on Meander Creek between the WWTP discharge and the reservoir. During most of the year Meander Creek provides no additional dilution for the WWTP effluent because the WTP removes all of the flow for public water supply purposes.

A five year review of monthly operating report (MOR) data (1990-1994) indicates violations for pH, BOD, total suspended solids, ammonia-N, cadmium, copper, lead, mercury, zinc, nickel, and fecal coliform. MOR data indicates relatively constant flows from 1983 to 1994, however, loadings of total suspended solids have more than doubled since 1987. A review of Ohio EPA Emergency Response Records from 1965 to 1994 list only two sewage spills (1989 and 1992). Although not as extensive as in Mill Creek, black sewage sludge deposits were also observed in Meander Creek downstream from the WWTP during the summer of 1994. The water quality impact is made worse by the fact that Meander Creek has little or no flow to dilute the discharge during critical low flows.

Ohio EPA personnel conducted four bioassays on Meander Creek effluent, two in 1990, one each in 1993, and one in 1994. No significant toxicity was observed in these bioassays; however, naphthalene (1.1 ug/l) and di-n-butyl phthalate (50.9 ug/l) were detected in the March 1990 effluent samples. Thirteen bioassays were also conducted by Mahoning County on the effluent between 1992 and 1993 as required by the NPDES permit. Results from these toxicity tests resulted in a 1.1 TU_c (August 1992) and 1.75 TU_c (June 1992) to fathead minnows, a 1.2 TU_c (June 1992), 2.0 TU_c (November 1992), and a 1.0 TU_c (January 1993) to *Ceriodaphnia,* and significant toxicity (June 1992) in the mixing zone to both organisms. Given the effluent dominated nature of the flow downstream from the WWTP discharge ($Q_{7,10}$ stream flow = 0.0 cfs, effluent flow = 6.2 cfs), the 1.1 to 2.0 TU_c results and toxicity in the mixing zone exceed the allowable effluent toxicity (AET) values of 0.3 TU_a and 1.0 TU_c thus demonstrating the potential for this discharge to have acute and chronic effects on the aquatic assemblages within Meander Creek.

Since 1980, minimum dissolved oxygen (D.O.) values have increased slightly downstream from the Meander Creek WWTP. The higher D.O. concentrations in 1994 may be due, in part, to the discontinued discharge of lime sludge upstream from the WWTP by the MVSD water treatment plant. Long term data also shows ammonia-N reductions below the Meander Creek WWTP since 1983 (maximum ammonia-N values declined from 2.23 mg/l at RM 1.7 in 1983 to 0.72 mg/l in 1994). Despite these improvements, the 1994 chemical results still showed an impact on water quality downstream from the Meander Creek WWTP (RM 1.8). Concentrations of eight parameters (lead, zinc, chemical oxygen demand, nitrate+nitrite, nitrate, ammonia-N, total kjeldahl nitrogen, and total phosphorus) were considerably higher at the two downstream locations. Maximum total phosphorus and total nitrate+nitrite-nitrogen values recorded downstream from the WWTP during 1994 were 3.51 and 13.6 mg/l, respectively. Nutrient enrichment impacts in Meander Creek were also visually evident downstream from the WWTP (*i.e.*, dense growths of filamentous algae and decaying organic matter). Instream violations of the daily minimum D.O. criterion were recorded at RM 1.8 and RM 0.8. Sediment data showed significant increases in concentrations of chromium, lead, and zinc from non-elevated levels upstream from the discharge (RM 2.0) to highly or extremely elevated levels downstream from the WWTP (RM 1.8).

The 1994 biological sampling results show non-attainment of the WWH aquatic life use both upstream and downstream from the Meander Creek WWTP (Table 1). Biological performance changed from fair immediately upstream to poor and very poor downstream from the WWTP. No mayflies, caddisflies, or tanytarsini midges were collected immediately downstream from the WWTP discharge (RM 1.6). The marked decline in total taxa suggests an acutely toxic impact to the macroinvertebrates while nutrient enrichment associated changes were evident by a marked increase in the total density of organisms (due to high numbers of tolerant taxa). Fish assemblages in Meander Creek declined from fair quality in the dam pool adjacent to the WTP to poor to very poor quality downstream from the Mahoning Co. Meander Creek WWTP despite exceptional quality habitat at RM 1.7. The results obtained during the August sample (RM 1.7) were indicative of acute toxicity downstream from the WWTP (*i.e.*, declines in species, density, and biomass). External anomalies on fish (DELT anomalies) increased from 1.0 - 2.2% upstream from the WWTP to 5.5 - 11.6% downstream. The primary causes associated with the non-attainment downstream from the WWTP are metals, excessive nutrients, ammonia-N, low dissolved oxygen (D.O.), and suspended solids. Impoundment and flow alterations appear to be the major associated causes of non-attainment upstream from the WWTP. The biological response signatures downstream from the Meander Creek WWTP were indicative of both nutrient and organic enrichment and acute toxicity.

The 1994 biological sampling results also show the WWH aquatic life use attainment status of Meander Creek has not significantly changed since 1980 (Table 1), although the comparison is somewhat limited by the single site sampled in 1980. The fish assemblages in the lower two miles of Meander Creek have improved slightly since 1980, but still reflected poor to very poor quality (Table 1). Electrofishing results yielded 3.3 mean fish species and MIwb and IBI scores of 1.8 and 17 at the single site in 1980 (RM 0.3) compared to 6.5 - 9.0 species and MIwb and IBI scores of 2.7 - 3.3 and 20 - 21 at two sites in 1994.

Ohio Edison Company, Niles Plant (Mahoning River RM 30.00-29.51)
The Ohio Edison, Niles Generating Plant (NGP) generates electric power by employing two 108 megawatt (Mw) coal fired steam generating units and one 30 Mw combustion unit. Between 1980 and 1994 the plant withdrew and returned to the Mahoning River between 100 and 150 MGD of cooling water on the average, with a 95th percentile volume of 200 MGD. In addition to the cooling water discharge from outfall 001, there are two sanitary wastewater outfalls (003, 008) and a fly ash and

coal pile runoff detention pond detention (002). Treatment for outfall 002 consists of pH neutralization and sedimentation. Originally designed as a baseload facility, the Ohio Edison, NGP now generates electricity on a cycling or peaking schedule. Thus the thermal load to the mainstem varies according to the electrical load of the NGP. The discharges occur between river mile (RM) 29.51 and 30.0.

Monthly operating report (MOR) data from 1989 to 1994 indicates NPDES permit violations as follows: outfall 002 (pH), outfall 003 (fecal coliform bacteria, chlorine, ammonia-N), and outfall 008 (fecal coliform, ammonia-N, $cBOD_5$). Bioassay data has either not been conducted on this entity or was not available at the time of this writing. Ohio EPA spill records indicate 11 incidents associated with the NGP from 1990 to 1993. Parameters reported included hydrochloric acid, fly ash, gasoline, and “wastewater”.

The current NPDES permit requires a thermal load management approach for the 001 thermal discharge. Real-time monitoring of upstream river flow and ambient temperature is used to maintain downstream water temperatures within the parameters prescribed by the load management plan. No single instream daily temperature can exceed 33.3C; no more than 12 single day values between June 15-Sept 15 can exceed 31.0C; and no more than 20, 7-day moving average values can exceed 30.3C.

Based on the 1994 survey data at RM 29.1 there was a significant increase in the water temperature of the Mahoning River downstream from the Ohio Edison, NGP discharge. Average instream temperature increased by about 5C. Exceedences of the average summer period (June 16-September 15) temperature criterion for the Mahoning River mainstem were recorded at five sites between RM 29.1 and RM 23.4. The average volume of cooling water discharged in 1994 was 128 MGD, which is well below the 218 MGD capacity. These results suggests that significant exceedences of the temperature criteria would be expected if the NGP was not under the current thermal load management program.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison, NGP at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites. An exception was that the highest BUN value occurred at RM 29.0. Elevated BUN values occur in waters with high ammonia and/or organic nitrogen levels, where ammonia is a component of toxic sediments, or as a result of gill and kidney disfunction.

Ambient biological sampling in the Mahoning River upstream (RM 30.0/30.2) from the Ohio Edison Niles outfall 001 showed non-attainment of WWH biocriteria with the biological indices in the poor range of community performance (Table 1). Upstream sources of pollution affecting the non-attainment upstream from the Niles NGP include the cumulative loading of municipal and industrial dischargers, industrial spills, and poor sediment quality. Downstream from the NGP the biological indices were likewise in the very poor or poor range of community performance.

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community. The relative number and biomass of fish collected downstream from the Niles WWTP (RM 28.5) has increased from 10 fish/km weighing 0.02 kg/km in 1980 to 109 fish/km weighing 30.5 kg/km in 1994. Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 32% for the IBI in the segment downsteam from Ohio Edison, Niles Generating Plant (RM 30.0) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

City of Niles WWTP (Mahoning River RM 28.86)
The Niles WWTP discharges at river mile (RM 28.86) and was recently upgraded (1988) to a secondary treatment facility. Treatment processes include grit removal, oxidation ditch with internal clarifier, and chlorine contact. The WWTP has had a problem with bypassing due to elevated influent flows. Although Ohio EPA spill records from 1989 to January 1994 contained no reported spills of sewage at the Niles WWTP, a total of 145.3 million gallons of partially treated wastewater was bypassed at the WWTP to the Mahoning River during January to August 1994.

Monthly operating report (MOR) data from 1989 to 1994 indicates NPDES permit violations for chemical oxygen demand (COD), cadmium, copper, fecal coliform, lead, mercury, oil and grease, pH, total suspended solids (TSS), and zinc. Based on 1994 annual mean loading values the Niles WWTP comprised 9.3% of the volume, 11.8% of the ammonia-N, and 9.5% of the $cBOD_5$ discharged by six major WWTPs to the lower mainstem. Chemistry data from 1994 shows higher concentrations of nitrate+nitrite-N (NO_2+NO_3-N) in the Mahoning River downstream from the Niles WWTP at RM 28.7 compared to upstream at RM 29.1 on the same sampling days. Sediment samples were collected upstream from the Niles WWTP near Ohio Edison (RM 30.0) and downstream from the Liberty Street dam (RM 26.1). While these samples did not show an impact from the Niles WWTP, they did reveal gross contamination from heavy metals, PAHs, and PCBs. Two Ohio EPA bioassays conducted in April and May 1994 showed no significant toxicity in the Niles WWTP effluents. However, chlorine was detected at 0.31 mg/l in the August effluent sample.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites. An exception was that the highest BUN value occurred at RM 29.0. Elevated BUN values occur in waters with high ammonia and/or organic nitrogen levels, where ammonia is a component of toxic sediments, or as a result of gill and kidney disfunction.

Ambient biological sampling in the Mahoning River upstream (RM 29.0/29.1) from the Niles WWTP showed extensive non-attainment of the WWH biocriteria with all the biological indices in the very poor and poor range (Table 1). Upstream sources of pollution associated with the extensive non-attainment include the cumulative loading of municipal and industrial dischargers, industrial spills, and very poor sediment quality. Downstream from the Niles WWTP all biological indices remained in the very poor and poor range. External anomalies on fish (DELT anomalies) increased from 4.2 % upstream from Niles WWTP (RM 29.0) to 8.1 % downstream (RM 28.5).

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community performance. The relative number and biomass of fish collected downstream from the Niles WWTP (RM 28.5) increased from 10 fish/km weighing 0.02 kg/km in 1980 to 109 fish/km weighing 30.5 kg/km in 1994. Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 32% for the IBI in the segment downsteam from Ohio Edison-Niles (RM 30.0) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

City of Girard WWTP (Little Squaw Creek RM 0.4, Mahoning River RM 25.28)
The Girard WWTP was constructed in 1962 and upgraded to a secondary WWTP in 1988. The discharge is to Little Squaw Creek just upstream from the confluence with the Mahoning River at river mile (RM) 25.28. Current wastewater treatment includes grit chamber, pre-aeration, primary settling, tricking filter, final clarifiers, equalization basin, and chlorine contact. The sewerage system has five combined sewer overflow (CSO) discharge locations. A review of long term data indicates a significant reduction in loadings of total suspended solids, ammonia-N, BOD_5, oil and grease, and lead following the 1988 upgrade. Average flows have declined from the mid 1980's to 1994. Ohio spill records from 1989 to 1994 contained one spill of sewage (August 1993) associated with the Girard WWTP.

Monthly operating report (MOR) data indicates NPDES permit violations between 1989 and 1994 for cadmium, chromium, copper, fecal coliforms, lead, mercury, oil and grease, pH, total suspended solids, and zinc. Based on 1994 annual mean loading values the Girard WWTP comprised 5.1% of the volume, 12.5% of the ammonia-N, and 7.2% of the $cBOD_5$ discharged by six major WWTPs to the lower mainstem. Ambient water chemistry data from 1994 shows slightly higher concentrations of nitrate+nitrite-N (NO_2+NO_3-N) and phosphorus in the Mahoning River downstream from Little Squaw Creek at RM 25.1 compared to upstream at RM 26.1 on the same sampling days. Sediment sampling was conducted upstream from Little Squaw Creek (RM 26.1) and downstream from North Star Steel (RM 23.4). The higher levels of chromium and PAHs observed in the sediment at the downstream site (RM 23.4) was not attributed to the Girard WWTP.

Results from an Ohio EPA bioassay conducted on the Girard WWTP effluent in April 1994 showed 60% to 80% toxicity to fish in effluent samples and 50% toxicity in mixing zone samples. In a September 1994 bioassay performed by Ohio EPA, no significant toxicity to either of two test organisms was observed in effluent samples.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River.

Ambient biological sampling in the Mahoning River upstream (RM 26.2/25.3) and downstream (RM 25.1) from Little Squaw Creek/Girard WWTP showed non-attainment of WWH biocriteria with all the biological indices in the poor or fair range (Table 1). Upstream sources of pollution affecting the non-attainment upstream from Little Squaw Creek include the cumulative loading of municipal and industrial dischargers, industrial spills, and very poor sediment quality. External anomalies on fish (DELT anomalies) increased from 6.4% upstream to 14.1% downstream.

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in fish community performance. The relative number and biomass of fish collected downstream from the Liberty Street dam (RM 26.2) increased from 10 fish/km weighing 0.02 kg/km in 1980 to 109 fish/km weighing 30.5 kg/km in 1994 while the cumulative number of fish species increased from 14 to 20. Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 30% for the IBI in the segment downstream from the Liberty Street dam (RM26.2) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

Boardman WWTP (Mill Creek RM 9.6, Mahoning River RM 21.63)
The Mahoning County Boardman WWTP discharges to Mill Creek at river mile (RM) 9.6. Downstream from the WWTP, Mill Creek flows through the Mill Creek Metropolitan Park to its confluence with the Mahoning River in Youngstown (RM 21.6). Major land uses within the 78.4 square mile watershed are a mixture of suburban development, agriculture, and forested park land.
The Boardman WWTP was constructed in 1962 as an activated sludge plant and upgraded in 1987 to advanced secondary treatment with nitrification, disinfection and post-aeration with a design flow of 5.0 MGD. During normal low-flow conditions (summer - fall), treated effluent makes up 90-100% of the stream flow in the lower 9.5 miles of Mill Creek. The facility currently disposes of sludge by landfilling, but also has the option of land application. The sewer system has a total of 12 bypasses and overflows. The overflows go into neighboring community sanitary sewers and all bypasses are to be reported as required by the NPDES permit. Although no overflows or bypasses have been reported, there is uncertainty regarding the status of three of the 12 structures. Two of the remaining overflows are located on the east side of Mill Creek within or between the Sawmill Run and Cranberry Run watersheds and a third structure is located in the park along the west side of Mill Creek downstream from the confluence with Indian Run.

The current NPDES permit has summer and winter limitations for total suspended solids (13/30 mg/l), ammonia-N (1/5 mg/l) and cBOD (10/25 mg/l). Due to ongoing permit violations at the Boardman WWTP, Mahoning County was referred to the Attorney General's Office and a consent order was signed in January 1994 requiring the county to hire class IV certified operators, submit MORs and bioassays on time, develop a plan to monitor mercury, and to develop a laboratory QA/QC program. The compliance history of the Boardman WWTP (number of months reporting violations at least once during that month) from 1989 to 1994 includes violations for ammonia (6), BOD_5 (2), cadmium (3), chlorine (3), copper (10), cyanide (6), dissolved oxygen (D.O., 1), fecal coliform (2), mercury (11), oil and grease (3), and total suspended solids (3). During the summer of l994 Ohio EPA personnel observed extensive sewage sludge deposits in Mill Creek downstream from the Boardman WWTP. Deposits were more than three feet deep in many spots and extended at least 150 meters downstream. Large floating mats in the stream and suspended solids in the Boardman effluent were also visually observed. Sludge deposits were also observed in Mill Creek approximately three miles downstream from the discharge.

Bioassays conducted by Ohio EPA resulted in no significant toxicity in 1988 (2 bioassays) or in August 1994; however, an April 1994 effluent bioassay showed marginal (25%) acute toxicity to fathead minnows. An October 1995 acute toxicity test by the entity showed 30% toxicity to *Ceriodaphnia* resulting in a TU_a of 0.6. Eight chronic toxicity bioassays were also conducted by the entity between December 1990 and October 1995. Results from these tests revealed Tu_c of 1.8 to both fathead minnows and *Ceriodaphnia* in May 1991 and a 1.1 Tu_c to *Ceriodaphnia* in October 1995. Given the effluent dominated nature of the flow downstream from the WWTP discharge (effluent design flow = 7.74 cfs, annual $Q_{7,10}$ stream flow = 2.02 cfs, annual $Q_{30,10}$ stream flow = 2.34 cfs), a comparison of the allowable effluent toxicity (AET) values of 0.38 TU_a and 1.3 TU_c to the reported values (0.6 and 1.8, respectively) and mixing zone toxicity results shows the potential of this discharge to have an acute and chronic effect on the aquatic assemblages within Mill Creek.

The 1994 ambient chemical results show that while water quality downstream from the Boardman WWTP has improved since 1982, serious problems remain due to elevated concentrations of ammonia-N (exceeded WWH criteria at RMs 9.5, 7.8 and 5.4) and phosphorus, extensive sludge deposits, and low D.O. Only 9% of the D.O. samples from upstream of the WWTP were below 5.0 mg/l, compared to 78% of the values between the WWTP and Shields Road (RM 5.4). The lowest D.O. values and highest ammonia-N concentration (4.5 mg/l) was recorded at RM 7.8 in 1994. The 1994 results do, however, show a reduction in the number of miles of severely degraded water quality downstream from the WWTP (*e.g.*, maximum phosphorus values were 12.6 mg/l [RM 7.8] in 1982 versus 1.2 mg/l [RM 5.4] in 1994 and large sludge deposits were not observed in the lower half of Mill Creek in 1994). The results of a 1993 nutrient loading study by Youngstown State University in the Mill Creek watershed and Lake Newport concluded the Boardman WWTP contributes approximately 55% of the total phosphorus load to Lake Newport versus 45% from nonpoint sources.

The 1994 biological sampling results show the WWH aquatic life use attainment status of Mill Creek has not significantly changed since 1982 (Table 1). While there have been incremental improvements in macroinvertebrate community performance immediately downstream from the Boardman WWTP and marked improvements further downstream, the non-attainment status is due to the continuation of poor and very poor fish community performance. Since 1982, the number of miles in non-attainment of WWH has remained at 11.3 while the miles in the poor to very poor ranges of community performance has decreased only slightly (from 10.6 to 9.9 miles). The principal causes of non-attainment associated with the impairment downstream from the Boardman WWTP were excessive levels of ammonia-N, low dissolved oxygen (D.O.), organic enrichment (including sludge deposits), nutrients, and siltation. Channelization (RM 11.0), flow alteration (water withdrawals), and impoundments were also associated with the impairment of the WWH aquatic life use at specific sites. The biological response signatures were more indicative of nutrient and organic enrichment effects as opposed to those associated with acute toxicity.

City of Youngstown WWTP (Mahoning River RM 19.43)
The Youngstown WWTP is the largest municipal discharge to the Mahoning River (RM 19.43), with a design flow of 35.0 MGD. A primary treatment plant was built in 1957 and construction for a secondary WWTP was completed in 1988. The current treatment process includes bar screen, grit chambers, primary clarifiers, activated sludge, and trickling filters for flows up to 35.0 MGD. Flow in excess of 35 MGD bypass the aeration system and is passed through microscreens to the chlorine contact tank. Blended effluent from the two treatment trains is chlorinated and passed through a cascade aeration system. The final step after the chlorine contact tank is dechlorination. The Youngstown sewer system has at least 96 combined sewer overflows (CSOs). The city of Youngstown and the state of Ohio are negotiating a consent decree to address both CSO and sanitary sewer overflow (SSO) problems.

A review of long term effluent loading data indicates a significant reduction in total suspended solids, BOD_5, and ammonia-N following the 1988 upgrade, with a slight reduction in average effluent flow from 1991 to 1994. The upgrades to the major municipal WWTPs along the mainstem have resulted in significant improvements to the instream concentrations of ammonia-N and dissolved oxygen

(D.O.) in the lower Mahoning River as evidenced by long term water quality data collected at the Lowellville fixed monitoring station.

Monthly operating report (MOR) data between 1989 and 1994 indicates NPDES permit violations for chlorine, copper, mercury, pH, and phenolics. Based on 1994 annual mean loading values the Youngstown WWTP comprised 51.6% of the volume, 29.8% of the ammonia-N, and 45.7% of the $cBOD_5$ discharged by six major WWTPs to the lower mainstem. Ambient water chemistry data from 1994 showed higher levels of copper, chemical oxygen demand (COD), total dissolved solids (TDS), nitrate+nitrite-N(NO_2+NO_3-N), and total phosphorus in the Mahoning River downstream (RM 19.2) from the Youngstown WWTP compared to upstream (RM 21.1) on the same sampling days. Concentrations of phosphorus and NO_2+NO_3-N were low in the Mahoning River from RMs 45.5 to 36.4, but showed two step wise increases, first below the Warren WWTP (RM 35.25) and next below the Youngstown WWTP (RM 19.43). Both NO_2+NO_3-N and total phosphorus concentrations were well above background levels at the Ohio-Pennsylvania state line, and maintained high levels down to the confluence with the Shenango River at New Castle, Pa. These data indicate that the Warren and Youngstown WWTPs had a major effect on nutrient enrichment in the lower Mahoning River. Ohio EPA spill records from 1989 to 1994 contained one reported incident associated with the Youngstown WWTP.

The segment of the Mahoning River between Mill Creek (RM 21.63) and the Youngstown WWTP (RM 19.43) receives numerous CSO/SSO discharges. Fecal coliform bacteria counts increased markedly downstream from Mill Creek in the city of Youngstown. Potential sources of this contamination included dry weather CSOs, SSOs, unsewered areas, and incomplete chlorination of WWTP effluents. One example is a siphon dam on Crab Creek (RM 19.5) which was overflowing most of the time during the 1994 survey. Data collected by volunteers at Crab Creek documented high concentrations of copper, lead and zinc between October 1993 and April 1994. In addition to these SSO discharges, the Mahoning River mainstem also receives periodic discharges of untreated wastewater from the numerous CSOs. One CSO in the Mahoning River near the mouth of Mill Creek was periodically observed discharging raw sewage during the 1994 survey. Volunteer monitoring data collected in the Mahoning River at Lowellville showed that the Pennsylvania lead criterion (7.0 ug/l) was exceeded in 19 out of 53 samples between May 1993 and December 1994. The highest values of instream lead concentrations collected during this period were at the mouths of Mill Creek (70 and 89 ug/l) and Crab Creek (64 and 88 ug/l). The mouth of Mill Creek also had the highest instream concentration of lead (31 ug/l) collected by the Ohio EPA during the 1994 survey (Crab Creek was not sampled by the Ohio EPA in 1994).

Ohio EPA conducted two bioassays on the Youngstown WWTP effluent and mixing zone in May and September 1994. No significant toxicity was observed to either of two test organisms in either bioassay. The entity conducted an acute toxicity test in October 1991 which resulted in marginal toxicity (20% adverse effects) to fathead minnows. There has been no chronic bioassay testing of the Youngstown WWTP effluent.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from

RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites.

Biological sampling in the mainstem upstream (RM 20.4) and downstream (RM 19.2/19.3) from the Youngstown WWTP indicated non-attainment of the WWH use (Table 1). All of the biological indices were in the poor or very poor range of community performance. The biological indices in 1994 were lower (-3 IBI, -1.5 MIwb, and -8 ICI units) in the Mahoning River at RM 19.2/19.3 downstream from the Youngstown WWTP compared to sites sampled upstream for fish at RM 20.4 and macroinvertebrates at RM 21.6. The downstream site at RM 19.2 had the lowest MIwb score (3.8) and the highest percent of external anomalies on fish (DELT anomalies, 26.9%) of any site sampled in the mainstem. The numbers of mayfly/caddisfly/stonefly taxa (EPT taxa) on the natural substrates, the density of the caddisfly *Hydropsyche valanis,* and total taxa richness on the artificial substrates were also reduced downstream from the Youngstown WWTP. Biological sampling in the Youngstown WWTP mixing zone also showed very poor to poor biological conditions. The character of the biological communities in this reach of the mainstem continued that which started downstream from WCI and Warren. The combination of deficiencies in community structure and organization, predominance of poor and very poor biological index scores, and extremely elevated anomalies fish (DELT anomalies) is a response to acutely toxic conditions in the mainstem.

While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results did show some incremental improvements in the fish community in the segment downstream from Youngstown. The relative number and biomass of fish increased in 1994 (*e.g.,* at RM 16.5 there was an increase from 36 fish/km weighing 1.3 kg/km in 1980 to 246 fish/km weighing 85.8 kg/km in 1994). Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 29% for the IBI in the segment from Mill Creek to the mouth (RM 23.0 to RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

Campbell WWTP (Mahoning River RM 15.89)

The Campbell WWTP was upgraded from a primary plant to a secondary WWTP in March, 1988 and discharges to the Mahoning River at river mile (RM) 15.89. Treatment processes include screening and grit removal, activated sludge aeration using two oxidation ditches, secondary clarification, and chlorination. The sewage system is a separate system with no known overflows, however, bypassing can occur at the WWTP and at various locations along the sewer system.

Monthly operating report (MOR) data from 1989 to 1993 indicates NPDES permit violations for chlorine, copper, cadmium, dissolved oxygen, mercury, nickel, pH, total suspended solids and zinc. The highest instream concentrations of fecal coliform (20,000/100 ml), lead (22 ug/l), and zinc (117 ug/l) recorded in the Mahoning River by Ohio EPA during 1994 was downstream (RM 15.5) from the Campbell WWTP. Based on 1994 annual mean loading values the Campbell WWTP comprised 2.4% of the volume, 7.2% of the ammonia-N, and 2.2% of the $cBOD_5$ discharged by six major WWTPs to the lower mainstem. Sediment chemistry data showed lower concentrations of most heavy metals and organics downstream from the Campbell WWTP at RM 15.5, except for the highest concentration of lead (1450 mg/kg) recorded in 1994. However, this site was in close proximity to the location of the old J&L Youngstown Sheet and Tube Campbell coke plant (RMs 16-17).

Ohio EPA spill records from 1978 to 1994 contained three reported sewage spills attributed to the Campbell WWTP (September 1989, March and April 1990). In 1989, there were alleged reports of a nearby industry, Finishing Corporation, dumping strong acids, alkalis, and detergents into the Campbell sewer system. The illegal dumping was alleged to be in high enough concentrations to kill the nitrifying bacteria in the WWTP biological treatment process. During 1994 another company, Cold Metals, allegedly dumped oil into the sewer system.

An oily sheen was observed on the Mahoning River at the LTV Campbell railroad bridge (RM 16.39) throughout the 1994 survey. A sheen this extensive represents a violation of the narrative provisions of the Ohio Water Quality Standards (Chapter 3745-1-04). On May 10, 1994 Ohio EPA personnel observed an oily discharge that was traced to a storm sewer outlet from Cold Metals. Further investigation indicated a cross connection between a process line and a non-contact cooling water discharge. The non-contact cooling water discharge for Cold Metals is located approximately one mile upstream from the RM 16.39 sampling location. While not the only potential source of oil in this vicinity, Cold Metals is a documented source of oil containing discharges. Other potential sources in this segment include groundwater seepage from the LTV property as the result of past steelmaking operations, and as yet unidentified sources entering storm sewers in Campbell.

Ohio EPA conducted two bioassays in 1994 on the Campbell WWTP effluent. In May, 45% to 75% toxicity to fathead minnows was reported in composite and grab effluent samples. No significant mortality was reported in a June bioassay, but total residual chlorine was measured at 0.31 mg/l in the effluent. An entity generated bioassay conducted in August 1994 reported no significant toxicity.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites.

Ambient biological sampling in the Mahoning River upstream from the Campbell WWTP showed extensive non-attainment of the WWH biocriteria with all the biological indices in the poor range. These results represent continued non-attainment of the WWH use which started upstream in the Warren area. Upstream sources of pollution affecting the non-attainment upstream from the Campbell WWTP include the cumulative loading of municipal and industrial dischargers, combined and sanitary sewer overflows (CSOs, SSOs) in Youngstown, industrial spills, and leachates and poor sediment quality, particularly that in close proximity to the old J&L Youngstown Sheet and Tube Campbell coke plant. Downstream from the Campbell WWTP all biological indices remained in the poor range. External anomalies on fish (DELT anomalies) increased from 11.1% upstream from Campbell WWTP (RM 16.3) to 15.3% downstream (RM 15.6).

Although no change has occurred in the use attainment status (non-attainment) from 1980 to 1994 in the lower Mahoning River from RM 35.4 to the mouth, the 1994 results did indicate some detectable improvements in the fish community performance. The relative number and biomass of fish collected downstream from the Campbell WWTP increased from 36 fish/km weighing 1.3 kg/km in 1980 to 246 fish/km weighing 85.8 kg/km in 1994. Biological index scores (IBI and MIwb) improved from near minimum values in the very poor range in 1980 to slightly higher values in the poor range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 65% for the MIwb and 38% for the IBI in the segment downstream from the Campbell WWTP (RM 15.6) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

Struthers WWTP (Mahoning River RM 14.32)
The Struthers WWTP has a design flow of 6.0 MGD and discharges to the Mahoning River at RM 14.32. In March 1987 the WWTP was upgraded from primary to secondary treatment. Current treatment processes include screening and aerated grit removal, flow equalization, primary settling, tricking filtration, secondary clarification, and chlorination. The Struthers WWTP has two bypasses, Bridge Street (15.4) and at the plant, which overflow to the Mahoning River.

Monthly operating report (MOR) data from 1990 to 1994 indicates NPDES permit violations for chlorine, copper, fecal coliforms, oil and grease, pH, and total suspended solids (TSS). Although biochemical oxygen demand (BOD5) loadings were reduced by 50% since the 1987 upgrade, ammonia-N and TSS loadings showed only a slight reductions. Average effluent flows have increased significantly from the early 1980's with average flows close to the 6.0 design capacity in 1994. Based on 1994 annual mean loading values the Struthers WWTP comprised 10.4% of the volume, 35.7% of the ammonia-N, and 19.5% of the $cBOD_5$ discharged by six major WWTPs to the lower mainstem. The effluent is mixed with storm water, which may contain leachate, prior to discharge. The downstream site at RM 13.2 had the highest sediment concentration of zinc (2880 mg/kg) recorded in the 1994 survey. Ohio EPA spill records from 1978 to 1994 contained two reported sewage spills attributed to the Struthers WWTP (1981 and 1984).

A May 1994 bioassay conducted by Ohio EPA reported no significant toxicity in the Struthers WWTP effluent. A June 1994 bioassay resulted in 80% to 85% mortality to fathead minnows in the effluent. Also, marginal toxicity was observed in the upstream sample which contained 0.060 mg/l of chlorine. The Campbell WWTP is located approximately 1.5 miles upstream from the Struthers WWTP and may be the source of the elevated instream chlorine measurement. While collecting bioassay samples, Ohio EPA personnel observed foam emanating from the WWTP discharge for an indefinite distance downstream in the Mahoning River.

Biomarker sampling conducted in the mainstem as part of the 1994 survey showed elevated EROD (ethoxyresorufin-o-deethylase) values for fish from all sites. This indicates exposure to EROD inducing chemicals (PAHs, PCBs, other hydrocarbons) with the highest induction occurring downstream from the Ohio Edison - Niles EGS at RM 29.0. Some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool. The benzo-a-pyrene (B(a)P)-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. There was an increasing trend in the median/mean values of B(a)P-type and NAPH-type metabolites in the fish collected from RM 57.8 to RM 12.0. This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River. Another biomarker, blood urea nitrogen (BUN), decreased in a downstream direction between RM 57.8 to RM 12.0, which was opposite the increasing trend for the liver metabolites.

Ambient biological sampling in the Mahoning River upstream from the Struthers WWTP showed extensive non-attainment of the WWH biocriteria with all the biological indices in the very poor and poor range. These results represent continued non-attainment of the WWH use which started upstream in the Warren area. Upstream sources of pollution affecting the non-attainment upstream from the Campbell WWTP include the cumulative loading of municipal and industrial dischargers, combined and sanitary sewer overflows (CSOs, SSOs) in Youngstown, industrial spills, and leachates and poor sediment quality, particularly that in close proximity to the old J&L Youngstown Sheet and Tube Campbell coke plant. Downstream from the Struthers WWTP and the Lowellville dam (RM 12.5) all biological indices remained in the poor range.

Although no change has occurred in the use attainment status (non-attainment) from 1980 to 1994 in the lower Mahoning River from RM 35.4 to the mouth, the 1994 results did indicate some detectable improvements in the fish community performance. The relative number and biomass of fish collected downstream from the Struthers WWTP and the Lowellville dam (RM 12.5) increased from 14 fish/km weighing 2.0 kg/km in 1980 to 547 fish/km weighing 105.0 kg/km in 1994. Biological index scores (IBI and MIwb) improved from near minimum values in the very poor range in 1980 to slightly higher values in the poor range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 65% for the MIwb and 38% for the IBI in the segment from downstream Campbell WWTP (RM 15.6) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

Brookfield WWTP (Yankee Creek RM 0.42)

The Trumbull County-Brookfield WWTP discharges to Yankee Creek at river mile (RM) 0.42. The treatment process employs a three stage vertical loop reactor with bar screen, aerated grit removal, secondary clarifiers, chlorination and dechlorination. Solids are removed using a gravity thickener, aerobic digestion, and sludge drying beds. The most recent expansion and upgrade (from primary treatment) was completed in 1989. The design flow is 1.3 MGD and less than five percent of the plant flow is derived from industrial sources. The collection system is 100% separate sewers.

Loadings of chemical oxygen demand (COD) and ammonia-N have not changed appreciably over the last 10 years. Monthly operating report (MOR) data collected between 1991 and 1994 indicated NPDES permit violations for $cBOD_5$, chlorine, copper, lead, nickel, total suspended solids (TSS), and zinc. Ambient water chemistry data from the 1994 survey showed higher levels of COD, TDS, total phosphorus, zinc, and especially nitrate+nitrite-N (average of 0.32 mg/l upstream to 3.68 ug/l downstream) in Yankee Creek downstream from the Brookfield WWTP. Ohio EPA spill records from 1978 to January 1994 contained no reported incidents associated with the Brookfield WWTP.

Ambient chemical water quality in Yankee Creek improved between the 1984 and 1994 surveys. The 1984 results showed degraded water quality downstream from the Brookfield WWTP due to organic enrichment, elevated ammonia-N and total Kjeldahl nitrogen (TKN) concentrations, and low dissolved oxygen levels. Field work conducted in 1994 revealed much improved water quality conditions below the WWTP. Dissolved oxygen levels now show an improving trend. Ammonia-N and TKN concentrations were consistently near or below minimum detection limits. The improvements in water quality observed in 1994 are directly linked to the recent improvements made at the Brookfield WWTP and the elimination of smaller WWTPs in the area.

Three of 14 bioassays conducted between May 1991 and February 1993 resulted in measurable toxic effects to fathead minnows of 1.0 TU_a and 1.6 TUc, and to *Ceriodaphnia*of 2.8 TU_c, 5.7 $Tu_{c,}$ and > 8.0 TU_c. Additionally, three other tests of effluent resulted in significant toxicity to fathead minnows. Mixing zone samples were significantly toxic to fathead minnows in three bioassays, but not to *Ceriodaphnia*. Because the Brookfield WWTP effluent dominates the summer-fall stream flow regime ($Q_{7,10}$ stream flow = 0.14 cfs, $Q_{30,10}$ stream flow = 0.41 cfs, effluent flow = 2.01cfs), the bioassay results exceed the Allowable Effluent Toxicity (AET) values of 0.3 TU_a and 1.2 TU_c, and demonstrate the high potential of this discharge to have deleterious acute and chronic effects on resident aquatic organisms.

Ambient biological sampling in Yankee Creek upstream (RM 0.6) from the Brookfield WWTP showed partial attainment of the applicable WWH biocriteria (Table 1) and was due to the failure of the fish community to perform at levels consistent with the WWH biocriteria. The qualitative macroinvertebrate sample at RM 0.6 had 46 total taxa with 12 species of mayflies, stoneflies, and caddisflies which indicates good water quality. Fish sampling results upstream from the WWTP in 1994 were similar to the those obtained in 1984 and indicated continued problems with upstream sources. District staff observed a heavy oil sheen on the water surface during a chemical water quality sampling event, but the specific source was not determined. The non-attainment status downstream from the WWTP was due to the poor performance of the macroinvertebrate community which has remained essentially unchanged since the 1984 survey, with low numbers of total taxa (13 and 11) and low EPT taxa (one and zero) in both years, respectively. Fish community performance in Yankee Creek downstream from the Brookfield WWTP (RM 0.3) have improved since 1984, with the mean IBI and MIwb values increasing from 18 (very poor) to 37 (marginally good, nonsignificant departure) and 5.4 (poor) to 6.8 (fair, significant departure), respectively. While these results indicate some quantitative improvement in biological community performance, the continued non-attainment is well correlated with the effluent performance indicators and findings of significant acute and chronic toxicity.

Hubbard WWTP (Little Yankee Creek RM 4.59)

The Hubbard WWTP discharges to Little Yankee Creek at river mile (RM) 4.59. The treatment process consists of a multiple channel orbital aeration plant with bar screens, grit removal,, settling, chlorination, dechlorination, and post-aeration. Solids are treated via aerobic digestion, polymer sludge conditioning, and belt press. The facility was last upgraded in 1989. The previous facility employed a secondary trickling filter with flows that were averaging twice the 0.8 MGD design capacity. The current design flow is 2.1 MGD and less than one percent is derived from industrial sources. The collection system is 100% separate sewers.

Annual flows were similar until the 1989 upgrade and have been rising steadily ever since. Total residual chlorine concentrations have been increasing steadily matching the increase in flows. Total zinc values have been highly variable during the past five years. The NPDES permit compliance history of the Hubbard WWTP from 1989 to 1994 includes (number of months with reported violations at least once during that month) ammonia-N (3), BOD_5 (2), $cBOD_5$ (2), cadmium (3), chlorine (6), copper (2), fecal coliform (18 in 1989), dissolved oxygen (3 in 1991), flow (1), mercury (2), pH (3), and total suspended solids (6). Ambient water chemistry data from the 1994 survey showed higher levels of copper, total Kjeldahl nitrogen (TKN), nitrite+nitrate-N, phosphorus, and zinc downstream from the Hubbard WWTP compared to upstream. In one of the Ohio EPA effluent bioassay samples naphthalene was detected at 0.6 ug/l. The Ohio EPA spill records contained two reported incidents associated with the Hubbard WWTP in July 1985 and June 1988, but no spills have been reported since.

Ambient chemical water quality in Little Yankee Creek has improved since the 1984 survey. The 1984 results showed degraded conditions below the Hubbard WWTP due to organic enrichment, elevated ammonia-N and TKN concentrations, and low dissolved oxygen levels. The 1994 results revealed much improved water quality conditions below the WWTP. Ammonia-N concentrations were consistently near or below minimum detection limits. Suspended solids concentrations were similar upstream and downstream of the WWTP. Total phosphorus and TKN concentrations increased significantly below the WWTP, but did not exceed the assimilative capacity of the stream. Dissolved oxygen levels now show an improving trend at the downstream stations. The improvements in water quality observed in 1994 are directly linked to the recent improvements made at the Hubbard WWTP.

Three of four bioassays (May and November 1990, June 1994) conducted by Ohio EPA resulted in no significant toxicity to either fathead minnows or *Ceriodaphnia*. However, the most recent bioassay conducted in June 1994 by Ohio EPA resulted in acute toxicity to *Ceriodaphnia* in both the grab effluent, composite effluent, and mixing zone samples. A 1.3 TU_a was calculated from this bioassay. Two bioassays conducted by the resulted in a 1.8 TU_c and 2.1 TU_c to *Ceriodaphnia*. Because the Hubbard WWTP effluent dominates the summer-fall stream flow regime ($Q_{7,10}$ stream flow = 0.36 cfs, $Q_{30,10}$ stream flow = 0.52 cfs, effluent flow = 3.25 cfs), the bioassay results exceed the Allowable Effluent Toxicity (AET) values of 0.33 TU_a and 1.2 TU_c, and demonstrate the high potential of this discharge to have deleterious acute and chronic effects on resident aquatic organisms.

Macroinvertebrates collected at the uppermost sampling location on Little Yankee Creek at RM 9.6 yielded results that indicated exceptional community performance. Numerous sensitive taxa were collected in the quantitative and qualitative samples including six typically coolwater taxa (the caddisflies *Hydropsyche (C.) slossonae*, *Diplectrona modesta*, and Glossoma *spp.*; and the midges *Parametriocnemus spp.*, *Polypedilum (Pollypedilum) aviceps*, and *Paratanytarsus n. sp.* 1). ImmediAtely upstream from the Hubbard WWTP at RM 4.9, the ICI score declined to 30 and reflected marginally good water quality. Immediately downstream the ICI declined to 26 which indicates fair performance. Further downstream at RM 1.6, increases in mayfly taxa and density in the artificial substrate samples along with an increase in the number of qualitative EPT taxa resulted in an ICI value of 34 which meets the WWH ecoregional biocriterion. The near mouth site (RM 0.2) was evaluated as fair which does not meet ecoregional expectations. Little Yankee Creek near the mouth is impounded resulting in nondetectable current and pool habitat. Compared to the clear and brown water color at the upstream sites, the water color at RM 0.2 was bright green due to nuisance growths of colonial green algae. The ICI score (28), number of qualitative EPT taxa (2), and median QCTV value (32.8) were all below ecoregional expectations and reflective of fair water quality. The Hubbard WWTP had only a minimal effect on the macroinvertebrate community, but likely contributed to the heavy algal growth observed at RM 0.2.

The quality of fish assemblages in Little Yankee Creek declined from marginally good at the upstream most site (RM 9.5) to very poor to fair quality at the remaining five sites. Down-stream from the Hubbard WWTP, IBI scores were similar to that immediately upstream from the discharge (RM 4.6) and the MIwb increased from the very poor to the fair range suggesting no additive impact from the Hubbard WWTP on the fish community. The number of fish species collected in Little Yankee Creek increased from 11 and 15 species at the two sites upstream from the WWTP to 20 and 19 species downstream (excepting the impounded segment near the mouth). Numerically predominant species shifted from bluegill (28.2%), common carp (21.8%), and green sunfish (11.5%) upstream from the WWTP to central stoneroller (39.7%), bluntnose minnow (38.0%), and creek chub (12.8%).

The WWH use attainment status in Little Yankee Creek has not changed since 1984, although index values were higher in 1994 (Table 1). The results also indicate problems upstream from the Hubbard WWTP and these include discharges from an unsewered area near the Ohio Turnpike. Despite not fully attaining the WWH use designation, fish and macroinvertebrate assemblages in Little Yankee Creek have markedly improved downstream from the Hubbard WWTP since the 1984 survey. Mean MIwb and IBI values increased from 1.5 to 6.7 and 13 to 26, respectively, immediately downstream from the WWTP (RM 4.4). The mean number of fish species has similarly increased from 3.5 in 1984 to 16.5 in 1994. In 1984, the macroinvertebrate and fish community performance was either poor or very poor at all sites between the Hubbard WWTP and the mouth. In 1994, at RM 1.6 the ICI was 38 which exceeded the WWH biocriterion, and at RM 4.4 and RM 0.2 the ICI indicated fair community performance.

CONCLUSIONS

Mahoning River

- The 1988-1989 upgrades of treament processses at the major municipal WWTPs have resulted in significant improvements in the instream concentrations of ammonia-N and D.O. in the lower Mahoning River mainstem as evidenced by water chemistry data collected at the Lowellville fixed monitoring station.

- The 1994 water chemistry data showed higher instream concentrations of nitrate+nitrite-N (NO_2+NO_3-N) and/or phosphorus in the Mahoning River downstream from the Warren WWTP, Girard WWTP, and the Youngstown WWTP compared to sites upstream from these sources. Higher instream concentrations of these nutrient parameters were also observed downstream from the Meander Creek WWTP, Boardman WWTP (Mill Creek), Brookfield WWTP (Yankee Creek), and Hubbard WWTP (Little Yankee Creek).

- Elevated levels of fecal bacteria above the Primary Contact Recreation (PCR) criterion were recorded at eight Mahoning River mainstem stations from Warren (RM 41.5) to below the Ohio-Pennsylvania state line (RM 7.0). There was a significant trend toward increased fecal coliform bacteria counts below Mill Creek within the city of Youngstown. The highest coliform bacteria count of 20,000/100 ml was found at RM 15.5 below the Campbell WWTP. Trend data indicated that the level of fecal bacteria at Lowellville (RM 12.5) has consistently exceeded the PCR fecal coliform bacteria criterion during the last 20 years. Sources of fecal bacteria in this segment include SSOs, CSOs, unsewered areas, and WWTPs. No significant fecal coliform bacteria problems existed at the upstream ambient fixed monitoring station in Leavittsburg, and more recent data indicated some improvement in bacterial quality at this station.

- There was a decreasing trend in blood urea nitrogen (BUN) values in fish between Newton Falls (RM 57.8) and Lowellville (RM 12.0), which was opposite the increasing trend for the bile metabolites (*e.g.*, EROD). The exception was in the Liberty Street dam pool (RM 29.0) which had the highest median BUN value. High BUN values may be expected from waters with high ammonia-N and/or organic nitrogen levels, where ammonia-N is a component of toxic sediments, or as a result of gill and kidney disfunction. In March 1996, Ohio EPA personnel discovered a discharge of raw sewage from an unsewered area in the Hilltop subdivision near McDonald in Trumbull County. It was estimated that raw sewage from 600-800 homes without any treatment (not even septic tanks) was entering the Mahoning River between the Ohio Edison - Niles EGS and the Niles WWTP (RM 30.0 to RM 28.7).

- The four major industrial sources on the Mahoning River mainstem between RMs 42.7 and 35.4 (Copperweld, Thomas Strip Steel, WCI, and LTV) reported NPDES permit violations for oil and grease. Naphthalene was detected in all four of these effluents during routine bioassay sampling. The Mahoning River was sampled for organic chemicals only at RM 45.1 and RM 12.42 during the 1994 survey and naphthalene was detected only at RM 12.42. The 1994 annual mean daily loadings of oil and grease for WCI outfalls 008 (168 kg/day) and outfall 013 (136 kg/day) represent approximately 46% of the total oil and grease loadings from all major Mahoning River point sources. Additionally, five (of 22) spills at WCI between 1989 and 1992, and seven (of 22) spills at LTV between 1989 and 1994 were petroleum related. The macroinvertebrate field crew observed oil throughout the mainstem downstream from the Warren WCI/LTV (RM 35.4) to the Ohio-Pennsylvania state line. An oil sheen on the water along with oil deposits on coarse subsrates was also observed in the Dickey Run storm sewer mixing zone (RM 39.17).

- Instream temperatures downstream from the Ohio Edison - Niles EGS at RM 29.1 were an average of 5˚C warmer than at the upstream site at RM 30.0. Exceedences of the daily average temperature criterion were recorded at five sampling stations between RM 29.1 and RM 23.4.

- Pollutant discharges from spills, overflows, permit violations, and unauthorized releases are significant sources of acute and chronic stresses for aquatic communities in the Mahoning River watershed. Approximately 550 incidents were recorded by the Ohio EPA Emergency Response Section during the 5 year period from 1989 to 1993. Sewage, released through unauthorized bypasses, SSOs, and CSOs, was the leading pollutant (by volume) released via spills into the Mahoning River between 1989 and 1994 (6,667,742 gallons - 96.9% of all spills), but not in frequency (24 episodes out of 193 reported spills = 12.4 %). The most frequently released pollutant were various types of petroleum products (120 episodes out of 193 spills - 62.1%).

- The August 1990 Mahoning River wasteload allocation (WLA) was modelled to maintain the Pennsylvania water quality criterion for lead (7 ug/l) at the Ohio-Pennsylvania state line. Ohio EPA survey data at the fixed monitoring location at Lowellville during June-September 1994 showed that one of five values exceeded the criterion and the average was 7.1 mg/l. Volunteer monitoring data collected in the Mahoning River at Lowellville showed that the 7.0 mg/l standard was exceeded on 19 out of 53 samples collected from May 1993 to December 1994. The highest values of instream lead concentrations observed by the volunteer monitoring program between 1993 and 1994 occurred at the mouths of Mill Creek (70 and 89 ug/l) and Crab Creek (64 and 88 ug/l). The mouth of Mill Creek also had the highest instream concentration of lead (31 ug/l) collected by the Ohio EPA in the 1994 Mahoning River survey (Crab Creek was not sampled). These data suggest that the discrepancy between the WLA modeling to maintain 7.0 ug/l lead at the state line and the 1993/1994 samples which showed lead values higher than 7.0 ug/l are due to sources other than NPDES permitted discharges and include malfunctioning CSOs, SSOs, urban runoff, unregulated industrial discharges, and/or industrial site seepage in the Youngstown area.

- Compared to the results obtained from previous surveys in the 1980s, the 1994 results indicate some detectable improvements in the overall performance of the biological communities. Use attainment status improved from non-attainment in 1980 to either partial or full attainment in 1994 from the Leavittsburg dam (RM 45.5) to upstream from Copperweld Steel (RM 43.3). Although the two sites downstream (RM 40.6/41.1 and 39.4) from Copperweld Steel were in non-attainment in 1994, fish numbers and biomass increased since 1980 and the ICI score at RM 41.1 was in the non-significant departure range for meeting ecoregional expectations. Use attainment status immediately downstream from Thomas Steel Strip and upstream from the impacts of WCI and the Warren WWTP improved from non-attainment in 1980 to partial in 1994. Biological index scores also improved moving from the very poor/poor range in 1980 to fair in 1994. While no changes have occurred in the use attainment status since 1980 in the lower Mahoning River between RM 35.4 and the mouth, the 1994 results do show some incremental improvements in the fish community. Biological index scores (IBI and MIwb) improved from near minimum values in the very poor to poor range in 1980 to slightly higher values in the poor and sometimes fair range in 1994. These improvements were quantified using the Area of Degradation Value (ADV) which declined by 52% for the MIwb and 33% for the IBI in the segment dowtream from WCI (RM 35.4) to the mouth (RM 1.1). Nevertheless, the current condition is still severely degraded and corresponds to the indicators of current and past pollutant loadings, particularly the contaminated sediments.

- Sediment chemistry data shows little or no indication that the lower Mahoning River sediments were less contaminated in 1994 than previous sampling years. Copper, chromium, iron, lead, PAHs, and zinc were found at potentially toxic concentrations in the lower mainstem sediments in 1994 and at levels comparable to that observed from 1975 to 1986. Long-term flushing and bacterial decomposition of the river sediments has not resulted in any significant improvement in lower Mahoning River sediments.

- The non-attainment of the WWH biological criteria in the lower Mahoning River from WCI/LTV (RM 35.4) to the mouth could not be attributed to poor sediment quality alone. Although there were contaminated sediments from Copperweld Steel (RM 41.1) to downtown Warren (RM 38.2), at least one biological index (ICI or MIwb) performed above the ecoregion biocriterion (or was in nonsignificant departure) at each of the sites (excepting the Summit Street dam pool) in this segment. None of the biological indices (ICI, IBI, or MIwb) attained or were in nonsignificant departure of WWH criteria downstream from WCI/LTV to the mouth (RM 35.4 to RM 0.1). With few exceptions the biological index scores were in the poor or very poor range of performance.

- Industrial sources and/or activities were the leading cause of fish kills from 1981 to 1994 accounting for 68.1% of the total animals killed (8,683) followed by agriculture (29.4%), public services (1.8%), and unknown causes (1.3%). Within the industrial category, the two principal causes of kills were metal fabrication (35.6%) and petroleum related (32.5%) activities.

- External DELT anomalies on fish increased markedly from the upper half to the lower half of the Mahoning River. In the upper Mahoning River eight of 13 sites had DELT anomalies greater than or equal to 3%, but no values exceeded 10%. In the lower mainstem, DELT anomalies were greater than or equal to 3% at 25 of 26 non-mixing zone sites between the Leavittsburg dam and the mouth (RM 45.5 to RM 0.2) and were greater than 10% at 17 of 20 sites between WCI/LTV and the mouth (RM 35.4 and RM 0.2). Five of the six sites with the highest DELT anomalies occurred in the Youngstown area (between RM 23.0 and RM 19.2) where values ranged from 20.3% to 26.9%.

- PCB concentrations in fish tissue were comparable in 1986 and 1994. Four whole body samples of common carp collected in 1986 between RM 30.4 and RM 12.8 contained 2400, 2700, 2600, and 4200 ug/kg of total PCBs. Three whole body samples of carp collected in 1994 between RM 35.0 and RM 12.5 contained 1720, 3100, and 3400 ug/kg of total PCBs. PCBs were detected in all 18 fish tissue samples collected from RM 38.8 (Perkins Park in Warren) to RM 12.5 (near the state line), but were not detected in any of nine samples collected upstream from Warren at RMs 70.3, 44.3, or 40.6. PCBs were detected in 10 of 13 sediment samples collected between RM 38.9 and RM 11.5 and ranged from 387 ug/kg to 3376 ug/kg.

- From 1989 to 1994, the single largest reported spill by volume was from the Beloit WWTP, a minor municipal point source. One spill (3,000,000 gallons reported) represented 57.4 % of the total volume of pollutants reported spilled in the Mahoning River basin during this time period. Those entities with the most frequent number of reported spills between 1989 and 1994 were: Beloit WWTP (37), LTV Steel Warren Coke Plant (27), WCI Steel (23), Ohio Edison-Niles EGS (18), North Star Steel (18), General Electric-Niles (15), Schaeffer Equipment (12), and RMI Titanium (8).

Meander Creek

- Since 1980, minimum dissolved oxygen (D.O.) values have increased slightly downstream from the Meander Creek WWTP. Long term data also shows ammonia-N reductions below the Meander Creek WWTP since 1983 (maximum ammonia-N values declined from 2.23 mg/l at RM 1.7 in 1983 to 0.72 mg/l in 1994).

- Despite these improvements, the 1994 chemical results still showed an impact on water quality downstream from the Meander Creek WWTP (RM 1.8). Concentrations of eight parameters (lead, zinc, chemical oxygen demand, nitrate+nitrite, nitrate, ammonia-N, total kjeldahl nitrogen, and total phosphorus) were considerably higher at the two downstream locations. Maximum total phosphorus and total nitrate+nitrite-nitrogen values recorded downstream from the WWTP during 1994 were 3.51 and 13.6 mg/l, respectively. Nutrient enrichment impacts in Meander Creek were also visually evident downstream from the WWTP (*i.e.*, dense growths of filamentous algae and decaying organic matter). Instream violations of the daily minimum D.O. criterion were recorded at RM 1.8 and RM 0.8. Sediment data showed significant increases in concentrations of chromium, lead, and zinc from non-elevated levels upstream from the discharge (RM 2.0) to highly or extremely elevated levels downstream from the WWTP (RM 1.8).

- The 1994 biological sampling results show non-attainment of the WWH aquatic life use both upstream and downstream from the Meander Creek WWTP (Table 1). Biological performance changed from fair immediately upstream to poor and very poor downstream from the WWTP. Impoundment and flow alterations appear to be the major associated causes of non-attainment upstream from the WWTP. The primary causes associated with the non-attainment downstream from the WWTP are metals, excessive nutrients, ammonia-N, low dissolved oxygen (D.O.), and suspended solids. The biological response signatures downstream from the Meander Creek WWTP were indicative of both nutrient and organic enrichment and acute toxicity.

Mill Creek Subbasin

- The 1994 ambient chemical results show that while water quality downstream from the Boardman WWTP has improved since 1982, serious problems remain due to elevated concentrations of ammonia-N (exceeded WWH criteria at RMs 9.5, 7.8 and 5.4) and phosphorus, extensive sludge deposits, and low dissolved oxygen (D.O.). The 1994 results do, however, show a reduction in the number of miles of severely degraded water quality downstream from the WWTP (*e.g.*, maximum phosphorus values were 12.6 mg/l [RM 7.8] in 1982 versus 1.2 mg/l [RM 5.4] in 1994 and large sludge deposits were not observed in the lower half of Mill Creek in 1994).

- The 1994 biological sampling results show the WWH aquatic life use attainment status of Mill Creek has not significantly changed since 1982 (Table 1). While there have been incremental improvements in macroinvertebrate community performance immediately downstream from the Boardman WWTP and marked improvements further downstream, the non-attainment status is due to the continuation of poor and very poor fish community performance.

- Similar to the mainstem of Mill Creek and also indicative of watershed wide impairment/impacts, biological assemblages in the headwater tributaries have also showed no significant change in aquatic life use attainment status. Only fair macroinvertebrate assemblages were found in all of the tributaries except Indian Run which supported a marginally good community. Poor or fair fish communities were observed in the four tributaries sampled.

Yankee Creek/Little Yankee Creek Subbasin

- Ambient chemical water quality in Yankee Creek and Little Yankee Creek improved between the 1984 and 1994 surveys. The 1984 results showed degraded water quality in Yankee Creek downstream from the Brookfield WWTP and in Little Yankee Creek downstream from the Hubbard WWTP, due to organic enrichment, elevated ammonia-N and total Kjeldahl nitrogen (TKN) concentrations, and low dissolved oxygen levels. Field work conducted in 1994 showed ammonia-N and TKN concentrations consistently near or below minimum detection limits, and dissolved oxygen levels now show an improving trend at the downstream stations. The improvements in water quality observed in 1994 are directly linked to the recent improvements made at the Brookfield WWTP and the Hubbard WWTP, and the elimination of smaller WWTPs in the area.

- Chemistry data from the 1994 survey showed higher levels of COD, TDS, total phosphorus, zinc, and especially nitrate+nitrite-N (average of 0.32 mg/l upstream to 3.68 ug/l downstream) in Yankee Creek downstream from the Brookfield WWTP. Chemistry data from the 1994 survey showed higher levels of copper, total Kjeldahl nitrogen (TKN), nitrite+nitrate-N, phosphorus, and zinc downstream from the Hubbard WWTP compared to upstream.

- Biological sampling in Yankee Creek upstream (RM 0.6) from the Brookfield WWTP showed partial attainment of the applicable WWH biocriteria (Table 1) and was due to the failure of the fish community to perform at levels consistent with the WWH biocriteria. Fish community performance in Yankee Creek downstream from the Brookfield WWTP (RM 0.3) have improved since 1984, with the mean IBI and MIwb values increasing from 18 (very poor) to 37 (marginally good, nonsignificant departure) and 5.4 (poor) to 6.8 (fair, significant departure), respectively. The non-attainment status downstream from the WWTP was due to the poor performance of the macroinvertebrate community which has remained essentially unchanged since the 1984 survey, with low numbers of total taxa (13 and 11) and low EPT taxa (one and zero) in both years, respectively. While these results indicate some quantitative improvement in biological community performance, the continued non-attainment is well correlated with the effluent performance indicators and findings of significant acute and chronic toxicity in effluent bioassays.

- Despite not fully attaining the WWH use designation, fish and macroinvertebrate assemblages in Little Yankee Creek have markedly improved downstream from the Hubbard WWTP since the 1984 survey. In 1984, the macroinvertebrate and fish community performance was either poor or very poor at all sites between the Hubbard WWTP and the mouth. In 1994, at RM 1.6 the ICI was 38 which exceeded the WWH biocriterion, and at RM 4.4 and RM 0.2 the ICI indicated fair community performance. Downstream from the Hubbard WWTP, IBI scores were similar to that immediately upstream from the discharge (RM 4.6) and the MIwb increased from the very poor to the fair range suggesting no additive impact from the Hubbard WWTP on the fish community.

Pymatuning Creek Subbasin

- Elevated fecal coliform and *E.coli* bacteria counts were observed in Pymatuning Creek downstream from the Kinsman area. The elevated counts frequently exceeded the Primary Contact Recreation and Secondary Contact Recreation criteria in Pymatuning Creek for both fecal coliform and *E.coli* bacteria. Failing septic system discharges in the Kinsman area did not significantly increase ammonia–N, TKN, or phosphorus concentrations in Pymatuning Creek.

- No decernable impact on conventional water quality parameters were attributed to the Horodisky Dump or the Vernon Sand and Gravel sites in the Pymatuning Creek subbasin.

RECOMMENDATIONS

Based upon the findings of this study, the following general recommendations are made:

Status of Aquatic Life Uses

- Aquatic life uses for some streams evaluated during this study were originally designated in the 1978 Ohio WQS without the presently employed standardized approaches to the collection of instream biological data and numerical biocriteria. This study represents the first use of biological data and numerical biocriteria to evaluate and establish aquatic life use designations. Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations made in 1978 (other than WWH) prior to basing any permitting actions on these existing, unverified use designations. Based on the 1994 survey results, there were no aquatic life use designation changes recommended for streams within the Mahoning River basin study area. The impounded segments of the mainstem technically meet a criterion for the Modified Warmwater Habitat (MWH); however, no recommendations are being made for revising the existing WWH use designation at this time. Future restoration plans for the mainstem should include considerations for breaching and/or removal of selected dams. Once this is determined any changes to the existing WWH use can then be reconsidered.

Status of Non-Aquatic Life Uses

- Results of the present study support the existing non-aquatic life uses (Agricultural Water Supply, Industrial Water Supply, Primary Contact Recreation, and Secondary Contact Recreation) currently designated for the Mahoning River and selected tributaries.

Future Monitoring

- Biological and water quality sampling should continue in the Mahoning River basin to track progress towards improved water resource quality. The next complete survey for the watershed is scheduled for 1999 according to the Five-Year Basin Approach to Monitoring and NPDES Permit Reissuance. In addition to re-sampling of the mainstem, biological and chemical monitoring should also be conducted in tributaries with recurring spills, fish kills, and other uncontrolled releases.

- Areas which showed a need for intensive biological and chemical sampling in the future include:

  1) Alliance area:
     Biological sampling showed impairment upstream and downstream from Ryans Run. Upstream sampling should focus on separating impacts from the Sebring WWTP and Beloit WWTP. Ryans Run sediment was covered with an orange precipitate. Chemical/physical measurements should be taken from upstream areas in Ryans Run and traced back to entity discharge locations.

  2) Warren area (Packard Park to Perkins Park):
     The occurrence of PCBs in the sediment and fish tissue in the lower mainstem was first detected at RM 38.8/38.9 which is downstream from the Red Run discharges, Thomas Strip Steel, and at least one known PCB source.

3) Warren area (LTV/WCI area):
Participation among several divisions in the Ohio EPA should be employed to adequately assess past and present causes of degradation along with possible solutions to clean up this segment.

4) Youngstown area:
Locations and impacts of CSOs and SSOs need to be documented. High concentrations of fecal coliform bacteria and lead detected in the Youngstown area and at the Ohio-Pennsylvania state line may be due to CSO/SSO problems such as the malfunctioning siphon dam on Crab Creek and the raw sewage discharge observed near the mouth of Mill Creek. Monitoring of the existing overflows and correcting the ones with the most serious impacts is recommended.

- Additional follow-up monitoring in the Warren area from upstream all WCI outfalls, slag piles, and leachates to downstream from LTV outfall 014 needs to be conducted and should include sediment, fish tissue, water chemistry (including organics), groundwater, and biology. Participation among several divisions in the Ohio EPA should be employed to adequately assess past and present causes of degradation along with possible solutions to clean up this segment. Upcoming permits and/or settlements with WCI and LTV should include provisions for additional monitoring and clean up actions in these directions.

- Organic chemistry data should be collected at more locations in the Mahoning River between Copperweld Steel and the Ohio-Pennsylvania state line. In 1994, there were only two sites in the lower mainstem with organics analyzed in the water column. Naphthalene was detected at the Ohio-Pennsylvania state line and in the effluents of Copperweld, Thomas Strip Steel, WCI, and LTV.

- Fish tissue was collected at only one site in the upper mainstem in 1994. Fish tissue sampling should be conducted near other areas of PCB contamination such as near Alliance at RM 85.0.

- Organic sediment data should be collected downstream from Ohio Edison and upstream from the Niles WWTP. Biomarker data showed that this area had the highest levels of EROD an NAPH-type metabolites.

STUDY AREA

General Description

The upper Mahoning River mainstem originates in western Columbiana County and flows 50.8 miles to the Leavittsburg dam in Trumbull County (Figure 2). The lower Mahoning River mainstem originates at the base of the Leavittsburg dam and flows 57.5 miles , in a southeasterly direction, to its confluence with the Shenango River, near New Castle, Pennsylvania, to form the Beaver River (Figure 3). Mill Creek is a major tributary which originates south of Columbiana in Columbiana County and flows 20.9 miles, in a northerly direction, to its confluence with the Mahoning River in Youngstown (Figure 4). Other major tributaries include the West Branch Mahoning River, Eagle Creek, Silver Creek, Mosquito Creek, and Meander Creek. The entire Mahoning River watershed basin is 1133 square miles (729,600 square acres) and encompasses most of Mahoning County and portions of Columbiana, Stark, Portage, Geauga, and Trumbull Counties in Ohio, plus the western portion of Lawrence County in Pennsylvania. The Mahoning River average gradient is 3.95 feet per mile, (from an elevation of 1197 to 7956 feet above sea level). The largest impoundments within the Mahoning basin are Berlin Reservoir (91,200 acre feet), M.J. Kirwan Reservoir (78,700 acre feet), Lake Milton (29,770 acre feet), Mosquito Creek Reservoir (104,100 acre feet), Meander Creek Reservoir (35,500 acre feet), and the Mill Creek Lake system (Newport, Cohasset, and Glacier).

Yankee Creek originates in eastern Trumbull County and flows 14.8 miles in a southeasterly direction to its confluence with the Shenango River near the Ohio/Pennsylvania state line (Figure 5). Little Yankee Creek originates northeast of Vienna Center in eastern Trumbull County and flows 13.2 miles southeasterly to Hubbard then northeasterly to its confluence with the Shenango River near the Ohio/Pennsylvania state line. The Yankee Creek watershed basin drains 45.8 square miles and Little Yankee Creek watershed basin drains 42.8 square miles. Both of these basins are located in eastern Trumbull County, a small portion of Mahoning County, plus a western portion of Mercer County in Pennsylvania. Yankee Creek falls an average gradient of 16.2 feet per mile (from an elevation of 1075 to 835 feet above mean sea level). Little Yankee Creek falls an average gradient of 20.3 feet per mile (from an elevation of 1102 to 834 feet above mean sea level).

Pymatuning Creek originates in the center of Dorset Township in Ashtabula County and flows 33.8 miles in a southerly direction to Orangeville in Trumbull County on the Ohio/Pennsylvania state line (Figure 6). The Pymatuning Creek watershed basin drains 174.4 square miles. This basin is located in southeastern Ashtabula County, northeastern Trumbull County, plus a western portion of Mercer County in Pennsylvania. The Pymatuning Creek average gradient is 6.2 feet per mile (from an elevation of 1080 to 870 feet above mean sea level).

The Mahoning River, Yankee/Little Yankee Creek, and Pymatuning Creek watersheds all lie within the gently rolling dissected glacial plateau of the Erie/Ontario Lake Plain ecoregion. The majority of streams in this area are perennial and shallow cutting. During the Pleistocene era varying thickness of glacial drift were deposited over Pennsylvanian shales and Mississippian sandstones. The preglacial valleys within the underlying bedrock shales and sandstone were also buried by glacial clays, sands, and gravels. This watershed exhibits a mosaic of cropland, pasture, woodland, and urban development.

Land use within the upper Mahoning River, Yankee/Little Yankee Creek, and Pymatuning Creek watersheds are predominantly agricultural. The lower Mahoning River is predominantly urban. According to a 1988 survey by the Ohio Department of Natural resources: only 13 % of the

Mahoning River had forest cover within 300 feet of the riverbanks, there were 425 permanent structures (private/commercial/industrial) within 300 feet of the riverbanks, there were 5.5 miles of primary roads and 1.8 miles of secondary roads within 300 feet of the Mahoning River, 54 miles of the Mahoning River flows through urban areas, and 19 miles of the Mahoning River is impounded.

Development is widespread throughout the Mahoning watershed and many of the communities continue to expand water and sewage services. Several of the WWTPs in the Mahoning watershed are operating at or above design capacity, which has contributed to violations of NPDES permit limits. In addition to increasing volumes of wastewater, changing land use patterns are altering the types and rates of nonpoint source pollutants impacting on the Mahoning River. Initial site preparations for construction can result in accelerated rates of runoff and increased soil erosion. Excessive sedimentation smothers stream bottoms, clogs fish gills, hinders photosyntheses, increases water temperature, lessens oxygen levels and fills lakes/channels. Loss of riparian cover also creates some of the same results listed above. Suburban developments generate large impermeable surfaces, (*i.e.*, driveways, roads, roofs, etc.). Unless the developer or community have taken steps to control runoff, the volumes of water entering local streams will be larger and more powerful. Different types of pollutants come from urban/suburban areas (*i.e.*, automotive fluids, lawn chemicals, de-icing chemicals, sewage discharges, heavy metals, etc.). The rural watersheds, upper Mahoning River, Yankee/Little Yankee Creek, and Pymatuning Creek, contribute pollutants from agriculture, silviculture, resource extraction, and sanitary landfills (*i.e.*, animal wastes, sedimentation, crop chemicals, acid drainage, leachate, failing septic systems, etc.).

Natural stream flows of the Mahoning River have been altered by an extensive reservoir system constructed for authorized uses of low flow augmentation, temperature control, flood control and water supply (Table 3). The natural stream morphology is also altered by nine low head dams used to create a sufficient pool depth for industrial water intakes along the lower mainstem (Table 4). Stream flow regulation results in higher summer minimum flows than winter minimum flows, opposite that of most natural streams in Ohio.

Lake Milton was constructed by the City of Youngstown in 1917 to provide low flow augmentation for steeel production during World War I. Berlin Reservoir and Mosquito Creek Reservoir were constructed during World War II, primarily for low flow augmrntation and flood protection. The M.J. Kirwan Reservoir (West Branch) was added in 1966 for additional low flow augmentation and flood protection. Meander Creek Reservoir was constructed in 1931 for water supply purposes only. Berlin Reservoir can be used to augment the water supply potential of Meander Creek Reservoir. The Army Corps of Engineers operates these reservoirs as a system, generally using Berlin Reservoir, Lake Milton, and Kirwan Reservoir to maintain the flow regulation schedule at Leavittsburg, and Mosquito Creek Reservoir to maintain the schedule at Youngstown.

Ohio Water Quality Standards (WQ;OAC 374501025) list the current use designations for the Mahoning River, Yankee/Little Yankee Creek, Pymatuning Creek, and the major tributaries to the Mahoning River as: Warmwater Habitat (WWH), Agricultural and Industrial Water Supply (AWS and IWS), and Primary Contact Recreation (PCR). Silver Creek, Eagle Creek, and part of Mill Creek (from Route 224 in Youngstown to confluence with the Mahoning) are also designated as State Resource Water (SRW). Three of the major tributaries have been impounded to serve as Public Water Supplies (PWS): Mosquito Creek Reservoir, Meander Creek Reservoir, and Deer Creek Reservoir. The City of Sebring in Mahoning County draws its water supply directly from the upper Mahoning River.

Nonpoint Sources

The quality of surface waters in Ohio have generally improved over the past 25 years. Credit must go to private industries and government entities who have improved point source discharges and upgraded sewage treatment facilities. Now Ohio's major water pollutants primarily come from non point sources; stormwater run-off which transports contaminants from broad areas of a landscape. Specific non point source pollution concerns include:

Construction Sites
Construction activities such as individual houses, residential developments, commercial properties and industrial sites are occurring throughout these watersheds. Uncontrolled stormwater runoff can carry tons of soil into local streams, which can devastate an aquatic community. If the excavated area is to exceed 5 acres, then an NPDES permit must be filed with the Ohio EPA and a stormwater plan developed. Each of the local Soil and Water Conservation Districts are to work with the Ohio EPA and developer to minimize soil loss from these properties.

Farms/Orchards/Nurseries
Pymatuning Creek, Yankee Run and the Upper Mahoning River are primarily agricultural. Plowing fields to the edg of waterways can cause significant soil loss into local streams. Sudden sediment loads can totally change a stream bottom habitat, which directly impacts on the entire aquatic community. Allowing livestock to enter streams can accelerate embankment erosion and increases nutrient levels in the water. Run off from feed lots, animal waste piles or improper manure applications contribute nutrients to local streams. Over application or untimely application of herbicides/pesticides can stress or eliminate aquatic organisms. Fertilizer run-off can cause aquatic plants to grow at uncontrollable rates, creating an imbalance in the ecosystem.

Local Soil and Water Conservation Districts have been working with farming operations on conservation prctices. The districts have encouraged practices such as no-till farming, animal waste storage structures, minimal usage of chemicals, filter stripping, livestock exclusion fencing, etc.. Many of these operators have discovered that new techniques may not only improve the environment, they often save time and money. Continuing education throughout the farming communities is imperative.

Failing Septic Systems
The Pymatuning Yankee Run and Upper Mahoning River watersheds are primarily rural and most areas are not serviced by sanitary sewers. A high percentage of the septic systems in these watershed are well beyond 20 years in age, (the expected life of a system). Additionally, high percentages of clay content in the local soils further contribute to high failure rates of septic systems. Inadequately treated sewage can impact on the water quality of roadside ditches, wetlands, streams and lakes. This can cause health hazards in drinking and recreational waters, decreased oxygen levels, excessive aquatic plant growth and offensive odors. Areas identified with large concentrations of failing septic systems:

Mahoning County
Cottages around Milton Reservoir
North Lima
Damascus

Trumbull County
SE section of Newton Falls
Vienna Center
Kinsman

Trumbull County (continued)
Bristolville
Lakeshore Allotment (Mecca Top.)
Leavittsburg
McKinley Heights (Warren)
White Oaks Drive (Hubbard)

Portage County
Silver Spur Allotment (Charleston Twp.)
Holcomb Road Allotment (Paris Twp.)
Cottages around Berlin Reservoir
Deerfield Center
Palmyra Center

Columbiana County
Cottages around Westville Lake
Georgetown and Lake Placentia area

Stark County
Indiana Street Allotment (Lexington Top.)
Marlboro Center

Data indicating how many failing systems are within these watersheds is currently not available. The Mahoning County Health Department recently received a 319 grant which will produce a computerized inventory of existing septic systems within the county. It also will help identify failing septic systems, order upgrades and educate homeowners.

Urban Runoff
Large and small communities have storm sewer systems which discharge to all of the watershed basins. Urbanized pollutants such as road salts, vehicle fluids, litter/debris, lawn chemicals, pet wastes, etc. can be detrimental to local water quality. City ordinances and programs which help control these concerns are important. Education of the community is very important.

Samitary Landfill/Industrial Sites
Up to the mid 1970's it was common for every community and township to have at least one garbage dump. Many of these dumps closed when state regulations required licensing and daily cover. Some of these abandoned garbage dumps certainly continue to degrade surface water and groundwater. The garbage dumps which survived the mid 1970's evolved into sanitary landfills. More stringent state regulations continue to upgrade all existing sanitary landfills. Leachate from closed and operating landfills can negatively impact local surface water quality. Major sanitary landfills in these watersheds are listed by county:

Mahoning County
Central Waste Landfill (Smith Twp.)
Mahoning Landfill (Springfield Twp.)
BFI Carbon Limestone (Poland Twp.)
BFI CLD/Lewis Landfill (Green Twp.) Closed

Trumbull County
Fowler Landfill (Fowler Twp.) Closed

Portage County
BFI Willow Creek (Deerfield Twp.)

Ashtabula County
New Lyme Landfill (New Lyme Twp.) Closed

Over the past 150 years industries have filled many areas with industrial wastes. At least 14 slag fills and one sludge pit have been identified immediately adjacent to the lower Mahoning River. The water quality impact from these non point sources is currently unknown, however, there is certainly some contribution of pollutants into the river. The Center for Urban Studies at Youngstown State University is currently evaluating these slag fills.

One industrial facility in Portage County which operated in the early 1970's was named Summit National Services (also referred to as the Deerfield Dump). This operation posed as a licensed incinerator facility and accepted thousands of gallons of industrial wastes. Surface and underground contamination occurred. Berlin Reservoir is southwest of this site. The U.S. EPA has been working on remediation of this Superfund site for two decades. To date, contamination from this site has not impacted on the water quality of Berlin Reservoir.

Mine Drainage
Surface and underground coal mining activities were prevalent throughout the Mahoning River and Yankee Run bains. Most of the mine operations are no longer active, however, some continue to generate mine acid drainage. Elevated iron and sulfate levels plus lowering of the pH, can devastate the aquatic life in a stream. Some of the abandoned strip mines in these watersheds have been reclaimed by sanitary landfill operations. Reclamation of the more recent mining operations has certainly helped improve local water quality.

Timber Harvesting Operations
All of these watersheds have timbering activities occurring. Poor road layout and construction can contribute enormous volumes of sediment during active operations. If the timber has been over harvested, erosion will continue until a natural vegetative cover has been established. Professional foresters are available to monitor and educate timber harvesting operations.

Oil and Gas Extraction
Hundreds of oil and gas well have been developed in these watershed basins. Oil and brine spills from a well or tank can devastate a local waterway. The Ohio Department of Natural Resources has jurisdiction over spills and disposal.

Riparian Corridor Protection
Vegetation along the embankments of streams and lakes offers many benefits; stream bank stabilization, filtration of run-off waters, food source, cooler water temperatures and habitat enhancement. Protection of existing riparian corridors is as critical as areas that need vegetation established. Conservation easements, land trusts, education and responsible legislation are valuable tools for riparian corridor protection.

These major non point source activities all contribute to the water quality in each of the watershed basins. Educating public officials and local citizens about non point source issues is imperative. Developing watershed plans and implementing best management practices is equally important. By establishing committed partnerships improved water quality in Ohio can be accomplished.

River Mile Delineations

Stream river mileage for the mainstem Mahoning River within the study area was determined from adding 1.63 to the river miles marked on Ohio EPA PEMSO marked USGS quads from the Ohio-Pennsylvania state line to the border of the Youngstown-Girard quadrangle, and 1.73 to all mainstem sites upstream from this border. This correction was necessary because a shortage of 1.63 miles was discovered at the state line on the Ohio EPA maps, and another error of 0.1 miles was discovered at the border of the Youngstown-Girard quadrangle. Past data from Ohio EPA and other sources was adjusted in this report to reflect these changes.

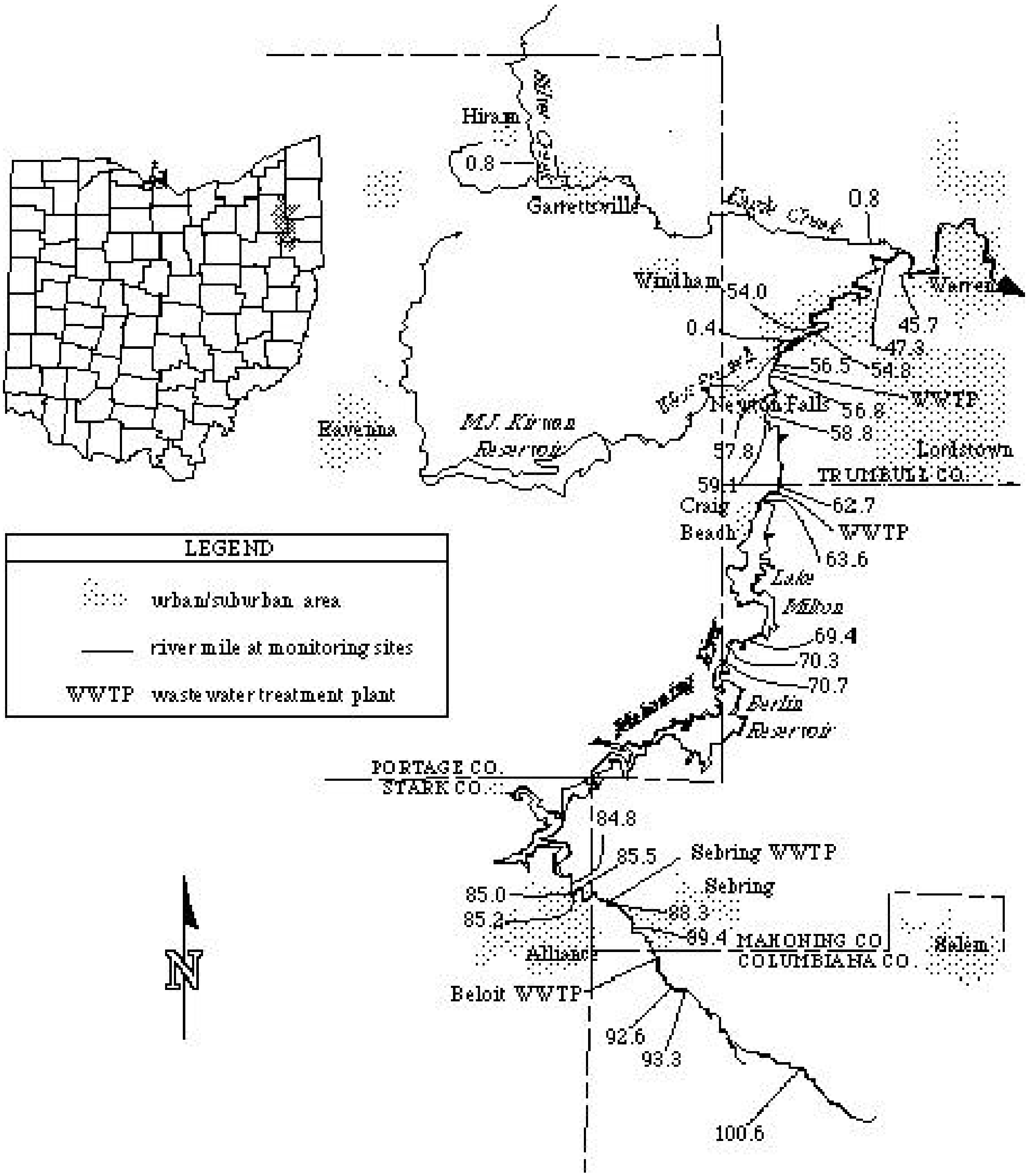


Figure 2. The Upper Mahoning River basin study area showing principal streams and tributaries, population centers, pollution sources, and ambient monitoring locations.

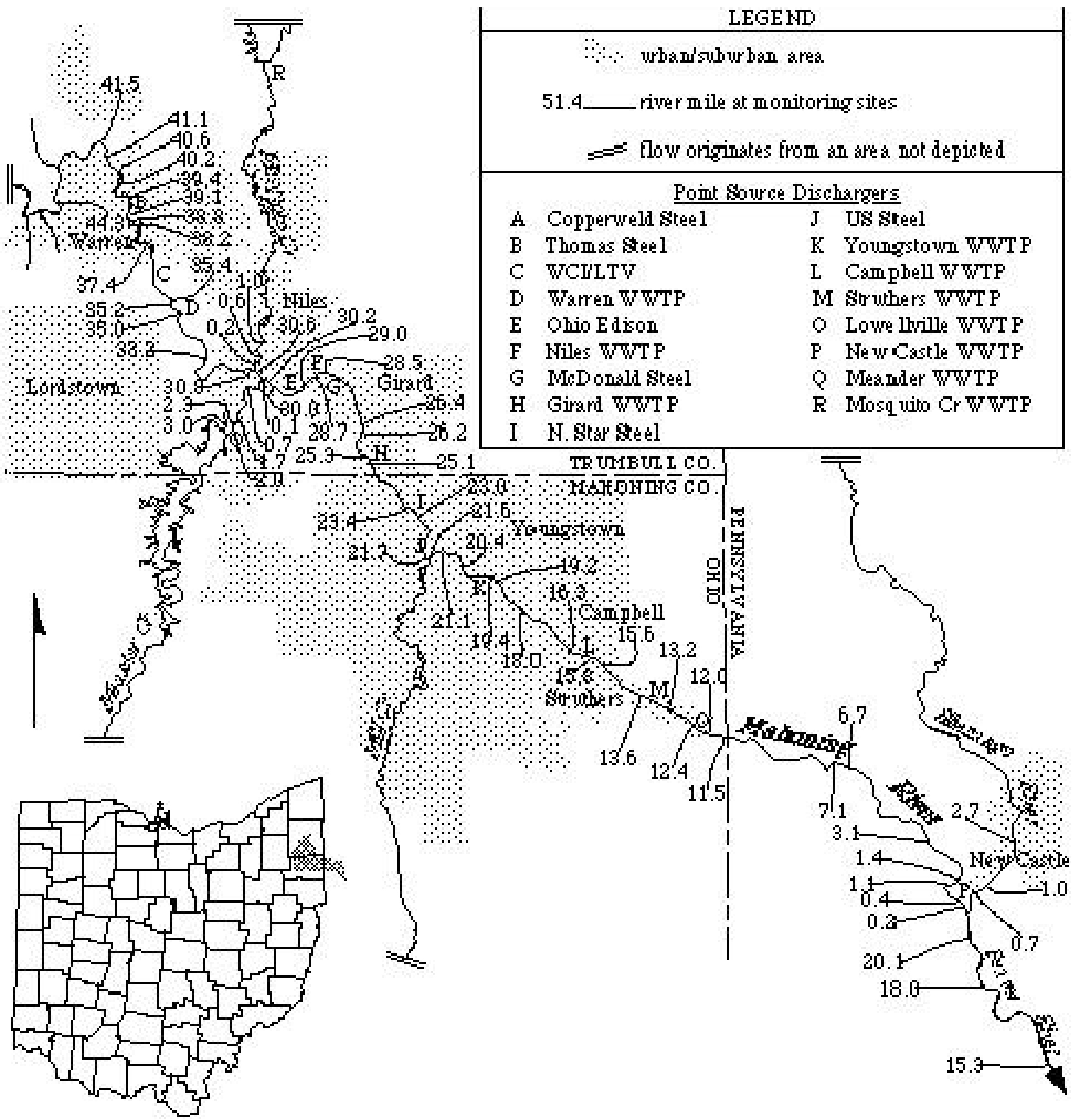


Figure 3. The Lower Mahoning River basin study area showing principal streams and tributaries, population centers, pollution sources, and ambient monitoring locations.

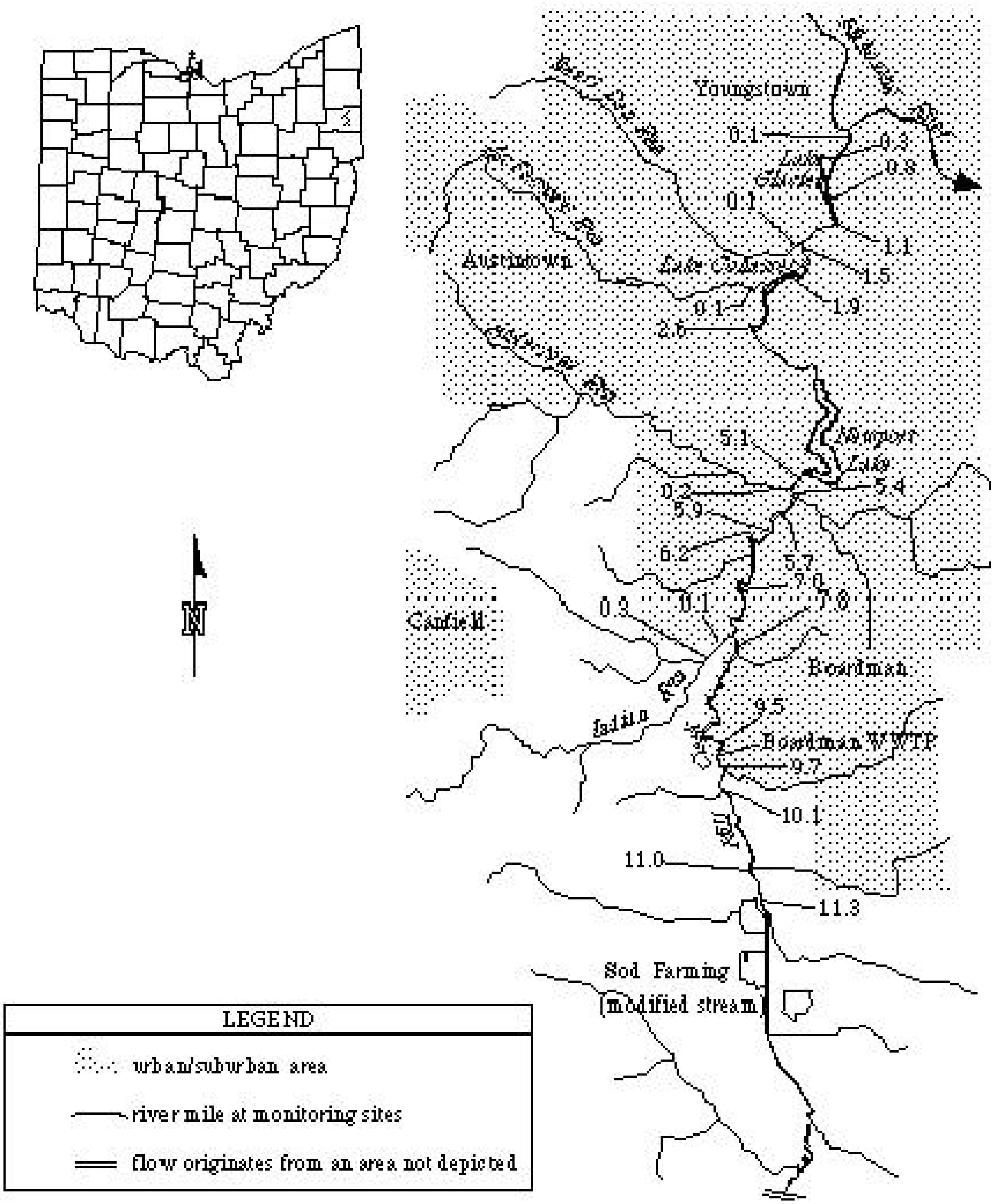


Figure 4. The Mill Creek subbasin study area showing principal streams and tributaries, population centers, pollution sources, and ambient monitoring locations.

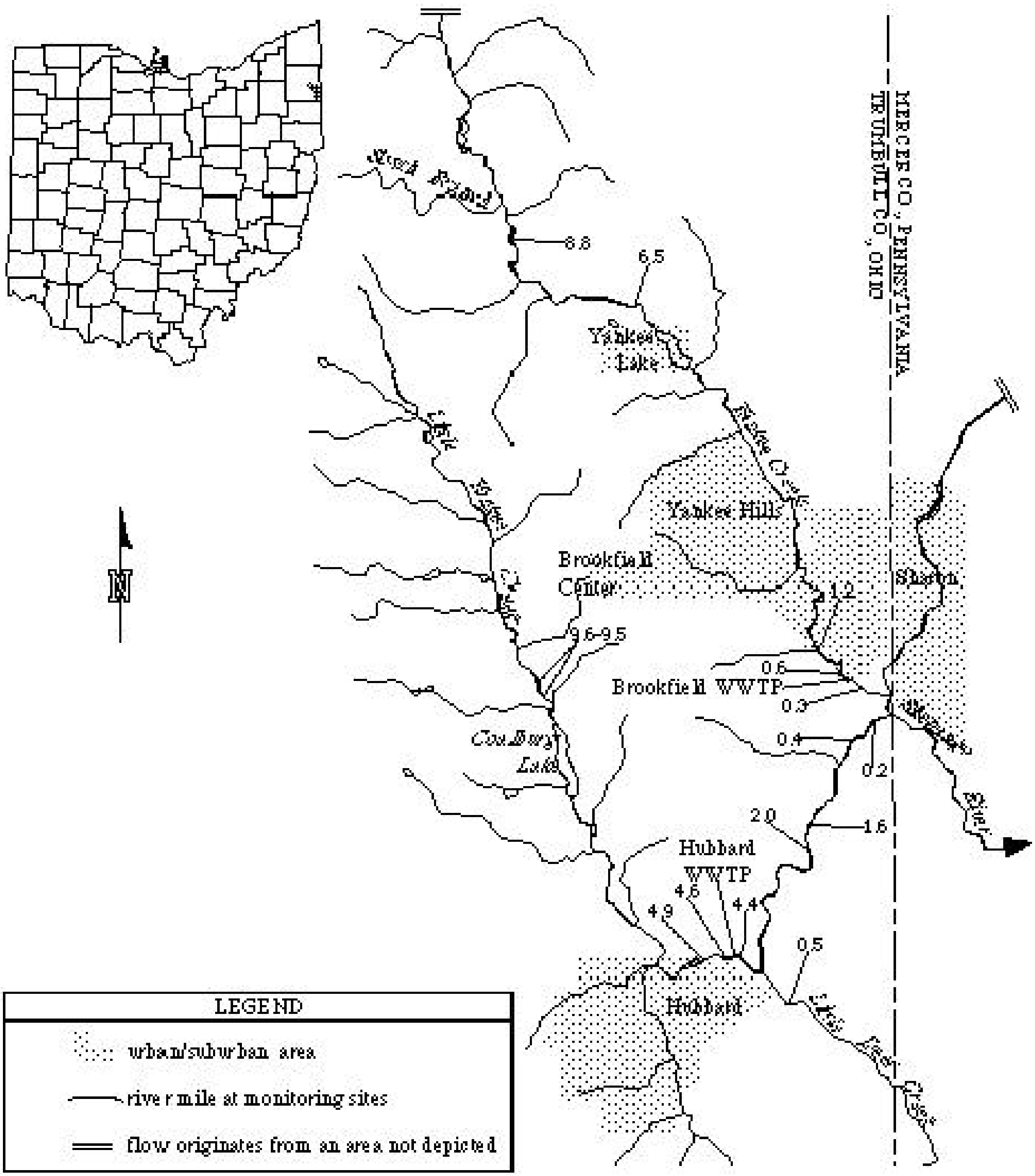


Figure 5. The Yankee Creek subbasin study area showing principal streams and tributaries, population centers, pollution sources, and ambient monitoring locations.

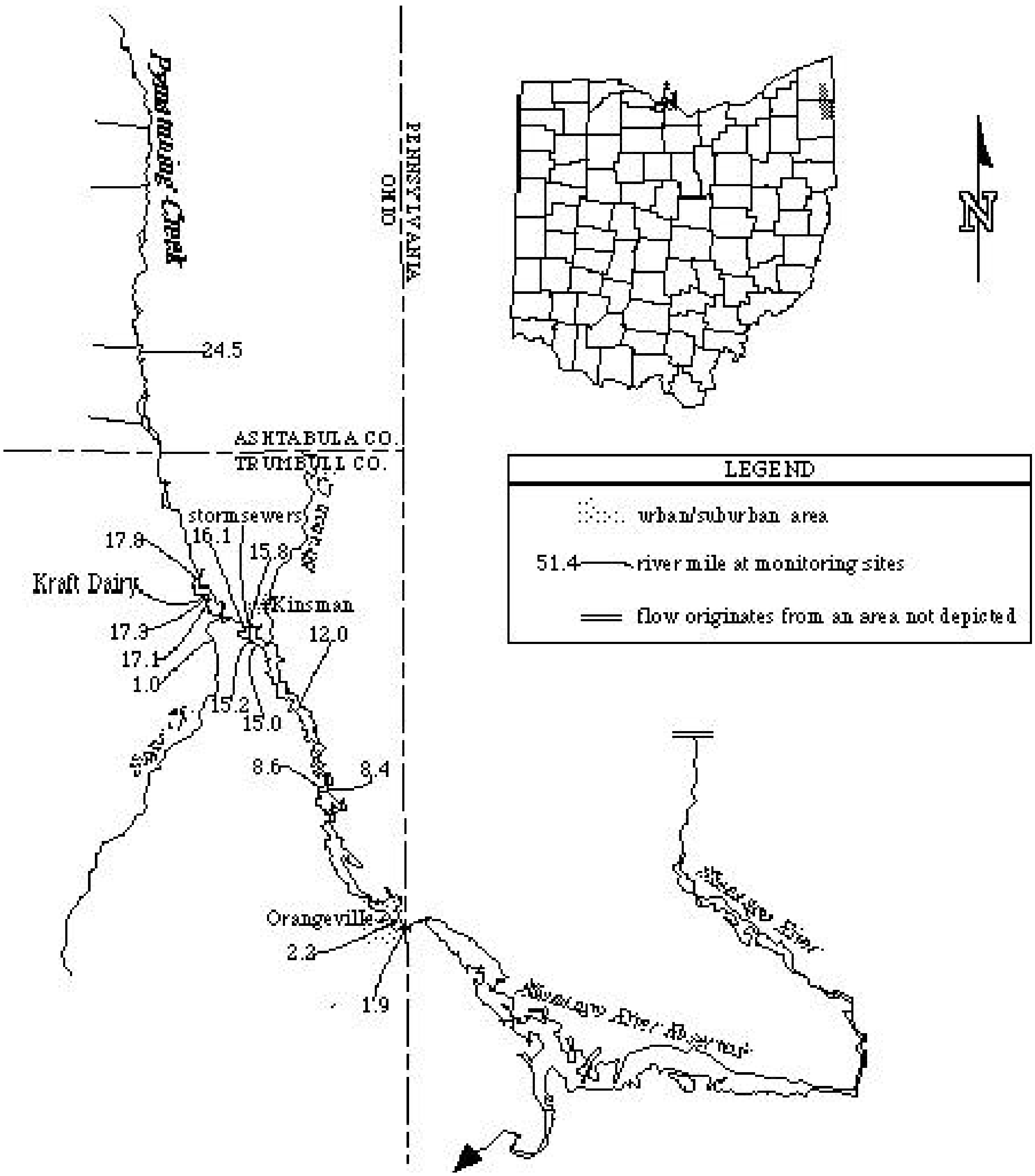


Figure 6. The Pymatuning Creek subbasin study area showing principal streams and tributaries, population centers, pollution sources, and ambient monitoring locations.

Table 2. Major and significant minor NPDES permitted dischargers to the Mahoning River and select tributaries. (SW=sanitary waste, NC=Non-contact cooling water, PW = process waste, BW= filter backwash water,SO=Stormwater))

Entity	Permit Number (Ohio EPA)	RM	Effluent Type	Design Flow (mgd)
Mahoning River Mainstem				
Arhaven Estates MHP WWTP	3PV00064	54.1	SW	0.018
City of Campbell WWTP	3PD00008	15.89	SW	3.800
City of Niles WWTP	3PD00036	28.86	SW	6.200
City of Sebring WTP	3IV00182		BW	
City of Struthers WWTP	3PD00026	14.32	SW	6.000
City of Youngstown WWTP	3PE00006	19.43	SW	35.00
City of Warren WWTP	3PE00008	35.25	SW	16.00
CSC Industries, Inc. (Copperweld Steel Co.)	3ID00050	41.83	PW,SO	2.690
Denman Tire Corp.	3IR00002	49.3	SW,SO	0.058
LTV Steel Corp.,Inc. (Campbell Works)	3ID00036	15.9-8	SO	NPR
LTV Steel Corp.,Inc. (Warren Coke Plant)	3ID00004	35.68	SO,NC	4.120
LTV Steel Corp.,Inc. (Youngstown Tube. Plant)	3ID00006	17.49-16.78	SO	NPR
Mah. Co.- Lake Milton WWTP	3PH00030	63.43	SW	1.000
North Star Steel of Ohio	3ID00066	23.60	SO	NPR
Ohio Edison Co., Niles Plant	3IB00007	30.00-29.51	NC,SO,SW	217.71
RMI Co., Niles Plant	3IC00026	33.63	PW,SO	0.500
Village of Newton Falls WWTP	3PD00015	56.85	SW	0.500
Village of Lowellville WWTP	3PC00007	12.22	SW	0.430
WCI Steel, Inc.	3ID00071	37.15-35.86	PW,SO,NC	78.239
Mahoning River Tributaries				
Unnamed trib to Mahoning R (RM 91.2)				
Village of Beloit WWTP	3PB00005	3.2	SW	0.190
Sulfur Cr., Fish Creek (RM 87.81)				
City of Sebring WWTP	3PC00011	4.1	SW	1.500
Ryans Run (RM 85.13)				
Alliance Tubular Products	3ID00043		PW,NC,SO	0.420
Gaskill Creek				
Babcock and Wilcox Co., Research	3ID00038		NC,SO	0.012
Beech Creek (RM 82.03)				
City of Alliance WWTP	3PD00000	0.35	SW	7.500

Table 2. (continued)

Entity	Permit Number (Ohio EPA)	RM	Effluent Type	Design Flow (mgd)
Mahoning River Tributaries				
Eagle Creek (RM 45.08)				
Village of Garrettsville WWTP	3PB00016		SW	0.356
South Fork Eagle Creek				
Village of Windham WWTP	3PC00019		SW	0.450
Silver Creek Tributary				
Village of Hiram WWTP	3PB00020		SW	0.2
Red Run (RM 40.30)				
Sharon Steel Corp.	3ID00059		PW,SO	NPR
Dicky Run Stormsewer (RM 39.06)				
Thomas Steel Strip Corp.	3IC00056	1.2	PW,NC,SO	2.52
Mosquito Creek (RM 30.64)				
Trum. Co.- Mosquito Creek WWTP	3PK00009	7.1	SW	4.200
General Electric, Niles Glass Plant	3IN00021	0.8	PW,SO,NC	0.424
Meander Creek (RM 30.27)				
Mah. Co. - Meander Creek WWTP	3PK00011	1.98	SW	4.000
Little Squaw Creek (RM 25.28)				
City of Girard WWTP	3PD00010	0.40	SW	5.000
Mill Creek (RM 21.63)				
Mah. Co. - Boardman WWTP	3PK00002	9.6	SW	5.000
Village of Columbiana WWTP	3PD00041		SW	1.300
Yankee Creek				
Brookfield WWTP	3PJ00001	0.42	SW	1.3
Little Yankee Creek				
Hubbard WWTP	3PD00028	4.59	SW	2.1
Pymatuning Creek				
Kraft Dairy	3IH00052	17.31	P	0.287

Table 3. Major Reservoirs in the Mahoning River Basin (from Amendola *et.al.* 1977)

Reservoir	Year Completed	Owner or Operator	Tributary Drainage Area (Sq. Mi.)	Total Storage Capacity (Acre Feet)	Summer low flow Storage Capacity (Acre Feet)	% Total
Lake Milton	1917	City of Youngstown	273	29,770	21,500	72
Meander Creek	1931	Mahoning Valley Sanitary District	84	35,500	-	0
Berlin	1943	Corps of Engineers	248	91,200	56,600	62
Mosquito Creek	1944	Corps of Engineers	98	104,100	69,400	68
Michael J. Kirwan	1966	Corps of Engineers	81	78,700	52,900	67

Table 4. Lower Mahoning River Dam Locations.

Dams	River Mile
1. Lowellville Dam	12.6
2. Campbell (oldYoungstown Sheet & Tube) Dam	15.83
3. Republic Steel Dam	17.6
4. Marshall Street Dam	20.6
5. U.S. Steel Dam	22.56
6. Liberty Street Dam	26.38
6. WCI (old Republic Steel) Dam	36.03
8. Summit Street Dam	39.28
9. Leavittsburg Dam	45.58

Table 5. Stream characteristics and significant pollution sources which were evaluated in the Mahoning River basin study area.

Stream/River	Length (mi.)	Gradient (ft./mi.)	Drainage Area (sq./mi.)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Mahoning River	108.3	4.0	11132.8	Agriculture Urban Unsewered areas Resource Extraction CSOs	Newton Falls WWTP Arhaven Estates MHP Denman Tire and Rubber CSC (Copperweld Steel) Unsewered areasWCI Steel LTV, Warren Coke Plant Warren WWTP Ohio Edison, Niles Niles WWTP Youngstown WWTP Campbell WWTP Struthers WWTP Lowellville WWTP
Fish Creek	4.2	12.6	7.71	Urban Landfills	Sebring WWTP
Ryans Run	0.7	1.55	93.55	Urban	Alliance Tubular Prod.
Beech Creek	10.2	17.7	32.6	Agriculture Urban	Alliance WWTP
West Branch	29.2	11.0	108.6	Agriculture	
Eagle Creek	21.5	15.4	109.08	Agriculture	Garettsville WWTP
Silver Creek	7.2	30.5	11.13	Agriculture	Hiram WWTP
Dicky Run Stormsewer	0.5	30.0	1.5	Urban	Thomas Steel Strip
Red Run	4.7	7.0	12.1	Urban Unsewered Area	Sharon Steel
Meander Creek	20.4	9.6	86.5	Agriculture Urban Resource Extraction	Mah. Co. Meander WWTP
Mosquito Creek	33.7	7.0	139.2	Agriculture Urban	Mosquito Creek WWTP General Electric, Niles
Little Squaw Creek	5.7	4.97	50.91	Urban	Girard WWTP

Table 5. (continued)

Stream/River	Length (mi.)	Gradient (ft./mi.)	Drainage Area (sq./mi.)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Mill Creek	20.9	17.8	79.8	Agriculture, Urban	Boardman WWTP Urban CSOs
Ax Factory Run	4.0	62.2	2.96	Urban	
Bears Den Run	4.1	54.8	3.89	Urban	
Anderson Run	4.5	27.5	6.24	Urban	
Indian Run	4.8	27.5	14.8	Urban	
Crab Creek	7.8	41.4	20.10	Urban	CSOs
Dry Run	7.1	31.6	10.02	Urban	CSOs
Yellow Creek	11.1	24.8	32.09	Urban	CSOs
Shenango River	90.0	5.3	1066.3	Urban	Agriculture
Pymatuning Creek	33.8	6.2	174.4	Agriculture Superfund (Ohio State Masters list)	Kraft Dairy Unsewered Village
Sugar Creek	8.1	24.1	25.79	Agriculture	
Yankee Creek	14.8	16.2	45.79	Agriculture	Brookfield WWTP
Little Yankee Creek	13.2	20.3	42.79	Agriculture	Hubbard WWTP Urban
Beaver River	3145	3.96	21.2	Mahoning River	

Table 6. List of sampling locations (effluent sample - E; conventional water chemistry - C; fecal coliform bacteria - FC; organic water chemistry - CO; sediment metals chemistry - S; sediment organics - SO; datasonde - D; modeling - M; flow [USGS - Q,]; macroinvertebrates - B; fish - F; and fish tissue - FT) in the Mahoning River study area, 1994. *Italics denote effluent mixing zone sampling locations.*

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Mahoning River				
100.60	F,B	40˚50’32”/80˚57’07”	King Road (ust. NPDES dischargers)	Hanover
100.57	C,FC,CO,SM,	40˚50’02”/80˚57’06”	King Road (ust. NPDES dischargers)	Hanover
93.30	F	40˚53’02”/81˚02’01”	Dst. Knox-School Road and WTP dam	Alliance
93.23	C,FC,D,SO,SM,	40˚53’02”/81˚01’53”	Knox-School Road	Alliance
92.60	B	40˚53’29”/81˚02’19”	Hartley Road	Alliance
89.40	F	40˚54’56”/81˚01’13”	Dst.. Park Lake Road (ust. Fish Creek)	Alliance
88.33	C,FC	40˚55’30”/81˚03’45”	Alliance-Sebring Rd. (ust. Fish Creek)	Alliance
85.51	C,FC,SO,SM,Q,F	40˚55’58”/81˚05’41”	Webb Rd. (ust. Ryan Run)	Alliance
85.20	B	40˚55’48”/81˚05’19”	Dst. Webb Rd. dam, ust. Ryan Run	Alliance
84.99	C,FC,D,F	40˚55’42”/81˚06’07”	Gashill Drive (dst. Ryan Run)	Alliance
84.80	B	40˚56’00”/81˚06’10”	Gashill Drive (dst. Ryan Run)	Alliance
70.75	C,D,FC	41˚02’54”/81˚00’06”	Berlin Lake Tailwaters (dst. Dam)	Deerfield
70.70	B	41˚02’55”/81˚00’05”	Berlin Lake Tailwaters (dst. Dam)	Deerfield
70.30	F	41˚03’22”/80˚59’50”	Dst. Berlin Lake	Lake Milton
69.40	F	41˚03’38”/80˚58’49”	Dst. Bedell/Shillings Mill Rds.	Lake Milton
69.33	C,FC,D,SM	41˚03’53”/80˚59’10”	Bedell/Shillings Mill Rds.	Lake Milton
69.30	B	41˚03’33”/80˚59’13”	Bedell/Shillings Mill Rds.	Lake Milton
63.60	F	41˚08’06”/80˚58’04”	Dst. Lake Milton WWTP and dam	Newton Falls
62.70	B	41˚08’02”/80˚58’09”	Pricetown (dst. Lake Milton WWTP)	Newton Falls
62.68	C,FC,Q	41˚08’03”/80˚58’04”	Pricetown (dst. Lake Milton WWTP)	Newton Falls
59.10	B	41˚09’59”/80˚58’32”	West River Rd., dst. Kale Creek	Newton Falls
58.8	C,FC,D,CO,SO,SM	41˚10’02”/80˚58’37”	West River Rd., dst. Kale Creek	Newton Falls
57.8	F	41˚10’55”/80˚58’13”	Dst. Kale Cr., ust. Newton Falls WWTP	Newton Falls
56.8	F	41˚11’39”/80˚58’04”	Dst. Newton Falls WWTP, ust.. dam	Newton Falls
56.53	C,FC	41˚11’48”/80˚57’59”	Dst. Newton Falls Dam & WWTP	Newton Falls
56.50	B	41˚11’48”/80˚57’58”	Dst. Newton Falls Dam & WWTP	Newton Falls
54.80	F	41˚12’50”/80˚56’08”	Dst. West Branch	Newton Falls
54.70	B	41˚12’38”/80˚56’36”	Dst. West Branch at I-80	Newton Falls
54.00	C,FC	41˚12’55”/80˚56’09”	Dst. West Branch Mahoning River	Newton Falls
47.5	F	41˚14’52”/80˚53’59”	Ust. Nelson Moser Rd. (ust. Eagle Cr.)	Newton Falls
47.35	C,FC	41˚14’50”/80˚53’47”	Nelson Moser Rd. (ust. Eagle Creek)	Newton Falls
47.30	B	41˚14’50”/80˚53’50”	Nelson Moser Rd. (ust. Eagle Creek)	Newton Falls
45.73	C,D,SM	41˚14’26”/80˚52’59”	Ust. Leavittsburg Dam	Newton Falls
45.70	F	41˚14’28”/80˚52’58”	Ust. Leavittsburg Dam	Newton Falls
45.51	C,FC,D,CO,SO,SM,Q	41˚14’22”/80˚52’52”	Dst. Leavittsburg Dam (Ambient Station)	Newton Falls
45.50	B,F	41˚14’20”/80˚52’50”	Dst. Leavittsburg Dam (Ambient Station)	Newton Falls
44.30	F	41˚14’27”/80˚52’36”	Dst. Leavittsburg Dam, ust. SR 422	Newton Falls

Table 6. (continued).

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Mahoning River, continued.				
43.33	C,FC,D,SO,SM	41˚15’27”/80˚51’54”	SR 422, Parkman Ave, ust. Copperweld	Champion
43.30	B,F	41˚15’38”/80˚51’51”	Dst. SR 422, ust.. Copperweld	Champion
41.50	C,FC,SO,SM	41˚16’05”/80˚50’30”	Dst. Copperweld at Burbank Park	Champion
41.10	B	41˚15’43”/80˚50’25”	Dst. Copperweld adjacent Todd St.	Champion
40.60	F	41˚15’36”/80˚50’20”	Dst. Copperweld, ust. Red Run	Champion
40.20	C,FC,D,SO,SM	41˚15’02”/80˚50’01”	Packard Pk, dst. Red Run, ust. Thomas SS	Champion
39.40	F	41˚15’00”/80˚50’06”	Packard Pk, dst. Red Run, ust. Thomas SS	Champion
39.10	B	41˚14’29”/80˚49’40”	Ust. Thomas SS Dickey Run Storm sewer	Champion
39.06	*E,SM,B,F*	*41˚14’33”/80˚49’41”*	*Thomas Steel Strip mix-zone*	*Warren*
38.9	FC,SO,SM	41˚14’10”/80˚49’46”	Perkins Park, dst. Thomas Steel Strip	Warren
38.80	F	41˚14’08”/80˚49’38”	Perkins Park, dst. Thomas Steel Strip	Warren
38.23	C,FC,D	41˚14’10”/80˚49’15”	Market Street	Warren
38.20	B	41˚14’07”/80˚49’17”	Market Street	Warren
37.43	SO,SM	41˚13’44”/80˚49’11”	Main St., ust. WCI/LTV complex	Warren
35.50	SO,SM	41˚12’09”/80˚48’19”	Adjacent WCI Slag piles, river left	Warren
35.40	C,D,SO,SM,B,F	41˚12’08”/80˚48’21”	Dst. WCI/LTV, ust. Warren WWTP	Warren
35.25	*E,B,F*	*41˚12’06”/80˚48’19”*	*Warren WWTP mixing zone*	*Warren*
35.10	B	41˚12’12”/80˚48’18”	Dst. Warren WWTP	Warren
35.00	F	41˚12’02”/80˚48’14”	Dst. Warren WWTP	Warren
33.20	B	41˚10’53”/80˚47’50”	West Park Ave.	Warren
33.15	C,FC,D,SO,SM	41˚10’51”/80˚47’19”	West Park Ave., dst. RMI	Warren
32.2	F	41˚10’25”/80˚47’24”	Dst. West Park Avenue and RR tracks	Warren
30.8	D	41˚10’39”/80˚45’56”	Main St., ust. Mosq. & Meander Creeks	Warren
30.20	B	41˚10’24”/80˚45’25”	Ust. Belmont Ave., ust. Ohio Edison	Warren
30.00	F	41˚10’19”/80˚45’20”	Ust. Belmont Ave., ust. Ohio Edison	Warren
29.98	C,FC,SO,SM	41˚10’15”/80˚45’09”	Belmont Ave., ust. Ohio Edison	Warren
29.10	B	41˚10’13”/80˚44’14”	Olive St., dst. Ohio Ed., ust. Niles WWTP	Girard
29.03	C,D	41˚10’13”/80˚44’14”	Olive St., dst. Ohio Ed., ust. Niles WWTP	Girard
29.00	F	41˚10’07”/80˚44’23”	Olive St., dst. Ohio Ed., ust. Niles WWTP	Girard
28.70	B	41˚10’20”/80˚40’08”	Dst. Niles WWTP	Girard
28.50	F	41˚10’30”/80˚43’56”	Dst. Niles WWTP	Girard
28.63	C	41˚10’29”/80˚43’58”	Dst. Niles WWTP	Girard
26.43	D	41˚09’19”/80˚42’24”	Ust. Liberty St. dam	Girard
26.20	F	41˚09’10”/80˚42’23”	Dst. Liberty St. dam	Girard
26.10	C,FC,SO,SM	41˚09’16”/80˚42’22”	Dst. Liberty St. dam	Girard
25.30	B	41˚08’35”/80˚42’16”	Ust. L. Squaw Cr. (Girard` WWTP)	Girard
25.16	C	41˚08’27”/80˚42’12”	100 m dst. L. Squaw Cr. (Girard` WWTP)	Girard
25.10	B,F	41˚08’32”/80˚42’14”	Dst. L. Squaw Cr. (Girard` WWTP)	Girard

Table 6. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Mahoning River, continued.				
23.43	C,FC,D,SO,SM	41˚07’20”/80˚41’01”	Division St., dst. YS&T (N. Star Steel)	Youngstown
23.00	F	41˚06’58”/80˚40’30”	Division St., dst. YS&T (N. Star Steel)	Youngstown
21.73	C,FC,SO,SM	41˚06’07”/80˚40’24”	Ust. Mill Creek & 3 CSOs, dst. old USS	Youngstown
21.70	B	41˚06’07”/80˚40’23”	Ust. Mill Creek	Youngstown
21.60	B	41˚06’09”/80˚40’19”	Dst. Mill Creek	Youngstown
21.14	C,FC,D,Q	41˚06’18”/80˚39’50”	West Ave., dst. Mill Creek	Youngstown
21.10	F	41˚06’12”/80˚39’41”	Dst. West Ave., dst. Mill Creek	Youngstown
20.40	F	41˚06’00”/80˚39’22”	Dst. Marshall St. dam	Youngstown
19.43	E	41˚05’41”/80˚38’21”	Youngstown WWTP Effluent	Youngstown
19.40	*B,F*	41˚05’38”/80˚38’24”	*Youngstown WWTP mixing zone*	*Youngstown*
19.30	B	41˚05’35”/80˚38’20”	Dst. Youngstown WWTP mix-zone	Youngstown
19.23	C,SM	41˚05’41”/80˚38’35”	Dst. Youngstown WWTP mix-zone	Youngstown
19.20	F	41˚05’32”/80˚38’17”	Dst. Youngstown WWTP	Youngstown
18.03	D	41˚04’47”/80˚37’19”	Center St., Campbell	Campbell
16.39	C,D,SO,SM	41˚03’50”/80˚36’01”	LTV RR Bridge,ust. Campbell WWTP	Campbell
16.30	F	41˚03’51”/80˚36’04”	Dst. LTV RR Bridge, ust. dam	Campbell
15.80	B	41˚03’42”/80˚35’22”	Dst. dam, s.w. bank, opposite Campbl.	Campbell
15.60	F	41˚03’39”/80˚35’14”	Dst. Campbell dam, ust. SR 616	Campbell
15.53	C,FC,SO,SM	41˚03’34”/80˚35’06”	SR 616, dst. Campbell dam	Campbell
15.50	B	41˚03’34”/80˚35’06”	Dst. SR 616, dst. Campbell dam	Campbell
13.20	C,SO,SM	41˚02’30”/80˚33’10”	Dst. Struthers WWTP at RR bridge	Campbell
12.50	F	41˚02’09”/80˚32’11”	Dst. dam, ust. Lowellville WWTP	Campbell
12.42	C,FC,D,CO,B	41˚03’28”/80˚32’11”	Dst. dam, ust. Lowellville WWTP	Campbell
12.00	F	41˚01’53”/80˚31’45”	Dst. Lowellville WWTP	Campbell
11.50	C,B	41˚01’48”/80˚31’09”	Ust. Ohio-Penna. state line	Campbell
10.40	D	41˚01’48”/80˚31’09”	Dst. Ohio-Penna. state line	Campbell
8.00	D	41˚01’24”/80˚29’46”	Hillsville Rd. (Pa)	Edinburg
7.12	F	41˚01’06”/80˚26’26”	Ust. U.S. Route 224 (Pa)	Edinburg
7.10	C,FC,D,F	41˚01’06”/80˚26’26”	U.S. Route 224 (Pa)	Edinburg
6.70	B	41˚01’04”/80˚26’18”	Dst. U.S. Route 224 (Pa)	Edinburg
4.39	C	40˚59’49”/80˚24’51”	Brewster Rd. (Pa)	Bessemer
3.10	F	40˚59’10”/80˚23’24”	Dst. Coverts (Pa)	Bessemer
1.43	C,D,SO,SM	40˚58’13”/80˚23’01”	SR 108, ust. New Castle WWTP	Bessemer
1.40	B	40˚58’15”/80˚23’02”	SR 108, ust. New Castle WWTP	Bessemer
1.10	F	40˚58’13”/80˚23’13”	Dst. SR 108, ust. New Castle WWTP	Bessemer
0.40	B	40˚57’32”/80˚22’49”	Dst. New Castle WWTP	Bessemer
0.25	C	40˚57’40”/80˚22’51”	Old SR 18, dst. New Castle WWTP	Bessemer
0.20	F	40˚57’38”/80˚22’50”	Ust. mouth	Bessemer

Table 6. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
West Branch Mahoning River				
0.40	C,B,F	40˚12'25"/80˚57'39"	1st Street, ust. mouth	Newton Falls
Eagle Creek				
6.60	B	41˚15'39"/81˚58'10"	Phalanx	Southington
3.12	C	41˚15'28"/80˚55'29"	Barclay Rd.	Southington
0.80	F	41˚15'18"/80˚53'47"	Ust. mouth, ust sportsman club	Southington
Silver Creek				
0.80	B,F	41˚17'38"/81˚07'30"	SR 82	Garrettsville
0.79	C	41˚17'38"/81˚07'28"	SR 82	Garrettsville
Mosquito Creek				
1.00	F	41˚11'27"/80˚45'37"	Ust. dam	Warren
0.60	B	41˚11'01"/80˚45'41"	Ust. SR 169	Warren
0.25	C	41˚10'48"/80˚45'48"	Park Ave.	Warren
Meander Creek				
3.00	F	41˚09'20"/80˚46'46"	Dst. Meander Cr. res., adj. WTP	Warren
2.30	F	41˚09'29"/80˚46'40"	Ust. small dam, adj. cemetery and WTP	Warren
2.00	C,SO,SM,B	41˚09'21"/80˚46'30"	Ust. Meander WWTP, dst. WTP	Warren
1.80	C,SO,SM	41˚09'27"/80˚46'21"	Dst. Meander WWTP mix-zone	Warren
1.70	F	41˚09'31"/80˚46'19"	Dst. Meander WWTP	Warren
1.60	B	41˚09'37"/80˚46'15"	Dst. Meander WWTP	Warren
0.80	C	41˚10'14"/80˚45'52"	SR 46	Warren
0.70	B	41˚10'12"/80˚45'55"	Dst. SR 46	Warren
0.10	F	41˚10'23"/80˚45'31"	Ust. mouth	Warren
Mill Creek				
11.30	C,D,CO,SO,SM	40˚59'17"/80˚41'25"	Western Reserve Rd.	Columbinia
11.20	B	40˚59'22"/80˚41'28"	Dst. Western Reserve Rd.	Columbinia
11.00	F	40˚59'24"/80˚41'30"	Dst. Western Reserve Rd., ust. pump	Columbinia
10.10	C	41˚00'11"/80˚41'49"	Ust. Boardman WWTP	Youngstown
9.70	B,F	41˚00'27"/80˚41'50"	Ust. Boardman WWTP	Youngstown
9.50	C,D,B,F	41˚00'38"/80˚41'51"	Dst. Boardman WWTP	Youngstown
7.80	C,D,SO,SM,B	41˚01'28"/80˚41'38"	SR 224	Youngstown
7.70	F	41˚01'28"/80˚41'39"	SR 224	Youngstown
6.99	D	41˚02'02"/80˚41'36"	At Ford Rd. and golf course	Youngstown
5.90	D	41˚02'30"/80˚41'17"	At Stilt pavilion	Youngstown

Table 6. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Mill Creek, continued.				
5.70	F	41˚02’45”/80˚40’59”	Ust. Shields Road	Youngstown
5.40	C,D,B	41˚03’12”/80˚40’43”	Shields Rd.	Youngstown
5.10	D	41˚03’01”/80˚40’49”	North of Sheilds Rd	Youngstown
2.70	B	41˚04’18”/80˚41’27”	USGS gage	Youngstown
2.59	C,D,F	41˚04’20”/80˚41’26”	Dst. Lake Newport, USGS gage	Youngstown
1.90	F	41˚04’42”/80˚41’17”	Lake Cohasset	Youngstown
1.60	B	41˚05’00”/80˚40’49”	Dst. Lake Cohasset	Youngstown
1.50	F	41˚04’42”/80˚41’17”	Ust. Slippery Rock bridge	Youngstown
1.07	C	41˚05’17”/80˚40’31”	Ust. Slippery Rock bridge	Youngstown
0.80	C,D,F	41˚05’31”/80˚40’36”	Lake Glacier	Youngstown
0.30	F	41˚05’45”/80˚40’31”	Lake Glacier	Youngstown
0.10	C,D,CO,SO,SM,B	41˚06’05”/80˚40’20”	Near Mouth, below final dam	Youngstown
Bears Den Run				
0.10	B,F	41˚05’10”/80˚40’57”	Adj. West Glacier Drive	Youngstown
0.05	C,SM	41˚05’15”/80˚40’48”	West Glacier Drive	Youngstown
Ax Factory Run				
0.10	C,SM,B,F	41˚04’46”/80˚41’20”	West Cohasset Drive	Youngstown
Anderson Run				
0.20	C,SM,B,F	41˚02’24”/80˚41’08”	West Newport Drive	Youngstown
Indian Run				
0.30	C,SM	41˚01’28”/80˚41’56”	US Rt. 224	Youngstown
0.10	F	41˚01’27”/80˚41’57”	US Rt. 224	Youngstown
Dry Run				
0.60	B,F	41˚05’14”/80˚37’13”	Ust. Gladst.one Road	Campbell
Yellow Creek				
1.00	B,F	41˚02’47”/80˚35’15”	Ust. Catherine Street	Campbell
Beaver River				
20.10	B,F	40˚56’43”/80˚22’37”	Dst. Shaw Island, ust. N. C. EGS (Pa)	New Castle S
18.58	C,	40˚55’25”/80˚22’17”	SR 168 at Moravia (Pa)	New Castle S
18.00	B,F	40˚55’24”/80˚22’14”	Dst. SR 168 at Moravia (Pa)	New Castle S
15.30	B,F	40˚53’19”/80˚20’11”	Ust. SR 288 at Wampum, PA	New Castle S
14.78	C,SO,SM,Q	40˚53’20”/80˚20’13”	SR 288 at USGS Gage	New Castle S

Table 6. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Shenango River				
2.70	F	40°59’09”/80°21’14”	Dst. Neshannock Creek	New Castle S
1.03	C	40°58’12”/80°22’10”	Cherry St.	New Castle S
1.00	B	40°58’09”/80°22’11”	Dst. Cherry St.	New Castle S
0.70	F	40°58’03”/80°22’30”	Ust. mouth	New Castle S
Yankee Creek				
11.30	C,SM,SO	41°18’45”/80°36’35”	Rt.305	Orangeville
8.80	F	41°17’10”/80°35’52”	Five Points Hartford Road	Orangeville
6.50	B	41°16’33”/80°34’19”	Ust SR 7	Orangeville
1.20	C,D,B	41°13’15”/80˚32’09”	Addison Rd.	Sharon, West
0.60	F	41°13’02”/80°31’31”	Ust. WWTP	Sharon, West
0.30	C,D,B,F	41°12’51”/80°31’30”	Dst. WWTP	Sharon, West
Little Yankee Creek				
9.60	B	41°12’51”/80°35’34”	Ust. Stewart Rd.	Sharon, West
9.50	C,SM,SO,F	41°12’49”/80°35’32”	Stewart Rd.	Sharon, West
4.90	B	41°10’09”/80°34’00”	Ust. Elmwood Rd.	Sharon, West
4.60	C,F	41°10’16”/80°33’18”	Elmwood Rd.	Sharon, West
4.40	C,SM,B,F	41°10’13”/80°33’00”	Dst. WWTP	Sharon, West
2.00	C,F	41°11’30”/80°32’08”	Fox North Rd.	Sharon, West
1.60	B	41°11’34”/80°32’04”	Ust. Chestnut Ridge Road	Sharon, West
0.40	F	41°12’25”/80°31’27”	Ust. Bedford Rd.	Sharon, West
0.30	C,F	41°12’27”/80°31’25”	Bedford Rd.	Sharon, West
0.20	B	41°12’29”/80°31’24”	Dst. Bedford Rd.	Sharon, West
Little Deer Creek				
0.50	F	41°09’51”/80°32’32”	Ust. SR 304	Sharon, West
0.40	C,SM,SO,B	41°09’51”/80°32’32”	SR 304	Sharon, West
Pymatuning Creek				
30.50	F	41°36’29”/80°37’44”	Ust. U.S.Route 6	Cherry Valley
30.38	C	41°36’25”/80°37’47”	U.S. Route 6	Cherry Valley
29.10	B	41°35’27”/80°37’51”	Mann Road	Cherry Valley
24.70	F	41°32’11”/80°38’03”	Ust. U.S. Route 322	Cherry Valley
24.50	C,SM	41°32’02”/80°38’03”	U.S. Route 322	Cherry Valley
22.70	B	41°30’37”/80°38’03”	Underwood Road	Cherry Valley
17.80	B	41°27’21”/80°36’45”	Ust. S.R. 87	Kinsman
17.78	C	41°27’19”/80°36’45”	S.R. 87	Kinsman
17.60	F	41°27’10”/80°36’45”	Dst. S.R. 87	Kinsman
17.30	C, FC,B	41°27’02”/80°36’32”	Dst. Kraft 001 Effluent	Kinsman
17.10	F	41°26’55”/80°36’25”	Dst. Railroad tracks	Kinsman

Table 6. (continued)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad. Map
Pymatuning Creek, continued.				
16.10	C, FC,B,F	41°26’40”/80°35’28”	Upstream Kinsman	Kinsman
15.90	FC	41°26’32”/80°35’22”	Upstream State Route 7	Kinsman
15.88	FC	41°26’34”/80°35’19”	Storm Sewer dst. S.R. 7	Kinsman
15.87	FC	41°26’33”/80°35’18”	Downstream S.S. #1	Kinsman
15.85	FC	41°26’34”/80°35’15”	Downstream Sewage Seep	Kinsman
15.81	FC	41°26’36”/80°35’14”	Storm Sewer #2	Kinsman
15.80	C, FC,B	41°26’35”/80°35’13”	Downstream Kinsman	Kinsman
15.70	F	41°26’35”/80°35’07”	Downstream S.R. 7	Kinsman
15.20	C, FC,B	41°26’19”/80°35’18”	South of Kinsman adjacent S.R. 7	Kinsman
15.00	F	41°26’12”/80°35’11”	South of Kinsman near S.R. 7	Kinsman
12.04	F,B	41°24’53”/80°34’05”	Near Job Greenville Road	Kinsman
8.60	F	41°23’20”/80°33’20”	Ust.. S.R. 88, Kinsman	Kinsman
8.40	C, SM,B	41°23’13”/80°33’27”	S.R. 88, Kinsman	Kinsman
2.20	F	41°20’39”/80°31’04”	Brockway Sharon Road	Kinsman
1.94	C	41°20’24”/80°31’10”	Brockway Sharon Road	Kinsman
Sugar Creek				
1.00	B,F	41°26’12”/80°36’09”	Ust.. Burnett Road	Kinsman
0.92	C	41°26’15”/80°36’13”	Burnett Road	Kinsman

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table 6 .

Determining Use Attainment Status

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

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

Chemical Sediment Quality Assessment

The quality of sediment concentrations was based on two classification schemes. The Kelly and Hite (1984) classification grades sediment quality from low concentrations (non-elevated) measured at relatively unimpacted areas to higher concentrations (ie. slightly, highly, or extremely elevated) measured at heavily impacted areas. The Ontario guidelines (1994) are based on the chronic, long term effects of contaminants on macroinvertebrates and grades sediment quality as no effect, lowest effect, and severe effect levels.

Fish Tissue Assessment

A total of 27 fish tissue samples were collected at ten sites on the Mahoning River from RM 70.3 to RM 12.5. Seven species of sport fish were analyzed as skin on filet samples; channel catfish, yellow bullhead, and one common carp sample were analyzed as skin off filets; and three samples of common carp were analyzed as whole body composites. Fish tissue sampling procedures are detailed in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a). Mercury and pesticides were compared to the U.S. FDA criteria. PCBs were compared to a tiered sportfish consumption advisory as modified from the Great Lakes Sport Fish Advisory Task Force, 1993. This classification scheme rates fish tissue PCB levels as slightly elevated (i.e., >50 and ≤300 ug/kg), elevated (i.e., >300 and ≤1000 ug/kg), highly elevated(i.e., >1000 and ≤5000 ug/kg), and extremely elevated (i.e., >5000 ug/kg).

Biomarker Assessment

White sucker and common carp were collected for biomarker processing during August 23 to 25, 1994. Fish were kept in a floating livewell until biomarker tissue samples could be taken. Fish were anesthetized with MS222 and length and weight was measured. Fish health/condition was assessed using procedures in Goede (1988). Blood was drawn from the caudal vein through a 21 gauge needle into heparin treated 3 ml blood drawing tubes. Whole blood was centrifuged on-site and the plasma removed (flash frozen at -100 ^{O}C in a liquid nitrogen dry shipper). The liver was excised, wrapped in aluminum foil and frozen in a liquid nitrogen dry shipper. Bile was removed, placed in amber microcentrifuge tubes and placed in a liquid nitrogen dry shipper. Sections of liver and spleen were excised from each fish and placed in buffered formalin for histological evaluation. Tissue samples were transported to the U.S. EPA in Cincinnati for laboratory analysis. Specific biomarker analyses included ethoxyresorufin-O-deethylase (EROD), total hepatic glutathione, blood urea nitrogen, plasma levels of pseudocholinesterase, and bile metabolites. Each bile sample was diluted with distilled/deionized water and measured by fixed fluorescence at four excitation/emission wavelength pairs according to Lin *et al.* (in preparation). Although more than one compound is known to fluoresce under these conditions, some compounds give a greater response. The metabolites are referred to by one of their most sensitive respondents: pyrenol-type at 340/380 nm, benzo(a)pyrenol-type at 380/430 nm, phenanthrol-type at 256/380 nm and naphthol-type at 290/335 nm. Microsomes for measuring EROD and cytosol for glutathione were prepared from liver tissue. Microsomes were prepared according to Lin *et al.* (1989) and the cytosolic supernatant resulting from the high speed centrifugation was reserved for glutathione measurement. EROD activity was measured fluorometrically according to Pohl and Fouts (1980) and modified Lin *et al.* (1989). Glutathione was measured according to Akerboum and Sies (1981) and adapted for use with an automated chemistry analyzer.

Habitat Assessment

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

Macroinvertebrate Community Assessment

During this survey, macroinvertebrate were sampled at many locations using mmodified Hester/Dendy multiple-plate artificial substrate samplers supplemented with a qualitative assessment of the available natural substrates. However, at many small tributary locations, only a qualitative natural substrate sample was collected. Artificial substrate data were evaluated using the ICI (Table 1).

During the present study, macroinvertebrates collected from the natural substrates were evaluated using an assessment tool currently in the testing and refinement phase. This method relies on tolerance values derived for each taxon, based upon the abundance data for that taxon from artificial substrate (quantitative) samples collected throughout Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations where the taxon has been collected are weighted by its abundance on the artificial substrates. The mean of the weighted ICI scores for the taxon results in a value which represents its relative level of tolerance on the ICI scale of 0 to 60. For the qualitative collections in the Mahoning River study area, the median tolerance value of all organisms from a site resulted in a score termed the Qualitative Community Tolerance Value (QCTV). This score is assessed by comparing it to the distribution of QCTV scores from other sites in the ecoregion where ICI scoring has determined achievement or nonachievement of the ecoregional biocriterion. The QCTV shows potential as a method to supplement existing assessment methods using the natural substrate collections. QCTV scores in the Mahoning River study area were used in conjunction with other aspects of the community data to make evaluations and were not unilaterally used to interpret quality of the sites or aquatic life use attainment status.

Fish Community Assessment
Fish assemblages were sampled using wading or boat method pulsed DC electrofishing gear (Plate 6). The wading method was used at a frequency of one or two samples at each site. The boat method was used at a frequency of two or three samples at each site. The specific electrofishing method and the number of samples for each sampling location are listed in Table 16.

Area of Degradation Value (ADV)
An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Fig. 7). The “magnitude” of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are also expressed as ADV/mile to normalize comparisons between segments and other streams and rivers.

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

ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993) here we are referring to the process for identifying biological integrity and causes/sources associated with observed impairment, not whether human health and ecosystem health are analogous concepts.

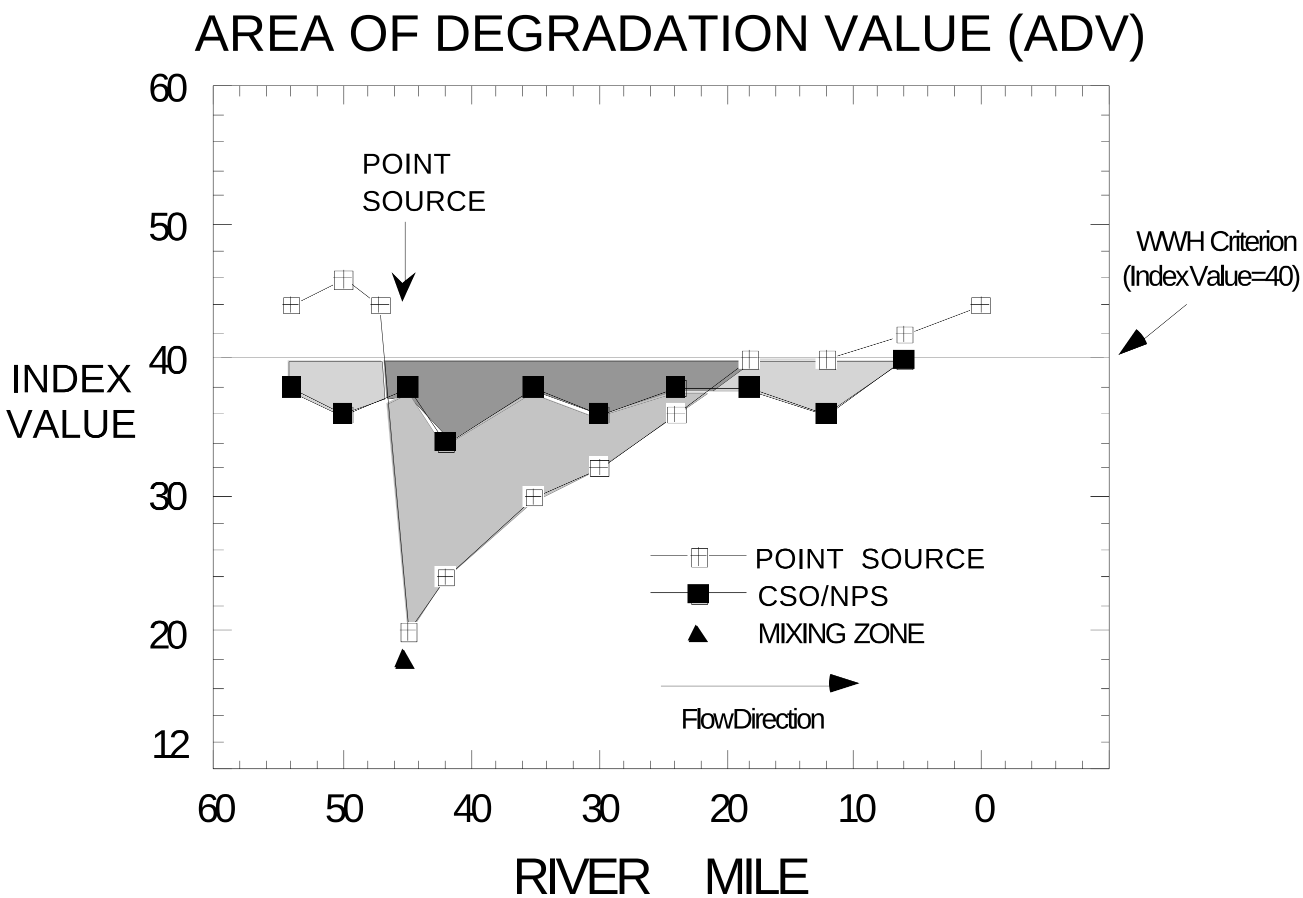


Figure 7. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

RESULTS AND DISCUSSION

Pollutant Loadings: 1976 - 1994 (Figures 8-29; Tables 2,7,8)
Upper Mahoning River (RM 100.57 - 45.73)

Unnamed tributary - Village of Beloit WWTP (RM 91.2, RM 3.2)

- The Village of Beloit WWTP was built in 1971 and modified in 1984. Current treatment includes equalization basin, aerated wet well, aeration tanks to handle 0.1 mgd, AERO-MOD system (aeration module) to handle 0.09 mgd, chlorination , and tertiary lagoon before discharge to the unnamed tributary of the Mahoning River. The WWTP has a long history of compliance problem with total suspended solids, BOD, and ammonia-N.

- Compliance sampling in October 1994 showed elevated total suspended solids (113 mg/l) in the Village of Beloit effluent discharge. The effluent was cloudy with large solids and pin floc. Heavy metals cadmium, copper, and zinc were also at elevated levels. Fecal coliform bacteria were 8000 counts per 100 ml. The downstream area was full of solids. The Ohio EPA emergency response section had 27 reported calls concerning poor effluent quality being discharged from the Beloit WWTP in 1993.

Fish Creek /Sulfur Creek - City of Sebring WWTP (RM 87.81, RM 4.1)

- The city of Sebring WWTP was built in 1917 and completely rebuilt in 1990. Treatment at the new plant includes bar screen, comminutor, aerated grit chamber, wet well, two oxidation ditches, clarifiers, cascade, and uv disinfection. Influent greater than 1.3 mgd is diverted to an equalization basin. Design flow of the WWTP is 1.75 mgd. Discharge is to RM 0.48 along Sulphur Creek, which flows into Fish Creek. The WWTP receives significant industrial wastewater and is discharging slightly elevated heavy metals, cadmium, copper, chromium, mercury, zinc, lead, and nickel. A review of MOR data indicates violations for total suspended solids, copper, zinc, and lead from 1990 to 1994.

- A district site survey was conducted in May of 1986 in Sulphur Ditch upstream and downstream from the old Sebring WWTP discharge. The results of the survey indicated a severe impact on the chemical and biological quality in Sulphur Ditch. Up to two feet of sewage sludge was observed in the ditch below the WWTP and only one type of aquatic invertebrate was collected, a hemoglobin type chironomid. No fish were found. Dissolved oxygen in Fish Creek below the WWTP was measured at 0.6 mg/l, a concentration that would be lethal to aquatic life in a stream.

- Since the new WWTP went on-line in 1990 no follow-up chemical or biological sampling in either Sulpher Ditch or Fish Creek has been conducted to document possible recovery of biological communities.

Ryans Run - Alliance Tubular Products (RM 85.13)

- This company is a manufacturer of electric resistance welding carbon steel tubular products. It was previously owned by Babcock and Wilcox Company. Two effluents 001 (0.180 mgd) and 002 (0.240 mgd) discharge to Ryans Run. Ryans Run enters the Mahoning River at RM 85.13. Outfall 001 discharges NC cooling water, boiler blowdown, non-destructive testing water, and storm water. Outfall 002 discharges all of the above plus treated process wastewater from station 602. Wastewater treatment for 602 includes neutralization, chemical precipitation, and sedimentation. The 002 outfall enters the Rush Street stormsewer and flows into the Ryans Run stormsewer.

- There is a history of periodic iron colored discharge from the Ryans Run stormsewer. In October 1991 the City of Alliance sewer department walked the stormsewer and found iron discoloration at the end of the Alliance Tubular 002 outfall. During the 1994 survey, total zinc values reported by the company ranged from 100-400 ug/l in the 002 outfall. Spills reported to OEPA include a milky white discharge of unknown amount in 1993 and 100 gallons of waste sulfuric acid in 1991.

- Evaluation of long term loadings from outfall 002 is not reliable because flow rate is estimated. Communications from the company indicate that the estimated flows from outfall 002 are not valid (Dec. 8, 1994 letter from R.T. Smith to Ohio EPA, NEDO). As of April 1995 no continuous flow meter has been installed.

- Long term loadings data from internal station 602 from 1986 to 1994 shown in Figure (RDD 100) indicates a reduction in flow between from 1991 to 1994. Annual loadings for total suspended solids, oil and grease, lead, and zinc were also reduced over this time period.

Gaskill Creek - Babcock and Wilcox Co., Research (Alliance)

- This facility conducts research on the combustion of fluids, fuels, design, manufacturing, materials, and advanced energy systems. The only wastewater discharged is from boiler blowdown and non-contact cooling water and stormwater runoff. Wastewater enters an oil skimmer and sedimentation pond prior to discharge to Gaskill Creek. Discharge results in an average flow of 0.012 mgd.

Beech Creek - City of Alliance WWTP (RM 82.03)

- The city of Alliance WWTP discharges to an impounded portion of the Berlin Reservoir. The discharge location corresponds to RM 0.35 of Beech Creek, which joins the Mahoning River at RM 82.03. The design capacity of the plant is 7.5 mgd. The Alliance WWTP was originally constructed in 1929. The facility was modified in 1958, added chlorination capabilities in 1970, and was modified again between 1982 and 1984. The current waste treatment consists of grit removal, primary settling, off-line flow equalization, single stage activated sludge, final setting, and chlorination. The WWTP receives both municipal and industrial waste. A new NPDES permit became effective Oct. 1, 1993. It requires plant improvements to meet more stringent $CBOD_5$ concentrations, total phosphorus limits, and ammonia-N limits, and dechlorination. Final construction is to be completed by Oct. 1, 1996.

- Analysis of MOR data submitted by the entity indicates a significant reduction in BOD, total suspended solids, and Oil and Grease loadings after 1984 (Figure 8). These loadings reduction coincide with WWTP improvements completed by 1984. MOR violations reported from 1989 to 1994 include pH, oil and grease, cadmium, nickel, mercury, zinc, chlorine, and total suspended solids. The WWTP reported spills of oils and diesel fuel totaling 140 gallons between 1991 and 1992.

- Bioassays conducted by the Ohio EPA on Alliance WWTP effluent showed no significant toxicity to either test organism in July 1987, October 1993, nor in June 1994 effluent samples.

Mahoning County, Lake Milton WWTP (RM 63.43)

- The Mahoning County Lake Milton WWTP was originally constructed in 1959. It was modified in 1968 and more recently in 1990 under a consent order. The current waste treatment includes an oxidation ditch, clarification, and chlorination. Analysis of MOR data indicates an average annual flow ranging from 0.2 - 0.4 mgd between 1990 and 1994. Since 1990 there has been a reduction in the 95th percentile loadings for ammonia-N and BOD, however, total suspended solids loadings have remained relatively constant with a slight yearly increase. No significant MOR violations have been reported at the WWTP since 1990.

Village of Newton Falls WWTP (RM 56.85)

- The Village of Newton Falls WWTP was originally constructed in 1959. It was modified in 1986. The current waste treatment includes manual screening, aerated grit removal, primary settling, rotating biological contactors (RBCs), final settling, and chlorination. The sewerage system is mostly combined, and contains 28 CSOs and two additional points of overflow at the WWTP. The design capacity is 0.5 mgd. Analysis of MOR data indicates that the plant has consistently exceeded its 0.5 mgd design capacity on an average annual basis from 1987 to 1994 (Figure 9). There was, however, a minor reduction in the 50th percentile annual loading of total suspended solids and BOD since the 1986 upgrade. Ammonia-N loadings since 1989 have remained constant with a maximum average annual loading in 1994.

- In addition to the known 28 CSOs, there are a number of unsewered areas in the Newton Falls area that can contribute untreated wastewater to the Mahoning River. In 1994, CSO #s 006, 015, and 026 were eliminated. Since 1990, numerous MOR violations have been reported for CBOD and total suspended solids most likely due to hydraulic overload. The current NPDES permit expired August 13, 1994. The permit has been reissued to include CSO strategy and schedule of compliance to meet final effluent limits.

Arhaven Estates MHP WWTP (RM 54.1)

- This small mobile home park WWTP has a design capacity of 0.0175 mgd. The current waste treatment consists of trash trap, extended aeration, and chlorination. Sludge holding facilities were not completely in operation during the 1994 survey. The NPDES permit does not limit ammonia-N. Ammonia-N values reported in 1994 ranged from 15-36 mg/l. MOR violations reported in 1994 included BOD, total suspended solids, and fecal coliforms. A December 27, 1994 compliance inspection noted poor overall operation.

Denmen Tire Corp. (RM 49.3)

- This company is a manufacturer of tires and rubber covered rolls and operates a facility with two existing discharge points. Discharge 002 is limited to stormwater runoff. Discharge 001 combines package plant, process oil wastewater, and stormwater runoff. An oil skimmer treats process and stormwater before mixing with WWTP effluent and discharge via underground pipe directly to the Mahoning River. Ohio EPA NEDO has investigated spills of diesel fuel (1993) and carbon black (1989) at the facility.

Lower Mahoning River, Ohio Waters (RM 45.51 - 11.43)

Historical Point Source Loadings

- Point source loadings from the major industrial facilities were documented in the early 1950's (Table 7). Pollution control in the Mahoning Valley during this time period was essentially non-existent, with the steel industry directly discharging untreated coke plant wastes, rudimentary solids removal for blast furnace gas wash water, scale pits with and without oil skimming for hot forming wastes, no treatment for emulsified cold rolling oils, direct discharge of spent pickling acids, and no treatment for coating wastes (Amendola *et.al.*, 1977).

- Since the 1950's, significant loading reductions of wastewater volume, total suspended solids, oil and grease, total iron, and phenolics have occurred (Table 7). These reductions became possible with pollution control improvements at several steel mills but mostly because of the partial to total shutdown (since 1978) of five major steel producing facilities. During 1974, eight major steel mills were discharging to the lower Mahoning River mainstem with a combined wastewater volume of 627 MGD (92% of the total wastewater volume discharged to the Mahoning River). It was estimated that in 1975 the major steel facilities used the entire flow of the Mahoning River 5.6 times during winter low flow and nearly 2.6 time during summer low flow (Amendola *et. al.*, 1977). The total volume of wastewater declined to 154 MGD in 1980, and to 56 MGD in 1985. These reductions reflected reduced inputs from steel making facilities.

- Municipal wastewater treatment within the lower Mahoning River mainstem study area was non-existent during the mid-1950's. Primary treatment at municipal wastewater treatment plants was not in operation until the late 1950's and early 1960's. The Youngstown WWTP, which is the largest municipal discharge to the Mahoning River, did not begin operations until 1965. Prior to this time, no treatment of Youngstown's municipal waste was provided. This resulted in raw sewage being directly discharged into the Mahoning River and adjacent tributaries. Biochemical oxygen demand 5-day (BOD_5) loadings from 1952 to 1954 averaged 20,360 kg/day for the major municipalities (Table 8). Small reductions in BOD_5 loadings between the early 1950's and 1974 was noted, and was attributed to the installation of primary wastewater treatment facilities. Little change in BOD_5 loadings occurred for the Mahoning River with regard to municipal inputs between 1974 and 1985, a reflection of no additional upgrading of municipal wastewater treatment facilities during this period.

- Dissolved oxygen and ammonia-N data collected at the Lowellville ambient station from the early 1970s to present indicate that there has been a significant improvement in DO and ammonia-N concentrations since the early 1980s. The most significant improvements are related to the 1988-1989 time period when most of the municipal WWTPs in the Mahoning valley converted to secondary levels of wastewater treatment and sharply reduced loadings of ammonia-N and BOD to the river (Table 8).

Table 7. Mean annual loadings (kg/day) to the lower Mahoning River mainstem (RM 44.3-17.0) of total suspended solids, oil and grease, total iron, and phenolics, and volume of wastewater (MGD) discharged by major industrial facilities from 1952 to 1994.

Year	Flow (MGD)	Total Suspended Solids	Oil & Grease	Total Iron	Phenolics
1952-54[a]	661	627,463	17,091	152,616	1,359
1974[b]	627	205,456	58,892	55,379	597
1976-1980: Shutdown of Republic Steel - Niles, Jones & Laughlin Steel Co (approx. Rm 30.0), United States Steel -McDonald, Youngstown Sheet & Tube - Brier Hill, United States Steel - Ohio Works, Fitzimmons Steel, and Youngstown Sheet & Tube - Struthers					
1980[b]	154	48,464	4,415	7,233	180
1980-1983: Shutdown of Youngstown Sheet & Tube - Campbell Drastic reduction at Republic Steel - Youngstown					
1983[b]	75	18,828	3,116	1,241	18
1983-1990: Shutdown of Republic Steel - Youngstown					
1985[c]	56	6,382	1,471	-	-
1990: Warren Consolidated Industries (WCI) buys LTV-Warren property (outfalls 001-013)					
1990[c]	56	4,909	328	-	-
1994[c]	52	2,673	367	-	-
1994: LTV-Warren outfall 014 tied into Warren WWTP					

a Source: Report of Water Pollution Study Mahoning River Basin, Ohio Dept. of Health, 1954.
b Source: Ohio EPA LEAPS (Monthly Operating Reports), N.E. District Office files.
c Source: Ohio EPA LEAPS (MOR) computer data file, Central Office, Columbus. Entities used in the 1985, 1990, and 1994 summary statistics include Copperweld, Thomas Strip Steel, Warren Consolidated Steel, and LTV-Warren. Loadings and flow data are annual 50th percentile values. Note that the flow for these years does not include the largest industrial outfall which is cooling water from Ohio Edison - Niles with an annual 50th percentile discharge of 109 MGD.

Table 8. Mean annual loadings (kg/day) to the lower Mahoning River mainstem (RMs 35.25-14.32) of total suspended solids, oil and grease, BOD, and ammonia, and volume of wastewater (MGD) discharged by major municipal WWTPs (Campbell, Girard, Niles, Struthers, Youngstown, and Warren) from 1952 to 1994.

Year	Flow (MGD)	Total Suspended Solids	Oil & Grease	BOD	Ammonia
1952-54[a]	(no treatment)	-	-	20,466	-
Late 1950s-early1960s: Installation of primary wastewater treatment facilities					
1974[b]	-	-	-	14,615	-
1980[c]	50.2	8,387	4,560[d]	12,899	2,101[e]
1985[c]	52.5	10,193	6,483[f]	12,720	2,327[f]
1988-1989: Time period when most of the municipal WWTPs in the Mahoning valley converted to secondary levels of wastewater treatment					
1990[c]	57.9	1,630	463	1,297[g]	182
1994[c]	44.1	1,222	464	890[h]	249

a Source: Report of Water Pollution Study Mahoning River Basin, Ohio Dept. of Health, 1954. Loading values are based on population equivalents, since municipal WWTPs were nonexistent at this time. One population equivalent is considered equal to 0.167 pounds of BOD per day.

b Source: Ohio EPA LEAPS Monthly Operating Report (MOR) data, N.E. District Office files.

c Source: Ohio EPA LEAPS (MOR) computer data file, Central Office, Columbus. Loadings and flow data are annual 50th percentile values.

d Based on loadings from 1980 for Niles and Girard WWTPs, 1979 for Warren WWTP, 1978 for Youngstown WWTP, and 1976 for Struthers WWTP.

e Based on loadings from 1980 for Girard, Niles, and Youngstown WWTPs; 1979 for Warren WWTP; and no data reported for this time period for Struthers WWTP.

f Based on loadings from 1985 for Girard, Campbell, Struthers, and Youngstown WWTPs; 1983 for Niles WWTP; and 1979 for Warren WWTP.

g Based on BOD loadings from 1990 for Campbell, Struthers, and Warren WWTPs; and on cBOD loadings from 1990 for Girard, Niles, and Youngstown WWTPs.

h Based on cBOD loadings for the major municipal WWTPs.

CSC Industries, Inc. /Copperweld Steel (RM 42.68)

- The Copperweld Steel plant has been in operation since 1939. The plant manufactures steel bars which can be hot rolled, thermal treated, and/or cold drawn. Processes include melting with electric furnaces, annealing, hardening, tempering, quenching, cold and hot rolling, and cold finishing. Treated process wastewater is discharged from outfall 002. Outfall 003 discharges pump house intake strainer backwash and 004 discharges pump house intake traveling screen backwash. Process water treatment includes neutralization, sedimentation, oil and grease skimming, and wastewater recycle. Sewage is treated by a small extended aeration plant with trickling filter and chlorination. Sewage is discharged to the final sedimentation lagoon and contributes to outfall 002 flow. A spill of sulfuric acid of unknown amount was reported to Ohio EPA emergency response section in 1990.

- Baghouse dust from the melt shop has been landfilled on site and is regulated as a hazardous waste under RCRA. Old waste acid neutralization lagoons are located near the Mahoning River, and the property also has an old solid waste landfill. MOR violations from 1990 to 1994 for outfall 002 include pH, oil and grease, total suspended solids, and lead. Copperweld filed for Chapter 11 bankruptcy protection on November 22, 1993 but remained in operation during the 1994 survey.

- Results of long term loadings from Figure 10 indicates a reduction in flow and loadings of total suspended solids, oil and grease, and lead beginning in 1993. From 1982 to 1992 flow and chemical loadings remained relatively constant.

- A 1987 U.S. EPA bioassay on CSC Industries effluent resulted in a 1.0 TU_a and 2.8 TU_c. These results were below Allowable Effluent Toxicity (AET) values of 17.1 TU_a and 57.0 TU_c calculated for CSC Industries. An Ohio EPA bioassay conducted 1988 showed no significant toxicity to either test organism. No further biomonitoring has been conducted on this entity.

- In June 1995, Ohio EPA DERR personnel collected six sediment samples along CSC property. These samples were tested for metals, PCBs, and sediment bioassay toxicity. None of the samples showed any sediment toxicity.

Red Run - Sharon Steel (RM 40.30)

- The Sharon Steel facility has a long history of discharging untreated wastewater from two outfalls (001, 002) into Red Run, a tributary of the Mahoning River. The facility conducts steel strapping, and electrogalvanized steel strips using lead, zinc, and chromium. Processes included heat treatment, lead quenching, painting, stenciling, chromatic steel strips, and electrogalvanizing. Discharge from 001 (Coil Coatings) and 002 (Brainard Strapping) effluents enters a tributary of Red Run. Flow from Red Run is diverted to the Mahoning River along Comstock Street via the comstock diversion stormsewer, which empties into the Mahoning River at RM 40.30.

- On March 30, 1987 the US EPA filed suit against Sharon Steel for the discharge of untreated wastewater. On April 17, 1987 Sharon Steel filed for Chapter 11 bankruptcy and continued to discharge until the plant was shut down in July 14, 1989. On February 5, 1990 the US EPA and Sharon Steel signed a Consent Decree. That Decree allowed a new owner to restart operations with discharge of untreated wastewater and a twelve month schedule to install treatment and meet final permit limits. In June, 1991 Coil Coating Company and Brainard Strapping, a Division of Sharon Steel began to discharge untreated wastewater from outfalls 001 and 002 under the terms of the US EPA Consent Decree. In October, 1991 an oil/water separator was installed at outfall 002. In March, 1992 outfall 002 contained only non-contact cooling water and storm water according to Brainard Strapping. Coil Coating Company began to discharge untreated wastewater in June, 1991 and the 001 discharge remained untreated until a WWTP was put on line sometime in June, 1992.

- A February 18, 1992 sample of the Red Run tributary immediately below the combined 001 and 002 discharge showed very high levels of metals (chromium 50 ug/l, copper 35 ug/l, lead 51 ug/l, and zinc 69,100 ug/l). This sample was collected before the new WWTP was placed in service.
- Sharon Steel again ceased operations on November 20, 1992 and filed for Chapter 11 bankruptcy on November 30, 1992. It has remained closed. No discharge occurred during the 1994 Ohio EPA survey of the Mahoning River.

- Red Run below the Sharon Steel tributary is largely an underground stormsewer, and flows through an unsewered area known as the "golden triangle". Numerous commercial sites discharge either untreated or partially treated wastewater to Red Run. A 1990 NEDO site survey of Red Run indicated that the stream water and sediment was grossly polluted. Violations for fecal coliforms (max = 92,000/100 ml) and oil and grease (max=107 mg/l) were recorded. Six priority VOCs were also detected in the water. Twenty two potential commercial and industrial sources were identified. For years the Ohio EPA NEDO has attempted to have the Red Run area sewered with no success.

Dickey Run Stormsewer - Thomas Steel Strip Corp. (RM 39.17)

- Outfall 001 from Thomas Steel Strip discharges to the Dickey Run stormsewer at approximately RM 1.2. The stormsewer empties into the Mahoning River at RM 39.17. There are no other known or permitted discharges to the Dicky Run sewer.

- The company produces cold reduced steel strip some of which is electroplated with nickel, copper, brass, or a nickel-zinc alloy. Processes include pickling, cold rolling, annealing, temper rolling, slitting, and electroplating. Treatment of wastewaters includes oxidation of cyanide waste with sodium hypochlorite and caustic soda, chromium destruction with sulfur dioxide and sulfuric acid, neutralization of acid, settling of solids, and oil skimmers. Spent rolling solution is treated with polymers to break oil emulsions. A review of MOR data indicates violations reported between 1990 and 1994 for total suspended solids, cyanide, oil and grease, and total lead. Effluent flow has gradually increased from 1976 to 1994 but no obvious trends in increased chemical loadings are noted (Figure 11). No spills from the facility were reported to Ohio EPA emergency response section between 1989 and 1993.

- Effluent compliance sample data collected by Ohio EPA between 1989 and 1994 indicates consistently elevated levels of total copper, total nickel, and total zinc. On the most recent sample in July, 1994 ammonia-N was recorded at 6.34 mg/l and free cyanide at 26 ug/l. A dissolved metals sample on the same day indicated 38 ug/l dissolved copper, 42 ug/l dissolved nickel, and 25 ug/l dissolved zinc. The same sample had the following levels of total metals for these chemicals respectively; 122 ug/l total copper, 235 ug/l total nickel, 241 ug/l total zinc.

- Results from two 1989 bioassays conducted by Ohio EPA personnel showed toxicity to *Ceriodaphnia* of 2.9 TU_a and 6.7 TU_a. The entity conducted biomonitoring on *Ceriodaphnia* in 1991, 1993, and 1994. Four of seven tests in 1991 showed toxicity ranging from 3.1 TU_a to greater than 10.0 TU_a. Three of twelve tests from 1993 and 1994 resulted in 1.38, 3.41, or 4.0 TU_a. A calculated AET of 17 TU_a based on dilution with the Mahoning River does not apply, because the discharge from the Dickey Run Stormsewer does not mix rapidly with the Mahoning River. NEDO District personnel and EAU biologists have observed that the flow from the Dickey Run Stormsewer hugs the bank as it enters the Mahoning River.

WCI Steel Inc. (RMs 37.15 to 35.86)

- WCI Steel Inc. is a manufacturer of flat rolled sheet and coiled steel. It is an integrated steel plant including blast furnace, basic oxygen furnace, slab mill, rolling mills, galvanize line, terne line, silicon line, and acid cleaning. Process wastewater for outfall 013 is treated at the central WWTP which includes clarification, flocculation, coagulation, and neutralization. For outfall 008 treatment includes settling basins, recycle lagoon, coagulation, and oil skimming. For outfall 010 treatment includes settling basins, coagulation, and oil skimming.
- WCI Steel Inc. purchased the steel plant from LTV Corp. in late 1988. LTV Corp. retained ownership of the coke plant including outfall 014. Between RMs 37.15 and 35.86 WCI has 9 NPDES outfalls with direct discharge to the Mahoning River. By far the largest in terms of flow and loadings is outfall 013, with an average daily flow of about 35 mgd. Outfall 008 is the next largest, with an average flow between 1993 and 1994 of about 7.0 mgd, and outfall 007 is the third largest at about 2.0 mgd flow (Figure 12). Loadings of total suspended solids and oil and grease from outfalls 013 and 008 have remained relatively constant between 1990 and 1994. WCI has reported MOR violations for all nine outfalls between 1990 and 1994, including the following parameters pH, oil and grease, zinc, copper, cyanide, lead, NH_3.-N . The company has indicated that some of the metals violations may be due to carryover from contaminated Mahoning River intake water. The WCI water intake is located above outfall 013 but below most of their other outfalls.

- In September, 1994 samples of possible slag leachate that was flowing into the Mahoning River from two areas along the left bank where WCI historically has landfilled slag and other wastes showed elevated pH (11.9 S.U.) and conductivity (ranging from 2000 to 4500 umhos/cm). Strontium (963 to 3190 ug/l) and barium (222 ug/l) were also elevated.

- Entity bioassay data collected between August 1990 and June 1991 showed significant toxicity to *Ceriodaphnia* (one of six tests) and fathead minnows (two of six tests) in outfall 008 effluent and to fish (one of six tests) in outfall 013 effluent. A 1992 biomonitoring review (Ohio EPA Permits Division) concluded that these outfalls did not have a chronic toxicity problem. There was significant toxicity to fish in the upstream sample on the October and December 1990 bioassays. Bioassays conducted by Ohio EPA personnel in July and October 1994 showed no significant toxicity to fish and *Ceriodaphnia* in outfalls 008 and 013, but did show some toxicity to *Ceriodaphnia* in the outfall 013 upstream control in the October sample. Outfalls 008 and 013 contained levels of the PAH naphthalene ranging from 0.8 to 2.4 ug/l on both bioassay sampling dates. This segment of the Mahoning River from upstream of all WCI outfalls and leachates to downstream from LTV outfall 014 should be studied in more detail to evaluate the cause(s) of the instream toxicity.

LTV Steel Corp., Inc. /Warren Coke Plant (RM 35.68)

- The LTV Steel Warren Coke Plant produces coke, tar, light oil, and ammonia sulfate from burning coal. All process water is sent to the city of Warren WWTP after pretreatment. Outfall 014 is limited to non-contact cooling water, groundwater, and stormwater runoff. Discharge from 014 is to a tributary which empties into the Mahoning River at RM 35.68 on the right bank, just below the final outfall from WCI steel which enters on the left bank. The unnamed tributary below the 014 discharge has been impounded and an oil boom is maintained to capture oil before discharge to the Mahoning River. Average annual flow reported by the company has ranged from 2-4 mgd from 1984 to 1994. Ammonia-N, total suspended solids, and oil and grease loadings have decreased from 1988 to 1994 as compared to pre-1998 levels (Figure 14).

- A review of monthly operating report (MOR) data for LTV Warren Coke Plant indicates violations for the following parameters between 1990 and 1994: ammonia-N, pH, $cBOD_5$, and oil and grease.

- A sediment sample of the unnamed tributary collected by the US EPA in April, 1986 had a total PAH concentration of 101,720 mg/kg. Sediment samples in the Mahoning River just above the coke plant tributary showed a total PAH level of 3.06 mg/kg and a sample just below the tributary had 262.9 mg/kg of PAH. This 1986 US EPA survey clearly documented the LTV coke plant 014 tributary as a source of PAH compounds to the Mahoning River.

- Ohio EPA bioassays conducted in November 1993 and May 1994 showed marginal toxicity in the effluents, and showed toxicity in the 1993 upstream sample. Naphthalene (6.7 ug/l) and benzene (60 ug/l) were detected in the effluent. This segment of the Mahoning River from upstream of all WCI outfalls and leachates to downstream from LTV outfall 014 should be studied in more detail to evaluate the cause(s) of the instream toxicity.

City of Warren WWTP (RM 35.25)

- The city of Warren WWTP is a 16.0 mgd design plant that was upgraded to advanced secondary treatment in February, 1988. Treatment processes include grit removal, detritus setting tanks, extended aeration activated sludge, primary and final settling tanks, chlorination, and post aeration. The sewage system is about 20 percent combined with CSOs and separate sewer bypasses.

- As shown in Figure 15, there was a significant reduction in loadings of BOD_5 and total suspended solids after the 1988 upgrade. A review of MOR data indicates violations for the following parameters between 1990 and 1994: dissolved oxygen, copper, zinc, and free cyanide. The city of Warren sewage system has a history of problems with SSO overflows. In 1991-1992 the city removed 10 SSOs (#’s 21-31), and between 1993 and 1995 removed 4 additional SSOs.

- Ohio EPA bioassays conducted in January 1992, October 1993, and August 1994 showed no significant toxicity to Warren WWTP effluents to either test organism. Total residual chlorine was detected at 0.42 and 0.31 mg/l in the 1994 bioassays. However, there was marginal mortality in the upstream samples in two of these bioassays. This segment of the Mahoning River from upstream of all WCI outfalls and leachates to downstream from LTV outfall 014 should be studied in more detail to evaluate the cause(s) of the instream toxicity.

RMI Co., Niles Plant (RM 33.63)

- This company is a manufacturer of titanium alloy in slabs, billets, and sheets and has one discharge to the Mahoning River. Wastewater includes non-contact cooling, process water, sanitary wastewater and stormwater. Treatment consists of two ponds and oil skimmer. A review of MOR data indicates a long history of violations for numerous parameters between 1989 and 1994 as follows: total suspended solids, pH, oil and grease, BOD, Fl, Ti, Al, and fecal coliforms. Loadings of total suspended solids, oil and grease, and Ti from 1986-1994 have remained relatively constant, but flow has gradually decreased since 1989 (Figure 16). The Ohio EPA emergency response section has on record six spills of various chemicals between 1990 and 1994 including PCB contaminated waste, oil, hydrofluoric acid, and “wastewater”.

Ohio Edison Co., Niles Plant (RM 30.00 -29.51)

- The Ohio Edison Company, Niles Plant generates electric power by employing two 108 megawatt coal fired steam generating units and one 30 mw combustion unit. The plant removes and returns to the Mahoning River between 100 and 150 mgd on the average between 1980 and 1994, with a 95th percentile cooling water discharge of 200 mgd over this time period (Figure 17). In addition to the cooling water discharge from outfall 001, the plant has two sanitary WWTP outfalls (003, 008) and a discharge from a fly ash and coal pile runoff detention pond (002). Treatment for outfall 002 consists of pH neutralization and sedimentation before discharge to the Mahoning River.

- The current NPDES permit allows for a Section 316(a) thermal water quality variance for the 001 thermal discharge. Both upstream and downstream real-time monitoring is used to maintain in-stream water temperature in the Mahoning River. The current permit indicates that no single stream daily temperature can exceed 33.3˚ C no more than 12 single day values between June 15-Sept 15 can exceed 31˚ C; and no more than 20 7-day moving average values can exceed 30.3˚ C. A review of MOR data indicated that following violations: outfall 002 (pH), outfall 003 (fecal coliforms, chlorine, ammonia-N), outfall 008 (fecal coliform, ammonia-N, CBOD). A review of Ohio EPA emergency response records indicates 11 reported spills from 1990 to 1993. Parameters reported included hydrochloric acid, fly ash, gasoline, and “wastewater”.

City of Niles WWTP (RM 28.86)

- The City of Niles WWTP was upgraded in 1988 to a secondary WWTP. Treatment processes include grit removal, oxidation ditch with internal clarifier, and chlorine contact. The plant has a problem with by-passing at the WWTP due to elevated peak flows. For the period from January to August 1994 a total of 145.3 million gallons of partially treated wastewater was by-passed at the WWTP to the Mahoning River. A review of MOR data from 1989 to 1994 indicates permit violations for the following parameters: total suspended solids, pH, cadmium, copper, lead, zinc, mercury, oil and grease, CBOD, and fecal coliforms. A review of long term loadings data indicates a significant reduction in the loadings of BOD, total suspended solids, and ammonia-N after the 1988 upgrade, with relatively constant loadings for these parameters from 1988 to 1994 (Figure 18). However, peak flows have significantly increased since 1988 (Figure RDD 012), which may indicate hydraulic problems with the new WWTP design.

- Results of two Ohio EPA bioassays conducted in April and May, 1994, showed no significant toxicity in the Niles WWTP effluents. However, chlorine was detected at 0.31 mg/l in the August effluent sample.

Little Squaw Creek - City of Girard WWTP (25.28)

- The city of Girard WWTP was built in 1962 and upgraded to a secondary WWTP in 1988.

Current wastewater treatment includes grit chamber, pre-aeration, primary settling, tricking filter, final clarifiers, equalization basin, and chlorine contact. The sewerage system has five CSO discharge locations under NPDES permit. A review of long term loadings data indicates a significant reduction in loadings of total suspended solids, ammonia-N, BOD, oil and grease, and lead after the 1988 upgrade (Figure 19). WWTP average flows have declined from the mid 1980's to 1994. A review of MOR data indicates permit violations for the following parameters between 1989 and 1994: total suspended solids, pH, cadmium, copper, lead, mercury, zinc, chromium, oil and grease, and fecal coliforms.

- Results from an Ohio EPA bioassay conducted on Girard WWTP effluent in April 1994 showed 60% to 80% toxicity to fish in effluent samples and 50% toxicity in mixing zone samples. In a September 1994 bioassay performed by Ohio EPA personnel, no significant toxicity to either test organism was observed in Girard WWTP effluent samples.

North Star Steel of Ohio (RM 23.60)

- The facility ceased discharge and tied into the city of Youngstown sewer system in 1991.

City of Youngstown WWTP (RM 19.43)

- The City of Youngstown WWTP is the largest municipal discharger to the Mahoning River, with a design flow of 35.0 mgd. A primary WWTP was built in 1957 and construction for a secondary WWTP was completed in 1988. Current treatment includes bar screen, grit chambers, primary clarifiers, activated sludge, and trickling filters for flow up to 35.0 mgd. Flow in excess of 35 mgd bypasses the aeration system and passes through microscreens to a chlorine contact tank. Blended effluent from the two systems is treated with chlorine and enters a cascade aeration system. Final treatment is to chlorine tank with dechlorination.

- The sewerage system has up to 96 CSOs and the City and the State are negotiating a Consent Decree to have the city address both SSO and CSO problems. A review of MOR data indicates permit violations from 1989 to 1994 for pH, mercury, chlorine, copper, and phenolics. A review of long term effluent loading data in Figure 20, indicates a significant reduction in loadings of total suspended solids, BOD and ammonia-N after the 1988 upgrade, with a slight reduction in average effluent flow from 1991 to 1994.

- Ohio EPA personnel conducted two bioassays in May and September, 1994, on the Youngstown WWTP effluent and mixing zone. No significant toxicity was observed to either test organism in these bioassays.

City of Campbell WWTP (RM 15.89)

- The City of Campbell WWTP was upgraded from a primary plant to a secondary WWTP in March, 1988. Treatment processes include screening and grit removal, activated sludge aeration using two oxidation ditches, secondary clarification, and chlorination. The sewage system is a separate system with no known overflows. A review of MOR data from 1989 to 1993 indicates permit violations for total suspended solids, dissolved oxygen, cadmium, mercury, zinc, nickel, copper, pH, and chlorine. A review of long term loadings data in Figure 21 indicates both a reduction in flow and for total suspended solids, BOD, and ammonia-N after the 1988 upgrade.

- In 1989, there were alleged reports of a nearby industry, Finishing Corporation, illegally dumping strong acids, alkalis, and detergents into the WWTP's sewer system (influent). The illegal dumping was alleged to be in high enough concentration to kill the bacteria used by the WWTP to treat sewage. During the 1994 survey another company, Cold Metals, allegedly dumped oil into the Campbell WWTP sewer system.

- The Ohio EPA conducted two bioassays in 1994 on the Campbell WWTP effluent. In May, 45% to 75% toxicity in effluents was reported. No significant mortality was reported in the June bioassay, but total residual chlorine was measured at 0.31 mg/l in the effluent.

City of Struthers WWTP (RM 14.32)

- The city of Struthers WWTP is a secondary WWTP with a design flow of 6.0 mgd. In March, 1987 the plant was upgraded from a primary to secondary treatment. Current treatment processes include screening and aerated grit removal, flow equalization, primary settling, tricking filtration, secondary clarification, and chlorination. There are two bypasses, the Bridge Street equalization tank and the plant equalization tank, and both overflow to the Mahoning River. A review of MOR data from 1990 to 1994 indicates permit violations for oil and grease, chlorine, pH, total suspended solids, copper, and fecal coliforms. A review of long term loadings data in Figure 22 indicates about a 50 percent reduction in BOD loadings after the 1988 upgrade, but total suspended solids and ammonia-N reductions were not as significant. Average effluent flows have increased significantly from the early 1980’s to 1994, with average flows close to the 6.0 design capacity.

- A May 1994 bioassay conducted by Ohio EPA personnel reported no significant toxicity to Struthers WWTP effluent. However, 80% to 85% fish toxicity in the effluent was observed in a June 1994 bioassay along with marginal toxicity observed in the upstream sample.

Village of Lowelville WWTP (RM 12.22)

- The village of Lowelville WWTP was the final major WWTP in the Mahoning River valley to upgrade to secondary treatment, which became final in 1992. The new treatment plant consists of oxidation ditch, flow equalization, clarification, and chlorination. The new plant receives about 40,000 gallons of leachate two or three times a month from the BFI Carbon Landfill. A review of MOR data from 1993 and 1994, after the upgrade, indicates permit violations for CBOD, pH, nickel, mercury, oil and grease, chlorine, and fecal coliforms. A review of long term loadings data in Figure 23 indicates a significant reduction in BOD and ammonia-N after the 1992 upgrade, however, peak flows also increased. A 1993 compliance inspection noted problems with plant construction including a poorly operating grit chamber. The village is also in need of a Class III operator.

- An April 1994 bioassay conducted by Ohio EPA personnel reported no significant toxicity to Lowelville WWTP effluent.

Mosquito Creek

Trumbull Co. Mosquito Creek WWTP (RM 30.64; 7.1).

- The Mosquito Creek WWTP is a 4.2 mgd design plant that discharges to Mosquito Creek at RM 7.1. The WWTP is owned and operated by the Trumbull County Board of Commissioners. The last major upgrade was in 1983. The current treatment consists of screening, flow equalization, grit removal, primary sedimentation, aerobic activated sludge, nitrification, clarification, chlorination, de-chlorination, and post-aeration.

- A review of MOR data from 1990 to 1994 indicates violations for the following parameters:

mercury, ammonia-N, cadmium, lead, oil and grease, pH, and CBOD. Long term loadings data as shown in Figure 24 indicates a gradual increase in effluent flow from 1986 to 1994, however, loadings for total suspended solids BOD, ammonia-N, and lead have remained relatively constant.

General Electric Niles Glass Plant (RM 30.64; 0.8).

- The General Electric Company, Mahoning Glass Plant manufactures glass lenses and reflectors for automobile headlamps. The discharge includes contact cooling water and stormwater. The facility has a history of problems with oil and grease. Process water is pretreated and discharged to the Niles WWTP.

Meander Creek

Mahoning County Meander Creek WWTP (RM 30.27; 1.98).

- The Meander Creek WWTP is a 4.0 mgd design plant that discharges to Meander Creek at RM 1.98, just below the Meander Creek Reservoir dam. The reservoir is used by the Mahoning Valley Sanitary District (MVSD) as a source of public drinking water for the city of Youngstown. For most of the year the flow of Meander Creek is stopped by the reservoir dam, thus Meander Creek has a zero low flow and does not provide any dilution for the Meander Creek WWTP effluent most of the year. Although the discharge is in Trumbull County, the Meander Creek WWTP is owned and operated by the Mahoning County Board of Commissioners.

- The Meander Creek WWTP was built in 1976 and treatment processes include prechlorination, grit removal, pure oxygen activated sludge, two stage, clarification, rapid sand filtration, and ozone disinfection. The plant is equipped for phosphorus removal. The sewage system is separate.

- A review of MOR data indicates violations for the following parameters between 1990 and 1994: pH, BOD, total suspended solids, ammonia-N, cadmium, copper, lead, mercury, zinc, nickel, and fecal coliforms. A review of long term MOR data indicates relatively constant flow from 1983 to 1994 (Figure 25). Median loadings of total suspended solids have more than doubled from 1988 to 1994 as compared to pre-1998 loadings.
- Ohio EPA conducted four bioassays on Meander Creek effluent, two in 1990, and one each in 1993 and 1994. No significant mortality was observed. From March 1992 to April 1993, the entity conducted biomonitoring as part of a permit requirement. Two of 13 bioassays resulted in a 1.1 TU_c or > 1.75 TU_c to fish. Three of the 13 bioassays resulted in 1.2 TU_c, 2.0 TU_c, or 1.0 TU_c to *Ceriodaphnia*.. The June 1992 bioassay reported significant toxicity in the near and far field mixing zones.

Mill Creek

Boardman WWTP (RM 21.63, 9.6)

- The Mahoning County Boardman WWTP was originally constructed in 1962 as a activated sludge plant. In 1987 the plant was upgraded to achieve a higher effluent quality and improve treatment and handling of sludge. The upgrade included advanced secondary treatment, nitrification, disinfection and post-aeration. The plant design flow was increased from 3 MGD to 5 MGD (Figure 26). The plant disposes of sludge via landfilling. It also has the option of land application but that option has not been utilized for several years.

- The NPDES permit has summer and winter limitation for total suspended solids(13,30), Ammonia (1,5) and cBOD (10,25). Mahoning County was referred to the AGO's for violations at the Boardman and Meander WWTPs. A consent order was signed in January 1994 in which the county was required to hire class IV certified operators, submit MOR and bioassays on time, develop a plan to monitor mercury, and to develop a laboratory QA/QC program.

- A review of the Boardman Operation and Maintenance Manual indicates that the collection has a total of 12 by-passes and overflows. This was highlighted in the last compliance evaluation inspection(April 25,26, 1994 and August 22,23, 1994) and requested the county to identify any problems with them. The county responded that the overflow flows into neighboring community sanitary sewers and that they report all by-passes as required by their NPDES permit.

- The compliance history of Boardman WWTP (number of months reporting violations at least once during that month) from 1989 to 1994 includes violations for ammonia(6), BOD_5(2), cadmium(3), chlorine(3), copper(10), cyanide(6), dissolved oxygen(1), fecal coliform(2), mercury(11), oil and grease(3), and total suspended solids(3).

- Bioassays conducted by Ohio EPA personnel on Boardman WWTP effluents resulted in no significant toxicity in 1988 (2 bioassays) and in August 1994. An April 1994 Ohio EPA bioassay showed marginal effluent toxicity. From December 1990 to June 1993 biomonitoring was conducted as a permit requirement by the entity. One of six bioassays resulted in a 1.8 Tu_c to both fish and *Ceriodaphnia*.. Three entity bioassays resulted in significant toxicity to fish in the mixing zone and two entity bioassays resulted in significant toxicity to *Ceriodaphnia* in the mixing zone.

Yankee Creek

Trumbull County - Brookfield WWTP (RM 0.42)

- The Trumbull County-Brookfield WWTP (RM 0.42) is a three stage vertical loop reactor plant with bar screen, aerated grit removal, secondary clarifiers, chlorination and dechlorination. Solids are managed using a gravity thickener, aerobic digestion, and sludge drying beds. The current expansion, an upgrade from a primary plant, was completed in 1989. The design flow of the plant is 1.3 MGD (Figure 27). Less than five percent of the plant flow is derived from industrial sources. The collection system is all separate sewers.

- Annual flows have been rising steadily. COD and ammonia-N loadings have not changed appreciably in the last ten years. Total suspended solids (TSS), BOD_5/$cBOD_5$, and total residual chlorine loadings dropped significantly following the 1989 upgrade. The compliance history of Brookfield WWTP (number of months reporting violations at least once during that month) from 1991 to 1994 include $cBOD_5$(3), chlorine(1), copper(2), lead(5), nickel(1), total suspended solids(8), and zinc(5).

- Ohio EPA personnel have not conducted any bioassays on the Brookfield WWTP. However, biomonitoring was required in their recent permit. Three of 14 bioassays conducted between May 1991 and February 1993 resulted in measured toxic effects to fish of 1.0 TU_a, 1.4 TU_c, and 1.6 TU_c; and to *Ceriodaphnia* of 2.8 TU_c, 5.6 TU_c, and 5.7 TU_c. Additionally, three other tests resulted in significant toxicity to fish in effluent samples. Mixing zone samples were significantly toxic to fish in three bioassays, but not to *Ceriodaphnia*..

Little Yankee Creek

Hubbard WWTP (RM 4.59)

- The Hubbard WWTP (RM 4.59) is a multiple channel orbital aeration plant with bar screens, grit removal,, settling, chlorination, dechlorination, and post-aeration. Solids are treated via aerobic digestion, polymer sludge conditioning, and belt press. The facility was upgraded in 1989. The previous plant was a secondary trickling filter design with flows that were averaging twice the 0.8 MGD design. The current design flow of the plant is 2.1 MGD. Less than one percent of the plant flow is derived from industrial sources. The collection system is all separate sewers.

- Annual flows were steady until the 1989 upgrade and have been rising steadily ever since. Total suspended solids (TSS), ammonia-N, and $cBOD_5$ concentrations declined significantly following the 1989 upgrade (Figure 28). Total residual chlorine values have been rising steadily matching the increase in flows. Total zinc values have been highly variable over the past five years. The compliance history of Hubbard WWTP (number of months reporting violations at least once during that month) from 1989 to 1994 includes ammonia(3), BOD_5(2), $cBOD_5$(2), cadmium(3), chlorine(6), copper(2), fecal coliform (18 in 1989), dissolved oxygen(3 in 1991), flow(1), mercury(2), pH(3), and total suspended solids(6).

- Three of four bioassays (May and November 1990, June 1994) conducted by Ohio EPA personnel resulted in no significant toxicity to either test organism. However, the most recent bioassay conducted in June 1994 by the Ohio EPA resulted in lethal conditions to *Ceriodaphnia* in the grab effluent, composite effluent, and mixing zone samples of Hubbard WWTP's effluent. A 1.3 TU_a was reported in this bioassay. As part of a permit requirement Hubbard WWTP effluent was sampled in 1991 and 1992. One of 13 bioassays resulted in a 1.8 TUc to fish. Two of these entity bioassays resulted in a 1.8 TU_c or a 2.1 TU_c to *Ceriodaphnia.*

Pymatuning Creek

Kraft Dairy Group – Farmdale Plant

- The Kraft Dairy Group produces cottage cheese and sour cream. Wastewater is produced from: backwash waters from the potable water treatment system; washings from cheese curd; waters from the whey evaporator; cleaning of process equipment; washwaters from milk truck cleaning and; sanitary wastes.

- Process waters flow through a screen to remove excess solid material and then into a concrete pit. This pit also contains backwash waters from the potable water treatment system and sanitary wastes following treatment in a 2500 gallon aeration plant. The combined wastewaters are pumped to two 18,000 gallon storage tanks. Wastewaters are then directed to a spray field (55 acres available) consisting of seven laterals with eight spray nozzles per lateral. Usually only one lateral and four nozzles are operated at any one time and the fields are rotated to avoided overloading. The spray fields are vegetated with grasses, mowed and the grass clippings removed. Runoff from the fields is directed via ditches to three lagoons operated in series. The lagoons are aerated with a fine bubble diffuser system which was installed in late 1993. The outfall from the lagoon(s) is metered and discharged to a ditch that flows along abandoned RR tracks before entering Pymatuning Creek.

- The Kraft dairy discharge creates nuisance conditions in the ditch immediately downstream from the 001 discharge. The nuisance conditions include color, odor and sludge deposits. These conditions are not present in the marsh/swamp prior to entering Pymatuning Creek.

- Average wastewater flow at Kraft Dairy is 200,000 gpd with a permitted load of 80/200 kg/day BOD and 120/310 kg/day total suspended solids (Figure 29).

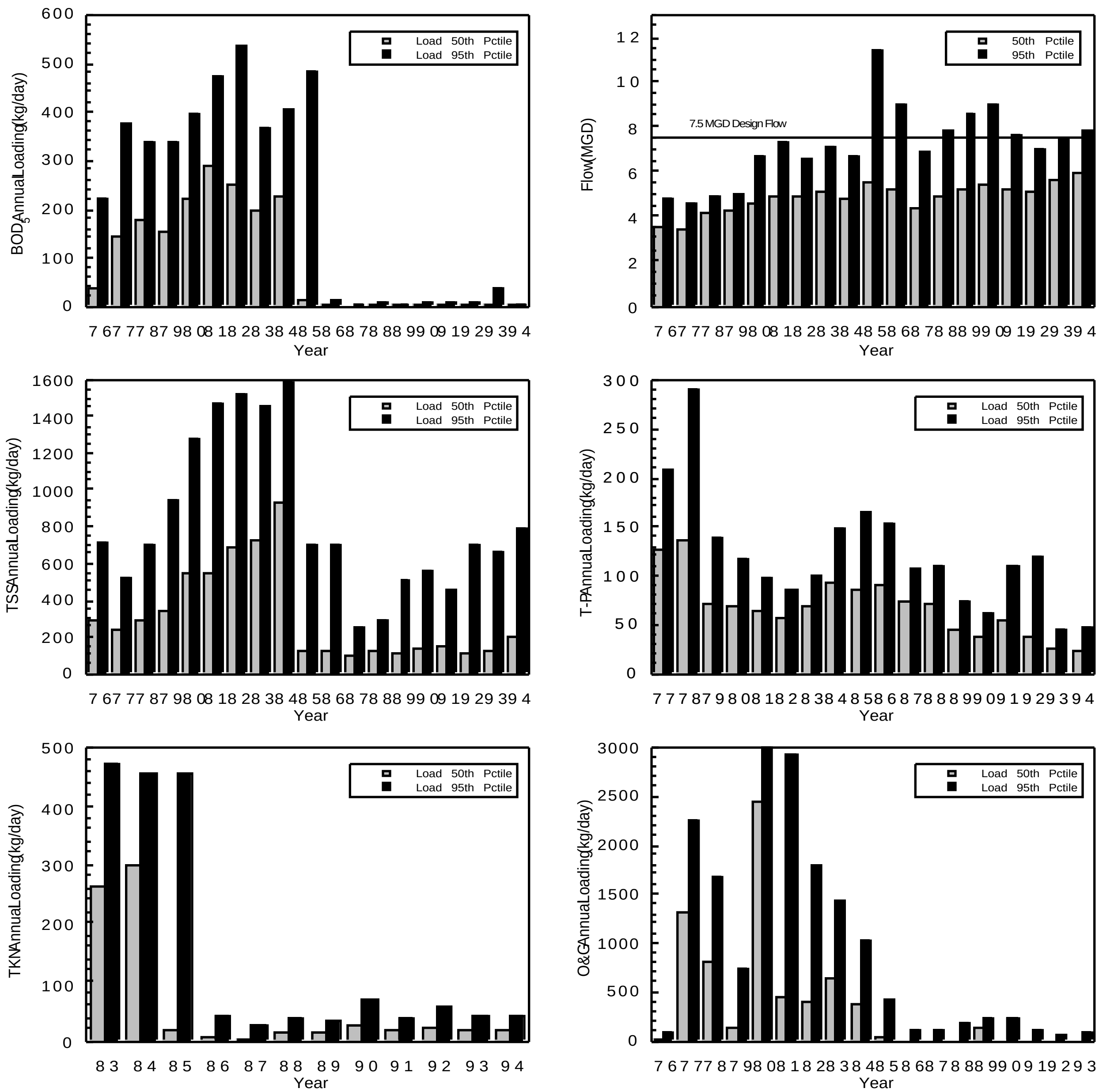


Figure 8. Median and 95th percentile annual loadings (kg/day) of BOD_5, total suspended solids (TSS), total kjeldahl-N (TKN), total phosphorus, oil & grease, and flow (MGD) for the Alliance WWTP 001 outfall.

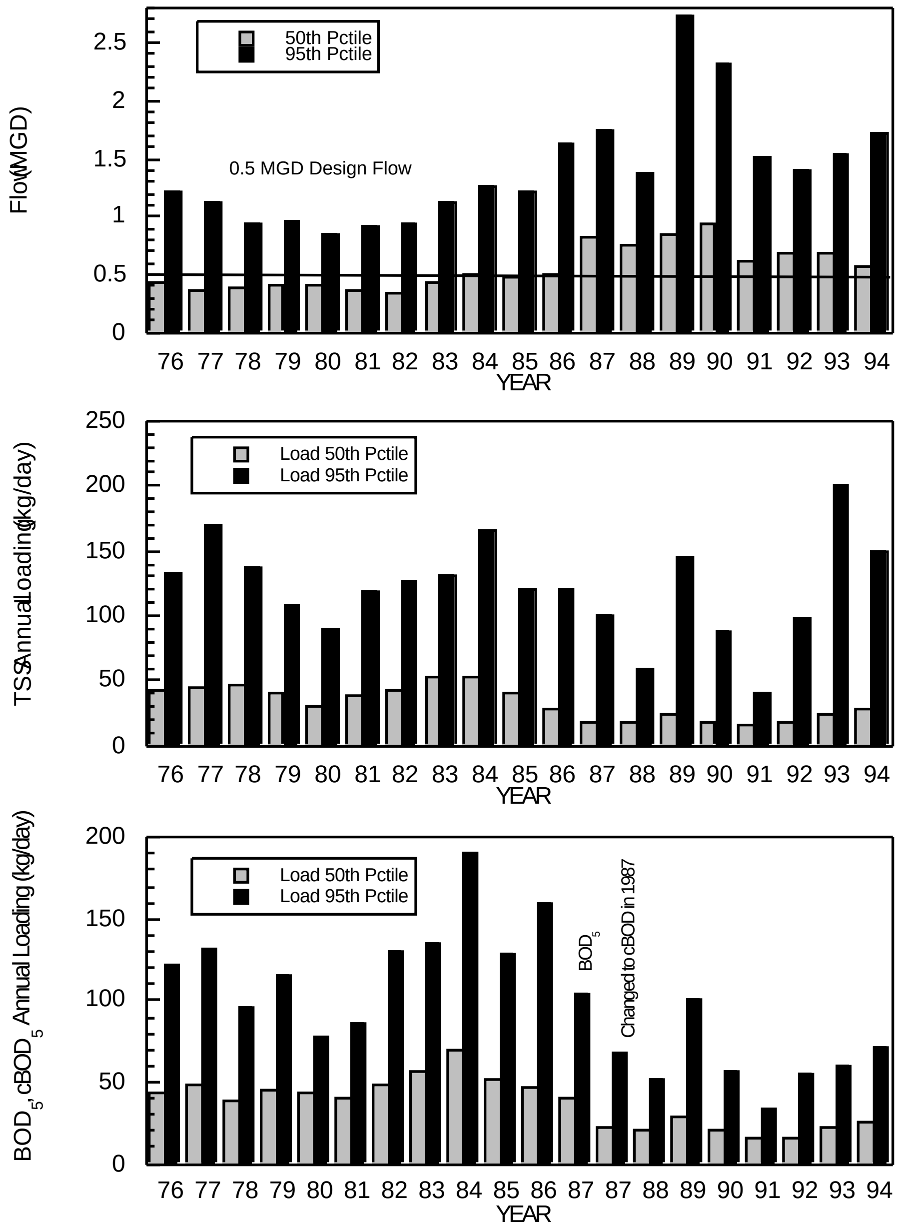


Figure 9. Median and 95th percentile annual loadings(kg/day) of BOD_5,$cBOD_5$, total suspended solids (TSS), and flow (MGD) for the Newton Falls WWTP 001 outfall.

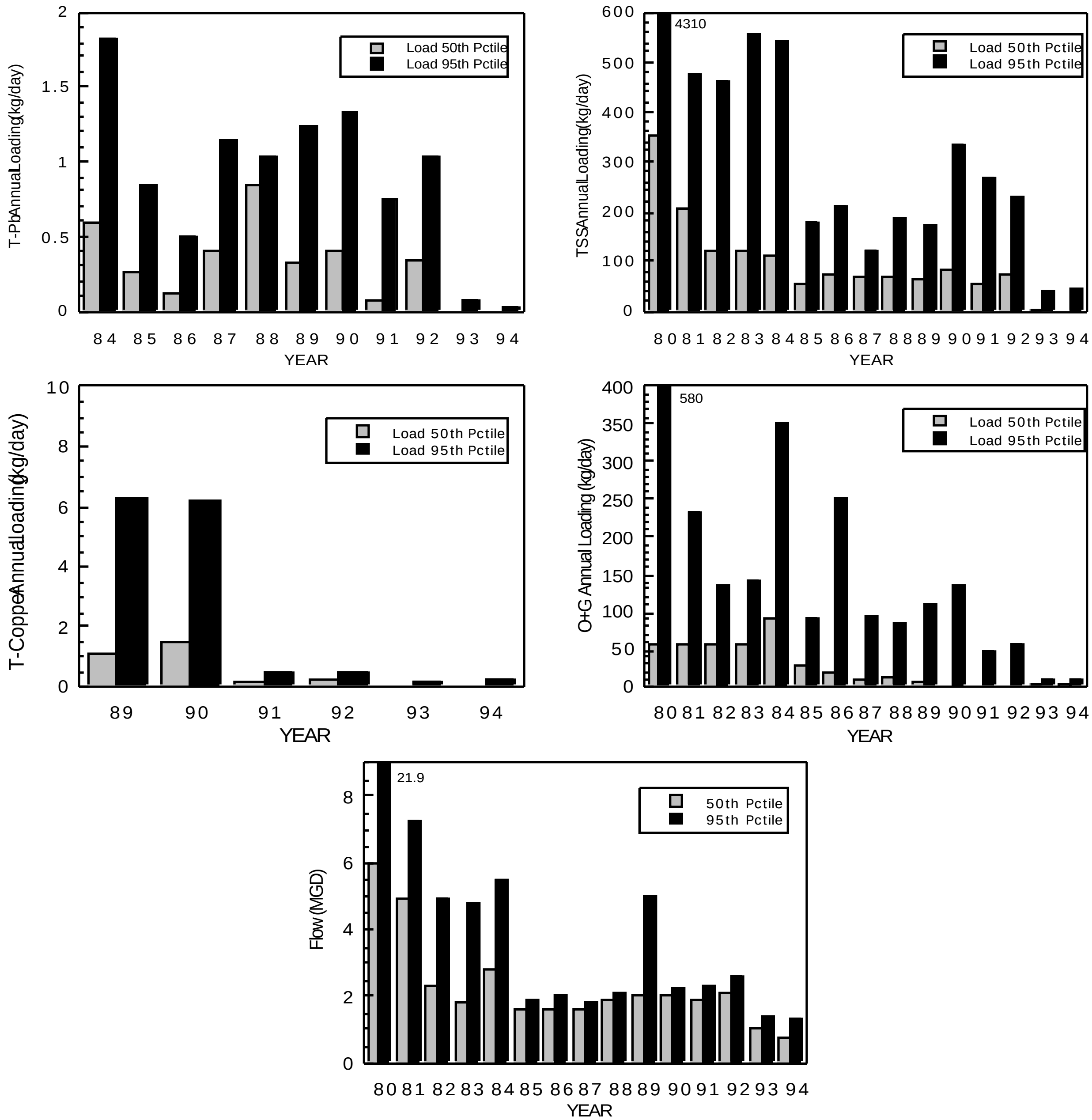


Figure 10. Median and 95th percentile annual loadings (kg/day) of total suspended solids (TSS), total copper, total lead, oil and grease, and flow (MGD) for the CSC Ind., Copperweld Steel 001 outfall.

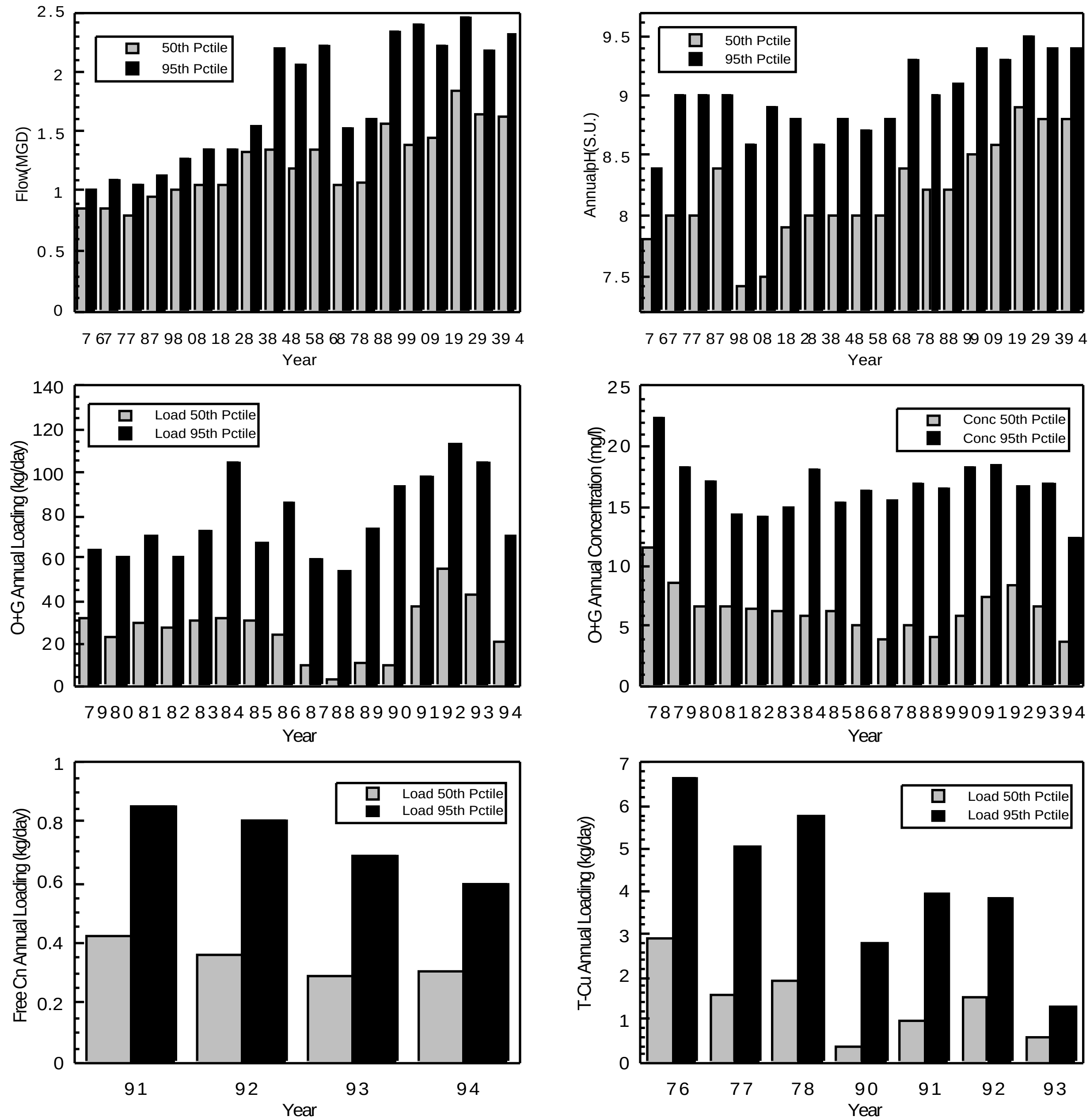


Figure 11. Median and 95th percentile pH, oil and grease concentrations, and annual loadings (kg/day) of total copper, free cyanide, oil and grease, and flow (MGD) for the Thomas Strip Steel 001 outfall.

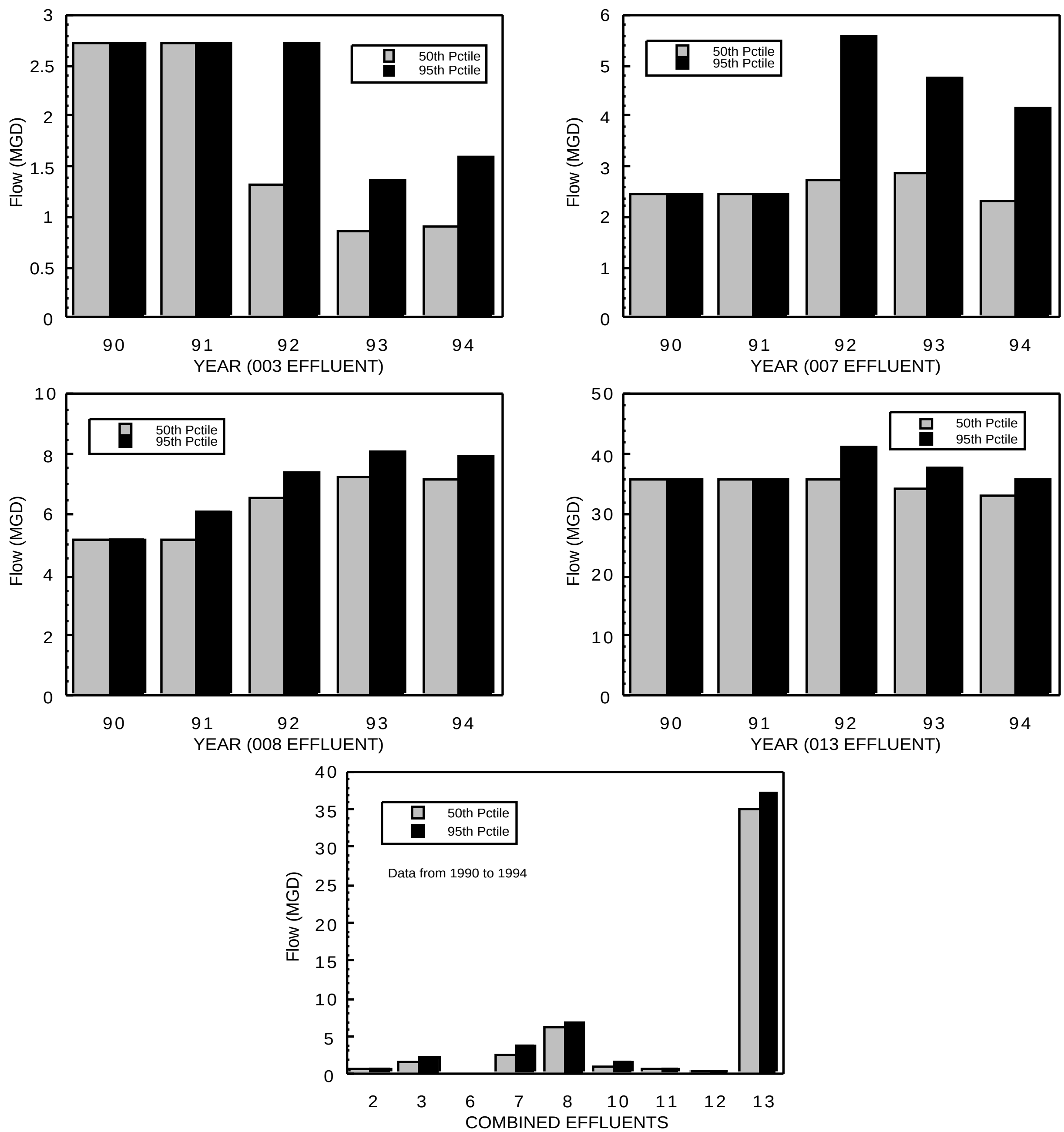


Figure 12. Median and 95th percentile annual flow (MGD) for the Warren Consolidated Industries (WCI) outfalls 003, 007, 008, 013, and combined outfalls.

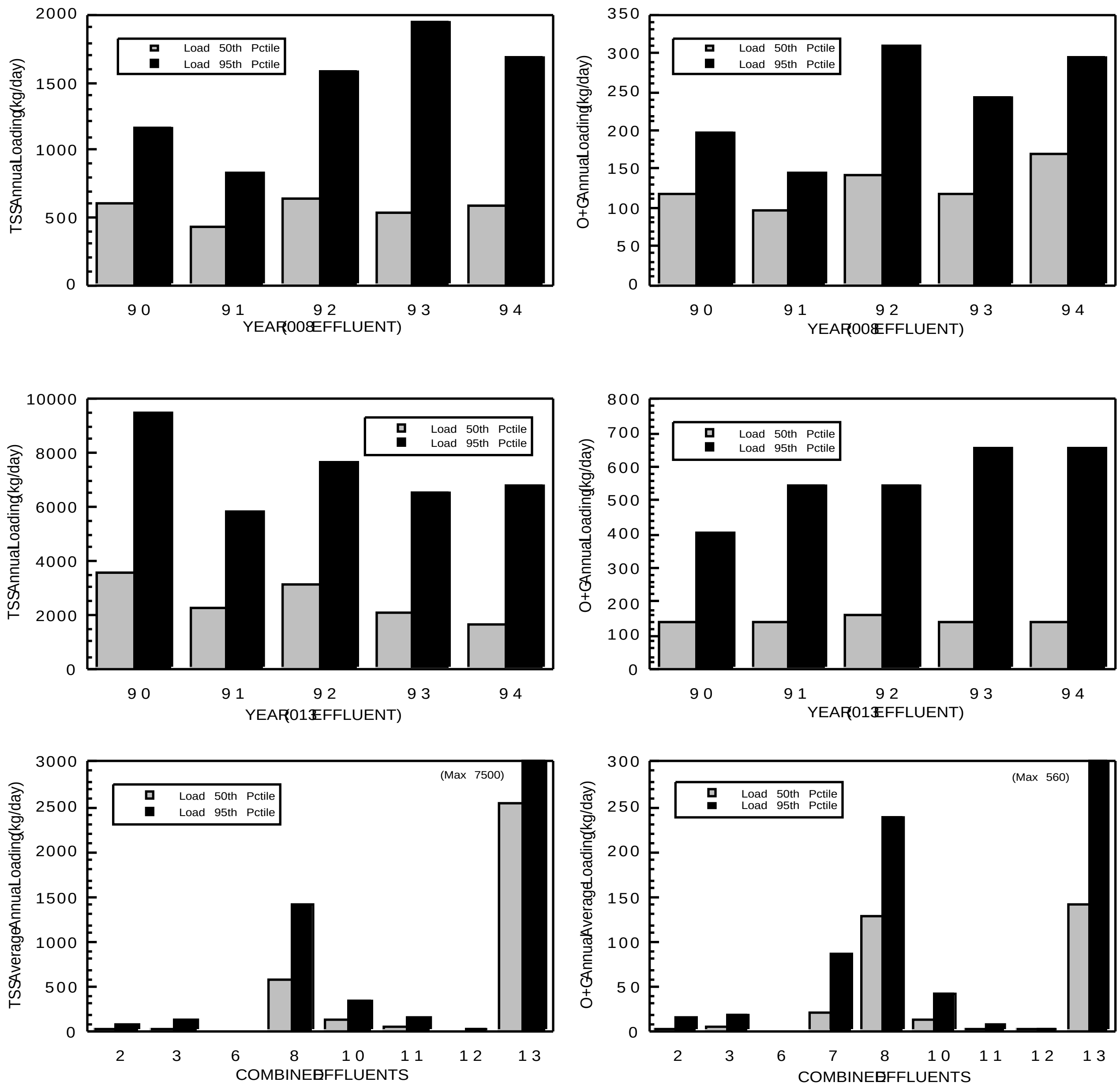


Figure 13. Median and 95th percentile annual loadings (kg/day) of total suspended solids (TSS) and oil & grease for the Warren Consolidated Industries (WCI) outfalls 008, 013, and combined outfalls.

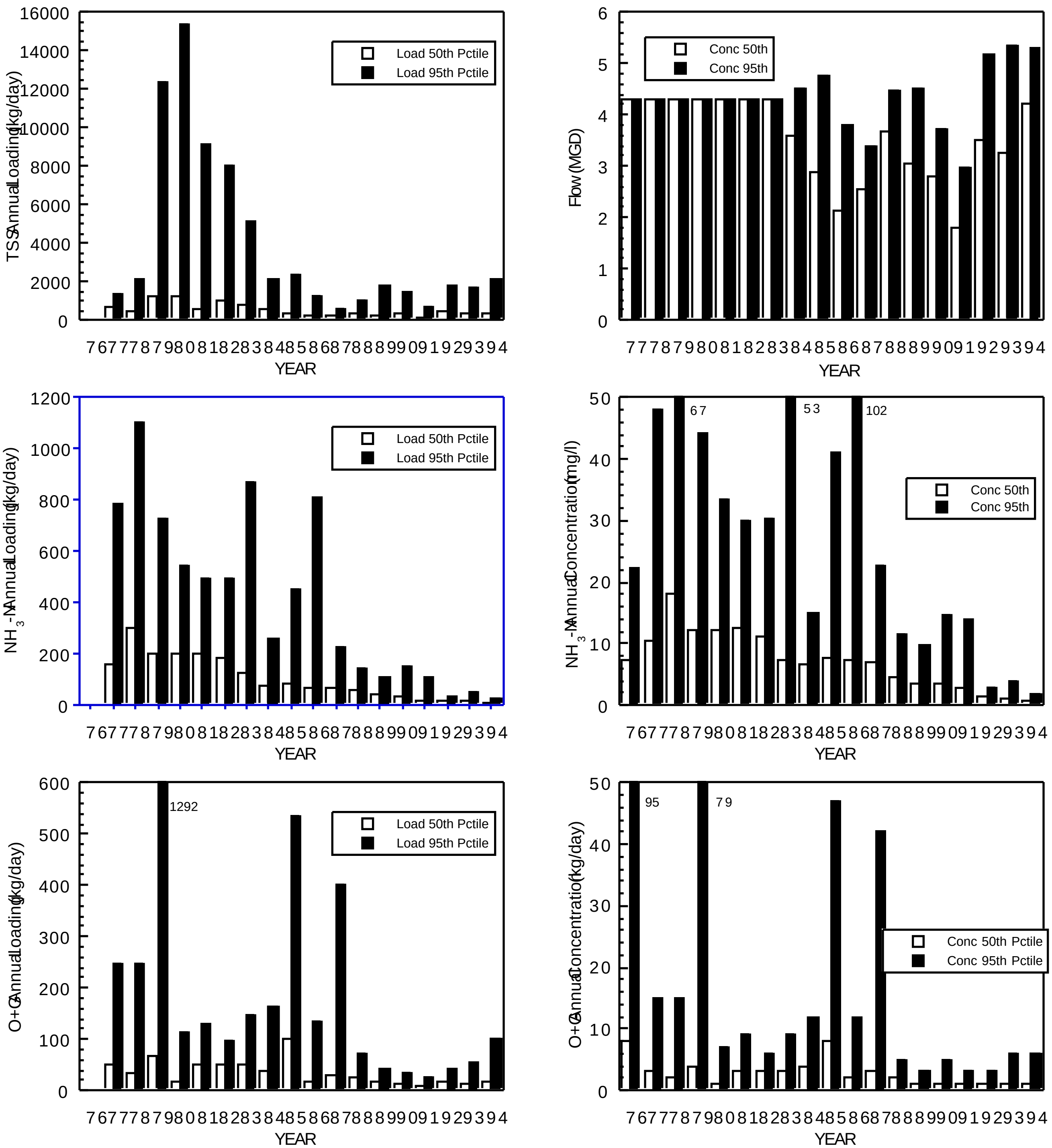


Figure 14. Median and 95th percentile annual concentrations (mg/l) of ammonia-N, and oil and grease, and annual loadings (kg/day) of ammonia-N, total suspended solids (TSS), and oil and grease, and flow (MGD) for the Warren LTV Coke 014 outfall.

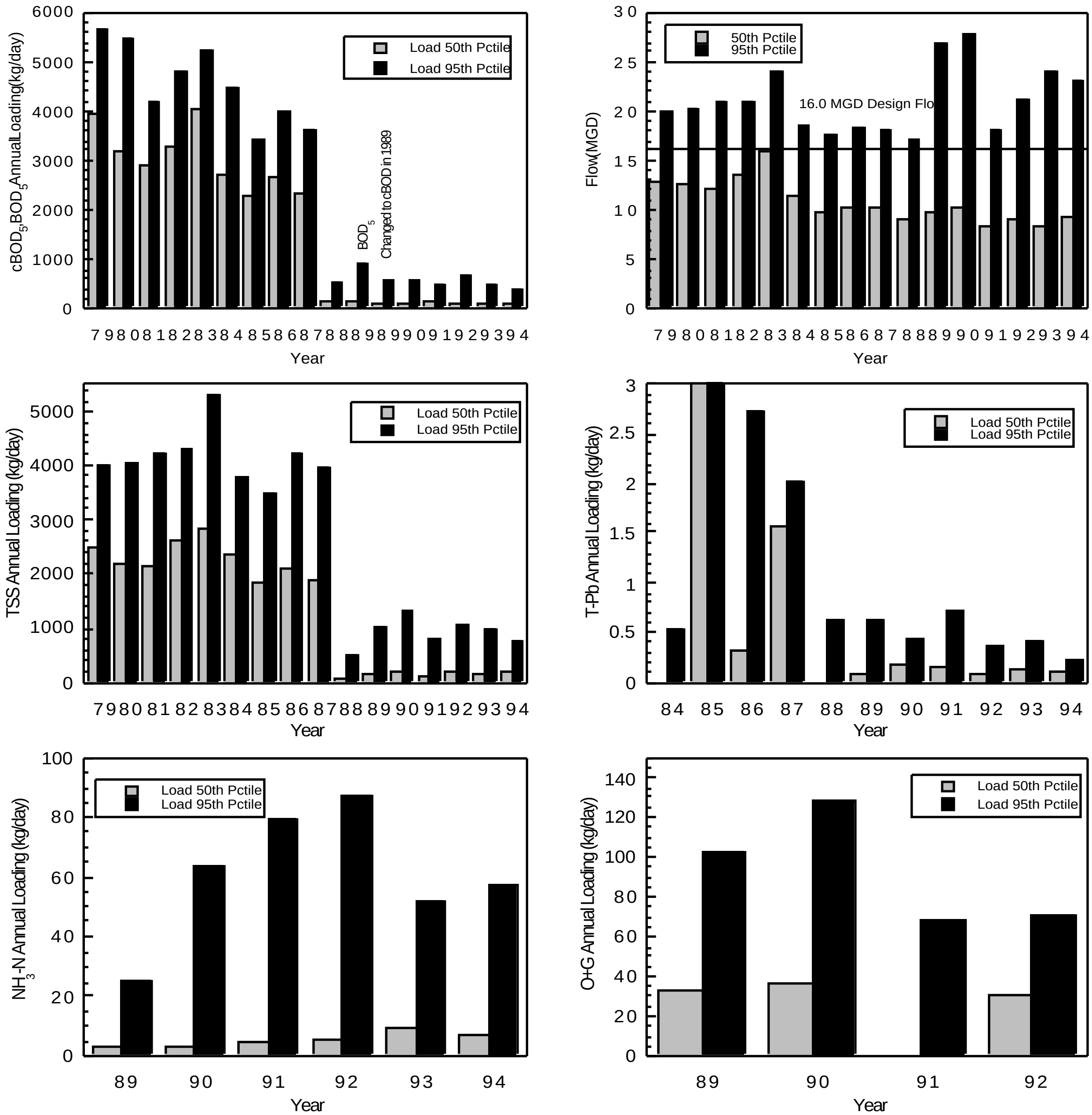


Figure 15. Median and 95th percentile annual loadings(kg/day) of BOD_5/$cBOD_5$, total suspended solids (TSS), ammonia-N, total lead, oil and grease, and flow (MGD) for the Warren WWTP 001 outfall.

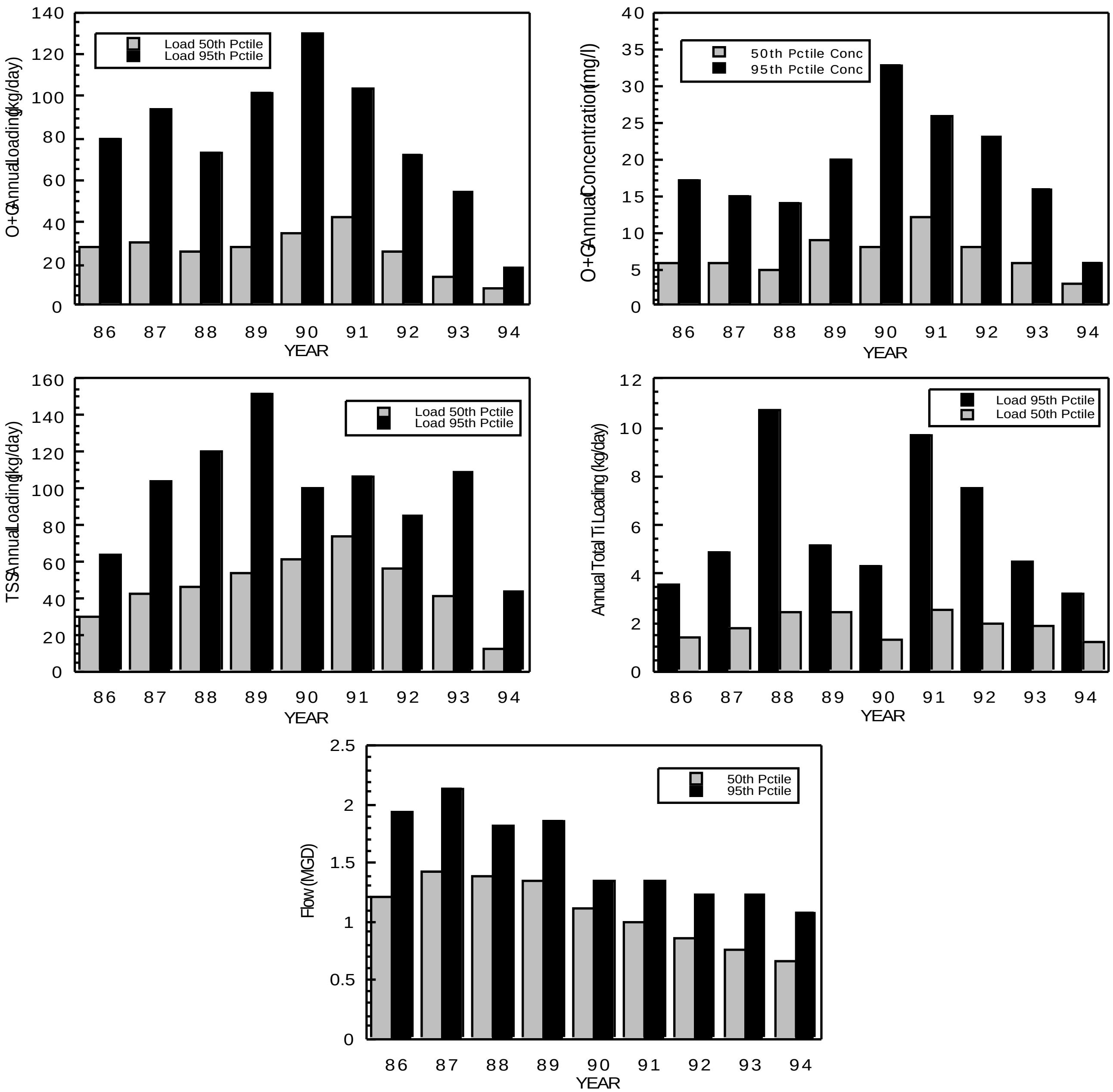


Figure 16. Median and 95th percentile annual loadings (kg/day) of total suspended solids (TSS), ammonia-N, total titanium, oil and grease; annual concentrations (mg/l) of oil and grease; and flow (MGD) from the Niles RMI 001 outfall.

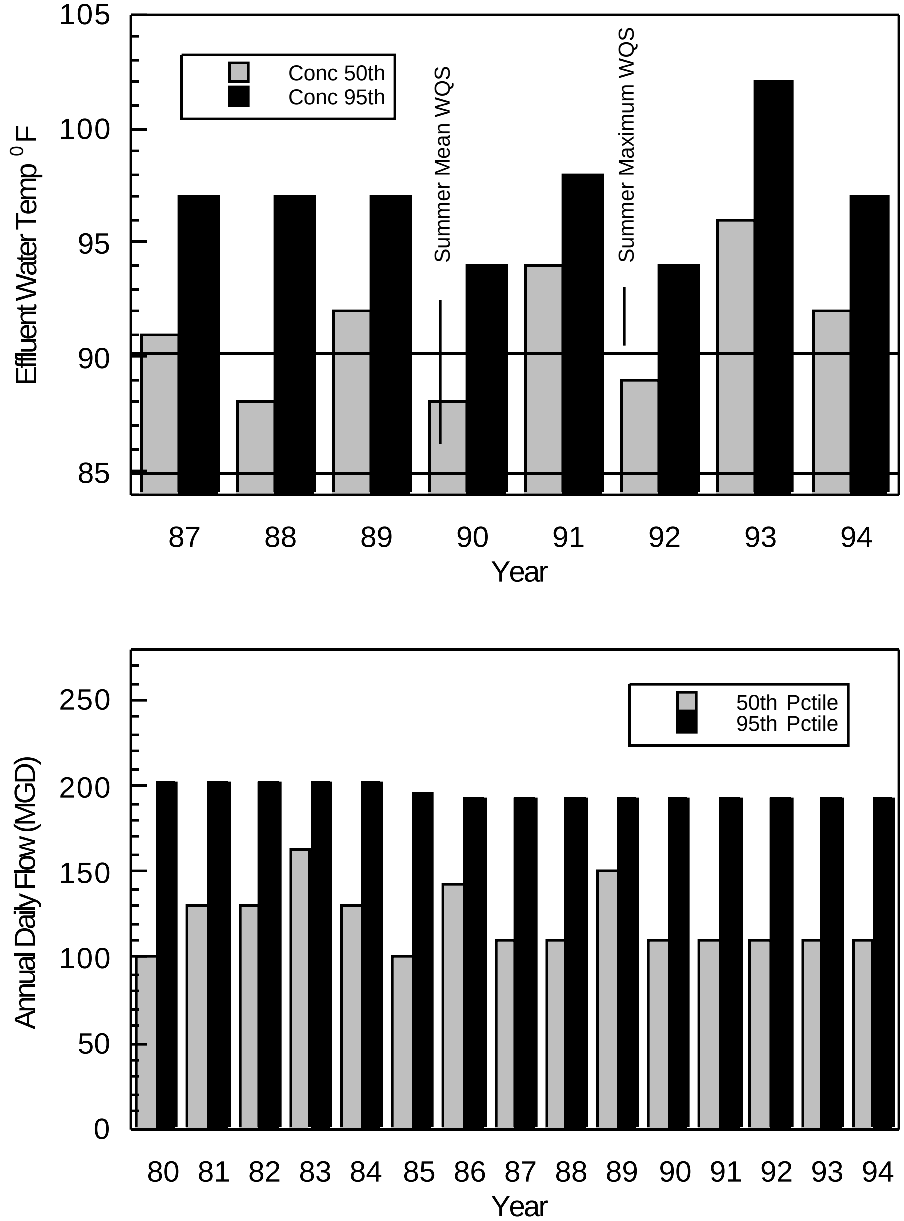


Figure 17. Median and 95th percentile annual effluent flow (MGD) and third quarter (July to September) temperature (˚F) for the Ohio Edison Niles 001 outfall.

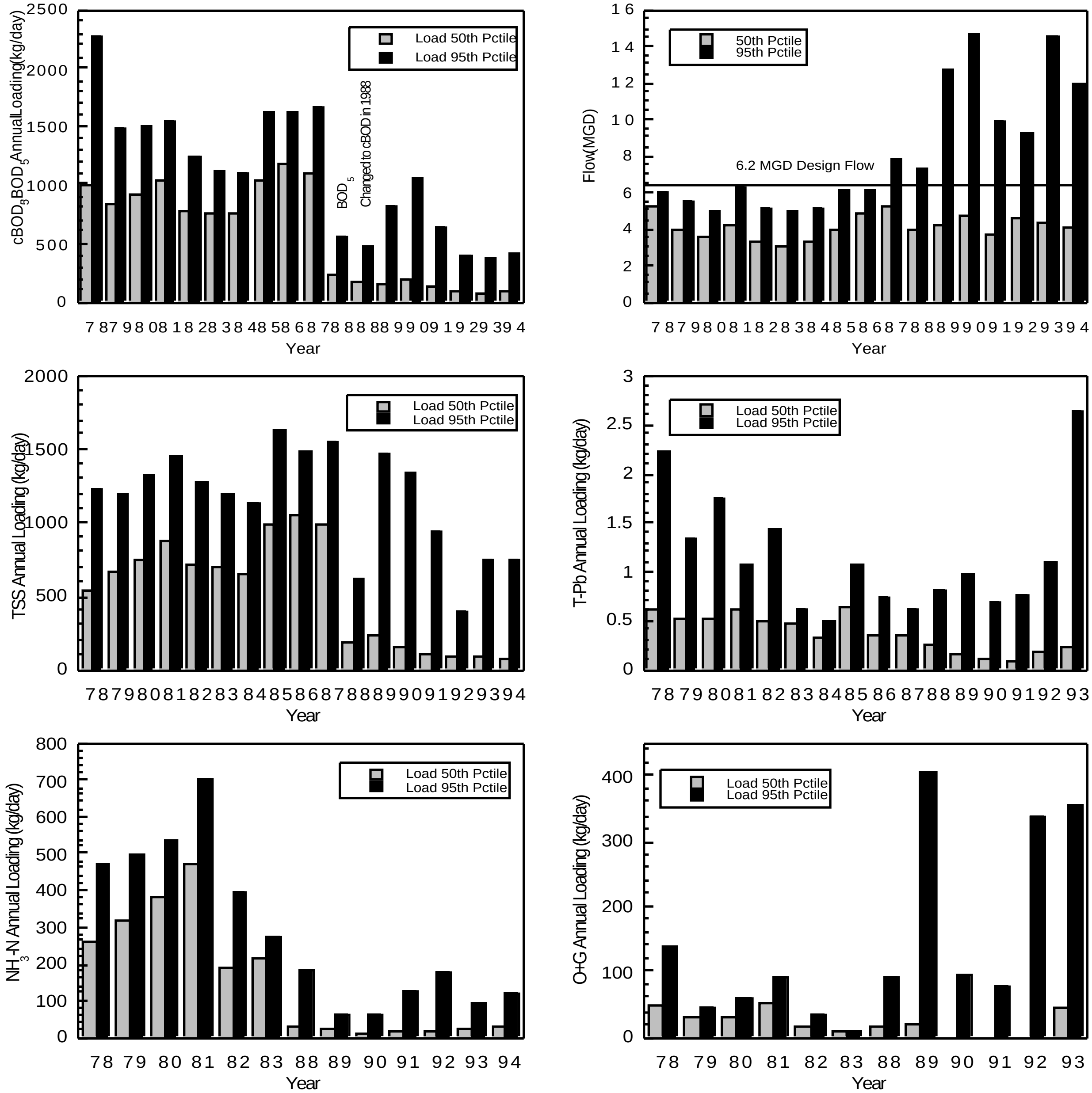


Figure 18. Median and 95th percentile annual loadings(kg/day) of BOD_5/$cBOD_5$, total suspended solids (TSS), ammonia-N, total lead, oil and grease, and flow (MGD) for the Niles WWTP 001 outfall.

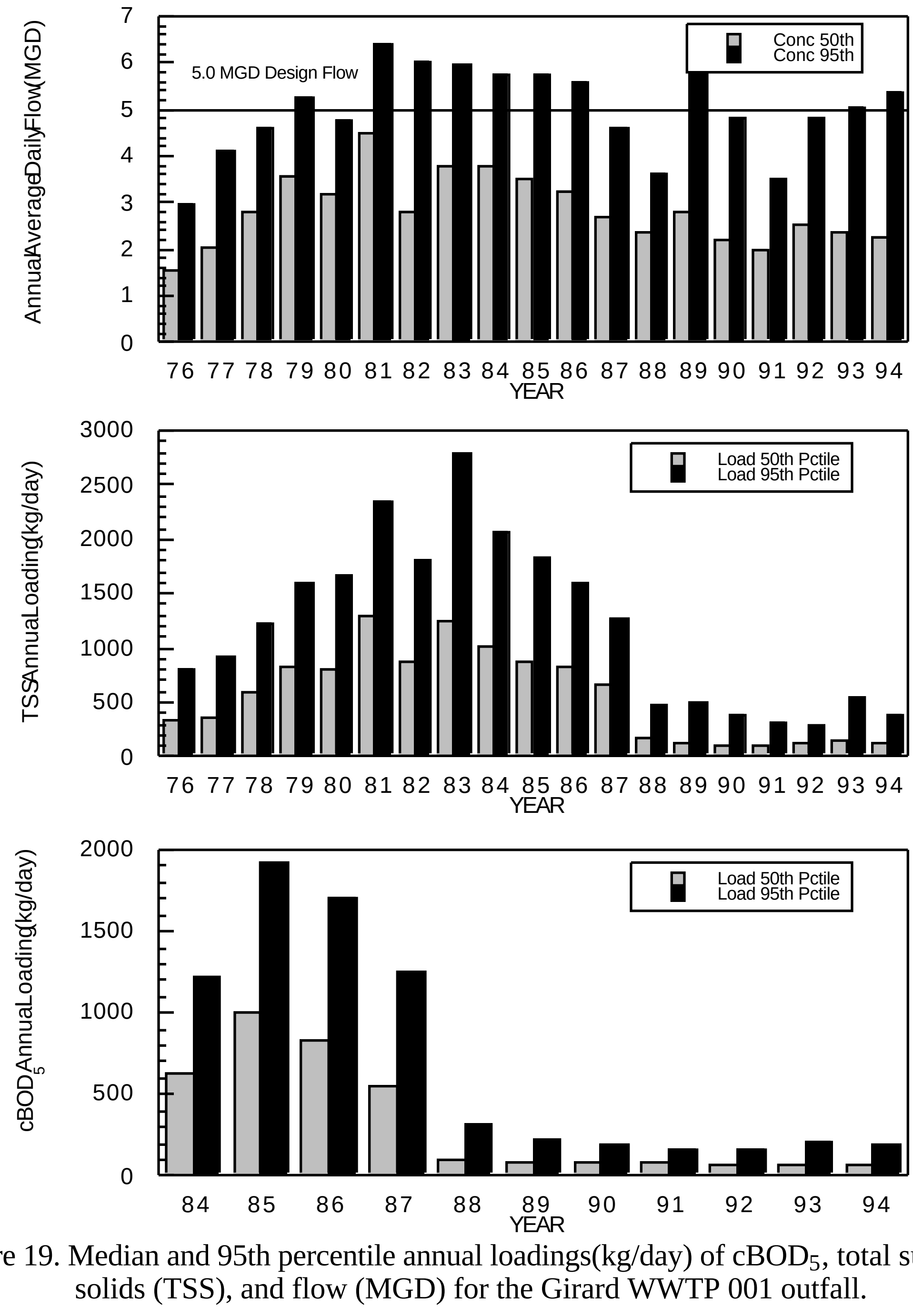


Figure 19. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), and flow (MGD) for the Girard WWTP 001 outfall.

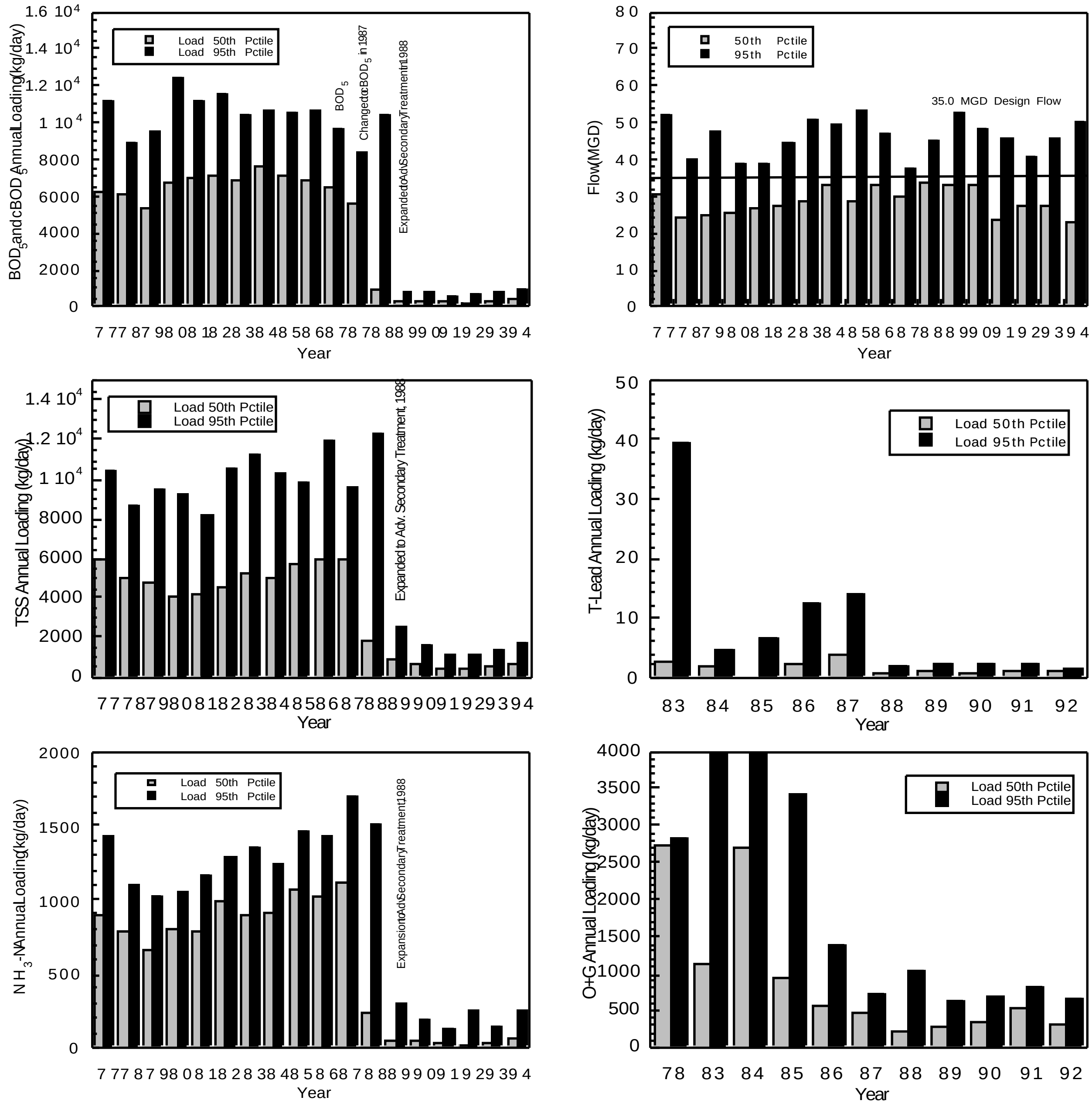


Figure 20. Median and 95th percentile annual loadings(kg/day) of BOD_5/$cBOD_5$, total suspended solids (TSS), ammonia-N, total lead, oil and grease, and flow (MGD) for the Youngstown WWTP 001 outfall.

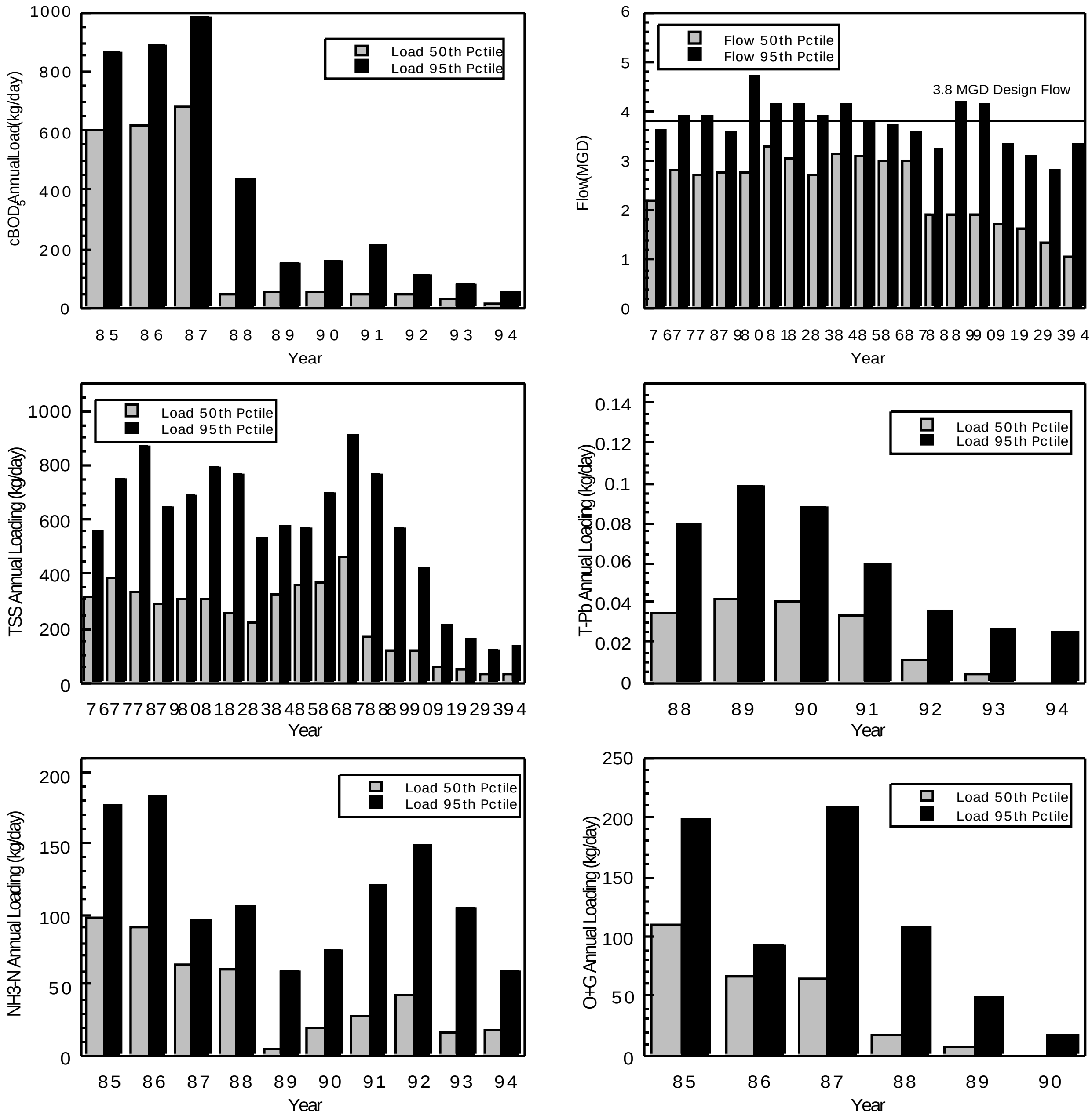


Figure 21. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), ammonia-N, total lead, oil and grease, and flow (MGD) for the Campbell WWTP 001 outfall.

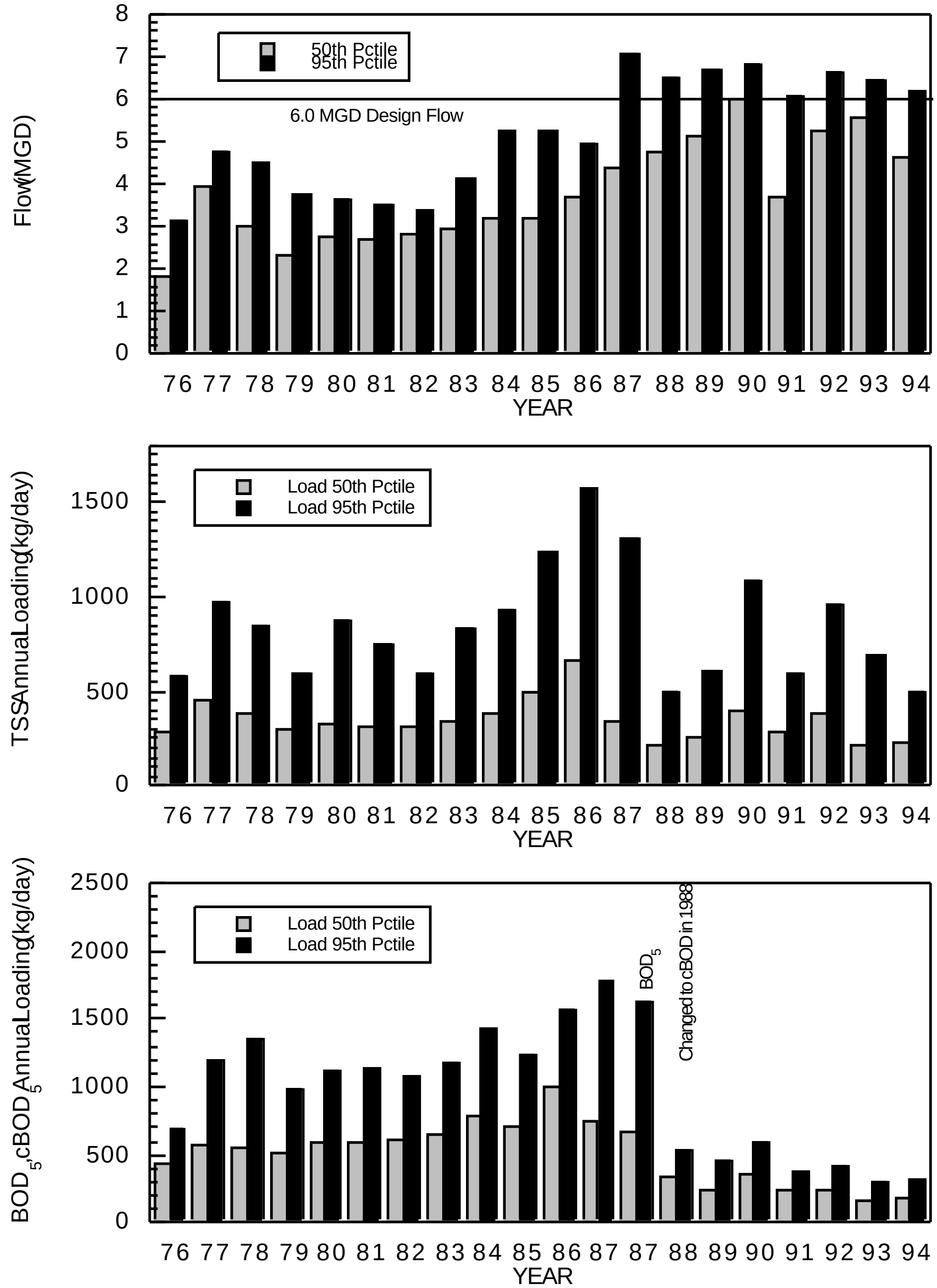


Figure 22. Median and 95th percentile annual loadings(kg/day) of BOD_5/$cBOD_5$, total suspended solids (TSS), and flow (MGD) for the Struthers WWTP outfall 001.

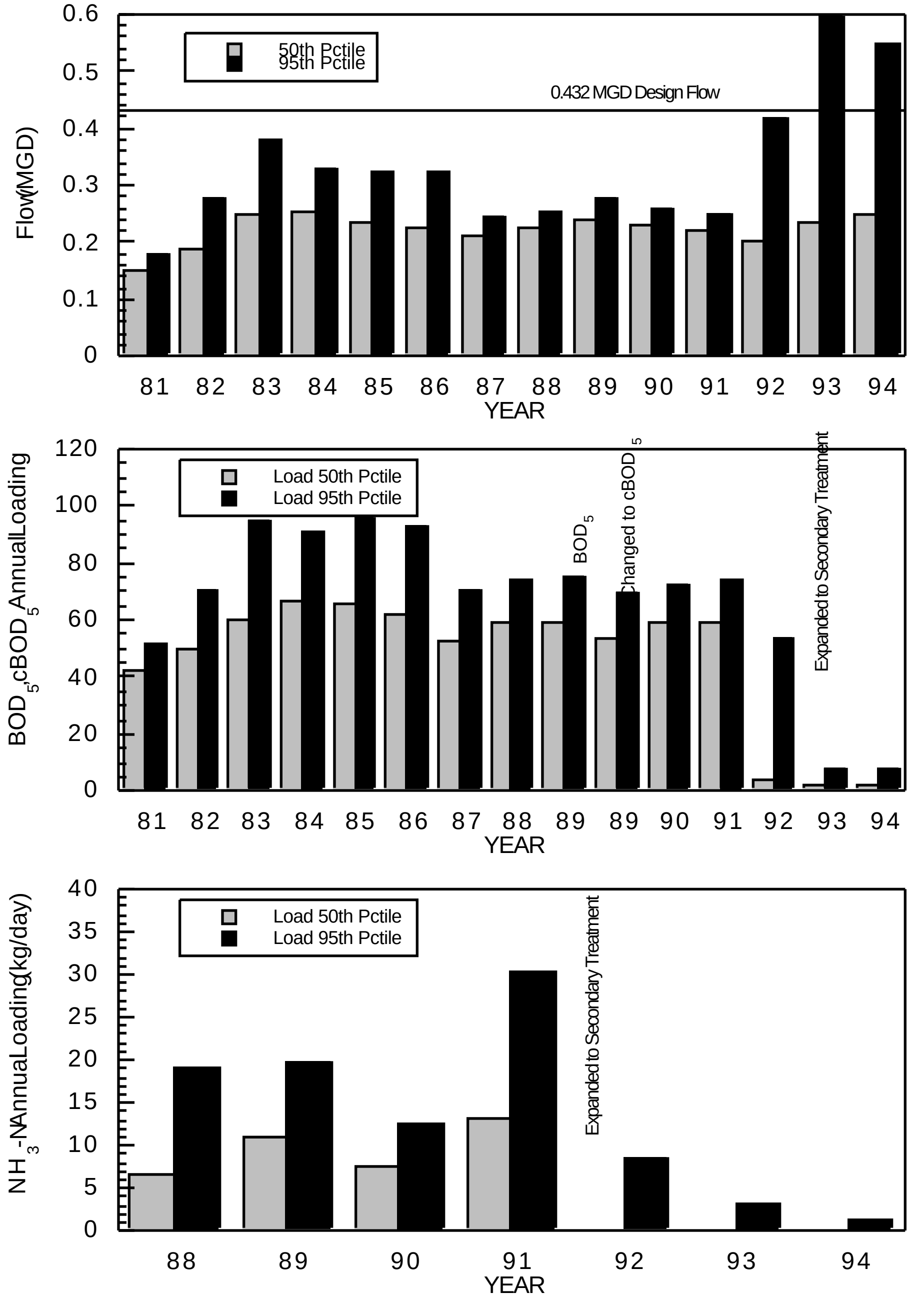


Figure 23. Median and 95th percentile annual loadings(kg/day) of BOD_5/$cBOD_5$, ammonia-N, and flow (MGD) for the Lowelville WWTP 001 outfall.

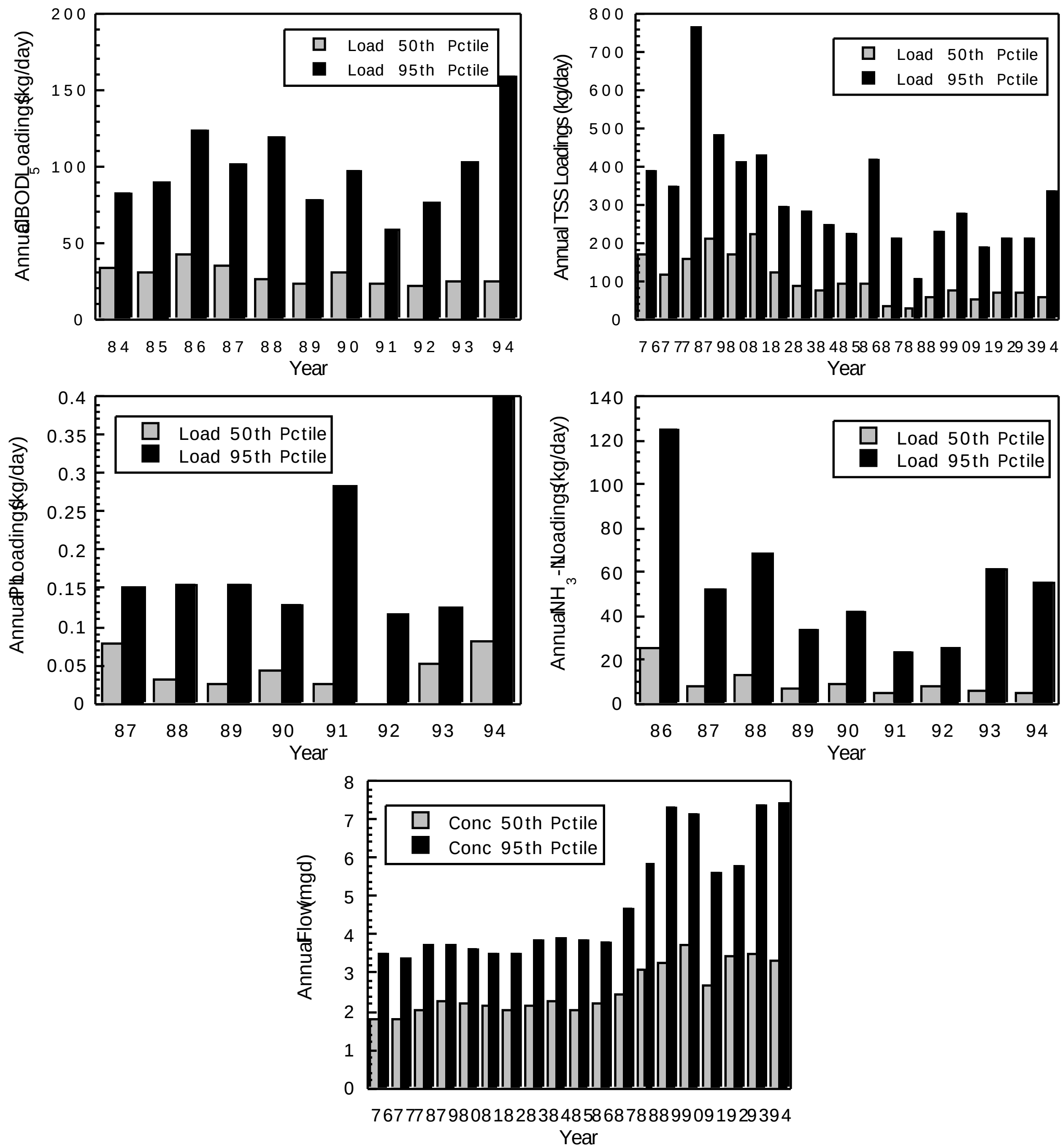


Figure 24. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), ammonia-N, total lead, and flow (MGD) for the Mosquito Creek WWTP 001 outfall.

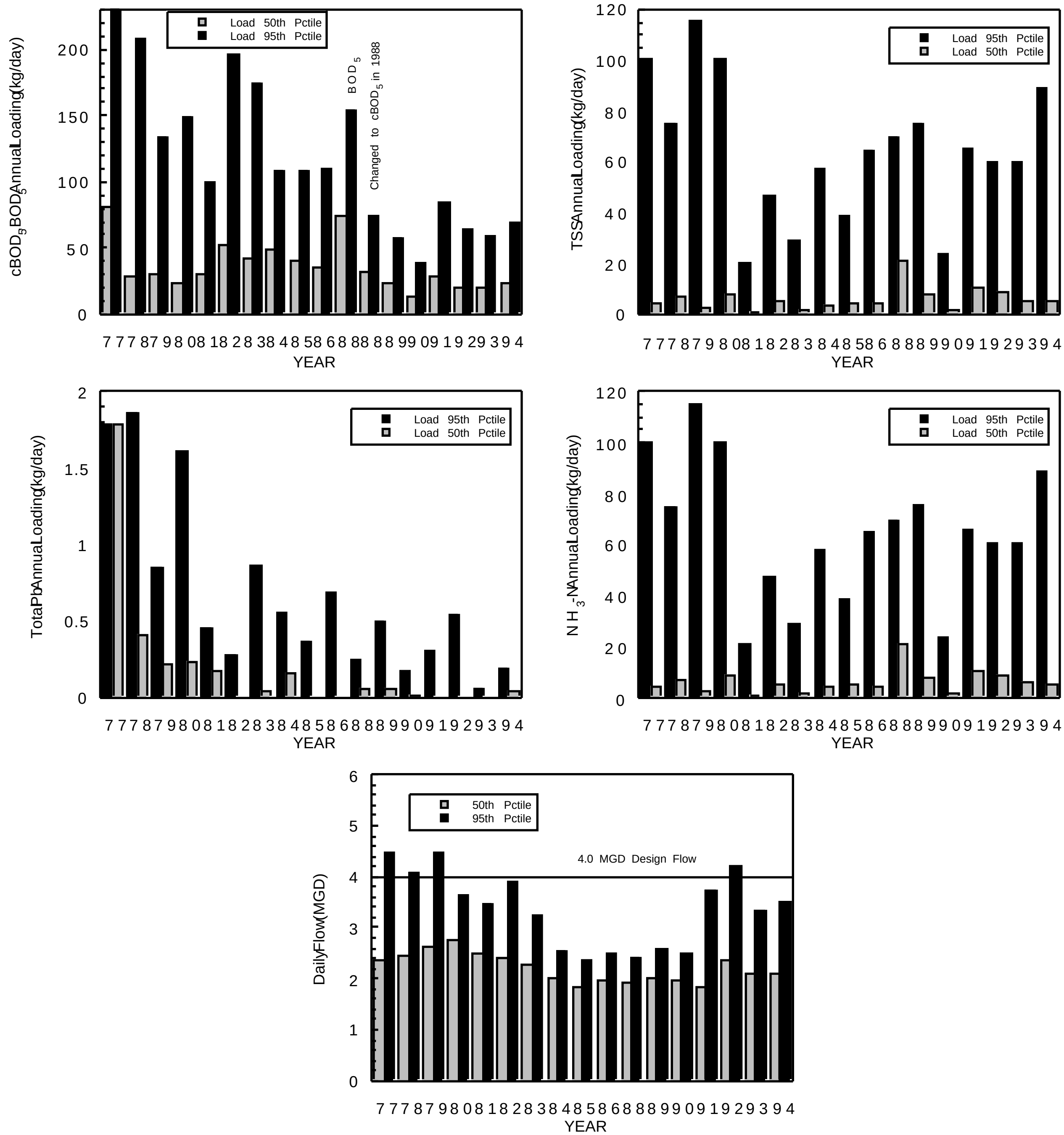


Figure 25. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), ammonia-N, total lead, and flow (MGD) for the Meander Creek WWTP 001 outfall.

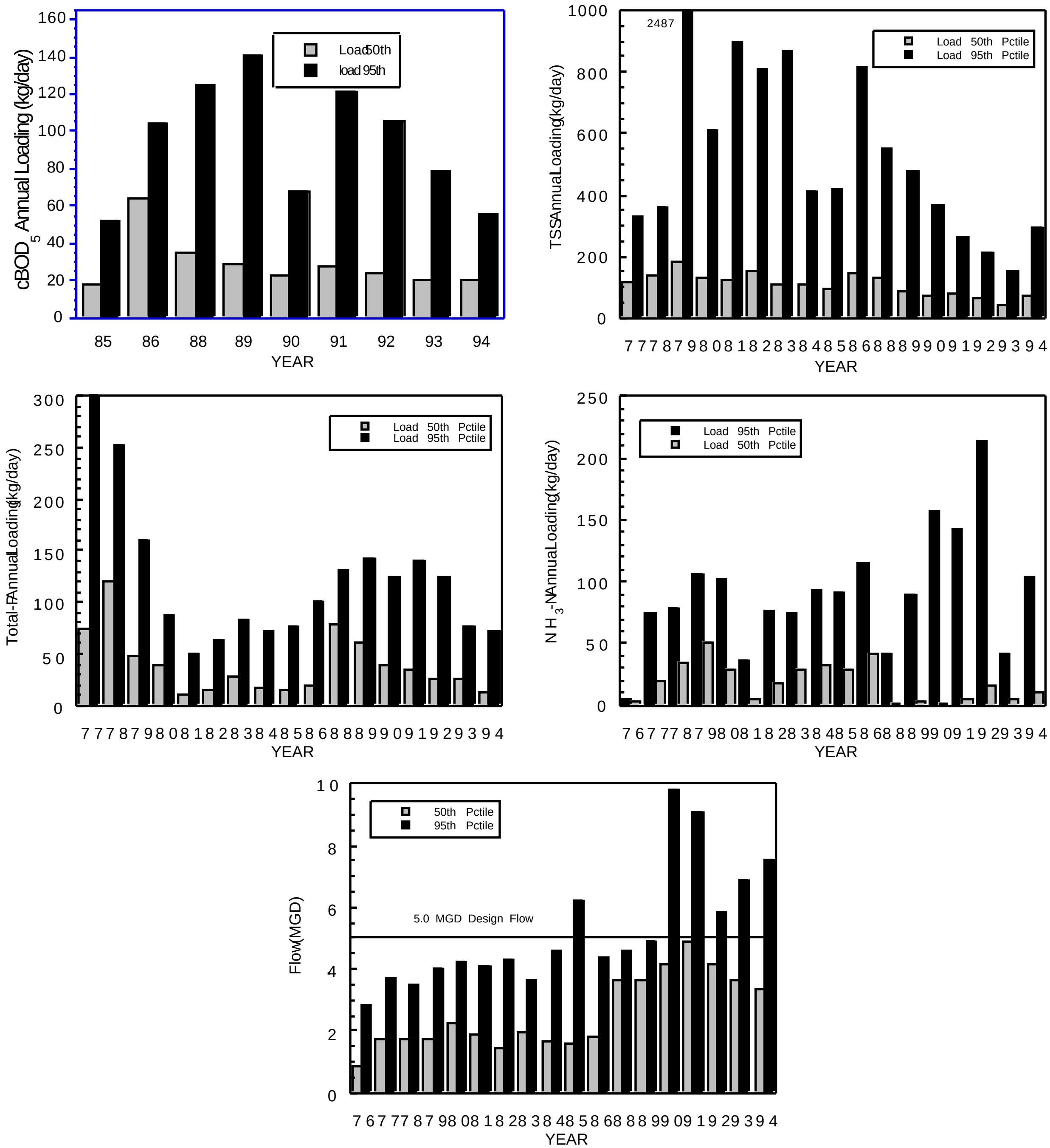


Figure 26. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), ammonia-N, total phosphorus, and flow (MGD) for the Boardman WWTP 001 outfall.

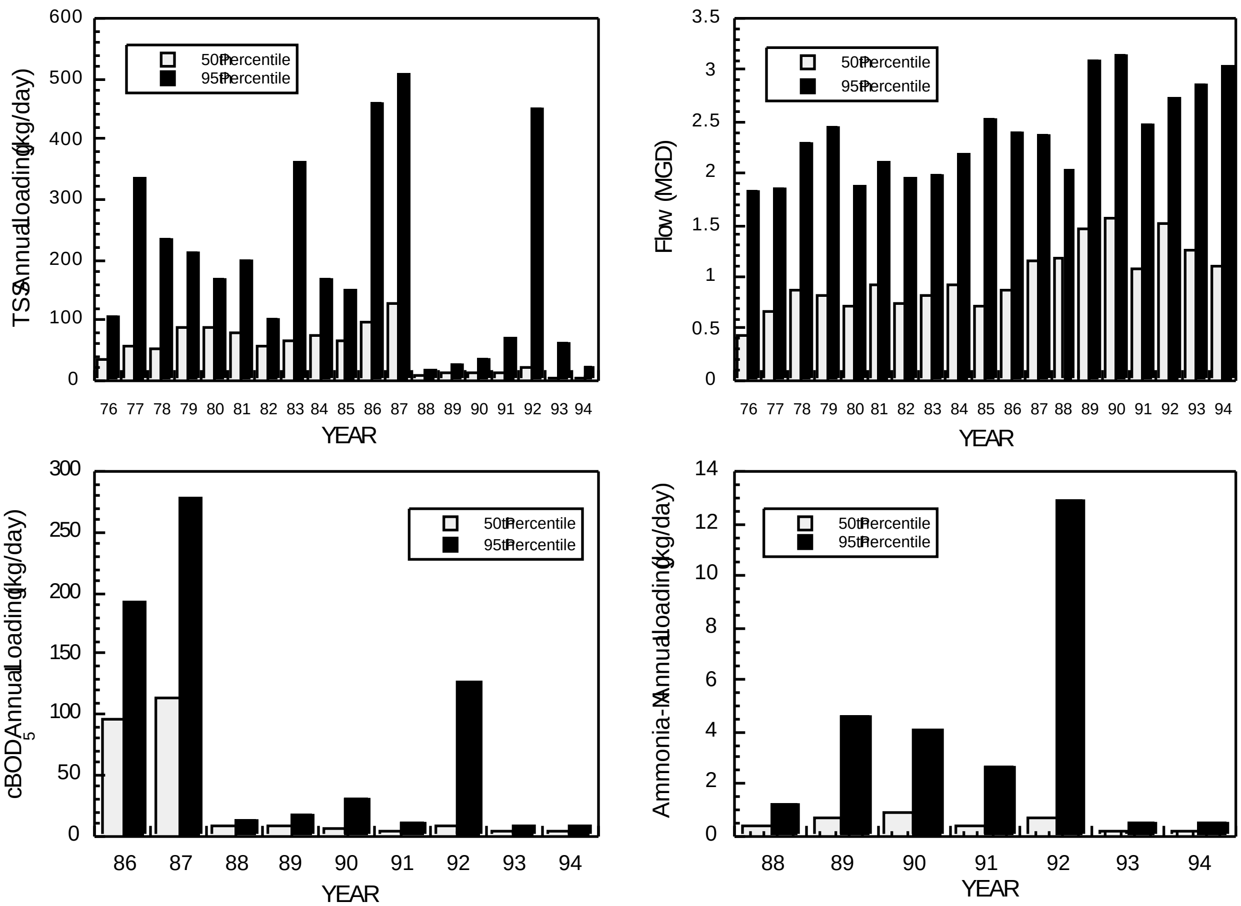


Figure 27. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), ammonia-N,and flow (MGD) for the Brookfield WWTP 001 outfall.

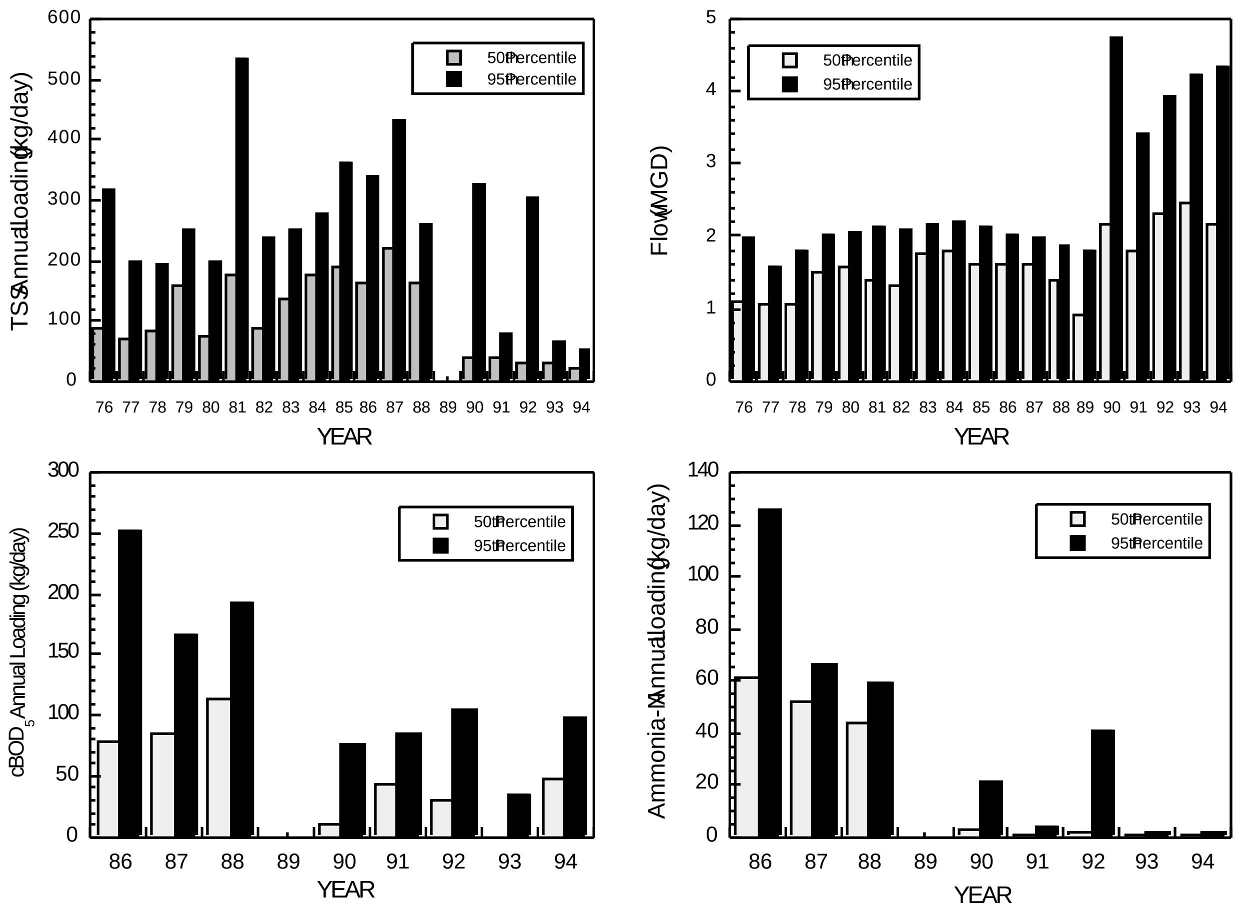
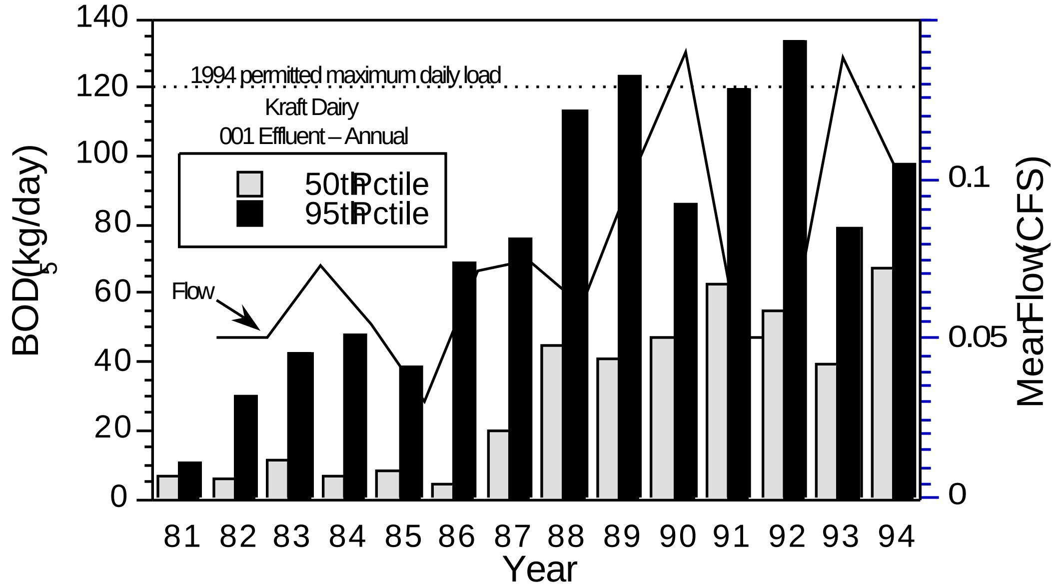


Figure 28. Median and 95th percentile annual loadings(kg/day) of $cBOD_5$, total suspended solids (TSS), ammonia-N,and flow (MGD) for the Hubbard WWTP 001 outfall.



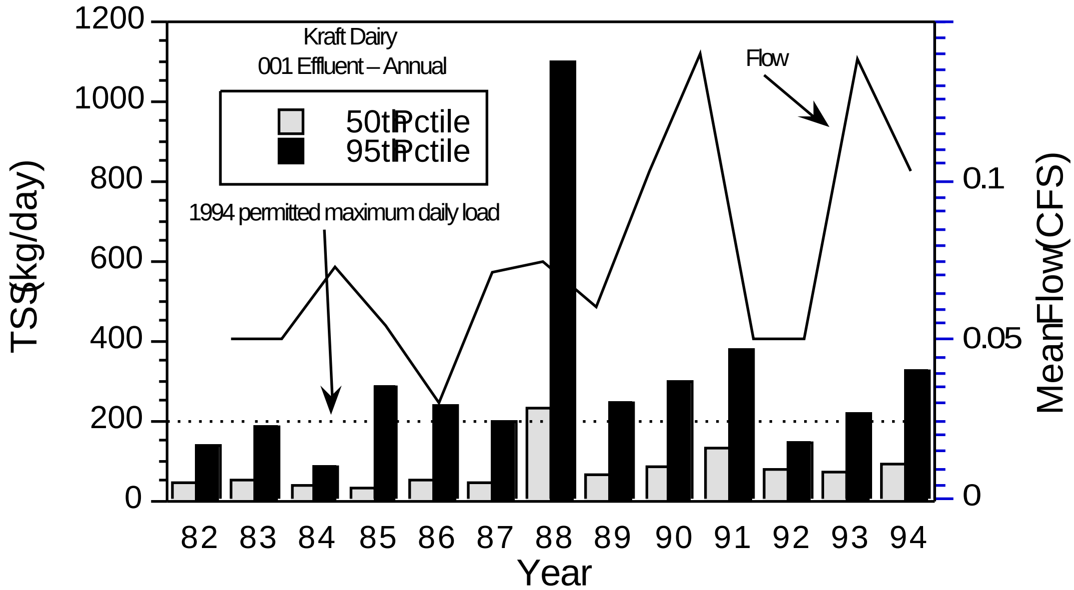


Figure 29. Median and 95th percentile annual loadings(kg/day) of BOD_5, and total suspended solids (TSS) for the Kraft Dairy 001 outfall.

Spills, Overflows, and Unauthorized Releases

Spills

- Pollutant discharges from spills, overflows, permit violations, and other unauthorized releases are a significant source of lethal and sublethal stresses for aquatic communities in the Mahoning River basin. Approximately 550 incidents were recorded by the Ohio EPA Emergency Response Section during the 5 year period between from 1989 to 1993. During this 5 year period,171 of the events cumulatively released 1,660,297 gallons of pollutants (see Appendix Tables). Only 7.9 % of the total gallons released were recovered. By county, for the period from 1989 to 1993, 56 spills were reported in Trumbull County, 52 in Mahoning County, 27 in Portage County, and 14 in Stark County.

- Twenty-two (22) quantified spills were recorded during 1994, which together released a total of 5,226,442 gallons of pollutants to the Mahoning River basin. However, 5,217,000 gallons were recorded as sewage releases from three spill events, leaving a total of 9,442 gallons that were released from the other 19 spills. An additional 86 spills with unknown amounts of pollutants were also reported to Ohio EPA in 1994. As was found between 1989 and 1993, petroleum products were the most common pollutants spilled during 1994.

- Sewage releases through unauthorized bypasses, SSOs, and CSOs events, was the leading spill pollutant discharged to the Mahoning River by volume between 1989 and 1994 (6,667,742 gallons = 96.9%) , but not frequency (24 events out of 193 quantified = 12.4 %). The most frequent pollutant released were various types of petroleum products (120 = 62.1%).

- Those entities with the most frequent number of reported spills between 1989 and 1994 were: village of Beloit (#=37), LTV Steel Warren Coke Plant (27), WCI Steel (23), Ohio Edison, Niles Plant (18), North Star Steel (18), General Electric, Niles (15), Schaeffer Equipment Inc (12), and RMI Titanium (8). The single largest spill by volume was at the village of Beloit on March 8, 1994 (3,000,000 gallons reported). This one spill represented 57.4 % of the total volume of pollutants spilled in the Mahoning River basin during this time period.

- Agricultural related spills (*i.e.,* fertilizer, pesticides, herbicides and manure) accounted for less than 1% (2 events).

Sewer Overflows (SSOs)

- The Mahoning River watershed receives periodic discharges of untreated sewage and other pollutants through SSOs. These are raw sewage overflows direct from sanitary sewers, and usually are caused by blockage at pump stations or inverted siphon dams. SSOs are found in both the cities of Warren and Youngstown sewerage systems.

Combined Sewer Overflows (CSOs)

- In addition to SSO discharges, the Mahoning River basin also receives periodic discharges of untreated wastewater from numerous Combined Sewer Overflows (CSO). The City of Newton Falls has 28 CSOs plus two bypasses at the WWTP. The City of Warren has about 20% of it’s sewerage system combined, with 4 remaining CSO outfalls. The City of Niles has a significant problem with CSO bypasses at the WWTP. In a six month period in 1994, the City of Niles discharged 145.3 million gallons of partially treated wastewater to the Mahoning River. The Niles sewerage system also has seven additional sewer overflows. The City of Girard has five CSOs, which are all under NPDES permit. The City of Youngstown has up to 96 CSOs. The City of

Campbell has a separate sewerage system, however, bypassing can occur at the WWTP and at various locations along the sewer system. The City of Struthers has two bypasses from equalization tanks; one at the plant, and the other at Bridge Street which becomes inundated by the Mahoning River during periods of high water.

- During the 1994 Ohio EPA survey, water chemistry samples were collected under baseflow conditions, thus the chemical data do not indicate the potential impact on chemical water quality from CSO discharges. However, given the large number of known CSOs in the Mahoning River basin suggest it is reasonable to expect that they would degrade the aquatic life use potential of biological communities.

Wild Animal Kills

- Pollution discharges from spills often result in toxic impacts to fish and other aquatic life. Water Pollution, Fish Kill, and Stream Litter Investigations conducted by ODNR (ODNR 1981 - 1990, Division of Wildlife unpublished data) from 1981 through 1994 lists 20 incidents within the Mahoning River watershed that killed a total of 8,683 wild animals. Industrial related activities were the leading cause of fish kills accounting for 68.1% of the total animals killed followed by agriculture (29.4%), public services (1.8%), and unknown causes (1.3%). Within industries, the main two causes of kills were metal fabrication (35.6%) and petroleum related (32.5%) incidents. By county, the highest number of incidents occurred in Trumbull (8), Portage (5), Mahoning (3) Columbiana (2), and Stark (2).

Chemical Water Quality (Tables 6 and 9, Figures 30-42)

Upper Mahoning River (RMs 100.57-45.73)

- Grab water samples were collected from 13 stations 5 times between 06/27/94 and 09/08/94 (Table 6). All samples along the mainstem (except for samples collected on the 7th and 8th of September) were collected on the same day. Samples were collected under relatively low stream flow conditions, ranging from 3.1 to 19.9 cfs at the U.S.G.S. gage at RM 85.51 (Webb Rd.). Low flow sampling was conducted to document possible exceedences of chronic (i.e.,30-day average) water quality standards.

- A relatively dry summer did not allow for collection of rain event samples. Water samples collected during higher stream flows would be expected to have much higher concentrations of TSS than the values recorded during this 1994 survey.

- Fecal coliform bacteria samples were collected twice (06/13/94; 06/20/94) at twelve stations under low flow conditions. Elevated fecal coliform bacteria counts were recorded at RMs 93.2, 88.3, and 47.3 (Figure 32, Table 9). Potential sources of bacteria at the RM 93.2 station include septic system discharges from the unsewered Westville Lake area and feedlot runoff. The RM 88.3 station is located downstream from potential agricultural sources, which are also the most likely cause for elevated bacteria at RM 47.3 at Nelson Moser Road.

- Violations of the 4.0 mg/l dissolved oxygen standard were detected from 24 hour continuous datasonde measurements at RM 93.2 (Knox-School Rd, Figure 33). This site is impounded by a low head dam and the river is used as a source of drinking water by the city of Sebring. Possible sources of organic enrichment include the unsewered Westville Lake area and non-point source agricultural runoff such as animal feedlots. No other problems with either dissolved oxygen or ammonia-N were observed at any other sample locations in the upper Mahoning River segment (Figures 33,34).

- Significant nutrient enrichment (phosphorus and nitrate-nitrite) was detected in the Sebring-Alliance area (RMs 88.3 - 84.9) as shown in Figure 35. Nutrient levels in the upper Mahoning River dropped significant below the Berlin Lake dam, and remained at background concentrations down to RM 45.7, just above the Leavittsburg dam. Sources of nutrients in the Sebring-Alliance area include the Sebring WWTP, agricultural runoff, and numerous potential sources from urban runoff, small package type of WWTPs, and unsewered areas in the Alliance-Sebring area.

- One of the most significant trends in the chemical water quality of the upper Mahoning River was a drastic reduction in water hardness ($CaCO_3$ hardness) in the mainstem below the Berlin Lake dam as shown in Figure 36. Average stream hardness dropped from about 330 mg/l above Berlin Lake to approximately 150 mg/l below the Berlin Lake dam. This trend is significant because the toxicity of many heavy metals increases as water hardness decreases. Relatively low water hardness values (140-160 range) were maintained throughout the next 70 river miles of the Mahoning River mainstem. Wetzel (1975) offers a possible explanation for the observed decrease in water hardness below the Berlin Lake dam. According to Wetzel, decalcification of the epilimnion of hardwater lakes has been documented under nutrient enriched conditions. Algal productivity can result in precipitation of $CaCO_3$ to the lake sediments. Sampling in Berlin Lake for the Clean Lakes Program by Ohio EPA in 1989 indicated elevated nutrient enrichment, with lake water trophic state ranging from hypereutrophic in the upper lake reaches to eutrophic conditions near the dam. Thus conditions exist in Berlin Lake to allow for epilimnion decalcification and subsequent reduction in the hardness of the upper Mahoning River during periods of high algal productivity (i.e., from May to September).

- Total suspended solids increased significantly from the headwater RM 100.57 station at King Rd. down to the next station at RM 93.2 (Figure 37). Further increases in TSS were found below the Berlin Lake dam and the Lake Milton dam and remained elevated down to RM 54.7. The increases in TSS may be related to the hypolimnetic discharge of water from these two reservoir dams. TSS values decreased to levels found at RM 93.2 at the two stations above the Leavittsburg dam. Elevated TSS levels under low flow stream conditions can have a significant effect on fish communities by decreasing potential sight feeding predatory activity. Exceedences of the 1000 ug/l total iron standard were detected at all of the upper Mahoning River stations, however, the average T-Fe significantly increased below the headwater RM 100.57 station, and did not drop until the two stations above the Leavittsburg dam (Figure 37). Sources of total iron in the upper Mahoning River basin include runoff from numerous strip mine sites and the fact that iron would be associated with the elevated levels of TSS found in the stream water.

- Priority pollutant heavy metals were found near or below laboratory detection limits in the upper Mahoning River during the low flow sampling conducted in this survey. These data suggest that chronic toxicity to aquatic life from heavy metals is not a problem in the upper Mahoning River. It is possible that higher levels of heavy metals would be detected from stream samples collected after rain induced runoff.

- Water samples for organic chemicals including pesticides were collected once under low flow conditions at RMs 100.57 and 58.8. Two compounds of the pesticide BHC were detected at 0.003 ug/l at the RM 58.8 station, however these levels are not exceedences of water quality standards. It is possible that higher concentrations of heavy metals and pesticides would be detected from stream samples collected after rain induced runoff.

Lower Mahoning River (RMs 45.51-mouth in Pa.)

- Grab water samples were collected from 25 mainstem stations 5 times between 06/29/94 and 08/17/94. Samples were also collected from select tributaries and from the Shenango and Beaver Rivers in Pennsylvania (Table 6). All samples from the 25 stations were collected on the same day to allow for longitudinal comparison of data, upstream and downstream from point sources, under similar stream flow conditions. Samples were collected under low-mid stream discharge, ranging from 175 to 656 cfs at the Leavittsburg U.S.G.S. gage. The Army Corps of Engineers regulates the summer flow of the lower Mahoning River to maintain a July discharge of 315 cfs at the Leavittsburg gage (Ohio EPA, 1990 Mahoning River WLA Report). Four of the five grab water samples collected during the 1994 survey were collected when the flow at the Leavittsburg gage was below 315 cfs. This type of sampling (low stream flow, low dilution) was conducted in order to document possible exceedences of chronic (i.e., 30-day average) water quality standards.

- A relatively dry summer did not allow for collection of rain event samples (Figure 30). Only two significant rain events occurred from June to October of 1994 (see Appendix). Water samples collected during higher stream flows, immediately after rain induced runoff, would be expected to have much higher concentrations of TSS and associated chemicals.

- A total design flow of 85.630 mgd (132.470 cfs) of treated sanitary wastewater can be potentially discharged to the Ohio waters of the lower Mahoning River mainstem and select tributaries from eleven major WWTPs (Figure 31). During 1994, the total median discharge from these WWTPs was 59.660 mgd, which was 69.7% of the total potential design flow. The combined WWTP median discharge in 1994 was the lowest recorded over the past ten years.

- Four industrial sources in Ohio (CSC Industries/Copperweld Steel, Thomas Steel Strip Corp., LTV Steel Corp./Warren Coke Plant, and RMI Co., Niles) have the potential to discharge 11.460 mgd of treated process wastewater at design flow. WCI Steel, Inc. in Warren can discharge an additional 78.239 mgd (121.03 cfs) of process and non-contact cooling water from 9 outfalls, and the Ohio Edison Co. in Niles has the ability to use and return 217.71 mgd (336.797 cfs) of non-contact cooling water during production of electrical power (Table 2). During 1994, the four industrial sources discharged 7.313 mgd of process water, WCI discharged a total of 45.613 mgd, and Ohio Edison discharged 128 mgd of cooling water. The combined median discharge of these six industrial sources was 182.926 mgd, which was 59.6 % of their total potential design flow.

- The combined design flow discharge of wastewater and cooling water from municipal and industrial sources in the Ohio waters of the lower Mahoning River equals 393.039 mgd (608.031 cfs). The total effluent flow reported in 1994 from these major dischargers was 237.643 mgd (367.633 cfs), which is slightly higher than the 315 cfs background summer (July) stream flow maintained at RM 45.51 by the Army Corps of Engineers.

- Fecal coliform samples were collected twice at ten locations and once at four locations under low flow conditions on 06/27/94 and 10/13/94. Elevated levels of bacteria above primary contact criteria were recorded at eight stations from RM 41.5 to RM 7.0 in Pa. (Figure 32). There was a significant trend toward increased fecal coliform below Mill Creek in the city of Youngstown. Potential sources include unsewered areas, dry weather sanitary overflows (SSOs), and improper chlorination of WWTP effluents. The highest coliform level of 20,000/100 ml was found at RM 15.5, which is below the Campbell WWTP discharge.

- The only violations of dissolved oxygen standards were from datasonde data at RM 30.8, above the confluence of Meander Creek and Mosquito Creek, and from grab sample data at RM 21.1 downstream from Mill Creek (Figures 33,34). However, irregular meter fluctuations occurred at the RM 21.1 station, perhaps due to the shallow fast flowing water encountered at this location. Dissolved oxygen measured from a bucket of water was 3.0 mg/l higher than that recorded instream, which suggests poor contact of the probe membrane with water. Thus the low dissolved oxygen recorded at RM 21.1 from the grab samples may not represent true stream conditions. All other mainstem stations showed dissolved oxygen concentrations well above the 5.0 mg/l daily criterion (Figures 33,34). The 1994 dissolved oxygen levels in the lower Mahoning River are much improved from values reported during the 1981 survey (see trends section).

- Concentrations of phosphorus and nitrate-nitrite remained low from RMs 45.5 to 36.4, but showed two step wise increases, first below the Warren WWTP and next below the Youngstown WWTP (Figure 35). Both nitrate-nitrite and total phosphorus concentrations were well above background levels at the Ohio-Pennsylvania line, and maintained high levels down to the confluence with the Shenango River. These data indicate that the Warren and Youngstown WWTPs had a nutrient enrichment effect on the water quality of the lower Mahoning River.

- Ammonia-N concentrations were relatively low throughout the entire lower Mahoning River mainstem in 1994, with average concentrations below 0.2 mg/l. No evidence of ammonia toxicity was found during this survey, which is a significant improvement from the elevated ammonia conditions found during the 1981 survey (see trends section).

- Water hardness values increased gradually through the lower mainstem, but never exceeded an average concentration above 160 mg/l $CaCO_3$ during the summer of 1994 (Figure 36). This observation differs significantly from the 50th percentile hardness value of 198 mg/l that was used to allocate NPDES permit limitations for heavy metals in the Ohio EPA 1990 Wasteload Allocation (WLA) report. Analysis of long term STORET data collected at Leavittsburg and Lowelville since 1982 also indicates that the 50th percentile water hardness of the lower Mahoning River mainstem has been consistently under 198 mg/l.

- The 1994 hardness data do agree with the 162 mg/l hardness value that was used to allocate metals loadings at Rt. 224 in Pennsylvania in the Ohio EPA 1990 WLA report. The reason for using two stream hardness values in the Ohio EPA WLA report (198 in Ohio, 162 in Pennsylvania.) is unclear. Both the 1994 survey data and long term STORET data indicate that the 162 mg/l value is more representative of the water hardness in both the Ohio and Pennsylvania sections of the lower Mahoning River.

- There was a significant increase in the water temperature of the Mahoning River below the Ohio Edison cooling water discharge at RM 29.1 (Figure 38). Average stream temperature increased by about 5 degrees C. Exceedences of the daily average temperature standard were recorded at five sample stations, from RM 29.1 to RM 23.4. The 1994 discharge of cooling water from Ohio Edison was 128 mgd, which is well below their 218 mgd design capacity. This suggests that significant violations of the temperature standard would be expected at design flow if there was not sufficient background dilution water.

- Total suspended solids were maintained at elevated levels throughout the entire Mahoning River mainstem (Figure 37). Because the samples were collected during low flow, these data indicate that the lower Mahoning River maintains an elevated level of turbidity. Water column turbidity can be used by silts, fine clays, colloids, and planktonic algae. This type of chronic elevated turbidity could have an effect on the ability of sight feeding fish species to capture prey.

- Exceedences of the 1000 ug/l total iron standard were detected in 98% of the samples collected in the lower Mahoning River. There was a gradual trend toward increased iron in the lower 30 river miles (Figure 37). Average total iron concentrations were above the 1000 mg/l standard at all 26 mainstem stations in the lower Mahoning River. Continuous chronic exposure to high iron, even during low flow times, could have a negative impact on the biological communities of the lower Mahoning River segment. It is interesting that the only station in the entire upper and lower Mahoning River mainstem that both fish and macroinvertebrate indices met or exceeded ecoregional expectations (without any index in the nonsignificant departure zone) was at RM 100.6, which was also the only station that had low average total iron concentrations.

- Throughout the 1994 survey, an oily sheen was observed on the Mahoning River at RM 16.39, at the LTV Campbell RR bridge. This sheen represents a violation of the “five free-froms” in the Ohio water quality standards (Chapter 3745-1-04 of OAC). On May 10, 1994 while conducting an compliance inspection at the Campbell WWTP, NEDO personnel observed an oily discharge that was traced to a stormsewer outlet of Cold Metal Products Co., Inc. Further investigation indicated a cross connection between a process line and a non-contact cooling discharge. This company has an NPDES to discharge non-contact cooling water (OEPA # 3IC00086) at a location about one river mile above the RM 16.39 station. While not the only possible source of oil to the river at RM 16.39, Cold Metal Products Co. is one documented source that could be the cause of the oily sheen observed at this station during the 1994 survey. Other possible sources in this stream segment are include groundwater seepage from the property of LTV from previous steel making operations, and unidentified sources entering stormsewers in the Campbell area.

- The macroinvertebrate sampling crew observed oil throughout the mainstem from Warren to the state line. An oil sheen on the water along with oil deposits on rocks was observed in the Dickey Run storm sewer mix zone RM 39.17, on 9/12/94. Oil was not observed at RM 38.2 on 9/13/94. At RM 35.4 downstream from WCI and LTV, oil deposits in the margin and an oil sheen on the water surface was observed on 9/14/94. Oil was observed in the margin sediments and on the water surface as a sheen at RM 30.2 on 9/13/94. Upstream from the Niles WWTP (RM 29.1) was observed in the margin sediments and on root wads along the submerged banks, and downstream at RM 28.7 oil was observed on the water surface. Downstream from the Liberty Street dam oil was observed at the macroinvertebrate stations from RM 25.3 to 15.5 during the week of September 12-15, 1994, but not in the quantities observed upstream at RM 35.4 to RM 28.7. Oil wasn't observed at the macroinvertebrate sites from the state line to the mouth.

- The only exceedences of water quality criteria for priority heavy metals in the surface water samples of the lower Mahoning River were for several total lead values, one at RM 19.3 and one at RM 15.5 (Figure 36). These exceedences of criteria were based on a water hardness value of 150 mg/l $CaCO_3$, which was near the average value recorded in the lower Mahoning River during the 1994 survey. The State of Pennsylvania has adopted much more stringent total lead standards, with a criteria number near 5 ug/l at a water hardness of 150 mg/l. As observed in Figure 36, widespread violations of the Pennsylvania lead standard were found throughout the lower Mahoning River mainstem. Total lead decreases at RM 7.1 in Pennsylvania to an average value near the 5.0 ug/l criterion, but increases at RM 4.2 down to the mouth. These data suggest a possible source of lead entering the Pennsylvania waters of the Mahoning River somewhere between RM 11.5 and 7.1.

- Stream water samples were collected once for organic chemicals at RMs 45.51 and 12.42. The following organic compounds were found: (RM 45.51: Aldrin (0.002 ug/l), a-BHC (0.003 ug/l); RM 12.42: Methylene chloride (1.0 ug/l), Naphthalene (0.5 ug/l), a-BHC (0.003 ug/l), d-BHC (0.005 ug/l), y-BHC (0.003 ug/l). Naphthalene was detected in Copperweld Steel, Thomas Steel Strip, WCI Steel Inc. outfalls 008 and 013, LTV Steel Corp outfall 014, Meander Creek WWTP, and Boardman WWTP effluents in conjunction with Ohio EPA bioassay testing. The aldrin and naphthalene (PAH criteria) concentrations violated the Ohio EPA human health standards, but did not violate the aquatic life standards. None of the other organics detected were above water quality standards.

West Branch Mahoning River

- Grab surface water samples collected near the mouth of the West Branch indicated no violations of chemical water quality criteria. Total phosphorus levels were at or near the 0.05 mg/l detection limit and dissolved oxygen values were well above the 6.0 mg/l criteria. A few samples showed total iron concentrations just above the 1000 ug/l water quality standard.

Eagle Creek

- Grab surface water samples collected at RM 3.12 showed no violations of chemical water quality criteria. Total phosphorus values were at or near the 0.05 mg/l detection limit. Dissolved oxygen ranged from 7-8 mg/l. A few samples showed total iron above the 1000 ug/l criteria, with a high value of 1850 ug/l.

Silver Creek

- Grab surface water samples collected at RM 0.17 showed no violations of chemical water quality criteria. Total phosphorus values were at or near the 0.05 mg/l detection limit. Dissolved oxygen ranged from 8-10 mg/l. A few samples showed total iron above the 1000 ug/l criteria, with a high value of 2120 ug/l. On the average, the water temperature of Silver Creek was much cooler than Eagle Creek, on the average about 2.5 degrees C cooler over the summer. Silver Creek also showed a slightly higher level of nitrate-nitrite nitrogen than Eagle Creek, with values in the 0.5-0.7 mg/l range as compared to Eagle Creek which was in the 0.3-0.4 mg/l range.

Mosquito Creek

- Grab surface water samples collected at RM 0.25 showed no violations of chemical water quality criteria. This station is below the Mosquito Creek WWTP and General Electric Niles Glass Plant discharges, and also receives urban runoff from the city of Niles. Evidence of slight nutrient enrichment is indicated by total phosphorus values that ranged from 0.07 to 0.20 mg/l. Total lead was also detected at each of the five grab samples, ranging from 2-5 ug/l. TSS levels were elevated, and ranged from 22-48 mg/l. Causes are unknown, but may involve the release of water from the Mosquito Creek Reservoir.

Meander Creek

- Grab water samples collected at three stations upstream and downstream from the Meander Creek WWTP indicated significant problems with chemical water quality. Violations of dissolved oxygen below the 4.0 mg/l criteria were recorded at both RM 1.8 and RM 0.8 during the survey. A total lead value of 21 ug/l was recorded at the RM 1.8 station. The Meander Creek Reservoir is used by the Mahoning Valley Sanitary District as the primary source of drinking water for the city of Youngstown and other communities. For the most part, there is no flow of water over the Meander Creek Reservoir dam, although some groundwater infiltration does occur to maintain a constant pool of water below the dam. Up to 1988, the MVSD WTP was periodically discharging lime sludge to Meander Creek from two stormsewers located just above the Meander Creek WWTP outfall at RM 1.9. During the 1994 survey no evidence of lime sludge was observed below the WTP stormsewers, however, an organic type sludge was observed at RM 1.8, which is downstream from the Meander Creek WWTP. It would appear that sludge from the WWTP has accumulated in the downstream segments of Meander Creek and its presence may have been masked by the heavy accumulation of lime sludge that was previously discharged by the WTP.

- Evidence of nutrient enrichment downstream from the Meander Creek WWTP was also indicated at RM 1.8 and 0.8 by the presence of dense growths of filamentous algae. Total phosphorus values as high as 3.51 mg/l and total nitrate+nitrite nitrogen as high as 13.6 mg/l were recorded at these stations. Nutrient concentrations were much higher downstream from the WWTP than upstream.

- The combined problems of nutrient enrichment, excessive organic sludge, zero low flow dilution, and dissolved oxygen below 4.0 mg/l indicate that the discharge from the WWTP contributes to a significant impact on downstream biological communities in Meander Creek.

Mill Creek

- The chemical water quality of Mill Creek has been severely impacted by the Boardman WWTP. This WWTP impacts Mill Creek resulting in water quality violations of NH3-N, D.O. and elevated levels of total phosphorus from RM 9.5 to RM 5.4. Additional water quality violations (D.O., pH and total iron) occur downstream at RM 5.1, 2.6, 0.8.

- During the summer of l994, Ohio EPA staff reported visual observations of extensive sewage sludge deposits in Mill Creek downstream from the Boardman WWTP discharge. Observations revealed sludge more than three feet deep in many spots and extended farther than 150 meters downstream from the Boardman WWTP discharge. Large floating mats of sludge in the stream and suspended solids in the Boardman effluent were also observed. Although not as extensive, sludge deposits were also evident in Mill Creek approximately three miles downstream from the discharge. Extensive sludge deposits can degrade stream quality by covering natural substrates and/or by increasing sediment oxygen demand.

- The 1994 Mill Creek survey documented a D.O. sag at approximately RM 7.8. The minimum day time dissolved oxygen concentrations in Mill Creek dropped below 5.0 mg/l downstream from the Boardman WWTP to Shields Road (9.5-5.4)(Figure 39) At RM 7.8 and 5.4 the oxygen levels dropped below 4 mg/l(WWH minimum at anytime criterion). The lowest level recorded was 0.6 mg/l at RM 7.8 (Figure 39). The lower oxygen levels and violations are most likely caused by the discharge from the Boardman WWTP. Minimum D.O. values increased substantially downstream at RM 2.6).

- Datasonde continuous monitors also recorded D.O. levels below 4.0 mg/l in Mill Creek at RM 11.3, 7.7, 6.2, 5.9 and 5.4. The majority of the below standard oxygen values were recorded at night when respiration exceeded photosynthesis. Excessive nutrient loadings from the Boardman WWTP would contribute to the D.O. exceedences.

- Ammonia-N concentrations were in violation of the WWH standard at RM 9.5, 7.8 and 5.4. The water quality data indicate that higher ammonia values were found below the Boardman WWTP rather than above it. The highest level(4.5 mg/l) was found at RM 7.8. (Figure 39)

- The nitrate+nitrite-N values were all above the 75th percentile background data except for RM's 0.8 and 0.1. (Figure 39)

- All sampling sites documented total phosphorus values above the 75th percentile background data. The highest phosphorus concentration (1.21 mg/l) was recorded at RM 5.4 which is below the Boardman WWTP discharge. (Figure 39)

- On 9-15-94 organic samples were collected in the Mill Creek water column at RM 11.3 (Western Reserve Road) and at the Mouth(RM 0.1). At the upstream site(RM 11.3) only y-

BHC was found at 0.003 ug/kg. At the Mouth of Mill Creek only d-BHC(0.004 ug/kg) and Endrin(0.003 ug/kg) were found at levels just above the detectable limit. At the above concentrations no impact would be expected on Mill Creek.

- The only other minor mainstem water quality exceedences include total iron(23% of all samples collected were in violation of the WWH stream standard probably due to natural sources) and pH(9.07,9.2) caused by lake algae (Lake Glacier).

- Other possible sources of nutrients between the Boardman WWTP and RM 5.4 include Indian Run and a golf course.

Bears Den Run
- Water samples from one site in Bears Den Run(RM 0.5) revealed good water quality with concentrations of most parameters well within water quality criteria.

Ax Factory Run
- Water quality in Ax Factory Run was also good and similar to Bears Den Run.

Anderson Run
- Water samples from one site(RM 0.2) in Anderson Run revealed good water quality. A daytime grab dissolved oxygen value however, dropped below the WWH minimum at anytime criterion of 4.0 mg/l.

Indian Run
- Water quality in Indian Run was also good and similar to Anderson Run except for a daytime grab dissolved oxygen value that was below the WWH minimum twenty-four hour average criterion.

Shenango River
- Grab water samples were collected from the Shenango River at RM 1.03 at Cherry Street near New Castle, Pennsylvania. This station is downstream from the urbanized area of New Castle, Pa. The Shenango River and the Mahoning River combine to form the Beaver River.

- In general, the 1994 chemical data indicate that the Shenango River at RM 1.03 had better overall chemical water quality than the Mahoning River at RM 0.25. Ammonia nitrogen, nitrate-nitrite, total phosphorus, total lead, and total iron were all significantly elevated at the mouth of the Mahoning River compared to the Shenango River station. Total lead ranged from 7-15 ug/l at the mouth of the Mahoning, whereas 4 of 5 samples at the mouth of the Shenango River were below 3 ug/l. Dissolved oxygen averaged about 2.0 mg/l lower in the Mahoning River (range from 6.4-8.1 mg/l) as compared to the Shenango River (range from 8.0-10.3). It is important to note that the New Castle WWTP discharges to the Mahoning River just above the RM 0.25 station, and would be a source of nutrients and oxygen demanding substances. However, heavy metals, nutrients, and oxygen demanding substances were also higher in the Mahoning River upstream from the New Castle WWTP as compared to the mouth of the Shenango River.

Beaver River
- Grab water samples collected at the RM 18.58 and 14.78 stations immediately downstream from the confluence of the Mahoning River and the Shenango River were not significantly different from each other. On a few dates, the dissolved oxygen was lower at the most

downstream station, and total copper was found at 12 and 18 ug/l at the two stations on 07/08/94 when stream flow was elevated after a rain event. Total iron was above 1000 ug/l, most likely due to the high loading of iron from the Mahoning River.

Yankee Creek

- Heavy metals concentrations were generally near or below detection limits throughout the study area.
- COD values generally decreased from upstream to downstream.
- Nitrates and total phosphorus concentrations increased significantly below the WWTP (Figure 40).
- Ammonia-N, TKN, and suspended solids concentrations did not change significantly throughout the study area.
- Dissolved oxygen concentrations gradually increased from upstream to downstream (Figure 40).

Little Yankee Creek

- Heavy metals concentrations were generally near or below detection limits throughout the study area.
- Dissolved oxygen levels generally decreased below the WWTP then showed good recovery downstream. Levels declined again near the mouth due to changes in channel morphology (Figure 41).
- COD, ammonia-N, and TKN levels remained constant throughout the study area (Figure 41).
- Suspended solids concentrations were generally higher upstream from the WWTP (Figure 41). Instream values declined due to the dilution effects of the Hubbard WWTP discharge.
- Nitrates and total phosphorus concentrations increased significantly below the WWTP then showed some recovery downstream, though not to background levels (Figure 41).

Pymatuning Creek

- Figure 42 shows the sampling results of the 1994 survey for total phosphorus, TKN, ammonia–N and nitrate/nitrite.The concentration of these compounds increased downstream from the Kraft Dairy discharge, remained slightly elevated through the Kinsman area and returned to near upstream values at the Pennsylvania border. There were no exceedences of the applicable Ohio EPA acute or chronic water quality standards for ammonia-N. The other compounds do not have numerical water quality criteria.

- Elevated fecal coliform and *E. coli* bacteria counts were documented in 7 of 12 (58%) samples in Pymatuning Creek downstream of Kinsman. *E. coli* (400 at RM 15.9 and 350 at RM 15.85) and fecal coliform bacteria (4000 at RM 15.87; 2500 at RM 15.85 and 2300 at RM 15.80) counts exceeded the primary contact recreation criteria. *E. coli* (600 at RM 16.1; 4700, 2700, 860 at RM 15.87; 5500, 12000, 2400 at RM 15.8; 1200, 7200, 900 at RM 15.80 and 1900 at RM 15.20) and fecal coliform bacteria (6400 at RM 15.87; 7600 at RM 15.85 and 9100 at RM 15.80) counts exceeded the secondary contact recreation criteria.

- Septic system discharges in the Kinsman area did not increase ammonia–N, TKN or phosphorus concentrations in Pymatuning Creek.

- No discernable impact on chemical/physical water quality could be attributed to the “Horodisky Dump” or Vernon Sand and Gravel sites.

- TKN and ammonia-N concentrations in samples collected near the mouth of Sugar Creek were slightly higher than concentrations in samples collected from the headwater sites in Pymatuning Creek. This indicates that there may be significant sources of nutrient loading to Sugar Creek. Trumbull County SCS NPS run-off model indicates significant potential for NPS pollution in this watershed. OEPA samples were not collected during high run-off events, however, and adverse NPS impacts must be evaluated using the biocriteria alone.

Table 9. Exceedences of Ohio EPA Warmwater Habitat criteria (OAC 3745-1) for chemical/physical water parameters (grab samples) from the Mahoning River study area during 1994 (µg/l for metals and organics, # colonies/100 ml for fecal coli., µmhos/cm for conductivity, ˚C for temperature, and mg/l for other parameters).

Stream	River Mile	Parameter (value)
Upper Mahoning River		
	93.23	F. Coliform (2500◊◊, 2700◊◊), Diss. Oxygen ((2.76‡‡)
	88.33	F. Coliform (2300◊◊)
	47.35	F. Coliform (1500◊)
Lower Mahoning River		
	45.51	Aldrin (0.002#)
	41.5	F. Coliform (2200◊◊, 15000◊◊◊)
	38.9	F. Coliform (1100◊)
	38.23	F. Coliform (1060◊)
	30.8	Dissolved Oxygen (0.78‡‡)
	29.03	Temperature (30.5*,31.0*)
	28.63	Temperature (30.5*,3.6*)
	26.43	Temperature (30.5*)
	25.16	Temperature (29.7*)
	23.43	Temperature (29.8*)
	21.73	F. Coliform (3900◊◊)
	21.14	Dissolved Oxygen (3.8‡‡)
	19.43	T-Lead (12*)
	15.53	T-Lead (22*), F. Coliform (8400◊◊◊, 20000◊◊◊)
	12.42	F. Coliform (2200◊◊, 10000◊◊◊)
	7.1	F. Coliform (6800◊◊◊)

Table 9. Continued.

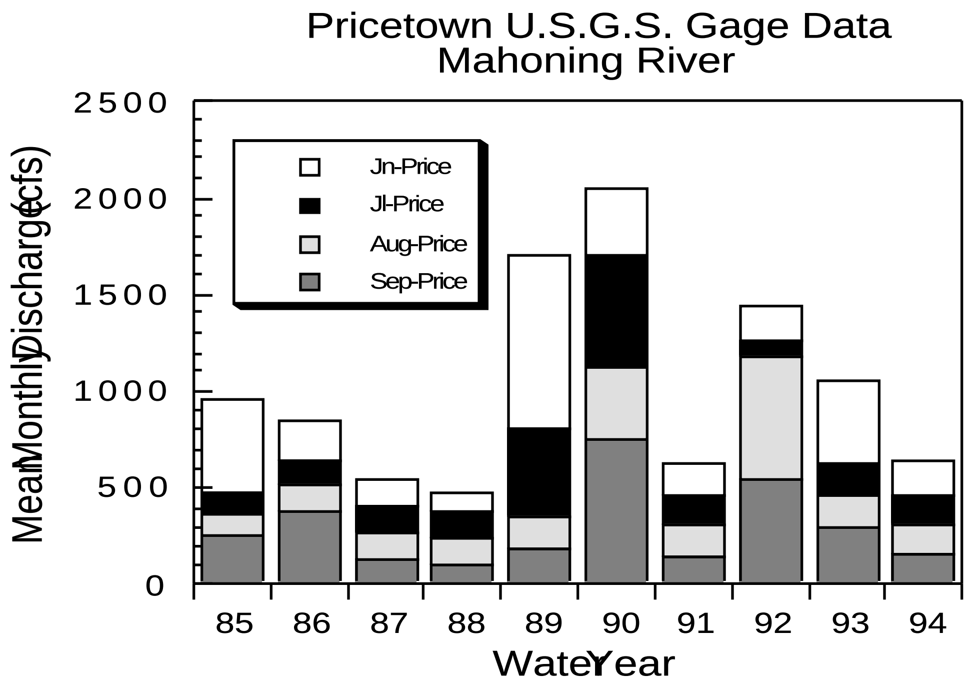
Stream	River Mile	Parameter (value)
Meander Creek		
	2.0	Dissolved Oxygen (4.5‡)
	1.8	Dissolved Oxygen (3.6‡‡), T-Lead (21*)
	0.8	Dissolved Oxygen (2.4‡‡, 3.5‡‡,3.8‡‡)
Mill Creek		
	11.3	Dissolved Oxygen (2.84‡‡)
	10.1	Dissolved Oxygen (3.4‡‡)
	9.5	Dissolved Oxygen (4.8‡,4.8‡),Ammonia-N (1.77*,2.05*,2.81*)
	7.8	Dissolved Oxygen (1.7‡‡,1.3‡‡,0.6‡‡,4.5‡,4,4.1‡),Ammonia-N (1.73,4.5,1.88)
	7.7	Dissolved Oxygen (1.33‡‡)
	5.9	Dissolved Oxygen (3.36‡‡)
	5.4	Dissolved Oxygen (3.7‡‡, 2.78‡‡, 2.7‡‡, 1.2‡‡) Ammonia-N (2.39*, 3.38*), T-Lead (13*)
	5.1	Dissolved Oxygen (3.8‡‡)
	2.6	Dissolved Oxygen (3.7‡‡, 3.9‡‡)
	0.8	Dissolved Oxygen (4.9‡,1.99‡‡), pH(9.07*,9.2*)
	0.1	T-Lead (31*)
Anderson Run		
	0.2	Dissolved Oxygen (3.3)*, T-Lead (14*)
Indian Run		
	0.3	Dissolved Oxygen (4.5)*, T-Lead (11*, 12*)
Yankee Creek		
	11.3	Dissolved Oxygen (4.2‡, 4.3‡)
	0.3	Zinc (505**)
Little Deer Creek		
	0.4	Dissolved Oxygen (4.8‡)

Table 9. Continued.

Stream	River Mile	Parameter (value)
Pymatuning Creek		
	17.78	Dissolved Oxygen (1.7‡‡, 1.7‡‡, 2.8‡‡, 3.0‡‡, 3.8‡‡, 4.3‡, 4.9‡)
	17.30	Dissolved Oxygen (2.0‡‡, 2.0‡‡, 2.3‡‡, 2.6‡‡, 3.3‡‡, 4.6‡, 4.8‡)
	16.10	Dissolved Oxygen (1.8‡‡, 2.0‡‡, 3.3‡‡, 3.6‡‡, 4.4‡)
	15.87	Dissolved Oxygen (1.7‡‡, 1.8‡‡); Fecal Coliform Bacteria (6400◊◊); Fecal Coliform Bacteria (4000◊)
	15.85	Dissolved Oxygen (1.8‡‡, 1.8‡‡); Fecal Coliform Bacteria (7600◊◊, 14000 ◊◊); Fecal Coliform Bacteria (2500◊)
	15.80	Dissolved Oxygen (1.6‡‡, 1.8‡‡, 2.6‡‡, 3.4‡‡, 4.0‡, 4.6‡, 4.9‡); Fecal Coliform Bacteria (2300◊)
	15.20	Dissolved Oxygen (1.8‡‡, 2.5‡‡, 2.6‡‡, 3.0‡‡,4.5‡, 4.6‡)
	8.40	Dissolved Oxygen (3.3‡‡, 4.6‡)
	1.94	Dissolved Oxygen (4.2‡)

* exceedence of numerical criteria for prevention of chronic toxicity (Chronic Aquatic Concentration [CAC]).
** exceedence of numerical criteria for prevention of acute toxicity (Acute Aquatic Concentration [AAC]).
\# exceedence of numerical criteria for human health 30-day average.
‡ exceedence of the average warmwater habitat dissolved oxygen (D.O.) criterion (5.0 mg/l).
‡‡ exceedence of the minimum warmwater habitat dissolved oxygen (D.O.) criterion (4.0 mg/l).
◊ exceedence of the average Primary Contact Recreation criterion (fecal coliform 1000/100 ml; E. coli 126/100 ml).
◊◊ exceedence of the maximum Primary Contact Recreation criterion (fecal coliform 2000/100 ml; E. coli 298/100 ml).
◊◊◊ exceedence of the maximum Secondary Contact Recreation criterion (fecal coliform 5000/100 ml; E. coli 576/100 ml).

NOTE: Iron exceeded 1.0 mg/l (the CAC) in 49 of 65 (75.4%) non-mixing zone samples in the upper Mahoning River study area, 127 of 130 (97.7%) samples in the lower Mahoning River, 32 of 78 (41%) samples in the Mill Creek basin, and 9 of 10 (90%) samples in the Pymatuning Creek basin.



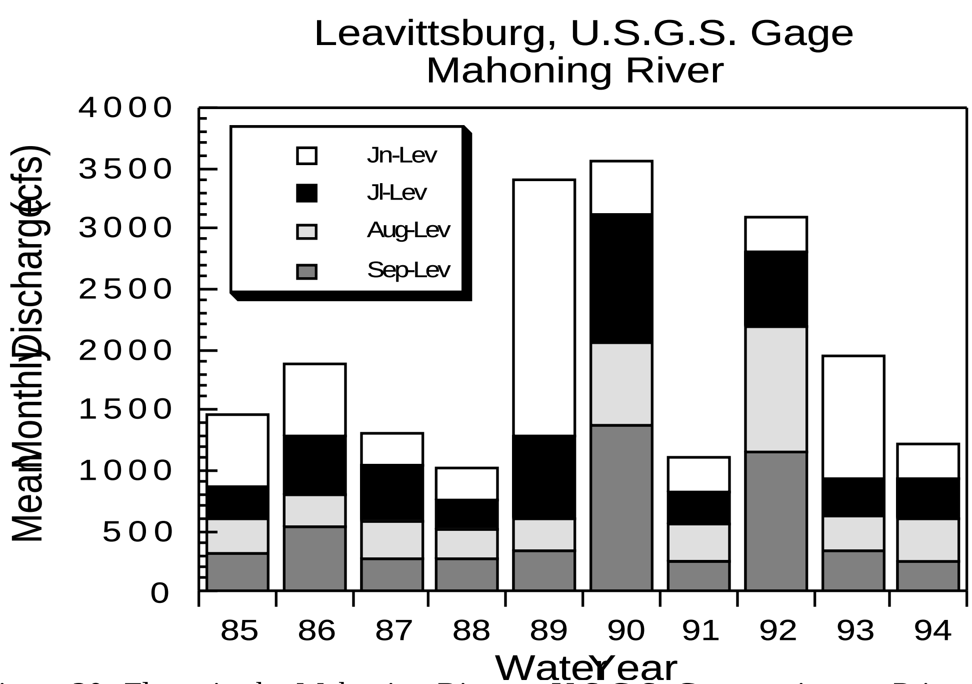


Figure 30. Flows in the Mahoning River at U.S.G.S. Gage stations at Pricetown (RM 63.12) and Leavittsburg (RM 45.51) during the summer months from 1985 to 1994..

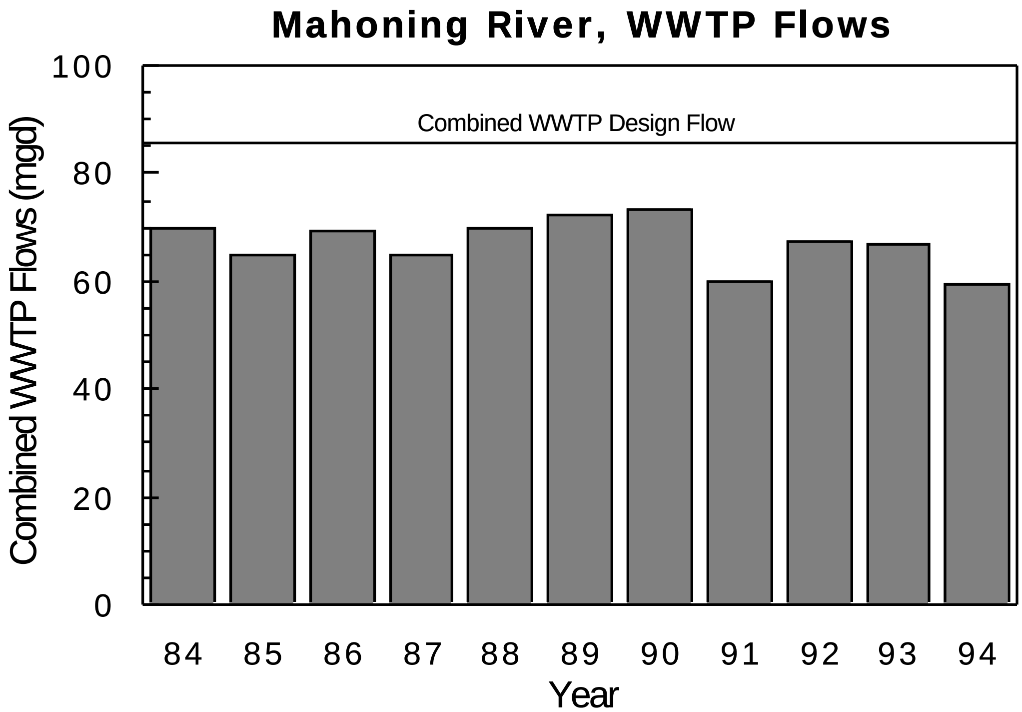
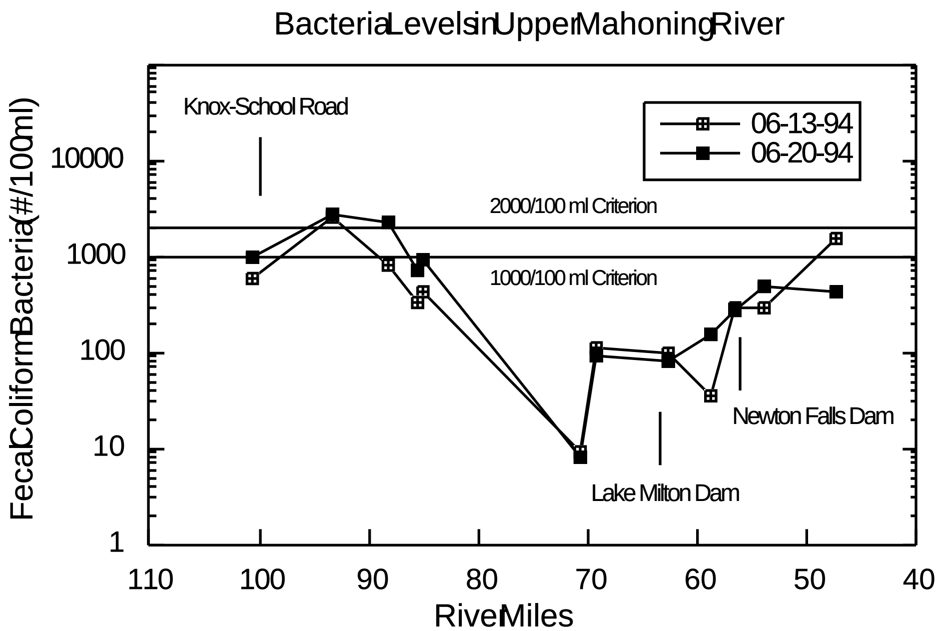


Figure 31. Combined annual median discharge from eleven major WWTPs in the Mahoning River basin, 1984 to 1994.



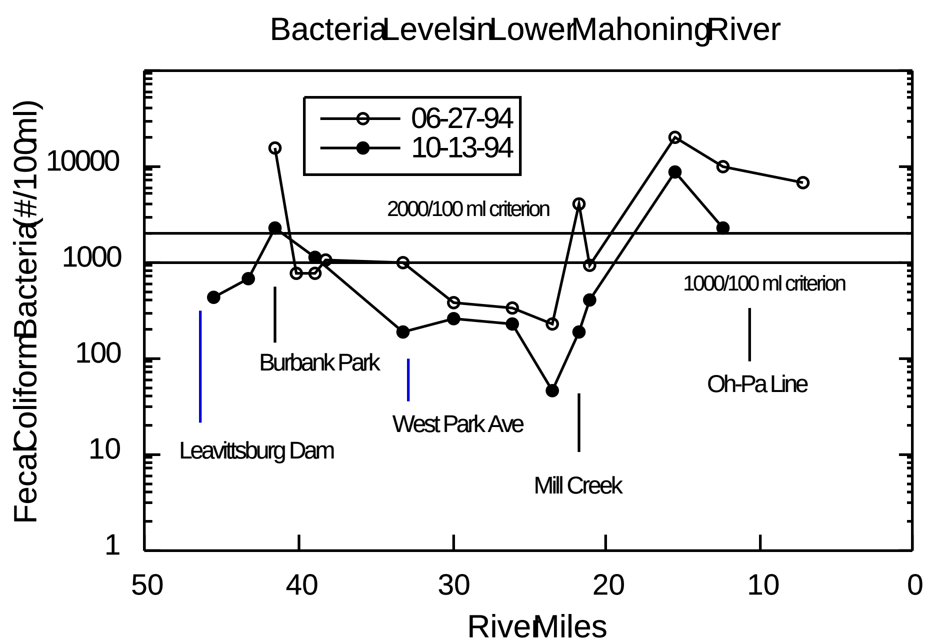


Figure 32. Longitudinal summary of fecal coliform in the Mahoning River, 1994.

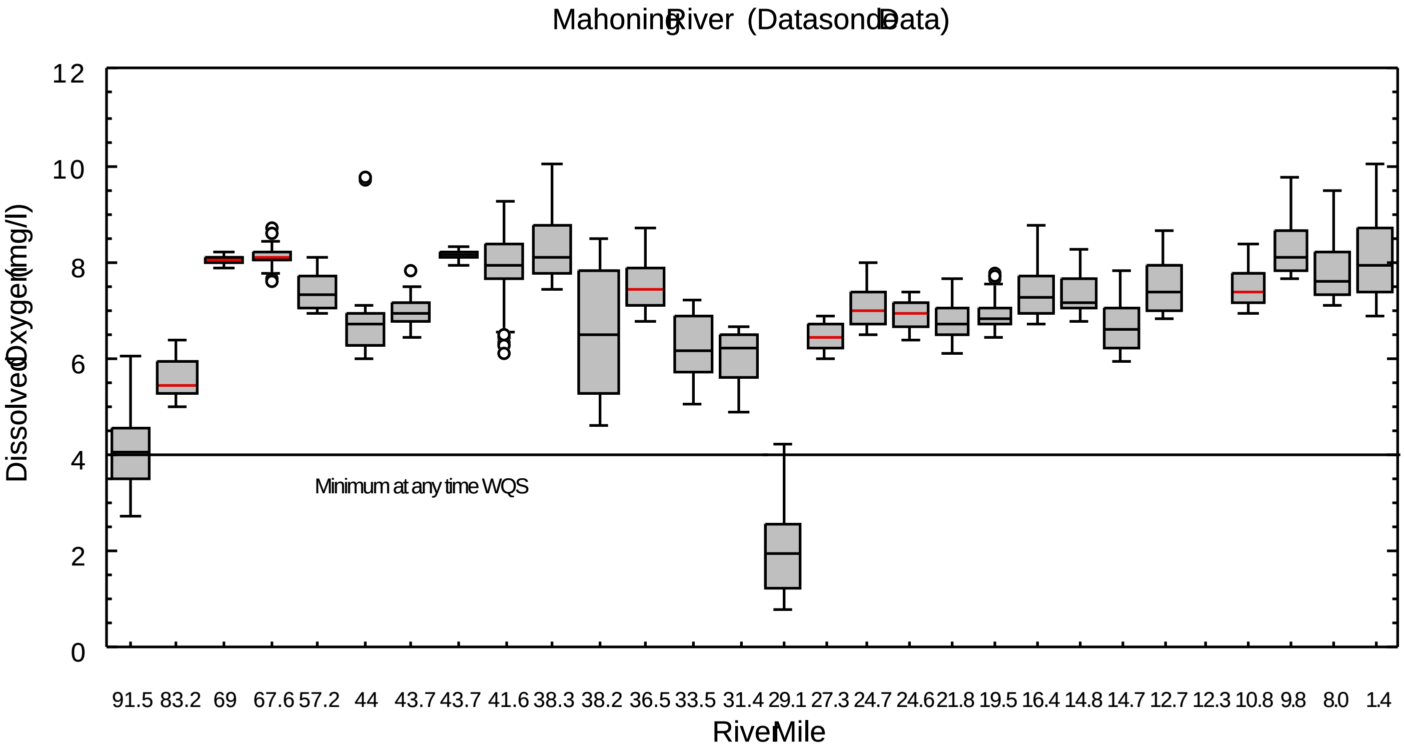


Figure 33. Longitudinal summary of dissolved oxygen (datasonde continuous 24-hour sampling) in the Mahoning River, 1994.

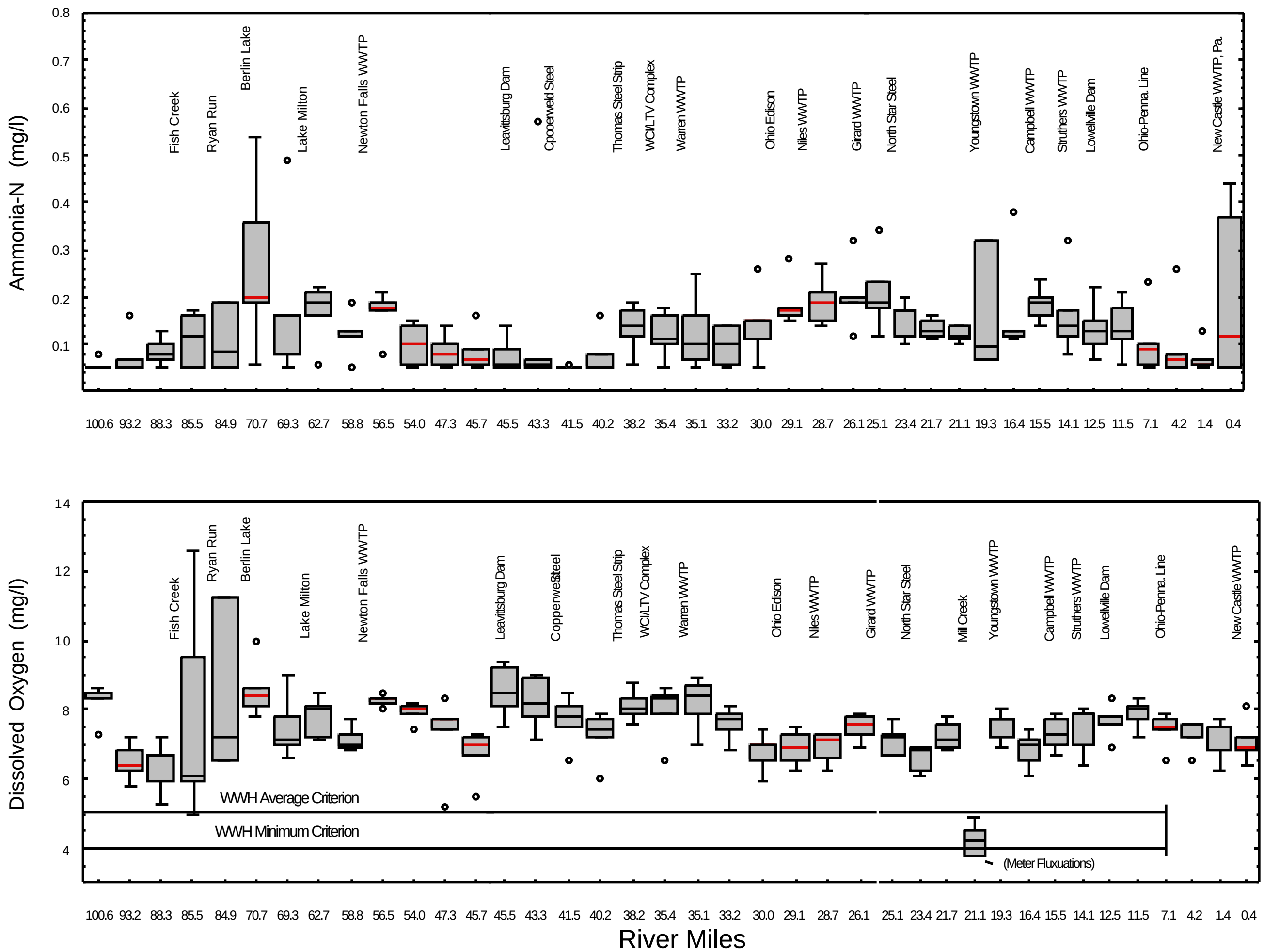


Figure 34. Longitudinal summary of dissolved oxygen (grab samples) and ammonia in the Mahoning River, 1994.

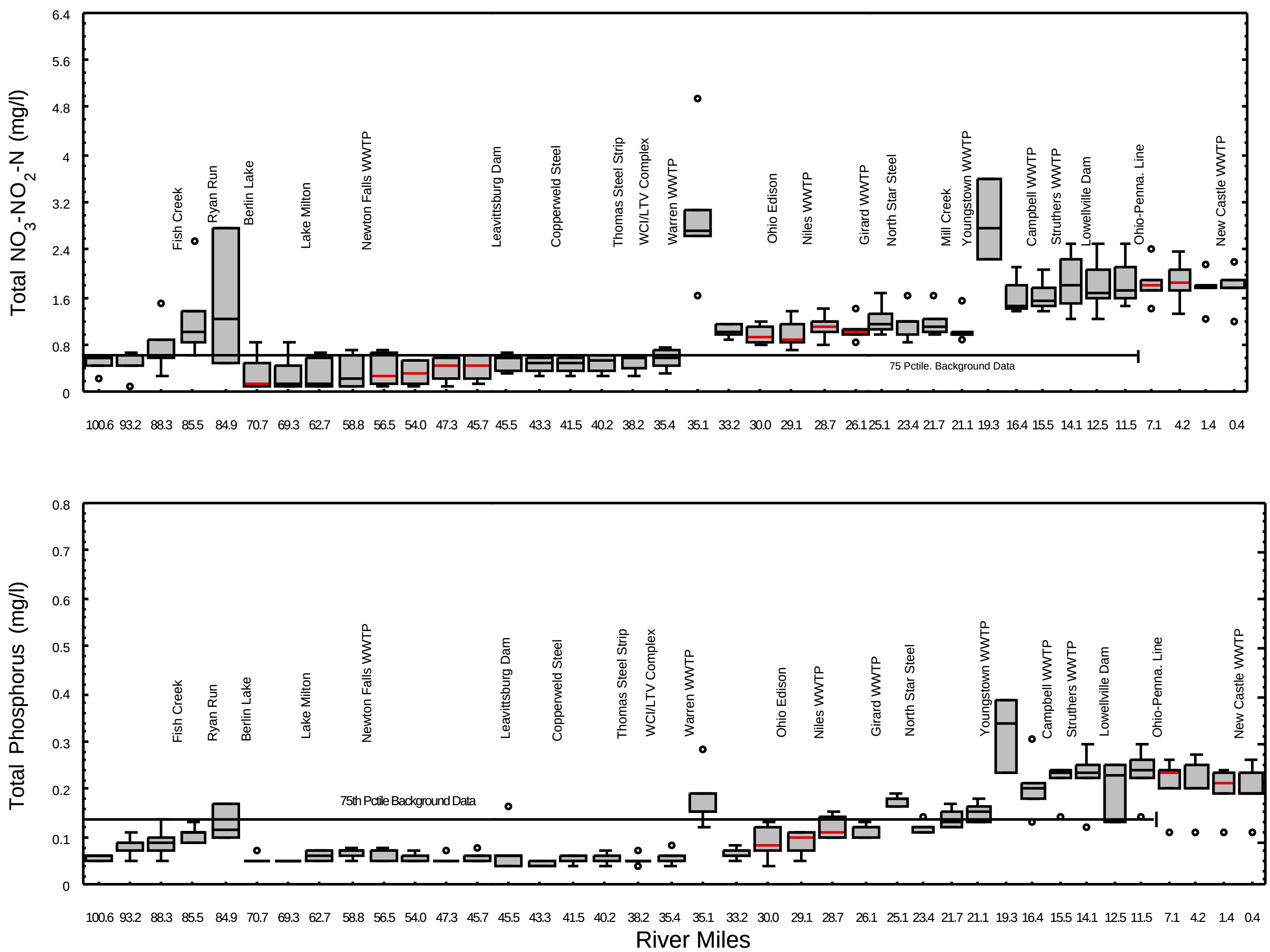


Figure 35. Longitudinal summary of nitrate+nitrite-N and total phosphorus in the Mahoning River, 1994.

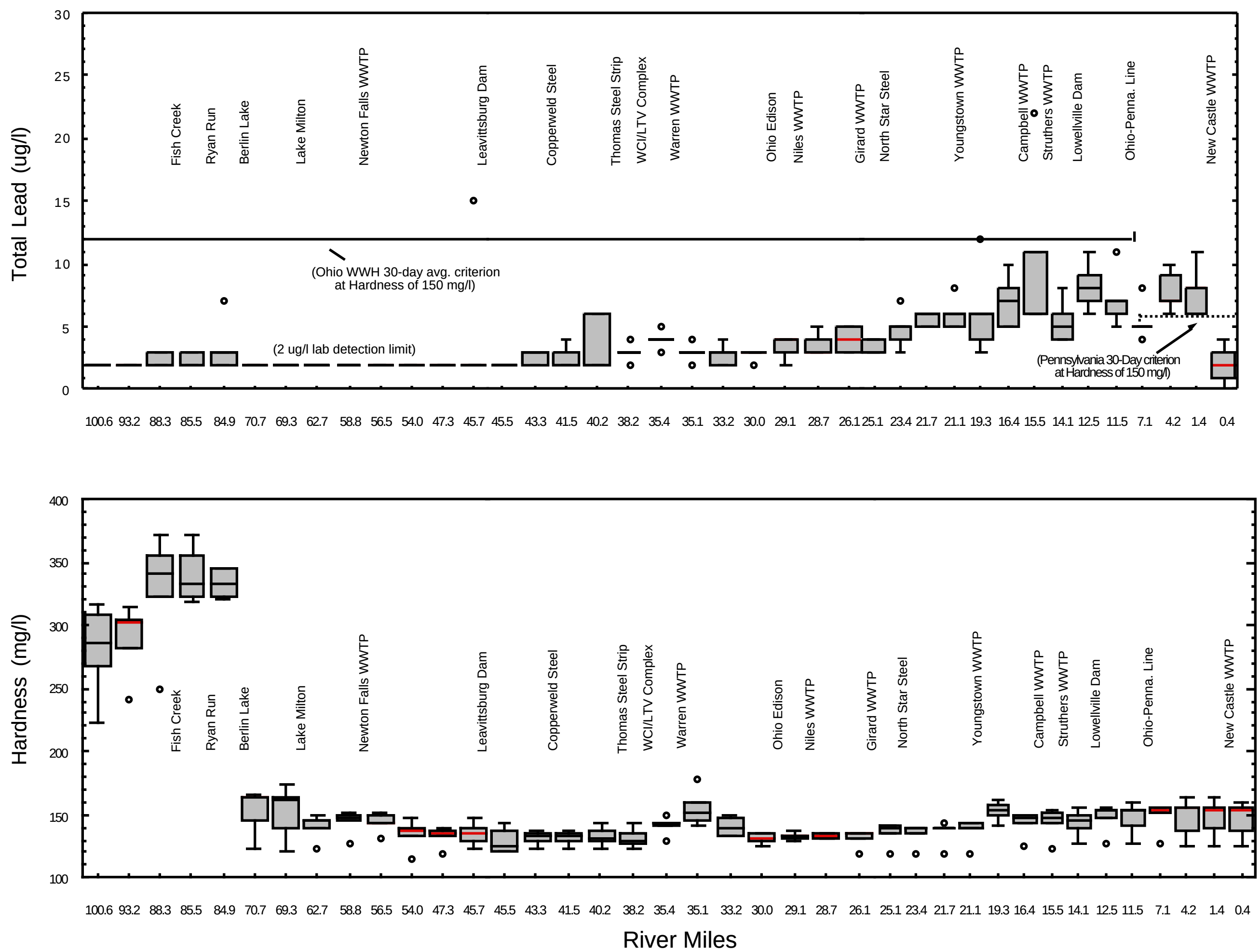


Figure 36. Longitudinal summary of total lead and hardness in the Mahoning River, 1994.

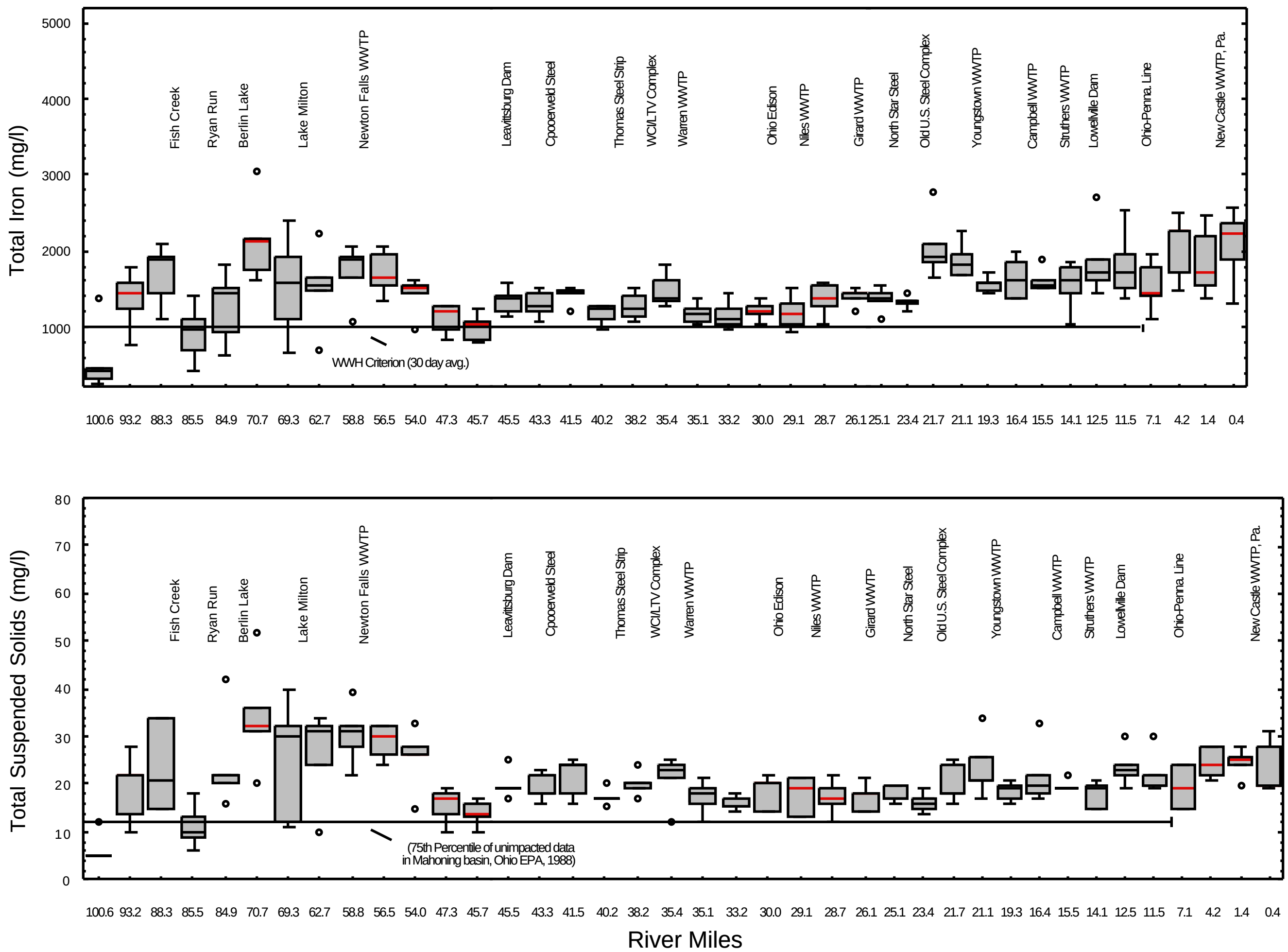


Figure 37. Longitudinal summary of total iron and total suspended solids (TSS)in the Mahoning River, 1994.

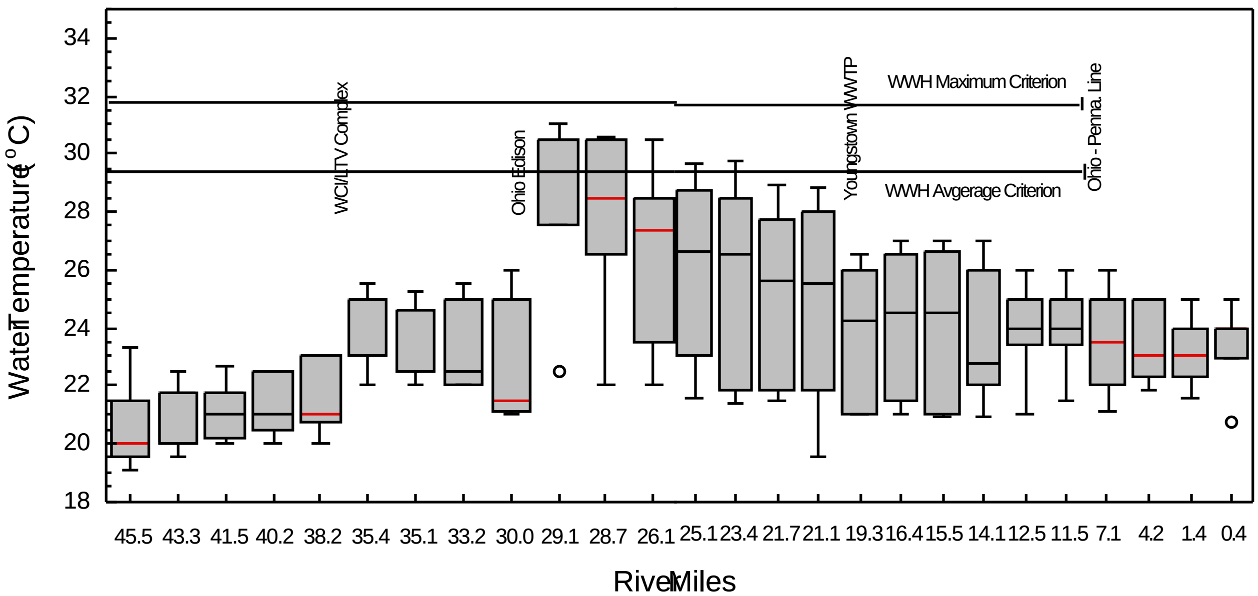


Figure 38. Longitudinal summary of temperature in the Mahoning River, 1994.

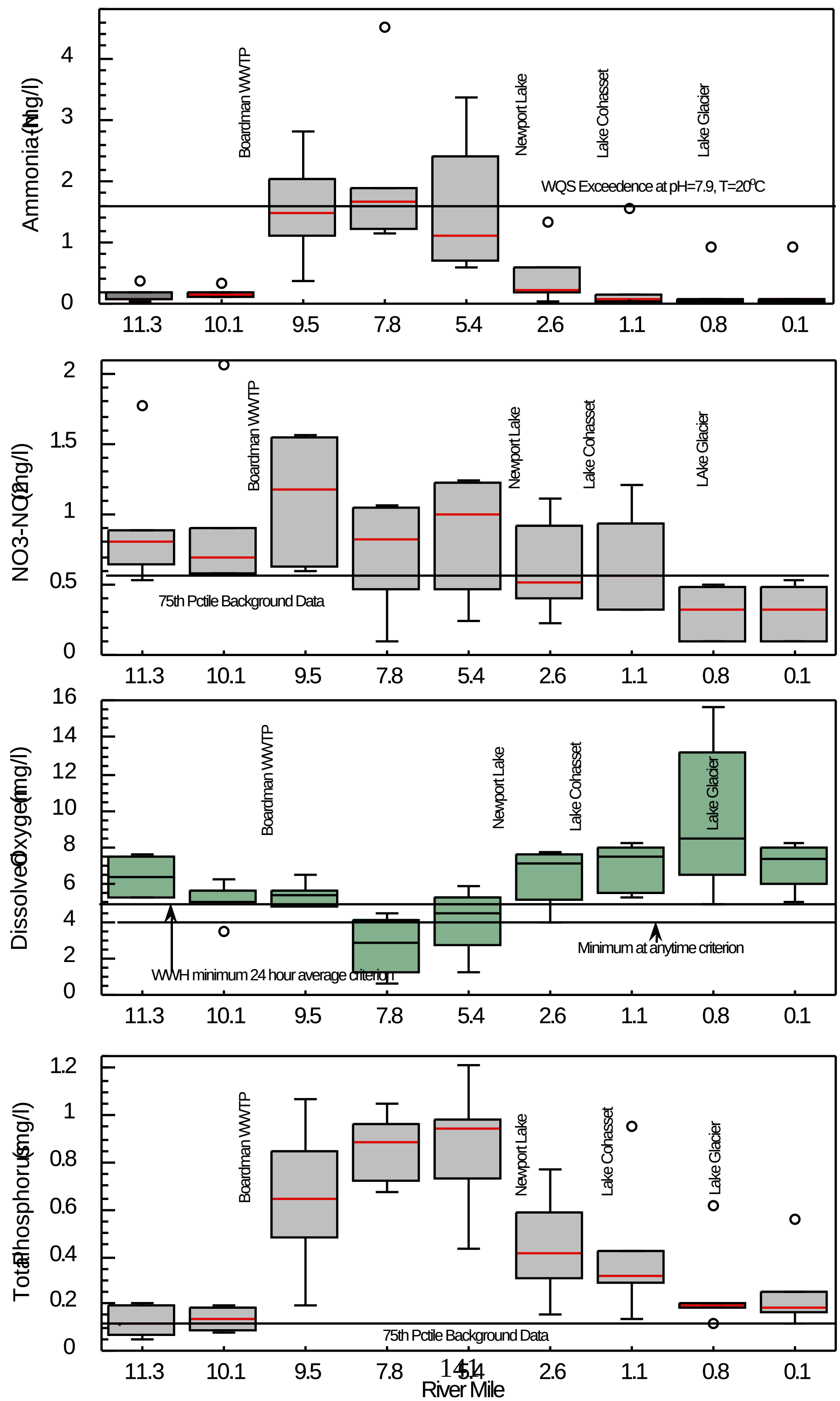


Figure 39. Longitudinal summary of ammonia, nitrate+nitrite-N, dissolved oxygen, and total phosphorus in Mill Creek, 1994.

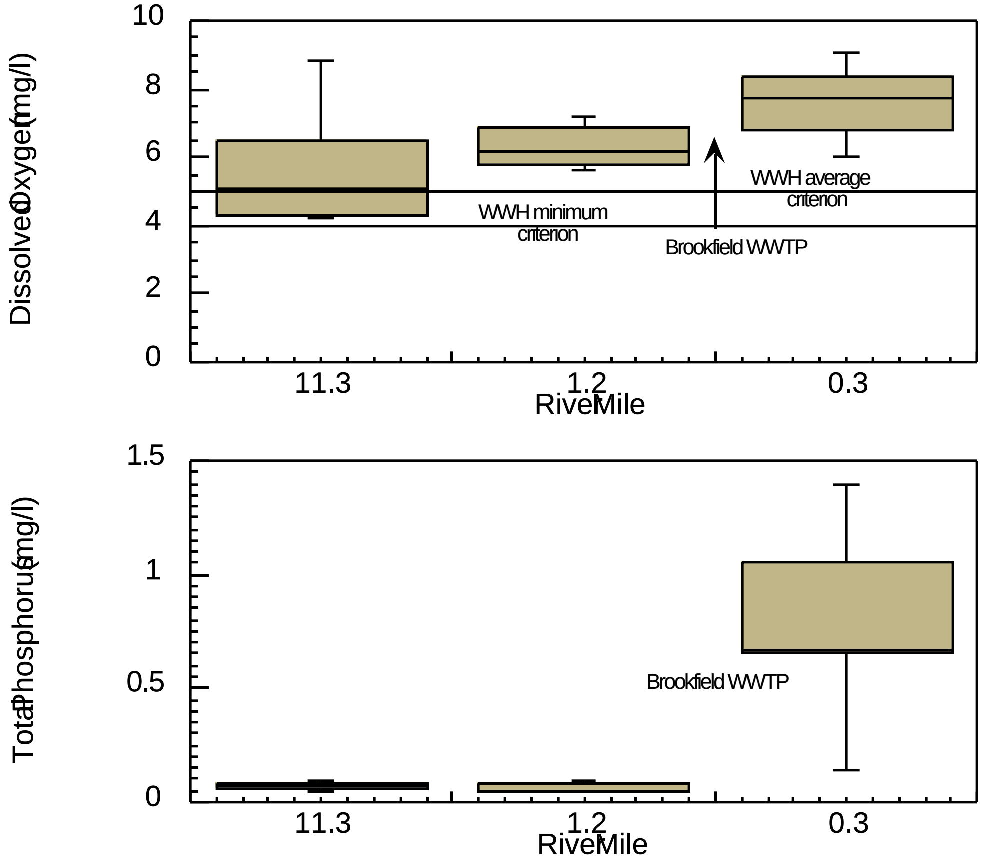


Figure 40. Longitudinal summary of total phosphorus and dissolved oxygen in Yankee Creek, 1994.

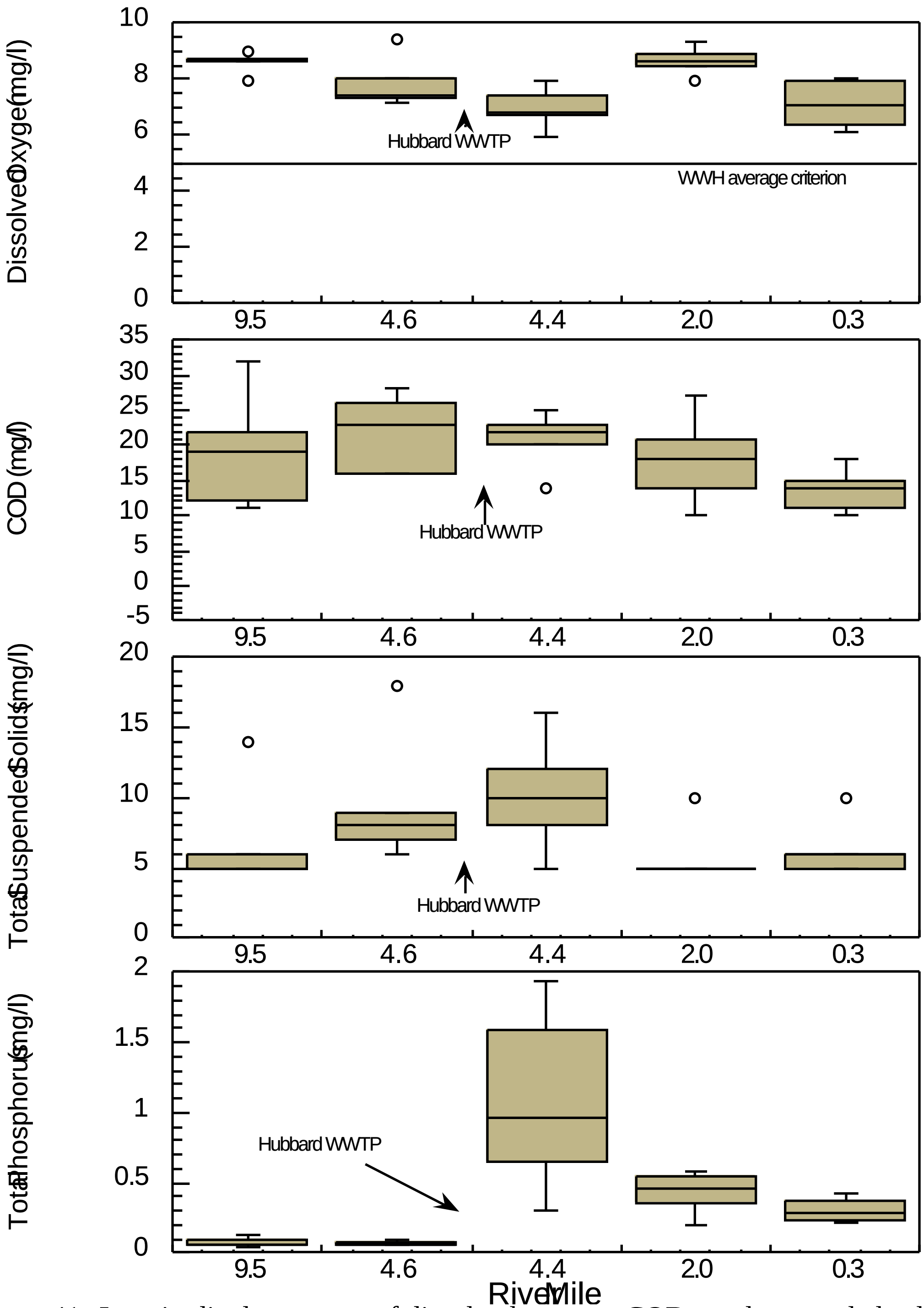


Figure 41. Longitudinal summary of dissolved oxygen, COD, total suspended solids, and total phosphorus in Little Yankee Creek, 1994.

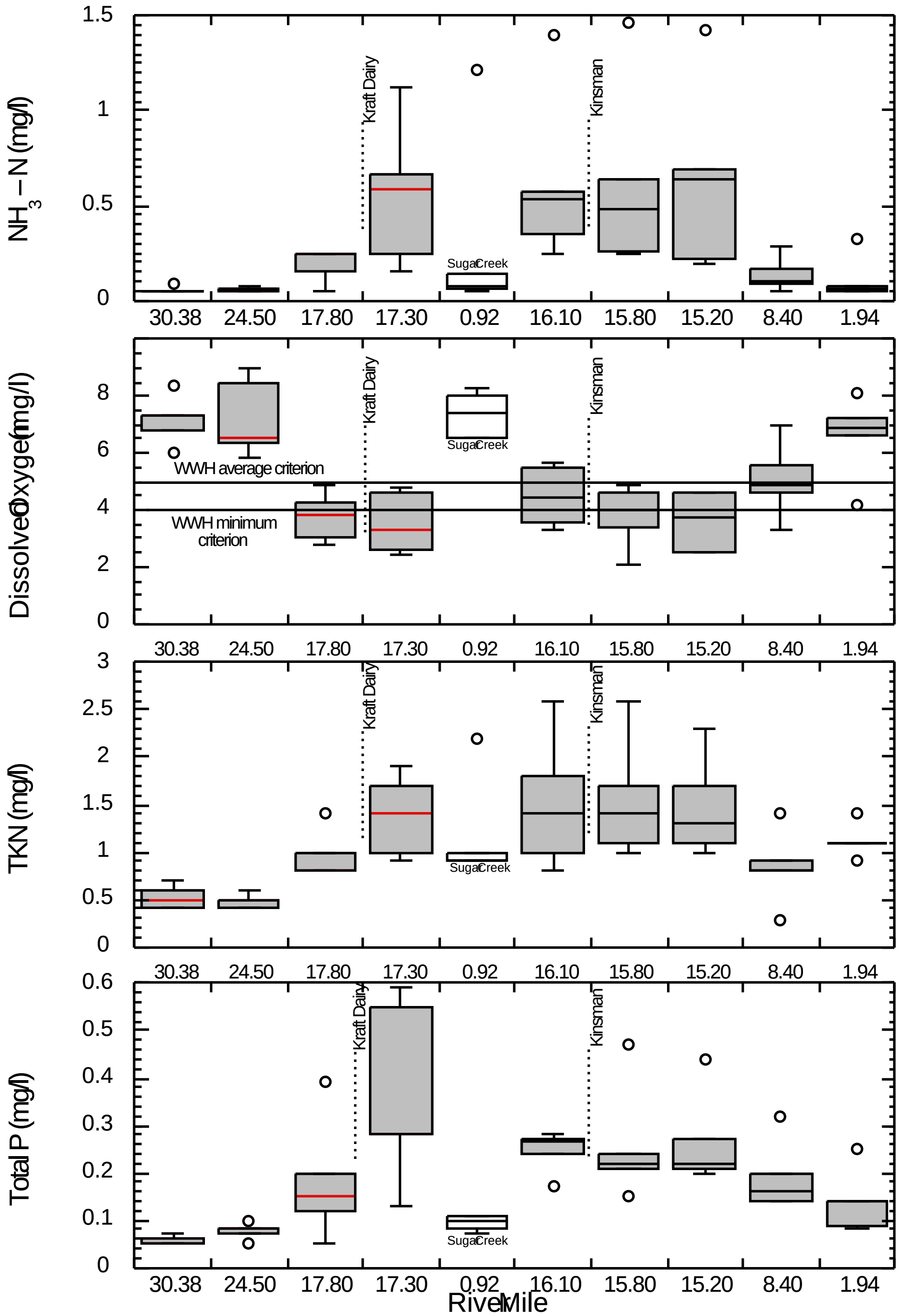


Figure 42. Longitudinal summary of ammonia, nitrate+nitrite-N, total kjeldahl nitrogen(TKN), and total phosphorus in Pymatuning Creek, 1994.

Sediment Quality (Tables 10-12, Figures 43-47)

- The Ohio Department of Health issued an advisory against swimming and wading (July 23, 1988) in a stretch of the Mahoning River from the Northwest Bridge in Warren (RM 40.77) extending downstream to the Pennsylvania border (RM 11.43). The advisory indicates that contact with the sediment on the river bottom and along the banks should be avoided. The advisory also recommended that the public not consume any fish species caught in the advisory area. The major chemicals of concern were PAH compounds, PCBs, phthalate esters, and heavy metals.

- During the fall of 1994 sediment samples were collected from 25 stations along the Mahoning River mainstem for heavy metals, and from 17 stations for extractable organics (e.g., PAHs), and 21 locations for PCBs and pesticides (Tables 10-12). Mercury was not sampled at any of the stations. Sediment sample locations were selected to match biological sample stations, and were not selected to specifically identify present or past effluents as potential sources. All samples were collected from the stream near the sides of the channel using a stainless steel scoop. Samples were from surface deposits, 4 -6 cm in depth.

- Sediment levels were evaluated according to a statistical scheme developed by Kelly and Hite (1984), and the recently published Ontario Guidelines from Canada (August 1993, reprinted March 1994). The Kelly and Hite guidelines represent the mean and standard deviation statistics from a large number of stream sediment samples collected in Illinois. Highly elevated values represent numbers that exceed four standard deviations of the mean. The Ontario guidelines are based on toxicity results from sediment bioassay, and use the criterion of “severe effect level” to indicate levels of pollutants that would have a very high probability of being toxic to aquatic life at the concentrations measured. Ontario recommends that any sites with levels above “severe effect levels” be further tested using sediment bioassay protocols.

Upper Mahoning River (RMs 100.57-45.73)

- Sediment results for heavy metals from 6 sites in the upper Mahoning River mainstem showed only one site, Webb Avenue in Alliance (RM 85.0), with highly elevated concentrations of copper, chromium, and lead based on the Kelly and Hite (1984) guidelines (Figures 43,44). However, none of these metals exceeded the Ontario severe effects levels. Samples for organic chemicals also indicated the presence of PCBs, pesticides, and two PAH compounds at the RM 85.0 Webb Road station. Additional sediment sampling in the Alliance-Sebring area will be required to define possible sources. Potential sources include spills, urban runoff, landfills, junk yards, and undocumented point sources. Because Ryans Run enters below the Webb Road station, discharge and runoff from the Alliance Tubular Products Co. is not a source for the contamination at RM 85.0.

Lower Mahoning River (RMs 45.51-mouth in Pa.)

- Sediment samples for heavy metal analysis were collected once at 19 locations in the lower Mahoning River mainstem (Figures 43,44). The first significant impact on sediment quality from heavy metals was found downstream from the CSC Inc., Copperweld Steel company property. From upstream Copperweld at RM 43.3 to downstream at RM 41.5 sediment concentrations increased an order of magnitude for copper (nonelevated to highly elevated), chromium (highly to extremely elevated), iron (highly to extremely elevated) , and nickel. Using the Ontario severe effects levels as guidelines, RM 41.5 was the first site on the Mahoning River that had severe effect levels of sediment metals (chromium, iron, and nickel). One possible source of these heavy metals at Copperweld Steel Co. is the historic landfilling of electric arc furnace dust. In June 1995, Ohio EPA DERR personnel collected six sediment samples along CSC property. These samples were tested for metals, PCBs, and sediment bioassay toxicity. None of the samples showed any sediment toxicity.

- Cadmium (slightly elevated) and zinc (extremely elevated) increased at the next downstream site at RM 40.2 at Packard Park. Although levels of copper, chromium, iron, and nickel were less at RM 40.2 compared to upstream, these levels increased again at RM 38.9 (Perkins Park), which is located downstream from the Thomas Steel Strip discharge at RM 39.17. Highly elevated levels of copper, nickel, and chromium were found in a sediment sample collected at the mix-zone of the Thomas Steel discharge outlet at the Dicky Run stormsewer. In addition, the highest level of barium (208 mg/kg) in the entire Mahoning River mainstem was detected at the mouth of the Dicky Run stormsewer.

- As shown in Figures 43 and 44, sediment metals well above the Ontario severe effects levels for chromium, copper, lead, nickel, and iron continued throughout the lower 40 river miles of the lower Mahoning River down to the mouth. Different metals peaked at different locations, which suggests numerous and multiple possible sources. However, the data clearly indicate that very poor heavy metal sediment quality exists in the lower Mahoning River beginning at RM 41.5 at levels suspected to be toxic to aquatic life. Potentially toxic levels of heavy metals in sediment may be the most important factor to explain the very poor biological communities found in the lower Mahoning River segment below RM 41.5. Potential sources include the extensive historical steel making facilities in the Mahoning valley, current NPDES loadings of heavy metals, spills, and urban runoff.

- Figure 46 shows levels of polynuclear aromatic hydrocarbons (PAHs) collected from the lower Mahoning River sediment. PAHs are a diverse class of compounds that occur in soot, coal tar, tobacco smoke, petroleum and cutting oils. They are also associated with industrial processes such as creosote, asphalt, coking operations, and steel production. Some chemicals in the PAH group, specifically benzo(a)anthracene, benzo(a)pyrene, flouranthene, and phenanthrene are considered to be carcinogenic.

- The results from Figure 46 indicate no PAH compounds in the lower Mahoning River sediments until Packard Park (RM 40.2). This site is below Red Run, an unsewered area with numerous industrial entities. Three subsequent peaks for total PAH compounds were found at RM 35.5 below the WCI/LTV Steel complex, at RM 16.4 near the current LTV Campbell plant, and at RM 11.5, just above the Ohio-Pennsylvania. state line. Historically, the Mahoning River between RM 36 and RM 16 had three coking operations, the current LTV Warren coke plant (RM 35.68), the old Republic Steel Youngstown coke plant (RMs 19-18), and the J&L Youngstown Sheet and Tube Campbell coke plant (RMs 17-16). Although not the only possible source of PAHs to the Mahoning River, the data from Figure 46 suggest higher PAH levels in areas of current or past coking operations. In their 1986 sediment PAH samples of the lower Mahoning River, the US EPA found highly elevated total PAHs in samples near historical coke plant discharge points (see Estenik, 1988). Thus it would be expected that much higher levels of PAHs exist in the stream sediment at sites closer to historical coke plant effluents and direct runoff from coking operations than the data collected for this 1994 survey. It is suggested that future sampling for PAHs in sediment be conducted closer to known coking operations in order to more accurately identify potential sources.

- Using the Ontario guidelines, none of the individual PAH compounds in the lower Mahoning

River were detected at severe effect levels, assuming a TOC of 10%, or 5%, however, the presence of the four common carcinogenic PAHs throughout the lower mainstem does suggest possible carcinogenic effects on fish and other aquatic life. Values of the four common carcinogenic PAH compounds found in the lower Mahoning River were within ranges where neoplasia has been reported in fish (Estenik, 1988).

- Figure 45 shows levels of PCBs in the lower Mahoning River sediment. The highest levels of PCBs were detected downstream from the WCI/LTV Warren complex, with values reaching close to 3500 ug/kg. A second peak was found downstream from the old Youngstown Sheet and Tube Company (RM 23.4), currently North Star Steel. Because PCBs are known to bioaccumulate through the food chain, their widespread presence throughout the lower Mahoning River downstream from Perkins Park (RM 38.9) in Warren indicates significant potential for fish contamination. The level of PCB 1260 (2469.8 ug/kg) collected downstream from the WCI/LTV Warren complex (RM 35.4), exceeded the Ontario severe effect level assuming a 10% TOC sediment concentration.

- Figure 47 shows levels of pesticides found in the lower Mahoning River sediment. As many as seven different pesticides were detected at a number of stations. Clusters of pesticides were detected at Packard and Perkins Parks (RMs 40.2 and 38.9), a peak for 4,4 DDD downstream from the WCI/LTV complex (RM 35.5), and three additional peaks at Belmont Ave (RM 29.9), upstream Mill Creek (RM 21.7), and downstream the Struthers WWTP (RM 13.2). Because there is no clear trend for any one specific pesticide, these data indicate numerous and multiple sources for these now illegal pesticides. Using the Ontario Guidelines, non of the specific pesticides were found above the severe effect levels assuming a TOC of 10% or 5%.

- Bis-2-ethyl-Phthalate was found in the sediment at seven sites in the lower Mahoning River from Perkins Park (RM 38.9) to RM 1.4 in Pennsylvania. The highest level in Ohio was downstream from the Struthers WWTP (RM 13.2), however, the highest level in the river was at Rt. 108 in Pensylvania (RM 1.4), upstream from the New Castle WWTP discharge.

- In summary, the elevated levels of heavy metals, PAHs, PCBs, and pesticides throughout the lower 40 river miles of the Mahoning River indicate that very poor and potentially toxic sediment quality would be expected to have a severe impact on the aquatic life use potential of the biological communities in the lower Mahoning River. The presence of carcinogenic PAHs and bioaccumulative PCBs also indicate potential effects on human health .

Meander Creek

- Sediment samples for heavy metals analysis were collected upstream (RM 2.0) and downstream (RM 1.8) from the Meander Creek WWTP discharge. All the heavy metals were significantly higher at the downstream station, which indicates that the discharge of metals from the WWTP has accumulated in the stream sediments over time. Highly elevated levels of chromium, lead, and zinc were found at the downstream station, however, none of the values exceeded the Ontario severe effects guidelines (Table 10).

- The sample at RM station 2.0 was located immediately downstream from the MVSD drinking Water Plant drains that had, prior to 1998, discharged lime sludge directly into Meander Creek. During the 1994 sampling, no evidence of lime sludge was observed at RM 2.0. Observations at RM 1.8, downstream from the Meander Creek WWTP discharge, indicated a layer of organic matter, most likely from decay of the excessive growths of filamentous algae observed growing at this site. The primary cause of this algal growth would be the high levels of phosphorus and nitrates being discharged from the Meander Creek WWTP.

Mill Creek

- Sediment samples were collected at three locations in the study area(RMs 11.3, 7.8, 0.1) to assess levels of contaminants present in Mill Creek and its tributaries. All sites except for the tributaries were analyzed for heavy metals, pesticides, and polychlorinated biphenyls (PCB's). The Mill Creek tributaries were only analyzed for heavy metals. The tributaries Bears Den Run, Ax Factory, Anderson Run and Indian Run were all sampled at their respective mouth's. The 1994 sediment metals data for the Mill Creek basin was evaluated based on sediment classification criteria described by Kelly and Hite(1984) and the 1994 revised Ontario Sediment Guide. Both of these evaluations can be found in Table 10.

- At RM 11.3 the most upstream station, iron and zinc were in the highly elevated range with chromium and lead in the elevated range. Nickel was in the severe effect level according to the Ontario guidelines. Cadmium was the only metal in the slightly elevated range. The sources of these metals at RM 11.3 are unknown, but most likely are from nonpoint sources found upstream. At RM 7.8 levels of chromium, zinc and iron are in the elevated range. All other metals are in the non-elevated or slightly elevated range. At RM 0.1 levels of iron, lead and zinc were in the elevated range. And again all other metal at this site were in the non-elevated or slightly elevated range.

- The summed total of DDT compounds(a total of 4,4'-DDE, 4,4'-DDT, 4,4'-DDD) analyses showed slightly elevated values at RM's 11.3 and 7.8. At RM 11.3 d-BHC was found at a concentration of 2.45 ug/kg.

Bears Den Run

- In the Bears Den Run tributary, chromium and iron were in the highly elevated range and arsenic and zinc were in the elevated range. All other metals at this site were in the non-elevated or slightly elevated range.

Ax Factory

- In the Ax Factory tributary, arsenic and iron were highly elevated with all other metals non-elevated or slightly elevated.

Anderson Run

- Metals were in the non-elevated or slightly elevated range except for iron, which was in the elevated range.

Indian Run

- Metals were in the non-elevated or slightly elevated range except for iron, which was in the elevated range.

Beaver River

- Sediment was sampled at RM 14.78 at the Rt. 288 USGS gage station in Pennsylvania. Highly elevated levels of arsenic, chromium, lead, and zinc were found, but none of the concentrations exceeded the Ontario severe effects levels. However, two metals, chromium at 95.5 mg/kg and zinc at 713 mg/kg were at concentrations within 10% of the Ontario severe effects values. Sediment at RM 14.78 in the Beaver River also contained nine PAH compounds at a total concentration of 15.6 mg/kg, which was lower than the 21.9 mg/kg total PAH concentration found near the mouth of the Mahoning River in Ohio (RM 1.4). PCBs were found at a total concentration of 502.96 ug/kg, and three pesticides (DDT,DDE, and dieldrin) were found at low concentrations in the river sediments.

Yankee Creek

- The sampling station at River Mile 11.3 was chosen to represent sediment quality conditions in the upper, agricultural portion of the basin. Arsenic and zinc concentrations were in the elevated range, an indication of runoff effects from local agricultural lands or natural glacial input. All of the other heavy metals were in the slightly elevated or non-elevated ranges.

- The sampling station at River Mile 0.3 was located below the Brookfield WWTP discharge. All results were in the non-elevated ranges.

Little Yankee Creek

- The sampling station at River Mile 9.5 was chosen to represent background conditions in the watershed. Fine grain material was very difficult to find at this site. All results were in the slightly elevated or non-elevated ranges.

- The sampling station at River Mile 4.4 was located below the Hubbard WWTP discharge. Arsenic results were in the highly elevated range, chromium and zinc were in the elevated range, and all others were in the slightly elevated or non-elevated ranges.

- The results from the Little Deer Creek site at River Mile 0.4 were all in the slightly elevated or non-elevated ranges.

Pymatuning Creek

- Sediment results for heavy metals from RMs 24.5 and 8.4 in Pymatuning Creek showed only one parameter with highly elevated concentrations at one site. State Route 88 (RM 8.4) had highly elevated concentrations of iron (35,600 mg/kg, Table 10). The highly elevated iron level can be attributed to natural background soils and the reducing environment of wetlands in the area. Other elevated heavy metals included arsenic (12.2 mg/kg) and iron (30,700 mg/kg) at U.S. 322 (RM 24.5) and chromium (25.8 mg/kg) and zinc (108 mg/kg) at S.R. 88 (RM 8.4). Twelve of sixteen samples (75%) were at least slightly elevated using the Kelly and Hite criteria. Values at all of the other sediment sampling sites were indicative of either slightly or non-elevated concentrations. None of the samples exceeded the severe effect level established in the Ontario guidelines.

Table 10. Concentrations of heavy metals in sediments of the Mahoning River Basin study area, 1994. (All parameter concentrations, excluding selenium and nickel, were ranked based on a stream sediment classification system described by Kelly and Hite [1984]. The Kelly and Hite classification system addresses relative concentrations, but does not directly assess toxicity.) Underlined values exceed the severe effects level established in the “Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario” These guidelines are based upon a 95th percentile Screening Level Concentration derived from field data on the occurrence in sediments of benthic infaunal species and different concentrations of contaminants.

Stream River Mile	**Sediment Concentration (mg/kg dry weight)** As	Cu	Cd	Cr	Fe	Pb	Ni	Zn	Se
Mahoning River									
100.9	*15.7* c	9.67 a	0.155 a	9.95 a	*31500* c	15.9 a	15.9	51.7 a	0.701
93.20	*10.2* b	11.9 a	0.212 a	*20.7* b	*23400* c	24.9 a	19. 0	73.2 a	1.07
85.00	*10.5* b	26.8 a	*1.32* c	**45.5 d**	*24100* c	**95.1 e**	25.2	**193 d**	0.466
69.30	*16.1* c	22.9 a	0.309 a	*19.2* b	*28100* c	17. 0 a	18.4	54.1 a	0.912
58.80	*8.64* b	13.6 a	0.323 a	*19.8* b	*21400* b	*30.4* b	22.6	*86.0* b	0.477
45.70	*15.1* c	18.6 a	0.475 a	*31.8* c	**32200 d**	26.8 a	50.2	*105* c	0.820
45.50	7.72 a	5.77 a	0.153 a	12.9 a	9810 a	*41.1* c	18. 0	46.2 a	0.224
43.30	*8.67* b	20.3 a	*0.613* b	**56.8 d**	**35100 d**	**71.1 d**	33.5	*91.8* b	1.90
41.50	*15.6* c	**115 d**	0.225 a	**449 e**	**127000 e**	**63.9 d**	288	*96.6* b	1.31
40.20	*16.9* c	*58.0* b	*0.521* b	**100 e**	**62000 e**	*58.4* c	216	**599 e**	1.28
38.90	*15.8* c	**124 d**	*1.29* c	**455 e**	**389000 e**	**136 e**	378	**317 e**	
37.40	*15. 0* c	**109 d**	*0.810* b	**187 e**	**74600 e**	**132 e**	158	**337 e**	2.17
35.50	**36.3 e**	**458 e**	**5.20 d**	**549 e**	**120000 e**	**484 e**	278	**2390 e**	
35.40	**25.9 d**	**243 e**	**2.38 d**	**360 e**	**348000 e**	**244 e**	326	**1030 e**	
33.20	**31.1 e**	**207 e**	**6.25 d**	**176 e**	**55000 e**	**265 e**	159	**1120 e**	
30.00	**21.1 d**	**171 d**	**2.72 d**	**232 e**	**134000 e**	**400 e**	161	**2510 e**	3.39
26.10	**20.8 d**	**164 d**	*1.17* c	**180 e**	**184000 e**	**149 e**	149	**618 e**	3.02
23.40	**17.9 d**	**127 d**	*1.83* c	**537 e**	**186000 e**	24 a	136	**595 e**	1.94
21.70	**60.1 e**	**416 e**	**3.82 d**	**174 e**	**326000 e**	**629 e**	231	**1060 e**	2.97
19.30	*11.3* c	*94.2* c	*0.62* b	**122 e**	**167000 e**	**190 e**	92.0	**356 e**	
16.40	**19. 0 d**	**186 d**	**2.99 d**	**423 e**	**132000 e**	**491 e**	116	**1990 e**	2.66
15.50	*14.6* c	*99.0* c	*0.865* b	**125 e**	**131000 e**	**1450 e**	44.7	**432 e**	1.57
13.20	**23.8 d**	**282 e**	**3.81 d**	**452 e**	**139000 e**	**667 e**	198	**2880 e**	3.36
11.50	*14.6* c	**123 d**	*0.781* b	**122 e**	**164000 e**	**198 e**	82.9	**454 e**	2.04
1.400	**22.3 d**	**140 d**	*1.82* c	**112 e**	**158000 e**	**214 e**	103	**933 e**	3.28
Meander Creek									
2.0	3.80 a	9.87 a	0.084 a	5.79 a	8150 a	14.9 a	-	53.5 a	0.71
1.8	7.12 a	72.7 c	1.420 c	**100 e**	13200 a	**60.1 d**	20.1	**300 e**	2.30
Mill Creek									
11.3	**18.6d**	21.4a	0.585b	26.5c	**34300d**	49.7c	76.1	**239d**	
7.8	9.9b	19a	0.364a	25.6c	23200c	35.9b	25.8	108c	
0.1	7.05a	16.2a	0.462a	18.7b	26600c	47c	18.6	146c	

Table 10. (Continued) Concentrations of heavy metals in sediments of the Mahoning River Basin study area, 1994. (All parameter concentrations, excluding selenium and nickel, were ranked based on a stream sediment classification system described by Kelly and Hite [1984]. The Kelly and Hite classification system addresses relative concentrations, but does not directly assess toxicity.) Underlined values exceed the severe effects level established in the "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" These guidelines are based upon a 95th percentile Screening Level Concentration derived from field data on the occurence in sediments of benthic infaunal species and different concentrations of contaminants.

Stream	Sediment Concentration (mg/kg dry weight)								
River Mile	**As**	**Cu**	**Cd**	**Cr**	**Fe**	**Pb**	**Ni**	**Zn**	**Se**
Bears Den Run									
0.5	11.7[c]	18.4[a]	0.159[a]	**38.4**[d]	**34900**[d]	20.2[a]	52.7	108[c]	
Ax Factory									
0.1	**19.7**[d]	10.2[a]	0.178	13.5[a]	**87800**[d]	23.5[a]	20	94.3[b]	
Anderson Run									
0.2	10.6[b]	9.59[a]	0.0868[a]	7.37[a]	24800[c]	9.24[a]	13.6	46.2[a]	
Indian Run									
0.3	6.77[a]	4.28[a]	0.0719[a]	5.57[a]	23700[c]	14[a]	9.88	41.9[a]	
Beaver River									
14.78	**20.8**[d]	84.3[c]	1.24[c]	**95.5**[e]	**120000**[e]	**141**[e]	59.6	**713**[e]	2.47
Yankee Creek									
11.3	*15.3*[c]	*19.5*[b]	*0.55*[b]	12.3[a]	17700[a]	*31.6*[b]		*111*[c]	
0.3	7.26[a]	5.88[a]	0.216[a]	7.16[a]	17600[a]	<13.5[a]		53[a]	
Little Yankee Creek									
9.5	*8.87*[b]	4.11[a]	0.104[a]	4.96[a]	12600[a]	<14.7[a]		38.3[a]	
4.4	**17**[d]	16.9[a]	0.256[a]	*23.5*[c]	10100[a]	*30.6*[b]		*162*[c]	
Little Deer Creek									
0.4	*10.2*[b]	11.1[a]	0.242[a]	*16.4*[b]	*21200*[b]	27.4[a]		*89.6*[b]	
Pymatuning Creek									
24.5	*12.2*[c]	12.6[a]	*0.568*[b]	*20.2*[b]	*30700*[c]	*<28.7*[b]	30.4	*80.9*[b]	
8.4	*10.0*[b]	14.0[a]	0.488[a]	*25.8*[c]	**35600**[d]	<27.3[a]	31.7	*108*[c]	

[a] Non-elevated. [b] *Slightly elevated.* [c] *Elevated.* [d] **Highly elevated.** [e] **Extremely elevated.**
____ Underlined values indicate Ontario "severe effect. Blank spaces indicate paramater was not analyzed

Table 11. Concentration (µg/kg) of pesticides and PCBs in the sediments of the Mahoning River study area during 1994. (All parameter concentrations were ranked based on a stream sediment classification system described by Kelly and Hite [1984].The Kelly and Hite classification system addresses relative concentrations, but does not directly assess toxicity.)

Stream River Mile	Total PCBs	*Hepta-chlor	*Hepta-chlor epoxide	*Aldrin	Dieldrin	*Endo-sulfan II	*Endosulfan sulfate	DDT[3] Total
Mahoning River								
93.2	-	-	-	-	-	-	-	-
85.0	**227** [d]	-	-	-	-	0.98	-	*14.55* [c]
58.8	-	-	-	-	-	-	-	-
45.5	-	-	0.5	-	-	-	-	-
43.3	-	-	-	-	-	-	-	-
41.5	-	-	-	-	0.99 [a]	-	-	-
40.2	-	-	-	-	-	-	-	*12.49* [c]
38.9	**395.5** [d]	-	-	4.56	-	-	-	*33.45* [c]
37.4	**432.01** [d]	-	-	-	-	-	-	2.98 [a]
35.6	**2459.8** [e]	**-**	**-**	**-**	**-**	**-**	**-**	**55.63** [d]
35.4	**3375.8** [e]	-	-	-	-	-	-	-
33.2	**387.2** [d]	-	-	3.11	-	-	-	0.85 [a]
30.0	**1008.39** [d]	-	-	11.76	1.12 [a]	-	0.99	*7.59* [b]
26.1	**516.87** [d]	0.98 [a]	-	-	0.82 [a]	-	-	-
23.4	**2299.0** [e]	-	-	-	-	-	1.35	-
21.7	-	**13.55** [d]	3.23	4.57	**18.74** [d]	-	-	-
16.4	**1360.6** [d]	-	1.54	7.2	**27.46** [e]	0.99	-	-
15.5	-	-	-	1.49	2.1 [a]	2.19	1.2	*6.26* [b]
13.2	**1193.8** [d]	-	-	10.48	*6.39* [c]	1.69	-	*25.08* [c]
11.5	-	-	-	-	-	-	-	*10.69* [c]
1.4	**477.72** [d]	-	-	-	1.85 [a]	-	1.2	*13.68* [c]
Yankee Creek								
11.3	-	-	1.46	-	-	-	-	4.52 [a]
Little Yankee Creek								
9.5	-	-	-	-	-	-	-	-
Little Deer Creek								
0.4	-	-	0.74	-	-	-	-	1.99 [a]
Beaver River								
14.8	**502.96**[d]							

a Non-elevated.
b Slightly elevated.
c Elevated.
d Highly elevated.
e Extremely elevated.
3 Sum DDT is total of 4,4’-DDE, 4,4’-DDT, 4,4’-DDD.
\- Parameter analyzed, but was below laboratory detection limit

Table 12. Concentration (mg/kg) of base-neutral acid extractable compounds in the sediments of the Mahoning River study area during 1994. Individual BNA compounds did not exceed the severe effects level at either 5% or 10% TOC concentration established in the "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" These guidelines are based upon a 95th percentile Screening Level Concentration derived from field data on the occurence in sediments of benthic infaunal species and different concentrations of contaminants.

River Mile	Bis-(2-ethyl-hexyl) Phthalate	Di-N-Octyl Phthalate	Acenapthene	Acenap-Thylene	Benzo(a) Anthracene	Benzo(a) Pyrene	Benzo(b&k) Fluoranthene	Benzo(g,h,i) Perylene	Chrysene
Mahoning River									
93.2	-	-	-	-	-	-	-	-	-
85.0	-	-	-	-	-	-	0.7	-	-
58.8	-	-	-	-	-	-	-	-	-
45.5	-	-	-	-	-	-	-	-	-
41.5	-	-	-	-	-	-	-	-	-
40.2	-	-	-	-	-	0.7	1.4	0.8	0.6
38.9	6.0	2.9	-	-	1.9	1.4	2.4	0.9	1.7
37.4	-	-	-	-	2.4	2.2	4.6	1.7	2.7
35.6	-	-	1.4	-	6.1	3.1	6.2	2.9	6.2
35.4	-	-	-	-	3.5	2.0	4.0	1.7	2.8
33.2	1.0	-	-	-	4.9	3.1	6.0	2.7	4.1
30.0	-	-	-	-	1.3	0.9	2.1	1.0	1.4
26.1	-	-	-	-	2.6	2.0	4.2	1.6	2.2
23.4	1.4	-	-	-	2.7	1.9	4.1	1.6	2.8
21.7	-	-	-	-	5.3	2.2	4.9	2.1	5.7
16.4	3.9	-	3.6	0.8	5.9	3.1	6.5	2.5	4.7
15.5	-	-	-	-	1.0	1.1	2.1	0.7	1.1
13.2	14.3	-	1.9	-	6.4	3.5	7.8	3.6	5.2
11.5	0.9	-	1.1	1.8	14.2	10.5	23.4	6.0	13.3
1.4	44.9	-	-	-	2.1	1.8	3.6	1.6	1.9
Yankee Creek									
11.3	-	-	-	-	-	1.4	2.6	0.9	1.4
Little Yankee Creek									
9.5	-	-	-	-	-	-	-	-	-
Beaver River									
14.8	-	-	-	-	1.5	1.3	2.7	1.1	1.4

\- Parameter analyzed, but was below laboratory detection limit

Table 12 (continued). Concentration (mg/kg) of base-neutral acid extractable compounds in the sediments of the Mahoning River study area during 1994.

River Mile	Fluor-anthen	Indeno-(1,2,3-cd) Pyrene	2-Methyl-Napthalene	Napthalene	Phenan-threne	Pyrene	Anthracene	Diben-zofuran
Mahoning River								
93.2	-	-	-	-	-	-	-	-
85.0	0.7	-	-	-	-	-	-	-
58.8	-	-	-	-	-	-	-	-
45.5	-	-	-	-	-	-	-	-
41.5	-	-	-	-	-	-	-	-
40.2	1.1	1.0	-	-	-	0.8	-	-
38.9	3.7	1.1	-	-	1.9	3.1	-	-
37.4	6.0	2.2	-	-	3.8	4.6	-	-
35.6	19.9	3.3	-	-	-	-	-	-
35.4	7.5	2.0	-	0.6	4.3	5.9	0.7	-
33.2	8.5	3.1	-	-	3.1	7.6	0.9	-
30.0	2.6	1.0	-	-	1.0	2.4	-	-
26.1	5.3	2.1	-	-	2.6	4.3	-	-
23.4	6.6	2.0	-	2.4	2.9	5.3	0.6	-
21.7	15.7	2.5	-	-	7.5	13.5	1.5	-
16.4	20.1	3.0	2.0	5.7	14.0	14.9	2.5	2.1
15.5	1.9	1.0	-	-	0.8	1.5	-	-
13.2	20.4	3.8	1.0	1.6	5.1	19.0	1.6	-
11.5	28.1	7.7	-	1.3	17.2	-	-	-
1.4	3.5	1.9	-	1.0	1.3	3.2	-	-
Yankee Creek								
11.3	1.4	-	-	1.6	2.5	-	-	-
Little Yankee Creek								
9.5	-	-	-	-	-	-	-	-
Beaver River								
14.8	1.3	-	-	1.4	2.2	-	-	-

- Parameter analyzed, but was below laboratory detection limit

Table 12 (continued). Concentration (mg/kg) of base-neutral acid extractable compounds in the sediments of the Mahoning River study area during 1994.

River Mile	Flurene	Dibenzo-(a,h) Anthracene	Total PAHs	14 Common PAHs	4 Carcenogenic PAHs
Mahoning River					
93.2	-	-	na	na	na
85.0	-	-	1.4	1.4	0.7
58.8	-	-	na	na	na
45.5	0.5	-	-	-	-
41.5	-	-	-	-	-
40.2	-	-	6.4	6.4	1.8
38.9	-	-	18.1	18.1	8.9
37.4	-	-	30.2	30.2	14.4
35.6	-	-	83.1	76.2	39.9
35.4	-	-	35.7	34.3	17.3
33.2	-	-	44.0	43.1	20.7
30.0	-	-	13.7	13.7	5.8
26.1	-	-	26.9	26.9	12.8
23.4	-	-	30.5	29.9	14.1
21.7	-	-	65.0	61.8	30.7
16.4	-	-	95.2	86.8	43.1
15.5	-	2.7	11.2	11.2	4.8
13.2	-	-	83.3	79.3	35.4
11.5	-	-	138.6	127.3	70.0
1.4	-	-	21.9	21.9	8.7
Yankee Creek					
11.3	14.8	-	14.8	14.8	6.0
Little Yankee Creek					
9.5	-	-	-	-	-
Beaver River					
14.8	-	-	15.6	15.6	6.9

- Parameter analyzed, but was below laboratory detection limit.
na Not analyzed.

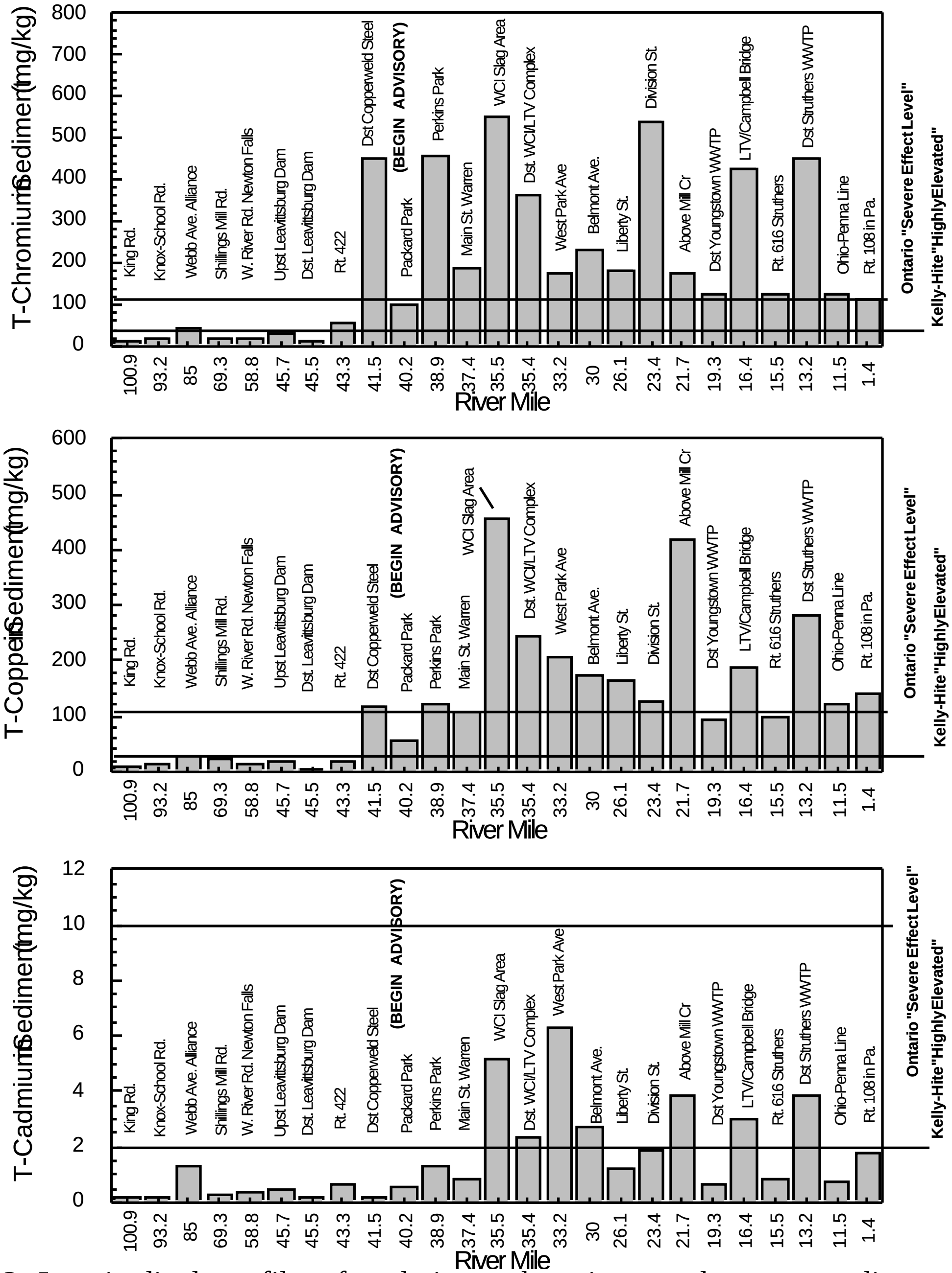


Figure 43. Longitudinal profile of cadmium, chromium, and copper sediment concentrations in the Mahoning River, 1994.

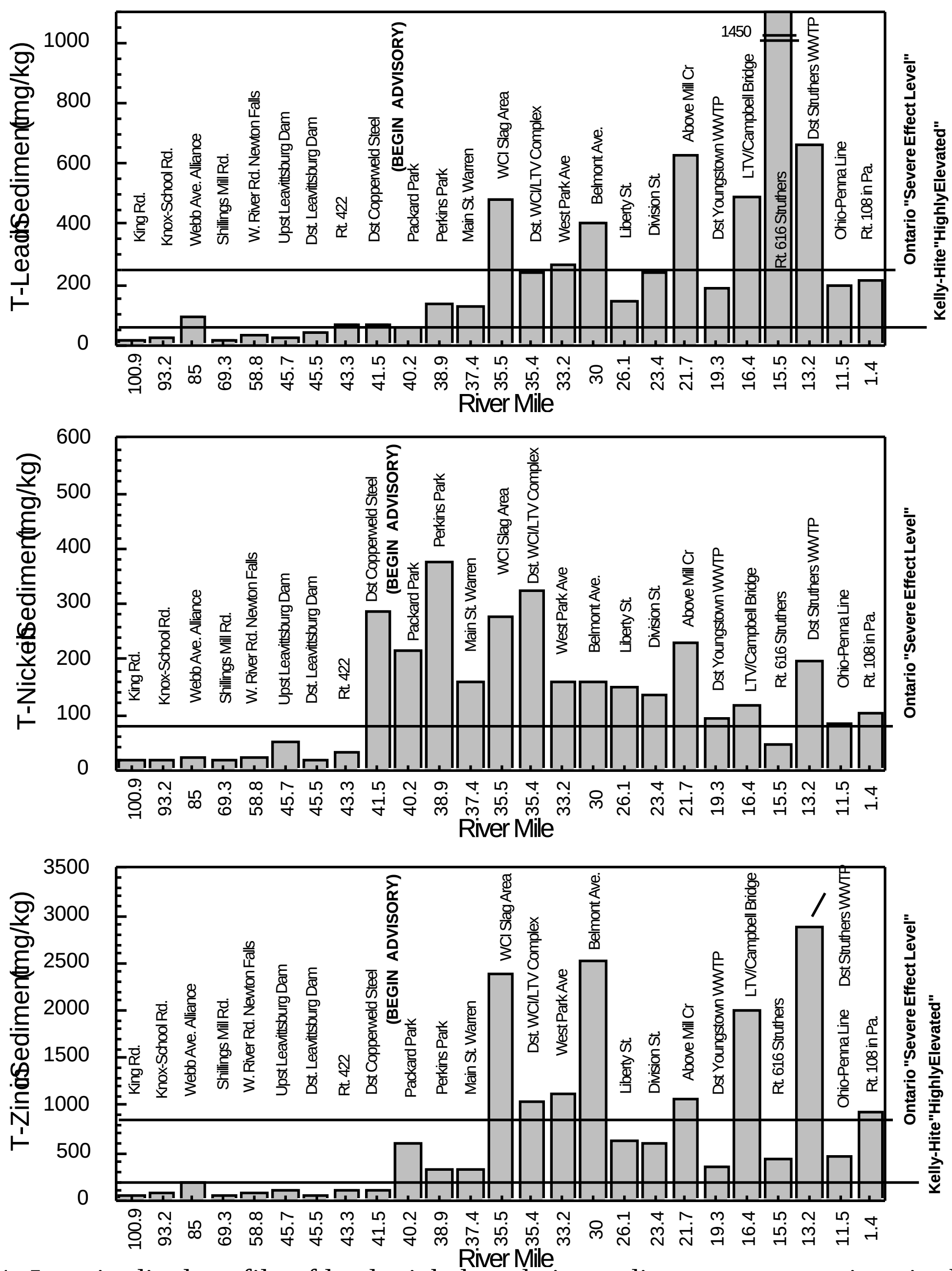


Figure 44. Longitudinal profile of lead, nickel, and zinc sediment concentrations in the Mahoning River, 1994.

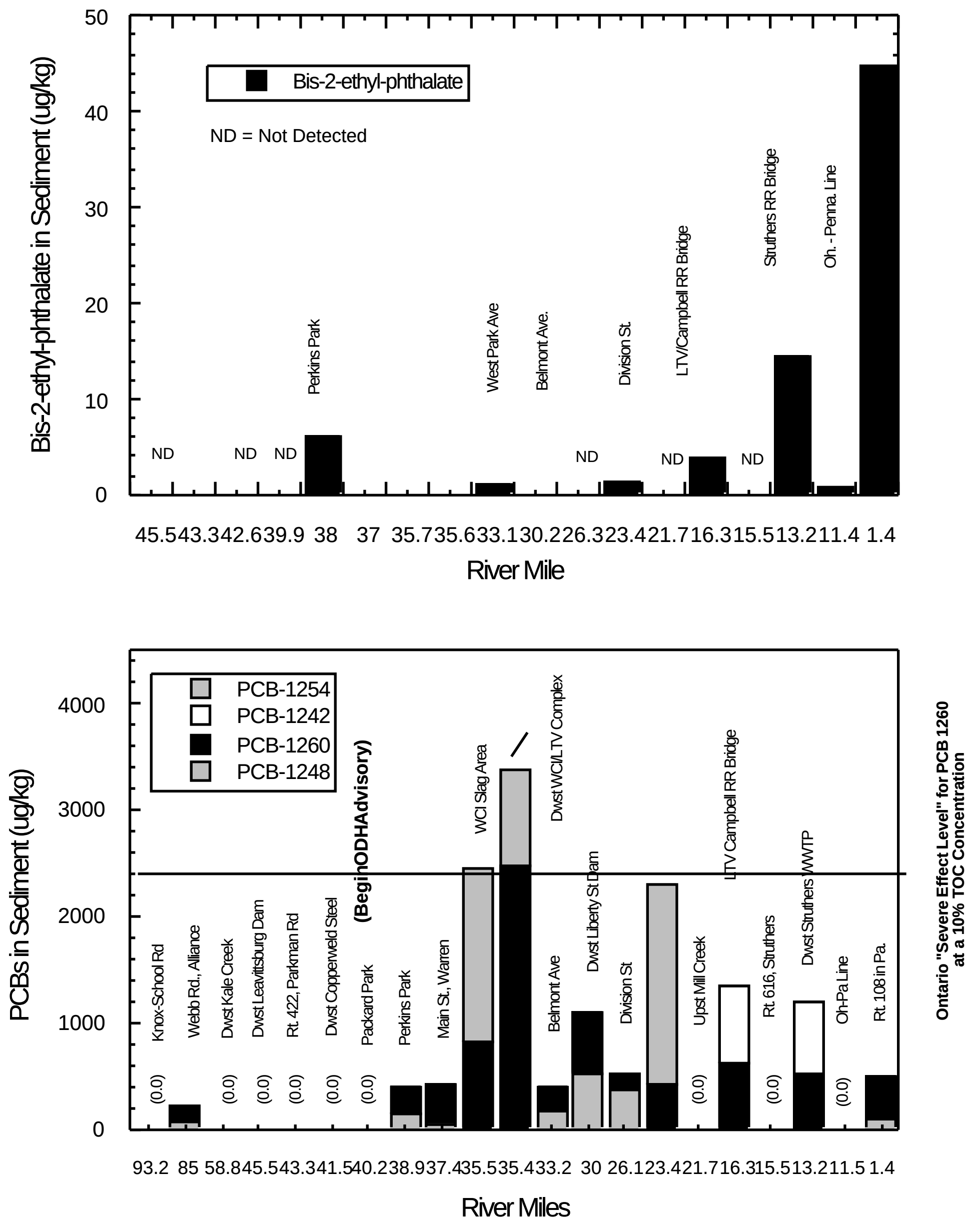


Figure 45. Longitudinal profile of Bis-(2-ethylhexyl) phthalate PCB sediment concentrations in the Mahoning River, 1994.

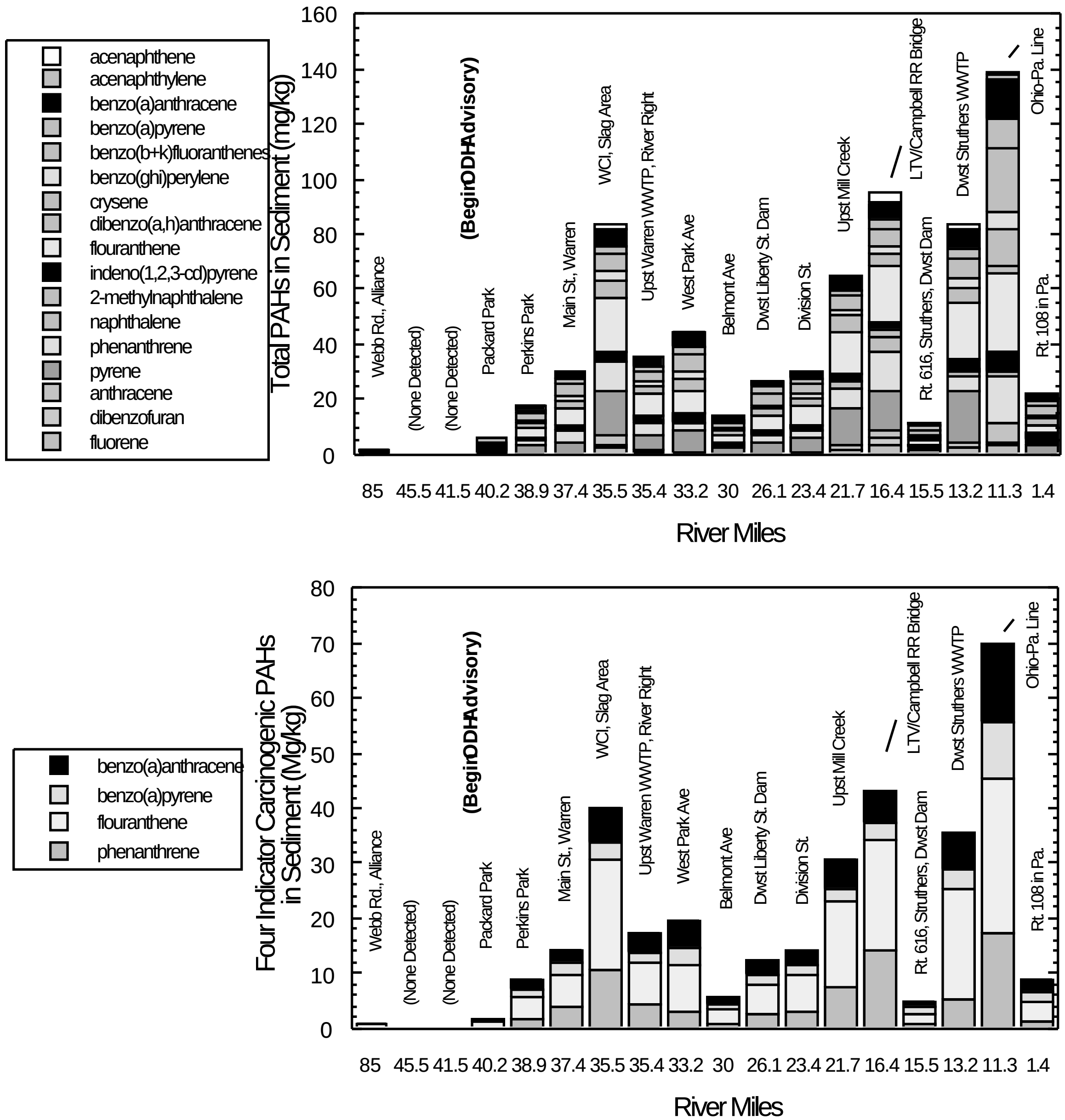


Figure 46. Longitudinal profile of PAH sediment concentrations in the Mahoning River, 1994.

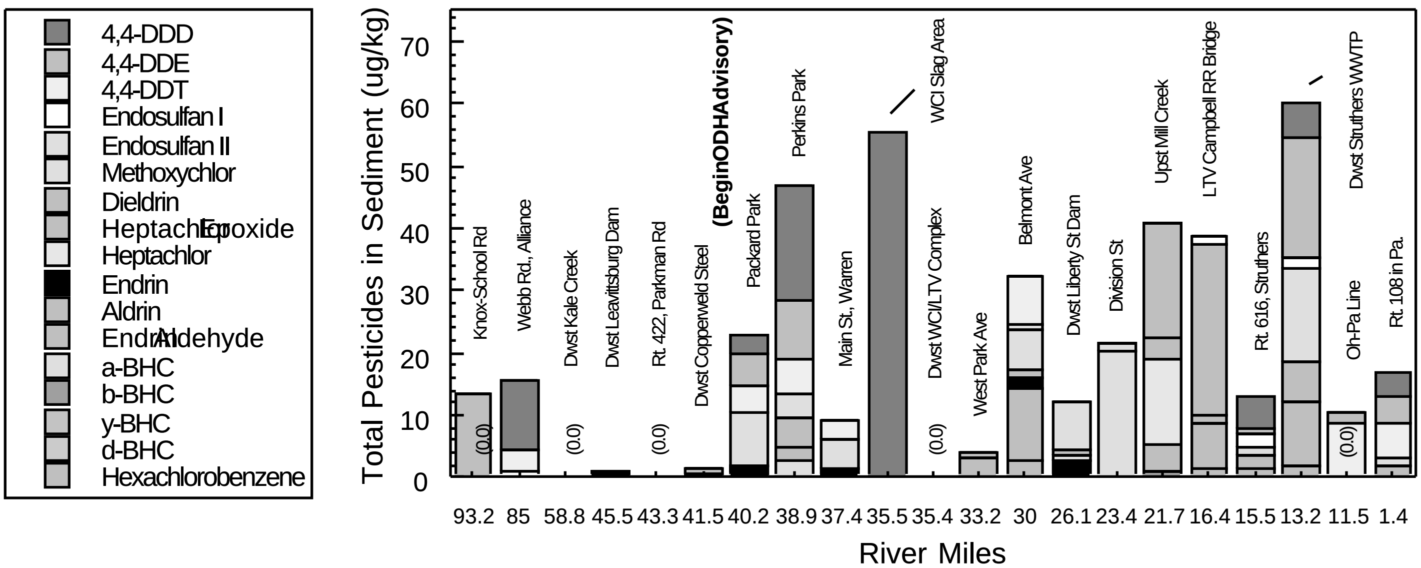


Figure 47. Longitudinal profile of pesticide sediment concentrations in the Mahoning River, 1994.

Fish Tissue

- Chemical analyses of 27 fish tissue samples for selected metals and pesticides showed relatively little contamination of fish throughout the Mahoning River mainstem, whereas the analyses of polychlorinated biphenyl (PCB) compounds showed slightly to extremely elevated levels at all sites sampled for fish tissue from RM 38.8 to RM 12.5 (see Appendix).

- Mercury was detected in all the 27 fish tissue samples (range from 0.0399 to 0.346 ug/g) collected in the Mahoning River in 1994, but were below the FDA Action Level of 1.0 ug/g. Three of the four lowest concentrations of mercury were detected in the whole body composite samples of common carp. Three of the five highest concentrations of mercury were detected upstream from Warren (at RM 44.3). Lead was detected in six samples. The three highest concentrations of lead were from the whole body composite samples of common carp (0.551, 0.579, 0.616 ug/g) and were an order of magnitude higher than the other three detections of lead in filet samples of a white crappie (0.0850 ug/g), smallmouth bass ((0.0767 ug/g), and a channel catfish (0.0812 ug/g). The only detections of cadmium in fish tissue were from the three whole body composite samples of common carp.

- A total of eight pesticides and their derivatives were detected, but most of these (DDTs, dieldrin, chlordane, and nonachlor) were detected in the three whole body composite samples of common carp. Other fish that contained pesticides were a walleye (11.69 ug/kg DDE), channel catfish (14 ug/kg trans nonachlor), and a skin off filet sample of common carp(15.68 ug/kg DDE).

- The most significant discovery from fish tissue analysis indicated that PCBs were not detected in any of the nine samples collected at the sites upstream from Warren (RMs 70.3, 44.3, and 40.6), but were detected downstream in all 18 fish tissue samples collected between Perkins Park (RM 38.8) and Lowellville (RM 12.5). Slightly elevated concentrations (i.e., >50 and ≤300 ug/kg) of PCBs were detected in one largemouth bass sample, one black crappie sample, two of three white crappie samples, and one of six walleye samples. Elevated PCB concentrations (i.e., >300 and ≤1000 ug/kg) were detected in one of four smallmouth bass samples, one carp fillet sample, one muskellunge sample, and three of six walleye samples. Highly elevated PCB concentrations (i.e., >1000 and ≤5000 ug/kg) were detected in all three whole body carp samples and two of three channel catfish skin off filet samples. One of three channel catfish samples had extremely elevated PCB concentrations (i.e., >5000 ug/kg).

Biomarker Assessment

- Blood, liver, and bile samples were collected from common carp (10 sites) and white sucker (3 sites) in the Mahoning River in 1994 at RMs 57.8, 43.3, 39.4, 35.4, 29.0, 26.2, 21.1, 16.3, 15.6, and 12.0. Biochemical analyses for ethoxyresorufin-o-deethylase (EROD) activity, bile metabolites, plasma levels of alanine transaminase (ALT), blood urea nitrogen (BUN), albumin (ALB), total protein (TP), pseudo-cholinesterase (CHE), cholesterol (CHOL), and triglycerides (TRIG) were performed for all samples from common carp. EROD measures a class of metabolic enzymes that are induced by planar xenobiotics such as polycyclic aromatic hydrocarbons (PAHs) and halogenated hydrocarbons. EROD activity is an indicator of the induction of hepatic detoxification systems. A common carp score below 50 pmol EROD/mg protein and a white sucker score below 100 pmol EROD/mg protein are a conservative indication of noninduction. Scores greater than these values indicate induction and are a measure of the exposure to these contaminants and detoxification activity by fish. In fish, metabolites of PAHs accumulate in the bile. Bile metabolites indicate recent exposure to PAHs. The benzo(a)pyrene (B(a)P-type metabolites are generally associated with combustion by-products. The naphthalene (NAPH)-type metabolites are associated with oil contamination. High BUN (blood urea nitrogen) values may be expected with fish in waters with a higher ammonia or organic nitrogen level, near sources of fertilizer or ammoniacal industrial chemical solutions, or in carp feeding in areas where ammonia is a component of the toxic sediments. Gill and kidney disfunction can also cause increased BUN.

- Elevated EROD values for fish from all sites indicated exposure to EROD inducing chemicals with the highest induction occurring below the thermal discharge of Ohio Edison at RM 29.0 (Figure 48). Median EROD values increased from RM 43.3 to RM 28.5 as did the PAH bile metabolite data. The median EROD values decreased from RM 28.5 to RM 12.0 and was not consistent with the bile metabolite data. This inconsistency was associated with the following causes: 1) other EROD inducing chemicals are present at RM 29.0 (some of the highest sediment concentrations of PAHs and PCBs in the mainstem occurred within this dam pool), 2) other agents suppressing EROD induction are present at other downstream river sites where PAH bile metabolite levels are similar or higher than at RM 29.0, and/or 3) the increase in temperature at RM 29.0 might have caused an increase in the EROD activity.

- Naphthalene-type (NAPH-type) and benzo(a)pyrene-type (B(a)P-type) metabolite values showed increasing trends from upstream to downstream (Figure 49). This corresponded to increased sediment concentrations of PAHs and cumulative loadings of oil and grease in the Warren to Youngstown segment of the Mahoning River. Some fish sampled from all sites exceeded both NAPH-type and B(a)P-type metabolite reference values. The presence of these bile metabolites indicates that PAHs are bio-available. The generally lower values for fish at RM 57.8 and RM 43.3 suggest only slight PAH contamination upstream from the heavily industrialized areas of the Warren and Youngstown areas. Levels of these metabolites were significantly higher at RM 16.3, 15.6, and 12.0 (and at RM 29.0 for NAPH-type) than at the upstream sites at RM 57.8 and 43.3. The highest NAPH-type median/mean value reported was below the Campbell WWTP (RM 15.6) and the highest B(a)P-type median/mean value was near the state line (RM 12.0).

- There was a decreasing trend in blood urea nitrogen (BUN) values from RM 57.8 to RM 12.0, which was opposite the increasing trend for the bile metabolites (Figure 48). The exception was at RM 29.0 which had the highest median BUN value. High BUN values may be expected from waters with high ammonia and/or organic nitrogen levels, where ammonia is a component of toxic sediments, or the result of gill and kidney disfunction. In March 1996, Ohio EPA NEDO personnel discovered an unsewered area in the Hilltop locale near McDonald in Trumbull County. It was estimated that raw sewage from 600-800 homes without any treatment (not even septic tanks) was entering the Mahoning River between Ohio Edison and the Niles WWTP (RM 30.0 to RM 28.7).

- White suckers were only collected at RM 43.3, RM 39.4, and RM 12.0. The data showed the same biomarker trends as the common carp.

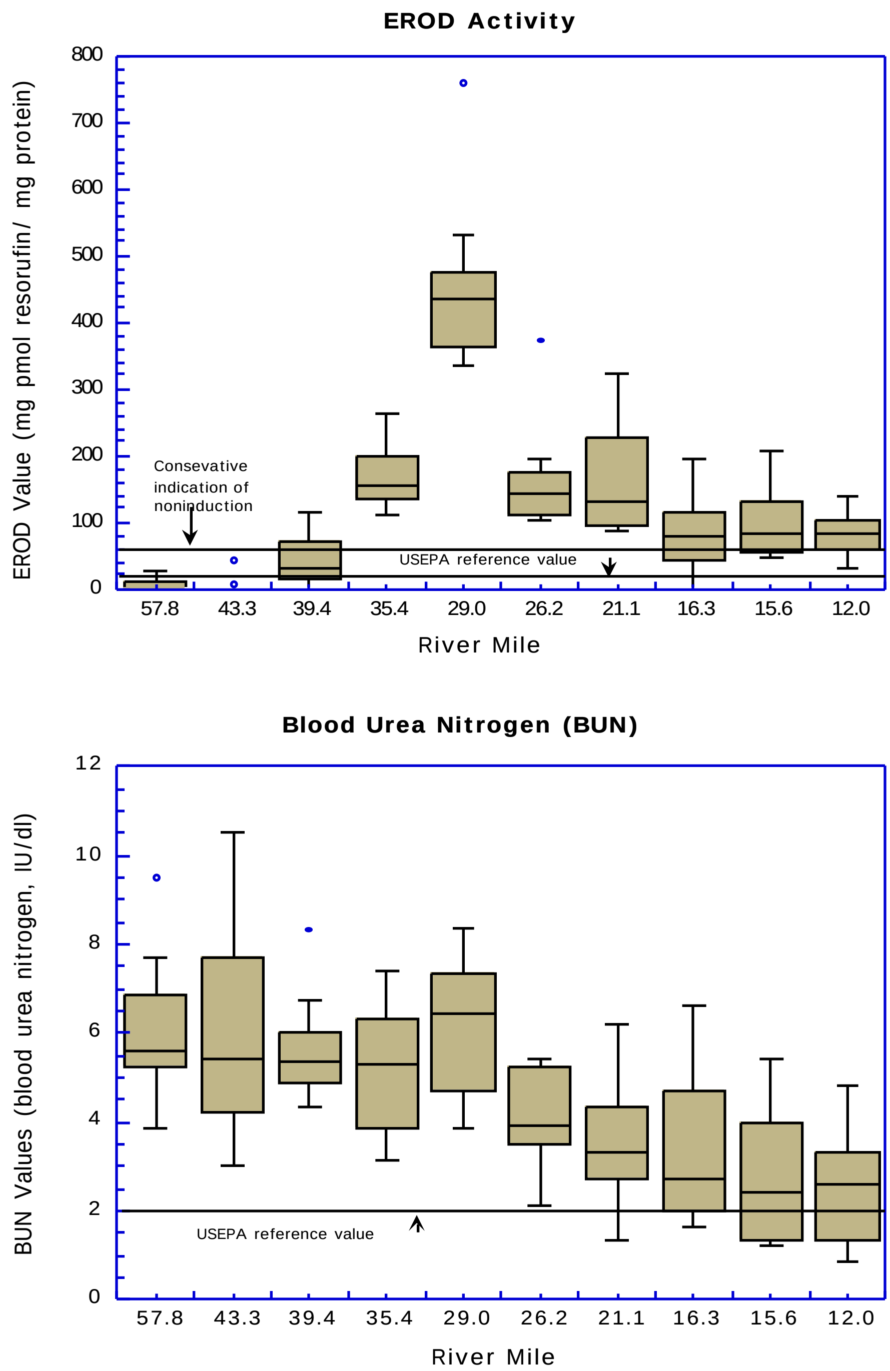
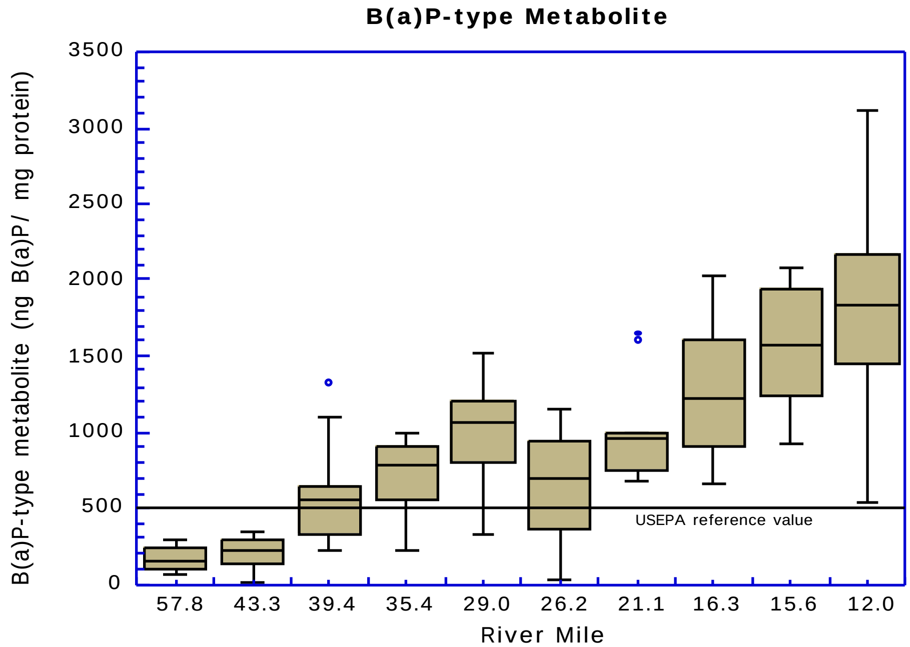


Figure 48. Biomarker data, ethoxyresorufin-o-deethylase (EROD) activity and blood urea nitrogen (BUN), collected in the Mahoning River, 1994.



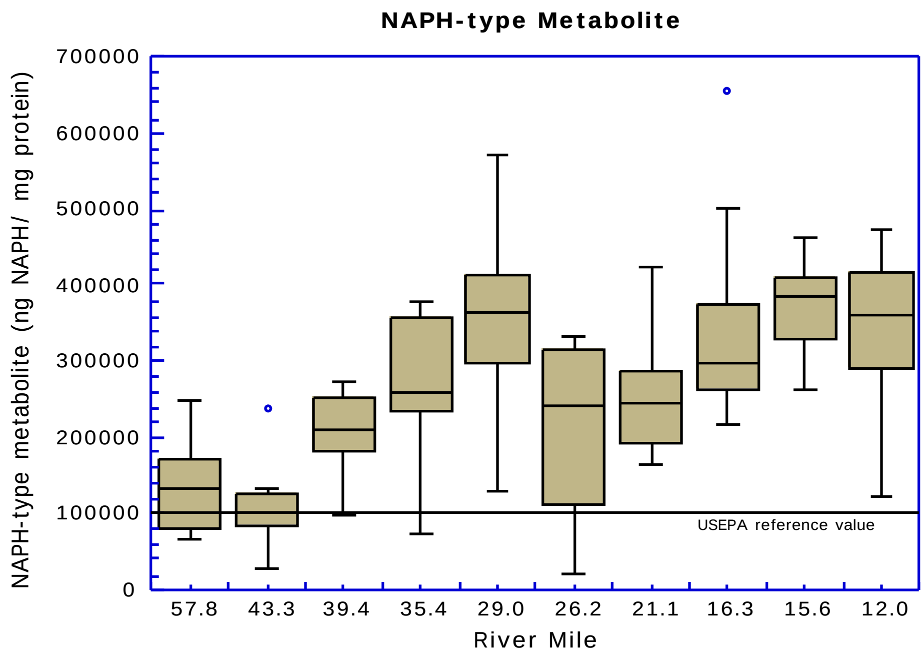


Figure 49. Biomarker data, benzo(a)pyrene (B(a)P) type and naphthalene (NAPH) type metabolites, collected in the Mahoning River, 1994.

Physical Habitat for Aquatic Life (Figure 50; Tables 13, 14)

Mahoning River

- Drainage patterns within the Mahoning River watershed were principally formed during the Wisconsin glacial period. Surface glacial deposits comprised of ground and end moraines cover most of the watershed and bedrock consists of a mixture of sandstone, conglomerate, shale, and limestone formed during the Pennsylvanian and Mississippian periods. The construction of numerous dams on the mainstem of the Mahoning River has adversely affected the natural habitats and created alternating series of free-flowing and impounded segments throughout its length. Table 10 lists 17 homogenous segments (based on QHEI scores) sampled during the 1994 survey. Segment means comprised of free-flowing sites have distinctly higher QHEI scores (*i.e.*, higher quality physical habitat for aquatic life) than the impounded segments. The segment average for free-flowing sites was 70.6 (range 78.8 - 60.5) compared to an average of 47.4 (range 55.0 - 42.5) for predominantly impounded sites. Physical habitat in the mainstem is also affected by impoundments on many of its tributaries (*e.g.*, controlled reservoir releases). The numerous impoundments throughout the watershed currently limit the aquatic life use attainment of the existing WWH use designation. The Mahoning River flow regime also changes from slightly to highly regulated from Alliance to Youngstown due to by reservoir releases and NPDES discharges. An estimated 393 MGD (is discharged throughout the watershed, however, approximately 217 MGD is comprised of once through cooling water from the Ohio Edison Niles Power Plant. Reservoir releases downstream from Berlin Lake, Lake Milton, and Mosquito Creek appeared very turbid from suspended sediment.

- From its headwaters to the first Leavittsburg dam, the mainstem changes from a small headwater stream to a medium size stream. Two large reservoirs, Berlin Lake and Lake Milton, impound approximately 20 river miles of the upper mainstem from RMs 84.0 to 64.0. From Levittsburg to the mouth the mainstem becomes a moderately large river. The longest segment of free-flowing habitat and highest QHEI scores is located between Lowellville and the mouth (RM 12.5 to 0.2).

West Branch Mahoning River

- The West Branch, near the mouth (RM 0.4), contained only fair development due to swift regulated flow and predominantly deep water habitats with sand and silt substrates. The QHEI scored a 67.0 and only one poorly defined riffle with cobble and boulder substrates was located near the First Street bridge. The stream did contain wide, forested riparian zones.

Eagle Creek and Tributary (Silver Creek)

- The Levittsburg dam on the Mahoning River impounds the lower reach of Eagle Creek resulting in predominantly deep-pooled habitat. Due to impoundment, the QHEI scored only a 51.5 and reflects sub-optimal WWH conditions at RM 0.8. A number of houses were located on the river's left bank and a septic odor was present in the stream. Small pipes were present along the bank adjacent to the homes. Eagle Creek contained clearer water than the Mahoning River.

- Silver Creek, a small headwater tributary located in the upper reach of Eagle Creek, contained high quality headwater habitat (*i.e.*,) indicative of very good to exceptional WWH conditions (QHEI = 79.0). In addition to well-defined riffles, runs, and pools; the stream had cool, clear water and appeared to be spring fed.

Mosquito Creek

- The lower reach of Mosquito Creek is also impounded from a low-head dam. At RM 1.0, the stream contains slow flowing pooled habitat typical of wetlands. Dense patches of aquatic macrophytes occupy both margins and the substrates were predominated by a thick layer of silt.

Meander Creek

- The quality of physical habitat in Meander Creek improves downstream from the Mahoning Co. Meander Creek WWTP. The QHEI score increased from 44.0 at both sampling locations (RMs 3.0 and 2.3) in the dam pool adjacent to the water treatment plant (WTP) to 84.5 in the free-flowing segment downstream from the WWTP. Downstream further, the quality of habitat declined again near the mouth due to impoundment from a dam on the Mahoning River. Predominant substrate types changed from silt and hardpan in the dam pool to cobble and boulder slabs downstream from the WWTP. Recent bypassing was evident, however, at RM 1.7. Black sewage sludge deposits in the pool and side channel substrates and litter (*e.g.,* pieces of condom and plastic) were observed. Algae was also abundant in the riffles and indicative of excessive nutrient enrichment and possibly high NH3-N levels. The discharged effluent appeared to provide the only flow which is removed upstream in the reservoir for public water supply. An intermittent dark gray discharge was observed entering Meander Creek upstream from the lowhead dam upstream from the WWTP (RM 2.3) and a few patches of blackish sediment were also observed further upstream (RM 3.0).

Mill Creek and Tributaries (Bears Den Run, Ax Factory Run, Anderson Run, and Indian Run)

- Mill Creek contained relatively poor quality WWH physical habitat at the upper sampling locations and was negatively affected at three of the other five downstream sites due to impoundment. Mill Creek had a very low gradient at the most upstream site (RM 11.0) and may have been previously channelized. QHEI scores between RMs 11.0 and 6.2 ranged from 37.0 to 60.5. No riffles were present and thick silt deposits covered most of the stream channel at the two sampling locations upstream from the Mahoning Co. Boardman WWTP (RM 11.0 and 9.7). The Mahoning Co. Boardman WWTP discharge improved the quality of stream habitat at RM 9.5 by adding flow to a nearly stagnant stream. Thick and extensive sewage sludge deposits, however, blanketed the stream channel downstream from the WWTP on August 2, 1994. Although not as extensive, sludge deposits were observed downstream as far as Cohasset Lake (RM 1.9). Only two free-flowing sites (RMs 2.6 and 1.5) in Mill Creek had QHEI scores above 70.0. Most of the lower 10 miles of Mill Creek is located within the Mill Creek Park district which provides forested riparian corridors and protection from stream encroachment.

- QHEI scores for the four headwater tributaries were higher than most sites in Mill Creek and ranged from 63.5 to 69.5. All four streams contained free-flowing habitat comprised of pools, riffles, and runs. Bears Den Run and Ax Factory Run were the most similar with high gradients and coarse substrates predominated by boulder slabs, cobble, and gravel. Anderson Run and Indian Run contained lower gradients with finer substrates predominated by fine gravel, sand, or silt.

Dry Run

- Dry Run, a small high gradient tributary of the Mahoning River, contained high quality headwater habitat. Upstream from Gladstone Road (RM 0.6), the stream flows through a deep wooded ravine and contains silt-free substrates predominated by bedrock and cobble. The channel lacked deep pools, but contained good development (well-developed riffles, runs, and shallow pools) with no obvious channel modification. Black sewage sludge deposits, however, were observed in the stream channel downstream from the sewer overflow structure located immediately downstream from the Gladstone Road bridge.

Yellow Creek

- Similar to Dry Run, Yellow Creek also contained high gradient headwater habitat. The stream lacked deep pools, but contained substrates predominated by silt-free bedrock and cobble, very clear water, wide forested riparian zones, and good channel morphology. Litter was common in the stream channel, however, and indicative of suburban influences. The QHEI scored slightly higher in Yellow Creek (64.5) than in Dry Run (61.5).

Beaver River

- Similar to the lower reaches of the Mahoning and Shenango Rivers, the Beaver River also contained diverse, free-flowing physical habitats with QHEI scores indicative of good to exceptional quality habitat (QHEI range 74.0 to 79.5). The most diverse physical habitat extended from its origin (downstream from the two tributaries) to the New Castle Electric Generating Station and contained deep pools, well-defined riffle-run complexes, an abundance of woody debris, braided channels, vegetated islands, and back-waters.

Shenango River

- The Shenango River also contained diverse, free-flowing habitats indicative of exceptional quality at both sampling locations (QHEIs = 80.5 - 84.5). The stream channel had good to exceptional development, little to no bank erosion, deep pools, well-defined riffle-run complexes with fast current, a high number of cover types including dense patches of water-willow, and substrates predominated by a mixture of boulders, cobble, and gravel.

Yankee Creek

- The three (3) fish sampling locations in Yankee Creek supported marginal WWH potential with QHEI scores ranging from 46.0 to 65.0. The stream channel contained substrates predominated by fine materials (*i.e.,* sand, silt, and hardpan), no riffles, and intermittent or slow flows. Heavy silt deposits were present at two (2) of the three sampling locations (RMs 8.8 and 0.3).

Little Yankee Creek

- Little Yankee Creek contained relatively good quality habitat at the four free-flowing sites between RMs 9.5 to 2.0 (QHEIs ranged from 66.0 - 80.5), but only marginal quality near the mouth (RM 0.3) due to impoundment by a dam on the Shenango River. Predominant substrate types changed from a mixture of sand, gravel, cobble, boulder, and bedrock in the free-flowing section to silt and hardpan at RM 0.3. Two sites contained no riffle or run habitat (RMs 4.4 and 0.2).

Little Deer Creek

- Little Deer Creek contained good quality headwater habitat (QHEI = 72) comprised of alternating series of riffles, runs, and pools with a diverse mixture (> 5 types) of substrates predominated by gravel and cobble. The landowner adversely affected the stream, however, before the second sample by removing bank vegetation and instream brush with a bulldozer.

Pymatuning Creek

- Pymatuning Creek is a natural low gradient wetland stream (1.7 ft/mi. average gradient) surrounded by a dense riparian corridor. Notable exceptions were at RM 24.7 (upstream SR 322) where the stream was flanked by open cattle pasture and at RM 0.2 (upstream Brockway-Sharon Rd.) where a low head dam created an artificial dam pool. Sand substrates were generally predominant. The amount of instream cover was moderate to extensive with deep pools (>70 cm) at all sites. Channel development was typically poor or fair and only one site (RM 15.0, near SR

7) exhibited functional riffles.

- Macrohabitats of Pymatuning Creek were evaluated at nine fish sampling sites. QHEI scores ranged from 82.0 (RM 15.0) to 45.5 (RM 24.7). Including all sites, the mean QHEI was 61.4.

- The two upstream sites (RM 30.5 and 24.7) were unusual in that an extensive amount of silt created heavily embedded substrate conditions. A mean QHEI score of 49.8 for this reach was indicative of this condition and the moderate amount of instream cover, fair morphology, and absence of riffles. Additionally, RM 24.7 was within a pasture where cattle were observed in the stream channel. Both sites were considered habitat impaired.

- The reach in the vicinity of Kinsman (RM 17.6 to 15.7) contained numerous log jams and other types of instream cover. Natural riparian conditions were excellent. Although the site QHEI scores (mean = 63.6) in this area were consistent with ecoregional expectations, the predominant WWH attributes were offset by morphological influences. The reach was entirely pool or glide habitat with slow currents. Without adequate morphology the biological communities would be expected to be represented by only those species adapted for pool conditions and tolerant of low dissolved oxygen conditions typical of wetland streams.

- The site at RM 15.0 was unlike any other in the study area. The channel narrowed to form several riffle, run sequences over predominantly gravel substrate. A QHEI score of 82 reflected the extensive amount of instream cover including boulders and good morphology with a variety of current velocities. This was the only site with these habitat characteristics. Macrohabitats at this site were considered to be capable of supporting a WWH biological community were it not for the overriding wetland limitations of the entire studied reach (Rankin 1989).

- The two downstream sites (RM 8.6 and 2.2) were similar (mean QHEI = 58.3) to the Kinsman area sites. However, less instream cover was present and a low head dam pool negatively influenced channel morphology at RM 2.2.

- Overall, macrohabitats in Pymatuning Creek reflected the significant influences of the wetland through which it flows. Although it is essentially an unmodified natural stream, its wetland heritage, related low gradient, fair to poor morphology and subsequent low dissolved oxygen levels were sufficient to be considered limiting to the biological communities' ability to perform at a level comparable to WWH ecoregional expectations.

Sugar Creek

- Macrohabitats of Sugar Creek were evaluated at RM 1.0 (Burnett Rd.). A QHEI score of 65.5 was recorded. An extensive amount of sand created moderately embedded conditions at this site with a sparse amount of instream cover. Otherwise, a good mixture of substrate types coupled with good development and riparian conditions created adequate warmwater habitat conditions.

Table 13. Mean 1994 Qualitative Habitat Evaluation Index (QHEI) scores for homogenous segments of the Mahoning River.

Stream **Segment Description**	Sampling Location (RM)	QHEI	**Segment Mean QHEI**
Upper Mahoning River			
King Road to Lake Park Road (RM 100.6 - 89.4)			
	100.6	74.5	**65.5**
	93.3	61.0	
	89.4	61.0	
Webb Avenue (RM 85.5)			
	85.5	42.5	**42.5**
Gas Hill Drive/downstream Lake Berlin (RM 85.0 - 70.3)			
	85.0	72.5	**70.0**
	70.3	67.5	
Lake Milton (RM 69.4)			
	69.4	55.0	**55.0**
Downstream Lake Milton (RM 63.6)			
	63.6	75.0	**75.0**
Newton Falls (RM 57.8 - 56.8)			
	57.8	48.5	**44.5**
	56.8	40.5	
Downstream West Branch (RM 54.8)			
	54.8	60.5	**60.5**
Nelson Moser Road to Leavittsburg (RM 47.5 - 45.3)			
	47.5	43.0	**43.5**
	45.7	40.5	
	45.3	47.0	
Lower Mahoning River			
Downstream 2nd Leavittsburg dam to downstream Copperweld Steel (RM 44.3 - 40.6)			
	44.3	65.5	**63.7**
	43.3	65.5	
	40.6	60.0	
Packard Park (City of Warren) (RM 39.4)	39.4	46.5	**46.5**

Table 13. Continued.

Stream **Segment Description**	Sampling Location (RM)	QHEI	**Segment Mean QHEI**
Lower Mahoning River, continued.			
Thomas Steel mixing zone to downstream West Park Road (RM 39.06 - 30.6)			
	39.06	75.0	**71.4**
	38.8	80.5	
	35.4	65.0	
	35.25	76.0	
	35.0	68.5	
	32.2	63.5	
Upstream Belmont Avenue to downstream Niles WWTP (RM 30.0 - 28.5)			
	30.0	56.0	**48.8**
	29.0	48.0	
	28.5	42.5	
Liberty Street Dam to downstream Little Squaw Creek (RM 26.2 - 25.1)			
	26.2	75.5	**77.0**
	25.1	78.5	
Division Street to West Avenue (RM 23.0 - 21.1)			
	23.0	44.0	**50.8**
	21.1	57.5	
Marshall Street Dam to downstream Youngstown WWTP (RM 20.4 - 19.2)			
	20.4	76.0	**73.5**
	19.4	79.0	
	19.2	65.5	
LTV/Campbell Road (RM 16.3)			
	16.3	47.5	**47.5**
Downstream SR 616 dam to mouth (RM 15.6 - 0.2)			
	15.6	73.5	**78.8**
	12.5	81.0	
	12.0	78.5	
	7.1	77.0	
	3.1	83.0	
	1.1	79.0	
	0.2	79.5	

Table 14. Qualitative Habitat Evaluation Index (QHEI)

Key QHEI Components

WWH 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 Overall Embeddedness; Max. Depth > 40 cm; Low/No Riffle Embeddedness

MWH Attributes – High Influence: Channelized or No Recovery; Silt/Muck Substrates; Low Sinuosity; Sparse/No Cover; Max. Depth < 40 cm (WD/HW)

MWH Attributes – Moderate Influence: 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

(18-001) Mahoning River

Year: 94

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes	Total WWH Attributes	MWH Attributes – High Influence	Total H.I. MWH Attributes	MWH Attributes – Moderate Influence	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
100.6	74.5	14.71	■■ ■ ■ ■ ■ ■ ■	8	●	1	▲ ▲	2	0.22	0.44
93.3	61.0	4.83	■ ■ ■ ■ ■ ■	6	●	1	▲ ▲ ▲▲	4	0.29	0.86
89.4	61.0	3.26	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲ ▲	5	0.33	1.17
85.5	42.5	0.10	■ ■ ■	3	●	1	▲ ▲ ▲▲ ▲▲ ▲	7	0.50	2.25
85.0	72.5	2.80	■■ ■ ■ ■ ■ ■	7		0	▲ ▲▲	3	0.13	0.50
70.3	67.5	0.10	■■ ■ ■ ■ ■ ■	7		0	▲ ▲ ▲	3	0.13	0.50
69.4	55.0	0.10	■ ■ ■	3	●	1	▲ ▲ ▲ ▲▲ ▲	6	0.50	2.00
63.6	75.0	10.99	■■■ ■ ■ ■ ■	7		0	▲ ▲ ▲	4	0.13	0.63
57.8	48.5	0.10	■ ■ ■ ■	4	●	1	▲ ▲ ▲▲ ▲	5	0.40	1.40
56.8	40.5	0.10	■ ■	2	● ●	2	▲ ▲▲▲ ▲▲ ▲	7	1.00	3.33
54.8	60.5	2.87	■ ■ ■ ■ ■	5	●	1	▲ ▲▲ ▲▲	6	0.33	1.33
47.5	43.0	0.89	■ ■ ■ ■	4	●	1	▲ ▲▲ ▲▲ ▲	6	0.40	1.60
45.7	40.5	0.10	■ ■ ■	3	● ●	2	▲ ▲▲▲ ▲▲ ▲	7	0.75	2.50
45.5	47.0	0.89	■ ■ ■ ■	4	●	1	▲ ▲▲▲ ▲▲ ▲	7	0.40	1.80
44.3	65.5	0.89	■ ■ ■ ■ ■ ■ ■ ■	8	●	1	▲ ▲	2	0.22	0.44
43.3	65.5	0.89	■■ ■ ■ ■	5	●	1	▲ ▲▲ ▲▲	6	0.33	1.33
40.6	60.0	3.92	■ ■ ■ ■	4	●	1	▲ ▲▲ ▲▲	6	0.40	1.60
39.4	46.5	0.10	■ ■ ■	3	●	1	▲ ▲ ▲ ▲▲ ▲	6	0.50	2.00
39.0	75.0	4.57	■■ ■ ■ ■ ■	6		0	▲▲ ▲	3	0.14	0.57
38.8	80.5	4.57	■■ ■ ■ ■ ■ ■ ■ ■	[illegible]		0	▲	1	0.10	0.20
35.4	65.0	0.93	■■ ■ ■ ■ ■ ■ ■	8	●	1	▲ ▲	2	0.22	0.44
35.2	76.0	0.93	■■ ■ ■ ■ ■ ■ ■	8		0	▲	1	0.11	0.22
35.0	68.5	0.93	■■ ■ ■ ■ ■ ■ ■ ■	[illegible]	●	1	▲ ▲	2	0.20	0.40
30.6	63.5	0.93	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲ ▲	5	0.33	1.17
30.0	56.0	0.10	■ ■ ■ ■	4	●	1	▲ ▲▲ ▲▲	5	0.40	1.40
29.0	48.0	0.10	■ ■ ■	3	●	1	▲ ▲▲ ▲▲ ▲	6	0.50	2.00
28.5	42.5	0.10	■ ■ ■	3	● ●	2	▲ ▲▲ ▲▲ ▲	6	0.75	2.25
26.2	75.5	2.56	■■ ■ ■ ■ ■	6		0	▲ ▲▲ ▲	5	0.14	0.86

Table 14. Qualitative Habitat Evaluation Index (QHEI)

Key QHEI Components

WWH 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 Overall Embeddedness; Max. Depth > 40 cm; Low/No Riffle Embeddedness; **Total WWH Attributes**

MWH Attributes – *High Influence*: Channelized or No Recovery; Silt/Muck Substrates; Low Sinuosity; Sparse/No Cover; Max. Depth < 40 cm (WD/HW); **Total H.I. MWH Attributes**

MWH Attributes – *Moderate Influence*: 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**; **MWH H.I./WWH Ratio**; **MWH M.I./WWH Ratio**

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes	Total WWH Attributes	MWH High Influence	Total H.I. MWH Attributes	MWH Moderate Influence	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(18-001) Mahoning River										
Year: 94										
25.1	**78.5**	2.56	■■ ■ ■ ■ ■ ■	7		0	▲ ▲▲	3	0.13	0.50
23.0	**44.0**	0.10	■ ■ ■	3	● ●	2	▲ ▲▲ ▲▲ ▲	6	0.75	2.25
21.1	**57.5**	0.10	■ ■ ■ ■ ■	5	● ●	2	▲ ▲▲ ▲	5	0.50	1.33
20.4	**76.0**	2.55	■■ ■ ■ ■ ■	6		0	▲ ▲▲	3	0.14	0.57
19.4	**79.0**	2.55	■■ ■ ■ ■ ■	6		0	▲ ▲▲	3	0.14	0.57
19.2	**65.5**	2.55	■ ■ ■ ■	4		0	▲ ▲▲ ▲▲	6	0.20	1.40
16.3	**47.5**	0.10	■ ■ ■ ■	4	● ●	2	▲ ▲ ▲▲ ▲	5	0.60	1.60
15.6	**73.5**	2.67	■■ ■ ■ ■ ■ ■	7		0	▲▲	2	0.13	0.38
13.6	**81.0**	2.67	■■ ■ ■ ■ ■ ■	7		0	▲▲	2	0.13	0.38
12.0	**78.5**	2.67	■■ ■ ■ ■ ■ ■	7		0	▲ ▲▲	3	0.13	0.50
7.1	**77.0**	3.17	■■ ■ ■ ■ ■ ■ ■	[illegible]	●	1	▲ ▲	2	0.22	0.44
3.1	**83.0**	3.17	■■ ■ ■ ■ ■ ■	8	■ ●	1	▲ ▲	2	0.22	0.44
1.1	**79.0**	3.17	■■ ■ ■ ■ ■ ■ ■	[illegible]	■	0	▲	1	0.10	0.20
0.2	**79.5**	3.08	■■ ■ ■ ■ ■ ■ ■	[illegible]		0	▲ ▲ ▲	3	0.11	0.44
(18-007) Yellow Creek										
Year: 94										
1.0	**64.5**	41.67	■■■ ■ ■ ■ ■	8	■	0	▲ ▲	2	0.11	0.33
(18-010) Dry Run										
Year: 94										
0.6	**61.5**	58.82	■■■ ■ ■ ■ ■	8	■ ● ●	2	▲▲ ▲	3	0.33	0.67
(18-015) Meander Creek										
Year: 94										
3.0	**44.0**	0.10	■ ■ ■	3	● ●	2	▲ ▲▲▲ ▲▲ ▲	7	0.75	2.50
2.3	**44.0**	0.10	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲ ▲	5	0.33	1.17
1.7	**84.5**	8.85	■■ ■ ■ ■ ■ ■	7		0	▲▲▲	3	0.13	0.50
0.1	**41.5**	0.10	■ ■ ■	3	●	1	▲ ▲▲▲ ▲▲ ▲	7	0.50	2.25
(18-020) Mill Creek										
Year: 94										

Table 14. Qualitative Habitat Evaluation Index (QHEI)

Key QHEI Components

WWH 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 Overall Embeddedness; Max. Depth > 40 cm; Low/No Riffle Embeddedness; **Total WWH Attributes**

MWH Attributes – *High Influence*: Channelized or No Recovery; Silt/Muck Substrates; Low Sinuosity; Sparse/No Cover; Max. Depth < 40 cm (WD/HW); **Total H.I. MWH Attributes**

MWH Attributes – *Moderate Influence*: 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**; **MWH H.I./WWH Ratio**; **MWH M.I./WWH Ratio**

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes	Total WWH Attributes	High Influence MWH Attributes	Total H.I. MWH Attributes	Moderate Influence MWH Attributes	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(18-020) Mill Creek										
Year: 94										
11.0	**37.0**	2.60	■ ■ ■	3	●	1	▲ ▲ ▲▲▲ ▲▲ ▲	8	0.50	2.50
9.7	**44.0**	2.60	■ ■ ■	3	●	1	▲ ▲▲ ▲▲ ▲	6	0.50	2.00
9.5	**59.0**	2.60	■ ■ ■ ■ ■	5	●	1	▲ ▲▲ ▲▲	6	0.33	1.33
7.7	**38.5**	1.62	■	1	● ●	2	▲ ▲ ▲▲▲ ▲▲ ▲	8	1.50	5.50
6.2	**60.5**	1.62	■■ ■ ■ ■	5	● ●	2	▲ ▲ ▲ ▲▲ ▲	6	0.50	1.50
2.6	**71.5**	35.71	■■ ■ ■ ■ ■ ■ ■ ■	[illegible]		0		0	0.10	0.10
1.9	**53.0**	0.10	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲ ▲	5	0.33	1.17
1.5	**73.0**	50.00	■■■ ■ ■ ■ ■ ■	[illegible]		0	▲ ▲▲	3	0.11	0.44
0.8	**67.0**	0.10	■■ ■ ■ ■ ■ ■ ■ ■	[illegible]	●	1	▲ ▲ ▲	3	0.20	0.50
0.3	**46.5**	0.10	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲ ▲	5	0.33	1.17
(18-021) Bears Den Run										
Year: 94										
0.3	**67.0**	47.62	■■ ■ ■ ■ ■ ■	7	●	1	▲ ▲	2	0.25	0.50
(18-022) Ax Factory Run										
Year: 94										
0.1	**69.5**	90.00	■■■ ■ ■ ■ ■ ■ ■	[illegible]		0	▲	1	0.10	0.20
(18-023) Anderson Run										
Year: 94										
0.3	**63.5**	8.45	■■ ■ ■ ■ ■	6		0	▲ ▲▲▲ ▲	5	0.14	0.86
(18-025) Indian Run										
Year: 94										
0.2	**65.0**	14.82	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲▲ ▲	6	0.33	1.33
(18-030) Mosquito Creek										
Year: 94										
1.0	**45.0**	0.10	■ ■ ■	3	●	1	▲ ▲▲▲ ▲▲ ▲	7	0.50	2.25
(18-040) Eagle Creek										
Year: 94										
0.8	**51.5**	0.10	■ ■ ■ ■	4	●	1	▲ ▲▲ ▲▲ ▲	6	0.40	1.60

Table 14. Qualitative Habitat Evaluation Index (QHEI)

Key QHEI Components

WWH 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 Overall Embeddedness; Max. Depth > 40 cm; Low/No Riffle Embeddedness; **Total WWH Attributes**

MWH Attributes — *High Influence*: Channelized or No Recovery; Silt/Muck Substrates; Low Sinuosity; Sparse/No Cover; Max. Depth < 40 cm (WD/HW); **Total H.I. MWH Attributes**

MWH Attributes — *Moderate Influence*: 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**

MWH H.I./WWH Ratio; **MWH M.I./WWH Ratio**

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes	Total WWH Attributes	MWH High Influence	Total H.I. MWH Attributes	MWH Moderate Influence	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(18-046) Silver Creek										
Year: 94										
0.8	**79.0**	26.32	■■ ■ ■ ■ ■ ■ ■	8		0	▲	1	0.11	0.22
(18-050) West Branch Mahoning River										
Year: 94										
0.4	**67.0**	2.39	■ ■ ■ ■ ■	5	●	1	▲ ▲ ▲▲ ▲	5	0.33	1.17
(18-100) Beaver River (Pa.)										
Year: 94										
20.1	**79.5**	2.59	■■ ■ ■ ■ ■ ■ ■	8		0	▲ ▲	2	0.11	0.33
18.0	**76.0**	2.59	■■ ■ ■ ■ ■ ■	7		0	▲ ▲▲	3	0.13	0.50
15.3	**74.0**	2.59	■■ ■ ■ ■ ■	6	●	1	▲ ▲ ▲	4	0.29	0.86
(18-500) Shenango River (Pa.)										
Year: 94										
2.7	**80.5**	2.14	■ ■ ■ ■ ■	5		0	▲ ▲ ▲▲	4	0.17	0.83
0.7	**84.5**	2.59	■■ ■ ■ ■ ■ ■ ■	[illegible]		0	▲	1	0.10	0.20
(18-504) Little Yankee Run										
Year: 94										
9.5	**80.5**	17.86	■■ ■ ■ ■ ■ ■ ■	8	●	1	▲ ▲	2	0.22	0.44
4.6	**66.0**	37.03	■■ ■ ■ ■ ■	6		0	▲▲ ▲ ▲	4	0.14	0.71
4.4	**80.0**	11.90	■■ ■ ■ ■ ■ ■ ■	8		0	▲	1	0.11	0.22
2.0	**76.0**	18.52	■■ ■ ■ ■ ■ ■ ■	8		0	▲	1	0.11	0.22
0.3	**54.0**	15.79	■ ■ ■ ■	4	●	1	▲ ▲ ▲▲ ▲	5	0.40	1.40
(18-505) Little Deer Creek										
Year: 94										
0.5	**72.0**	15.38	■■ ■ ■ ■ ■ ■	7		0	▲ ▲▲	3	0.13	0.50
(18-506) Yankee Run										
Year: 94										
8.8	**46.0**	5.88	■ ■ ■	3	● ●	2	▲ ▲▲▲ ▲▲ ▲	7	0.75	2.50
0.6	**65.0**	7.52	■ ■ ■ ■ ■	5	●	1	▲▲ ▲▲ ▲	5	0.33	1.17
0.3	**57.5**	9.26	■ ■ ■ ■	4	●	1	▲ ▲▲ ▲▲ ▲	6	0.40	1.60

Table 14. Qualitative Habitat Evaluation Index (QHEI)

Key QHEI Components

River Mile	QHEI	Gradient (ft/mile)	WWH 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 Overall Embeddedness	Max. Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	MWH Attributes – High Influence: Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max. Depth < 40 cm (WD/HW)	Total H.I. MWH Attributes	MWH Attributes – Moderate Influence: 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	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(18-550) Pymatuning Creek																																		
Year: 94																																		
30.5	54.0	3.68	■					■			■		3	●	●				2	▲			▲	▲				▲	▲	▲		6	0.75	2.25
24.7	45.5	3.05	■				■	■				■	4	●		●			2	▲				▲			▲	▲		▲		5	0.60	1.60
17.6	55.0	1.27	■				■	■			■	■	5						0				▲					▲		▲		3	0.17	0.67
17.1	64.0	1.27	■				■	■			■	■	5						0				▲					▲		▲		3	0.17	0.67
16.1	68.0	1.27	■	■			■	■			■	■	6						0				▲					▲		▲		3	0.14	0.57
15.7	67.5	1.27	■	■			■	■			■	■	6						0				▲					▲		▲		3	0.14	0.57
15.0	82.0	1.27	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
8.6	62.0	1.32	■	■			■	■			■	■	6						0	▲				▲				▲		▲		4	0.14	0.71
2.2	54.5	1.78	■					■		■		■	4	●					1				▲	▲				▲		▲		4	0.40	1.20
(18-556) Sugar Creek																																		
Year: 94																																		
1.0	65.5	7.83	■	■	■		■	■			■	■	7			●			1								▲		▲			2	0.25	0.50

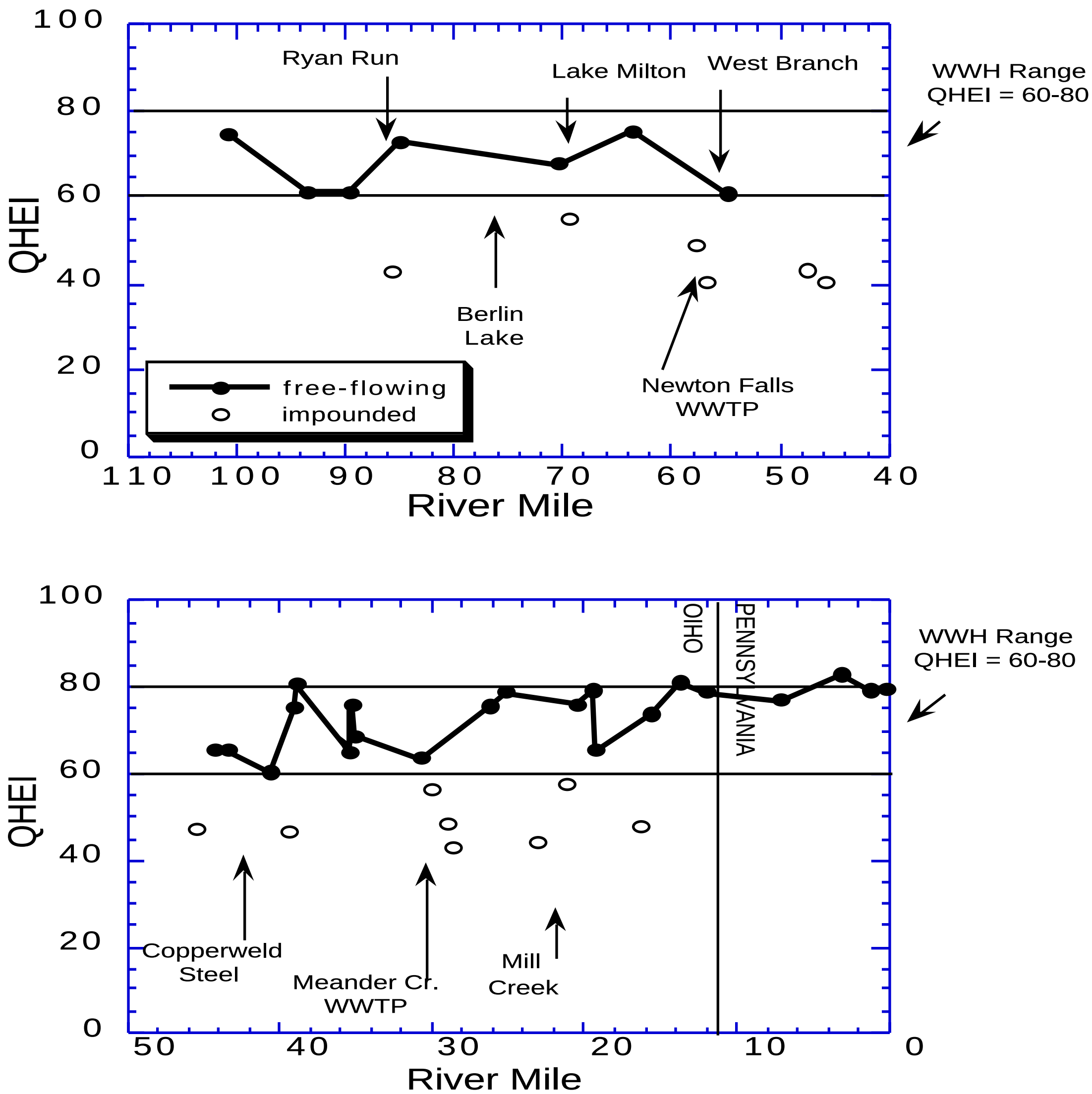


Figure 50. Longitudinal trend of the Qualitative Habitat Evaluation Index (QHEI) in the upper half (Top Graph) and lower half (Bottom Graph) of the Mahoning River during 1994.

Macroinvertebrate Assemblages (Figures 51-53 ; Table 15)

Mahoning River

- Macroinvertebrate assemblages were sampled and evaluated at 37 sites in the Mahoning River during the 1994 survey. Narrative evaluations of the assemblages ranged from poor to very good quality (Table 15). Invertebrate Community Index (ICI) scores, excluding mixing zone and impounded stations, ranged from a low of 4 (downstream from Ryans Run in Alliance at RM 84.8, and downstream from the Warren WWTP at RM 35.1) to a high of 42 (upstream from Alliance at RM 100.5, and downstream from the Newton Falls dam at RM 56.5).

Upper Mainstem: Upstream Alliance to Leavittsburg Dam

- Macroinvertebrate communities sampled upstream from the Alliance area (RMs 100.6 and 92.6) exceeded WWH ecoregional expectations (Figure 51). At RM 100.6 the ICI score was 42 even though the current velocity over the artificial substrates was less than the required minimum of 0.3 ft/sec. Qualitative sampling at this station yielded the second highest number of EPT taxa (17) and the second highest Qualitative Community Tolerance Value (QCTV) score in the survey. The numbers of mayfly and caddisfly taxa collected from the artificial substrates and from the natural substrates were reduced at RM 92.6 resulting in the slightly lower ICI score of 36.

- The next two sites were located in Alliance at RMs 85.2 and 84.8 where macroinvertebrate communities reflected fair and very poor conditions. The ICI score dropped to 16 at RM 85.2 and to 4 just 0.4 miles further downstream at RM 84.8. The latter site was the only macroinvertebrate station on the upper Mahoning mainstem where no mayfly, stonefly, or caddisfly taxa were collected from the artificial or natural substrates.

- Differences in macroinvertebrate community structure in the upper section of the Mahoning River between Berlin Lake and the Leavittsburg dam (RMs 70.7 to 47.3) were more reflective of stream current velocities and habitat conditions rather than point source impacts (Figure 47). The sites located in the free flowing sections of the river had ICI scores in the marginally good to very good range, while those located in impounded conditions had ICI scores in the fair range.

- Immediately downstream from the Berlin Lake and Lake Milton dams (RMs 70.7 and 62.7) ICI scores of 32 and 36 were in the marginally good and good range, respectively. Midges of the *Rheotanytarsus exiguus* group comprised 89.3% and 45.3% of the organisms collected from the artificial substrates and hydropsychid caddisflies were collected in abundant numbers. Both groups are filter feeders and are commonly collected in large numbers in free flowing reaches below large impoundments.

- The ICI score of 42 at RM 56.5, in the very good range, dropped to 32 (marginally good) at RM 54.7. The decrease in the percentage of tanytarsini midges from 25.3% to 9.9% and increases in the percentage of other kinds of dipterans and tolerant organisms accounted for the major difference between the macroinvertebrate compositions at these sites. Mayfly and caddisfly densities were relatively similar.

- Stations located at RMs 69.3, 59.1, and 47.3 were located in impounded habitats. The ICI scores (18, 20, and 24, respectively) were in the fair range, below the Erie Ontario Lake Plain WWH biocriterion (34). Ecologically, the impounded habitats are similar to inundated Lake Erie river mouths which are evaluated using an interim biocriterion of 22. Macroinvertebrates collected from artificial substrates at RMs 69.3, 59.1, and 47.3 had relatively low percentages of mayflies, caddisflies, and tanytarsini midges (11.1% to 19.5%) compared to the free flowing sites from RMs

70.7 to 54.7 (49.5% to 93.4%). Predominant organisms were the midge genus *Glyptotendipes* (22.6% to 29.9%) and oligochaetes (3.4% to 42.5%) at these impounded sites. The primary cause of the depressed community was probably due to suboptimal habitat quality (*i.e.,* slow current velocity and fine particle size substrates).

Lower Mainstem: Leavittsburg Dam to the mouth

- The macroinvertebrate communities at RMs 45.5 and 43.3 achieved the WWH criterion with ICI scores of 38 and 34, respectively (Figure 51). These communities had the highest numbers of combined mayfly and caddisfly taxa (14) and total taxa (41) collected from artificial substrates on the Mahoning mainstem. Caddisflies were predominant (38.2%) at RM 45.5 compared to mayflies (42.0%) at RM 43.3.

- Downstream from Copperweld Steel, the ICI score dropped to 30 (marginally good) at RM 41.1. The densities and percentages of mayflies and caddisflies collected from the artificial substrates were similar; however, the number of mayfly and caddisfly taxa were reduced.

- A slight drop in community performance occurred between RM 39.10 (ICI=34) and RM 38.20 (ICI=26). A decrease in caddisfly density on the artificial substrates was accompanied by an increase in the densities of dipterans and non-insects. Visual observations by Ohio EPA personnel at the time of sample collection noted brown particulate matter in the water column and on the natural substrates at RM 38.2. The Thomas Steel effluent via the Dickey Run storm sewer enters the Mahoning River at RM 39.06. The predominant macroinvertebrates collected in the mixing zone of the Dickey Run storm sewer were the tolerant midge taxon *Cricotpus bicinctus* and aquatic worms (oligochaetes). During the sampling season, this storm sewer and mixing zone ranged in color from gray to brown and oil sheens were observed on the water surface.

- The macroinvertebrate community structure in the next reach of the lower mainstem was drastically different from the upstream sites. The six stations sampled downstream from WCI and LTV-Warren to the Liberty Street Dam (RMs 35.4, 35.1, 33.2, 30.2, 29.1, and 28.7) included no mayfly, caddisfly, or tanytarsini midges collected from artificial or natural substrates. These stations were located in pool/slow run habitats without good riffle development. Although the habitat conditions were suboptimal, this alone could not explain the reason for no EPT or tanytarsini midge taxa. Similar habitat conditions existed upstream at RM 43.3 where mayflies, caddisflies, and tanytarsini midges accounted for 63% of the organisms collected from the artificial substrates and five EPT taxa were collected in the qualitative sample. The ICI score of 34 met ecoregional expectations. An obvious toxics problem existed at these lower sites and persisted throughout the rest of the mainstem.

- The site at RM 35.4, downstream from WCI and Warren-LTV, scored an ICI value of 6 (poor). The next two sites were located in the Warren WWTP mix zone (RM 35.25)and downstream at RM 35.1. The highest percentage of tolerant organisms (93.5% and 89.3%) in the Mahoning study area were collected at these two sites. Tolerant taxa collected were oligochaetes (aquatic worms); the midges *Cricotopus* (*Cricotopus) bicinctus*, *Cricotopus* (*Isocladius) sylvestris* group, *Chironomus* (*Chironomus*) spp., and *Polypedilum* (*Polypedilum*) *illinoense*; and the gastropods *Ferrissia*spp. and *Physella* spp. These two sites, along with the station downstream from Ryans Run at RM 84.8, recorded the lowest ICI scores (4) on the mainstem.

- Percentages of tolerant organisms were reduced to 62.9% at RM 33.2 and further to 40.3% at RM 30.2. However, these sites were still dominated by non-tanytarsini dipterans and non-insects, and had ICI scores of 8 and 10 (poor).

- Macroinvertebrates were collected upstream and downstream from the Niles WWTP. The major difference in community structure was an increase in the abundance of tolerant organisms from 6.3% at RM 29.1 to 43.4% at RM 28.7, due mostly to the increase in number of oligochaetes (aquatic worms). The ICI scores of 6 at both sites remained in the poor range.

- Downstream from the Liberty Street Dam the mayfly genus*Stenacron.* and caddisfly species *Hydropsyche valanis* were collected at all the macroinvertebrate sites; however, the diversity and density of mayflies and caddisflies remained low and were reflective in the low ICI scores ranging from 6 to 18. Tanytarsini midges remained virtually absent in the Mahoning mainstem from RM 35.4 to the mouth.

- Macroinvertebrates sampled upstream and downstream from Little Squaw Creek at RMs 25.3 and 25.1 were reflective of continued poor conditions. Despite the appearance of mayflies and caddisflies, the ICI score at RM 25.1 was only 12. The only qualitative EPT taxa at these two sites were the mayfly *Stenacron* and caddisfly *Hydropsyche (H.) valanis*.

- ICI scores increased into the low fair range (14 and 18) at RMs 21.7 and 21.6, upstream and downstream from Mill Creek. The densities of *Hydropsyche (H.) valanis* increased to 16.5% and 16.9% respectively, the highest percentages of caddisflies in the lower mainstem between RM 35.4 and the mouth. Six EPT taxa were collected in the qualitative sample at RM 21.6, which coincidentally, were the same six EPT taxa collected from the natural substrates in Mill Creek at RM 1.6. The ICI score of 18 at RM 21.6 was the highest recorded in the lower 35.4 miles of the mainstem. Immediately upstream from Mill Creek a CSO discharges raw sewage during rain events. This combined with a possible nutrient input from Mill Creek, may account for the higher densities of caddisflies at these two sites. The location of RM 21.6 just downstream from Mill Creek may have had a localized effect on the increase in number of EPT taxa in the Mahoning River.

- ICI scores dropped back down into the poor range from RM 19.4 to 1.4. Compared to RMs 21.6, numbers of EPT taxa collected from the natural substrates, and densities of *Hydropsyche valanis* and total species richness collected from the artificial substrates were reduced at the lower sites. This may not have reflected an overall worsening of water quality. As noted above, it may have been that the sites located around the Mill Creek confluence had a localized positive influence on the number of EPT taxa.

- The Youngstown WWTP mixing zone and downstream site at RMs 19.4 and 19.3 respectively, had ICI scores of 10. The flow conditions and pool-run habitat at RM 19.3 were similar to RM 43.3 which attained ecoregional expectations with an ICI score of 34.

- Macroinvertebrates were collected at RM 15.8 to serve as an upstream control for the Campbell WWTP. The artificial substrates were placed on the opposite side (near the right bank) of the river from the discharge. The Campbell WWTP discharge enters the river on the left bank of the river just above a riffle. The ICI score of 10 at RM 15.8 remained in the poor range as did the next downstream site at RM 15.5 which scored an ICI of 6. The drop in the ICI score was a result of lower taxa richness between the upstream and downstream sites. Densities of predominant taxa were similar between sites except for an increase in oligochaetes (aquatic worms) at RM 15.8.

- The sites located from RM 15.8 to the mouth were similar in predominant species densities. The midge species *Hayesomyia senata, Cricotopus (C.) bicinctus, and Polypedilum (P.) scalaenum* comprised 65% to 77% of the organisms collected from the artificial substrates. These sites scored ICIs between 6 and 10 (poor), except for the mouth site at RM 0.4 which scored an ICI of 16 due to scoring increases in two metrics (% tanytarsini midges and qualitative EPT taxa).

West Branch Mahoning River
- The macroinvertebrate community collected from artificial substrates at RM 0.4 met ecoregional expectations with an ICI score of 34 (good). Total species richness along with caddisfly diversity and density were high.

Eagle Creek
- Quantitative data from RM 6.6 was in the very good range (ICI=44) with high species richness and low percentages of non-insects and tolerant organisms.

Silver Creek
- Artificial substrate samplers were lost at RM 0.9. Fifty-six qualitative taxa were collected including nine types of mayflies and caddisflies. The QCTV value of 36.3 showed community performance was above the ecoregional minimum expectation of 35.7 as determined by the 25th percentile QCTV score of EOLP sites achieving the ICI biocriterion. The macroinvertebrate community was evaluated as good.

Mosquito Creek
- The ICI score of 30 at RM 0.6 marginally achieved the WWH criterion. Tanytarsini midges were predominant on the artificial substrates with a relatively low percentage of tolerant organisms. Hydropsychid caddisflies were numerous on both the artificial and natural substrates, however there were few mayflies overall. The natural substrates had a medium to heavy silt cover, and densities of organisms were low.

Meander Creek
- The macroinvertebrate community at RM 2.0 was considered fair; the ICI score of 22 was well below the WWH criterion.

- No mayflies, caddisflies, or tanytarsini midges were collected at RM 1.6 downstream from the Meander Creek WWTP. The impact continued to RM 0.7 which was also devoid of these organisms (except for one individual caddisfly). ICI scores of 4 (RM 1.6) and 8 (RM 0.7) were in the poor range.

Mill Creek
- Macroinvertebrate communities were evaluated at eight locations on Mill Creek from RMs 11.2 to 0.1 (Figure 52). Community performance ranged from poor to good with the lowest ICI scores recorded in the section of the creek affected by the Boardman WWTP effluent.

- The two sites located upstream from the Boardman WWTP scored ICI values of 28(fair) at RM 11.2, and 30 (marginally good) at RM 9.7. Quantitative samples were very similar in the numbers of tanytarsini midges and caddisflies of the genus *Cheumatopsyche* collected. The major difference was an increased number of other dipteran and non-insects and tolerant organisms at RM 11.2. Very few mayflies were collected at either site (<1% of the total organisms), but they were present in the quantitative and qualitative samples.

- ICI scores dropped abruptly downstream from the Boardman WWTP to 14 (fair) at RM 9.5 and 12 (poor) at RM 7.8. Densities of tolerant taxa (oligochaetes, *Dicrotendipes simpsoni*, *Polypedilum (P.) fallax* group, and *Polypedilum (P.) illinoense)* were predominant (58.3% at RM 9.5 and 55.4% at RM 7.8) on the artificial substrates. No mayflies were collected with either sampling protocol downstream from the Boardman WWTP between RM 9.5 and RM 5.4.

- Community performance in Mill Creek began to recover from the effect of the Boardman WWTP effluent at RM 5.4. The percentage of tolerant organisms declined (6.9%) and tanytarsini midge density increased resulting in an ICI score of 24. The communities improved from fair at RM 5.4, to good at RMs 2.7 and 1.6 (ICIs = 40 and 38, respectively). There was higher species richness and higher percentages of caddisflies on the artificial substrates at the lower sites.

- Near the mouth, the ICI score dropped to 24. Densities of tolerant organisms (oligochaeta and the midge *Nanocladius (N.) distinctus*) and other dipterans and non-insects increased while densities of tanytarsini midges were reduced on the artificial substrates.

Bears Den Run

- Qualitative sampling at RM 0.1 reflected fair conditions. Only five EPT taxa were collected with blackflies, hydropsychid caddisflies, and midges predominant. The median QCTV value of 34.2 was below the 25th percentile QCTV value of sites which do attain ecoregional expectations.

Ax Factory Run

- Ax Factory Run was sampled qualitatively at RM 0.1 and evaluated as fair. Only 20 total taxa (and only five EPT taxa) were collected with amphipods, isopods, and blackflies predominant on the natural substrates. The median QCTV value of 34.8 was below the 25th percentile of sites which do attain ecoregional criteria.

Anderson Run

- Macroinvertebrate communities sampled on the natural substrates at RM 0.2 were similar to the communities collected in Bears Den and Ax Factory Run and reflective of fair water quality. All three tributaries had only five EPT taxa and total taxa ranging from 20 to 32. Although hydropsychid caddisflies were common or predominant; other more facultative organisms such as amphipods, isopods, baitid mayflies, or blackflies were also predominant at each of these sites. The median QCTV value ranged from 34.2 to 35.6, below the 25th percentile QCTV value of sites within this ecoregion with ICI values that do attain WWH.

Indian Creek

- Qualitative sampling at RM 0.3 yielded a total of 50 taxa with a QCTV value of 36.3. These numbers indicated Indian Creek was performing at ecoregional expectations. However, there were only six EPT taxa collected which was below ecoregional expectations. Substrates were almost exclusively sand which may gave been a factor in the low number of EPT taxa. This site was evaluated as marginally good.

Dry Run

- Numerous high quality organisms were collected in qualitative sampling at RM 0.6 but most were present in very low densities. A total of 35 total taxa were collected including 10 EPT taxa; the QCTV value was 37.1. These values fall in a range generally associated with good community conditions and reflective of WWH expectations.

Yellow Creek

- The ICI score of 32 on Yellow Creek (RM 1.0) was in the nonsignificant departure range of the WWH criterion; however, only three of the five artificial substrates were collected; the other two were out of the water. Qualitative sampling yielded 51 total taxa including 12 EPT taxa; the QCTV value was 38.9. Hydropsychid caddisflies were predominant in low to moderate densities. The overall performance of the macroinvertebrate community was good.

Beaver River

- Macroinvertebrates collected at RMs 20.1, 18.0, and 15.3 were similar in overall composition and densities, and reflected good resource conditions. High species richness of mayflies, caddisflies, dipterans, and total taxa collected from the artificial substrates, combined with a high percentage of hydropsychid caddisflies, resulted in ICI scores of 38 at all three sites.

Shenango River

- The macroinvertebrate community at RM 0.1 achieved the WWH criterion with an ICI score of 36. The taxa richness and species composition were very similar to the sites sampled in the Beaver River.

Yankee Creek

- Artificial substrate samplers were not retrieved at RM 6.5. Sixty-three qualitative taxa were collected including 19 mayfly, stonefly, and caddisfly taxa. The QCTV value of 40.3 was one of the three highest recorded in the Mahoning study area. Three coldwater species and a rare caddisfly genus, *Psilotetra*, were collected. The community performance based on these numbers exceeded ecoregional expectations and was evaluated as exceptional.

- Habitat conditions changed from areas with good riffle-run-pool development at RM 6.5, to mostly pooled habitats at RMs 0.6 and 0.4. Artificial substrates samplers were located in areas with little or no current at these lower sites. Results showed a substantial decrease in community quality as measured by ICI scores of 28 at RM 0.6 upstream from the Brookfield WWTP and 0 downstream at RM 0.4. The qualitative sample at RM 0.6 had 46 total taxa with 12 species of mayflies, stoneflies, and caddisflies; these numbers fall in a range generally associated with good communities. The qualitative sample at RM 0.4 had only 11 total taxa and no EPT taxa; the macroinvertebrate community was evaluated as very poor.

Little Yankee Creek

- The uppermost sampling location on Little Yankee Creek at RM 9.6 yielded results that exceeded the criterion for Exceptional Warmwater Habitat (EWH) aquatic life use. The ICI score of 52 and the QCTV value of 41.4 were the highest values recorded in the Mahoning study area. Numerous pollution intolerant taxa were collected in the quantitative and/or qualitative samples including six cool-water taxa (caddisflies *Hydropsyche (C.) slossonae, Diplectrona modesta*, and *Glossosoma*; and midges *Parametriocnemus* , *Polypedilum (Polypedilum) aviceps,* and Paratanytarsus n. sp. 1).

- The ICI score declined to 30 at RM 4.9 and reflected marginally good community quality. Substrates at this site, RM 4.9, and the next downstream site, RM 4.5, were covered with moderate to heavy amounts of silt. The macroinvertebrate community at RM 4.9 had fewer mayfly and caddisfly taxa, and reduced densities of tanytarsini midges compared to the excellent conditions observed upstream.

- Below the Hubbard WWTP, the ICI dropped to 26 which was in the fair range. This drop in community performance from marginally good to fair was not as severe as the drop from exceptional at RM 9.6 to marginally good at RM 4.9. The Hubbard WWTP appeared to have a minimal effect on the macroinvertebrate community.

- At RM 1.6, increases in mayfly taxa and density collected from the artificial substrates along with an increase in the number of qualitative EPT taxa resulted in an ICI value of 34 which met the ecoregional criterion.

- The mouth site (RM 0.2) was evaluated as fair and not meeting ecoregional expectations. This section of Yankee Creek has a low gradient resulting in very low current velocity and mostly pooled habitats. Compared to clear and brownish water at the upstream sites, the water color at RM 0.2 was bright green probably due to a bloom of colonial green algae. The ICI score (28), number of qualitative EPT taxa (2), and QCTV value (32.8) were all below ecoregional expectations and reflected fair community condition.

Little Deer Creek

- Little Deer Creek at RM 0.4 was evaluated as fair. The habitat near the mouth was pooled with no current velocity and with substrates composed of fine sediments. The ICI score (20), number of qualitative EPT taxa (4), and QCTV value (33.9) all performed below ecoregional expectations.

Pymatuning Creek

- The two upper sites performed at ecoregional expectations with ICI scores of 34 at RM 29.1 and 36 at RM 22.7. The macroinvertebrate communities collected from the artificial substrates were very similar at these two sites, except that RM 22.7 had a noticeable increase in tanytarsini midge density and richness. The natural substrates were very different at these two sites. RM 29.1 had a pool-riffle-run zone, gravel and sand substrates, good margin habitat, and a good riparian vegetation zone. At RM 22.7 there was only a pool-run zone, fair to good margin habitat, mostly sand and silt substrates, and no riparian zone. It was an open pasture with extensive bank erosion from animal movement. This difference was probably reflected in the qualitative sampling which showed a drop in taxa from 43 to 35, and a drop in the QCTV value from 37.2 to 26.4.

- The next free flowing site was at RM 15.2 downstream from Kinsman. The ICI score of 22 was in the fair range and well below the WWH criterion of 34. The macroinvertebrate community differed from the upper sites in that caddisfly density was reduced and tolerant midges increased.

- Pymatuning Creek between RMs 17.8 and 17.3 flows through a swamp. Located immediately upstream from RM 17.8 was a beaver dam with a small lake/impoundment formed behind it. The creek weaves through the swamp with 150 feet to a half mile of swamp vegetation on either side of the creek. Sites located between RMs 16.1 and 15.8 were not swamplike but were channelized with 200 to 300 feet of trees, shrubs, and grass/weed riparian vegetation. At RM 8.4, Pymatuning Creek was impounded by the Shenango Reservoir. All locations described above had no or very little current over the artificial substrates. The ICI scores ranged from 4 to 14. The macroinvertebrates collected from the artificial substrates were predominated by oligochaetes (aquatic worms) and the midges *Dicrotendipes simpsoni* and *Glyptotendipes.* Mayflies were collected in limited numbers and caddisflies were collected only at RM 15.8 which had some water movement over the substrates. Natural substrates yielded at most one EPT taxon at these sites. The failure of the macroinvertebrate communities at these sites to meet ecoregional expectations was attributed mostly to the lack of lotic conditions at these sites.

Sugar Run

- Sugar Run was qualitatively sampled at RM 1.0 and evaluated as marginally good. The nine EPT taxa collected and the QCTV value of 35.5 were slightly below ecoregional expectations. However, this site had high species richness (49 total taxa) with several pollution intolerant taxa collected including the stonefly *Acroneuria evoluta*..

Table 15. Summary of macroinvertebrate data collected from artificial substrates (quantitative evaluation) and natural substrates (qualitative evaluation) in the Mahoning River study area, July-September, 1994. Mixing zone samples are denoted in italics.

Stream River Mile	Density (#/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total Taxa	ICI	Evaluation
			Quantitative Evaluation				
Mahoning River							
100.6	526	36	59	17	71	42	Very Good
92.6	583	38	46	7	60	36	Good
85.2	318	28	325	2	44	16*	Fair
84.8	213	16	25	0	32	4*	Poor
70.7	13172	16	25	6	31	32[ns]	Marginally Good
69.3	218	28	22	4	42	18*	Fair
62.7	2030	26	44	8	52	36	Good
59.1	316	35	30	5	50	20*	Fair
56.5	504	37	28	6	49	42	Very Good
54.7	496	39	26	4	54	32[ns]	Marginally Good
47.3	308	36	25	6	47	24*	Fair
45.5	644	41	48	8	69	38	Good
43.3	588	41	39	5	64	34	Good
41.1	364	36	36	8	55	30[ns]	Marginally Good
39.1	560	30	35	7	51	34	Good
39.06	*378*	*24*	*5*	*0*	*28*	*16*	*Fair*
38.2	300	34	31	6	51	26*	Fair
35.4	205	20	10	0	25	6*	Poor
35.25	*297*	*13*	*7*	*0*	*15*	*4*	*Poor*
35.1	316	13	8	0	16	4*	Poor
33.2	169	19	16	0	28	8*	Poor
30.2	145	24	18	0	32	10*	Poor
39.1	309	18	14	0	27	6*	Poor
28.7	243	19	8	0	24	6*	Poor
25.3	-	-	20	2	-	-	Poor
25.1	482	21	22	2	32	12*	Poor
21.7	401	18	34	3	40	14*	Fair
21.6	546	26	28	6	37	18*	Fair
19.4	*733*	*18*	*19*	*3*	*27*	*10*	*Poor*
19.3	329	19	23	2	32	10*	Poor
15.8	470	21	21	3	29	10*	Poor
15.5	509	16	22	2	28	6*	Poor
12.4	457	16	31	3	33	8*	Poor
11.5	609	21	23	2	28	10*	Poor
6.7	882	17	18	3	25	8*	Poor
1.4	657	18	21	3	29	10*	Poor
0.4	580	21	31	6	38	16*	Fair

Table 15. Continued.

Stream River Mile	Density (#/ft^2)	Quant. Taxa	***Quantitative Evaluation*** Qual. Taxa	Qual. EPT[a]	Total Taxa	ICI	Evaluation
West Branch Mahoning River							
0.4	656	41	40	9	61	34	Good
Eagle Creek							
6.6	777	40	50	9	66	44	Very Good
Mosquito Creek							
0.6	643	27	31	6	46	30[ns]	Marginally Good
Meander Creek							
2.0	146	28	36	7	48	22*	Fair
1.6	1152	20	12	0	25	4*	Poor
0.7	389	20	12	0	26	8*	Poor
Mill Creek							
11.2	842	31	21	2	42	28*	Fair
9.7	595	23	13	3	30	30[ns]	Marginally Good
9.5	1345	22	17	2	31	14*	Fair
7.8	1842	19	15	0	26	12*	Poor
5.4	2677	22	25	2	34	24*	Fair
2.7	452	33	29	5	46	40	Good
1.6	2126	30	30	6	42	38	Good
0.1	2153	26	31	4	42	24*	Fair
Yellow Creek							
1.0	489	29	51	12	61	[32[ns]][c]	Good[c]
Beaver River							
20.1	1269	45	44	17	65	38	Good
18.0	988	39	34	12	55	38	Good
15.3	1199	44	51	10	61	38	Good
Shenango River							
1.0	787	38	41	13	60	36	Good
Yankee Creek							
6.5	-	-	63	19	-	-	Exceptional
0.6	447	40	46	12	65	[28][c]	Good[c]
0.4	210	12	11	0	17	0*	Very Poor

Table 15. Continued.

Stream River Mile	Density (#/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total Taxa	ICI	Evaluation
			Quantitative Evaluation				
Little Yankee							
9.6	786	44	42	16	62	52	Exceptional
4.9	384	37	36	6	55	30[ns]	Marginally Good
4.4	305	34	25	3	41	26*	Fair
1.6	242	35	34	9	53	38	Good
0.2	491	42	25	5	56	28*	Fair
Little Deer Creek							
0.4	467	34	35	4	55	20*	Fair
Pymatuning Creek							
29.1	959	49	43	4	67	34	Good
22.7	836	40	35	4	59	36	Good
17.8	2832	17	26	1	32	8*	Poor
17.3	1394	17	16	1	25	4*	Poor
16.1	845	20	12	0	27	8*	Poor
15.8	1248	24	16	1	30	14*	Fair
15.2	1112	35	37	5	52	22*	Fair
8.4	293	19	30	1	42	4*	Poor

Stream River Mile	No. Qual. Taxa	QCTV[b]	Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[d]
			Qualitative Evaluation			
Mahoning River						
25.3	20	24.6	2	Moderate	Midges, *Stenacron* (mayfly), *Hydropsyche valanis* (caddisfly)	Poor
Silver Creek						
0.9	56	36.3	9	Moderate	*Atherix lantha* (dipteran), *Isonychia* (mayfly) red midges	Good
Bears Den Run						
0.1	30	34.2	5	Low	Hydropsychid caddisflies, blackflies, midges	Fair

Table 15. Continued.

			Qualitative Evaluation			
Stream River Mile	No. Qual. Taxa	QCTV[b]	Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[d]
Ax Factory Run						
0.1	20	34.8	5	Low	Amphipods, isopods, midges	Fair
Anderson Run						
0.2	32	35.6	6	Moderate	Hydropsychid caddisflies, midges, amphipods	Fair
Indian Run						
0.3	50	36.3	6	Low	Hydropsychid caddisflies, midges	Marginally Good
Dry Run						
0.6	35	37.1	10	Low	Caddisflies, midges, *Ferrissia* (clam)	Good
Yellow Creek						
1.0	51	38.9	12	Low-Moderate	Hydropsychid caddisflies, amphipods, midges	Good
Yankee Creek						
6.5	63	40.3	19	Moderate	Caddisflies, midges, mayflies	Exceptional
0.4	46	33.9	12	Low-Moderate	Midges, mayflies	Good
0.2	11	23.5	0	Low	Midges, flatworms	Very Poor
Sugar Creek						
1.0	49	35.5	9	Low	Midges, *Helicopsyche borealis* (caddisfly), clams	Marginally Good

Table 15. Continued.

Ecoregion Biocriteria: Invertebrate Community Index (ICI)

	WWH	EWH	MWH[e]
Erie Ontario Lake Plain (EOLP)	34	46	22

[a] EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa richness.
[b] Qualitative Community Tolerance Value (QCTV) derived as the median of the tolerance values calculated for each qualitative taxon present (see discussion in text).
[c] The quantitative sample was affected by slow current speed; evaluation was based primarily on the qualitative sample.
[d] The qualitative narrative evaluation is based on best professional judgement utilizing sample attributes such as taxa richness, EPT richness, and QCTV score and is used when quantitative (artificial substrate) data are not available to calculate an Invertebrate Community Index (ICI) score.
[e] MWH (Modified Warmwater Habitat) for channel modified areas.
* Significant departure from ecoregional biocriterion (>4 ICI units); poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregional biocriterion (≤4 ICI units).

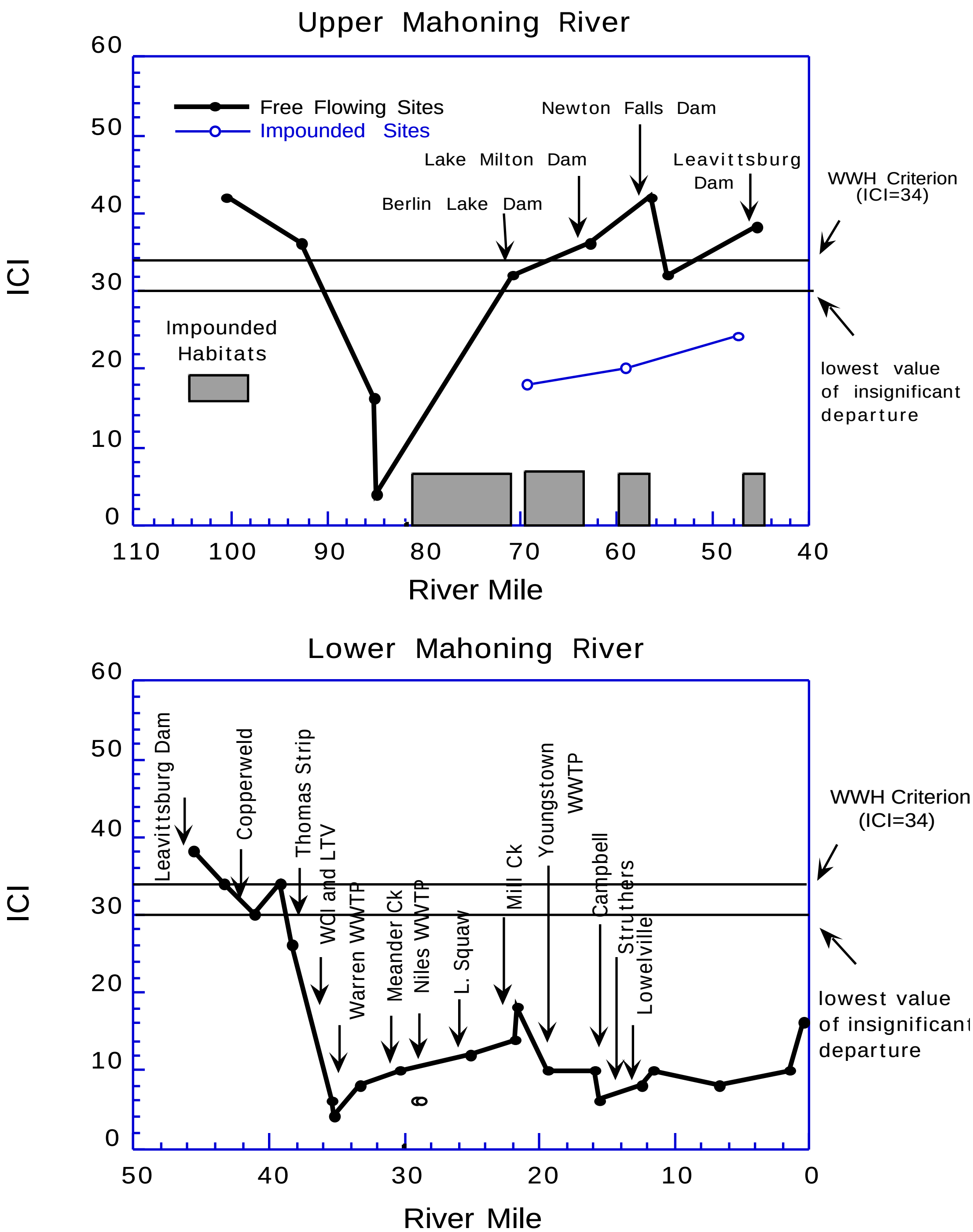


Figure 51. Longitudinal trend of the Invertebrate Community Index (ICI) in the upper and lower Mahoning River, 1994.

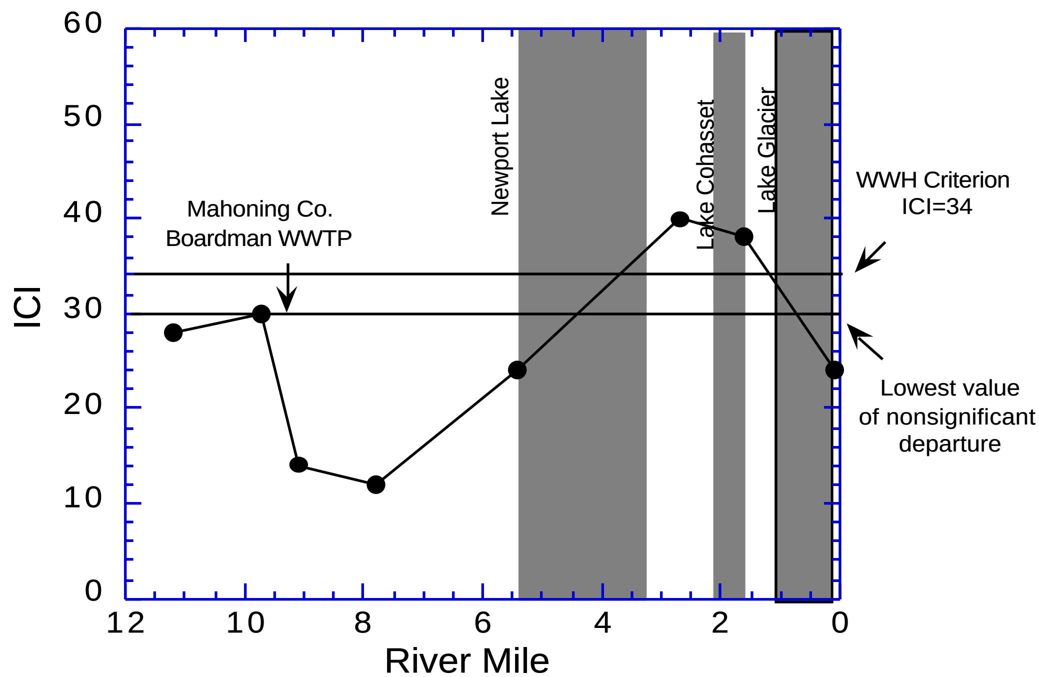


Figure 52. Longitudinal trend of the Invertebrate Community Index (ICI) in Mill Creek, 1994.

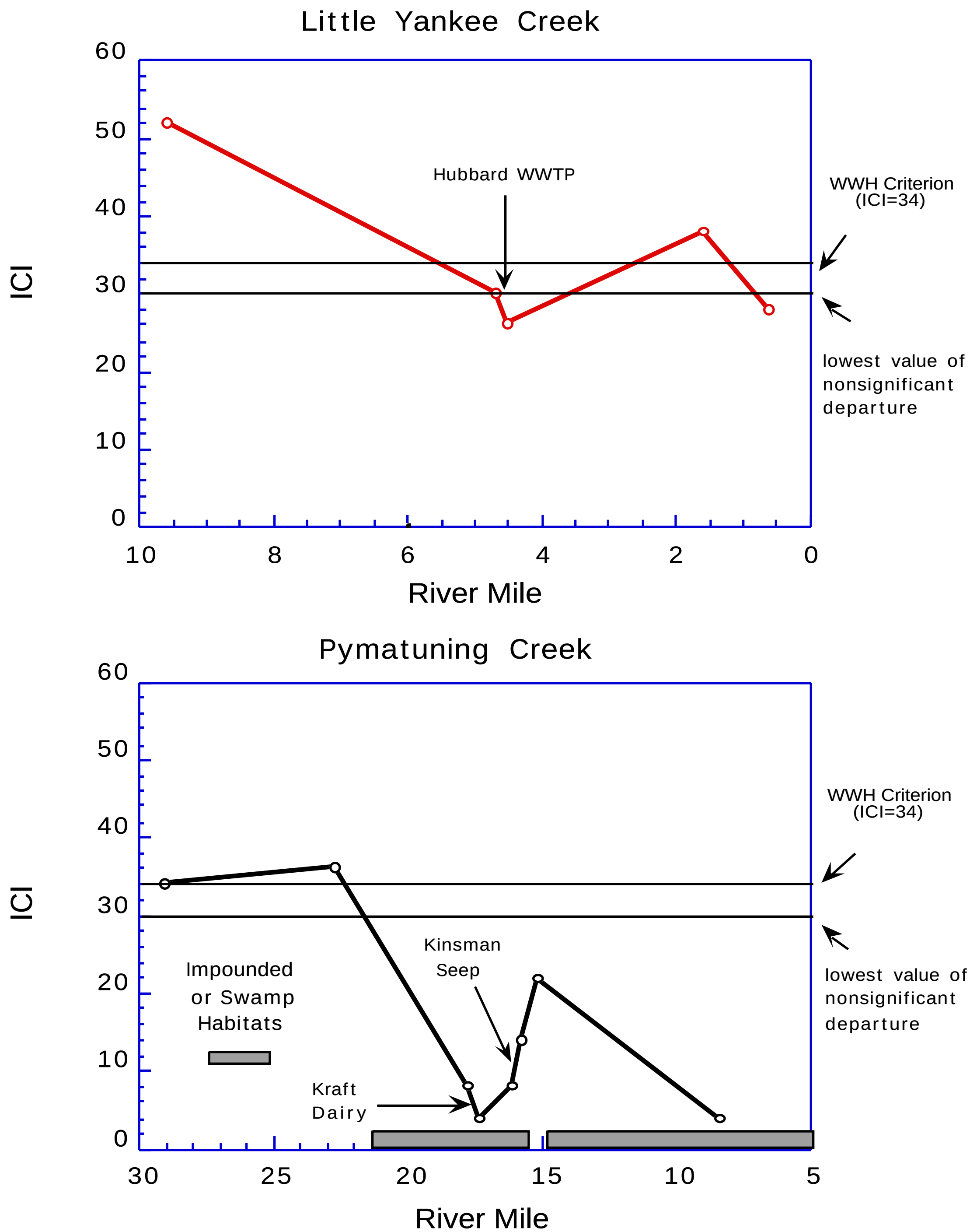


Figure 53. Longitudinal trend of the Invertebrate Community Index (ICI) in Little Yankee Creek and Pymatuning Creek, 1994.

Fish Assemblages (Figures 54-62; Table 16)

Mahoning River

- Electrofishing at 42 locations throughout the Mahoning River yielded a total cumulative catch of 15,840 fish comprised of 55 species and eight (8) hybrids. Mean MIwb values were indicative of exceptional to very good quality fish assemblages at three locations (7.1%), good to marginally good fish assemblages at four locations (9.5%), fair fish assemblages at 17 locations (40.5%), and poor to very poor fish assemblages at 18 locations (42.9%) (Table 16). Mean IBI values were indicative of an exceptional quality fish assemblage at only one location (2.4%), good to marginally good quality fish assemblages at three locations (7.1%), fair fish assemblages at 14 locations (33.3%), and poor fish assemblages at 24 locations (57.1%). The mean percentages of fish with DELT anomalies in the mainstem ranged from a low 0.0% in the headwaters to a maximum of 26.9% in Youngstown (Table 16). Of the 42 locations sampled, 3% or more of the fish caught contained one or more DELT anomalies at eight (8) of the 13 upper mainstem sites and 27 of the 29 lower mainstem sites.

Upper Mahoning River - North Georgetown to Levittsburg(RMs 100.6 to 45.7)

- A total of 6,253 fish comprised of 45 species were collected from the upper half of the Mahoning River (RM 100.6 - 45.7). The total catch was numerically dominated by bluegill (11.9%), gizzard shad (10.4%), bluntnose minnows (9.2%), white sucker (8.8%), and common carp (8.0%). By weight, the cumulative catch was overwhelmingly dominated by common carp (63.8%). The relative number of fish captured ranged from a high of 932 per 0.3 km in the headwaters to a low of 86 per km downstream from the West Branch. The relative weight of fish ranged from 28.2 kg per 0.3 km to 193.8 kg per km downstream from Berlin Lake. The highest number of cumulative fish species (28) was collected downstream from Knox School Road (RM 93.3) and upstream Newton Falls (RM 57.8). Conversely, the lowest cumulative number of species (13) was collected in the dam pool near Webb Avenue in Alliance (RM 85.5).

- Narrative evaluations of the mean IBI and MIwb values upstream from the Leavittsburg dam (RM 45.7) ranged from exceptional quality in the headwaters to fair to poor quality near Alliance and downstream from the West Branch (Table 16). Numerically, IBI and MIwb values both attained WWH biocriteria (or were within the area of nonsignificant departure) only at the three most upstream wading locations (RMs 100.6, 93.3, and 85.0). At the 9 boat sites, the boat criteria was met by the MIwb at only one location, downstream from Lake Berlin (RM 70.3). The IBI scored below the boat criterion at all nine (9) boat sampling locations.

- The mean percentages of fish with DELT anomalies in the upper mainstem increased markedly from 0.0% at King Road (RM 100.6) to 9.1% at Lake Park Road (RM 89.4). Percentages remained elevated (> 3%) at eight (8) of the 10 downstream locations (Figure 57; Table 16).

Lower Mahoning River - Downstream Levittsburg to the Beaver River(RMs 45.5 to 0.2)

- A total of 9,587 fish comprised of 51 species were collected from the lower half of the Mahoning River (RM 45.5 - 0.2). The total catch was numerically dominated by bluntnose minnows (20.2%), white sucker (8.8%), spotfin shiners (16.8%), and common carp (10.3%). By weight, the cumulative catch was overwhelmingly dominated by common carp (71.0%). Excluding mixing zones, the relative number of fish captured ranged from a high of 547 fish per km downstream from the Lowellville dam to a low of 90 per km near the LTV/Campbell Road upstream from the SR 616 dam. The relative weight of fish ranged from a high of 145.3 kg per km downstream from the Leavittsburg Dam to a low of 19.6 kg per km near the LTV/Campbell Road upstream from the SR 616 dam. The highest number of cumulative fish species (30) was collected near the mouth (RM 0.2). The lowest cumulative number of species (10) was collected downstream from the Youngstown WWTP (RM 19.2).

- Of the 29 locations sampled in the lower half of the Mahoning River, mean IBI and MIwb values attained (marginally good to very good) the boat biocriteria at only one site, downstream from the second Levittsburg dam (RM 44.3; Table 16). At other sites, IBI and MIwb scores were indicative of fair to marginally good quality at two locations (upstream from Copperweld [RM 43.3] and at Perkins Park [RM 38.8]). One or both of the index scores were indicative of poor or very poor quality fish assemblages at 22 of the 29 locations.

- The mean percentages of fish with DELT anomalies ranged from 2.17 to 26.9 % (Figure 57; Table 16**.** The highest percentages (>20%) were recorded between Division Street to downstream from the Youngstown WWTP (RM 23.0 -19.2) and in Pennsylvania near US 224 (RM 7.1). The levels of DELT anomalies appears to be related to the degree of sediment contamination. Longitudinal scatter plots of the mean percentages of DELT anomalies(Figures 55 and 56) throughout the mainstem show high DELT values in areas with high concentrations of summed polycyclic aromatic hydrocarbons (PAHs), summed polychlorinated biphenyls (PCBs), and selected metals. On a statewide level, the severity and extensiveness (*i.e.*, miles affected) of contaminated sediments and corresponding high percentages of DELT anomalies are among the highest of all rivers and streams sampled in Ohio by the Ohio EPA.

- The relative number (#/km) of smallmouth bass declined markedly downstream from the LTV and WCI discharges and adjacent to the WCI slag piles (Figure 56). Populations of this sport fish remained severely impacted throughout the lower 35 miles, but showed slight signs of recovery near the mouth. In contrast to the abundance of smallmouth bass, the relative number of common carp in the lower half of the mainstem remained relatively high downstream from Warren and increased downstream from Lowellville.

West Branch Mahoning River

- Electrofishing near the mouth of the West Branch yielded a total catch of 29 species, but a low relative number and weight of fish (141 fish per km and 1.8 kg/km, respectively). The IBI was indicative of a good quality fish assemblage (IBI=40), but due to the low number and weight of fish the MIwb value was representative of only fair quality (MIwb=6.3). The most abundant species consisted of bluntnose minnow (16.6%), white suckers (14.9%), johnny darter (11.5%), and northern hog suckers (11.1%). No DELT anomalies were observed on the captured fish. Although mostly present in low numbers, six (6) pollution sensitive species (including the eastern sand darter) were collected during each of the two wading samples. Pool depths greater than four feet prevented the sampling of all available habitat.

Eagle Creek

- Two boat method samples near the mouth of Eagle Creek yielded a total catch of only 220 fish comprised of 21 species. Numerically the fauna was dominated by bluntnose minnows (14%), white suckers and rock bass (11.4% each), and black crappie (10.9%). IBI and MIwb scores were indicative of poor and fair quality, respectively (Table 16). A higher than expected number of fish captured also had DELT anomalies (5.9%), further suggesting water quality or sediment quality impacts. The site is impounded within the Leavittsburg pool of the Mahoning River.

Silver Creek

- A good quality fish assemblage comprised of 15 species was found in Silver Creek, a headwater tributary of Eagle Creek. The total catch consisted of 1,168 fish with no DELT anomalies observed. A high percentage of tolerant fishes caused this metric of the IBI to score a “1” possibly due to channelization or riparian vegetation removal downstream from the bridge. Two headwater species and three sensitive species were collected at the site. The catch, which included mottled sculpin, brook stickleback, and redside dace, was indicative of a spring-fed cool water fauna.

Mosquito Creek

- Two boat samples within the impounded segment of lower Mosquito Creek (RM 1.0) yielded only 15 species of fish and IBI and MIwb scores indicative of poor quality. A high percentage (7.9%) of the fish captured in Mosquito Creek also had DELT anomalies further indicating water/chemical quality impacts.

Meander Creek

- Fish assemblages in Meander Creek appeared impacted throughout the lower 3 miles, but declined from fair to poor quality in the dam pool adjacent to the WTP to poor to very poor quality downstream from the Mahoning Co. Meander Creek WWTP despite exceptional quality habitat at RM 1.7. The wading results obtained during the August sample were indicative of acute toxicity downstream from the WWTP. DELT anomalies increased from 1.0-2.2% upstream to 5.5-11.6% downstream from the WWTP. RM 0.1 is impounded by the Mahoning River.

Mill Creek and Tributaries

- Fish assemblages in Mill Creek were also impacted throughout the 11 miles sampled. The total catch consisted of 5,697 fish comprised of 20 species and four hybrids. A highly tolerant fish, common carp, overwhelmingly dominated the fauna and consisted of 52.8% numerically and 74.8% of the weight. IBI values were indicative of very poor quality from Western Reserve Road to US 224 (RM 11.0 to 7.7), followed by slight signs of some improvement to the fair range near Lake Glacier (RM 0.8-0.3, Figure 60, Table 16). MIwb values fluctuated from the poor to very poor quality range throughout the 11 miles surveyed.

- Fish sampling results from the four headwater tributaries of Mill Creek were also indicative of severely impacted fish assemblages. IBI values represented only poor quality fish assemblages in three of the headwater tributaries (Bears Den Run, Anderson Run, and Indian Run) and a fair quality community in Ax Factory Run. Indian Run contained the most diverse community with 12 fish species and Bears Den Run the least diverse community with only one fish species (creek chubs). Numerically dominant species included small yellow bullheads and bluntnose minnows in Ax Factory Run; white suckers, green sunfish, bluntnose minnows, and creek chubs in Indian Run; and creek chubs and green sunfish in Anderson Run.

Dry Run

- Dry Run's fish community included seven fish species numerically dominated by two headwater species, blacknose dace followed by creek chubs. The IBI scored a 28 which is indicative of a fair quality headwater community. No DELT anomalies were observed on the collected fish.

Yellow Creek

- Fish sampling results from Yellow Creek were indicative of a poor quality fish community at RM 0.1 (IBI = 22). Values for ten of the 12 metrics strongly deviated from the expected (i.e., scored a "1") and only two metrics (percentage of simple lithophils and DELT anomalies) scored within the expected range. The fauna was numerically dominated by only tolerant species.

Beaver River

- Mean IBI scores from all three sites in the Beaver River were indicative of fair quality fish assemblages (Table 16) with high percentages of tolerant fishes, omnivores, and DELT anomalies in combination with low percentages of round-bodied suckers and top carnivores. Most sites also contained a lower than expected numbers of nontolerant fishes. The total cumulative catch included 35 species and was numerically dominated by spotfin shiners (34%) and common carp (14.8%). The percentage of fish with DELT anomalies was highly elevated at all three locations and increased at the most downstream site (from 10.1-9.8 at RMs 20.1 and 18.0 to 15.9% at RM 15.8). The highest number of intolerant fish species (8) were collected at the most upstream site most likely due to its close proximity to the Shenango River which supported a higher quality fish community than the lower Mahoning or Beaver rivers.

Shenango River

- Electrofishing at two sites in the lower Shenango River yielded a total catch of 1,012 fish comprised of 33 species and two hybrids. The combined catch was predominated numerically by northern hog suckers (14.5%), silver shiner (12.0%), striped shiners (10.4%), and smallmouth bass (10.3%). By weight, the cumulative catch was dominated by common carp (66.0%) followed by smallmouth bass (11.9%). Mean IBI and MIwb scores were indicative of a good quality fish assemblage at the upstream site, but only marginally good quality downstream from Cherry Street (RM 0.7). The highest number of fish species (33 versus 23), however, was collected at RM 0.7.

Yankee Creek

- Electrofishing at three sites in Yankee Creek yielded a total catch of 1,711 fish comprised of 39 species and two hybrids. The combined catch was predominated numerically by bluntnose minnows (17.7%) and white suckers (17.1%). By weight, the cumulative catch was overwhelmingly dominated by common carp (70.5%). IBI and MIwb scores were indicative of fair to poor quality at the two upstream sites, but improved slightly to the fair to marginally good range downstream from the Brookfield WWTP. The lower than expected index scores may have been due to marginal to submarginal quality physical habitat at all three sampling locations.

Little Yankee Creek

- The quality of fish assemblages in Little Yankee Creek declined from marginally good (IBI only) at the headwater site to very poor to fair quality at all five downstream locations. The cause/source of the impact is unknown but is located between RM 9.5 and 4.6. Downstream from the Hubbard WWTP, the IBI score remained similar to immediately upstream from the discharge and the MIwb increased from the very poor to fair range suggesting no immediate impact from the NPDES discharge. The number of fish species collected in Little Yankee Creek increased from 11 to 15 species upstream from the discharge to 20 to 19 species downstream except for the impounded segment near the mouth. Numerically dominant species shifted from bluegill (28.2%), common carp (21.8%), and green sunfish (11.5%) upstream from the WWTP to central stoneroller (39.7%), bluntnose minnow (38.0%), and creek chub (12.8 %).

Little Deer Creek

- Fish sampling at RM 0.5 yielded a total catch of 2,094 fish comprised of 19 species. The mean IBI was 35 (one unit below a nonsignificant departure for WWH) and did not appear to be significantly affected by the channel modifications which occurred between the two samples. The first catch yielded a 36 and the second sample (post channel modification) scored a 34. The lower than expected IBI scores were due to a combination of metrics which scored a “1” including the number of headwater species, percentages of tolerant fishes, omnivores, and insectivores, and relative number of non tolerant fishes. The fauna was dominated numerically by bluntnose minnows (51.4%) and central stonerollers (20.4%).

Pymatuning Creek

- Thirty five species and three hybrids (3,418 individuals) were collected in Pymatuning Creek in 1994. Sampling occurred twice at nine sites between RM 30.5 (SR 6, near Cherry Hill) and RM 2.2 (Brockway-Sharon Rd., upstream of the Ohio - Pennsylvania state line). Overall, the fish assemblage in Pymatuning Creek was poor (Table 16). Fish community indices ranged from fair (mean IBI=34 at RM 30.5) to poor (mean IBI=23; mean MIwb=4.4 at RM 24.7). Including all sites, the mean IBI was 27.7. The mean MIwb for applicable wading sites was 5.4. Ecoregional expectations for the WWH use designation were not met at any site.

- In aggregate, the most abundant fish collected were: white sucker (17%), common carp (16%), bluegill sunfish (15%), and bluntnose minnow (12%). Based on biomass the predominate species were: common carp (86%) and white sucker (7%). The mean number of species caught at each site was 15.2. Essentially, Pymatuning Creek was home to a simple, tolerant, and mostly omnivorous fish community.

- Individual IBI metrics at each site tended to score in the medium range for total number of species and in the high range for number of sunfish species. Other metrics, including the number of sucker species and intolerant species and the percent of tolerant or omnivorous fish generally scored in the low range. Habitat in Pymatuning Creek was favorable to some pool species as evidenced by the sunfish group. Otherwise, the sluggish wetland stream lacked the habitat heterogeneity or variety necessary to support a diverse, complex fish community.

- Streams with a significant wetland influence often exhibit low dissolved oxygen levels. The predominance of tolerant fish in Pymatuning Creek was attributed to this stress as well as the habitat limiting factors. Signs of stress in the fish community were indicated by a high incidence of DELT anomalies. A low IBI metric score for percent of fish with DELT anomalies was common through out the study area. A particularly high proportion (32.6%) of fish with DELT anomalies was documented in August, 1994 downstream of Kinsman (RM 15.7).

- Kinsman lacks a centralized waste water treatment facility. Numerous raw sewage seeps were observed entering the Creek in this vicinity. The higher than background incidence of DELT anomalies in this area was potentially related to the stress created by bacterial pollution.

- Despite the generally poor fish community performance compared to ecoregional WWH expectations, the fish community in Pymatuning Creek seemed intact and reflective of its specific habitat characteristics. In order to more accurately assess its performance, it is recommended that IBI metrics be developed which consider the wetland influences of this and other similar Ohio streams.

Sugar Creek

- Twenty one fish species (705 individuals) were collected in Sugar Creek in 1994. Sampling occurred twice at RM 1.0 (Burnett Rd.) which yielded marginally good fish community performance (mean IBI=37). Individual IBI metrics tended to score in the moderate range. The fish community was considered typical for its habitat conditions.

Table 16. Fish community summaries for 91 locations in the Mahoning River study area based on pulsed D.C. electrofishing catches during June through October, 1994. The number of samples collected at each location is listed with the sampling method. The relative number and weight are based on distances of 1.0 km for boat sites and 0.3 km for wading sites. *Mixing zone samples are denoted by italics.*

Stream RM	Sampling Method/ # Passes	Mean # Species	Total # Species	Mean Rel. #	Mean Rel. kg	Mean % DELT	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Mahoning River										
100.6	Wading 2	16.5	19	932	NA	0.0	74.5	51	NA	Exceptional
93.3**R**	Wading 2	23.5	28	673	34.1	1.1	61.0	36^{ns}	8.2	Marginally Good-Good
89.4	Boat 2	12.0	16	518	92.8	9.1	61.0	23*	6.7*	Poor-Fair
85.5	Boat 2	10.0	13	219	33.7	5.5	42.5	28*	6.2*	Fair-Poor
85.0	Wading 2	21.0	27	880	59.5	1.3	72.5	36^{ns}	8.5	Marginally Good-Good
70.3	Boat 3	16.7	24	439	193.8	7.4	67.5	27*	9.1	Fair-Very Good
69.4	Boat 3	14.7	21	373	74.3	2.2	55.0	29*	7.8*	Fair
63.6	Wading 2	18.0	22	202	28.2	2.3	75.0	33*	7.5*	Fair
57.8	Boat 3	21.0	28	253	122.1	5.1	48.5	26*	7.7*	Fair
56.8	Boat 3	18.3	23	327	150.7	4.8	40.5	27*	6.7*	Fair
54.8	Boat 3	12.0	18	86	82.7	6.0	60.5	22*	7.3*	Poor-Fair
47.5	Boat 3	16.0	23	141	55.1	9.7	43.0	25*	6.8*	Poor-Fair
45.7**M**	Boat 3	16.0	25	174	40.4	3.2	40.5	30*	7.3*	Fair
45.5	Boat 1	16.0	16	214	145.3	11.1	47.0	26*	6.9*	Fair
44.3	Boat 2	23.5	28	450	73.9	2.9	65.5	37^{ns}	9.2	Marg. Good-Very Good
43.3	Boat 3	19.7	28	237	81.9	7.2	65.5	28*	8.5^{ns}	Fair-Marginally Good
40.6	Boat 3	17.0	24	267	90.6	7.6	60.0	25*	7.9*	Poor-Fair
39.4	Boat 3	18.3	24	421	87.8	4.2	46.5	25*	7.2*	Poor-Fair
39.06	*Boat 2*	*12*	*15*	*915*	*158.1*	*2.17*	*75.0*	*27*	*7.7*	*Fair*
38.8	Boat 3	20.0	24	491	125.4	3.0	80.5	34*	8.3^{ns}	Fair-Marginally Good
35.4	Boat 3	18.0	25	178	103.6	11.5	65.0	25*	6.5*	Poor-Fair
35.25	*Boat 3*	*15.0*	*18*	*830*	*113.6*	*6.5*	*76.0*	*37*	*8.3*	*Fair*
35.0	Boat 3	17.7	24	202	82.0	10.8	68.5	22*	6.0*	Poor
32.2	Boat 3	15.3	21	172	86.1	10.7	63.5	27*	5.4*	Fair-Poor
30.0	Boat 3	13.3	19	137	71.9	11.3	56.0	25*	6.0*	Poor
29.0	Boat 3	9.3	13	125	45.3	4.2	48.0	22*	4.4*	Poor-Very Poor
28.5	Boat 3	11.3	14	109	30.5	8.1	42.5	21*	4.9*	Poor-Very Poor
26.2	Boat 3	16.0	20	401	53.8	6.4	75.5	24*	7.1*	Poor-Fair
25.1	Boat 3	15.0	21	260	33.3	14.1	78.5	23*	5.8*	Poor
23.0	Boat 3	10.3	13	113	27.1	20.3	44.0	18*	4.4*	Poor-Very Poor
21.1	Boat 2	9.5	12	119	51.4	22.8	57.5	19*	4.2*	Poor-Very Poor
20.4	Boat 1	13.0	13	264	101.2	24.4	76.0	20*	5.3*	Poor
19.4	*Boat 2*	*8.0*	*9*	*520*	*315.5*	*21.4*	*79.0*	*19*	*4.9*	*Poor-Very Poor*
19.2	Boat 2	8.5	10	132	107.0	26.9	65.5	17*	3.8*	Poor-Very Poor
16.3	Boat 1	11.0	11	90	19.6	11.1	47.5	16*	4.2*	Poor-Very Poor
15.6	Boat 3	11.7	20	246	85.8	15.3	73.5	18*	4.5*	Poor-Very Poor
12.5	Boat 3	19.5	25	547	105.0	11.2	81.0	18*	7.8*	Poor-Fair
12.0	Boat 3	12.7	19	348	48.2	15.0	78.5	21*	6.2*	Poor
7.1	Boat 3	15.7	24	253	65.9	24.0	77.0	22*	5.8*	Poor
3.1	Boat 3	16.3	24	279	42.7	10.5	83.0	21*	5.6*	Poor

Table 16. Continued.

Stream RM	Sampling Method/ # Passes	Mean # Species	Total # Species	Mean Rel. #	Mean Rel. kg	Mean % DELT	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Mahoning River										
1.1	Boat 3	18.7	26	341	59.6	14.7	79.0	<u>23*</u>	<u>6.2*</u>	Poor
0.2	Boat 3	20.3	30	372	60.6	14.0	79.5	26*	7.1*	Fair
West Branch Mahoning River										
0.4	Wading 2	22.0	29	141	1.8	0.0	67.0	40	6.3*	Good-Fair
Eagle Creek										
0.8	Boat 2	18.5	21	220	92.9	5.9	51.5	<u>23*</u>	7.2*	Poor-Fair
Silver Creek										
0.8**R**	Wading 1	15.0	15	2,336	NA	0.0	79.0	44	NA	Good
Mosquito Creek										
1.0	Boat 2	14.0	15	206	112.0	7.9	-	<u>21*</u>	<u>5.1*</u>	Poor
Meander Creek										
3.0	Boat 2	13.0	14	296	48.3	1.0	44.0	26*	<u>5.8*</u>	Fair-Poor
2.3	Boat 2	16.5	21	470	81.2	2.2	44.0	28*	7.4*	Fair
1.7	Wading 2	9.0	14	103	17.0	5.5	84.5	<u>20*</u>	<u>3.3*</u>	Poor-Very Poor
0.1	Boat 2	6.5	10	137	37.1	11.6	-	<u>21*</u>	<u>2.7*</u>	Poor-Very Poor
Mill Creek										
11.0	Wading 2	13.0	15	625	131.5	7.3	37.0	<u>17*</u>	<u>3.4*</u>	Very Poor
9.7	Wading 2	9.5	12	1,428	180.2	3.4	44.0	<u>16*</u>	<u>2.9*</u>	Very Poor
9.5	Wading 2	8.5	11	1,664	93.6	0.7	59.0	<u>15*</u>	<u>1.5*</u>	Very Poor
7.7	Wading 1	7.0	7	367	178.5	5.4	38.5	<u>16*</u>	<u>1.5*</u>	Very Poor
6.2	Wading 2	9.5	11	365	18.6	0.5	60.5	<u>18*</u>	<u>4.0*</u>	Poor-Very Poor
2.6	Wading 2	8.0	10	230	43.3	2.9	71.5	<u>18*</u>	<u>4.5*</u>	Poor-Very Poor
1.9	Boat 2	13.0	15	315	79.9	13.4	53.0	<u>20*</u>	<u>4.0*</u>	Poor
1.5	Wading 2	9.0	12	299	27.4	1.8	73.0	<u>24*</u>	<u>4.7*</u>	Poor
0.8	Boat 2	0.8	12	550	58.4	2.9	67.0	27*	<u>4.8*</u>	Fair-Poor
0.3	Boat 2	11.5	12	620	73.3	1.7	46.5	31*	<u>4.1*</u>	Fair-Very Poor
Bears Den Run										
0.1	Wading 1	1.0	1	40	NA	NA	67.0	<u>20*</u>	NA	Poor
Ax Factory Run										
0.1	Wading 1	8.0	8	364	NA	2.8	69.5	30*	NA	Fair
Anderson Run										
0.2	Wading 1	5.0	5	122	NA	0.0	63.5	<u>20*</u>	NA	Poor

Table 16. Continued.

Stream RM	Sampling Method/ # Passes	Mean # Species	Total # Species	Mean Rel. #	Mean Rel. kg	Mean % DELT	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Indian Run										
0.2	Wading 1	12.0	12	464	NA	1.3	65.0	24*	NA	Poor
Dry Run										
0.6	Wading 1	7.0	7	407	NA	0.0	61.5	28*	NA	Fair
Yellow Creek										
1.0	Wading 1	8.0	8	298	3.4	0.0	64.5	22*	5.3*	Poor
Beaver River										
20.1	Boat 2	22.0	30	284	55.8	10.1	79.5	30*	6.6*	Fair
18.0	Boat 2	20.0	23	322	88.0	9.8	76.0	27*	6.7*	Fair
15.8	Boat 2	22.0	27	252	79.0	15.9	74.0	26*	7.2*	Fair
Shenango River										
2.7	Boat 2	18.5	23	478	89.4	5.5	80.5	42	8.8	Good
0.7	Boat 2	26.5	33	534	173.4	8.7	84.5	37ns	8.3ns	Marginally Good
Yankee Creek										
8.8	Wading 2	21.5	27	820	23.0	0.0	46.0	33*	5.5*	Fair-Poor
0.6	Boat 2	21.5	26	516	77.0	1.5	65.0	28*	7.0*	Fair
0.3	Boat 2	18.5	23	492	75.6	1.3	57.5	37ns	6.8*	M. Good-Fair
Little Yankee Creek										
9.5R	Wading 2	10.0	11	744	3.4	0.0	80.5	35ns	NA	Marginally Good
4.6	Wading 2	13.5	15	197	60.4	4.1	66.0	25*	4.0*	Poor-Very Poor
4.4	Wading 2	16.5	20	1,761	16.9	0.1	80.0	26*	6.7*	Poor-Fair
2.0	Wading 2	16.5	19	967	20.6	0.5	76.0	28*	7.5*	Fair
0.4	Boat 1	19.0	19	218	18.4	10.1	-	24*	6.9*	Poor-Fair
0.2	Boat 1	14.0	14	288	69.8	0.7	54.0	30*	6.3*	Fair-Poor
Little Deer Creek										
0.5R	Wading 2	17.5	19	2,094	4.5	0.0	72.0	35*	NA	Fair
Pymatuning Creek										
30.5	Wading 2	16.5	21	259	21.7	0.7	54.0	34*	NA	Fair
24.7	Wading 2	16.5	23	451	24.7	0.9	45.5	23*	4.4*	Fair-Very Poor
17.6	Boat 2	15.5	19	351	148.8	3.5	55.0	25*	5.6*	Poor
17.1	Boat 2	13.0	17	433	148.6	0.7	64.0	28*	5.9*	Fair-Poor
16.1	Boat 2	14.5	17	376	105.6	1.8	68.0	26*	5.3*	Fair-Poor
15.7	Boat 2	14.0	17	298	118.1	17.0	67.5	23*	4.8*	Poor-Very Poor
15.0	Wading 2	19.0	26	190	58.2	2.8	82.0	32*	6.2*	Fair
8.6	Boat 2	14.5	19	271	138.0	1.2	62.0	25*	4.9*	Poor-Very Poor
2.2	Boat 2	13.0	16	513	158.1	5.3	54.5	33*	6.5*	Fair

Table 16. Continued.

Stream RM	Sampling Method/ # Passes	Mean # Species	Total # Species	Mean Rel. #	Mean Rel. kg	Mean % DELT	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Sugar Creek (WWH)										
1.0	Wading 2	16.5	21	529	NA	0.0	65.5	37[ns]	NA	Marginally Good

Ecoregional Biological Criteria:

Erie-Ontario Lake Plain (EOLP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters	40	50	24
IBI - Wading	38	50	24
IBI - Boat	40	48	24
Mod. Iwb - Wading	7.9	9.4	6.2
Mod. Iwb - Boat	8.7	9.6	5.8
ICI	34	46	22

* Significant departure from ecoregional biological criterion (>4 IBI or >0.5 MIwb units); underlined values are in the poor and very poor range.

ns Nonsignificant departure from biocriterion ($\leq$4 IBI units or $\leq$ 0.5 MIwb units)

a Narrative evaluation is based on both MIwb and IBI scores.

NA Headwater site; MIwb is not applicable.

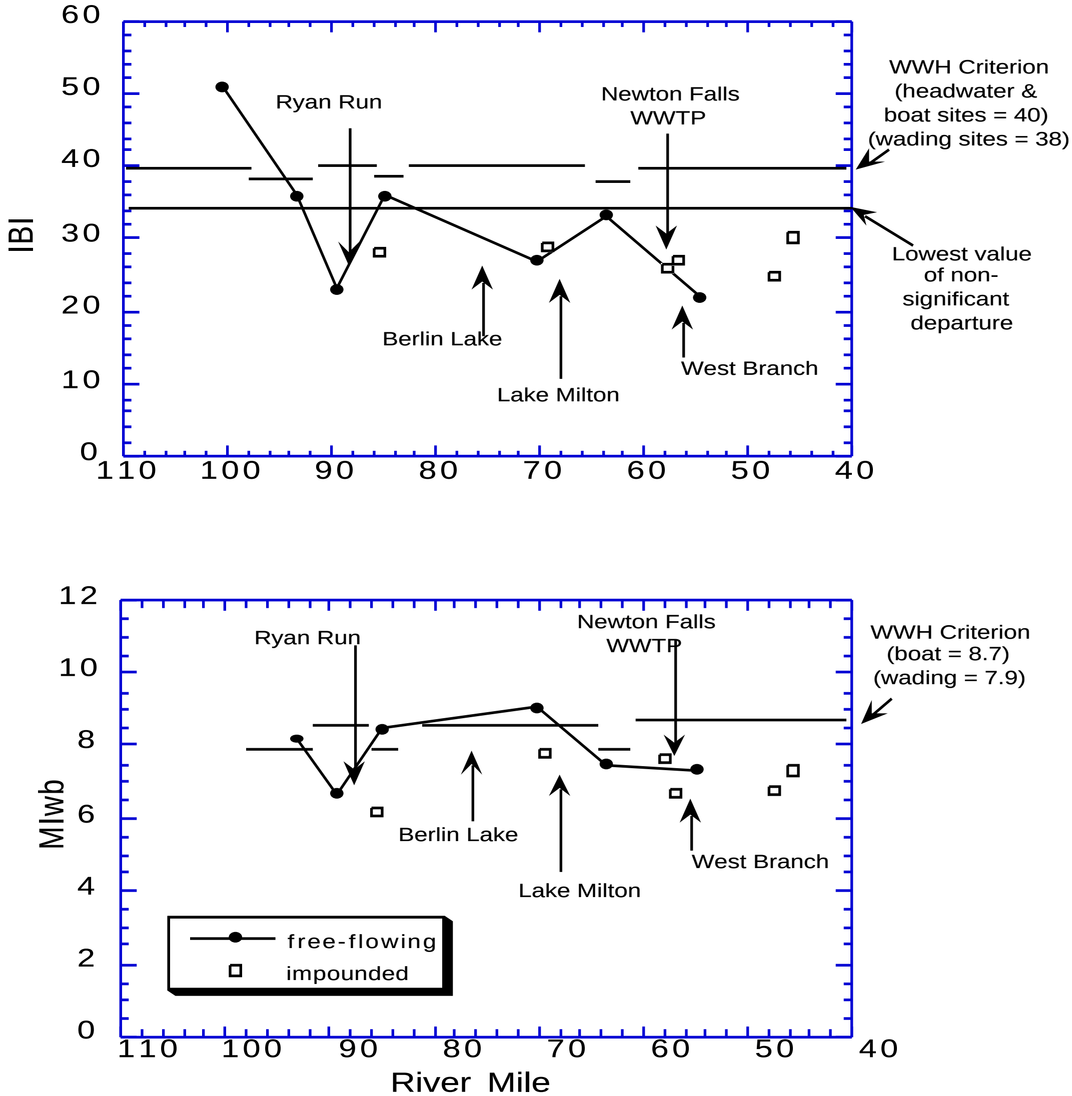


Figure 54. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the upper half of the Mahoning River mainstem during 1994.

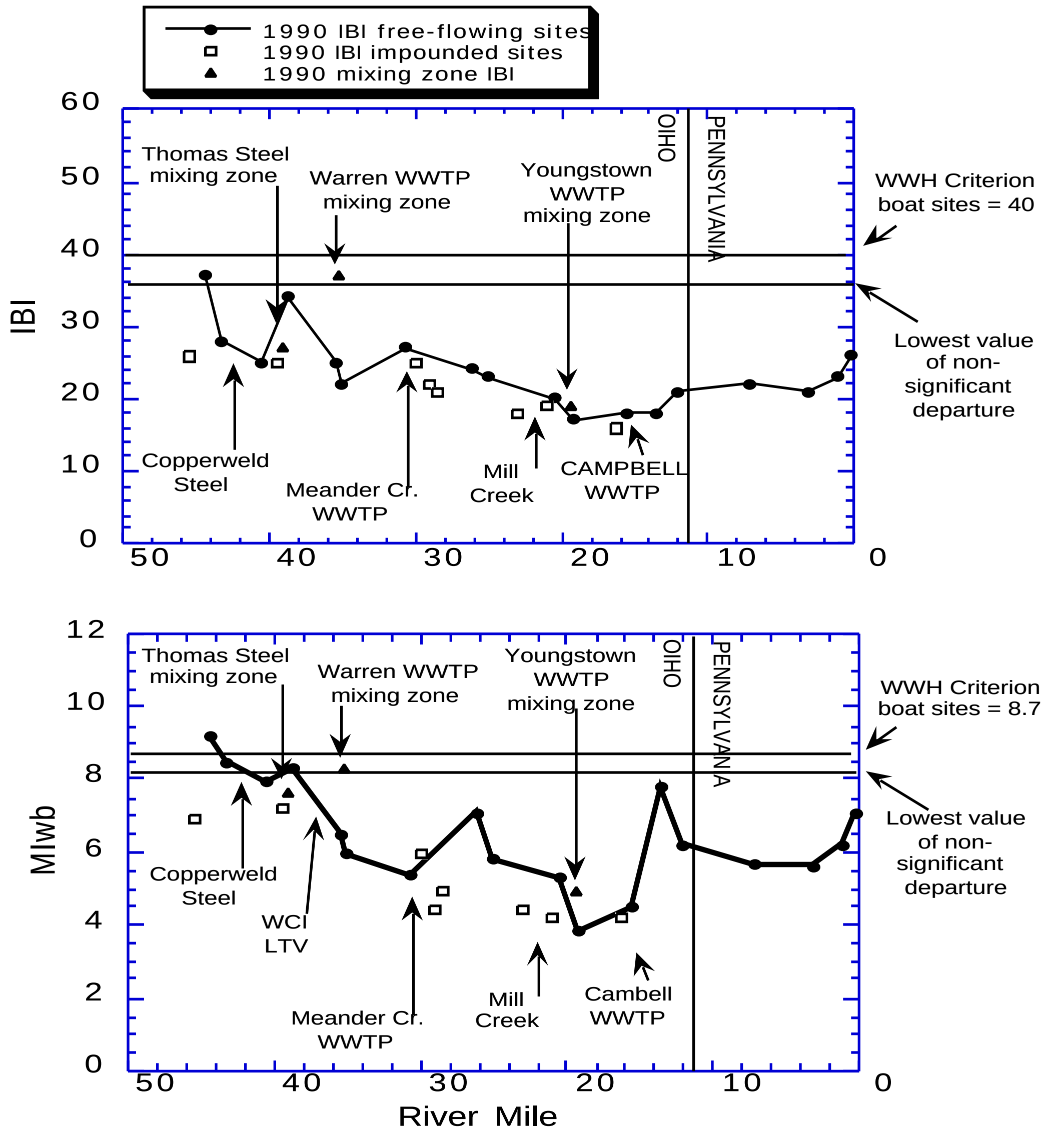


Figure 55. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the lower half of the Mahoning River mainstem during 1994.

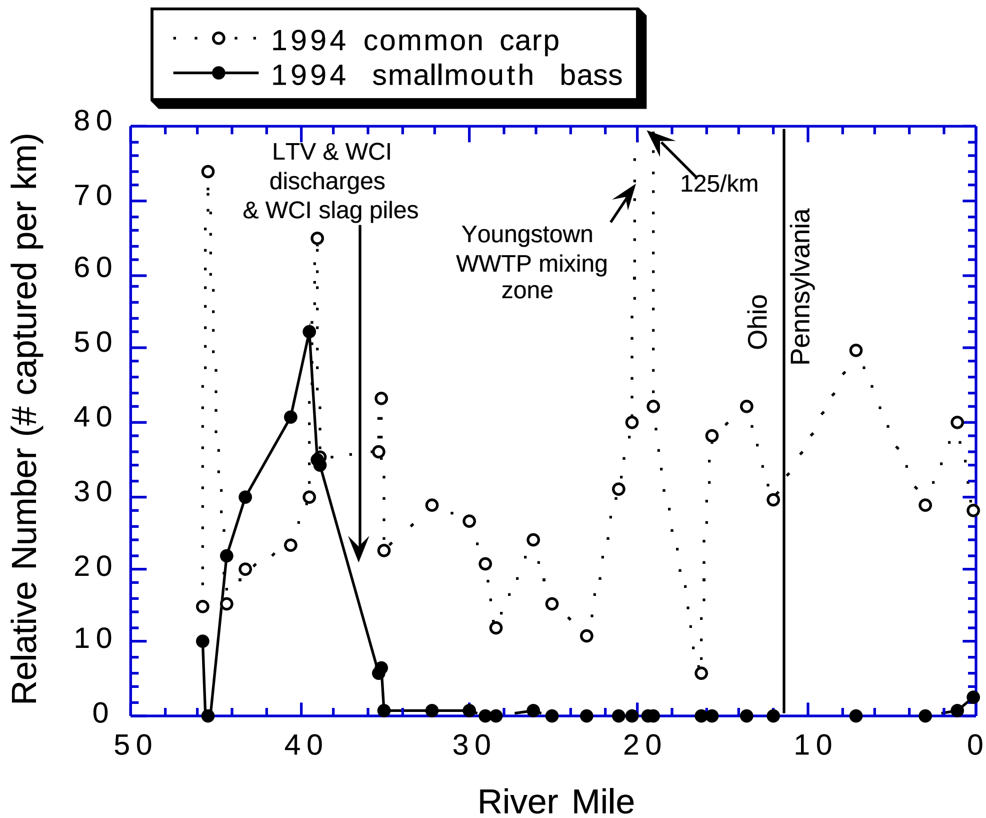


Figure 56. Longitudinal trends of the mean relative number of smallmouth bass and common carp in the lower half of the Mahoning River during 1994.

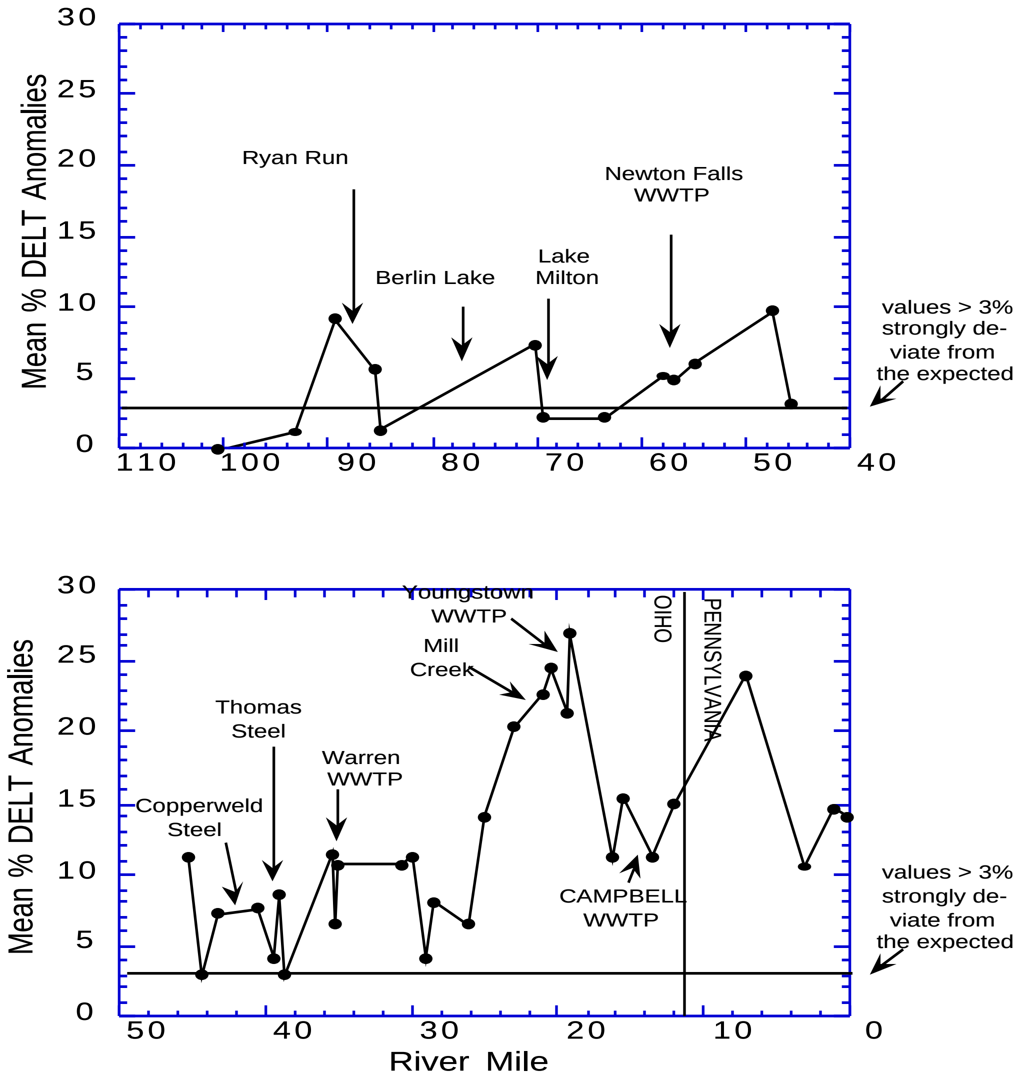


Figure 57. Longitudinal plots of the mean percentage of fish with DELT (deformities, eroded fins, lesions, and tumors) external anomalies in the upper half (Top Graph) and lower half (Bottom Graph) of the Mahoning River during 1994.

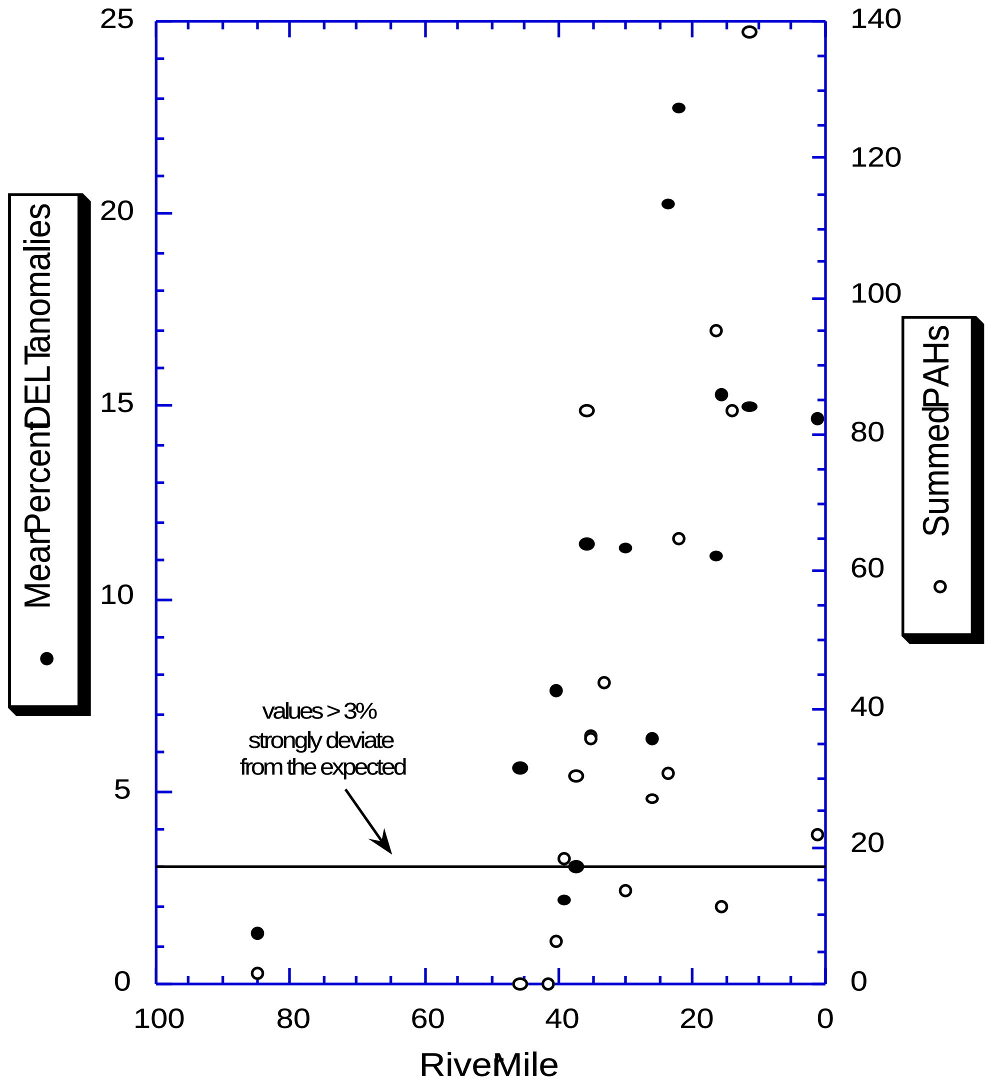


Figure 58. Longitudinal scatter plots of the mean percentage of fish with external DELT (deformities, eroded fins, lesions, and tumors) anomalies and sediment concentration (ug/kg) of summed polycyclic aromatic hydrocarbons (PAHs) in the Mahoning River during 1994.

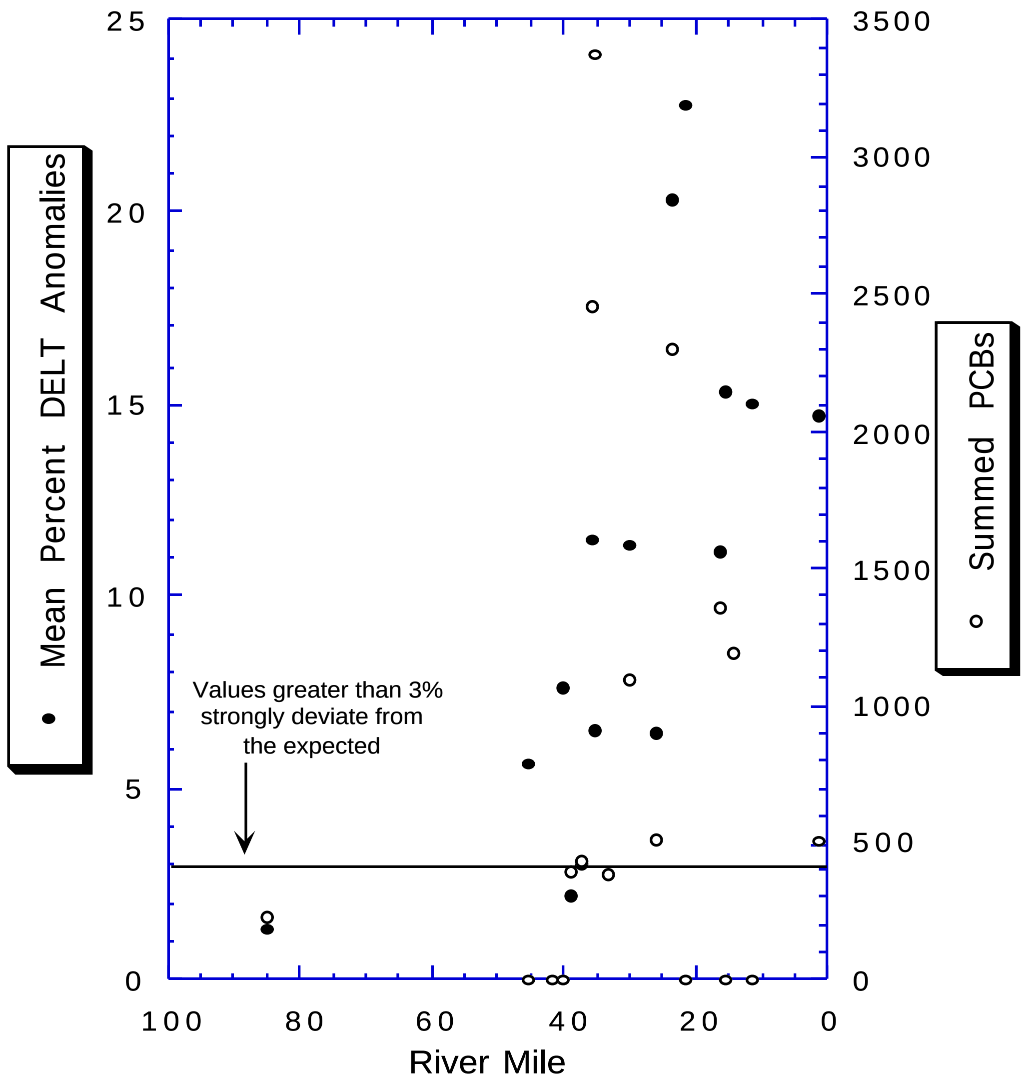


Figure 59. Longitudinal scatter plots of the mean percentage of fish with external DELT (deformities, eroded fins, lesions, and tumors) anomalies and sediment concentration of summed polychlorinated biphenyls (PCBs) in the Mahoning River during 1994.

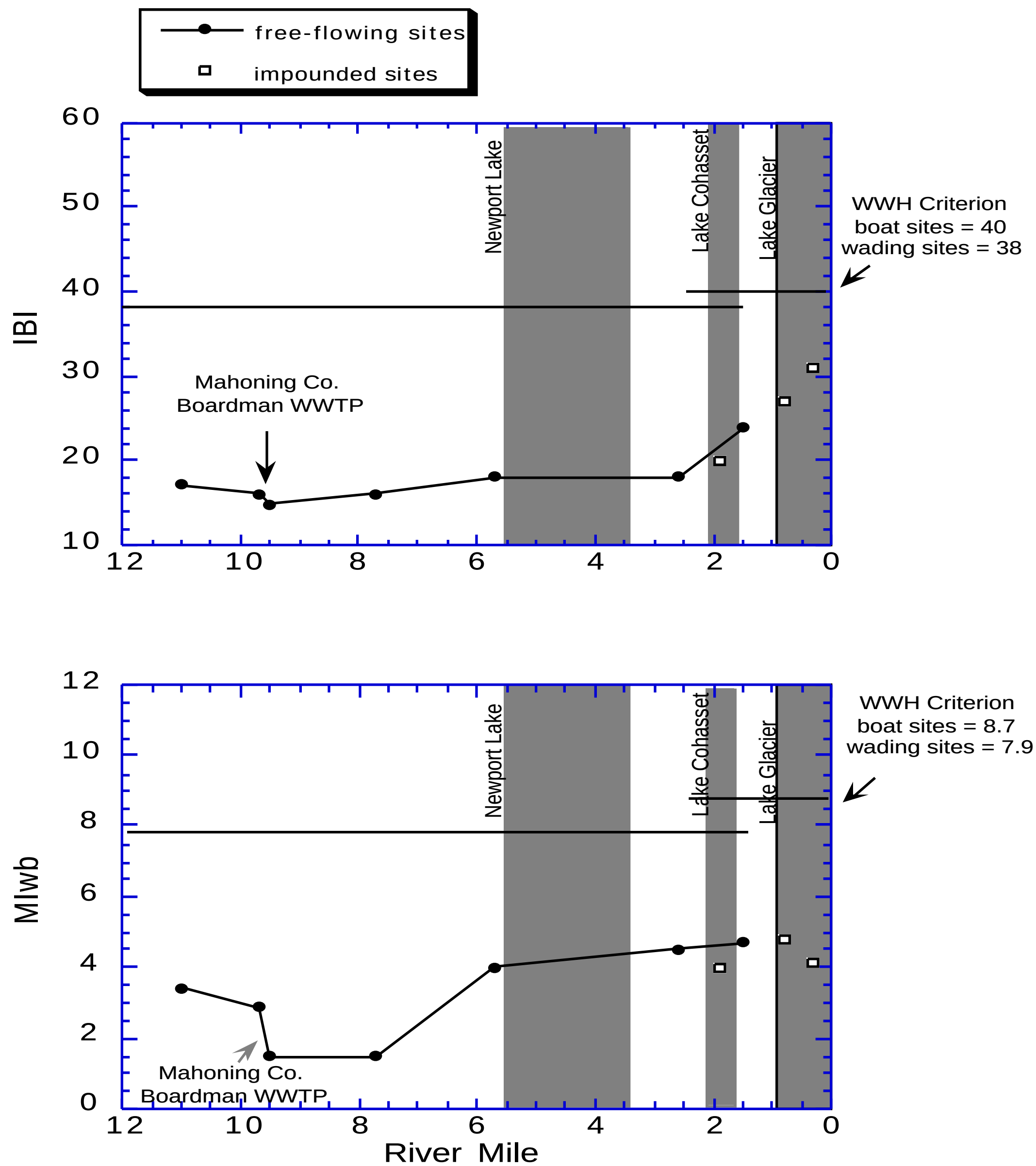


Figure 60. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in Mill Creek during 1994.

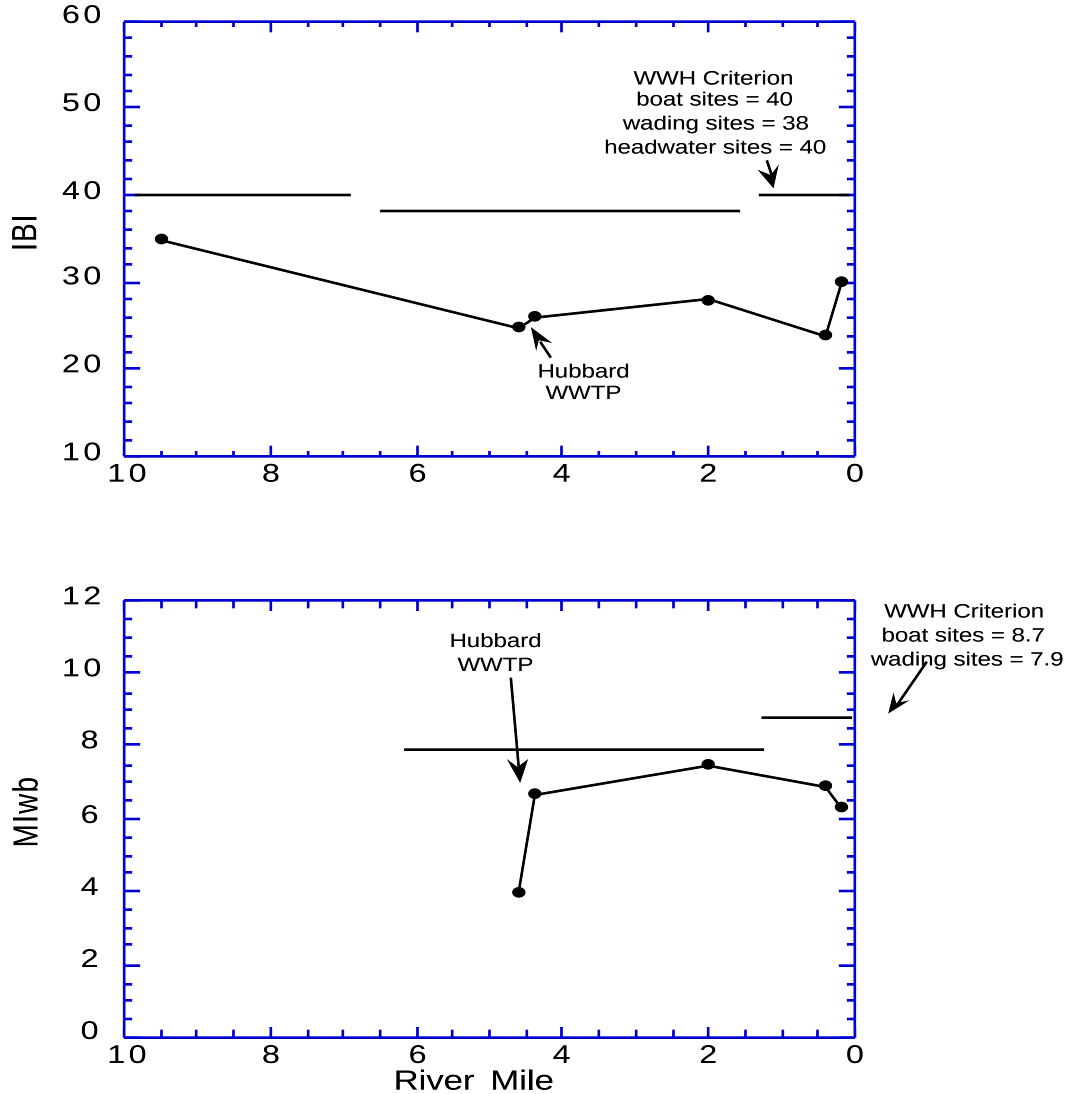


Figure 61. Longitudinal trend of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in Little Yankee Creek during 1994.

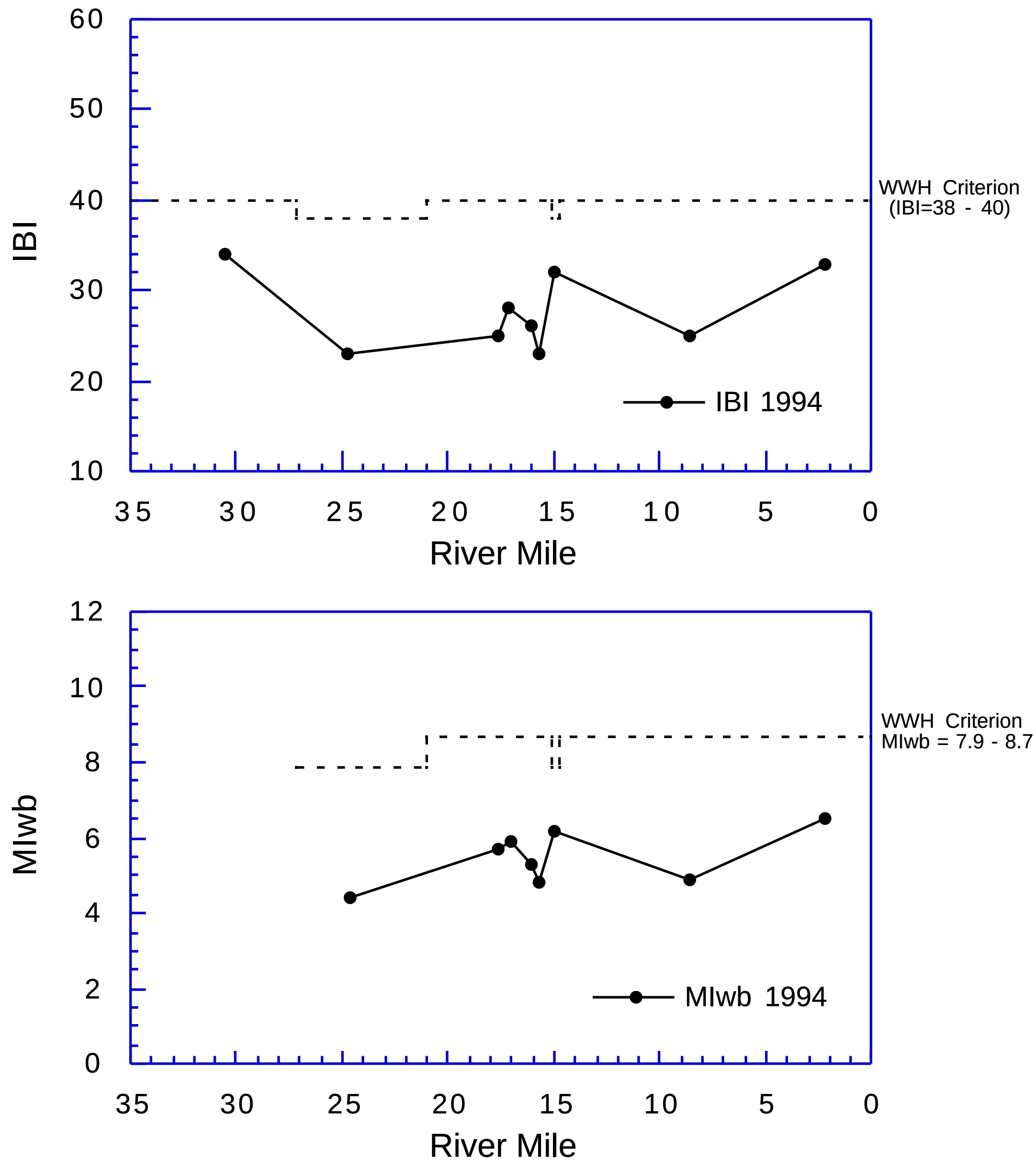


Figure 62. Longitudinal trend of the Indix of Biotic Integrity (IBI, Top Graph) and the Modified Index of Well-Being (MIwb, Bottom Graph) in Pymatuning Creek, 1994.

TREND ASSESSMENT: 1972 - 1994

Chemical Water Quality Trends (Figures 63-69)

Upper Mahoning River (RMs 100.57-45.73)

- No intensive chemical or biological surveys of the upper Mahoning River basin have been conducted by the Ohio EPA. Historical ambient chemical data was collected in the mid-1970s at two stations, RM 85.51 at Webb Road and RM 62.68 at Pricetown Road.

- Data from 1976 and 1977 collected at the Webb Road station (RM 85.51) indicated significant problems with dissolved oxygen, with values as low as 2.2 mg/l recorded. Dissolved oxygen values were recorded below 3.0 mg/l for a three month period. Ammonia-N was elevated ranging from 0.20-1.54 mg/l, and three samples showed lead over 20 mg/l. Water chemistry data from the 1994 survey at Webb Road indicated that the DO and ammonia-n problems from the 1970s have improved. No violations for either of these parameters were recorded during the summer of 1994.

- Samples collected at the Pricetown Road station in 1974 and 1975 showed no problems with DO or ammonia-N. Continued good water quality was found at this station during the 1994 survey.

- In 1983 and 1984 the Ohio EPA collected monthly samples at Knox School Road (RM 93.23) as part of a statewide ecoregion reference site evaluation project. The chemical data from the 1983-84 survey did not indicate any violations of water quality standards. Comparison of the historic data to data collected in 1994 indicates no significant difference in chemical water quality over the past 10 years at this station.

- The Ohio EPA has no historical water chemistry data for the Mahoning River in the stream segment from Newton Falls (about RM 56.5) downstream to the Leavittsburg dam at RM 45.6.

Lower Mahoning River, Ohio Waters (RM 45.51 - 11.43)

- The Ohio EPA conducted an intensive survey of the lower Mahoning River between 1980 and 1982, which was reported in the 1984 Water Quality Technical Support Document (Ohio EPA, May, 1994). The 1984 report provides a detailed summary of historical water quality studies conducted by various consultants and government agencies up to 1980.

- Long term STORET chemical data are available at two ambient monitoring stations at Leavittsburg and Lowellville. Grab water samples have been collected monthly by the Ohio EPA from the early 1970s to the present. Until 1992, continuous USGS monitoring data for water temperature and dissolved oxygen were available at the Lowellville monitoring station. In June, 1992 the continuous monitoring station was moved upstream to the USGS West Avenue gage station. In 1987, the USGS established a flow gage above the Ohio Edison Niles Plant, located about 0.2 miles upstream from Belmont Road.

- The 1980-1982 Ohio EPA lower Mahoning River survey was conducted at a time when most of the steel making facilities along the lower Mahoning River valley were in the process of being closed, however, none of the municipal WWTPs had been expanded to secondary levels of wastewater treatment. At the time of the survey 1980-1982 survey there were significant violations of water quality standards recorded for dissolved oxygen, and ammonia-N throughout the Mahoning River mainstem.

- Dissolved oxygen and ammonia-N data collected at the Lowellville ambient station from the early 1970s to present indicate that there has been a significant improvement in DO and ammonia-N concentrations since the early 1980s (Figure 63). The most significant improvements are related to the 1988-1989 time period when most of the WWTPs in the Mahoning valley converted to secondary levels of wastewater treatment and sharply reduced loadings of ammonia-N and BOD to the river. Longitudinal trends show a decrease in ammonia and a corresponding increase in dissolved oxygen in the lower Mahoning River from data collected in 1980 compared to 1994 (Figure 64).

- Reduced industrial point source loadings of phenolic (Figure 65) and cyanide compounds in the early 1980s resulted in a significant reduction in the in-stream concentrations of these compounds found at the Lowellville ambient station. Both cyanide and phenolic compounds have been effectively eliminated from the water, except during high flows when sediment is resuspended into the water.

- Heavy metals data collected by the Ohio EPA during their 1980 and 1994 intensive surveys of the Mahoning River mainstem indicates reductions in total zinc, chromium, and nickel in 1994. However, as shown in Figure 65, there has been little change in the concentration of total lead in water collected at the Lowellville ambient station from 1980 to 1994, with average annual concentrations in the 8-10 ug/l range. Stream samples for total copper and cadmium were below detection limits and also show no change between the 1980 to 1994 surveys throughout the lower Mahoning River mainstem. Hardness values at both the Leavittsburg and Lowellville stations has been consistently under 200 mg/l.

- Figure 66 shows long term fecal coliform samples collected on the same day at the Leavittsburg and Lowellville ambient stations. These data indicate that the level of bacteria at Lowellville (RM 12.5) has consistently been well above the 1000-2000/100 ml fecal coliform bacteria standard over the past 20 years. Numerous potential sources of fecal coliforms located upstream from the Lowellville station include SSOs, CSOs, unsewered areas, and WWTP point source discharges. No significant fecal coliform problems exist at the upstream Leavittsburg ambient station, and more recent data indicates some improvement in bacteria quality at this station.

Mosquito Creek (RM 30.64)

- The Ohio EPA sampled near the mouth of Mosquito Creek in 1980 and 1983 (RM 0.5) and slightly further downstream in 1994 (RM 0.25). Five additional stations were sampled in 1983 that were not sampled in either 1980 or 1994.

- During the 1980 and 1983 surveys low dissolved oxygen values were reported at the mouth of Mosquito Creek (minimum of 2.7 in 1980, and minimum of 3.9 mg/l in 1983). Low dissolved oxygen was not observed during the 1994 survey (minimum = 6.8 mg/l). The Mosquito Creek WWTP was upgraded (1983 completion) and the Warren WTP has stopped their discharge of lime sludge (mid 1980s). Ammonia-N concentrations have been significantly reduced since the early 1980s. Maximum values of 1.22 mg/l ammonia-N in 1980 have been reduced to 0.11 mg/l in 1994. Total lead was detected in all samples at low concentrations in both 1980 (5-10 ug/l range) and 1994 (2-5 ug/l range), but not at levels that exceed water quality standards.

- Perhaps the most significant difference in water quality at the mouth of Mosquito Creek was the much higher concentration of TSS found in 1994 (22-48 mg/l range) compared to 1980 (4-21 mg/l range) and 1983 (14-20 mg/l range). This trend is significant and difficult to explain because the 1994 samples were collected during dry weather conditions. Elevated levels of dry weather TSS could have a negative impact on the aquatic use potential of Mosquito Creek near the mouth. A more intensive survey of the entire Mosquito Creek basin will be needed to determine the source of the elevated TSS.

Meander Creek (RM 30.27)

- The Ohio EPA sampled near the mouth of Meander Creek in 1980 (RM 1.7), at RMs 1.7 and 0.8 in 1983, and at RMs 2.0, 1.8, and 0.8 in 1994. The Meander Creek WWTP discharges to Meander Creek at RM 1.98, thus only the 1994 survey sampled above the WWTP to determine background conditions.

- Long term data for dissolved oxygen at RM 0.8 in 1983 and 1994 shows a continued problem, with values as low as 1.6 mg/l at RM 0.8 in 1983 and 2.4 mg/l in 1994. Low dissolved oxygen had also been recorded at RM 1.8 in 1983 (min. of 0.1 mg/l), and in 1994 (min. 3.6 mg/l). Somewhat higher dissolved oxygen at RM 1.8 in 1994 compared to 1983 may be explained by the fact that the MVSD water treatment plant continued to discharge lime sludge into Meander Creek (just above the WWTP discharge at RM 1.98) until 1988. The presence of the lime sludge at the downstream stations during the 1980 and 1983 surveys would have masked the effect of the WWTP discharge. Low dissolved oxygen in Meander Creek below the WWTP discharge would be expected because the MVSD completely stops the flow of water over the Meander Creek Reservoir dam.

- Long term data also shows elevated phosphorus and nitrate-nitrite concentrations from 1983 to 1994 below the Meander WWTP. These nutrients have resulted in excessive growths of algae at the downstream RM 1.8 and 0.8 stations in 1994. Ammonia-N values have been reduced from 1983 (max. of 2.23 mg/l at RM 1.7) to 1994 (max. 0.72 mg/l). The discharge of lime sludge from the MVSD water treatment until 1988 appears to have masked the potential effects on water from the WWTP discharge in previous sampling by Ohio EPA. However, the documentation of continued low dissolved oxygen and high nutrients during the 1994 survey indicates that the Meander Creek WWTP has the potential to have a significant negative effect on the aquatic life of the stream. The water quality impact is enhanced by the fact that Meander Creek has little or no flow below the reservoir dam during the critical summer months.

Mill Creek

- Ohio EPA conducted an intensive biological and water quality study of the Mill Creek mainstem in 1982. A comparison of 1982 and 1994 mean chemical results are presented in Figure 67.

- The most important trend that shows the historical impact of the Boardman WWTP is that of dissolved oxygen. The dissolved oxygen sag (caused from the Boardman WWTP's effluent) has occurred at approximately RM 8 on both years sampled even though, the Boardman plant has made improvements. In 1987 the plant was upgraded to achieve a higher effluent quality and improve treatment and handling of sludge. The upgrade included advanced secondary treatment, nitrification, disinfection and post-aeration. The curve fit line(mean) on the dissolved oxygen trend graph (Figure 67) is very similar between sampling years, with the 1982 survey having an overall lower dissolved oxygen mean(approximately 1 to 2 mg/l) from RM 8.0 through 0.1. The mean dissolved oxygen concentration recorded in 1994 was in violation of the WWH minimum average criterion for at least four miles downstream of the Boardman WWTP while the 1982 survey recorded approximately five miles of this oxygen violation downstream of the Boardman WWTP.

- Another important parameter to discuss is the total phosphorus trend. Historically (1982) improperly treated wastes have elevated total phosphorus levels to above 6 mg/l at RM 9.5 and as high as 12.6 mg/l at RM 7.8. During the 1994 survey the highest level(1.21 mg/l) was also observed at RM 7.8.

- The mean ammonia-N concentrations recorded in 1994 was lower than the mean ammonia concentration recorded in 1982. At an ammonia WQS of 1.6 mg/l (pH=7.9, temperature =20˚ C) the

1994 mean data showed only a two mile segment downstream of the Boardman WWTP in potential violation of the ammonia standard, while the 1982 mean data showed a six mile segment (downstream Boardman) in potential violation of ammonia.

Yankee Creek

- Chemical water quality in Yankee Creek appears to have improved from 1984 to 1994. The 1984 survey showed degraded conditions below the Brookfield WWTP due to organic enrichment, elevated ammonia-N and TKN concentrations, and low dissolved oxygen levels. Field work conducted in 1994 revealed much improved water quality conditions below the WWTP. Dissolved oxygen levels now show an upward trend (Figure 68). Ammonia-N and TKN concentrations were consistently near or below detection limits (Figure 68). Suspended solids concentrations, though relatively high, were similar upstream and downstream of the WWTP. Total phosphorus concentrations were slightly elevated throughout the basin and increased somewhat below the WWTP (Figure 68). These improvements in water quality are a direct result of improvements at the waste water treatment facility and the elimination of small WWTPs in the vicinity.

Little Yankee Creek

- Chemical water quality in Little Yankee Creek appears to have improved from 1984 to 1994. The 1984 survey showed degraded conditions below the Hubbard WWTP due to organic enrichment, elevated ammonia-N and TKN concentrations, and low dissolved oxygen levels. Field work conducted in 1994 revealed much improved water quality conditions below the WWTP. Ammonia-N concentrations were consistently near or below detection limits (Figure 69). Suspended solids concentrations were similar upstream and downstream of the WWTP. Total phosphorus and TKN concentrations increased significantly below the WWTP but were assimilated at the downstream sampling stations (Figure 69). Dissolved oxygen levels now show an upward trend at the downstream stations (Figure 69). These improvements in water quality are a direct result of improvements at the waste water treatment facility.

Pymatuning Creek

- Little historical chemical/physical water quality data has been collected by Ohio EPA for Pymatuning Creek. The vast majority of sampling prior to the present study occurred in 1983-84 for the ecoregional studies project. There appears to be little change in ambient water quality in Pymatuning Creek from that sampling to the present. Results from samples collected by Ohio EPA in 1994 were similar to results reported in a 1992 Kent State University study.

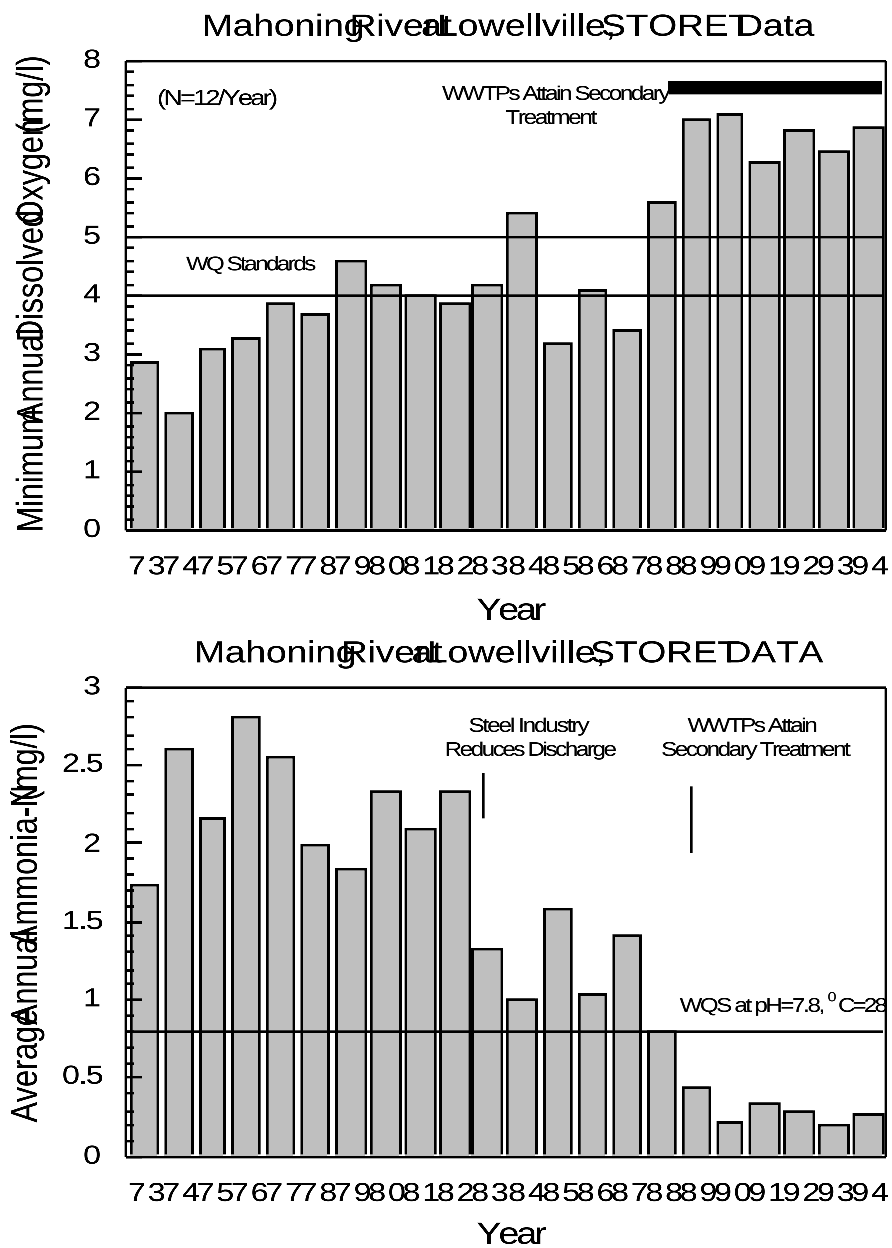


Figure 63. Trend data for minimum concentrations of dissolved oxygen(minimum of twelve samples - one sample per month) and average ammonia-N (annual average of twelve samples - one sample per month) in the Mahoning River at Lowellville.

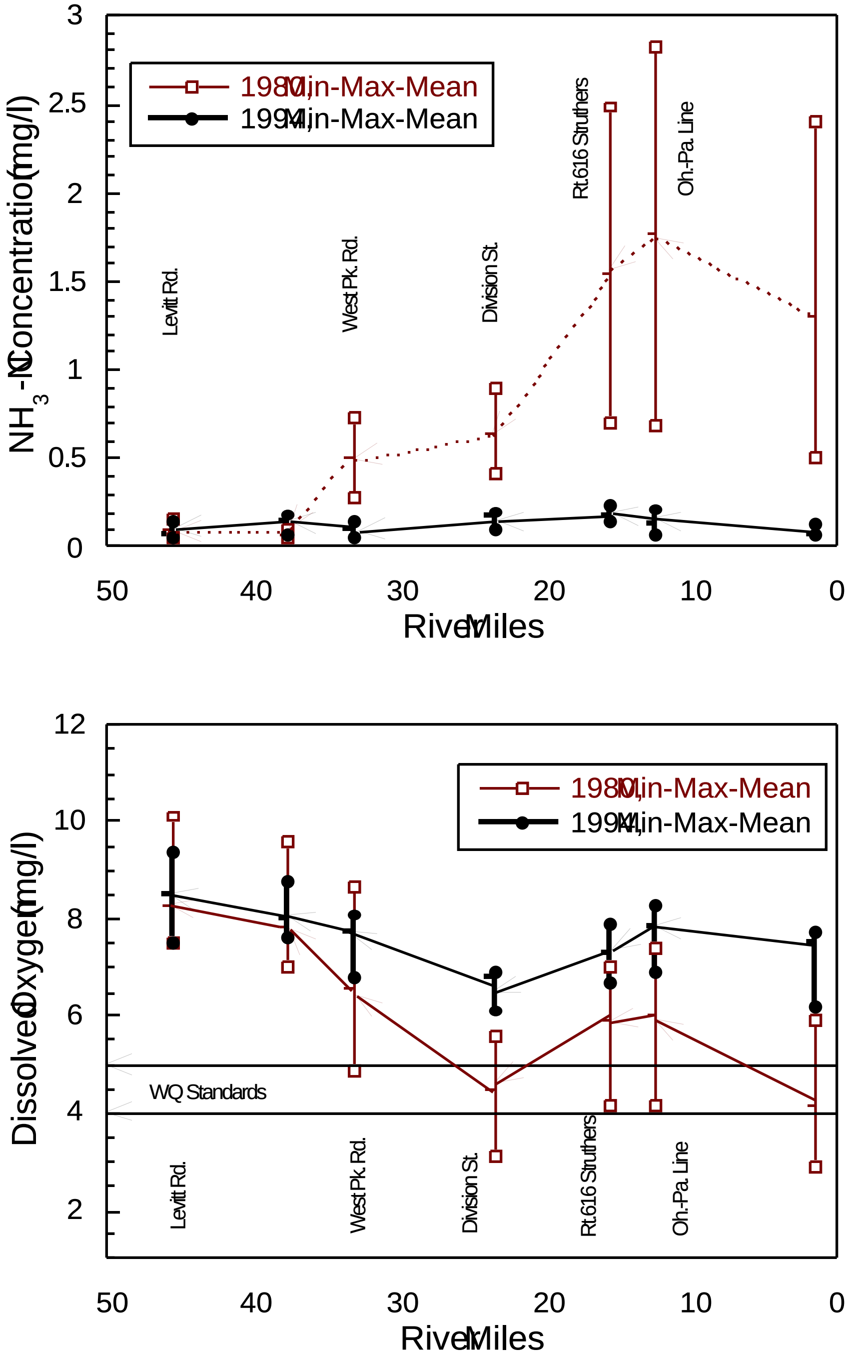
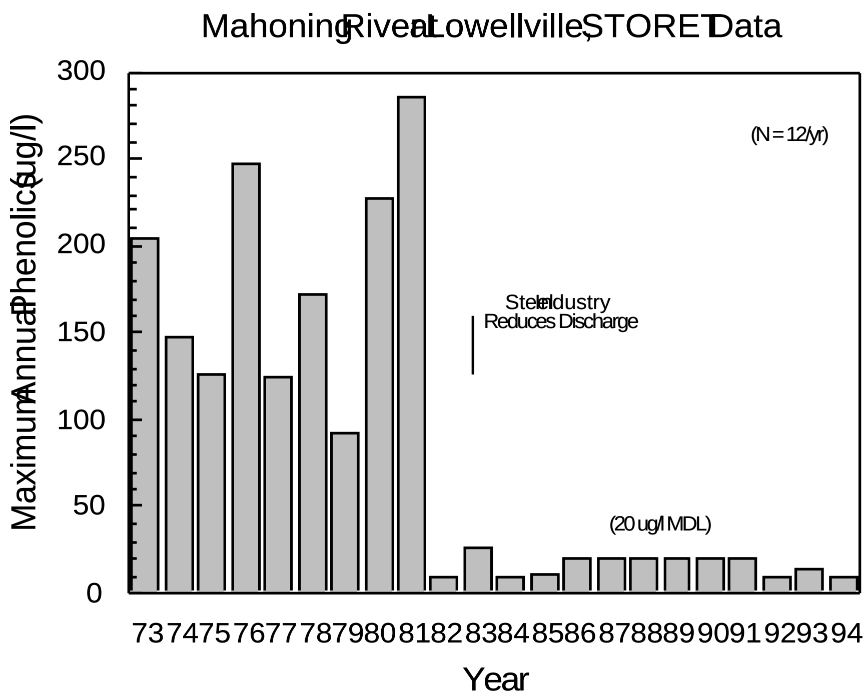


Figure 64. Longitudinal trend data for dissolved oxygen and ammonia-N (grab samples) in the lower Mahoning River from 1980 to 1994.



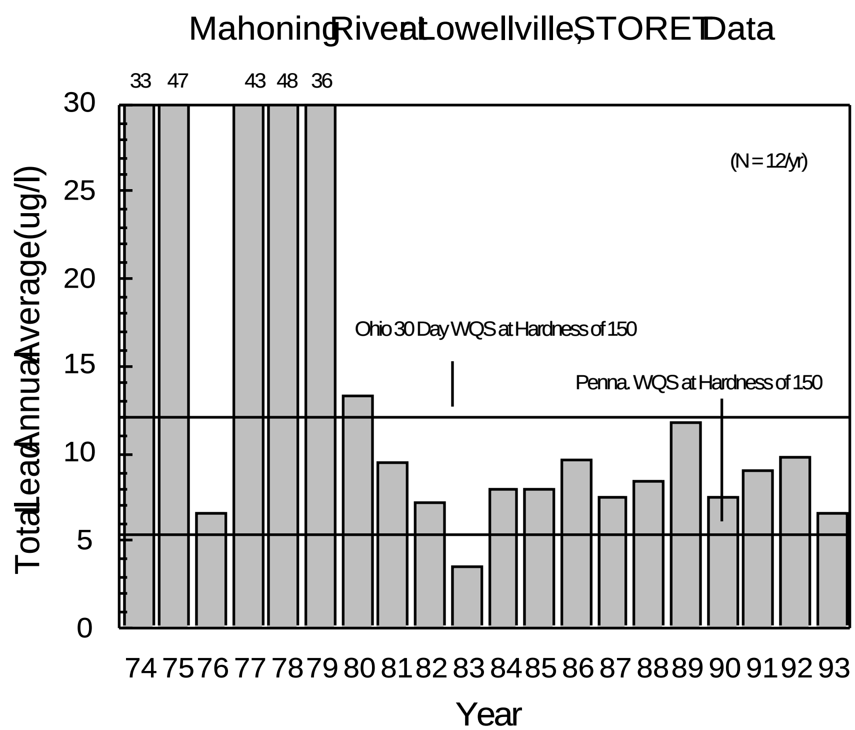
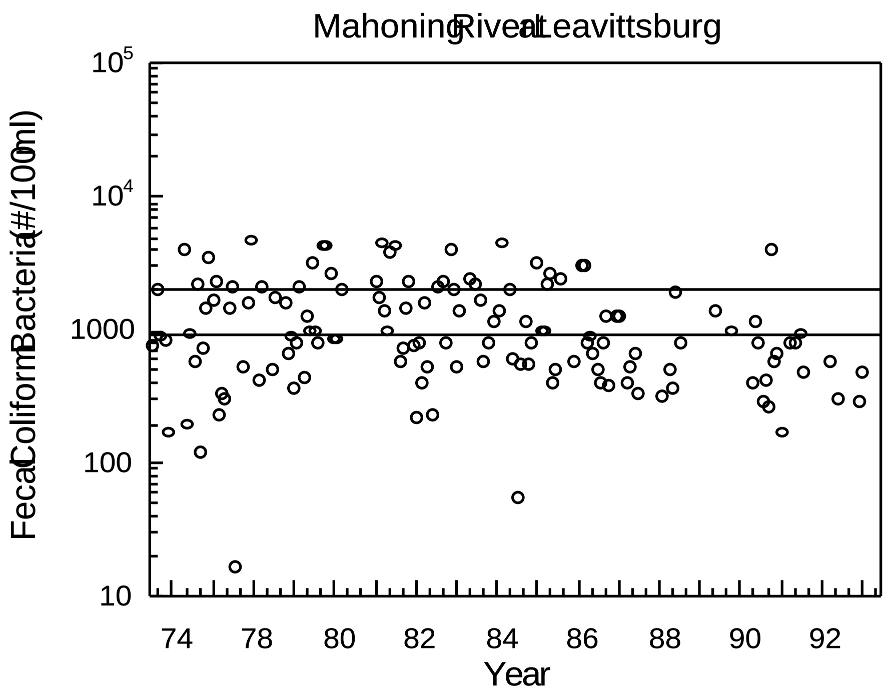


Figure 65. Trend data for total phenolics and total lead in the Mahoning River at Lowellville (STORET data).



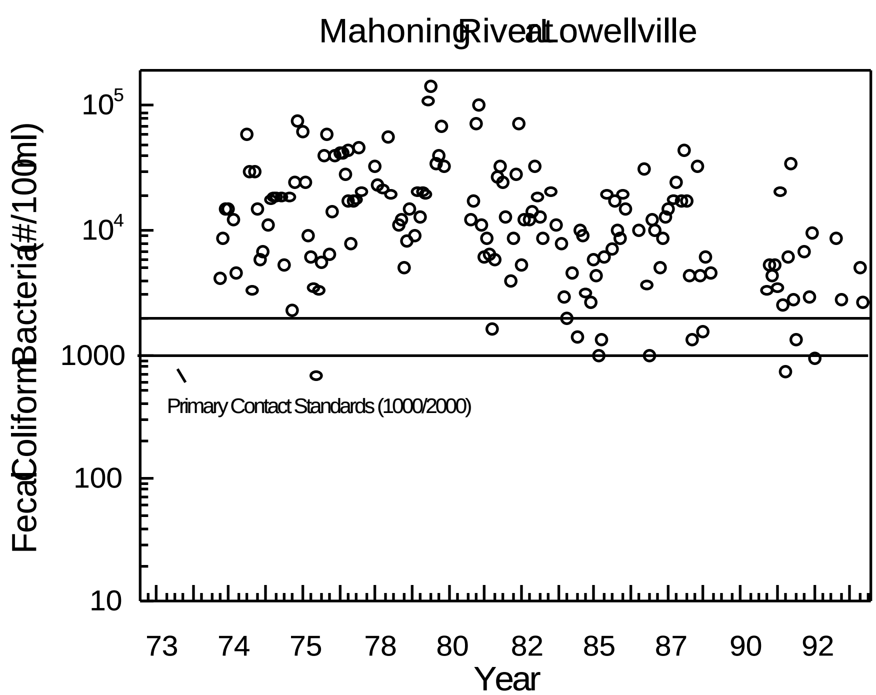


Figure 66. Trend data for fecal coliform bacteria in the Mahoning River at Leavittsburg and Lowellville (STORET data).

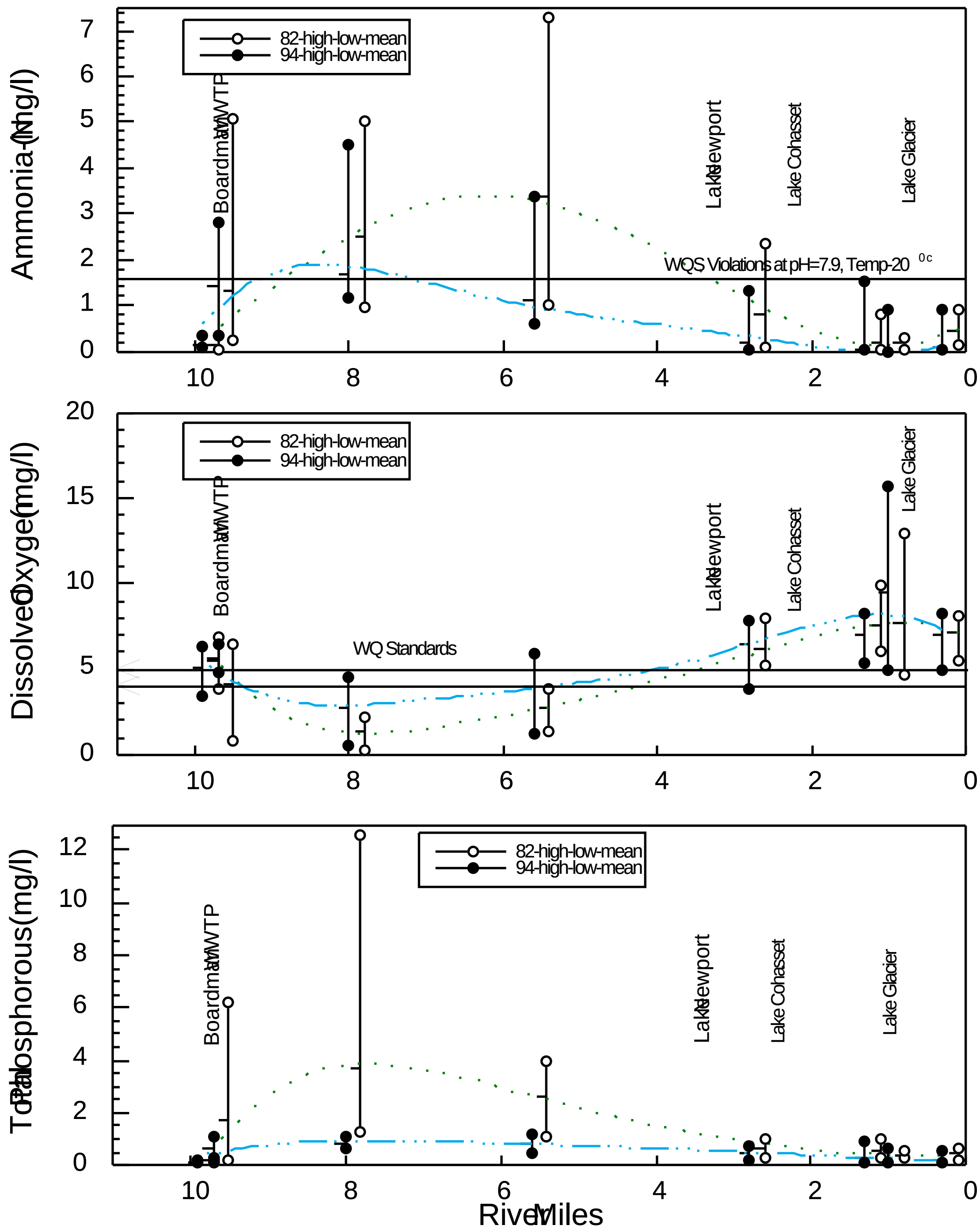


Figure 67. Longitudinal trend data for ammonia-N, dissolved oxygen, and total phosphorus (grab samples) in Mill Creek from 1982 to 1994.

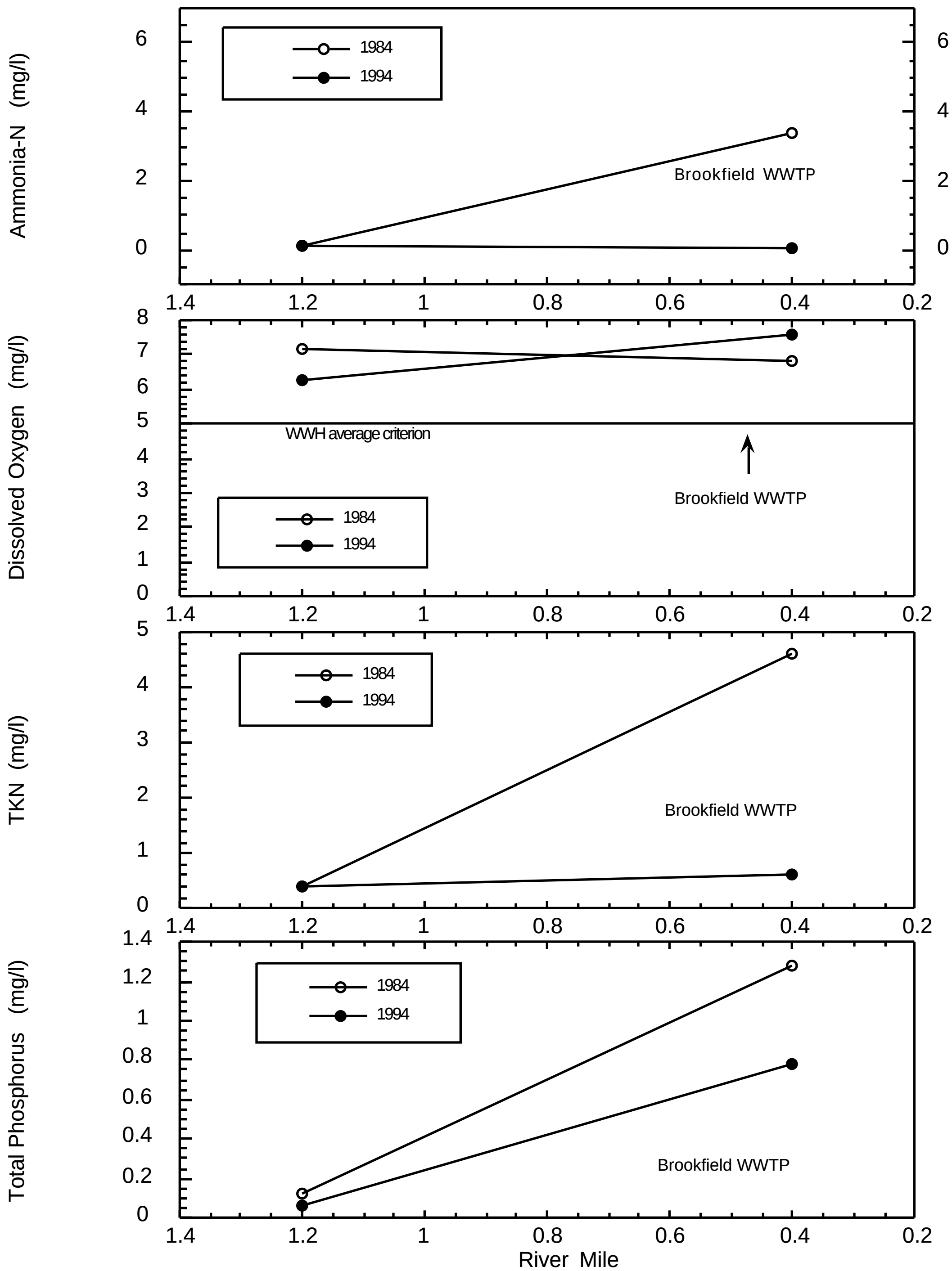


Figure 68. Longitudinal trend data (grab samples) for ammonia-N, dissolved oxygen, total kjeldahl nitrogen (TKN), and total phosphorus in Yankee Creek from 1984 to 1994.

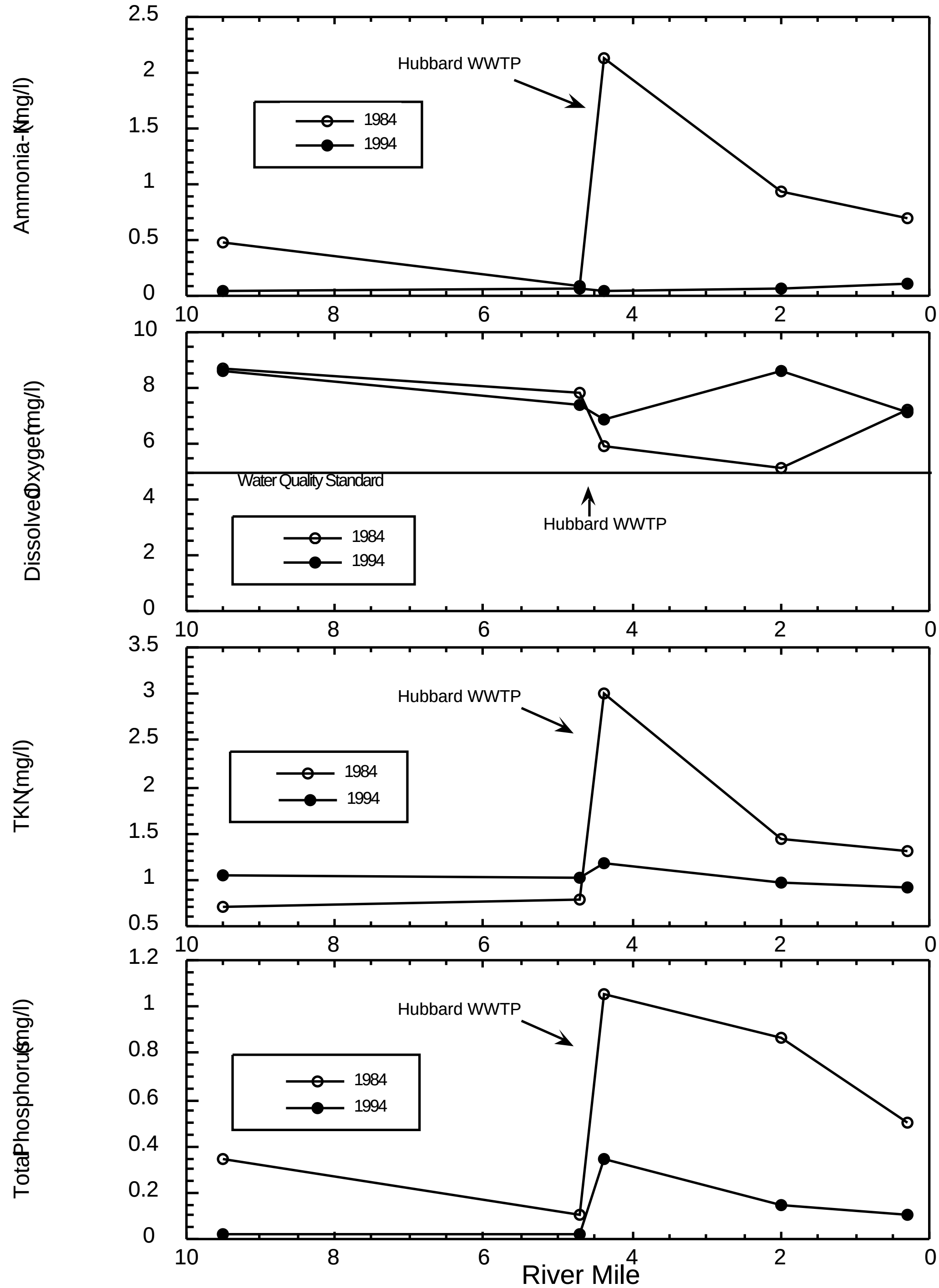


Figure 69. Longitudinal trend data (grab samples) for ammonia-N, dissolved oxygen, total kjeldahl nitrogen (TKN), and total phosphorus in Little Yankee Creek from 1984 to 1994.

Sediment Quality Trends (Figure 70, Table 17)

Mahoning River

- A summary of historical data collected by the Ohio EPA and U.S. EPA (1986) on the Mahoning River stream sediments is provided in the Ohio EPA May 28, 1994 Lower Mahoning River Basin WQTSD report and the June 24, 1988 Ohio EPA report on fish tissue and sediment organic chemical evaluation (Estenik, 1988). These reports indicated highly contaminated sediment at stations downstream from the steel making facilities in Warren. The U.S. EPA report on PAH compounds documented highly contaminated river sediments adjacent to the three historical coking operations in Warren, Youngstown, and Campbell. These reports lead the Ohio Department of Health to issue a health advisory on July 23, 1988 for the river from Bridge Street in Warren to the Ohio-Pennsylvania state line. The advisory recommended no contact with the stream sediments and no consumption of fish.

- A report on the feasibility of removing bank and river bottom sediments in the Mahoning River was conducted for the Army Corps of Engineers, Pittsburgh District, by Havens and Emerson, LTD (June, 1976). This 1976 report summarized heavy metal, nutrient, oil and grease, cyanide, and phenol concentrations from 21 sites along the lower Mahoning River. All sites, except the most upstream at the Leavittsburg dam were considered to be grossly contaminated. The report estimated that the removal of 287,800 cu.yds. of contaminated river sediment would be required from twelve different stream reaches at an estimated cost of $ 1,411,500. The removal of an additional 380,000 cu. yds. of oil-soaked river bank sediment was estimated to cost $1,886,800. These costs would be significantly increased in 1996 dollars.

- Table 17 provides a summary of historical data for heavy metals collected from lower Mahoning River bottom sediments from 1975 to 1994. The data indicate that the upstream site, just below the Leavitt Road dam (RM 45.5), has maintained relative good sediment quality over the nineteen year period. All metals have consistently showed non-elevated or slightly elevated concentrations. The data also show relatively small statistical variances from year to year, even though the samples were collected by different people, using different sampling techniques, and analyzed by different laboratories. The sediment data at RM 45.5 underscore the validity of using sediment samples, collected at the same location, to document potential long term trends in stream chemical quality and upstream pollutant loadings.

- In contrast to the data at the upstream Leavitt Road station, data from RM 29.98 (near Belmont Road) down to RM 1.5 in Pennsylvania indicate a long term trend of contaminated sediment for heavy metals. Five heavy metals (Cu, Cr, Fe, Pb, and Zn) were found at potentially toxic concentrations during the 1994 survey, with little or no indication that the lower Mahoning River sediment has improved over time (Table 17).

- A significant historical impairment of the lower Mahoning River sediment are the elevated levels of polynuclear aromatic hydrocarbons (PAHs). The Ohio EPA 1988 report (Estenik, 1988) documented very high levels of PAH compounds downstream from the three historical coking operations (current LTV coke plant at RM 35.68; the old Republic Steel Youngstown coke plant at RMs 19-18; and the old J&L Youngstown Sheet and Tube Campbell coking operation at RMs 17-16. Comparison of historical PAH sediment data with data collected in 1994 is complicated by errors with historical river mile calculations and the fact that samples were not collected at the same location. Figure 70 shows PAH data from both 1986 and 1994. The highest values from 1986 were collected close to the discharge point of coke operations. Sediment samples were located close to biological stations in 1994 which were not as close to coking operation discharge points as the data with high values from 1986. It is apparent from Figure 70 that those locations not near the coke discharge points are very similar in concentration between 1986 and 1994. PAH sediment data from RM 13.2 at the P&LE RR bridge below Struthers were collected at the same exact location by Ohio EPA in 1986 and 1994, which allows direct year to year evaluation. The total PAH concentration at the station in 1986 was 77.7 mg/kg and in 1994 it was 83.3 mg/kg. Clearly there has been no significant change in PAH sediment quality over the past eight years at this location (RM 13.2). This may be due to the fact that the sediment at this station is impounded by the Lowellville lowhead dam, and does not have the ability to naturally flush itself. It may also indicate that contaminated sediment from upstream sites are being continually moved into the impounded area at RM 13.2.

- These long term data for heavy metals and PAH compounds indicate that, contrary to the opinion of the 1976 Havens and Emerson report, long term flushing and bacterial decomposition of the river sediment has not resulted in any significant improvement in the lower Mahoning River. Potential reasons for lack of improvement include the impoundment of sediment behind low head dams, and continued discharge of heavy metals via point sources, urban runoff, and spills. Sediment resuspension during elevated stream flows and subsequent deposition may also help to maintain a constant downstream loading of heavy metals and PAH compounds into Pennsylvania.

Table 17. Historical concentrations of heavy metals in sediments of the Lower Mahoning River Basin study area, 1975 to 1994, Sampling in 1975 was conducted by U.S. EPA, all other samples by Ohio EPA. All parameter concentrations, excluding nickel, were ranked based on a stream sediment classification system described by Kelly and Hite (1984). Underlined values exceed the severe effects level (based on sediment bioassay toxicity) established in the "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (1993, 1994).

River Mile- (Date)	Sediment Concentration (mg/kg dry weight) As	Cu	Cd	Cr	Fe	Pb	Ni	Zn	Hg
Mahoning River Mainstem									
RM 45.5 (upstream Leavitts Road bridge, below dam)									
(1975)	3.0 [a]	6 [a]	K1.0	15 [a]	7800 [a]	15 [a]	50	36 [a]	K0.10
(1980)	K18	14 [a]	0.2 [a]	*28 [c]*	11700 [a]	*79 [c]*	47	65 [a]	0.04 [a]
(1983)	*14.6 [c]*	K10	0.2 [a]	8 [a]	7870 [a]	*47* b	10	65 [a]	--
(1986)	3.2 [a]	6 [a]	0.09 [a]	10 [a]	7530 [a]	20 [a]	12	36 [a]	--
(1994)	7.7 [a]	6 [a]	0.15 [a]	13 [a]	9810 [a]	*41* b	18	46 [a]	--
RM 29.98 (near Belmont Road bridge)									
(1975)	*13.0 [c]*	**330 [e]**	**4.0 [d]**	**370 [e]**	**200000 [e]**	**670 [e]**	360	**1990 [e]**	**0.20 [d]**
(1994)	**21.1 [d]**	**171 [d]**	**2.7 [d]**	**232 [e]**	**134000 [e]**	**400 [e]**	161	**2510 [e]**	--
RMs 21.7 to 22.4 (upstream Mill Creek confluence)									
(1975)	**26 [d]**	**115 [d]**	**3.0 [d]**	*23 [c]*	**410000 [e]**	**290 [e]**	50	**530 [e]**	K0.10
(1980)	*10.5* [d]	**130 [d]**	0.3 [a]	**89 [e]**	**79500 [e]**	**232 [e]**	58	**530 [e]**	*0.14 [c]*
(1983)	**42.6 [e]**	**350 [e]**	**7.0 [d]**	**570 [e]**	**119000 [e]**	**1060 [e]**	300	**7390 [e]**	--
(1986)	**17.7 [d]**	**315 [e]**	**5.0 [d]**	**240 [e]**	**182000 [e]**	**590 [e]**	119	**1970 [e]**	--
(1994)	**60.1 [e]**	**416 [e]**	*3.8 [c]*	**174 [e]**	**326000 [e]**	**629 [e]**	231	**1060 [e]**	
RM 15.5 (St. Rt. 616, dwst dam in 1994)									
(1975)	*14 [c]*	**190 [d]**	**4.0** [d]	**220 [e]**	**190000 [e]**	**640 [e]**	190	**1240 [e]**	**0.20** [d]
(1994)	*15 [c]*	*99 [c]*	0.86	**125 [e]**	**131000 [e]**	**1450 [e]**	45	**432 [e]**	--
RM 13.2 (RR bridge, dwst Struthers WWTP)									
(1980)	*14.5 [c]*	**196 [d]**	**2.5 [d]**	**167 [e]**	**103000 [e]**	**617 [e]**	92	**2520 [e]**	**0.80[e]**
(1983)	**20.7 [d]**	**455 [e]**	**8.3 [d]**	**520 [e]**	**56900 [e]**	**471 [e]**	190	**4830 [e]**	--
(1986)	*13.0 [c]*	**166 [d]**	*1.7 [c]*	**166 [e]**	**86100 [e]**	**256 [e]**	66	**1370 [e]**	--
(1994)	**23.8 [d]**	**282 [e]**	**3.8 [d]**	**452 [e]**	**139000 [e]**	**667 [e]**	198	**2880 [e]**	--
RM 1.5 (State Rt. 108 in Penna.)									
(1975)	*14.0* c	**255 [e]**	**6.0 [e]**	**150 [e]**	**230000 [e]**	**690 [e]**	200	**2900 [e]**	**0.50 [e]**
(1980)	**25.9 [d]**	**440 [e]**	**3.7 [d]**	**672 [e]**	**94800 [e]**	**590 [e]**	138	**3020 [e]**	**1.19 [e]**
(1983)	**16.8 [d]**	**195 [d]**	**3.1 [d]**	**190 [e]**	**62100 [e]**	**505 [e]**	130	**2400 [e]**	--
(1994)	**22.3 [d]**	**140** [d]	*1.8 [c]*	**112 [e]**	**158000 [e]**	**214 [e]**	103	**933 [e]**	--

[a] Non-elevated. *[b] Slightly elevated.* *[c] Elevated.* **[d] Highly elevated.** **[e] Extremely elevated.**
(__) Underlined values indicate Ontario "severe effect. (-) indicates paramater was not analyzed. (K) indicates below laboratory detection limit.

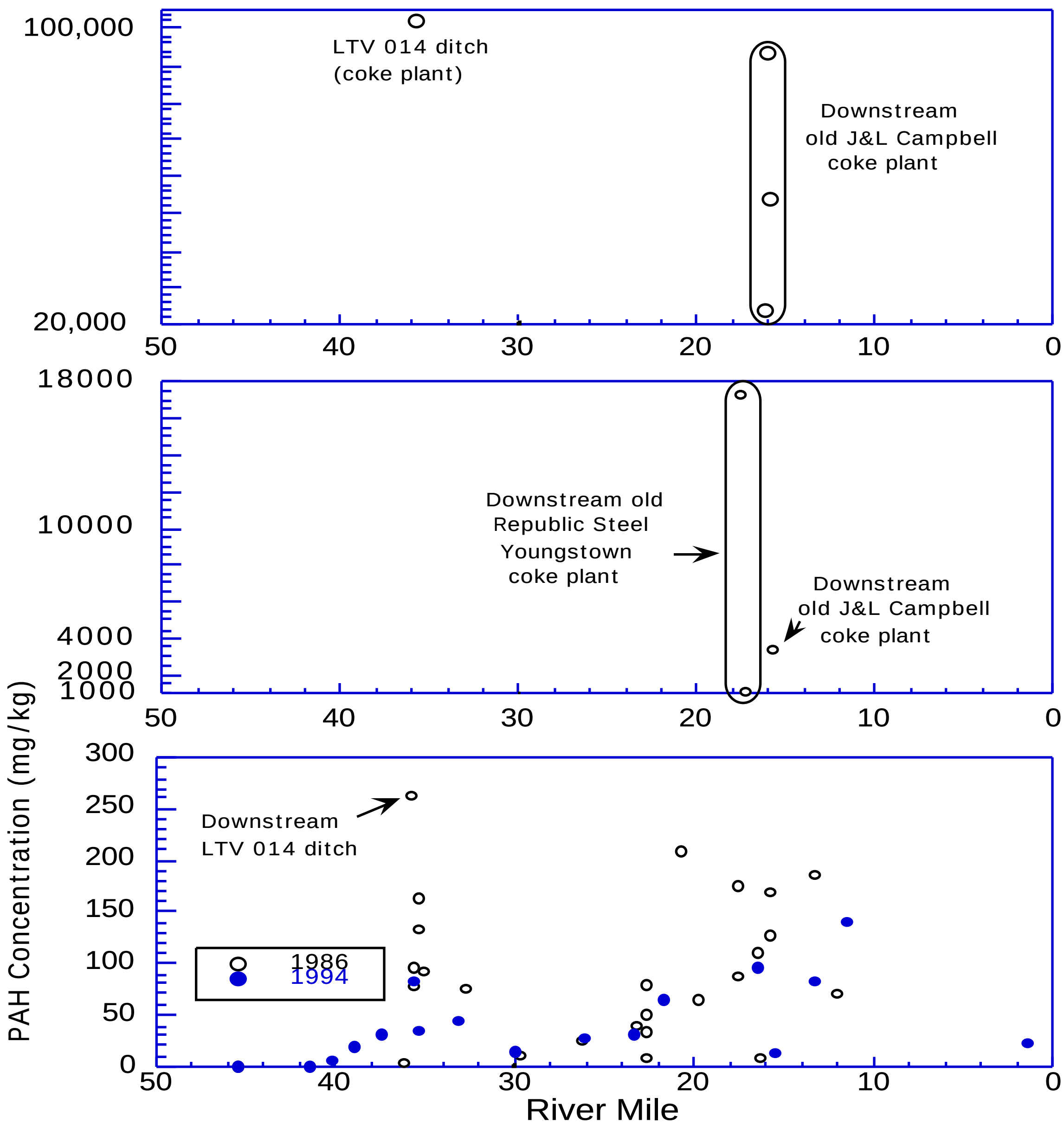


Figure 70. Longitudinal trend data for PAH sediments in the lower Mahoning River from 1986 to 1994. Extremely high values from 1986 were collected close to coking operation discharge points, otherwise the data from both years appeared similar.

Biological and Aquatic Life Use Attainment Trends (Figures 71-75; Table 18)

Upper Mahoning River

- Prior to 1994, no intensive biological survey of the upper Mahoning River mainstem was conducted by the Ohio EPA . Biological and chemical sampling was conducted at RM 93.3/92.6 in 1983/1984 in conjunction with the Ohio Stream Regionalization Project and again in the 1994 survey. There was no significant difference in biological water quality (full WWH attainment) indicated between these time periods.

Lower Mahoning River

- Unlike most of Ohio's larger streams, the 1994 survey results show only slight improvement in the WWH aquatic life use attainment status of the lower half of the Mahoning River mainstem during the past 14 years (Table 18). Since 1980, the number of miles in full attainment increased to only 0.3, the number in partial attainment increased from 1.8 to 5.8 while the number of miles in non-attainment decreased from 45.2 to 41.3. The number of miles of poor to very poor quality has remained unchanged (i.e., 38.2 in 1980 and 38.2 in 1994).

- Although fish assemblages remain severely impacted at many locations, some improvements have occurred during the 14 year period. Since 1980, ADV per mile values decreased from 179.5 to 126.5 for the IBI and 237.0 to 105.3 for the MIwb (Table 18). Longitudinal plots of both indices in the lower half show similar trends with the greater improvement shown by the MIwb due to increases in the densities and biomass of fish in the lower half of the Mahoning River (Figure 71). Comparison of the 1980 and 1994 total cumulative catches from the lower half of the Mahoning Rivers shows improvement (*i.e.,* increases) in the total mean relative number of fish from 62.5/km in 1980 to 318/km in 1994, total mean relative weight of fish from 8.7 to 81.2 kg/km, and total cumulative number of fish species from 41 in 1980 to 51 species in 1994. Thirty five (35) species were collected during both surveys; 16 species were collected only in 1994 (muskellunge, black redhorse, blacknose dace, emerald shiner, silver shiner, rosyface shiner, spotfin shiner, sand shiner, blackstripe topminnow, brook silverside, white bass, white perch, spotted bass, warmouth, fantail darter, and mottled sculpin); and six (6) species were collected only in 1980 (central mudminnow, spottail shiner, black bullhead, eastern banded killifish, redear sunfish, and blackside darter). Overall, the changes in species composition represents a positive change from highly tolerant species to less tolerant or more pollution sensitive species. The mean relative number of smallmouth bass increased from 1.3/km in 1980 to 8.7/km in 1994. Smallmouth bass were only collected at six out of 21 sites (28.6%) in 1980 compared to 15 out of 30 locations (50%) in 1994.

- Longitudinal plots of the relative number (#/km) and weight (kg/km) of fish and cumulative number of fish species collected during 1980 and 1994 are shown in Figure 72. Results from individual sites show the mean relative number of fish captured (#/km) has increased from 10 fish/km in 1980 to 109/km in 1994 downstream from the Niles WWTP (RM 28.5), from 36 to 246/km at SR 616 (RM 15.6), from 14 to 547/km downstream from the Lowellville dam (RM 12.5), and from 11 to 253/km near US 224 in Pennsylvania (RM 7.1). The weight of fish collected has similarly increased from 0.02 to 30.5 kg/km downstream from the Niles WWTP (RM 28.5), from 1.3 to 85.8 kg per km at SR 616 (RM 15.6), from 2.0 to 105.0 downstream from the Lowellville dam (RM 12.5), and from 0.8 to 65.9 kg/km near US 224 in Pennsylvania (RM 7.1). The cumulative number of fish species has increased from four (4) to 14 species downstream from the Niles WWTP (RM 28.5), from 14 to 20 species downstream from the Liberty Street dam (RM 26.2), from four (4) to 24 species near US 224 in Pennsylvania (RM 7.1), and from 12 to 26 species upstream from the New Castle WWTP (RM 1.1).

- Figure 73 is a comparison of temporal IBI and MIwb trends at four mainstem locations sampled between 1980 and 1994.

- In most of the recent surveys throughout Ohio, fish indices have larger ADV values than the macroinvertebrate ICI. It appears that for certain types of pollutional impacts, it may take longer for fish species to recolonize and to build up biomass and numbers as reflected in the IBI and MIwb indices than it does for macroinvertebrates as reflected in the ICI index. This seems to be true of the Mill Creek basin discussed below. However, ICI values from the 1994 lower Mahoning River survey showed a higher ADV than the fish indices. This may suggest a toxic impact associated with bottom sediments in the lower Mahoning River.

- The only macroinvertebrate station sampled by the Ohio EPA in the lower Mahoning River prior to the 1990s was at RM 12.4 in Lowellville. The ICI increased from 0 (very poor) in 1979 and 1982 to 8 (poor) in 1994.

Eagle Creek and Silver Creek

- Fish results from Eagle Creek RM 0.8 show declines in MIwb (7.8 to 7.2) and IBI (31 to 23) scores, but a slight increase in the mean number of species (17.3 to 18.5). The attainment status has remained as non-attainment at RM 0.8 (an impounded section), although the macroinvertebrate community showed attainment upstream from this station in a free flowing section of Eagle Creek (RM 6.6) in 1994.

- In the headwaters of Eagle Creek, the IBI in Silver Creek at the fish reference site (RM 0.8) declined slightly (48 to 44), but the relative number and mean number of fish species has remained similar (2084 to 2,336 fish per 0.3 km and 16 to 15 fish species). Macroinvertebrates were sampled twice in 1981 at RM 0.8 and once in 1994 at RM 0.9. All three samples had 9 to 11 EPT taxa in the qualitative samples and QCTV scores between 36.3 and 39.1, indicating good community condition during both time periods. The attainment status has remained full.

Mosquito Creek

- Fish results from RM 1.0 in 1994 were similar to the 1980 results at RM 1.4 except for the IBI which declined from 28 to 21. The MIwb score remained 5.1 and the mean number of species was 15.0 in 1980 and 14.0 in 1994. An improvement in macroinvertebrate community performance was observed at the mouth of Mosquito Creek (RM 0.6) from poor in 1983 (ICI=6) to marginally good in 1994 (ICI=30). The attainment status at RM 1.0/0.6 has remained as non-attainment due to the poor quality fish community.

Meander Creek

- Fish assemblages in the lower two miles of Meander Creek have remained poor to very poor quality since 1980. In 1980, sampling at RM 0.3 yielded mean values of 3.3 fish species and MIwb and IBI scores of 1.8 and 17, respectively. Fish sampling in 1994 yielded 6.5 to 9.0 species and MIwb and IBI scores of 2.7 to 3.3 and 20 to 21, respectively. The attainment status has remained as non-attainment.

Mill Creek and Tributaries

- Biological results from Mill Creek have shown significant improvement in the macroinvertebrate communities between 1982 and 1994. ICI scores increased from 22 to 28 at RM 11.2/11.3, from 0 to 12 at RM 7.8, from 0 to 40 at RM 2.6/2.7, and from 6 to 24 at the mouth (Figure 74). The improvement observed at RM 2.6/2.7 was only the second time in Ohio EPA sampling history that an increase of 40 ICI units has been documented. The miles in non-attainment, however, has remained consistent (11.3) due to the poor quality fish community. The miles in poor or very poor status has only decreased from 10.6 to 9.9. Macroinvertebrate assemblages have improved more than the fish (Figure 74). From 1982 to 1994, the ICI ADV value has decreased from 255.0 to 59.4, the MIwb ADV from 271.4 to 201.3, and the IBI ADV from 172.9 to 154.3 (Table 18, Figure 74). The number of fish species downstream from the Mahoning Co. Boardman WWTP (RMs 9.5 to 7.7) has improved from 1.0 - 3.7 species in 1982 to 7.0 - 8.5 in 1994.

- Similar to the mainstem of Mill Creek and also indicative of watershed wide impairment/impacts, biological assemblages in the headwater tributaries have also showed no significant change in aquatic life use attainment status. Only fair macroinvertebrate assemblages were found in all of the tributaries except Indian Run which supported a marginally good community.

- Bears Den Run near the mouth (RM 0.1) supported only one fish species, creek chubs, in 1982 and 1994. Since 1982, the relative number of chubs increased from 2 to 40 resulting in a change in the IBI from 12 to 20. Although macroinvertebrate taxa richness increased from nine to 30 from 1982 to 1994, EPT taxa (3 and 5, respectively) and QCTV scores (35.5 and 34.2, respectively) remained low.

- The IBI in Ax Factory Run increased slightly (24 to 30) between 1982 and 1994, but remained below the WWH biocriterion. The mean number of fish species collected also changed from five to eight species. Macroinvertebrate communities remained about the same between 1982 and 1994 with similar total taxa (20 and 21), EPT taxa (6 and 5), and the same QCTV score of 34.8; all reflected fair quality communities.

- The IBI at RM 0.2 in Anderson Run has remained similar (19 and 20) since 1982, however, the mean number of fish species declined from 7.0 to 5.0 in 1994. Macroinvertebrate communities were considered fair in 1982 and 1994 with only five EPT taxa collected each year and relatively low QCTV scores (31.0 and 35.6, respectively).

- Macroinvertebrates were evaluated as good at Indian Run RM 1.8 in 1982 and marginally good at Indian Run RM 0.3 in 1994. Although the 1994 data had relatively high total taxa (50) and QCTV score (39.7), there were only six EPT taxa collected compared to nine EPT taxa in 1982. The fish community in Indian Run appeared to have improved slightly since 1982. The IBI increased from 19 in 1982 to 24 in 1994. Other changes included increases in the mean number of fish species (8 to 12), and density (189 to 464 fish per 0.3 km). The attainment status at RM 1.0/0.6 has remained as **NON** attainment due to the poor quality fish community

Beaver River

- Fish assemblages in the Beaver River improved slightly from 1980 to 1994, but remained below WWH biocriteria. ADV values for the MIwb and IBI showed similar decreases from 186.5 to 68.8 and 125.8 to 88.5, respectively. Macroinvertebrate assemblages were not sampled in 1980, but were achieving the ICI WWH biocriterion in 1994. Based on the macroinvertebrate results and improvement of the fish community from very poor quality in 1980 to fair quality in 1994, the WWH attainment status throughout the 4.9 mile segment has improved from non to partial. The mean number of fish species has increased from 7 - 14 species in 1980 to 20 - 22 species in 1994.

Shenango River

- The lower two miles of the Shenango River has improved more than any other stream in the study area. The aquatic life use attainment status has improved from non-attainment in 1980 to FULL attainment in 1994. The mean number of fish species collected has improved from 12 -15 in 1984 to 18.5 -26.5 in 1994.

Yankee Creek

- Fish assemblages in Yankee Creek downstream from the Brookfield WWTP (RM 0.3) have improved since 1984. The mean IBI and MIwb values increased from 18 to 37 and 5.4 to 6.8, respectively, and the mean number of fish species has increased from 7.5 in 1984 to 18.5 in 1994. Fish results upstream from the WWTP have remained similar. This is in contrast to the macroinvertebrate results in which upstream conditions improved from fair in 1984 to good in 1994 with increased numbers of total taxa (22 to 40) and EPT taxa (6to 12). Macroinvertebrate communities collected downstream from the Brookfield WWTP were evaluated as poor in both years with low numbers of total taxa (13 and 11) and low EPT taxa (1 and 0). These results have changed the upstream site at RM 0.6/1.2 to partial attainment while the downstream site remains in non-attainment due to the poor quality macroinvertebrate community.

Little Yankee Creek

- Fish and macroinvertebrate assemblages in Little Yankee Creek have markedly improved downstream from the Hubbard WWTP since 1984. Mean MIwb and IBI values have increased from 1.5 to 6.7 and 13 to 26 at RM 4.4 immediately downstream from the WWTP (Figure 75). The mean number of fish species has similarly increased from 3.5 in 1984 to 16.5. In 1984, there was no site between the Hubbard WWTP and the mouth (RM 0.2) where the macroinvertebrate community performance met ecoregional expectations. In 1994 at RM 1.6, the ICI was 38 which exceeded the macroinvertebrate criterion and indicated recovery. The attainment status at RM 2.0/1.6 (partial) and RM 4.9 (non) was due to the fair/poor quality fish communities at these sites. Impacts from upstream may be the predominant reason for the continued non-attainment at most locations.

Little Deer Creek

- For both sample passes in 1994, the IBI scored slightly below the mean 1984 score of 37. The first catch yielded an IBI of 36 and the second sample (post channel modification) scored a 34. Metrics with scores strongly deviating from the expected (i.e., scored a “1”) included the number of headwater species, percentages of tolerant fishes, omnivores, and insectivores, and relative number of non-tolerant fishes. The IBI decline caused the status of the fish community to change from a nonsignificant departure of the headwater criteria in 1984 to non-attainment in 1994. During the same period, the mean number of fish species increased slightly from 16.0 to 17.5.

Pymatuning Creek

- Little historical biological water quality data has been collected by Ohio EPA for Pymatuning Creek. The vast majority of sampling prior to the present study occurred in 1983-84 for the ecoregion studies project. There was no change in use attainment status at two Pymatuning Creek stations sampled in 1983 and 1994. Fish index scores at U.S. Route 6 (RM 24.3/24.7) declined from 1983 (IBI = 31, MIwb = 5.2) to 1994 (IBI = 23, MIwb = 4.4) and showed non-attainment both years. The macroinvertebrate index score exceeded ecoregional expectations at Underwood Road (RM 22.7), but declined from an ICI of 42 (1983) to 36 (1994).

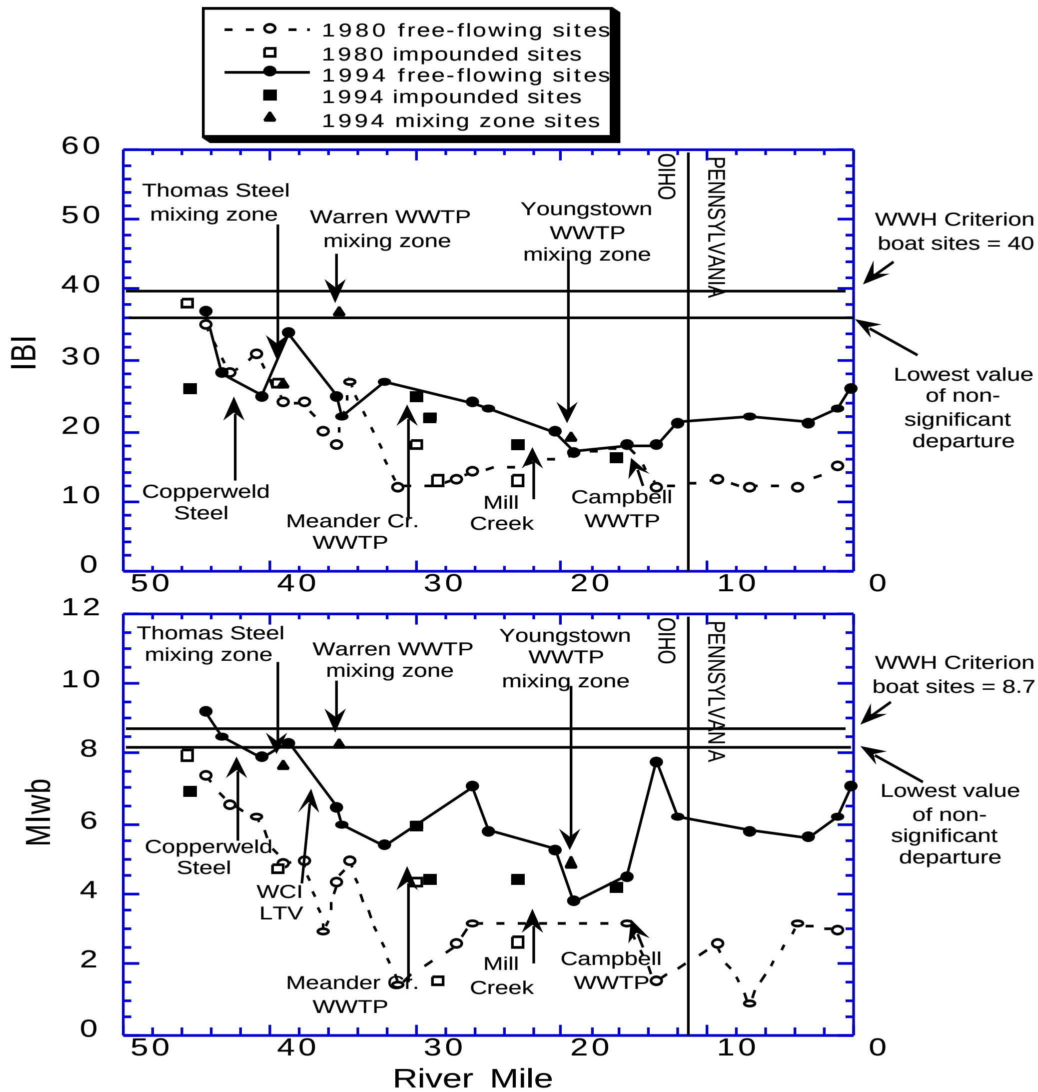


Figure 71. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the lower half of the Mahoning River, 1980 and 1994.

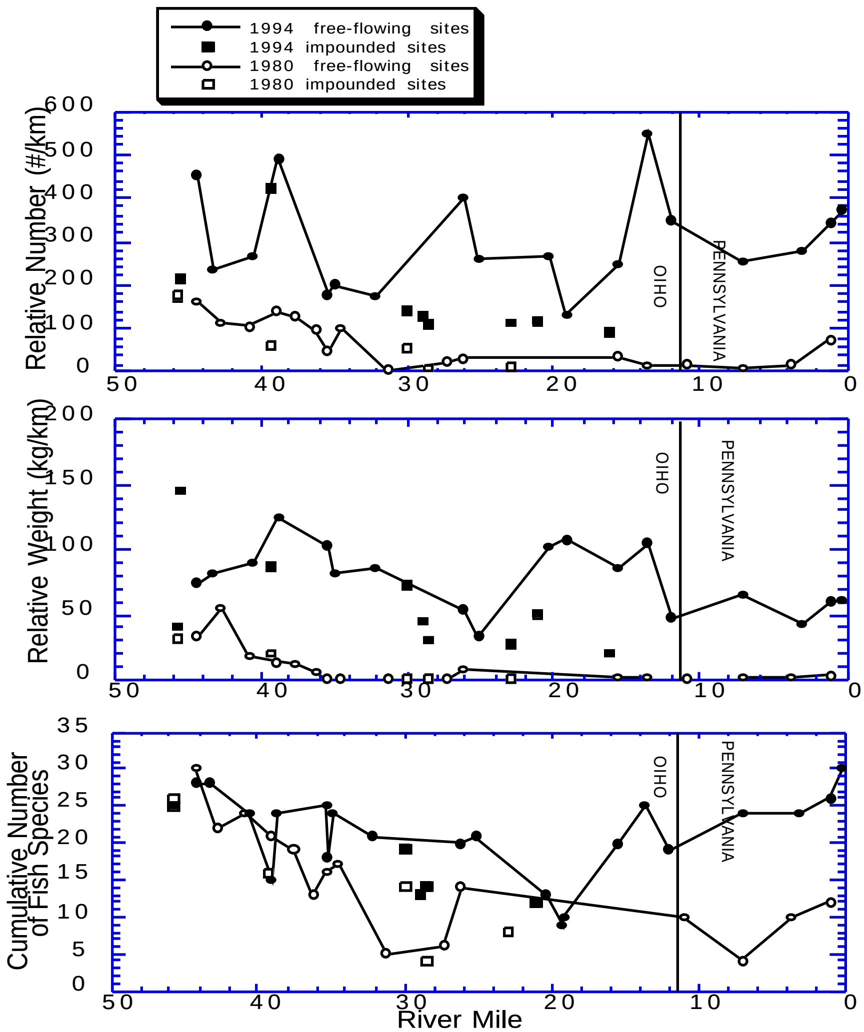


Figure 72. Longitudinal fish community trends of the relative number (Top Graph), relative weight (Middle Graph), and the cumulative number of fish species (Bottom Graph) collected at sampling locations in the lower half of theMahoning River, 1980 and 1994.

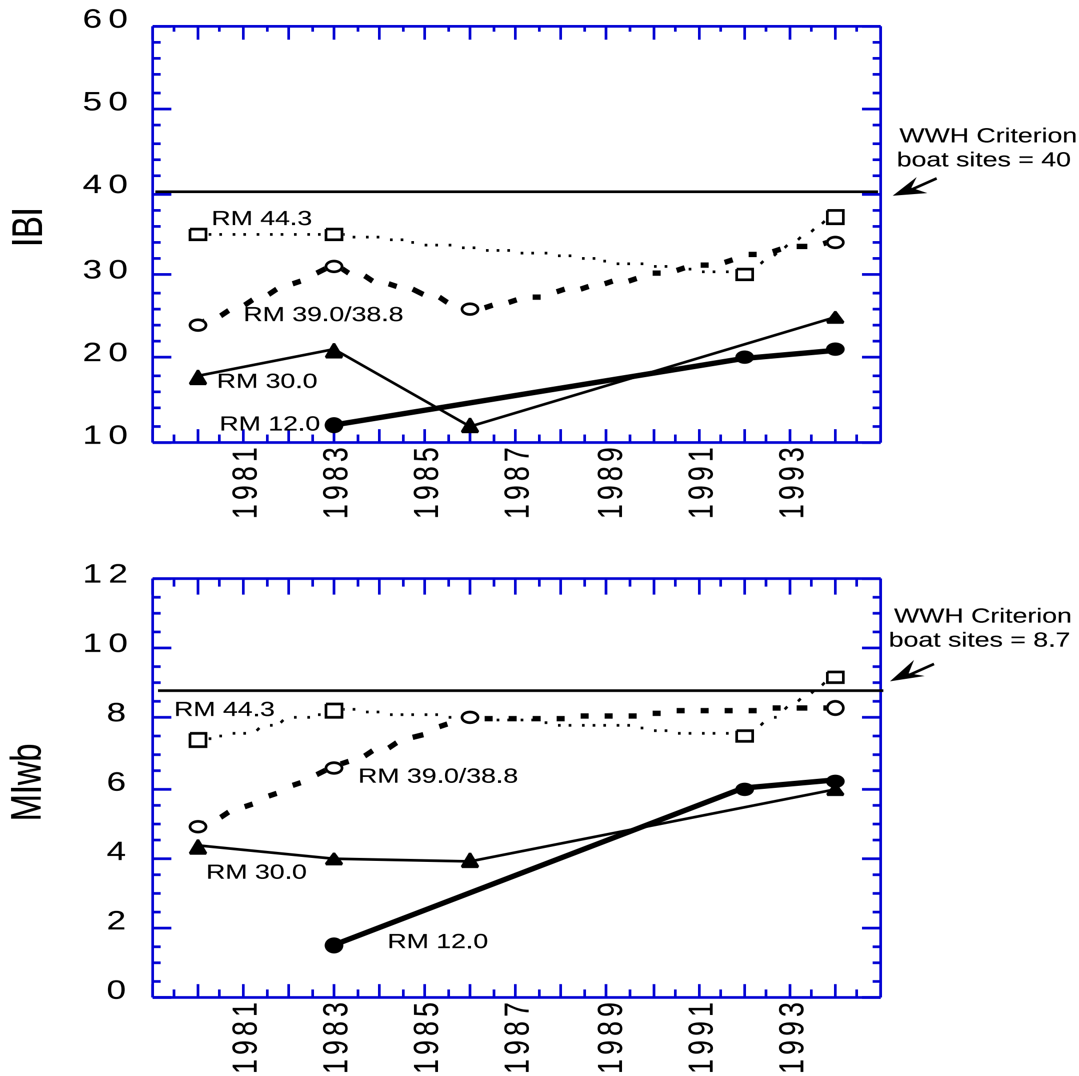


Figure 73. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in the lower half of the Mahoning River downstream from Leavittsburg (RM 44.3), Perkins Park in Warren (RM 39.0-38.8), Belmont Avenue (RM 30.0), and downstream from Lowellville (RM 12.0) 1980 and 1994.

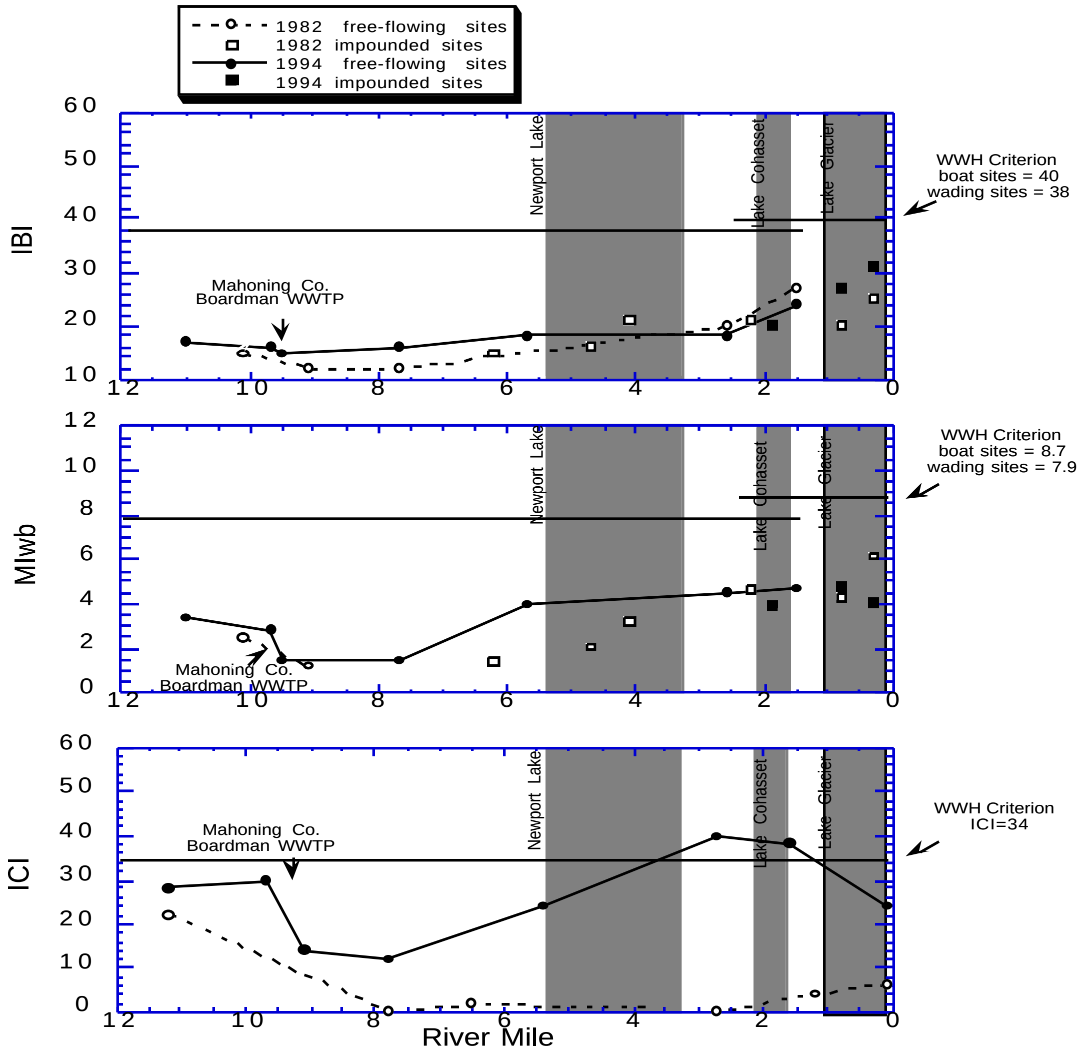
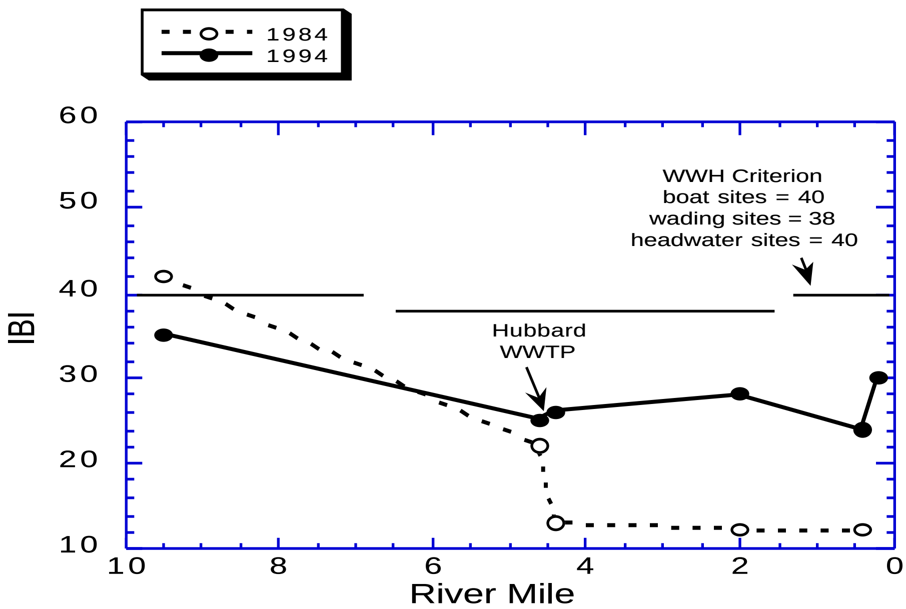


Figure 74. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph), the Modified Indexof Well-Being (MIwb; Middle Graph), and the Invertebrate Community Index (ICI; Bottom Graph) in Mill Creek, 1982 and 1994.



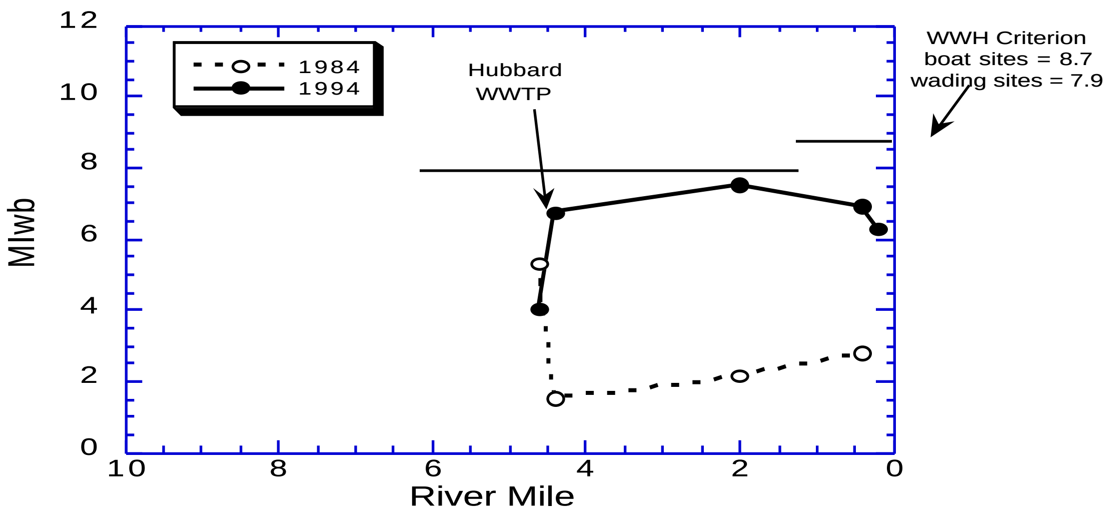


Figure 75. Longitudinal trends of the Index of Biotic Integrity (IBI; Top Graph) and the Modified Index of Well-Being (MIwb; Bottom Graph) in Little Yankee Creek, 1984 and 1994.

Table 18. Comparison of 1994 and 1980 Area of Degradation (ADV) statistics for the Mahoning River mainstem and selected tributaries in the study area (calculated using the ecoregion biocriterion as the background community performance).

Stream Index	Upper RM	Lower RM	Mini-mum	Maxi-mum	ADV	**ADV/ Mile**	P-VP ADV	Miles FULL	PARTIAL	NON	Poor-VP
Lower Mahoning River (1994)											
IBI			17	37	5,985	**126.5**	1,232				
MIwb	47.5	0.2	3.8	9.2	4,980	**105.3**	288	0.3	5.8	41.3	38.1
ICI			4	38	7,550	**159.6**	1,008				
Lower Mahoning River (1980)											
IBI			12	38	8,330	**179.5**	3,733				
MIwb	47.5	1.1	0.9	7.9	10,995	**237.0**	1,361	0.0	1.8	45.2	38.2
ICI			-	-	-	-	-				
Mill Creek (1994)											
IBI			15	31	1,713	**154.3**	917				
MIwb	11.2	0.1	1.5	5.6	2,235	**201.3**	263	0.0	0.0	11.3	9.9
ICI			12	40	659	**59.4**	0				
Mill Creek (1982)											
IBI			12	27	1,937	**172.9**	876				
MIwb	11.3	0.1	0.0	6.2	3,040	**271.4**	414	0.0	0.0	11.3	10.6
ICI			0	22	2,856	**255.0**	906				
Beaver River (1994)											
IBI			26	30	425	**88.5**	0				
MIwb	20.1	15.3	6.6	7.2	330	**68.8**	0	0.0	4.9	0.0	0.0
ICI			38	38	0	**0.0**	0				
Beaver River (1980)											
IBI			20	26	604	**125.8**	72				
MIwb	20.1	15.3	4.0	5.5	895	**186.5**	86	0.0	0.0	4.9	4.2
ICI			-	-	-	-	-				
Shenango River (1994)											
IBI			37	42	0	**0**	0				
MIwb	2.7	0.7	8.3	8.8	0	**0**	0	2.1	0.0	0.0	0.0
ICI			36	36	0	**0**	0				
Shenango River (1980)											
IBI			24	30	186	**97.9**	2				
MIwb	2.6	0.7	4.8	6.7	250	**131.6**	12	0.0	0.0	2.1	0.5
ICI			-	-	-	-	-				

References

Akerboum, T.P.M. And H. Sies. 1981. Assay of glutathione, glutathione disulfide and glutathione mixed disulfides in biological samples. In W. Jakoby ed., Methods in Enzymology Vol. 77, Academic Press, New York. pp. 373-382.

Cross, W. P. 1967. Drainage areas of Ohio streams (supplement to Gazetteer of Ohio streams). ODNR, Div. Water, Ohio Water Plan Inventory Rpt. No. 12a.

Cummings, K. S. and C. A. Mayer 1992. Field guide to freshwater mussels of the midwest. Manual 5, Illinois Nat. History Survey, Champaign Il.

DeShon, J. E. 1995. Development and application of the Invertebrate Community (ICI). *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor. (in press).

Durrell, L. M. and R. H. Durrell. 1979. Today's Landscape. Pages 48-57 *in* M. B. Lafferty, editor-in-chief. Ohio's natural heritage. The Ohio Academy of Science, Columbus, OH.

Eagleson, K. W., D. L. Lenat, L. W. Ausley, and F. B. Winborne. 1990. Comparison of measured instream biological responses with responses predicted using the *Ceriodaphniadubia* chronic toxicity test. In: Env. Toxicology and Chemistry, 9:1019-1028.

Estenik, J. 1988. Fish tissue and sediment organic chemical evaluation Lower Mahoning River.

Fausch, D.O., Karr, J.R. and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River. Tech. Report No. 86. Purdue University, Water Resources Research Center, West Lafayette, IN. 73 p.

____ A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. pp. 307-324. In: Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 703, J.M. Bates and C.I. Weber (eds.). Philadelphia, PA.

Goede, R.W. 1988. Fish health/condition assessment procedures. Procedures manual and color atlas of autopsy classification categories. Utah Division of Wildlife Resources.

Goldthwait, R. P. 1979. Ice over Ohio. Pages 33-47 *in* M. B. Lafferty, editor-in-chief. Ohio's natural heritage. The Ohio Academy of Science, Columbus, OH.

Hindall, S. M. 1989. Summary of fluvial-sediment studies in Ohio, through 1987. Water-Res. Inv. Rpt. 89-4066, U.S. Geological Survey, Columbus, OH.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. Env. Mgmt. 10(5): 629-635.

Johnson, D. P. and K. D. Metzker 1981. Low-flow characteristics of Ohio streams. U.S. Geological Survey & Ohio EPA, Columbus, OH.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21-27.

____ and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55-68.

____ K. D. Fausch, P. L. Angermier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5. 28 p.

____ 1991. Biological integrity: a long-neglected aspect of water resource management. Ecological Applications 1(1):66-84.

Kelly, M. H., R. L. Hite. 1984. Evaluation of Illinois stream sediment data: 1974-1980. Illinois Environmental Protection Agency, Div. of Water Pollution Control, Springfield, IL.

Krolczyk, J. C., ed. 1960. Gazetteer of Ohio streams. ODNR, Div. of Water, Ohio Water Plan Inventory Rpt. No. 12. Columbus, OH.

Lin, E.L.C., J.E. Klaunig, J.K. Mattox, C.M. Weghorst, B.H. McFarland and M.A. Pereira. 1989. Comparison of the effects of acute and subacute treatment of phenobarbital in different strains of mice. Cancer Letters 48:43-51.

Miner R. and D. Borton. 1991. Considerations in the development and implementation of biocriteria, Water Quality Standards for the 21st Century, U.S. EPA, Offc. Science and Technology, Washington, D.C., 115.

Ohio Department of Natural Resources 1983. Water pollution, fish kill, and stream litter investigations. Division of Wildlife, Pub. 7., Columbus, OH.

____ 1984. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.
____ 1985. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.
____ 1986. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.
____ 1987. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.
____ 1988. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.
____ 1989. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.
____ 1990. Water pollution, fish kill, and stream litter investigations. Div. of Wildlife, Pub. 7., Columbus, OH.

Ohio Environmental Protection Agency 1987a. Biological criteria for the protection of aquatic life: Vol. I. The role of biological data in water quality assessment. Div. of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, OH.

____ 1987b. Biological criteria for the protection of aquatic life: Vol. II. Users manual for biological field assessment of Ohio surface waters. Div. of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, OH.

____ 1989a. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Div. of Environmental Services, Columbus, OH.

____ 1989b. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Div. of Water Quality Planning and Assessment, Surface Water Section, Columbus, OH.

____ 1989c. Biological criteria for the protection of aquatic life: Vol. III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Water Quality Planning and Assessment, Columbus, OH.

____ 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, OH.

____ 1992a. State of Ohio water quality standards: Chapter 3745-1 of the administrative code. Div. of Water Quality Planning and Assessment, Columbus, OH.

Omernik, J. M. 1988. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Persaud D., J. Jaagumagi, and A. Hayton. 1994. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Toronto. 24 pp.

Pohl, J. And J.R. Fouts. 1980. A rapid method for assaying the metabolism of 7-ethoxy resorufin by microsomal subcellular fractions. Anal. Biochem. 107:150-155.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, OH.

____ and C. O. Yoder 1991 Calculation and uses of the Area of Degradation Value (ADV). Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, OH.

____ C. O. Yoder and D. Mishne 1992. Ohio water resource inventory. Vol. 1: Summary, status, and trends. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, OH.

____ 1995. Habitat indices in water resource quality assessments. *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor. (in press).

Shindel, J., H. Klingler, J. P. Mangus, and L. E. Trimble 1991. Water resources data for Ohio: water year 1990. Vol. 1, Ohio River basin excluding project data. Water-Data Report OH-90-1, Columbus, OH.

____ 1992 Water resources data for Ohio: water year 1991. Vol. 1, Ohio River basin excluding project data. Water-Data Report OH-91-1, Columbus, OH.

Simpson, K. W. 1980. Abnormalities in the tracheal gills of aquatic insects collected from streams receiving chlorinated or crude oil wastes. Freshwater Biology 10:581-583.

Stansbery, D. H. and M. B. Lafferty. 1979. Ohio waters. Pages 110-131 *in* M. B. Lafferty, editor-in-chief. Ohio's natural heritage. The Ohio Academy of Science, Columbus, OH.

Suter, G. W. 1993. A critique of ecosystem health concepts and indexes. Env. Tox. and Chem. 12:1533-1539.

Trautman, M. B. 1981. The fishes of Ohio, revised edition. Ohio State Univ. Press, Columbus, OH.

United States Department of the Interior 1968. Benthic biology Beaver River Basin, Ohio, Pennsylvania. Work Document No. 24. Federal Water Pollution Control Administration, Ohio Basin Region, Wheeling Field Station, Wheeling, West Virginia.

Yoder, C. O. 1989. The development and use of biological criteria Ohio surface waters. U. S. EPA, Criteria and Standards Div., Water Quality Stds. 21 st Century, 1989: 139-146.

____ 1991. Answering some concerns about biological criteria based on experiences in Ohio. In: Gretchin H. Flock, editor. Water quality standards for the 21st century. Proceedings of a National Conference, U. S. EPA, Office of Water, Washington, D.C.

____ 1995. Policy issues and management applications of biological criteria, *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor. (in press).

____ and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multi-metric data, *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor. (in press).

Nonpoint Source Section References

Ashtabula Soil and Water Conservation District 1995. Letter from Nathan Paskey (Manager) dated March 29, 1995. Jefferson, Ohio.

Columbiana County Health Department. Discussion with Robert Moorehead (Health Commissioner) on November 7, 1995. Lisbon, Ohio.

Columbiana Soil and Water Conservation District 1995. Letter from Mitch Cattrell (NRCS) dated March 29, 1995. Lisbon, Ohio.

Eastgate Development and Transportation Agency (EDATA) 1995. Discussion with Paul Joseph on March 6, 1995.

Mahoning County Health Department. Discussion with Christine Mc Elhaney (319 Grant Coordinator) on June 20, 1995. Youngstown, Ohio.

Natural Resources Conservation Service (Mahoning County) 1995. Letter from Gary Gray (NRCS) dated May 4, 1995. Salem, Ohio.

NEFCO 1995. Watershed Profiles/Mahoning River. Fact Sheet 32

Ohio Department of Natural Resources

____ 1960. Gazetteer of Ohio Streams.

____ 1960. Underground Water Resources-Mahoning River Basin (T-1-T-2, T-3). Ohio Water Plant Inventory.

____ 1988. ODNR Scenic Rivers Study. Discussion with Steve Roloson on September 8, 1995.

____ 1993. Ohio Nonpoint Source Management Program. Ohio EPA and ODNR

Ohio EPA

____ 1984. Lower Mahoning Basin WQTSD.

____

____ 1995. Storm Water Management or Construction Sites Requirements of the General Storm Water NPDES. D. Bogoevski.

____

Portage County Health Department 1995. Discussion with Duane Porter (Environmental Supervisor) on March 8, 1995. Ravenna, Ohio.

Portage Soil and Water Conservation District. Discussion with Richard Wetzel on March 7, 1995. Ravenna, Ohio.

Stark County Health Department. Discussion with Robert Somerak (Enviromental Supervisor) on November 13, 1995. Canton, Ohio.

Stark Soil and Water Conservation District. Discussion with Andrew Bayham (NRCS) on July 6, 1995. Canton, Ohio.

Trumbull County Health Department 1995. Discussion with Steve Yovich (Environmental Supervisor) on July 3, 1995.

Trumbull Soil and Water Conservation District 1995. Discussion with John Knapp (NRCS) on July 3, 1995.

U.S. EPA

____ 1987. The Ohio Stream Regionalization Project: A Compendium of Results

____

Youngstown State University.

____ 1993. EDATA Mahoning River Corridor Study. Center for Urban Studies.

____ 1995. Discussion with Dr. Gil Peterson (Director) on March 6, 1995. Center for Urban Studies.

____ 1995. Youngstown State University. Discussion with Dr. Ann Harris (Deep Mine Geologist) on November 27, 1995.