# Biological and Water Quality Study of the Little Miami River Basin, 1998

Clark, Greene, Montgomery, Warren,
Clermont, and Hamilton Counties

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Errata

In Figures 11, 13, 15, 16, 19, 20, 22, 23, 25, 26, 28, 29, 30, and 32 the panel refering to instream ammonia-nitrogen concentrations should read mean instead of median.

In Figure 32, the y-axis for the panel refering to third quarter ammonia-nitrogen loads should read kg/day instead of mg/l.

# NOTICE TO USERS

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

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

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

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

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment 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
Columbus, Ohio 43228-3809
(614) 728-3377

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# FOREWORD

*What is a Biological and Water Quality Survey?*

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

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

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

*Hierarchy of Indicators*

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in

health,ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

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

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio 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 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 Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses.

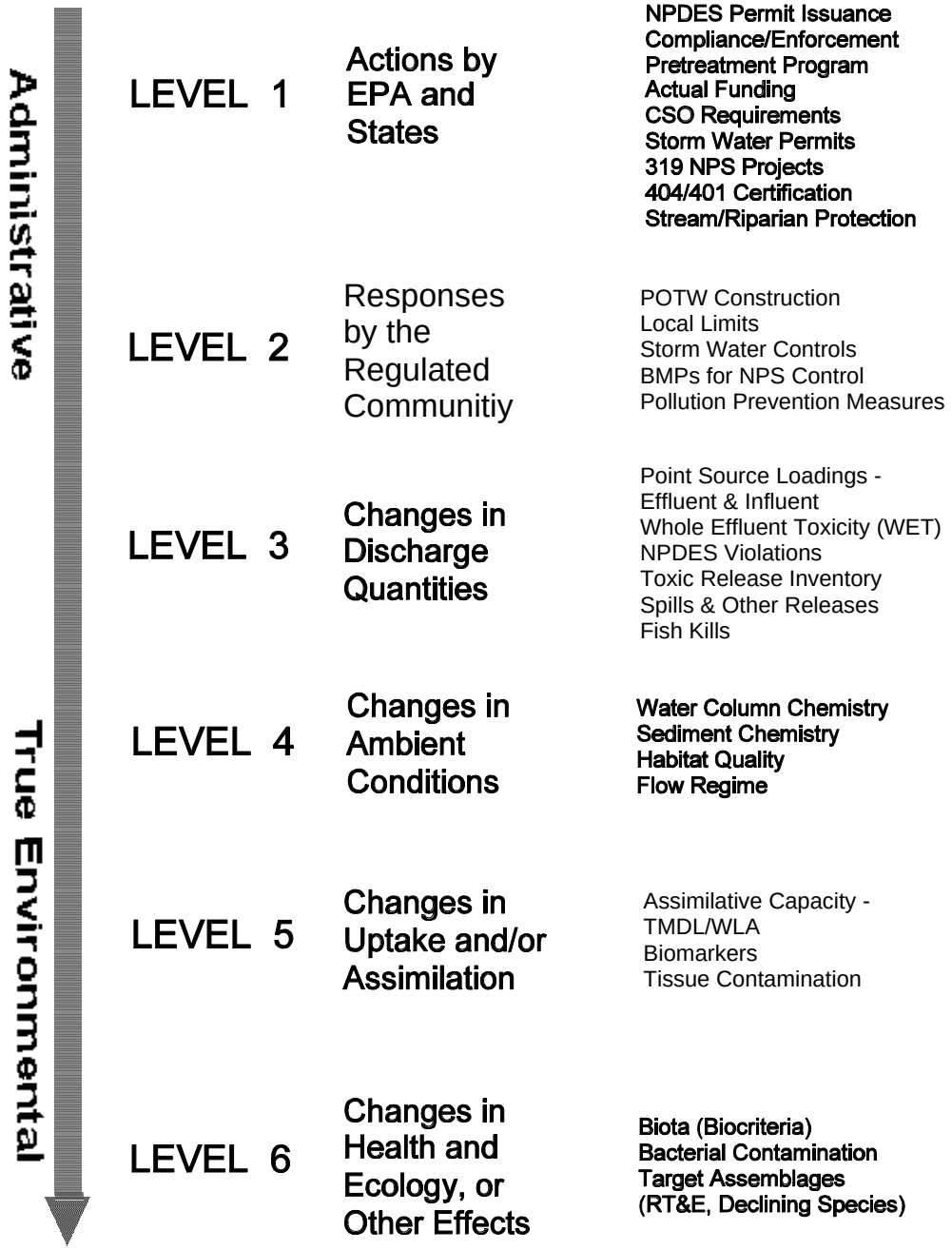



*Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995).*

The five different aquatic life uses currently defined in the Ohio WQS 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.*

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.*

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.

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.

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.

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, $NH_3$-N, 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.

# INTRODUCTION

Biological, physical, surface water and sediment samples were collected from the Little Miami River (LMR) basin in 1998. The information gathered from this survey evaluates ambient conditions, existing environmental impacts from both point source discharges and nonpoint sources of pollution, attainment of designated stream uses, and will be used, in part, to develop Water Quality Based Effluent Limits. Also, sources and causes of impairment identified in this study will help guide development of a Total Maximum Daily Load (TMDL) model for the Upper Little Miami River Basin (defined as the watershed upstream from River Mile 45.0, near Mathers Mill). The areas sampled in this survey included the Little Miami River mainstem, tributaries with major wastewater dischargers, miscellaneous tributaries in the upper LMR basin, the Todd Fork subbasin, the Beaver Creek subbasin, and Massie Creek subbasin. This report DOES NOT cover the East Fork of the Little Miami River.

Specific objectives of this study were:

1) evaluation of impacts to water quality and aquatic life from the following point source dischargers[1]:

| | |
|---|---|
| Village of South Charleston WWTP | Jamestown WWTP |
| Village of Clifton WWTP | Airborne Express |
| City of Yellow Springs WWTP | City of Wilmington WWTP |
| City of Xenia-Ford Road WWTP | City of Mason WWTP |
| Village of Cedarville WWTP | City of Lebannon WWTP |
| Montgomery Co. East Regional WWTP | Warren County Lower LMR WWTP |
| Greene County Beaver Creek WWTP | O'Bannon Creek WWTP |
| Greene County Sugar Creek WWTP | Hamilton Co. MSD Polk Run WWTP |
| City of Xenia-Glady Run WWTP | Hamilton Co. MSD Sycamore Cr. WWTP |
| Village of Waynesville WWTP | |

2) evaluate nonpoint pollution impacts in the Little Miami River headwaters, and the Massie Creek and Caesar Creek subbasins.

3) determination of attainment status of aquatic life and non-aquatic life use designations, and recommend changes where appropriate,

4) where attainment of aquatic life uses are not met, determine the causes and sources of

[1]The following dischargers were not specifically evaluted for biological and water quality impacts to receiving waters but were included in the Pollutant Loadings section: Village of Blanchester WWTP, Clermont County Miami Trails WWTP, Clermont County Wards Corners WWTP, and Totes, Inc.

impairment, and

5) comparison of results from this survey with previous surveys in 1983 and 1993 to assess changes in water quality and biological integrity.

## SUMMARY

The biological communities and water quality of the Little Miami River and its tributaries, as a whole, show relatively little change since the 1993 survey. The Beaver Creek subbasin, Lytle Creek, and the headwaters of the Little Miami River mainstem continue to be the most impaired segments, in terms of length and severity, in the entire basin (Table 1; Figures 3 and 4). A toxic impact to Little Beaver Creek by the Montgomery County East Regional WWTP was evident in the macroinvertebrate community sampled in the mixing zone, and contaminated sediments in the reach downstream from the WWTP through the old Lammars Barrel location were also a cause biological impairment. The Beaver Creek subbasin was otherwise impacted by intensive landuse and habitat modifications. Lytle Creek was severely impaired by pollutant loadings of deicing chemicals from ABX, and was further impaired by organic and nutrient enrichment from the Wilmington WWTP. Organic and nutrient enrichment from the South Charleston WWTP impacted biological communities in Gilroy Ditch and the Little Miami River mainstem upstream from Clifton. Upstream from Gilroy Ditch, Pay Gro contributed to nutrient enrichment. The Little Miami River upstream from Clifton was also impaired by habitat modifications, unfenced livestock, and lack of riparian buffers. Combined sewer overflows, collection system failures, wastewater toxicity, and urban runoff impaired the biological communities in the lower 20 miles of the Little Miami River.

Exceedences of Water Quality Standards for *Escherichia Coli* and fecal coliform bacteria were widespread throughout the basin due to the intensity of landuse throughout the basin, the fact that most of the wastewater treatment plants are either approaching design capacity or are over capacity, and for the Xenia-Glady Run, Waynesville and Warren County Lower LMR WWTPs, spills or bypasses due to collection system failures. For 19 WWTPs examined, design flow was exceeded five percent of the time at 17 plants, and 50% of the time at five plants (Table 3).

Nutrient enrichment from either wastewater loadings, livestock, sedimentation, or combinations of all three resulted in massive growths of filamentous algae in Muddy Creek, O'Bannon Creek, Lytle Creek, the North Branch of Massie Creek, Anderson Fork, and the Little Miami River upstream from Clifton. Wide diel swings in dissolved oxygen concentrations resulting from excessive algal abundance were observed in the Little Miami River mainstem from the headwaters downstream to Spring Valley (river mile 60), and in Gilroy Ditch, Massie Creek, and Caesar Creek. Nutrient enrichment, and secondarily, sedimentation were responsible for the wide-spread partial attainment of the EWH use designation for the Little Miami River downstream from Clifton, and for the EWH designated segments in the Caesar Creek subbasin.

# RECOMMENDATIONS

## Little Miami River

*Status of Aquatic Life Uses*

The Little Miami River is designated as Exceptional Warmwater Habitat (EWH) from the headwaters to river mile 3.0. Of the 103.3 EWH river miles assessed in 1998, 46.7 miles fully attained the use designation, 43.5 miles partially attained the use designation, and 13.1 miles did not attain the use designation. In 1993, all segments either fully attained (40.9 miles), or partially attained (58.2 miles) the use designation. Comparing sites sampled in common between 1998 and 1993 shows a slight decrease in overall biological performance (Figure 2, Table 2). Two factors are responsible for the difference in attainment status. First, the macroinvertebrate community did not perform as well in 1998 compared to 1993. The decrease in macroinvertebrate community performance in 1998 signals a decrease in water quality between 1993 and 1998 for the reach upstream from Yellow Springs. And second, the MIwb scores were lower in the reach between Yellow Springs and the confluence with Beaver Creek in 1998 compared to 1993.

Coincidentally, continuous oxygen monitors also recorded lower dissolved oxygen concentrations in this reach in 1998 compared to 1993. The Village of Clifton WWTP came on line subsequent to 1993, and so is an additional load to the LMR mainstem. However, upstream from Clifton, no new or expanding point source loads were added upstream. The negative effects of nutrient enrichment were evident throughout this reach, and may have been more manifest in 1998 than 1993. Wide diel swings in dissolved oxygen concentrations caused by the effects of nutrient over-enrichment were noted for this reach in 1998. So the change in biological and water quality observed in this reach does not necessarily represent a trend, so much as it represents variation due to an existing stress. For the reach receiving the highest waste water loads very little change was observed between 1993 and 1998 (Figure 2), and the gains made since 1983 through treatment plant upgrades were maintained, though the trend toward recovery of full EWH performance was no longer evident. Reduced ammonia-n loads from the Greene County Sugar Creek WWTP coincided with improved fish and macroinvertebrate communities in the reach downstream from the plant. However, nutrient enrichment, and secondarily, sedimentation were partly responsible for the continued wide-spread partial attainment of the EWH use designation. Combined sewer overflows, collection system failures, wastewater toxicity, and urban runoff impaired the biological communities in the lower 20 miles of the river, and a direct impact from either Duck Creek, CSOs or both was documented at RM 3.7. The near saturation of wastewater treatment capacity is another cap on biological performance, and will remain so until additional improvements are effected.

In short, the river as a whole has not improved since 1993, and is at risk of back-sliding from suburban development and increased wastewater loading. Reduced nutrient and sediment loads are needed for the river to fully meet EWH.

The EWH aquatic life use designation is clearly appropriate for the mainstem from the confluence with the North Fork (RM 91.64) to RM 3.0 based on habitat quality and biological community

performance in 1998 and 1993. Upstream from there, however, the poor habitat conditions and intensive agricultural landuse preclude the fish community from achieving EWH expectations. This reach was designated EWH prior to the establishment of numerical biological criteria in the Ohio WQS, and consequently was not subjected to a use attainability- use analysis as now practiced (see ***Determining Use Attainment Status*** in the **Methods** section below). Therefore, the recommended use designation for the reach upstream from the confluence with the North Fork is Warmwater Habitat (WWH). A summary of recommended use designation changes is given in Table 4.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate. The Primary Contact Recreational Use was not met at RMs 101.3, 83.14 and 80.63 due to levels of *E. coli* exceeding the Water Quality Standard in more than ten percent of the water quality samples taken within a thirty-day period.

The Little Miami River is also designated a State Scenic River from the headwaters to the Ohio River (105 mi), and a National Scenic River from Clifton to Foster, and a National Recreational River form Foster to the Ohio River (totaling 92 miles of National designation).

*Future Monitoring Concerns and Other Recommendations*

Future monitoring needs to be directed at better quantifying the scope and extent of diel oxygen variation as related to periphytic and sestonic algal abundance and composition, the fate and transport of sediments, and success of TMDL implementation measures. Sources of bacterial contamination in the reach upstream from Clifton need to be identified and addressed. The extent of impact to the mainstem from Duck Creek should be ascertained.

**Upper LMR Tributaries**

*Status of Aquatic Life Uses*

The following tributaries are fully meeting their Warmwater Habitat Aquatic Life use designation (WWH): Lisbon Fork, North Fork Little Miami River, Goose Creek, Jacoby Branch, Conner Branch, Ludlow Creek, Sugar Creek, Little Sugar Creek, Shawnee Creek, Mill Run, and Newman Run. The EWH designation is recommended for Jacoby Branch, and Newman Run. Yellow Springs Creek is meeting its EWH designation. A Coldwater Habitat Aquatic Life use designation (CWH) is recommended for Conner Branch. Gilroy Ditch is partially meeting its WWH designation.

The recommended Aquatic Life use designations for the following presently undesignated tributaries based on biological performance are: unnamed tributary to the mainstem at RM 69.85, Warmwater Habitat; unnamed tributary to the mainstem at RM 62.01, Warmwater Habitat; unnamed tributary to the mainstem at RM 60.05, Exceptional Warmwater Habitat.

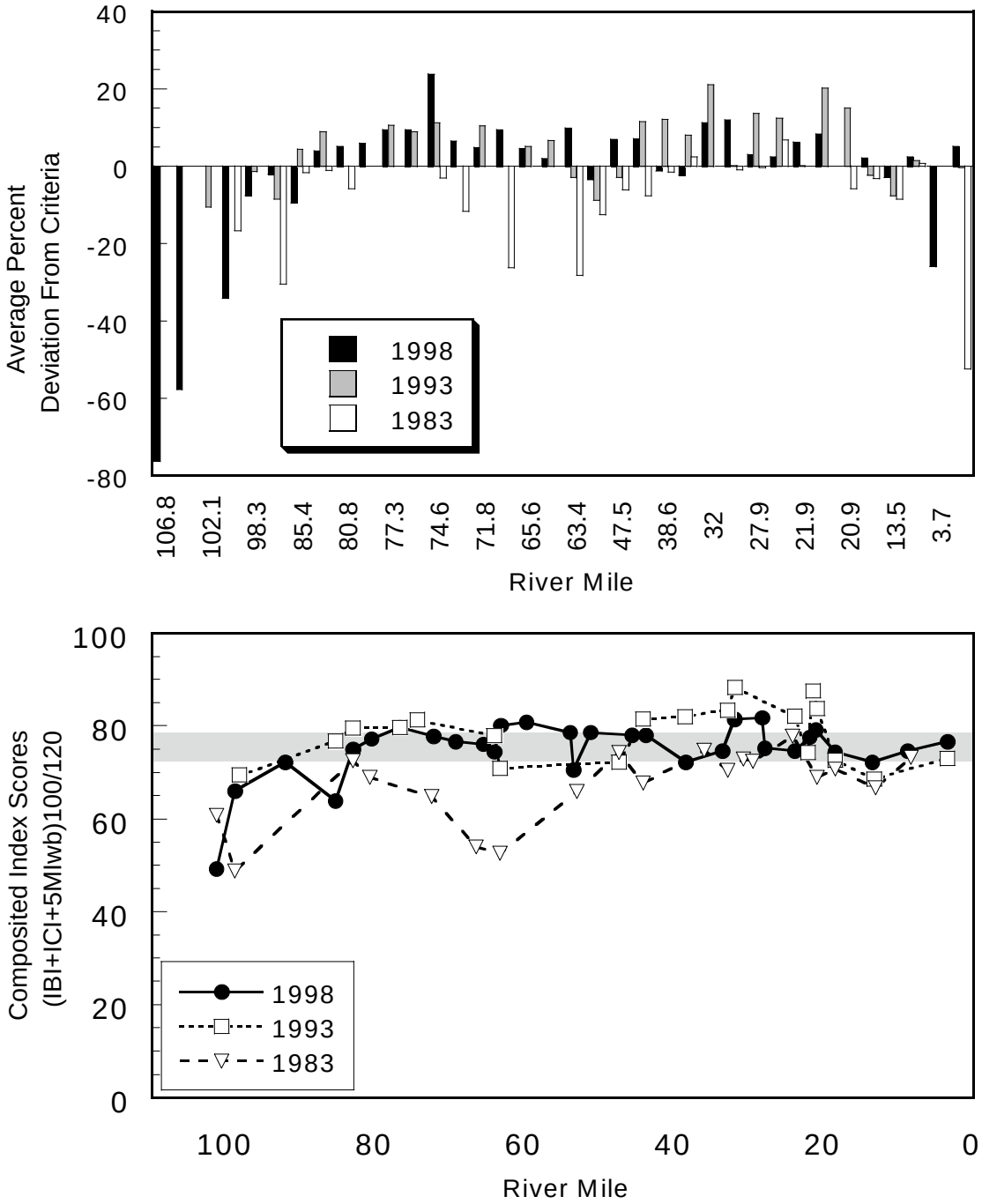



Figure 2. Average percent deviation of IBI, MIwb and ICI scores from their respective minimum EWH criterion by river mile for the Little Miami River mainstem (top - note that the x-axis is not spatially correct with respect to river mile), and composited biological index scores for 1998, 1993, and 1983 plotted by river mile.

*Status of Non-aquatic Life Uses*
Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate for all of the above mentioned tributaries. Contamination by *E. coli* in excess of the standard for Primary Contact Recreation was detected in more than ten percent of the water quality samples taken within a thirty-day period in Lisbon Fork, Goose Creek, Jacoby Branch, Newman Run and Conner Branch. The Secondary Contact Recreational use designation was met for Gilroy Ditch.

*Future Monitoring Concerns and Other Recommendations*
Suburban development on the southeast side of Dayton threatens the existing and proposed Aquatic Life use designations for all affected tributaries; therefore, further biological and water quality monitoring per the 5-year basin approach, as it relates to patterns of suburban development, is warranted.

**Massie Creek Subbasin**
*Status of Aquatic Life Uses*
The Aquatic Life use designations for all segments evaluated in the Massie Creek subbasin were fully met, except for a small portion of the North Fork that partially attained. Clark Run has an existing WWH use designation that should be upgraded to EWH. The unnamed tributary to Massie Creek at RM 5.3 should be designated EWH. Four sites were sampled in common in the 1993 and 1998 surveys; the attainment status did not change at three sites, and improved from partial to full attainment in the South Fork.

*Status of Non-aquatic Life Uses*
Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate for Massie Creek and its tributaries. The Primary Contact Recreational Use was not met for Massie Creek, Oldtown Creek and the unnammed tributary to Massie Creek at RM 5.31 due to levels of *E. coli* exceeding the Water Quality Standard in more than ten percent of the water quality samples taken within a thirty-day period.

*Future Monitoring Concerns and Other Recommendations*
Of all the tributaries to the Little Miami River, Massie Creek has the greatest potential to be restored to EWH due to its parent hydrogeology. For EWH to be realized, riparian buffers in the North and South Fork of Massie Creek need to be restored, and the Cedarville WWTP needs to be upgraded. At present, the North and South Fork are channelized and lack riparian buffers, and consequently act as sediment conduits. Sewage bypasses by the Cedarville WWTP result in bacterial contamination and are also likely acting as a cap on biological performance.

**Beaver Creek Subbasin**
*Status of Aquatic Life Uses*
Of the approximately 7.0 miles of Beaver Creek assessed, 2.1 miles fully attained, 2.7 miles partially attained, and 2.2 miles did not attain WWH. The entire length of Little Beaver Creek did

not meet WWH. These results are similar to those of 1993 with the exception that biological index scores, especially the ICI, were decidedly lower at RM 0.1 of Little Beaver Creek in 1998. The Montgomery County East Regional WWTP clearly impaired the biological communities in Little Beaver Creek from the outfall to the mouth. Additionally, sediments throughout Little Beaver Creek are contaminated by nonpoint urban pollution, particularly next to the old Lammars Barrel factory, and are another cause of biological impairment. The causes for non- and partial attainment in Beaver Creek were primarily habitat degradation and nonpoint source pollution.

The unnamed tributary to Little Beaver Creek at RM 6.1 did not meet WWH due to urban runoff.

*Status of Non-aquatic Life Uses*
Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation exist for Beaver Creek and Little Beaver Creek. The Secondary Contact Recreational use designation applies to the unnamed trib to Little Beaver Creek at RM 6.1 and is appropriate. The Primary Contact Recreational Use was not met in either Beaver Creek nor Little Beaver Creek due to levels of *E. coli* exceeding the applicable Water Quality Standards in more than ten percent of the water quality samples taken within a thirty-day period.

*Future Monitoring Concerns and Other Recommendations*
Monitoring for chronic toxicity by the Montgomery County East Regional WWTP is recommended. An approach to dealing with the contaminated sediments should be formulated.

**Glady Run**
*Status of Aquatic Life Uses*
Of the 3.7 miles of Glady Run assessed, 0.5 miles fully attained, 1.4 miles partially attained, and 1.8 miles did not attain WWH. Glady run was impaired by the Xenia-Glady Run WWTP due to organic enrichment and chronic toxicity.

*Status of Non-aquatic Life Uses*
Agricultural and Industrial Water Supply use designations are appropriate for Glady Run. Glady Run has a Secondary Contact Recreational use designation; however, this designation is not appropriate for the lower reach of Glady Run as pools greater than 1 m deep exist from Hedges Road to its confluence with the Little Miami River. As such, the reach from Hedges Road (RM 4.0) to the confluence with the Little Miami River should be designated Primary Contact Recreation.

*Future Monitoring Concerns and Other Recommendations*
The Xenia-Glady Run WWTP is currently undergoing an expansion from 2.6 MGD to 4.0 MGD, with the expansion completed by mid-2000; therefore, further biological and water quality monitoring per the 5-year basin approach is warranted.

**Caesar Creek**

*Status of Aquatic Life Uses*

Aquatic Life Use designations for Caesar Creek were based on the 1978 WQS rulemaking that lacked supporting biological and habitat information. Biological communities sampled in 1993 and 1998 indicate that EWH is the proper designation from the confluence with the Little Miami River to the confluence with the South Branch at RM 23.78. Upstream from there, WWH is the appropriate designation. Thus designated, and excluding the reservior, there are 4.1 miles of Full attainment, 5.1 miles of Partial attainment and 2.5 miles of Non-attainment. For the WWH designated reach there are 4.2 miles of Full attainment.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate. The Primary Contact Recreational Use was not met at RM 26.5 due to levels of *E. coli* exceeding the Water Quality Standard in more than ten percent of the water quality samples taken within a thirty-day period.

*Future Monitoring Concerns and Other Recommendations*

A package plant servicing Shawnee Hills is planned. The stream should be monitored following construction to document recovery or impact.

**Anderson Fork**

*Status of Aquatic Life Uses*

Anderson Fork is designated EWH from its confluence with Caesar Creek to its confluence with Grog Run. Of those 11.0 miles, 8.9 miles partially attained, and 2.1 miles did not attain EWH. Because the biological communites showed EWH potential in this reach in 1998, and at RM 5.0 in 1993, the EWH use designation is appropriate. Upstream from Grog Run, Anderson Fork is designated WWH. Of the 8.1 miles of WWH segment evaluated, 4.2 attained, 1.3 partially attained, and 2.6 miles did not attain. Sediment from nonpoint agricultural pollution was responsible for the impairment in both reaches.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate. The Primary Contact Recreational Use was not met for Anderson Fork due to levels of *E. coli* exceeding the Water Quality Standard in more than ten percent of the water quality samples taken within a thirty-day period.

*Future Monitoring Concerns and Other Recommendations*

Anderson Fork is impaired by nonpoint pollution, primarily sedimentation from bank and overland erosion. Therefore, agricultural best management practices and riparian zone reforestation are recommended. Local health departments should survey onsite sewage systems within the subwatershed to locate sources of bacterial contamination.

**North Branch Caesar Creek**

*Status of Aquatic Life Uses*

The North Branch is designated EWH. Of the approximately 7.0 miles evaluated, 3.5 miles partially attained, and 3.5 miles did not attain EWH. As all miles would fully attain WWH, and the North Branch was designated EWH under the 1978 WQS without a supporting survey, and as there are no defined causes or sources impairing the existing EWH designation, a WWH designation is appropriate and recommended.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate.

*Future Monitoring Concerns and Other Recommendations*

Biological communities in the North Branch are limited by low flow and sedimentation. Riparian reforestation would address both causes of impairment.

**South Branch Caesar Creek**

*Status of Aquatic Life Uses*

The South Branch is designated WWH. The biological community sampled at RM 2.1 met EWH criteria, however, the community sampled at RM 8.2 did not. Therefore, the South Branch should be designated EWH from its confluence with Caesar Creek to Paintersville - New Jaspar Road (RM 4.0). Of the approximately 8.5 miles evaluated, all fully attained WWH. The WWH designation is appropriate.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate.

*Future Monitoring Concerns and Other Recommendations*

An upgrade to the Jamestown WWTP is needed as the plant was responsible for fecal coliform and *E. coli* contamination in the receiving stream, the macroinvertebrate community showed signs of organic enrichment, and operational problems at the plant have been documented.

**Miscellaneous Tributaries in the Caesar Creek Subbasin**

*Status of Aquatic Life Uses*

Buck Run, Trace Run, Jonahs Run and Flat Fork are designated WWH. Those respective designations were met for Buck Run and Trace Run, partially met for Jonahs Run, and not met for Flat Fork. The reason for the respective non- and partial attainment in Flat Fork and Jonahs Run were not identified. Painters Creek is designated EWH, and although that use was narrowly met, both indicator groups were in nonsignificant departure of EWH; therefore, a WWH use designation is appropriate and recommended.

*Status of Non-aquatic Life Uses*
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate. The Primary Contact Recreational use was not met for Painters Creek, Buck Run and Trace Run due to levels of *E. coli* exceeding the Water Quality Standard in more than ten percent of the water quality samples taken within a thirty-day period.

*Future Monitoring Concerns and Other Recommendations*
As with all the headwater tributaries to Caesar Creek, riparian reforestation is needed to minimize sediment delivery and to help dampen flow extremes. Sources of bacterial contamination need to be identified.

**Todd Fork and East Fork Todd Fork**
*Status of Aquatic Life Uses*
Todd Fork was designated as Exceptional Warmwater Habitat under the 1978 Water Quality Standards, and that designation appears overly optimistic given the performance of the biological communities during this survey. Judged by EWH standards, 3.3 miles fully meet, 8.0 miles partially meet, and 9.7 do not meet the use. By WWH standards, 18.4 miles fully meet, and 2.6 partially meet the use. A WWH use designation for Todd Fork is appropriate and is recommended. Impacts to water quality and the fish community were realized in the lower 5.0 miles of Todd Fork due to excessive nutrients.

East Fork Todd Fork is undesignated. The attributes of the biological communities indicate that WWH is the appropriate use designation.

*Status of Non-aquatic Life Uses*
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation for Todd Fork are appropriate, and should be applied to East Fork Todd Fork.

*Future Monitoring Concerns and Other Recommendations*
To confirm the nutrient impacts from Lytle Creek to Todd Fork, diel concentrations of dissolved oxygen and pH should be monitored in Todd Fork during the late summer low-flow regime.

**Lytle Creek**
*Status of Aquatic Life Uses*
Biological communities sampled from Lytle Creek did not meet the existing WWH use designation at any site sampled in 1998 (approximately 10 miles). The biological communities were impaired by the Wilmington WWTP discharge, and by deicing chemicals used at the ABX airport.

*Status of Non-aquatic Life Uses*
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate. Lytle Creek was contaminated with *E. coli* in excess

of the Primary Contact Recreational Use Water Quality Standard due to, in part, to sewer collection system failure.

*Future Monitoring Concerns and Other Recommendations*
Because the fish and macroinvertebrates sampled from the Wilmington WWTP mixing zone indicated toxicity, and mortality of fathead minnows was marginally significant in a 96 h chronic toxicity test (OEPA, 7-13-98), the source and cause of the toxicity should be determined. Sewer collection system problems resulting in fecal contamination need to be fixed.

**Cowan Creek and Indian Creek**
*Status of Aquatic Life Uses*
Of the 13.5 miles evaluated in Cowan Creek, 11.8 miles fully attained, 0.9 miles partially attained, and 0.8 miles did not attain WWH. The impairment in Cowan Creek upstream from Indian Run was due to unknown causes. Downstream from Indian Run, discharge from the ABX airport may have . The site sample in Indian Run did not meet WWH due to poor habitat.

*Status of Non-aquatic Life Uses*
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate for Cowan Creek. A Secondary Contact Recreational use designation is appropriate for Indian Run. The Primary Contact Recreational Use was not met for Cowan Creek at RMs 12.45 and 10.95 due to levels of *E. coli* exceeding the Water Quality Standard in more than ten percent of the water quality samples taken within a thirty-day period.

*Future Monitoring Concerns and Other Recommendations*
A spot check in Cowan Creek (downstream from Indian Run) for presence of deicing chemicals or their by-products should be conducted during winter.

**Turtle Creek**
*Status of Aquatic Life Uses*
Biological communities sampled in Turtle Creek in the reach downstream from where Cincinnati Milacron formerly discharged improved, and fully met WWH compared to the same reach sampled in 1993, when the discharge was still active, and WWH was only partially met.

*Status of Non-aquatic Life Uses*
The existing Agricultural and Industrial Water Supply use designations are appropriate. A Secondary Contact Recreational use designation exists, and was confirmed by a past survey, though pools at least 1 m deep and of sufficient areal extent exist to warrant a Primary Contact Recreational use designation.

*Future Monitoring Concerns and Other Recommendations*
The upper reach of Turtle Creek should be resampled per the 5-year monitoring approach to assess potential impacts from the rapid development in northeast suburban Cincinnati.

**Muddy Creek**

*Status of Aquatic Life Uses*

Of the 3.5 miles of Muddy Creek assessed, the biological communities in 1.5 miles fully met, and partially met in the remaining 2.0 miles. Nonpoint urban and suburban runoff was responsible for the partial attainment upstream from the Mason WWTP, while organic and nutrient enrichment from the Mason WWTP contributed to the partial attainment downstream.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate.

*Future Monitoring Concerns and Other Recommendations*

Muddy Creek should be monitored to assess potential impacts from the rapid development in northeast suburban Cincinnati.

**Simpson Creek**

*Status of Aquatic Life Uses*

The WWH use was partially met in the lower 0.1 mile reach at the mouth of Simpson Creek, but was not met upstream from the Warren County Lower LMR WWTP discharge as the creek goes dry due to an instream impoundment.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate.

*Future Monitoring Concerns and Other Recommendations*

An overflowing sewer, which presumably feeds the Warren County Lower LMR WWTP, contaminated Simpson Creek with raw sewage on at least one date, as recorded by SWDO personnel, and caused an exceedence of the ammonia-nitrogen WQS in the Little Miami River. The condition of the collection system should be checked.

**O Bannon Creek and Stony Run**

*Status of Aquatic Life Uses*

O'Bannon Creek is designated WWH. The 2.5 miles sampled downstream from the O'Bannon Creek WWTP fully met WWH, and the 2 miles sampled upstream partially met WWH due to intermittent stream flow. The WWH designation for Stoney Creek was fully supported by biological communities.

*Status of Non-aquatic Life Uses*

The existing Agricultural and Industrial Water Supply use designations are appropriate for both O'Bannon Creek and Stoney Creek. The Secondary Contact Recreational use designation for O'Bannon Creek should be changed to a Primary Contact Recreational use designation as pools

with depths exceeding 1 meter and having areas greater than 100 $ft^2$ exist.

*Future Monitoring Concerns and Other Recommendations*
O'Bannon Creek should be resampled per the 5-year monitoring approach to assess potential impacts from the rapid development within the watershed, and to gauge the success of the recent WWTP upgrade.

**Sycamore Creek**
*Status of Aquatic Life Uses*
Biological communities sampled in Sycamore Creek upstream and downstream from the Hamilton County Sycamore Creek WWTP partially met the existing WWH use designation.

*Status of Non-aquatic Life Uses*
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreational use designation are appropriate.

*Future Monitoring Concerns and Other Recommendations*
Sycamore Creek should be monitored for impacts from continued suburban development.

Table 1. Aquatic life use attainment status for stations sampled in the Little Miami River basin July-September, 1998. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

| River Mile Fish/Invert. | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Little Miami River (11-001)** | *Eastern Corn Belt Plain EWH (existing)/WWH proposed* | | | | | |
| --/106.8 | -- | -- | P* | -- | (NON)/(NON) | Ust Pay Gro |
| 104.9 | 28* | NA | P* | 47.5 | NON/NON | Dst Pay Gro |
| 101.3/101.8 | 41* | NA | 18* | 44.5 | NON/Parital | Dst Pay Gro/ Ust GilroyDitch/NPS |
| 98.3/98.8 | 37* | 7.6* | 44ns | 54.0 | Partial/Partial | Dst Gilroy Ditch/NPS |
| | | *Eastern Corn Belt Plain EWH (existing)* | | | | |
| 92.2/92.1 | 41* | 7.8* | 50 | 67.0 | Partial | Ust Clifton WWTP/NPS |
| --/88.0 | -- | -- | G* | -- | (NON) | Dst Clifton WWTP |
| 85.4/85.3 | 38* | 7.8* | 38* | 68.0 | NON | Ust Yellow Springs Cr |
| 83.1[A] | 48 | 9.8 | 40* | 81.5 | Partial | Dst Yellow Springs Cr |
| 83.1[D] | 48ns | 9.0ns | 40* | 81.5 | Partial | Dst Yellow Springs Cr |
| 80.6[A] | 44ns | 9.2ns | 48 | 79.0 | Full | Ust Xenia Ford WWTP |
| 80.6[D] | 46ns | 9.2ns | 48 | 79.0 | Full | Ust Xenia Ford WWTP |
| --/77.1 | -- | -- | E | -- | (Full) | Ust Xenia Ford WWTP |
| *77.0* | *39* | *9.0* | *F/G* | -- | *NA* | Xenia Ford WWTP mix zone |
| 76.8/76.9 | 47ns | 9.3ns | 50 | 79.5 | Full | Dst Xenia Ford WWTP |
| --/74.6 | -- | -- | 52 | -- | (Full) | Ust Beaver Cr |
| 72.3 | 48 | 9.2ns | 46 | 82.0 | Full | Dst Beaver Cr |
| 69.3/69.9 | 47ns | 9.0* | 46 | 79.0 | Partial | Trends |
| --/66.9 | -- | -- | 46 | -- | (Full) | Trends |
| 65.6/64.5 | 43* | 8.8* | 50 | 77.0 | Partial | Ust Sugar Cr WWTP |
| *64.4* | *34* | *8.0* | *P/MG* | -- | *NA* | *Sugar Cr WWTP mix zone* |
| 64.2 | 42* | 9.2ns | 46 | 74.5 | Partial | Dst Sugar Cr WWTP |
| 63.3/63.0 | 44ns | 8.8* | 56 | 78.0 | Partial | Dst Glady Run |
| 59.8/60.9 | 44ns | 9.1ns | 56 | 77.0 | Full | Trends |
| 54.0/54.3 | 50 | 9.5ns | VG | -- | Full | Ust Waynesville WWTP |
| 53.6/53.2 | 39* | 8.8* | 44ns | 65.0 | Partial | Dst Waynesville WWTP |
| 51.2/50.7 | 46ns | 9.5ns | 48 | 85.5 | Full | Trends |
| | | | *Interior Plateau EWH (Existing)* | | | |
| 45.7/47.5 | 42* | 9.3ns | 52 | 78.5 | Partial | Trends |
| 43.8/43.9 | 46ns | 9.3ns | 48 | 82.0 | Full | Trends |
| 38.5/36.0 | 43* | 9.0* | 42ns | 81.0 | Partial | Trends |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Little Miami River (11-001)** *Interior Plateau EWH (Existing)* | | | | | | |
| 33.6/32.9 | 45[ns] | 9.1[ns] | VG | 81.0 | Full | Ust Lebanon WWTP |
| *32.1* | *44* | *8.9* | *F/MG* | -- | *NA* | *Lebanon WWTP mix zone* |
| 32.0 | 48 | 10.1 | 48 | 84.0 | Full | Dst Lebanon WWTP |
| 28.3/29.2 | 48 | 10.2 | 48 | 80.5 | Full | Ust Simpson Cr |
| 27.9/28.0 | 44[ns] | 9.9 | 42[ns] | 81.5 | Full | Dst Simpson Cr |
| 23.9/24.2 | 41[*] | 9.1[ns] | 48 | 82.5 | Partial | Trends |
| 21.9 | 43[*] | 9.7 | 48 | 76.5 | Partial | Ust Polk Run WWTP |
| *21.8* | *35* | *8.3* | *F/P* | -- | *NA* | *Polk Run WWTP mix zone* |
| 21.1/20.6 | 45[ns] | 9.9 | 48 | 81.5 | Full | Dst Polk Run WWTP |
| 18.5/19.1 | 40[*] | 9.6 | E | 79.0 | Partial | Dst Sycamore Creek |
| 13.5/13.6 | 37[*] | 9.8 | VG | 81.0 | Partial | Trends |
| 10.9/8.8 | 39[*] | 9.9 | E | 84.5 | Partial | Trends |
| 3.7/-- | 22[*] | 8.9[*] | -- | 75.5 | (NON) | Trends/CSO |
| 3.5/3.4 | 38[*] | 10.0 | 50 | -- | Partial | Trends |
| **Gilroy Ditch (11-044)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 1.5 | 32[*] | NA | G | 62.0 | Partial | Ust South Charleston WWTP |
| 1.3 | 40 | NA | F[*] | 59.0 | Partial | Dst South Charleston WWTP |
| 0.5/0.4 | 42 | NA | 28[*] | 49.0 | Partial | Impact/Recovery |
| **Lisbon Fork (11-043)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.4 | 40 | NA | E | 52.0 | Full | Status |
| **North Fork Little Miami (11-041)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 7.1 | 40 | NA | G | 54.0 | Full | Status |
| 2.6/0.3 | 42 | NA | E | 43.0 | Full | Status |
| **Goose Creek (11-042)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| --/0.8 | -- | -- | MG | | (Full) | Status |
| **Yellow Springs Creek (11-040)** *Eastern Corn Belt Plain EWH (existing)* | | | | | | |
| 0.1 | 52 | NA | 50 | 70.5 | Full | Status/Dst Yellow Springs WWTP |
| **Jacoby Branch (11-039)** *Eastern Corn Belt Plain WWH (existing)/EWH proposed* | | | | | | |
| 0.3/0.5 | 48 | NA | E | 67.5 | Full /Full | Status |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Conner Branch (11-038)** *Eastern Corn Belt Plain WWH (existing)/CWH proposed* | | | | | | |
| 0.1 | 50 | NA | E | 76.5 | Full /Full | Status |
| **Massie Creek (11-400)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 7.7 | 42 | 9.1 | 46 | 88.0 | Full | Dst Cedarville WWTP |
| 5.6/5.5 | 42 | 8.4 | 46 | 82.5 | Full | Status/Trends |
| 4.3/4.4 | 38[ns] | 7.8[ns] | 44 | 88.0 | Full | Status/Trends |
| 1.2 | 42 | 7.8[ns] | 46 | 80.5 | Full | Status/Trends |
| **North Fork Massie Creek (11-403)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 5.9/7.9 | 36[ns] | NA | G | 33.5 | Full | Status - NPS impacted |
| 1.2/1.1 | 34[*] | 8.6 | E | 63.5 | Partial | Status/Trends |
| **South Fork Massie Creek (11-404)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 2.3/2.1 | 40 | NA | E | 44.5 | Full | Status/Trends |
| 0.3/0.2 | 36[ns] | NA | VG | 56.0 | Full | Status/Trends |
| **Trib. to Massie Creek @ RM 5.3 (11-405)** *Eastern Corn Belt Plain EWH (proposed)* | | | | | | |
| --/0.3 | -- | -- | E | -- | (Full) | Status |
| **Clark Run (11-402)** *Eastern Corn Belt Plain WWH (existing/EWH proposed)* | | | | | | |
| 0.5 | 50 | NA | VG | 74.0 | Full /Full | Status |
| **Oldtown Creek (11-401)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.1/0.4 | 50 | NA | G | 61.5 | Full | Status/Trends |
| **Ludlow Creek (11-037)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.2 | 36[ns] | NA | G | 42.5 | Full | Status |
| **Shawnee Creek (11-045)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.7 | 48 | NA | G | 85.5 | Full | Status |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Beaver Creek (11-035)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 6.1 | 26* | NA | P* | 35.0 | NON | Status |
| 3.9/4.0 | 38ns | NA | 36 | 37.5 | Full | Status |
| 1.6 | 28* | 6.6* | 36 | 57.0 | Partial | Ust Little Beaver Cr |
| 0.5 | 32* | 7.4* | 48 | 76.0 | Partial | Dst L Beaver Cr/Ust WWTP |
| *0.4* | *37* | *7.3* | *F* | *NA* | | *Beaver Cr WWTP mix zone* |
| 0.3 | 30* | 7.1* | 42 | 70.5 | Partial | Dst Beaver Cr WWTP |
| **Little Beaver Creek (11-036)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| --/6.1 | -- | -- | P* | -- | (NON) | Status |
| 4.7 | 30* | NA | 30* | 58.5 | NON | Ust Miami Co E Regional WWTP |
| *4.6* | *24* | *NA* | *VP/P* | *NA* | | *Miami Co E Regional WWTP mz* |
| 3.5 | 29* | NA | 20* | 60.0 | NON | Dst Miami Co E Regional WWTP |
| --/2.0 | -- | -- | 22* | -- | (NON) | Status |
| 0.1 | 31* | 6.3* | 22* | 62.0 | NON | Status |
| **Unnamed trib to Little Beaver @ RM 6.1 (11-056)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| --/0.3 | -- | -- | P* | -- | (NON) | Status |
| **Trib. to Little Miami River @ RM 69.85 (11-055)** *ECBP WWH (proposed)* | | | | | | |
| --/0.1 | -- | -- | VG | -- | (Full) | Status |
| **Sugar Creek (11-033)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 2.4/2.2 | 46 | NA | G | 71.5 | Full | Status |
| 0.4/0.3 | 44 | 8.2 | G | 71.5 | Full | Status |
| **Little Sugar Creek (11-034)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.5 | 50 | NA | G | 56.5 | Full | Status |
| **Glady Run (11-032)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 5.8 | 36ns | NA | 34ns | 51.5 | Full | Ust Xenia Glady Run WWTP |
| *4.9* | *31* | *NA* | *VP* | *NA* | | *Xenia Glady Run WWTP mz* |
| 4.0 | 33* | NA | 28* | 66.5 | NON | Dst Xenia Glady Run WWTP |
| 2.1 | 37ns | NA | 42 | 67.5 | Full | Status |
| **Trib. to Little Miami River @ RM 62.01 (11-054)** *ECBP WWH (proposed)* | | | | | | |
| 0.6/0.5 | 48ns | NA | G | 71.0 | Full | Status |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Trib. to Little Miami River @ RM 60.05 (11-053)** *ECBP EWH (proposed)* | | | | | | |
| 0.2 | 48[ns] | NA | VG | 67.0 | Full | Status |
| **Mill Run (11-031)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.9/-- | 44 | NA | -- | 61.5 | (Full) | Status |
| **Newman Run (11-030)** *Eastern Corn Belt Plain WWH (existing)/EWH proposed* | | | | | | |
| 0.3 | 54 | NA | VG | 61.5 | Full /Full | Status |
| **Caesar Creek (11-300)** *Eastern Corn Belt Plain EWH (existing)/WWH proposed* | | | | | | |
| 26.5 | 42[*] | NA | G[*] | 65.5 | NON/Full | Shawnee Hills Unsewered |
| | | *Eastern Corn Belt Plain EWH (existing)* | | | | |
| 23.1 | 36[*] | 7.6[*] | G[*] | 70.5 | NON | |
| 16.6/16.5 | 48[ns] | 9.8 | VG | 72.0 | Full | Status |
| | | *Eastern Corn Belt Plain WWH (existing)/EWH proposed* | | | | |
| 0.2 | 48[ns] | 8.5[*] | 44[ns] | 95.0 | Full/Partial | Status |
| **North Branch Caesar Creek (11-312)** *ECBP EWH (existing/WWH proposed)* | | | | | | |
| 6.1/6.7 | 36[*] | NA | G[*] | 61.0 | NON /Full | Status |
| 1.2 | 48[ns] | 9.5 | G[*] | 56.0 | Partial/Full | Status |
| **South Branch Caesar Creek (11-311)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| --/8.2 | -- | -- | G | -- | Full | Status |
| | *Eastern Corn Belt Plain WWH (existing)/EWH proposed* | | | | | |
| 2.1 | 56 | NA | VG | 67.0 | Full | Status |
| **Anderson Fork (11-306)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 18.8 | 26[*] | 6.7[*] | G | 46.5 | NON | Status - NPS impacted |
| 13.9 | 38[ns] | 8.6 | G | 64.0 | Full | Status |
| | | *Eastern Corn Belt Plain EWH (existing)* | | | | |
| 9.4/9.5 | 50 | 9.8 | G[*] | 74.5 | Partial | Status |
| 5.0/4.9 | 40[*] | 8.2[*] | VG | 63.0 | Partial | Status/NPS impacted |
| **Painters Creek (11-307)** *Eastern Corn Belt Plain EWH (existing)/WWH proposed* | | | | | | |
| 0.4 | 46[ns] | NA | VG | 64.5 | Full /Full | Status |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Buck Run (11-305)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 1.6/1.2 | 42 | NA | G | 73.5 | Full | Status |
| **Trace Run (11-303)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 1.8 | 44 | NA | G | 67.0 | Full | Status |
| **Jonahs Run (11-302)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 1.3/2.1 | 28* | NA | MG | | Partial | Status - No flow |
| **Flat Fork (11-301)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | 1.7 |
| 18* | NA | G | 44.0 | NON | Status - No flow | |
| **Todd Fork (11-200)** *Eastern Corn Belt Plain EWH (existing)/WWH proposed* | | | | | | |
| 20.3/-- | 48ns | 7.8* | -- | 76.0 | (Partial)/(Full) | Fish Reference Site |
| 19.5/19.6 | 50 | 8.6* | 36* | 67.5 | Partial/Full | Macroinvert. Reference Site |
| 15.2/15.1 | 48ns | 9.7 | VG | 79.0 | Full/Full | Dst Landfill |
| | *Interior Plateau EWH (existing)/WWH proposed* | | | | | |
| --/8.6 | -- | -- | G* | -- | (NON)/(Full) | Status |
| 5.6/-- | 42* | 8.8* | -- | 79.0 | (NON)/(Full) | Status |
| 2.6/2.5 | 38* | 7.3* | 46 | 78.0 | NON/Partial | Status |
| 0.3/0.4 | 44* | 9.0ns | VG | 67.5 | Partial/Full | Status |
| **Lytle Creek (11-212)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 9.3 | 24* | NA | F* | -- | NON | Dst ABX deicing |
| 7.0 | 28* | NA | F* | 65.5 | NON | ABX impact/recovery |
| *6.7* | *24* | *NA* | *P* | -- | *NA* | *Wilmington WWTP mix zone* |
| 6.1 | 32* | NA | F* | 71.5 | NON | Dst Wilmington WWTP |
| 2.6 | 30* | NA | F* | 57.5 | NON | WWTP impact/recovery |
| **Lytle Creek (11-212) - 1996** | | | | | | |
| 10.2 | 12* | NA | VP* | -- | NON | |
| 9.6 | 16* | NA | P* | -- | NON | |
| 8.8/8.6 | 26* | NA | P* | -- | NON | |
| 8.1 | 22* | NA | P* | -- | NON | |
| 7.0 | 32* | NA | P* | -- | NON | |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Lytle Creek - continued.** | | | | | | |
| 6.0 | 28* | NA | P* | -- | NON | |
| 2.9/2.8 | 28* | NA | F* | -- | NON | |
| 1.4 | 56 | NA | -- | -- | (Full) | |
| 0.6/0.7 | 46 | NA | G | -- | Full | |
| **Cowan Creek (11-209)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 13.3 | 34* | 4.4* | F* | 58.5 | NON | Ust Indian Run - ABX |
| 12.4 | 34* | 7.2* | G | 71.5 | Partial | Dst Indian Run - ABX |
| 10.9 | 44 | 8.9 | G | 73.5 | Full | ABX impact/recovery |
| 8.5 | 50 | 9.3 | VG | 64.0 | Full | ABX impact/recovery |
| 1.2 | 38ns | 7.8ns | G | 63.0 | Full | Status |
| **Cowan Creek (11-209) - 1996** | | | | | | |
| 13.3/13.2 | 46 | 7.2* | F* | -- | Partial | |
| 12.4/12.5 | 40 | 5.9* | G | -- | Partial | |
| 10.9 | 46 | 8.4 | G | -- | Full | |
| 8.5/8.4 | 42 | 9.1 | G | -- | Full | |
| 7.0/6.9 | 36 | 8.6 | G | -- | Full | |
| **Indian Run (11-211)** *Eastern Corn Belt Plain WWH (existing)* | | | | | | |
| 0.4/0.2 | 28* | NA | F* | 35.5 | NON | ABX - Poor habitat |
| **Indian Run (11-211) - 1996** | | | | | | |
| 0.4/0.3 | 30* | NA | MG | – | Partial | |
| **East Fork Todd Fork (11-217)** *Eastern Corn Belt Plain WWH (proposed)* | | | | | | |
| 1.2/1.6 | 44 | 7.9ns | VG | 79.5 | Full | Status |
| **Turtle Creek (11-021)** *Interior Plateau WWH (existing)* | | | | | | |
| 0.3 | 50 | 9.1 | 48 | 70.5 | Full | Status/Trends |
| **Muddy Creek (11-020)** *Interior Plateau WWH (existing)* | | | | | | |
| 3.5/3.3 | 33* | NA | G | 75.0 | Partial | Ust Mason WWTP/Bio Ref |
| *3.2* | *36* | *NA* | *F* | *NA* | | *Mason WWTP mix zone* |
| 2.5 | 30* | NA | G | 69.5 | Partial | Dst Mason WWTP |
| 0.7 | 42 | NA | G | 73.5 | Full | recovery |

Table 1. Continued.

| River Mile Fish/Invertebrate | IBI | MIwb[a] | ICI[b] | QHEI | Attainment Status[c] | Comment |
|---|---|---|---|---|---|---|
| **Simpson Creek (11-017)** *Interior Plateau WWH (existing)* | | | | | | |
| 0.9/0.2 | 16* | NA | F | 65.5 | NON | Ust Warren Co WWTP/ no flow |
| *--/0.14* | *--* | *--* | *P* | *--* | | *Warren Co WWTP mix zone* |
| 0.1 | 42 | NA | 26* | 57.0 | Partial | Dst Warren Co WWTP |
| **O Bannon Creek (11-010)** *Interior Plateau WWH (existing)* | | | | | | |
| 4.3/4.5 | 44 | 7.6* | F | 72.0 | Partial | Ust Clermont Co WWTP |
| *2.6* | *35* | *8.0* | *G* | *NA* | | *Clermont Co WWTP mix zone* |
| 2.4/2.0 | 37ns | 8.2 | G | 69.5 | Full | Dst Clermont Co WWTP |
| 0.3/0.2 | 40 | 7.9ns | G | 56.5 | Full | Nutrient Enriched |
| **Stony Creek (11-012)** *Interior Plateau WWH (existing)* | | | | | | |
| --/0.2 | -- | -- | G | -- | (Full) | Status |
| **Sycamore Creek (11-007)** *Interior Plateau WWH (existing)* | | | | | | |
| 0.4/0.5 | 35* | 7.6ns | G | 70.5 | Partial | Ust Hamilton Co WWTP |
| *0.3* | *34* | *6.6* | *F* | *NA* | | *Hamilton Co WWTP mix zone* |
| 0.2/0.1 | 36ns | 7.1* | F | 63.5 | Partial | Dst Hamilton Co WWTP |

| | Biological Criteria | | | | | |
|---|---|---|---|---|---|---|
| | Eastern Corn Belt Plains (ECBP) | | | Interior Plateau (IP) | | |
| Index-Site Type | EWH | WWH | MWH | EWH | WWH | MWH |
| IBI-Headwaters | 50 | 40 | 24 | 50 | 40 | 24 |
| IBI-Wading | 50 | 40 | 24 | 50 | 40 | 24 |
| IBI-Boat | 48 | 42 | 24 | 48 | 38 | 24 |
| MIwb-Wading | 9.4 | 8.3 | 6.2 | 9.4 | 8.1 | 6.2 |
| MIwb-Boat | 9.6 | 8.5 | 5.8 | 9.6 | 8.7 | 5.8 |
| ICI | 46 | 36 | 22 | 46 | 30 | 22 |

a The Modified Index of Well-being is not applicable (NA) to headwater site types.

b A qualitative narrative evaluation used when quantitative data were not available or unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates (P = Poor, F = Fair, MG = Marginally Good, G = Good, VG = Very Good, E = Exceptional).

c Use attainment status based on one organism group is parenthetically expressed.

A Boat sampling method

D Wading method

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

ns Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

d Modified Warmwater Habitat criteria for channel modified habitats.

Table 2. Area of Degradation Values (ADV) comparing the longitudinal area of departure from established numeric criteria and attainment status for the Little Miami River, 1998 and 1993.

| | | | Miles by Attainment Status | | | | Miles by Narrative Status | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Index | ADV | **ADV/mi** | Full | Partial | **NON** | Poor/VP | Execpt. | Good | Fair | Poor | V. Poor |
| **1998** | | | | | | | | | | | |
| IBI | 2412 | **24.4** | | | | | 43.7 | 54.9 | 0.0 | 0.0 | 0.0 |
| MIwb | 1304 | **13.2** | 18.2 | 71.2 | **9.2** | 0.0 | 50.3 | 38.1 | 10.2 | 0.0 | 0.0 |
| ICI | 669 | **6.7** | | | | | 87.8 | 9.0 | 1.8 | 0.0 | 0.0 |
| **1993** | | | | | | | | | | | |
| IBI | 3848 | **39.0** | | | | | 41.5 | 44.6 | 12.5 | 0.0 | 0.0 |
| MIwb | 712 | **7.2** | 37.9 | 60.6 | **0.1** | 0.0 | 69.5 | 29.1 | 0.0 | 0.0 | 0.0 |
| ICI | 160 | **1.6** | | | | | 87.0 | 11.6 | 0.0 | 0.0 | 0.0 |

Table 3. Summary of performance and impacts to receiving waters for NPDES dischargers evaluted in the 1998 survey of the Little Miami River Basin

| NPDES Discharger | Flow (mgd) Design /Median/ 95th | Toxcity Bioassay /Biosample | Receiving Water Impairment |
|---|---|---|---|
| Air Borne Express (ABX) | NA | NA / Fish & Macro | Severe |
| O'Bannon Creek WWTP | 2.2 / 1.0 / 3.0 | ND/ ND | Indirect through nutrient enrichment |
| Clifton WWTP | 0.03 / 0.19/ NA | NA | Moderate; fish and macro lower in 1998 than 1993 downstream |
| Cedarville WWTP | 0.48 / 0.40 / 0.90 | NA / ND | ND, but overriding NPS impacts may mask |
| Beaver Creek WWTP | 4.7 / 6.0 / 10.0 | ND / Macro | Slight, decline in macro relative to upstream |
| Sugar Creek WWTP | 4.9 / 6.0 / 11.0 | ND / ND | Indirect through combined loadings |
| Polk Run WWTP | 6.0 / 4.0 / 8.0 | Acute / ND | Indirect through combined loadings |

Table 3. Continued.

| | | | |
|---|---|---|---|
| Sycamore Creek | 6.0 / 6.0 / 17.0 | Acute / Macro | Fish decline dst in LMR |
| Jamestown WWTP | 0.30 / 0.24 / 0.40 | NA / ND | Slight, macro indicate organic enrichment |
| Lebannon WWTP | 3.0 / 2.0 / 5.0 | Acute / ND | None |
| Mason WWTP | 5.0 / 3.0 / 6.0 | Acute / ND | Moderate due to organic enrichment |
| Montg. Co. East. Reg. WWTP | 13.0 / 8.0 / 16.0 | ND / Macro | Severe with addition of urban & legacy impacts |
| South Charleston WWTP | 0.24 / 0.20 / 0.50 | NA / ND | Moderate due to nutrient and organic enrichment |
| Warren Co. Lower LMR WWTP | 7.3 / 3.0 / 5.0 | NA/ ND | Moderate due to collection system failures |
| Waynesville WWTP | 0.71 / 0.40 / 0.8 | ND / NA | Moderate, I&I problems lead to bypassing |
| Wilmington WWTP | 3.0 / 2.0 / 5.5 | ND / Macro | Moderate, delays recovery from ABX impact, high nutrient load delivered to Todd Fork |
| Xenia-Ford Road WWTP | 3.6 / 2.6 / 4.5 | ND / ND | None - mild, organic enrichment dectected dst |
| Xenia-Glady Run WWTP | 4.0 / 2.1 / 3.4 | ND / ND | Moderate, I&I problems lead to bypasses and organic enrichment |
| Yellow Springs WWTP | 0.6 / 0.8 / 2.0 | NA / ND | None, slight organic enrichment detected dst |

NA - Not Assessed or Not Applicable
ND - Not Detected

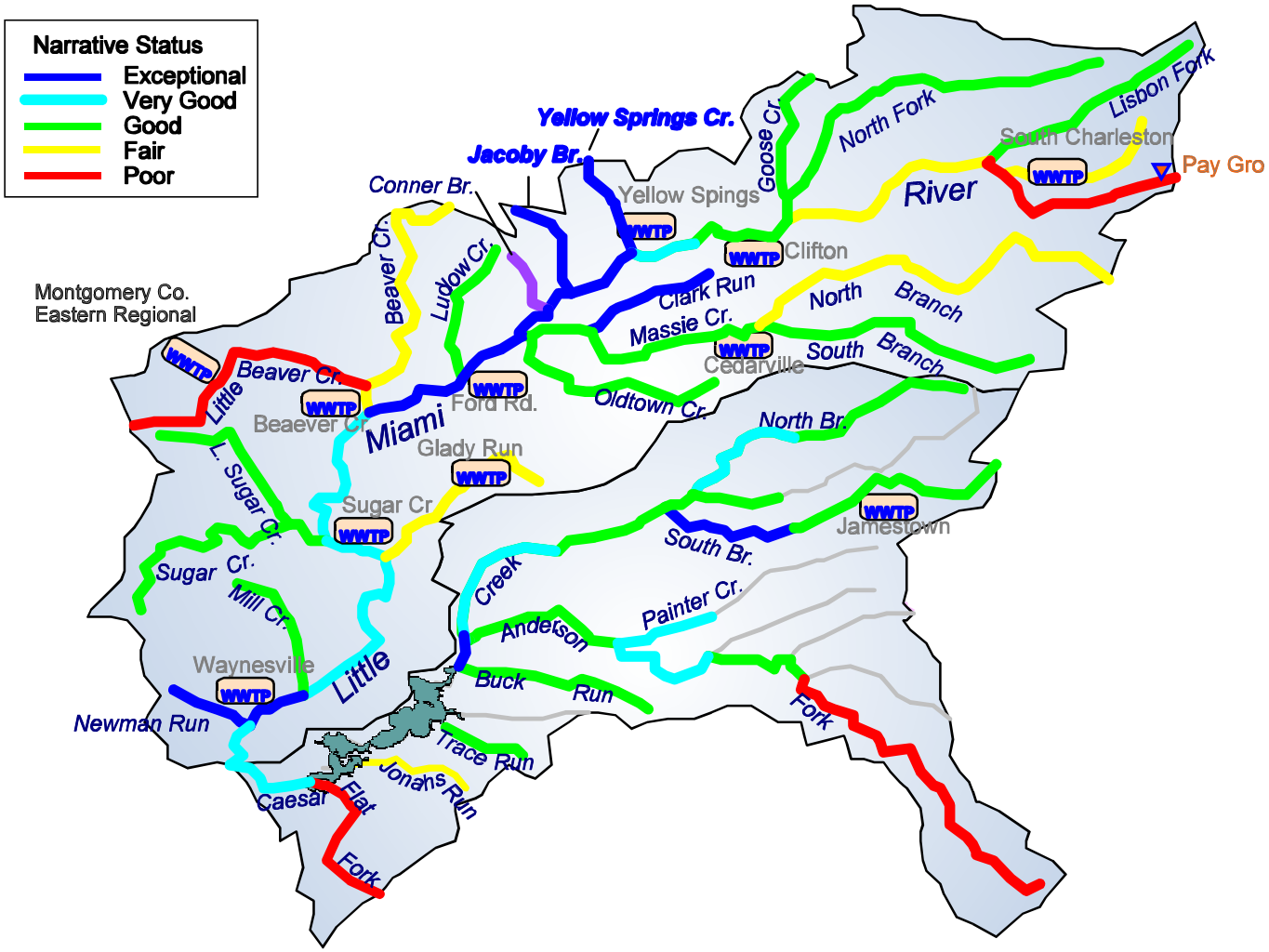



Figure 3. Narrative status of stream segments sampled in the upper Little Miami River basin based on the condition biological communities sampled during 1998.

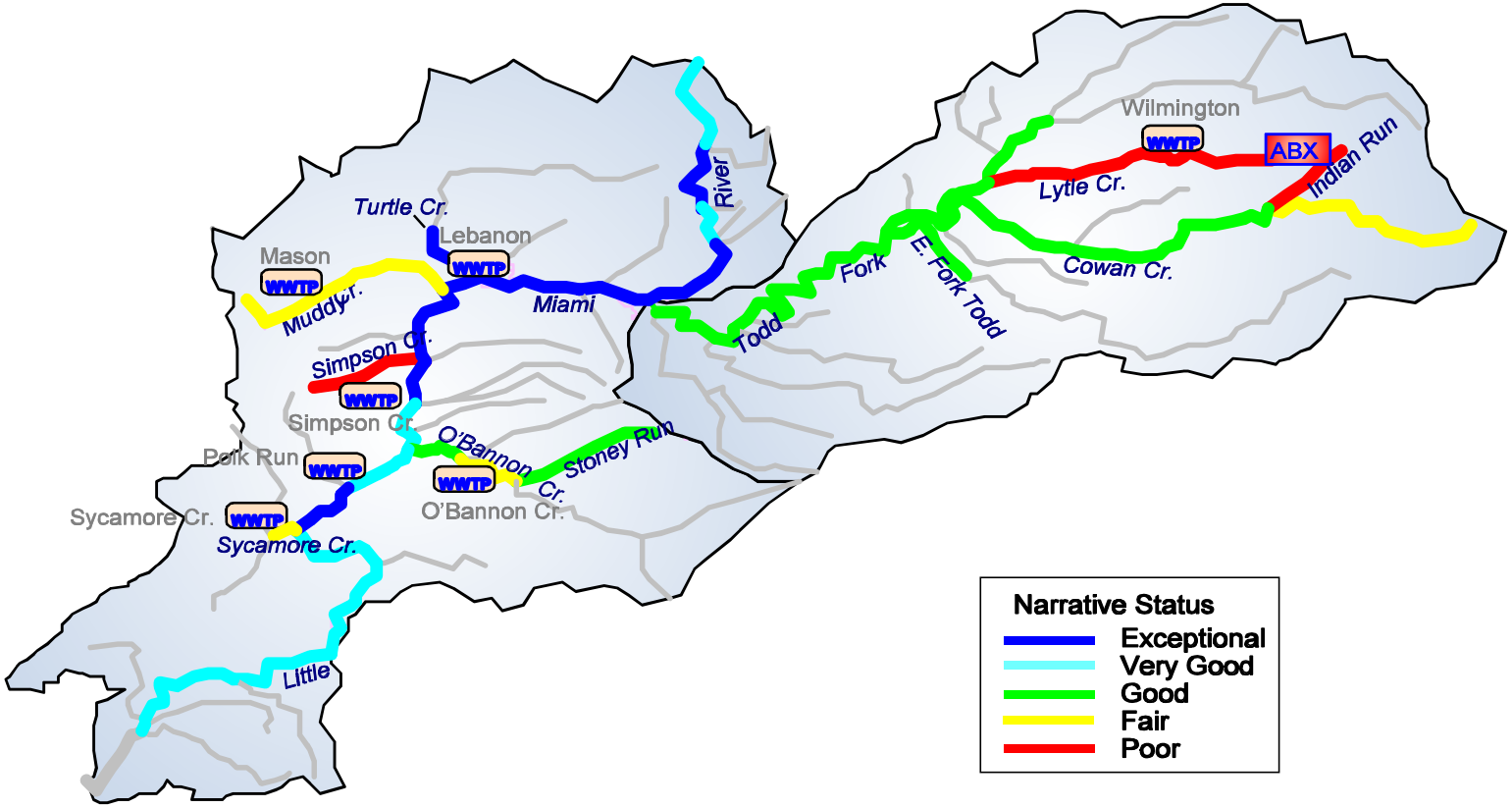



Figure 4. Narrative status of stream segments sampled in the lower Little Miami River basin based on the condition biological communities sampled during 1998.

| Table 4. Water Quality Use Designations<br><br>SEGMENT | SRW | WWH | EWH | MWH | SSH | CWH | LRW | AWS | IWS | PWS | BW | PCR | SCR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Miami River - (RM 3.0) to the mouth | + | + | | | | | | + | + | | | + | |
| - RM 3.0 to RM 91.64 | | | + | | | | | + | + | | | + | |
| ***RM 91.64 to the headwaters*** | | ▲ | | | | | | | | | | | |
| Cluff Creek (Clough Creek) | | * | | | | | | * | * | | | * | |
| McCullough Run | | * | | | | | | * | * | | | * | |
| Duck Creek - confluence of East and West Fork (RM 3.9)to Red Bank Road (RM 2.4) | | | | | | | + | * | * | | | | + |
| - Downstream of Red Bank Road (RM 2.4) to the mouth | | + | | | | | | * | * | | | + | |
| East Fork Duck Creek | | | | | | | + | * | * | | | | + |
| West Fork Duck Creek | | | | | | | + | * | * | | | | + |
| Dry Run | | * | | | | | | * | * | | | * | |
| Horner Run | | * | | | | | | * | * | | | * | |
| Sycamore Creek | | + | | | | | | + | + | | | + | |
| North Branch | | * | | | | | | * | * | | | * | |
| Polk Run | | * | | | | | | * | * | | | * | |
| ***O Bannon Creek*** | | + | | | | | | + | + | | | ▲ | + |
| Grog Run | | * | | | | | | * | * | | | * | |
| ***Stony Run*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| Indiancamp Creek | | * | | | | | | * | * | | | * | |
| Ertel Run | | * | | | | | | * | * | | | * | |
| Salt Run | | * | | | | | | * | * | | | * | |
| Hen Run | | * | | | | | | * | * | | | * | |
| ***Simpson Creek*** | | + | | | | | | + | + | | | */+ | |

| Table 4. Water Quality Use Designations<br>SEGMENT | SRW | WWH | EWH | MWH | SSH | CWH | LRW | AWS | IWS | PWS | BW | PCR | SCR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bear Run | | * | | | | | | * | * | | | * | |
| Union Run | | * | | | | | | * | * | | | * | |
| ***Muddy Creek*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Turtle Creek*** | | + | | | | | | + | + | | | ▲ | + |
| Dry Run | | + | | | | | | + | + | | | | + |
| Little Muddy Creek | | * | | | | | | * | * | | | | + |
| Bigfoot Run | | * | | | | | | * | * | | | * | |
| Halls Creek | | | * | | | | | * | * | | | * | |
| ***Todd Fork*** | | ▲ | * | | | | | */+ | */+ | | | */+ | |
| First Creek | | * | | | | | | * | * | | | * | |
| Martin Run | | * | | | | | | * | * | | | * | |
| Second Creek | | * | | | | | | * | * | | | * | |
| Lick Run | * | | * | | | | | * | * | | | * | |
| Sugar Run | | * | | | | | | * | * | | | * | |
| ***East Fork Todd Fork*** | | ▲ | | | | | | ▲ | ▲ | | | ▲ | |
| Little East Fork | | * | | | | | | * | * | | | * | |
| Stony Hollow | | * | | | | | | * | * | | | * | |
| Sewell Run | | * | | | | | | * | * | | | * | |
| ***Cowan Creek - Cowan Lake to confluence with*** | | | | | | | | | | | | | |
| ***Todd Fork*** | * | */+ | | | | | | */+ | */+ | | | */+ | |
| ***- all other segments*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| Wilson Creek | | * | | | | | | * | * | | | * | |
| **Indian Run** | | */+ | | | | | | */+ | */+ | | | */+ | ▲ |
| ***Lytle Creek*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| Little Creek | | * | | | | | | * | * | | | * | |

| Table 4. Water Quality Use Designations<br>SEGMENT | SRW | WWH | EWH | MWH | SSH | CWH | LRW | AWS | IWS | PWS | BW | PCR | SCR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moore Branch | | * | | | | | | * | * | | | * | |
| Dutch Creek | | | * | | | | | * | * | | | * | |
| Dry Run | | * | | | | | | * | * | | | * | |
| Stony Run | | * | | | | | | * | * | | | * | |
| Cowan Run | | * | | | | | | * | * | | | * | |
| Randall Run | | * | | | | | | * | * | | | * | |
| Olive Branch | * | + | | | | | | + | + | | | * | |
| ***Caesar Creek - headwaters to confluence with South Branch*** | | ▲ | * | | | | | */+ | */+ | | | */+ | |
| ***- confluence with South Branch to confluence with Anderson Fork*** | * | | */+ | | | | | */+ | */+ | | | */+ | |
| ***- confluence with Anderson Fork to confluence with Little Miami River*** | * | * | ▲ | | | | | */+ | */+ | | | */+ | |
| ***Flat Fork*** | * | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Jonahs Run*** | * | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Trace Run*** | * | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Turkey Run*** | * | * | | | | | | * | * | | | * | |
| ***Buck Run*** | * | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Anderson Fork - confluence with Grog Run to*** | | | | | | | | | | | | | |
| ***confluence with Caesar Creek*** | * | ▲ | * | | | | | */+ | */+ | | | */+ | |
| ***- all other segments*** | * | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Painters Creek*** | | ▲ | * | | | | | */+ | */+ | | | */+ | |
| ***Grog Run*** | | * | | | | | | * | * | | | * | |
| ***Love Run*** | | * | | | | | | * | * | | | * | |
| ***Grassy Run*** | | * | | | | | | * | * | | | * | |

| Table 4. Water Quality Use Designations<br>SEGMENT | SRW | WWH | EWH | MWH | SSH | CWH | LRW | AWS | IWS | PWS | BW | PCR | SCR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***South Branch - confluence with Caesar Creek to RM 4.0 (Paintersville - New Jasper Road)*** | | | ▲ | | | | | */+ | */+ | | | */+ | |
| ***South Branch - RM 4.0 to headwaters*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***North Branch*** | | ▲ | * | | | | | */+ | */+ | | | */+ | |
| ***Newman Run*** | | + | ▲ | | | | | + | + | | | */+ | |
| ***Mill Run*** | | + | | | | | | + | + | | | */+ | |
| ***Unnamed tributary to LMR @ RM 60.05*** | | ▲ | | | | | | ▲ | ▲ | | | ▲ | |
| ***Unnamed tributary to LMR @ RM 62.01*** | | ▲ | | | | | | ▲ | ▲ | | | ▲ | |
| ***Glady Run RM 4.0 to Headwaters*** | | + | | | | | | + | + | | | | + |
| ***Glady Run RM 4.0 to confluence with Little Miami River*** | | + | | | | | | + | + | | | ▲ | |
| ***Glady Run Swale*** | | + | | | | | | * | * | | | | + |
| ***Sugar Creek - within Sugar Creek Reserve*** | o | */+ | | | | | | */+ | */+ | | | */+ | |
| ***- all other segments*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Little Sugar Creek*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Unnamed tributary to LMR @ RM 69.85*** | | ▲ | | | | | | ▲ | ▲ | | | ▲ | |
| ***Beaver Creek*** | | + | | | | | | + | + | | | + | |
| ***Little Beaver Creek*** | | + | | | | | | + | + | | | + | |
| Unnamed tributary (RM 6.1) | | + | | | | | | + | + | | | | + |
| ***Shawnee Creek*** | | + | | | | | | + | + | | | + | |
| ***Ludlow Creek*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Massie Creek*** | | + | | | | | | + | + | + | | */+ | |
| ***Oldtown Creek*** | * | + | | | | | | + | + | | | */+ | |
| ***Unnamed trib to Massie Cr. @ RM 5.31*** | | | ▲ | | | | | ▲ | ▲ | | | ▲ | |
| ***Clark Run*** | | | */+ | | | | | */+ | */+ | | | */+ | |

| Table 4. Water Quality Use Designations<br>SEGMENT | SRW | WWH | EWH | MWH | SSH | CWH | LRW | AWS | IWS | PWS | BW | PCR | SCR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***North Fork*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***South Fork*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Conner Branch*** | | * | | | | ▲ | | */+ | */+ | | | */+ | |
| ***Jacoby Branch*** | | * | ▲ | | | | | */+ | */+ | | | */+ | |
| ***Yellow Springs Creek*** | * | | + | | | | | + | + | | | + | |
| ***North Fork*** | * | + | | | | | | + | + | | | */+ | |
| ***Goose Creek*** | | */+ | | | | | | */+ | */+ | | | */+ | |
| ***Lisbon Fork*** | | + | | | | | | + | + | | | */+ | |
| Gilroy Ditch | | + | | | | | | + | + | | | | + |

* Use Designation based on either the 1978 or 1985 WQS.
\+ Use Designation verified by biological and water quality survey.
▲ Recommended use designation based on the results of this survey.

**Study Area**

The Little Miami River flows 107 miles from its headwaters in southeastern Clark County to its confluence with the Ohio River in Hamilton County east of Cincinnati (Figure 3 ). The Little Miami flows southwesterly from Clark County through Greene and Warren counties, then continues in a southerly direction to form a portion of the border between Clermont and Hamilton Counties. The watershed also encompasses portions of Montgomery, Clinton, Brown, Highland and Madison Counties. The drainage area of the Little Miami covers 1,757 square miles. Along its course the river drops from an elevation of 1,137 feet to 448 feet with an average gradient of 6.5 ft./mile. Major tributaries include: East Fork Little Miami River, Caesar Creek, Todd Fork, Massie Creek, Beaver Creek, Turtle Creek, Muddy Creek, O'Bannon Creek, and Sycamore Creek. Impoundments in the watershed include Caesar Creek Reservoir (6,110 acres), William Harsha Reservoir (4,600 acres), Cowan Lake (720 acres), Shawnee Lake (190 acres), and Stonelick Lake (171 acres). The city of Wilmington also maintains an upground reservoir for water supply.

The topography of the Little Miami River Watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. The northern portion of the watershed is within the Eastern Corn Belt Plains ecoregion which is characterized by level to gently sloping land, and relatively low gradient streams. South of Waynesville the river flows into the Interior Plateau ecoregion which has greater relief and tributaries tend to have steeper gradients before entering the Little Miami flood plain. For most of its length the Little Miami flows atop a buried valley aquifer composed of highly permeable sands and gravel from past glacial events. Deviations from this pattern include the Clifton Gorge near Clifton and The Narrows in Greene County. Smaller tributaries in this area are known to disappear into the ground during dry periods due to high infiltration rates associated with the sand and gravel aquifer.

This aquifer was designated a Sole Source Aquifer by USEPA. Designation requires extra review for any federally funded projects proposed for the surface above the aquifer. Most of the communities in the watershed rely heavily on groundwater for a source of raw water. Some communities in the southeastern portion of the watershed (Wilmington and Fayetteville) utilize surface water for supply. A combination of development pressures and limited supply have caused some communities to begin drawing water from the Caesar Creek and William Harsha Reservoirs.

Aquatic life use designations for the streams in the watershed reflect the generally good conditions in the watershed. The Little Miami River is designated Exceptional Warmwater Habitat (EWH). Caesar Creek upstream of the confluence with Anderson Fork and Anderson Fork downstream of Grog Run are also designated EWH, though those designations have not been confirmed by an intensive biological and water quality survey until now. All other tributaries are designated Warmwater Habitat (WWH). Criteria for achievement of a designated use vary somewhat within the watershed due to the change in ecoregions. State Resource Water (SRW) designation is also applicable to the Little Miami River due to its status as a State and National Scenic River. By definition, East Fork Little Miami River, Caesar Creek, Cowan Creek and Stonelick Creek also qualify for SRW because of the presence of state parks at the reservoirs. With a few exceptions the

streams in the watershed are also designated for Agricultural and Industrial water supply and Primary Contact Recreation.

Land uses in the watershed are principally agricultural in the northern and eastern portions with relatively limited development near cities. Beginning with the Dayton-Xenia corridor there is an increasing impact from population and development. Many communities are trying to keep pace with the pressures that attend growth including provision of water and sewage services. To this end Warren County has developed a well field adjacent to the river at SR 48 to maximize use of the sand and gravel aquifer at that location. A waterline was installed under the river at the same location to provide for development on the south side of the river. Another waterline has been installed near SR 22 to carry water from Cincinnati to the Morrow area. As a result existing wastewater treatment infrastructure must expand and sometimes the rate of expansion does not keep pace with the rate of growth. Some private water companies provide water to regions that do not have adequate groundwater for domestic wells. Several sewage treatment plants are operating at or beyond the design capacity and as a result often violate permit NPDES limits. Changing land uses are reflected in nonpoint source pollution pattern changes. Land cleared for construction can result in greatly accelerated rates of erosion and sedimentation of streams. After development there is usually more impervious surface which increases the rate and volume of runoff. Materials deposited on the surface of the land are incorporated into the runoff and enter streams during rainfall events.

While most developing areas in the Little Miami watershed are not immediately adjacent to the river the impacts of development are still a potential problem. Numerous residential, industrial, and commercial developments are recently completed, underway, or proposed within the watershed. Some local programs and the NPDES general permit for construction sites attempt to control sediment laden runoff from these sites during construction. Enforcement of these regulations has not kept pace with the development, however, and a significant amount of sediment enters streams in the watershed as a result. This increased amount of sediment is eventually transported to the Little Miami via tributaries. Already developed areas contribute different types of pollutants to the watershed (oil & grease, lawn chemicals, PAHs). Problems have been reported from combined sewer overflows along Duck Creek. Another area of concern is deicing chemicals applied to aircraft and runways at Airborne Express in Wilmington and at Lunken Airport near the mouth of the Little Miami River.

Several watershed projects have been initiated to reduce nonpoint source pollution inputs to the various streams in the watershed. The upper reaches of the watershed were included in the "Clark-Greene Little Miami River Restoration Project" that concentrated on demonstrations of agricultural best management practices appropriate for that portion of the watershed. It covered the portion of the watershed upstream from the confluence with Massie's Creek. A successor to this project is the "Upper Little Miami River 319 Project" which will include all of the watershed to upstream from the confluence with Caesar Creek. This project will be different in that it will address the nonpoint source pollution generated by runoff from the rapidly developing corridor between Dayton and Xenia. The Caesar Creek watershed has been the site of a previous 319 project that installed filter

strips and wetlands to buffer runoff from agricultural fields. Another project is in process to include the Caesar Creek watershed with the Upper Little Miami 319 project described above. Within the East Fork Little Miami River several watershed initiatives are also underway. One of the early 319 projects in the state was located in the watershed upstream from William Harsha Reservior for a three year span and then expired. The Clermont County Combined Health District has been awarded two 319 grants. The first of these grants was to investigate the feasibility of innovative systems for on-site treatment of wastewater on the very limiting soils of the county. The most recent grant will provide for increased inspection and maintenance of existing on-site systems in the special sanitary district surrounding William Harsha Reservior. The Clermont County Engineer's office also received a grant to demonstrate the use of non-structural controls to prevent streambank erosion. In addition to these Section 319 projects the Clermont County Commissioners have been working with USEPA and Ohio EPA on a Project XL initiative to address economic development and environmental concerns in a coordinated manner.

In addition to the waterline crossings mentioned above, some other in-stream projects should be mentioned. A major streambank erosion control project was completed at Lake Isabella by the Hamilton County Park District. Several utility lines were in danger because of the extent of erosion and the possibility existed that the separation between the river and Lake Isabella would be lost. The park district, ODNR Scenic Rivers, Ohio EPA, and the Corps of Engineers worked together to plan the project for minimal impact on the natural and aesthetic resources in the river. The Boy Scouts of America have recently been granted permission to construct an 18 acre lake on an unnamed tributary to the river. The process of negotiation led to a change in design of the project to greater protection on the river. A concern in the watershed is the rate at which headwater streams are being lost due to development. Many of these streams have very small watersheds and high gradients over exposed bedrock. As a result they do not support populations of fish and cannot be designated under existing regulations. These streams are also prone to rapid streambank erosion which is accelerated by the increased runoff from developing areas.

Table 5. Stream characteristics and significant identified pollution sources in the Little Miami River study area.

| Stream Name | Length (Miles) | Average Fall ft/mi | Drainage Area $mi^2$ | Nonpoint Source Pollution Categories | Point Sources Evaluated |
|---|---|---|---|---|---|
| Little Miami River | 105.5 | 6.5 | 1755.3 | Agriculture<br>Urban<br>Resource Extraction | S. Charleston WWTP<br>Clifton WWTP<br>Xenia-Ford Rd. WWTP<br>Greene County<br>Sugar Creek WWTP<br>Waynesville WWTP<br>Lebanon WWTP<br>Polk Run WWTP |
| Gilroy Ditch | 7.15 | | 6.9 | Urban | South Charleston WWTP |
| Lisbon Fork | 6.0 | 14.2 | 12.22 | Agriculture | |
| North Fork Little Miami River | 13.2 | 8.8 | 37.7 | Agriculture<br>Channelization | |
| Goose Creek | 3.6 | 5.8 | 5.42 | Agriculture | |
| Yellow Springs Creek | 2.5 | 42.0 | 11.5 | Urban | Yellow Springs WWTP |
| Jacoby Branch | 3.1 | 46.1 | 6.28 | Agriculture | |
| Conner Branch | 1.9 | 58.4 | 2.45 | Agriculture | |
| Oldtown Creek | 6.0 | 31.2 | 10.09 | Agriculture | |
| Massie Creek | 9.5 | 22.0 | 86.6 | Agriculture<br>Urban | Cedarville WWTP |
| North Fork Massie Creek | 12.6 | 7.2 | 28.12 | Agriculture | |
| South Fork Massie Creek | 9.6 | 7.2 | 21.73 | Agriculture<br>Channelization | |
| Clark Run | 5.0 | 39.2 | 6.37 | Agriculture | |
| Ludlow Creek | 5.0 | 20.8 | 6.93 | Agriculture | |

Table 5. Continued.

| Stream Name | Length (Miles) | Average Fall ft/mi | Drainage Area $mi^2$ | Nonpoint Source Pollution Categories | Point Sources Evaluated |
|---|---|---|---|---|---|
| Shawnee Creek | 8.69 | | 11.2 | Urban | |
| Beaver Creek | 8.4 | 7.4 | 46.98 | Agriculture<br>Urban<br>Resource Extraction | Greene County<br>Beaver Creek WWTP |
| Little Beaver Creek | 9.0 | 18.8 | 25.97 | Urban | Montgomery County<br>East Regional WWTP |
| Sugar Creek | 9.6 | 23.4 | 34.04 | Agriculture<br>Urban<br>Land Disposal | |
| Little Sugar Creek | 2.1 | 38.6 | 12.55 | Urban<br>Land Disposal | |
| Glady Run | 6.3 | 26.5 | 14.0 | Agriculture | Xenia<br>Glady Run WWTP |
| Newman Run | 4.0 | 62.5 | 9.89 | Agriculture<br>Urban | |
| Mill Run | 5.8 | 40.7 | 8.74 | Agriculture<br>Urban<br>Land Disposal | |
| Caesar Creek | 33.9 | 10.6 | 238.6 | Agriculture | |
| North Branch Caesar Creek | 10 | 10.1 | 27.04 | Agriculture | |
| South Branch Caesar Creek | 11.5 | 11.6 | 17.98 | Agriculture | Jamestown WWTP |
| Anderson Fork | 28.28 | 8.1 | 93.3 | Agriculture | |
| Painters Creek | 8.1 | 17.4 | 12.26 | Agriculture | |
| Buck Run | 4.7 | 31.7 | 9.65 | Agriculture | |
| Trace Run | 3.5 | 45.7 | 9.78 | Agriculture | |

Table 5. Continued.

| Stream Name | Length (Miles) | Average Fall ft/mi | Drainage Area $mi^2$ | Nonpoint Source Pollution Categories | Point Sources Evaluated |
|---|---|---|---|---|---|
| Jonahs Run | 4.3 | 36.5 | 8.36 | Agriculture | |
| Flat Fork | 3.7 | 17.3 | 16.76 | Agriculture | |
| Todd Fork | 35.0 | 11.6 | 261.3 | Agriculture<br>Urban<br>Land Disposal | |
| Lytle Creek | 10.1 | 22.5 | 20.05 | Agriculture<br>Urban<br>Land Disposal | Wilmington WWTP<br>ABX |
| Cowan Creek | 22.4 | 11.3 | 54.9 | Agriculture<br>Land Disposal | |
| Indian Run | 2.0 | 14.0 | 4.85 | Agriculture<br>Urban | ABX |
| East Fork Todd Fork | 19.6 | 12.5 | 40.6 | | |
| Turtle Creek | 12.0 | 23.5 | 65.55 | Agriculture<br>Urban | |
| Muddy Creek | 8.9 | 31.9 | 15.67 | Agriculture<br>Urban | Mason WWTP |
| Simpson Creek | 4.0 | 67.5 | 4.33 | Agriculture<br>Urban | Warren County<br>Lower LMR WWTP |
| Sycamore Creek | 4.5 | 65.8 | 24.45 | Urban<br>Hydromodifications | Hamilton County<br>Sycamore Cr. WWTP |
| O'Bannon Creek | 12.0 | 24.0 | 58.5 | Agriculture<br>Urban | Clermont County<br>O'Bannon Cr. WWTP |

Table 6. Sampling locations and samples collected from the Little Miami River basin study area in 1998 (B - quantitative benthic macroinvertebrate sample ($B_q$ - denotes a qualitative sample), C - conventional water chemistry, $C_o$ - conventional and organic water chemistry, D - datasonde, E - effluent, F - fish, M - modeling (may include cross section, time of travel or water chemistry data), Q - flow (USGS), $Q_M$ - flow (manual), S - sediment chemistry. *Italics denote effluent and mixing zone sampling locations.*

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***Little Miami River*** | | | | |
| 106.95 | $B_q$,C,D,M | 39°49’15”/83°35’19” | Ust. Huntington Rd., Ust. Paygro | Florence |
| *106.73* | *E,$Q_M$* | *39°49 14 /83°35 33* | *Field tile sample* | *Florence* |
| *106.65* | *E,$Q_M$* | *39°49 15 /83°35 39* | *Paygro effluent* | *Florence* |
| *106.54* | *E,$Q_M$* | *39°49 16 /83°35 46* | *Paygro effluent* | *Florence* |
| *106.37* | *E,$Q_M$* | *39°49 18 /83°35 58* | *Paygro effluent* | *Florence* |
| 106.35 | $C_o$,D,M,$Q_M$,S | 39°49’17”/83°35’59” | Huntington Rd., Dst. Paygro | Florence |
| 104.88 | $B_q$,$C_o$,D,F,M | 39°48’40”/83°37’15” | SR 41, Dst. Paygro | Florence |
| 103.10 | D,M | 39°48’19”/83°38’50” | Jamestown Rd. | South Charleston |
| 102.00 | M | 39°48’55”/83°39’21” | SR 42 | South Charleston |
| 101.30 | B,C,D,F,M | 39°49’23”/83°39’40” | Clifton Rd., Ust. Gilroy Ditch | South Charleston |
| 98.98 | B,$C_o$,D,F,M,$Q_M$,S | 39°49’57”/83°41’40” | Dolly Varden Rd. | South Charleston |
| 95.00 | D,M | 39°48’36”/83°44’20” | Selma Pike | South Charleston |
| 93.50 | D,M | 39°48’23”/83°45’50” | Garlough Rd. | Clifton |
| 92.27 | B,C,D,F,M | 39°48’20”/83°46’52” | Pitchin Rd., Ust. Clifton WWTP | Clifton |
| 89.80 | M,$Q_M$ | 39°47’43”/83°48’50” | Adj. North River Rd. | Clifton |
| 89.40 | D,M | 39°47’41”/83°49’14” | Clifton River Road Reserve Park | Clifton |
| 89.00 | B,$C_o$,D,F | 39°47’38”/83°49’36” | Wilberforce Clifton Rd. | Clifton |
| 88.40 | $B_q$, D,M | 39°47’56”/83°50’03” | Clifton Gorge @ Bear’s Den | Clifton |
| 87.65 | D,M | 39°47’26”/83°50’28” | John Bryan St. Park @ footbridge | Clifton |
| 86.40 | D,M,$Q_M$ | 39°47’08”/83°51’43” | John Bryan St. Park @ plaque | Clifton |
| 85.38 | B,C,D,F,M,S | 39°46’57”/83°52’32” | Grinnel Rd., Ust. Yellow Springs Creek | Yellow Springs |
| 83.14 | B,$C_o$,D,F,M | 39°45’51”/83°54’06” | Jacoby Rd., Dst. Yellow Springs Creek | Yellow Springs |
| 80.90 | D,M | 39°44’47”/83°55’35” | Ust. US 68 | Xenia |
| 80.63 | B,$C_o$,F,Q,S | 39°44’54”/83°55’53” | US 68 | Xenia |
| 79.55 | D,M | 39°44’13”/83°56’25” | End of waterworks lane, Ust. Massie Cr. | Xenia |
| 77.70 | C,D,F,M | 39°43’27”/83°57’50” | Fairgrounds Road Ust. Ford Rd. WWTP | Xenia |
| 77.07 | $B_q$ D,M,$Q_M$ | 39°43’03”/83°58’07” | Ust. Xenia-Ford WWTP | Xenia |
| *77.0* | $B_q$,*F* | *39°42 58 /83°58 12* | *Xenia-Ford WWTP mixing zone* | *Xenia* |
| 76.90 | B,$C_o$,F,S | 39°42’56”/83°58’16” | Dst. Xenia-Ford WWTP | Xenia |
| 74.46 | B,C | 39°42’05”/83°59’58” | US 35 | Xenia |
| 72.30 | B,$C_o$,F,S | 39°41’29”/84°01’43” | Indian Ripple Rd. | Bellbrook |
| 69.84 | B,C,D,F | 39°39’43”/84°02’26” | Upper Bellbrook Rd. | Bellbrook |
| 68.60 | D,M,$Q_M$ | 39°38’42”/84°02’35” | Washington Mill Rd. | Bellbrook |
| 66.56 | B,$C_o$,D,M,S | 39°37’58”/84°03’05” | Lower Bellbrook Rd. | Bellbrook |
| 65.25 | B,C,D,F,M,S | 39°37’04”/84°02’38” | Dst. SR 725, End of Cook Rd. | Waynesville |
| *64.43* | *E* | *39°36 57 /84°01 44* | *Sugar Creek WWTP effluent* | *Waynesville* |
| *64.4* | *$B_q$,F* | *39°36 58 /84°01 42* | *Sugar Creek WWTP mixing zone* | *Waynesville* |
| 64.28 | B,$C_o$,F,S | 39°36’57”/84°01’36” | Dst. Sugar Creek WWTP | Waynesville |

Table 6. continued.

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***Little Miami River (continued)*** | | | | |
| 63.28 | B,$C_o$,D,F,M,S | 39°36’19”/84°00’49” | Dst. Glady Run @ Spring Valley Park | Waynesville |
| 60.84 | B,$C_o$,D,F,M,S | 39°35’00”/84°01’47” | Roxanna - New Burlington Rd. | Waynesville |
| 59.30 | D,M | 39°33’57”/84°01’19” | Ust. Spring Valley Lake | Waynesville |
| 58.30 | M | 39°33’19”/84°01’50” | Dst. Sandy Cr. | Waynesville |
| 57.10 | D,M | 39°32’40”/84°02’32” | Dst. powerlines | Waynesville |
| 55.40 | D,M | 39°31’58”/84°03’47” | Adj. New Burlington Rd., Ust. mill dam | Waynesville |
| 55.25 | $C_o$,S | 39°31’55”/84°03’51” | Adj. New Burlington Rd., Dst. mill dam | Waynesville |
| 54.0 | $B_q$,F | 39°31’33”/84°04’39” | Corwin Ave | Waynesville |
| 53.80 | D,M | 39°31’28”/84°05’18” | Ust. Waynesville WWTP | Waynesville |
| *53.79* | *E* | *39°31 28 /84°05 19* | *Waynesville WWTP effluent* | *Waynesville* |
| 53.69 | B,$C_o$,F,S | 39°31’25”/84°05’25” | Dst. Waynesville WWTP | Waynesville |
| 53.15 | D,M | 39°30’58”/84°05’35” | Ust. Newman Run | Waynesville |
| 51.30 | D,F,M,$Q_M$ | 39°29’53”/84°06’05” | Ust. Middletown Rd. | Oregonia |
| 50.75 | B,C,S | 39°29’34”/84°06’28” | Adj. Waynesville Rd., Dst. Caesar Creek | Oregonia |
| 47.50 | B,C,D,F,S | 39°27’08”/84°05’54” | Old Oregonia Road (Closed bridge) | Oregonia |
| 43.76 | B,C,D,F,S | 39°24’24”/84°06’03” | SR 350 - near Ft. Ancient | Oregonia |
| 35.98 | B,C,D,F,S | 39°21’48”/84°10’29” | Dst. Stubbs Mill Rd., Dst. Bigfoot landfill | S. Lebanon |
| 32.95 | B,C,F | 39°22’07”/84°13’31” | SR 48, Ust. Lebanon WWTP | S. Lebanon |
| *32.1* | *$B_q$,F* | *39°21 57 /84°14 22* | *Lebanon WWTP mixing zone* | *S. Lebanon* |
| 31.96 | B,$C_o$,F,S | 39°21’53”/84°14’30” | Dst. Lebanon WWTP | S. Lebanon |
| 28.20 | B,C,D,F | 39°19’17”/84°15’09” | Foster Maineville Rd., Ust. Simpson Cr. | Mason |
| 28.00 | B,C,F,S | 39°19’13”/84°15’10” | Dst. Simpson Creek | Mason |
| 24.35 | B,C,D,F,S | 39°16’29”/84°15’29” | Ust. O’BANNON Creek | Mason |
| 21.93 | B,C,F | 39°15’03”/84°17’15” | Ust. Polk Run WWTP, Dst. Totes | Mason |
| *21.8* | *$B_q$,F* | *39°14 53 /84°17 38* | *Polk Run WWTP mixing zone* | *Mason* |
| 21.45 | $C_o$,F | 39°14’48”/84°14’42” | Branch Hill New Guinea Rd. | Madeira |
| 20.60 | B,C,D,S | 39°14’08”/84°17’57” | Dst. I-275, Lake Isabella canoe access | Madeira |
| 18.14 | $B_q$,C,F | 39°12’38”/84°18’44” | Ust. old Camargo Rd., Dst. Sycamore Cr. Madeira | |
| 13.07 | $B_q$,C,F,Q | 39°10’18”/84°17’55” | Wooster Pike | Madeira |
| 10.9 | F | 39°09’03”/84°18’34” | Jct. Round Bottom & Mt. Carmel Rd | Madeira |
| 8.14 | B,$C_o$,S | 39°08’13”/84°21’11” | Newtown Rd. | Madeira |
| 3.7 | F | 39°06’38”/84°24’01” | Ust Beechmont Ave | Newport |
| 3.5 | B,F | 39°06’32”/84°24’07” | Beechmont Ave. | Newport |
| ***Gilroy Ditch*** | | | | |
| 1.45 | $B_q$,C,D,F,M,$Q_M$ | 39°49’47”/83°38’36” | Ust. South Charleston WWTP | South Charleston |
| *1.40* | *E* | *39°49 46 /83°38 40* | *South Charleston WWTP effluent* | *South Charleston* |
| 1.35 | $B_q$,F,M | 39°49’43”/83°38’42” | Dst. South Charleston WWTP | South Charleston |
| 0.50 | B,$C_o$,D,F,M,$Q_M$,S | 39°49’49”/83°39’32” | Dst. South Charleston WWTP | South Charleston |
| 0.01 | D,M | 39°49’47”/83°40’03” | @ mouth | South Charleston |
| ***Lisbon Fork*** | | | | |
| 0.40 | $B_q$,C,D,F,M,$Q_M$ | 39°50’28”/83°40’20” | Old Springfield Rd. | South Charleston |

Table 6. continued.

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***North Fork Little Miami River*** | | | | |
| 7.15 | $B_q$,C,F | 39°52’38”/83°44’15” | Mitchell Rd. | New Moorefield |
| 2.6 | F | 39°49’42”/83°46’37” | Jackson Rd. | Clifton |
| 0.37 | $B_q$,$C_o$,D,M,$Q_M$,S | 39°48’29”/83°47’24” | North River Rd. | Clifton |
| ***Goose Creek*** | | | | |
| 0.92 | $B_q$,C | 39°49’42”/83°47’44” | Jackson Rd. | Clifton |
| ***Yellow Springs Creek*** | | | | |
| 0.10 | B,$C_o$,D,F,M,$Q_M$,S | 39°47’10”/83°52’40” | Grinnel Rd. | Yellow Springs |
| ***Jacoby Branch*** | | | | |
| 0.50 | $B_q$,C,D,F,M,$Q_M$ | 39°46’03”/83°54’57” | Ust. US 68 | Yellow Springs |
| ***Conner Branch*** | | | | |
| 0.16 | $B_q$,C,D,F,M,$Q_M$ | 39°45’16”/83°55’35” | Dst. US 68 | Yellow Springs |
| ***Massie Creek*** | | | | |
| 8.96 | D,M | 39°44’21”/83°49’04” | Ust. Cedarville WWTP | Cedarville |
| *8.95* | *E* | *39°44 21 /83°49 03* | *Cedarville WWTP effluent* | *Cedarville* |
| 8.25 | D,M,$Q_M$ | 39°44’19”/83°49’46” | Indian Mound Park | Cedarville |
| 7.71 | B,$C_o$,F,S | 39°44’14”/83°50’20” | Tarbox Cemetary Rd. | Cedarville |
| 7.16 | D,M | 39°44’09”/83°50’51” | Dst. Tarbox Cemetary Rd. | Cedarville |
| 5.58 | B,D,F,M | 39°43’45”/83°52’15” | Charelton Mill Rd. | Cedarville |
| 4.38 | B,C,D,F,M,Q | 39°43’21”/83°52’56” | Wilberforce Clifton Rd. | Xenia |
| 2.75 | D,M,$Q_M$ | 39°44’06”/83°53’56” | Stevenson Rd | Xenia |
| 1.20 | B,C,D,F,M,$Q_M$ | 39°44’24”/83°55’13” | Fawcett Drive, Dst. Clark Run | Xenia |
| 0.26 | $C_o$,M,$Q_M$, S | 39°44’09”/83°56’09” | Ust. US 68, Ust. Oldtown Creek | Xenia |
| 0.20 | D,M,$Q_M$ | 39°44’09”/83°56’12” | Dst. US 68, Dst. Oldtown Creek | Xenia |
| 0.05 | D,M,$Q_M$ | 39°44’11”/83°56’23” | Near mouth | Xenia |
| ***North Fork Massie Creek*** | | | | |
| 7.95 | $B_q$,C | 39°45’48”/83°41’40” | Selma - Jamestown Rd. | South Charleston |
| 5.9 | F | 39°46’51”/83°43’38” | @ Walkman Rd and Old US 42 | South Charleston |
| 1.17 | $B_q$,$C_o$,F,M,$Q_M$ | 39°45’21”/83°47’30” | James Barber Rd. | Clifton |
| ***South Fork Massie Creek*** | | | | |
| 2.15 | $B_q$,C,F,M,$Q_M$ | 39°44’17”/83°45’55” | Weimer Rd., Ust. Cedarville Limestone | Cedarville |
| 0.14 | $B_q$,C,F | 39°44’32”/83°48’04” | Dst. Cedarville Limestone | Cedarville |
| ***Tributary to Massie Creek @ RM 5.31*** | | | | |
| 0.65 | $B_q$,C | 39°43’23”/83°51’36” | Adj. Charleton Mill Rd. | Cedarville |
| ***Clark Run*** | | | | |
| 0.44 | $B_q$,C,F,M,$Q_M$ | 39°44’27”/83°53’38” | Stevenson Rd | Xenia |

Table 6. Continued.

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***Oldtown Creek*** | | | | |
| 0.10 | $B_q$,C,F,M,$Q_M$ | 39°44’09”/83°56’08” | Near mouth | Xenia |
| ***Ludlow Creek*** | | | | |
| 0.25 | $B_q$,$C_o$,F,M,$Q_M$,S | 39°42’54”/83°58’32” | Hilltop Rd. | Xenia |
| ***Shawnee Creek*** | | | | |
| 0.65 | $B_q$,$C_o$,F,M,$Q_M$,S | 39°42’13”/83°57’59” | Hawkins Rd. | Xenia |
| ***Beaver Creek*** | | | | |
| 6.30 | $B_q$,C,F,S | 39°46’01”/84°00’28” | New Germany - Trebein Rd. | Fairborn |
| 3.86 | B,C,F | 39°44’17”/84°00’38” | Fairgrounds Rd. | Bellbrook |
| 1.57 | B,$C_o$,F,$Q_M$ | 39°42’50”/84°01’16” | Dayton - Xenia Rd., Ust. L. Beaver Cr. | Bellbrook |
| 0.50 | B,C,F,S | 39°42’35”/84°01’43” | Ust. Beaver Creek WWTP | Bellbrook |
| *0.39* | *$B_q$,F* | *39°42 01 /84°01 39* | *Beaver Creek WWTP mixing zone* | *Bellbrook* |
| 0.20 | B,$C_o$,F,$Q_M$,S | 39°41’53”/84°01’37” | Dst. Beaver Creek WWTP | Bellbrook |
| ***Little Beaver Creek*** | | | | |
| 6.23 | $B_q$,C | 39°42’25”/84°07’01” | Vale Rd. | Bellbrook |
| 4.62 | B,$C_o$,F,S | 39°43’35”/84°06’12” | Ust. Mont. Co. E. Regional WWTP | Bellbrook |
| *4.57* | *$B_q$,F* | *39°43 39 /84°06 12* | *Mont. Co. E. Reg. WWTP mixing zone* | *Bellbrook* |
| 4.40 | $C_o$,S | 39°43’41”/84°06’08” | Dst. Mont. Co. E. Reg. WWTP | Bellbrook |
| 3.54 | S | 39°43’37”/84°05’08” | Ust. Grange Hall Rd. | Bellbrook |
| 3.47 | B,C,F,S | 39°43’37”/84°05’04” | Dst. Grange Hall Rd. | Bellbrook |
| 1.95 | B,C | 39°43’22”/84°03’30” | North Fairfield Rd. | Bellbrook |
| 0.05 | B,$C_o$,F,$Q_M$,S | 39°42’35”/84°01’43” | Factory Rd. | Bellbrook |
| ***Tributary to Little Beaver Creek @ RM 6.1*** | | | | |
| 0.15 | $B_q$,C | 39°42’30”/84°07’06” | Galewood Rd. | Bellbrook |
| ***Sugar Creek*** | | | | |
| 2.13 | $B_q$,C,F | 39°37’40”/84°04’46” | Spring Lakes entrance-Ferry Rd. | Bellbrook |
| 0.40 | $B_q$,$C_o$,F,M,$Q_M$,S | 39°37’15”/84°03’26” | Penewit Rd. | Waynesville |
| ***Little Sugar Creek*** | | | | |
| 0.45 | $B_q$,C,F,S | 39°38’06”/84°04’31” | Adj. Maple St. | Bellbrook |
| ***Glady Run*** | | | | |
| 5.8 | B,F | 39°40’01”/83°57’27” | Ust. Xenia-Glady Run WWTP | Xenia |
| 4.99 | C | 39°39’39”/83°57’51” | Ust. Xenia-Glady Run WWTP | Xenia |
| *4.9* | *$B_q$,F* | *39°39 36 /83°57 53* | *Xenia Glady Run WWTP mixing zone* | *Xenia* |
| 4.08 | B,$C_o$,F,$Q_M$,S | 39°39’00”/83°58’32” | Hedges Rd. | Xenia |
| 2.08 | B,C,F | 39°37’58”/83°59’45” | Schnebly Rd. | Xenia |
| 0.54 | M,$Q_M$ | 39°37’02”/84°00’38” | SR 725 | Waynesville |

Table 6. Continued.

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***Tributary to LMR @ RM 69.85*** | | | | |
| 0.10 | $B_q$,C,$Q_M$ | 39°39’43”/84°02’35” | Ust. Upper Bellbrook Rd. | Bellbrook |
| ***Tributary to LMR @ RM 62.01*** | | | | |
| 0.55 | $B_q$,C,F,$Q_M$ | 39°35’02”/84°00’47” | Houston Rd. | Waynesville |
| ***Tributary to LMR @ RM 60.5*** | | | | |
| 0.20 | $B_q$,C,F,$Q_M$ | 39°34’48”/84°01’59” | US 42 | Waynesville |
| ***Mill Run*** | | | | |
| 1.74 | C,F,$Q_M$ | 39°33’21”/84°03’60” | Xenia Old Stage Rd. | Waynesville |
| ***Newman Run*** | | | | |
| 0.27 | $B_q$,C,F,$Q_M$,S | 39°31’04”/84°05’53” | US 42 | Waynesville |
| ***Caesar Creek*** | | | | |
| 26.50 | $B_q$,C,F,S | 39°38’33”/83°49’11” | New Jasper - Paintersville Rd. | Cedarville |
| 23.10 | $B_q$,$C_o$,F | 39°37’60”/83°52’11” | Stone Rd., Dst. N&S Branch Caesar Cr. | Cedarville |
| 16.52 | B,$C_o$,D,F,S | 39°35’58”/83°57’53” | Spring Valley - Paintersville Rd. | New Burlington |
| 2.70 | D | 39°28’57”/84°03’53” | O’Neall Rd., Dst. Caesar Creek Lake | Oregonia |
| 0.15 | $B_q$,C,F,S | 39°29’34”/84°06’06” | Corwin Rd., Dst. Caesar Creek Lake | Oregonia |
| ***North Branch Caesar Creek*** | | | | |
| 6.66 | $B_q$,C,F | 39°40’51”/83°46’20” | Junkin Rd. | Cedarville |
| 1.23 | $B_q$,C,F,S | 39°39’28”/83°49’45” | Jaspar Rd. | Cedarville |
| ***South Branch Caesar Creek*** | | | | |
| 8.23 | $B_q$,C | 39°38’53”/83°44’51” | Cemetary Road (Sheeley) | Jamestown |
| 2.10 | $B_q$,$C_o$,F,S | 39°37’48”/83°50’04” | Hoop Rd. | Cedarville |
| ***Anderson Fork*** | | | | |
| 18.80 | $B_q$,C,F | 39°30’58”/83°45’08” | Haley Rd. | Port William |
| 13.87 | $B_q$,$C_o$,F | 39°33’12”/83°47’45” | Port William Rd. | Port William |
| 9.45 | $B_q$,C,F,S | 39°32’37”/83°51’01” | US 68 | Port William |
| 4.90 | B,$C_o$,F,S | 39°33’59”/83°54’10” | Old Winchester Trail | New Burlington |
| ***Painters Creek*** | | | | |
| 0.43 | $B_q$,C,F | 39°33’51”/83°52’43” | Eleazer Rd. | New Burlington |
| ***Buck Run*** | | | | |
| 1.18 | $B_q$,C,F | 39°32’44”/83°57’31” | SR 380 | New Burlington |
| ***Trace Run*** | | | | |
| 1.83 | $B_q$,C,F | 39°30’31”/82°58’11” | Brimstone - Mills Rd. | New Burlington |

Table 6. Continued.

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***Jonahs Run*** | | | | |
| 1.32 | $B_q$,C,F | 39°29’41”/84°01’35” | Near Lunkens Rd. | Oregonia |
| ***Flat Fork*** | | | | |
| 1.70 | $B_q$,C,F | 39°28’26”/84°02’46” | Oregonia Rd. | Oregonia |
| ***Todd Fork*** | | | | |
| 20.3 | F | 39°26’45”/83°56’19” | Adj. SR 380 | Clarksville |
| 19.50 | B,$C_o$,F | 39°26’09”/83°56’40” | US 22/3 | Clarksville |
| 15.17 | B,F,S | 39°24’22”/83°59’20” | Spring Hill Rd. | Clarksville |
| 8.53 | $B_q$,C | 39°21’44”/84°03’28” | Ust. Middleboro Rd. | Pleasant Plain |
| 5.6 | F | 39°21’07”/83°04’30” | Roachester-Osceola Rd | Clarksville |
| 2.65 | B,C,F | 39°20’28”/84°06’14” | Achterman Rd., Dst. Second Creek | Pleasant Plain |
| 0.14 | $B_q$,$C_o$,F,S | 39°21’13”/84°07’47” | US 22/3 @ Morrow | S. Lebanon |
| ***Lytle Creek*** | | | | |
| 9.25 | $B_q$,$C_o$,F,S | 39°26’15”/83°49’09” | Adj. Townsend Field, Dst. ABX | Wilmington |
| 7.01 | $B_q$,$C_o$,D,F,S | 39°26’18”/83°51’05” | Nelson Rd. | Wilmington |
| *6.7* | *$B_q$,F* | *39°26 17 /83°51 18* | *Wilmington WWTP mixing zone* | *Wilmington* |
| 5.94 | $B_q$,$C_o$,F,S | 39°26’27”/83°52’01” | Buffalo Farm off US 22/3 | Wilmington |
| 2.76 | $B_q$,C,F | 39°25’49”/83°54’35” | Ogden Rd. | Clarksville |
| ***Cowan Creek*** | | | | |
| 13.20 | $B_q$,$C_o$,D,F,S | 39°24’26”/83°47’52” | Jenkins Rd., Ust. Indian Run & ABX | Wilmington |
| 12.45 | $B_q$,$C_o$,D,F,S | 39°24’10”/83°48’05” | Adj. Jenkins Rd., Dst. ABX/Indian Run | Wilmington |
| 10.95 | $B_q$,C,F | 39°24’18”/83°49’23” | Adj. Ireland Rd. | Wilmington |
| 8.38 | $B_q$,C,D,F,S | 39°23’25”/83°50’50” | Cuba Pike | Wilmington |
| 1.34 | $B_q$,$C_o$,F,S | 39°24’15”/83°57’01” | Adj. Cowan Creek Rd., Dst. Cowan Lake | Clarksville |
| ***Indian Run*** | | | | |
| 0.10 | $B_q$,$C_o$,F,S | 39°24’33”/83°47’54” | Near mouth, Dst. ABX | Wilmington |
| ***East Fork Todd Fork*** | | | | |
| 1.60 | $B_q$,$C_o$,F,S | 39°23’55”/83°58’59” | SR 132 | Clarksville |
| ***Turtle Creek*** | | | | |
| 0.4 | B,F | 39°22’19”/83°13’16” | Dst. old Cincinnati Milacron discharge | S. Lebanon |
| ***Muddy Creek*** | | | | |
| 3.50 | $B_q$,C,F | 39°22’21”/84°17’18” | SR 741, Ust. Mason WWTP | Mason |
| *3.24* | *$B_q$,F* | 39°22’29”/84°17’07” | *Mason WWTP mixing zone* | *Monroe* |
| 2.50 | $B_q$,$C_o$,F,S | 39°22’26”/84°16’30” | Mason-Morrow Rd., Dst. Mason WWTP | Mason |
| 0.70 | $B_q$,C,F | 39°22’19”/84°15’03” | Ust. I-71@ Columbia Rd. | Mason |

Table 6. Continued.

| ***Stream*** RM | Type of Sampling | Latitude/Longitude | Landmark | USGS Quad.Map |
|---|---|---|---|---|
| ***Simpson Creek*** | | | | |
| 0.15 | $B_q$,C,F | 39°19’17”/84°15’19” | Foster Rd., Ust. Lower LMR WWTP | Mason |
| *0.14* | *$B_q$,F* | 39°19’15”/84°15’17” | *Warren Co. Lower LMR WWTP mz* | *Mason* |
| 0.01 | B,$C_o$,F,S | 39°19’13”/84°15’12” | Foster Rd., Dst. Lower LMR WWTP | Mason |
| ***O BANNON Creek*** | | | | |
| 4.37 | $B_q$,C,F | 39°14’57”/84°12’05” | Gibson Rd., Ust. O’Bannon WWTP | Goshen |
| *2.57* | *$B_q$,F* | *39°15 34 /84°13 21* | *O Bannon WWTP mixing zone* | *S. Lebanon* |
| 2.4 | $B_q$,F | 39°15’32”/84°13’25” | | |
| 1.84 | $C_o$ | 39°15’53”/84°13’57” | O'Bannonville Rd., Dst. WWTP | S. Lebanon |
| 0.26 | $B_q$,C,F,S | 39°16’07”/84°15’21” | SR 48 | Mason |
| ***Stony Run*** | | | | |
| 0.12 | $B_q$,C | 39°15’02”/84°11’59” | Gibson Rd. | S. Lebanon |
| ***Sycamore Creek*** | | | | |
| 0.53 | $B_q$,C | 39°13’21”/84°19’44” | Spooky Hollow Rd., Ust. N. Branch Cr. | Madeira |
| 0.4 | F | 39°13’22”/84°19’41” | Ust. Sycamore Creek WWTP | Madeira |
| *0.26* | *$B_q$,F* | 39°13’30”/84°19’25” | *Sycamore Cr. WWTP mixing zone* | *Madeira* |
| 0.20 | $B_q$,$C_o$,F,S | 39°13’33”/84°19’21” | Dst. Sycamore Creek WWTP | Madeira |

# METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995). Chemical, physical and biological sampling locations are listed in Table 5.

***Determining Use Attainment Status***

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-14). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (see Table 1) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and comments and observations for each sampling location.

The attainment status of aquatic life uses (*i.e.,* full, partial, and non-attainment) 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 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 1987). 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 is fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS.

***Habitat Assessment***

Physical habitats were 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 habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer 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 whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

***Macroinvertebrate Community Assessment***

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

Macroinvertebrates were sampled at 128 locations (Table 6) in the Little Miami River basin. Artificial (quantitative) and natural substrate (qualitative) samples were collected at 49 locations, and natural substrate only samples were collected at the remaining 79 sites. Lists of macroinvertebrate taxa and ICI metric scores from each site in the study area are available electronically on the Ohio EPA Division of Surface Water home page at http://chagrin.epa.ohio.gov/.

***Fish Community Assessment***

Fish communities were sampled twice at the same location 4 to 5 weeks apart in the Little Miami River mainstem, and in tributaries receiving wastewater from a permitted discharger. The only exception to this was downstream from the Waynesville WWTP were three samples were collected. Otherwise only one fish sample was collected. All samples were collected using either the longline or wading electrofishing methodology. Lists of fish species and their relative abundance and IBI metric scores from each site in the study area are available electronically on the Ohio EPA Division

of Surface Water home page at http://chagrin.epa.ohio.gov/.

***Area of Degradation Value (ADV)***

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Figure 5). 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 expressed as ADV/mile to normalize comparisons between segments, sampling years, and other streams and rivers. The ADV was simplified to an average percent deviation from respective criterion for the IBI, ICI and MIwb in Figure 2.

***Causal Associations***

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al*. 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem “health” compared to human patient “health” (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

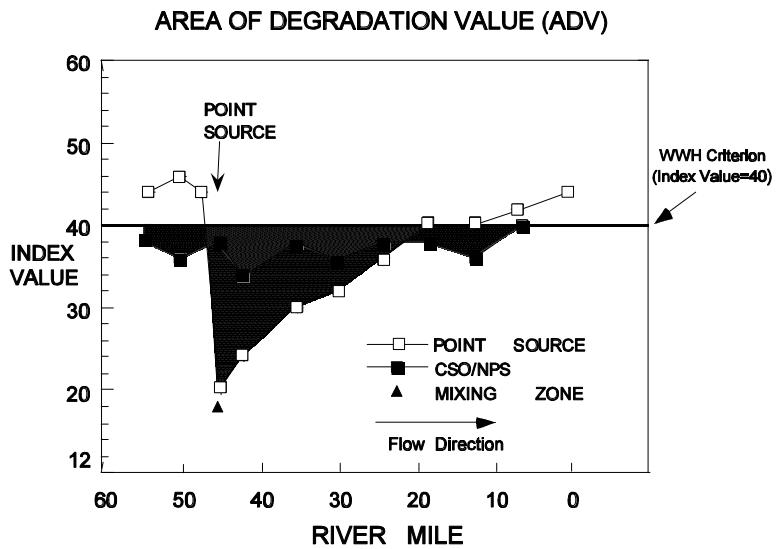



Figure 5. Conceptual illustration of how the Area of Degradation Value (ADV) is calculated based on the ecoregion biocriterion (WWH = 40 in this example). Hypothetical biological index scores for two scenarios are plotted as unfilled boxes and solid boxes. The unfilled boxes represent a typical response to a point source impact (the mixing zone appears as a solid triangle), and the solid shading shows the associated area of departure; the filled boxes represent a typical response to a nonpoint source or combined sewer overflow impact with the dashed shading showing its associated area of departure. The blended shading represents the overlapping impact of the point and nonpoint sources. The ADV in either example is calculated from the area bounded by the criterion line, in this case 40, and the line created by joining the plotted scores.

## Pollutant Loadings and NPDES Discharger Descriptions

### Airbone Express

A detailed description of the ABX stormwater collection and discharge system is found in the "Alternative Effluent Limitations Study Report" prepared by Malcolm Pirnie, Inc., 1998, and submitted to the Ohio EPA. In short, ABX uses propylene glycol as a deicer for aircraft and potasium formate for the runways. Spent propylene glycol is discharged via a series of outfalls directly to Lytle Creek and Indian Run, and indirectly to Cowan Creek via Indian Run. Propylene glycol released to surface waters is removed mainly by biological processes, consequently biological oxygen demand is the major concern regarding its release. Current loadings of propylene glycol result in frequent anoxia in Lytle Creek and occasional anoxia in Indian Run. Residual contamination from discontinued urea-based deicers results in measurable loadings of ammonia-nitrogen to Lytle Creek and Indian Run. Those loadings have decreased in each of the last 3 years (Figures 6 - 8), and did not adversely impact water quality measured during the summer low-flow period in 1998. However, peak loadings during wet weather in winter may result in high instream concentrations of ammonia given that the 95th percentile effluent concentration at the 002 outfall in 1998 was 5.33 mg/l.

### Village of Blanchester WWTP (RM 10.10)

The Blanchester WWTP discharges to Second Creek operating as a primary treatment works employing two polishing ponds. The service area is 100% sewered (two percent being combined sewers), serving a current population of 4,700 with slow population growth expected. Enforcement action against the Village of Blanchester initially commenced in 1988 (modified 1992). The village was found to be in violation of Ohio Water Pollution Control Laws. The Village of Blanchester WWTP was converted into an activated sludge plant in 1989 by converting the effluent polishing ponds into an aeration lagoon. Oxidation ditches were added and on-line by January, 1998. Blanchester's original design flow of 0.78 MGD was expanded to a design flow of 0.99 MGD in 1996. Initially compliance with total suspended solids (TSS), due primarily to operational approaches, was not achievable and created an even longer record of noncompliance for the facility however compliance for this parameter has been reported below NPDES limits.

As an additional condition of the enforcement action by Ohio EPA against the Village of Blanchester (Consent Decree) the Village of Blanchester was required to investigate their inflow/infiltration (I/I) contribution to the collection system and propose a plan to correct sewer system defects. The preliminary investigation was conducted from November, 1997 to June, 1999. As part of the I/I evaluation precipitation totals (rain and snow), WWTP flows and water treatment plant distribution numbers (minus percent return factors) are considered. Additional requirements to the Consent Decree involved The Village of Blanchester assessing options of separating the combined sewer system on Main Street which currently receives inflow originating from paved and grassy surfaces and roof drains. The I/I project is targeted for completion by April of 2001 at a cost of $950,000.

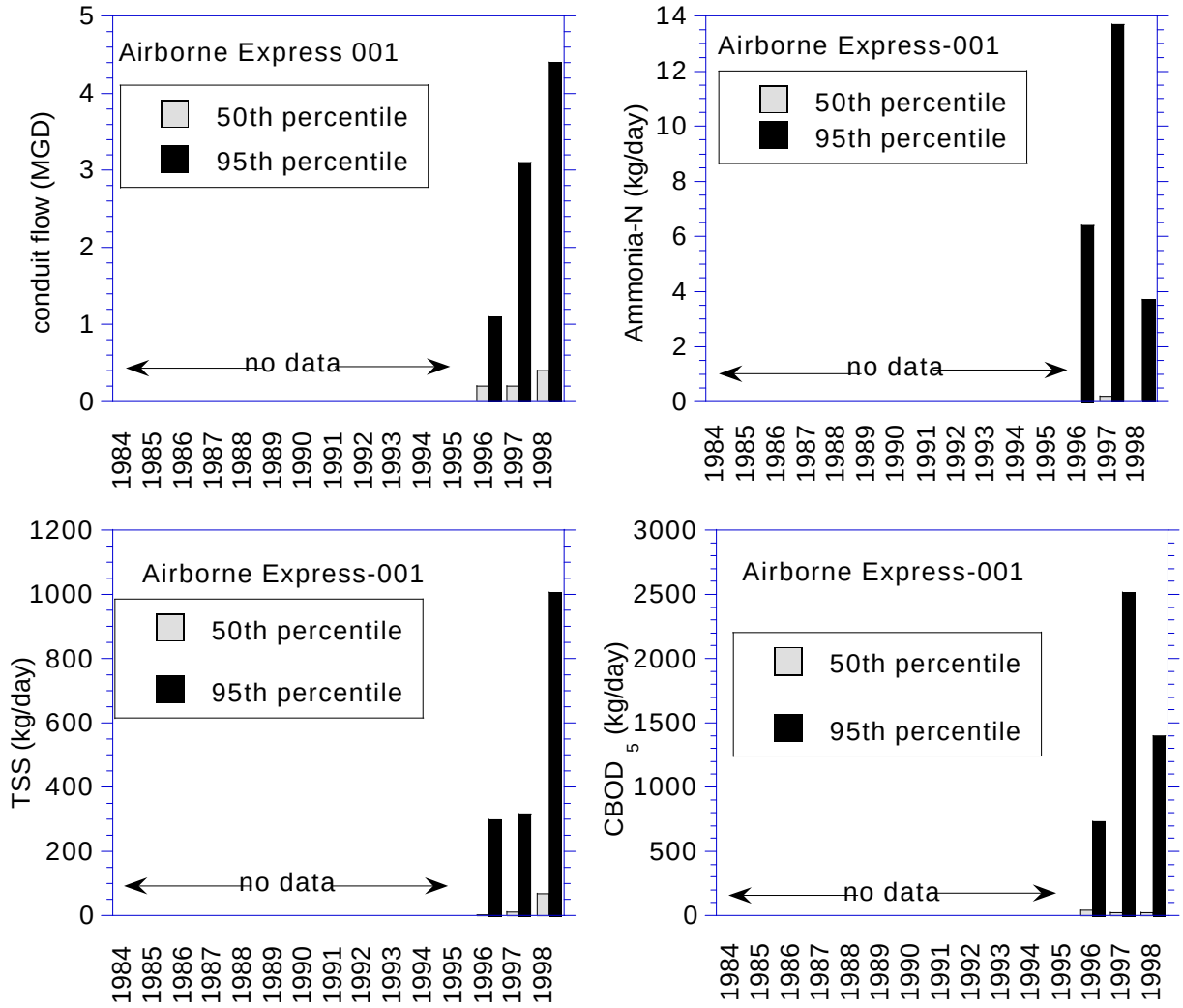



Figure 6. Annual median and 95th percentile conduit flow and loadings of ammonia-N, total suspended solids, and five-day biochemical oxygen demand from the Airborne Express 001 outfall to Lytle Creek.

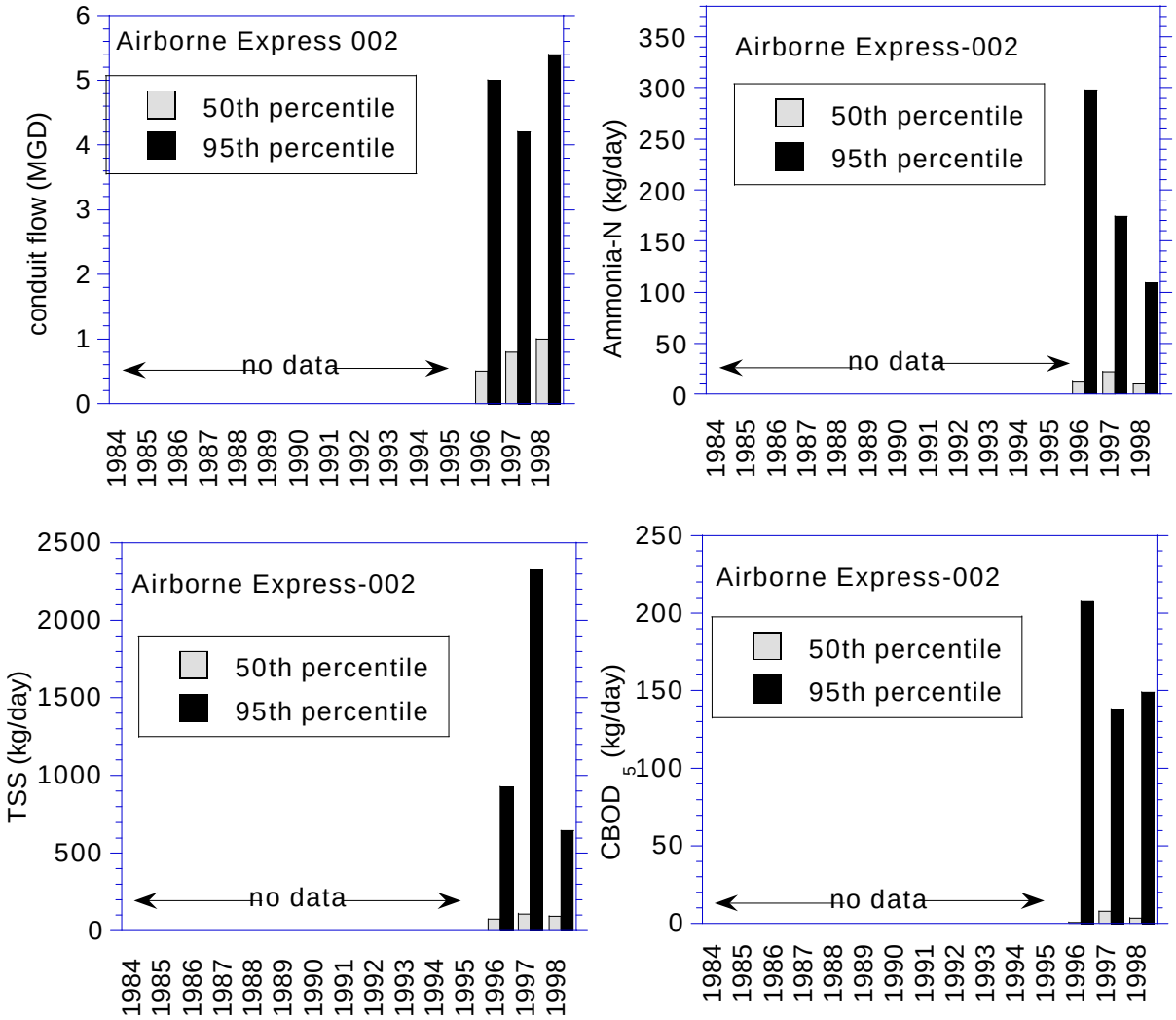



Figure 7. Annual median and 95th percentile conduit flow and loadings of ammonia-N, total suspended solids, and five-day biochemical oxygen demand from the Airborne Express 002 outfall to Lytle Creek.

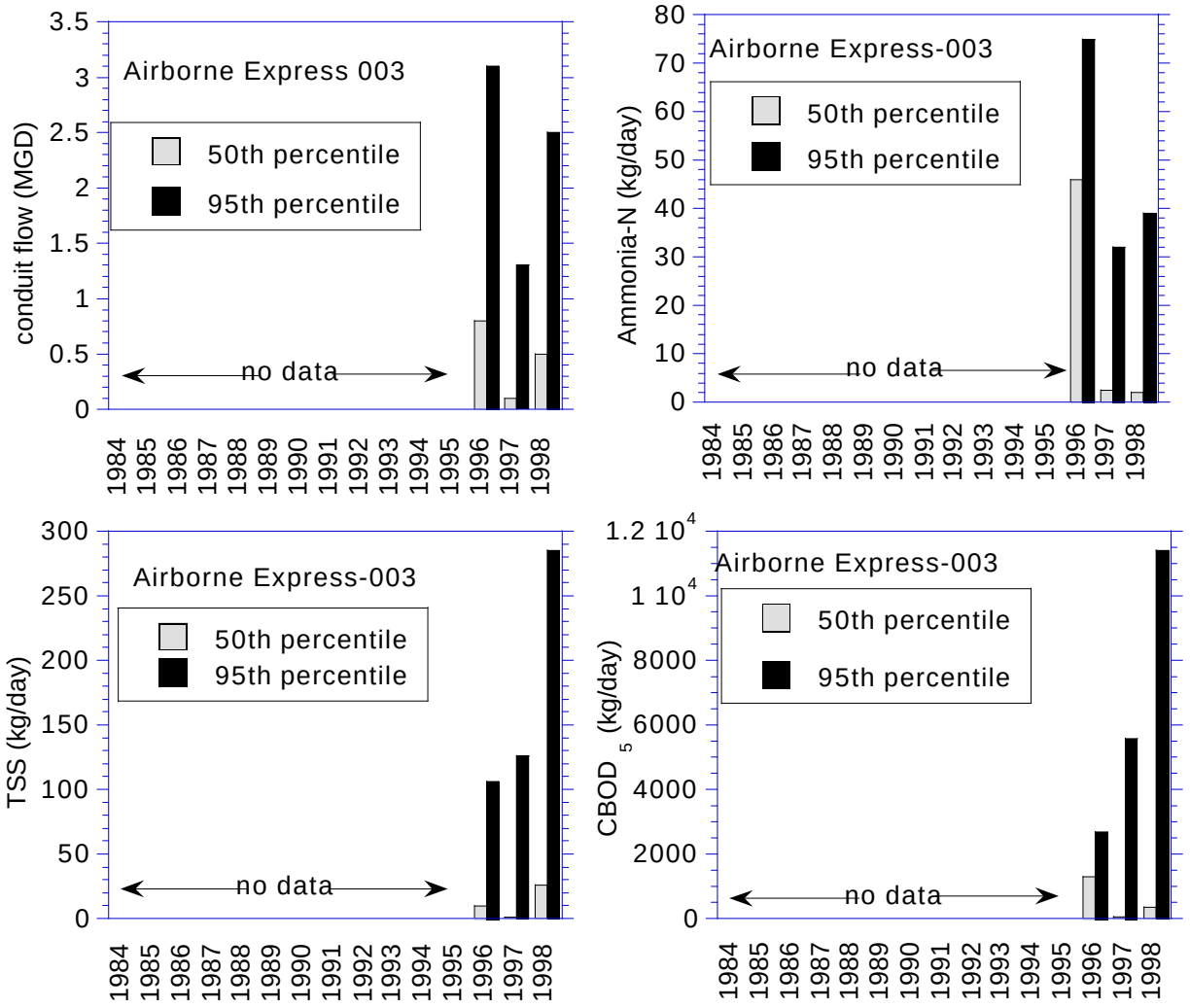



Figure 8. Annual median and 95th percentile conduit flow and loadings of ammonia-N, total suspended solids, and five-day biochemical oxygen demand from the Airborne Express 003 outfall to Lytle Creek.

Aging onsite systems (and recently a few onsite system failures) north of the Village of Blanchester, have occurred in the relatively dense and unsewered area of Northview, increasing connection pressure on the Village of Blanchester. A proposed sewer extension, that would connect the unincorporated and unsewered Village of Midland (east of Blanchester), was presented to the Village of Blanchester in 1994. Blanchester declined to extend their system at that time due to cost concerns. Following a site inspection by Ohio EPA in 1997, unsatisfactory ratings and suggestions for improvements were provided to the Village of Blanchester in the areas of Effluent/Receiving Waters, Sludge Storage/Disposal and Compliance Schedules. Unsatisfactory ratings for Effluent/Receiving Waters were due to current plant configurations where approximately 50% of primary clarifier effluent was being sent to trickling filters. Inadequate waste sludge storage prompted unsatisfactory ratings for the Sludge Storage/Disposal section. Delays in WWTP improvements and collection system investigations rendered unsatisfactory ratings in the Compliance Schedules section of the inspection. Multimedia observations at the WWTP, that included visual inspection of the outfall area and facility ground housekeeping , were also noted during the inspection and reported such items as distressed vegetation near the outfall and unsecured drums, liquids or damaged containment facilities.

Annual median conduit flow typically exceeded the average design flow of 0.7800 MGD from 1990 until 1996 when an expansion eliminated design exceedences. Variability in percentiles and NPDES violations decreased minimally after the upgrade in 1994 and expansion in 1996. Conventional parameter variability mimicked flow fluctuations graphically correlating with NPDES violations observed from1996-1998. Inflow and infiltration problems, due to degrading collection systems, are evident at this plant. Fifty-nine (59) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to five parameters: ammonia-N, $cBOD_5$, total residual chlorine, fecal coliform and copper (total). Forty-nine percent (49%) of the NPDES violations occurred between 1996 and 1998 (26 violations in 1997) with all conventional parameters appearing in all years. Blanchester ranked fourth in number of NPDES violations, from 1993-1998, of 29 dischargers evaluated.

**Clermont County Miami Trails WWTP (RM 22.60 at mainstem)**

Constructed in 1988 and modified in 1992 (Phase III-aeration tank and clarifier) and 1994, the Clermont County Miami Trails WWTP utilizes bar screen, flow equalization tank, extended aeration, secondary settling, fixed media clarification, surface sand filtration, disinfection, post aeration and sludge holding tanks. The facility WWTP was constructed to serve one to two subdivisions (no commercial development) of approximately 400-500 single family homes. The collection system is separate with three lift stations (no reported bypasses or overflows) and 100% of the service area is sewered. Currently Clermont County Miami Trails WWTP design flow is 0.203 gpd and discharges through a long effluent sewer to an unnamed tributary to the LMR (200’ east of LMR) downstream of the Hamilton County MSD’s Polk Run WWTP’s outfall (001). Recently the facility has submitted an application for expansion to 0.400 gpd which is currently under review. Numerous facility bypass incidences (no reportable quantities or duration) were reported from 1996-1999 and ascribed primarily to weather conditions.

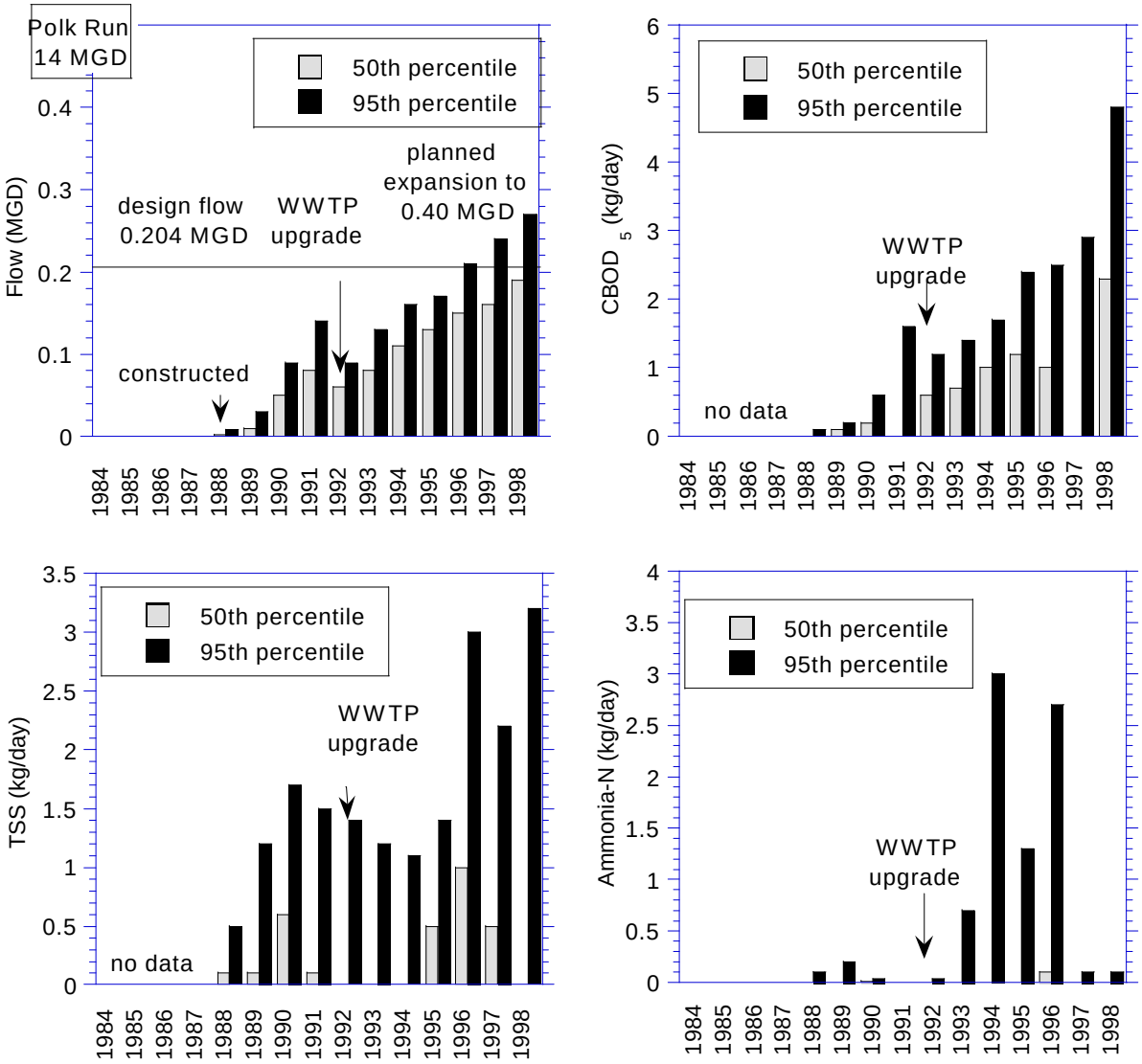



Figure 9. Median and 95th percentile annual flows and loadings of five-day biochemical oxygen demand, total suspended solids and ammonia-nitrogen from the Miami Trails WWTP to the Little Miami River, 1984 - 1998. The Polk Run WWTP median discharge is shown for comparison.

Annual median and 95th percentile conduit flow shows a moderately increasing trend between 1988 and 1998 (Figure 9). Conduit flows for 95th percentile began exceeding design flow in 1996 demonstrating a present need to expand current design capacity either due to increased inflow and infiltration (I/I) concerns or rapid population growth for the area. Annual median and 95th percentiles for $cBOD_5$ and ammonia-N were commensurate with flow percentile behavior revealing negligible variance in the conventional parameters in response to fairly predictable flows . Annual median and 95th percentile variance for TSS from 1996-1998 was likely in response to exceeded design flow capacity for those same years.

**Clermont Co.-O Bannon Creek WWTP (RM 2.57)**

Constructed in 1984 and upgraded in 1994 , the O'Bannon Creek WWTP is a secondary clarification treatment plant consisting of two stage aeration and rapid sand filters. Ultraviolet light disinfection was added in 1998 and went on-line in 1999. The collection system is separate and contains two lift stations. Eighty percent (80%) of the service area is sewered and serves a population of 11,400. Moderate to high growth is predicted for the service area. The final effluent discharges to O'Bannon Creek with a current plant design flow of 2.200 MGD (1.200 MGD prior to 1994). Reported plant bypasses and overflows have been attributed to inflow and infiltration (I&I). An improvement plan is being developed to address the I&I problems. Upgrades since 1993 include UV disinfection (online in May, 1999) and two equalization basins (total storage capability of 2.135 MGD), online in September, 1994. This provides a diversion capability of 6.0 MG to the basins and primary treatment, and 4.0 MG through the plant. Wastewater reduction at the facility is achieved seasonally by pumping treated effluent (~300,000 gpd) to a local golf course for irrigation purposes.

In 1995 numerous sewage backup incidences (occurring over several years) at the Paxton Woods Subdivision prompted corrective actions that involved inspecting and installing manhole inserts near the Paxton Lake Subdivision. Also, self sealing manhole lids were installed on the 8" trunk line. More flow monitors were also installed along with extensive televising and smoke testing of sewers. Numerous bypasses of the equalization basins occurred during storm events in 1997 and 1998, causing continued basement backups and flooding. Additionally, numerous critical equipment failures occurred in 1997 contributing to the estimated 15 bypass or overflow events. No current pretreatment program is in place at the O'Bannon WWTP as no known industries currently discharge to the facility.

Three (3) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to two parameters: copper (total) and ammonia-N. Total mercury accounted for 75% of notifications by the entity (occurring primarily in 1997 and 1998), however concentrations remained below the Practical Quantification Level (PQL) for the facility and therefore were considered to be in compliance with the NPDES limit. Preliminary data for 1999 indicate mercury discharges continued for the facility.

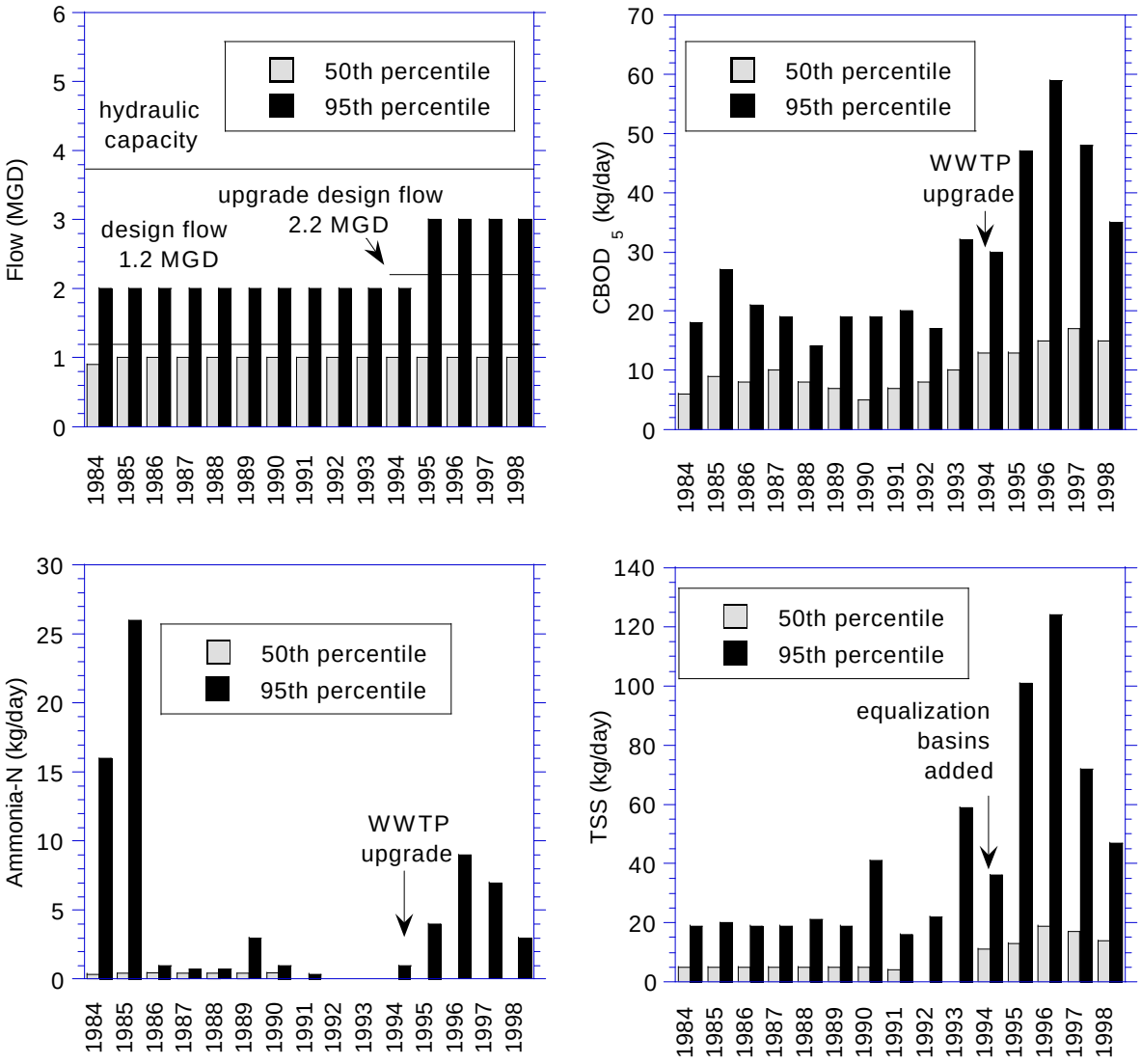



Figure 10. Clockwise from top left: Median and 95th percentile annual flows and effluent loadings of five-day biochemical oxygen demand, ammonia-nitrogen, and total suspended solids by the Clermont County O'Bannon Creek WWTP, 1984 to 1998.

Two acute bioassay testing events, conducted by Ohio EPA in the spring and summer of 1998, revealed no acute toxicity to either *Ceriodaphnia dubia or Pimephales promelas,* in effluent samples or ambient waters. Survival in the laboratory control waters were 95% or greater for both test species. Entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute is measured as lethality) were performed utilizing *C. dubia* and *P. promelas* in two testing events (48-hour) in 1995 and 1996. Test results revealed no acute toxicity to *C. dubia or P. promelas* for the October of 1996 or February of 1995 testing events.

Ninety-fifth percentile flows were typically greater than the 1.200 MGD WWTP design flow, for the majority of the record. Flow increased in percentile variance from 1995-1998 even after the introduction of equalization basins in 1994 (Figure 10). For an estimated 40 days in 1997, plant inflow was above the plant design of 2.20 MGD demonstrating the continued influence of I&I on the facility treatment system. A year prior to and subsequent to the addition of equalization basins (1994), variation in loadings of conventional parameters (*i.e.*, 5-day biochemical oxygen demand ($cBOD_{5)}$, total suspended solids (TSS), and ammonia-nitrogen [$NH_3$-N]) increased commensurate with increased inflow to the plant.

**Clermont County-Wards Corner WWTP (RM 16.8 at mainstem)**

Constructed in 1986, the Wards Corner WWTP was an extended aeration plant utilizing secondary settling, fixed media, clarification, surface sand filtration, post aeration and chlorination. Historically the facility was privately owned by Tipton Associates Inc. In 1995 the Clermont County Sewer District proposed taking over and expanding the Wards Corner WWTP. The Clermont County Wards Corner WWTP currently discharges to an unnamed tributary of the Little Miami River. The service area is 100% sewered with steady population growth predicted. The original facility design flow in 1986 was 0.050 MGD with a hydraulic capacity of 0.100 MGD. The plant expanded in 1997 to a design flow of 0.135 MGD. Expanded design capacity was achieved by improvements to the secondary facility such as equalization basins, additional aeration tanks and U.V disinfection. The efforts in part were to accommodate planned development in the Wards Corner region of a Research and Development (R&D) facility for the International Paper Company. High strength waste will be diverted to a nearby wastewater facility with the appropriate capacity while Wards Corner receives the washwater and sanitary sewage from the new facility.

**Greene County Clifton WWTP (RM 89.1)**

Constructed and online in 1994 the Greene County Clifton WWTP is a secondary treatment facility implementing bar screen, flow equalization, activated sludge and extended aeration, secondary clarification, chlorination (dechlorination) and post aeration. On January 2, 1997, Greene County assumed responsibility of the facility. Discharge is through a four inch pipe that traverses by way of a roadside ditch on the west side of S.R 72 for approximately 100 feet. The discharge cascades down the riverbank (bedrock-terraced waterfall) into the Little Miami River which is flowing through the Clifton Gorge area at RM 89.1 (pool area). The current design flow rate is 0.029 mgd. Average annual 1999 daily flow rates were 0.185 mgd. The facility has one backup generator capable of powering the entire facility. Expansion of the plant is not under review as population growth is expected to be slow with a current population of 210 and a population equivalent of 290.

Collection system is 100% separate and has no bypasses or overflows. Sludge disposal is by land application at agronomic rates and is contracted by Burch Hydro, Inc.

An estimated average inflow and infiltration rate for the facility is 6,000 gpd. The system is a three year old vacuum system and no plans currently exist to minimize I&I at this time. The facility currently has no approved pretreatment program having no significant or minor industrial discharges. Violations of the minimum NPDES limit for dissolved oxygen were noted while reviewing Monthly Operating Reports (MORs) from 1997.

**Greene County-Cedarville WWTP (RM 8.95)**

Constructed in 1952 and upgraded by 1971 with a new plant, the Cedarville WWTP is a secondary treatment plant utilizing contact stabilization, and chlorination. The collection system is 100% separate sewers throughout the service area. The facility design capacity is 0.48 MGD and the discharge is to Massie Creek into a ravine upstream of the Clifton Falls area. The population averages 3,800 during June-September and seasonally increases to 4,800 when Cedarville College is in session. The Village of Cedarville has no industrial input making Cedarville College the only user monitored by Greene County.

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

In 1991 numerous notices of violation (NOV) letters were sent to Cedarville for failure to submit Monthly Operating reports (MOR) by the required date. Sludge management is a problem and is presently stored in the sludge lagoon for indefinite time periods. When the design capacity of the WWTP is exceeded, biosolids are subsequently bypassed to Massie Creek. Detailed plans for a WWTP upgrade are being discussed.

Greene County began operation and maintenance of the Cedarville WWTP in October, 1995. Process and operations improvements are currently underway and Greene County has proposed to have the WWTP upgrade completed by late 2000. No flow expansion is proposed due to the saturated service area and stagnant population growth. Collection system and facility bypasses occurring in the spring have been reported since 1996. Fourteen (14) bypass incidences were reported as a reoccurring problem totaling ~722,865 gallons of raw sewage occurring at a manhole located east of the South Lift Station. In 1997 two reported bypasses occurred at the plant discharging to Massie Creek and again at the South Lift Station. Facility and lift station bypasses were attributed primarily to weather and human error. In 1996 an Inflow and Infiltration Study was initiated to determine the extent of stormwater influx into the collection system. Collection system and plant bypasses continued to occur from 1996-1998. As of 1998, I&I problems have been identified and remediation discussions have begun between the Greene County commissioners and contractors.

Thirty-three (33) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to four parameters: $cBOD_5$, TSS, ammonia-N and dissolved oxygen (DO). Sixty one percent of the NPDES violations occurred in 1994, 50% of those were $cBOD_5$. In 1995, thirty percent (30%) of the NPDES violations were split between TSS and $cBOD_5$. No violations were reported by Cedarville WWTP from 1996-1998.

Two acute bioassay events, conducted by the Ohio EPA in August and September, 1993, showed toxicity to both fathead minnows (*Pimephales promelas*) and *C. dubia* in effluent samples. August, 1993 test results revealed *P. promelas* mortality in grab and composite effluent samples for both sampling days. Adverse effects to *C. dubia* occurred in effluent samples but no adverse effects were observed in the Massie Creek samples. September, 1993 consisted of grab samples only and were acutely toxic to both test organisms, *P. promelas* demonstrated nearly 100% mortality for both test days while *C. dubia* exhibited a slightly reduced die-off the first day. Toxicity persisted into the mixing zone for both organisms and test results noted chlorine did not appear to be a causative agent for the toxicity. Definitive bioassay tests (indicates magnitude of toxicity) were invalid due to excessive control mortality, however the LC50 of 27.3% (test result) indicates a potential for chronic toxicity. No violations of the NPDES for ammonia-N were reported in 1993 however violations were reported from 1994-1995. Ohio EPA field crews noted in September of 1993 approximately three feet of solids in Massie Creek at the final outfall location.

Annual median flow averaged 0.300 MGD for the period of record, never exceeding the design flow capacity (Figure 11). Ninety-fifth percentile flow throughout the period were typically greater than the 0.048 MGD design capacity for all fifteen years examined. Plant performance may be periodically disrupted by excessive in-fluent loads, evidenced by annual flows greater than plant capacity. Erratic ninety-fifth percentile loadings, for all conventional parameters, reflect treatment irregularities during the entire period of record. There have been minimal changes within the service area and median flows from the plant have remained consistent indicating operational problems are the likely cause of erratic parameter behavior and not hydraulic overloading.

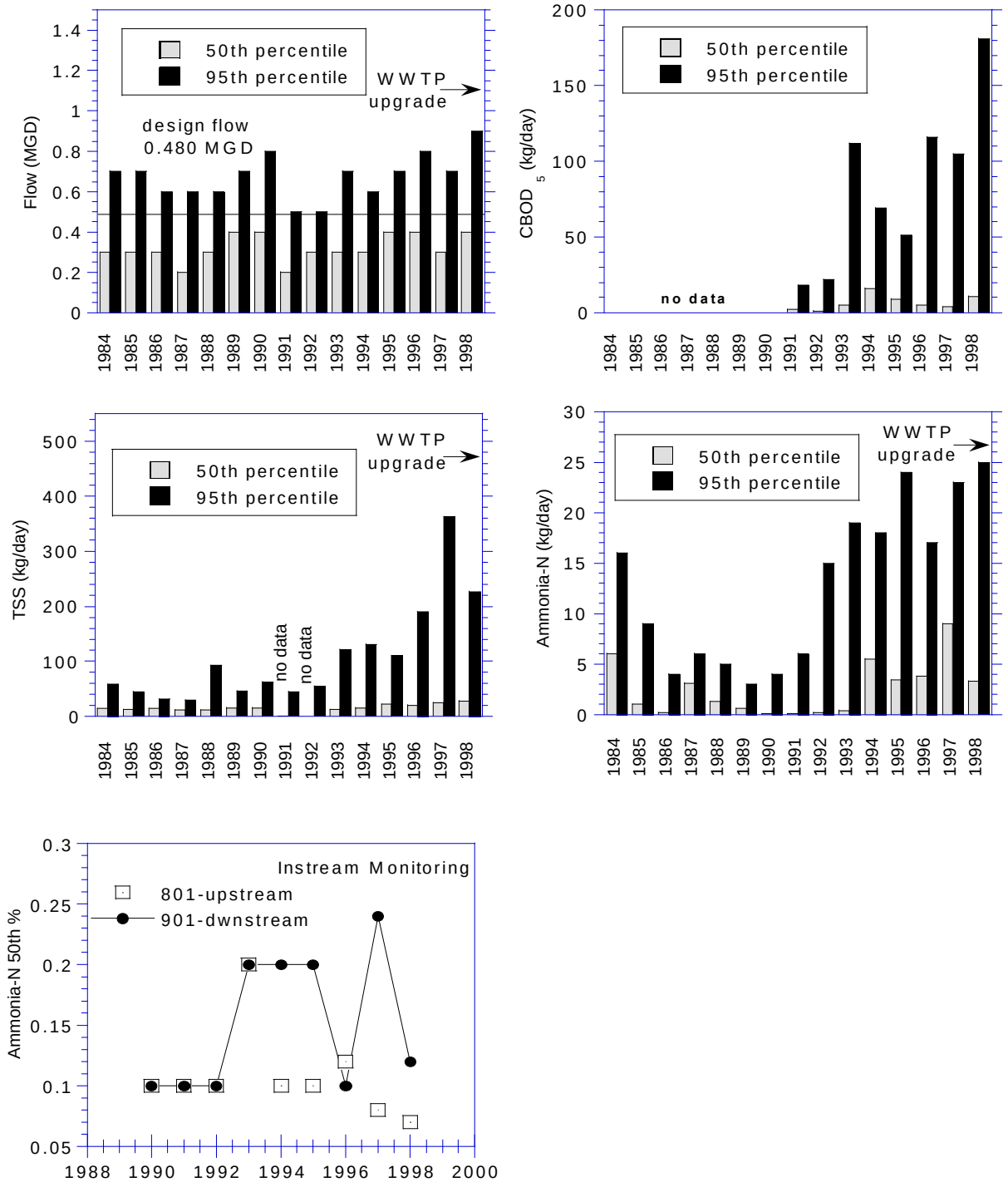



Figure 11. Left to right from the top: Median and 95th percentile annual flows, effluent loadings of biochemical oxygen demand, total suspended solids, ammonia-nitrogen, and mean ammonia-nitrogen concentrations from instream monitoring by the Cedarville WWTP, 1984 to 1998.

**Greene County-Beaver Creek WWTP (RM 72.74 )**

Constructed in 1965 and upgraded in 1988 and 1999, the Beaver Creek WWTP is a secondary plant discharging to the Beaver Creek and served by separate sewers within 100% of the service area. Population is estimated at 32,784 with continued rapid population growth predicted for the area. The Beaver Creek WWTP underwent a major expansion and improvement project completed in September of 1999 (two years to completion). The upgrade increased design flow from 4.70 MGD to 8.50 MGD, more than doubling the size of the plant, which should serve growth through 2015. Improvements included: new in-fluent pumping station receiving preliminary and primary treatment, six horizontal centrifugal pumps, septage handling station, flow equalization, jet mixing system utilizing recirculative basin flow and forced air keeping contents in suspension. Two positive displacement blowers were added along with a distribution structure added to the primary effluent diversion box at the existing plant site. Also added were the addition of a Biological Nutrient Removal system to the secondary treatment, two new secondary clarifiers and a secondary pumping station, U.V disinfection, package pump station for spring wash water and wash down water, new standby power building, and a new lab.

Industrial input to the plant is estimated at 2% and consist of a significant flow from Elano Corporation (metal cleaner) and minor contributions from Universal Technologies (transparency manufacturer), Kray International (government research facility) and JBK Manufacturing (pipe bending). Elano Corporation is the only industrial user that is monitored as part of the pretreatment program and had no reported pretreatment violations from 1996-1998.

Ten (10) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to five parameters: oil & Grease, TSS, fecal coliform, ammonia-N and $cBOD_5$. Total mercury accounted for 33% of notifications by the entity (occurring primarily in 1996 and 1997), however concentrations remained below the Practical Quantification Level (PQL) for the facility and therefore were considered to be in compliance with the NPDES limit. All of the NPDES violations occurred between 1996 and 1998 with all parameters appearing in all years, except 1998, where only one violation of $cBOD_5$ was reported. The Greene County Beaver Creek WWTP modified NPDES permit requirements (for final effluent from 1992 to 2000) eliminated phosphorus and toxicity monitoring and removed limits for cadmium, copper, zinc, and chromium. Cyanide monitoring and limits were established and the chlorine limit reduced. Modified upstream and downstream monitoring (801/901) minimized the frequency of sampling to once a month for most parameters.

Three Ohio EPA conducted acute bioassays in the spring and early summer of 1990, using the test organisms *P. promelas* and *C. dubia,* revealed acute toxicity to *C. dubia* only. Testing conducted in March of 1990 was technically invalid due to excessive mortality for both test organisms in control waters. First day grab samples for April and May of 1990, were acutely toxic and adversely effected motility in nearly all *C. dubia* exposed. Entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* in one testing event (48-hour) in 1996. Test results revealed no acute toxicity to *C. dubia or P.*

*promelas* for the September, 1996 testing event.

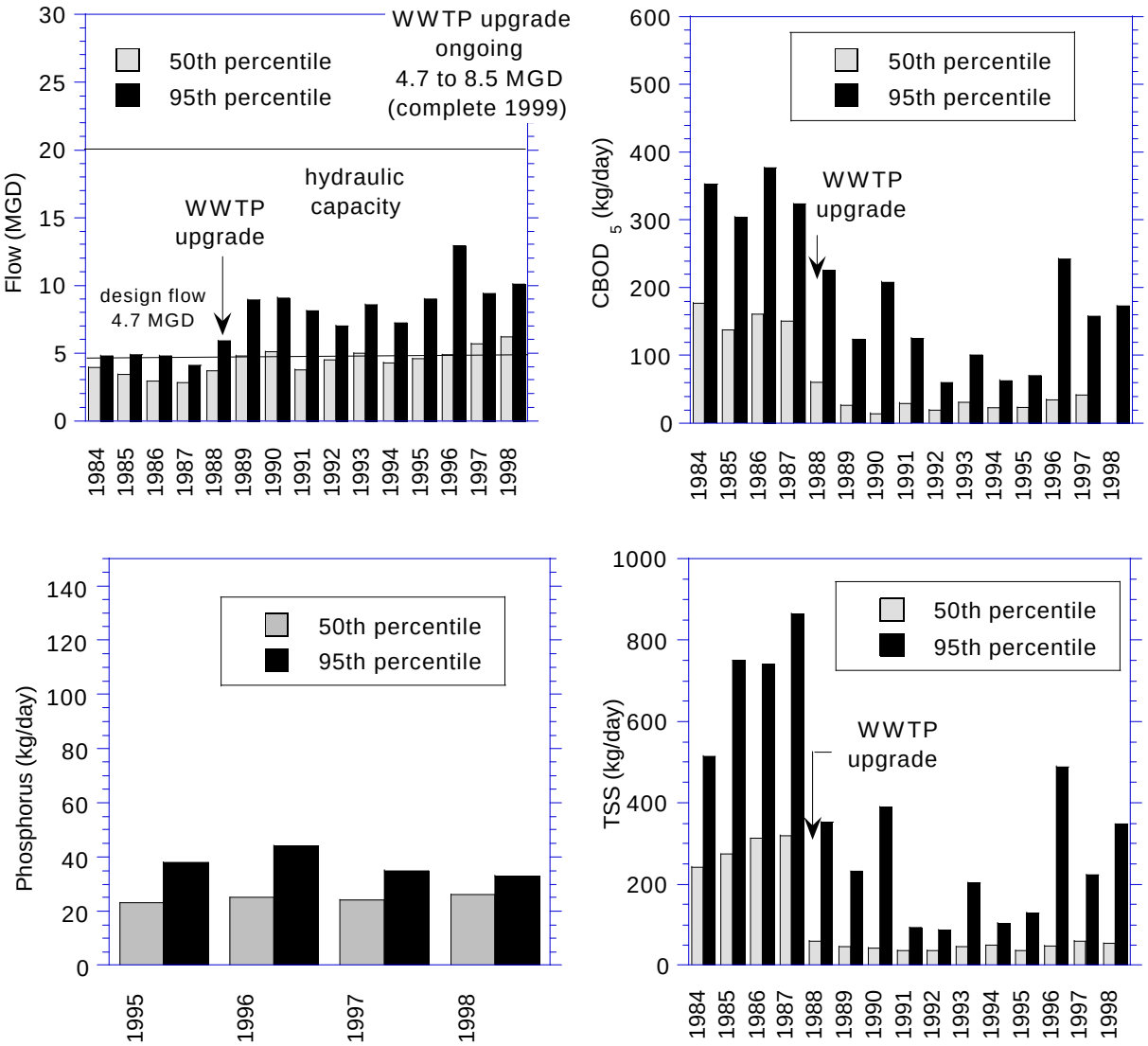



Figure 12. Median and 95th percentile annual flows, and loadings of five-day biochemical oxygen demand, total phosphorus, and total suspended solids from the Greene County Beaver Creek WWTP for the period of record indicated.

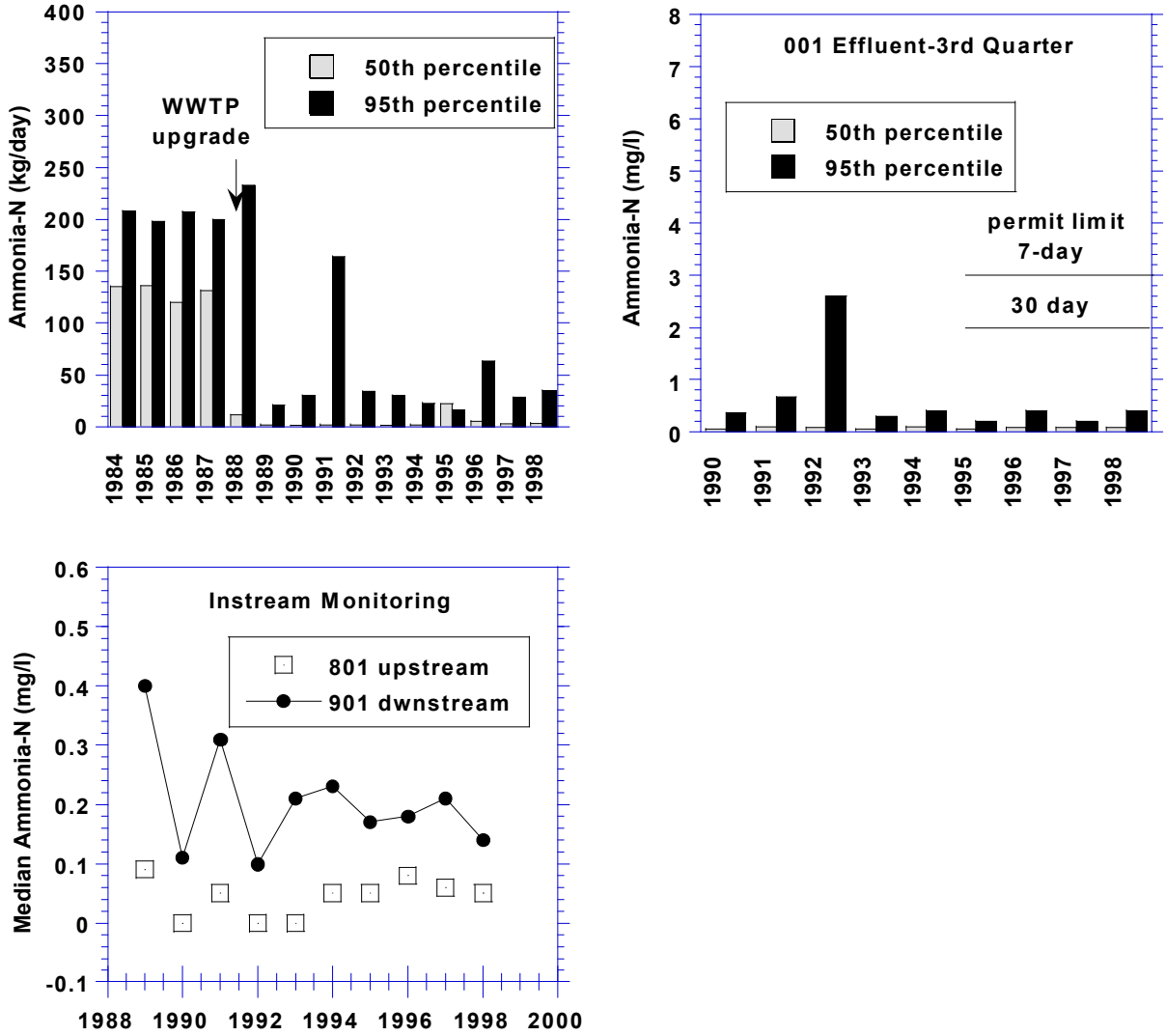



Figure 13. Median and 95th percentile annual and third quarter effluent loadings of ammonia-nitrogen, and instream mean ammonia-nitrogen concentrations from the Greene County Beaver Creek WWTP for the period of record indicated.

Generally, median flows have risen at the plant from 1993 to 1998 by 65% (average) linking the increased flow to the explosive development observed in this area (Figure 12). Between 1991 and 1998 the 95th percentile loadings, for all conventional parameters, were reduced (exception-1996 above average precipitation year statewide) and appeared commensurate with median loads, and ammonia-N loadings have remained relatively stable since 1993 despite increased effluent flows suggesting consistent plant performance. Wastewater improvements completed in 1988 resulted in notable declines overall for ammonia-N (Figure 13). Annual loadings of ammonia-N, based on 50th percentile values, declined from 11 kg/day in 1988 to 3.3 kg/day in 1998. This decreasing trend resulted in 70% reduction in ammonia-N loadings to the Little Miami River. The Greene County Beaver Creek WWTP median ammonia-N load for 1998 comprised 9% of the aggregate load of 10 major dischargers evaluated that discharge in the Little Miami River Watershed.

**Greene County Sugar Creek WWTP (RM 64.43)**

Constructed in 1977 with a major modification in 1987, Sugar Creek WWTP is a secondary treatment plant consisting of pre-aeration, secondary clarifiers, aerobic sludge digestion and chlorination. The plant has a design flow of 4.90 MGD (hydraulic capacity of 23 MGD ) and discharges directly to the Little Miami River. The collection system consist of separate sewers and 100% of the service area is sewered. The collection system contains seven lift stations with no reported overflows or bypasses. General plans for a study of residual chlorine reduction (in response to lower NPDES limits) was submitted in November 1992. An ultraviolet light disinfection system was installed and on-line in 1994. A new sludge processing facility, receiving sludge from all of Greene County plants was constructed at the Sugar Creek facility in 1998. Sludge is lime stabilized and then land applied at agronomic rates by a contractor. The Greene County Sugar Creek WWTP median ammonia-N load for 1998 comprised 5% of the aggregate load of fourteen major dischargers to the Little Miami River Watershed.

Industrial input comprise <10 % of the inflow with the most significant input from Dimco Gray Corporation (machine shop) and Union Camp (cardboard corrugator). Minor contributors are Finishing Touch (furniture stripper), Marble Molders (sink-top manufacturers) , N/R labs (shampoo manufacturer) and Dayton Wheel Products (electroplating). Dimco-Gray Corporation reported having violated lead, copper, zinc and oil and grease one time through 1997. They continued to violate oil and grease limits in 1998 and had one pH limit violation. Dayton Wheel Products moved into the area in 1997 and since then has reported only two minor pH violations.

Twenty (20) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to six parameters: TSS, $cBOD_5$, dissolved oxygen (D.O), pH, oil and grease and fecal coliform. Graphically, third quarter ammonia-N NPDES limits (30-day) for 95th percentiles were exceeded in 1997, however, the NPDES violation database did not reflect a problem with this parameter for the six years evaluated. Total mercury accounted for 30% of notifications by the entity (occurring primarily in 1996 and 1997), however concentrations remained below the Practical Quantification Level (PQL) for the facility and therefore were considered to be in compliance with the NPDES limit. Preliminary data for 1999 indicate mercury discharges continued for the facility. All of the NPDES violations

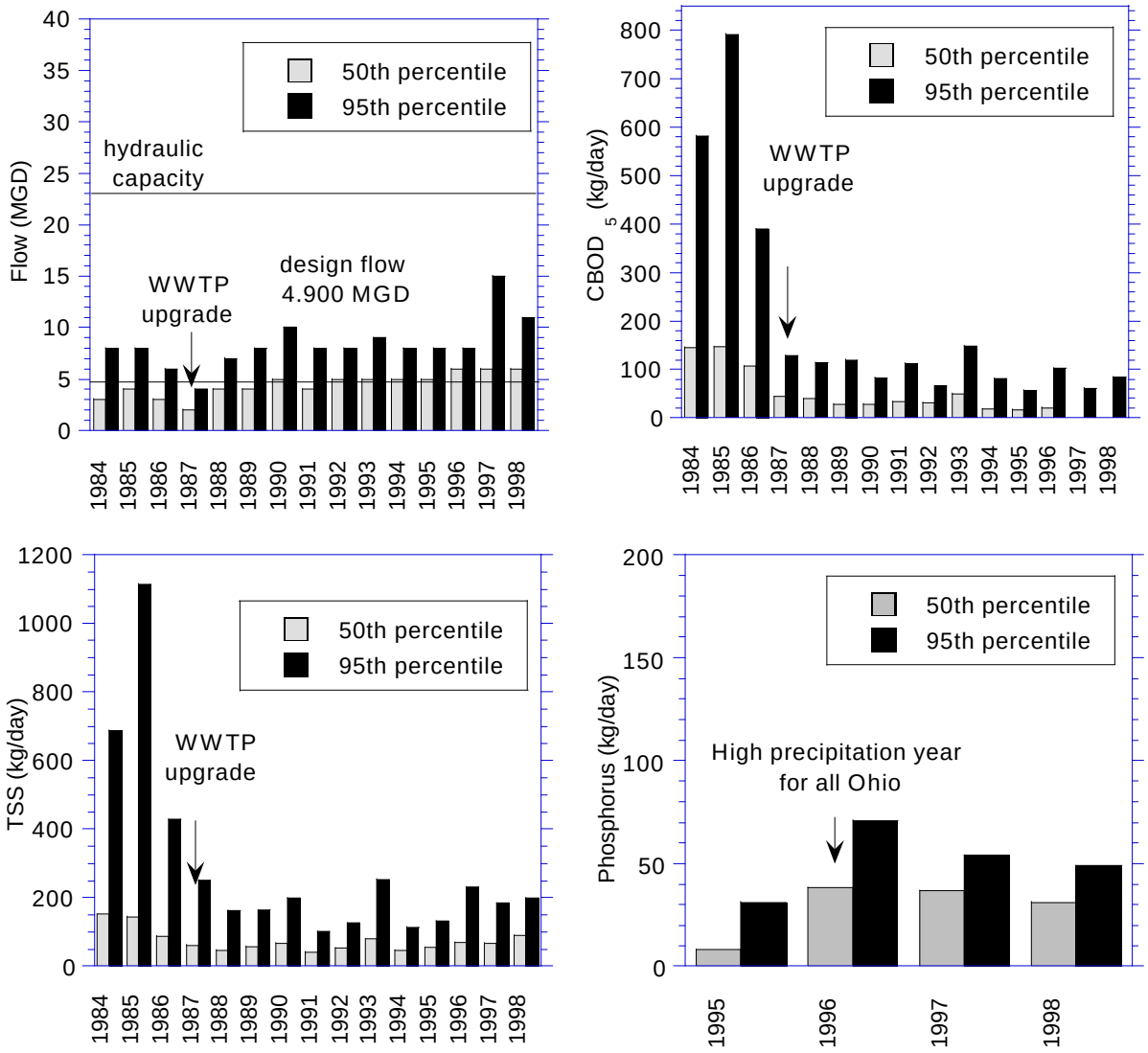



Figure 14. Median and 95th percentile annual flows, and loadings of five-day biochemical oxygen demand, total suspended solids, and phosphorus from the Greene County Sugar Creek WWTP for the period of record indicated.

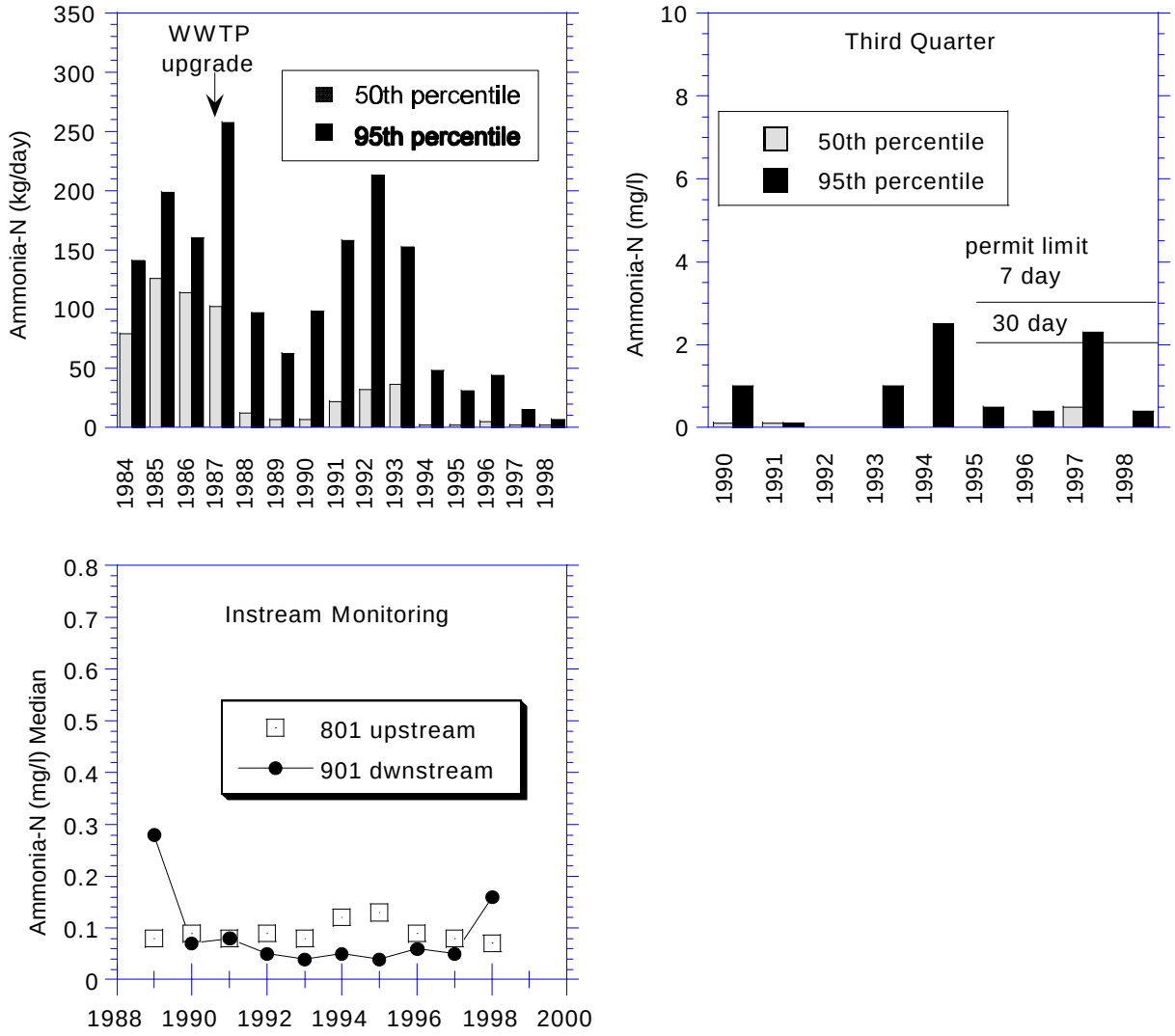



Figure 15. Median and 95th percentile annual and third quarter effluent loadings of ammonia-nitrogen, and instream mean ammonia-nitrogen concentrations from the Greene County Sugar Creek WWTP for the period of record indicated.

occurred from 1996 to 1998, with all but D.O and pH violations persisting until 1998. Pretreatment records denote Dimco-Gray Corporation has been in non-compliance for oil and grease violations from 1997-1998 and may be contributing to NPDES violations for oil and grease at Greene County Sugar Creek WWTP.

Three acute bioassay events, conducted by Ohio EPA in the winter, 1993, fall of 1997 and spring 1998, revealed no acute toxicity to either *C. dubia* or *P. promelas* test organisms in effluent samples or ambient waters. One *C. dubia* died in the Little Miami River upstream water after 24-hours exposure in March of 1998. No additional mortality or any other adverse effects occurred in the effluents and ambient waters. Survivorship in the laboratory controls was 100% for both test species. Entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* in one testing event (48-hour) in 1996. Test results revealed no acute toxicity to *C. dubia or P. promelas*.

Median flows increased nearly 67% from 1991 to 1998, reflecting both increased growth and an aging collection system (Figure 14). Due to an expanding service area and high rates of inflow and infiltration, the instances and severity of peak flow events increased in 1997 and 1998 hydraulically overloading the plant. Variation in TSS and $cBOD_5$ loads did not change appreciably indicating predictable plant performance. Percentile variance from 1989-1993 for ammonia-N were typical of the other conventional parameters demonstrating steady declines in the last five years of record (Figure 15). Greene County Sugar Creek WWTP's median ammonia-N load for 1998 was 2.0 kg/day comprising 13% of the aggregate load from all five WWTP's (four majors) discharging directly to the Little Miami River. The Greene County Sugar Creek WWTP median ammonia-N load for 1998 comprised 5% of the aggregate load of 10 major dischargers evaluated that discharge in the Little Miami River Watershed. Wastewater improvements completed in 1988 resulted in notable declines overall for ammonia-N. Annual loadings of ammonia-N, based on 50th percentile values, declined from 12 kg/day in 1988 to 2.0 kg/day in 1998. This decreasing trend resulted in 83% reduction in ammonia-N loadings to the Little Miami River. Inversely, median concentration and loads for nitrite-nitrate increased dramatically from 1993 until 1998.

**Hamilton County Metropolitan Sewer District Polk Run WWTP (RM 21.80)**

Constructed in 1970 with a new plant in 1988, the Polk Run WWTP is an advanced secondary treatment plant consisting of secondary clarification and dechlorination. The 1988 upgrade and expansion increased the design capacity from 1.00 to 6.00 MGD. The 6.00 MGD design capacity is expected to be reached by 2000 and another expansion is currently being planned to meet the rapid growth projected for the service area. The collection system is separate with 50% of the service area sewered. Less than 1% of the collection system is combined (a few remain in ?old" Loveland). The facility discharges to an unnamed tributary of the Little Miami River, approximately 50 feet upstream from the mainstem confluence. The facility has seven smaller lift stations and two larger stations at Polk Run pump station and Harper Ave. pump station.

Historical and recent collection system bypasses have been reported at four pump stations (Glen Lake Pump Station, Harper Ave, Bears Run Rd and Polk Run Rd.). Collection system and facility

bypasses (historically) have been reported for a number of years and have reoccurred on a consistent basis. Recent upgrades at the facility include two new screening devices and the collection system rehabilitation of the Harper Ave. pump station (including a new force main). A facility bypass (due to weather related infiltration and inflow) in May 1990 discharged approximately one million gallons of wastewater receiving only primary treatment. A Taylor St. sewer replacement should help reduce the inflow/infiltration problem at the facility. However, additional connections, extending service lines to cover annexed areas in the Twenty Mile area, may only increase the reoccurrence of overflowing systems.

As of Sept 22, 1992 a Director's Findings & Orders (DFFO) required identification of all separate sanitary overflows (SSO's) by June of 1993. The order has been pending to allow for the elimination of the SSO's. As of 1997 several SSO's are still active in the basin however these are described by the Metropolitan Sewer District as not highly or generally active. Results obtained on one particular SSO involves the Separate Sanitary Overflow (SSO) #565 located approximately 900 feet upstream of the Polk Run pump station. This station alone has had 16 overflows since July, 1992 until March, 1997 (10 occurred in 1996). The 30-inch overflow discharges to Polk Run. Short term and long term approaches for elimination of the SSO's overflow points have been discussed. One long term solution being evaluated is the expansion of the Polk Run WWTP from six to eight million gallons per day average design flow (12 mgd to 18 mgd). Additional treatment units gained from the expansion would be utilized in the form of equalization basins. Another option, under consideration, is construction of equalization basins only and deferring a plant expansion. Industrial flow from one minor user, Donisi Glass ( manufactures mirrors and fabricated glass table tops) accounts for approximately 5% of the total inflow. Currently the pretreatment program states that no Significant Industrial Users (SIU) exist in MSD's approved program.

Four NPDES violations in 1995 occurred in May and October ( D.O, fecal coliform, and two ammonia-N). Violations of the NPDES permit were also reported to Ohio EPA for outfall 001 between 1997-1998. The violations were limited to four parameters: ammonia-N, fecal coliform, total residual chlorine and dissolved oxygen (D.O). Annual, third quarter ammonia-N loadings graphically verify NPDES database exceedences for 1997 and 1998 (Figure 16). The 95th percentiles exceeded the 30-day limit undeniably in 1997 and to a lesser degree in 1998.

One acute bioassay event, conducted by Ohio EPA in the spring of 1993 using test organisms *C. dubia* and *P. promelas,* resulted in acute toxicity to *C. dubia* in all effluent samples. Mortality (100%) to *C. dubia* persisted into the mixing zone. Two acute bioassay events were conducted by Ohio EPA in (May and June), 1993. No acute toxicity to either test organisms in effluent samples or ambient waters occurred in the June, 1993 event. The May, 1993 sampling event was acutely toxic to *C. dubia* in all effluents and mixing zone samples while *P. promelas* results indicated minor mortality (10%) in effluent samples. Survival in the laboratory controls was 100% for both test organisms.

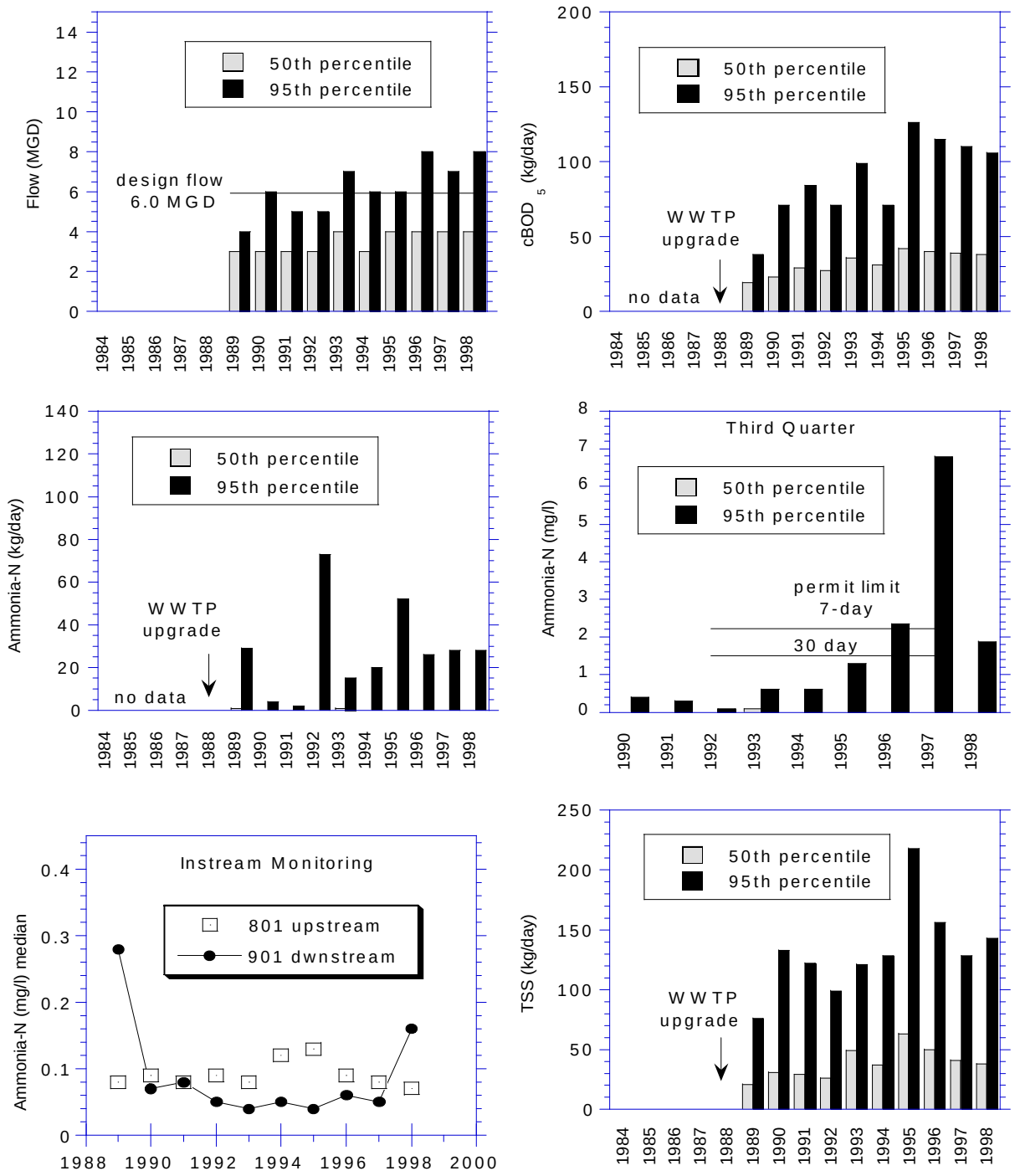



Figure 16. Median and 95th percenitile flows and loadings of five-day biochemical oxygen demand, ammonia-nitrogen, third quarter ammonia-nitrogen, instream ammonia-nitrogen concentrations, and total suspended solids from the Hamilton County MSD Polk Run WWTP, 1989 - 1998.

Entity conducted Whole Effluent Toxicity (WET) acute (48-hour) bioassays (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* on nine occasions within four years (1994-1997). Results revealed no significant toxicity to *C. dubia* in the nine, 48-hour acute tests. Whole effluent (100% effluent) was acutely toxic to *P. promelas* in 22% of toxicity tests conducted. Two of nine tests resulted in values greater than the Allowable Effluent Toxicity (AET) limit of 2.43 TUa for this test organism. Entity conducted Whole Effluent Toxicity (WET) 7-day chronic bioassays were performed utilizing *C. dubia* and *P. promelas* on five occasions within three years (1995-1997). Chronic toxicity tests (a chronic effect can be measured in lethality, growth or reduced reproduction) were conducted using both test organisms in five testing events over three years. *Ceriodaphnia dubia* populations were affected the most resulting in 40% of chronic tests above the AET of 9.56. This indicated the chronic toxicity potential to *C. dubia*. Chronic potential did not appear as an endpoint in the five testing events for *P. promelas.*

Annual median and 95th percentile flow moderately increased between 1988 and 1998 (Figure 17). Flows began exceeding design in 1996 (exception-1993), demonstrating increased pressure on the average design capacity of 6.00 MGD. All conventional parameters reacted similarly with high variation in loadings apparently influenced by flow behavior**.** Annual median ammonia-N loads appeared reduced and fairly stable. Annual median loadings of $cBOD_5$ and TSS appeared fairly stable through the period of record. Median loads for TSS ranged from 20 to 65 kg/day and $cBOD_5$ 15 to 35 kg/day. The MSD's Polk Run WWTP median ammonia-N load for 1998 comprised <1% of the aggregate load of five (four majors) facilities discharging directly to the Little Miami River.

**Hamilton County-MSD Sycamore Cr. WWTP (RM 0.26)**

Constructed in phases (1954, 1970) and upgraded in 1988 and 1991 (sand filters), the MSD Sycamore Creek WWTP is a secondary treatment plant with rapid sand filters and chlorination. The collection system is separately sewered with 70% of the area servicing Symmes township, Madeira, Indian Hill and Montgomery. The population of the service area is a minimum 30,000. The plant has a design capacity of 6.00 MGD and discharges to Sycamore Creek near the mouth. There are 26 lift stations with no bypasses and five lift stations with overflows. A Consent Order was issued recently to address sanitary sewer overflows, mercury exceedences and the extension of service to unsewered areas. Upgrades since 1993 include two new clarifiers and a replacement sewer project covering nearly 5,000 homes in Loveland. In May of 1994, chlorination and dechlorination disinfection units went online. A Phase II project began replacement of the deteriorating trunk sewers in the Sycamore Creek region. Primary treatment can handle peak flows up to 20 MGD while peak flows of 10 MGD receive secondary treatment. Inflows ranging from 10 to20 MGD are diverted to sand filtration and disinfection prior to final discharge. Twenty or more internal plant bypasses were reported in 1995, over 40 in 1996, several in 1997 and 1998. Recently inflow to the collection system was reduced by implementing a downspout program whereby approximately 120 downspouts were removed from the collection system throughout the drainage basin. Metropolitan Sewer District (MSD) has an ongoing program to remove sources of rain dependent inflow/infiltration. A new facility location may be selected due to lack of expansion space at the existing facility. Industrial contributions amount to only 1% of the total inflow and pretreatment records for 1996-1999 indicate that no industries were in significant non-compliance (SIU).

Industrial contributors include two metal finishers, Steelcraft and H.B Fuller Company.

Forty-one (41) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to seven parameters: TSS, $cBOD_5$, dissolved oxygen (D.O), copper, zinc, lead and ammonia-N. Total suspended solids and $cBOD_5$ accounted for 63% of NPDES violations for all years and occurred primarily from 1996-1998. All of the NPDES violations occurred from 1996 to 1998. Dissolved oxygen, TSS and $cBOD_5$ persisted until 1998. Modified NPDES Permit requirements for final effluent ammonia-N from 1995 to 2000 reduced limits an average 34% for summer and wintering monitoring. Phosphorus monitoring was added and zinc, copper and lead limits generally decreased. Modified upstream and downstream monitoring (801/901) will require toxicity testing at both locations.

One acute bioassay event, conducted by Ohio EPA in early summer of 1990, using *P. promelas* and *C. dubia,* indicated the first day grab sample of effluent, mixing zone and upstream samples were acutely toxic to *C. dubia* only. Toxicity in the mixing zone was insignificant and survival in control waters was 100% for both test organisms.

Entity conducted Whole Effluent Toxicity (WET) acute (48-hour) bioassay's (acute is measured in lethality) were performed utilizing *C. dubia* in 14 testing events within four years (1995-1998). Results revealed 14% of the tests were acutely toxic to for *C. dubia*. Entity conducted Whole Effluent Toxicity (WET) tests, for 7-day chronic (a chronic effect can be measured in lethality, growth or reduced reproduction) bioassays, were performed utilizing *C. dubia* in 13 events within four years (1995-1997). *Ceriodaphnia dubia* populations exhibited chronic effects by reduced reproduction in 42% of tests. Twenty-five percent (25%) of tests for lethality exceeded the AET of 1.0 TUc for both chronic endpoints. Violations of the NPDES for ammonia-N, copper, lead and zinc occurred between 1996 and 1998 possibly linking the source of toxicity to the acute and chronic toxicity endpoints noted in the entity conducted bioassay's.

Ninety-fifth percentile flow exceeded average design capacity for the entire period of record, approaching 6.00 MGD (the design limit where effluent bypasses primary treatment) from 1996-1998. This indicated the increased pressure from inflow/infiltration concerns currently being addressed by replacement of deteriorating trunk sewers in the area (Figure 16). Variability between annual 95th and median percentile for TSS was generally two to three times greater than variability observed earlier in the record. It was most likely attributed to increased in-fluent flow from an aging collection system. The Sycamore Creek WWTP median ammonia-N load for 1998 comprised 1% of the aggregate load of 19 major dischargers evaluated in the Little Miami River Watershed (Figure 37).

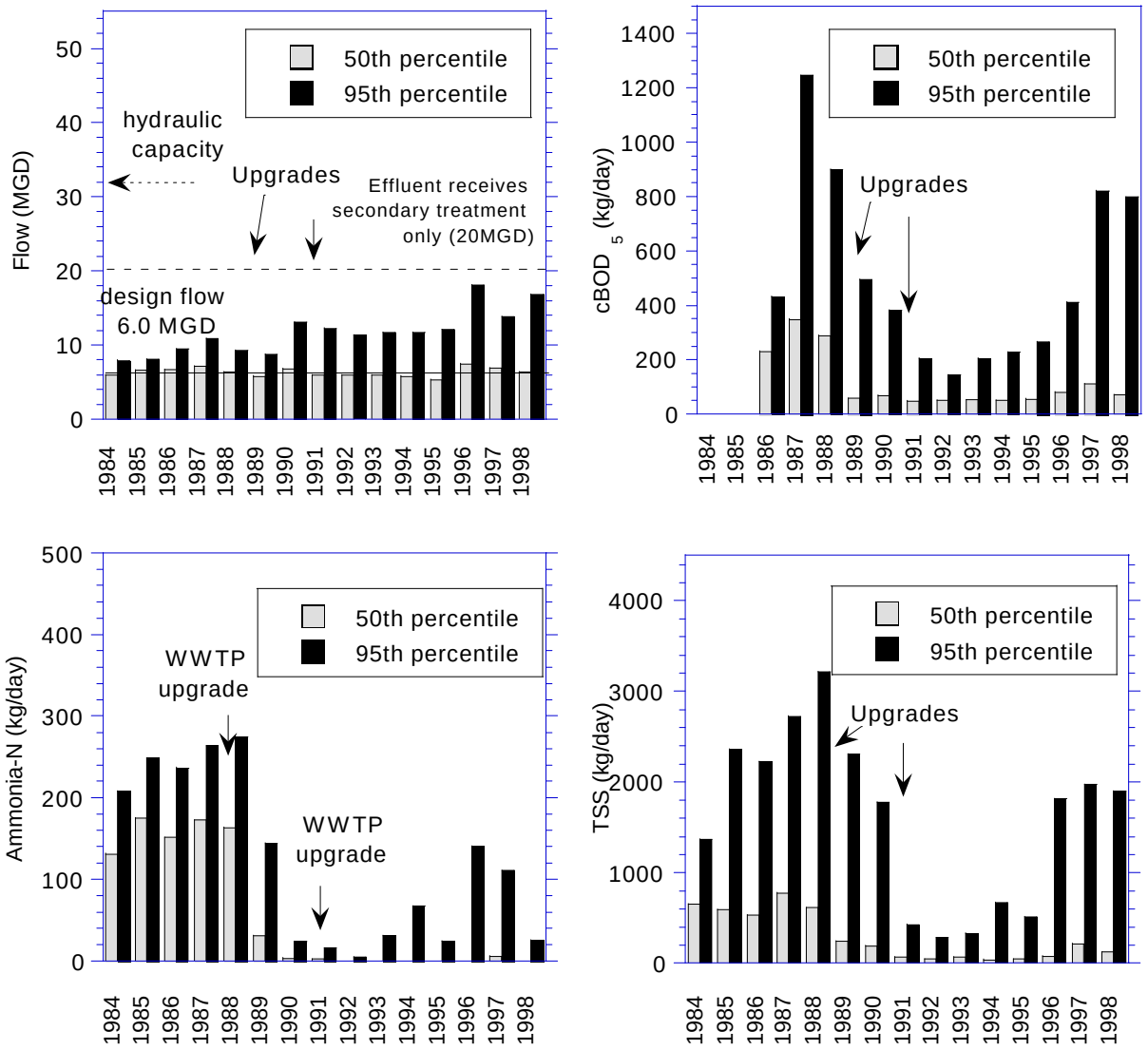



Figure 17. Median and 95th percentile annual flows and loadings of five-day biochemical oxygen demand, ammonia-nitrogen and total suspended solids for the Hamilton County MSD Sycamore Creek WWTP, 1984 - 1998.

**Jamestown WWTP**

Jamestown WWTP was an activated sludge plant when built in 1938 with upgrades ensuing in 1956 and 1984. The facility originally discharged 60,000 gpd and consisted of an aeration tank, primary settling tank, secondary settling, sludge digestion tank and sludge drying beds. Jamestown currently discharges into the South Branch of Caesar Creek in Greene County. Currently, plant discharge volume is 0.300 MGD, with an expansion of 0.65 MGD requested in 1997. The submitted expansion proposal was a general plan upgrade to the facility of which the status is currently pending. No commencement or completion dates were set and construction is still a few years away from inception. Ultraviolet light disinfection has been proposed with the expansion/upgrade. Currently sewage flows exceeding 0.30 MGD bypass main plant treatment and discharge to the receiving stream with chlorine disinfection only.

Thirty-nine (39) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to seven parameters: total residual chlorine, fecal coliform, ammonia-N, dissolved oxygen (D.O), pH, TSS and oil and grease. Total chlorine accounted for 64% of NPDES violations for all years and occurred repeatedly in 1995-1998. The majority (66%) of the NPDES violations occurred between 1995 and 1998 as chlorine, ammonia-N and fecal coliform. Total suspended solids and pH were the two most recurrent parameters exceeded. Permit violations exhibit a general decreasing trend from 1996-1998 however preliminary data for 1999 indicate total residual chlorine violations.

Annual median flow was typically 0.25 MGD for the entire record (Figure 18). Ninety-fifth percentile flows were typically greater than the 0.300 MGD average design capacity, demonstrating the need for expansion to increase confidence in properly treating the effluent. Currently effluents exceeding 0.300 MGD bypass plant treatment and discharge untreated. Percentile variances and trends for $cBOD_5$, TSS and ammonia-N revealed no evident patterns, suggesting high variability in effluent quality.

**Lebanon WWTP (RM 32.12)**

Constructed as a new facility in 1987 and upgraded in 1993, the Lebanon WWTP is a secondary treatment plant utilizing counter current aeration, plastic media sludge drying beds and chlorination. The facility replaced the original Lebanon WWTP which discharged to Turtle Creek. The collection system is separate with 60% of the service area sewered (population is 12,500). The discharge is to the Little Miami River with a facility capacity design of 3.00 MGD. Two lift stations exist on the collection system with no reported bypasses or overflows. Industrial inputs comprise 30-35% of the inflow with the most significant contribution from FujiTec, Inc (producing elevators and escalators) and a contribution from Vickers (formerly Cincinnati Milacron).

Currently the facility is negotiating a design flow increase to 6.00 MGD as sewer extension requests continue to keep pace with suburban development. In May of 1998 the Lebanon WWTP began accepting industrial waste from Vickers. This connection eliminated their discharge to Turtle Creek in Warren County which historically contained concerning levels of copper resulting in aquatic life kills and impairments. Vickers and FujiTec are the only regulated industries in the pretreatment

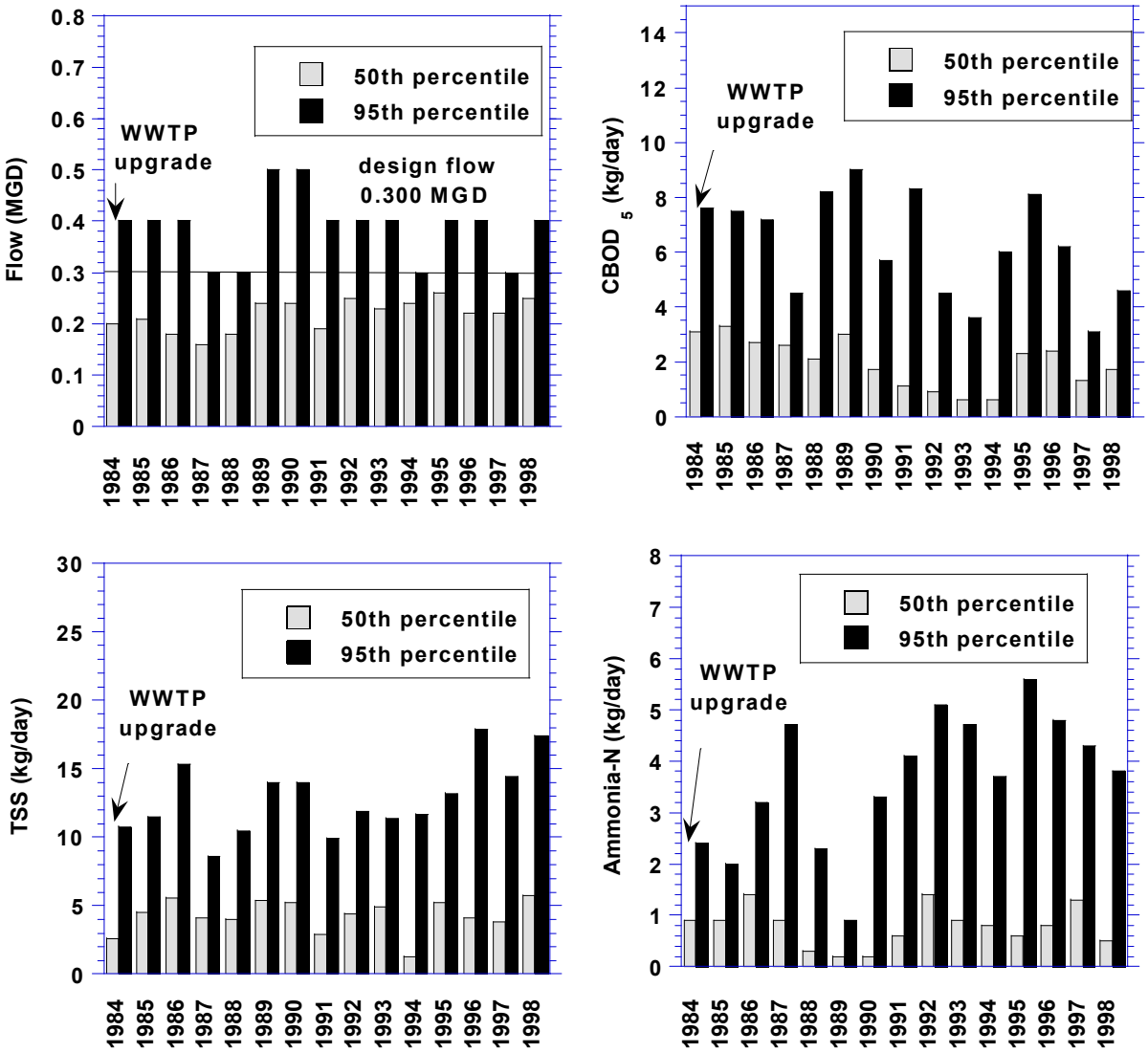



Figure 18. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids and ammonia-nitrogen from the Jamestown WWTP, 1984 - 1998.

program for Lebanon. Neither industry has reported a violation of pretreatment standards from 1996-1998.

Ten (10) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to five parameters: TSS, pH, dissolved oxygen (D.O), fecal coliform and $cBOD_5$. Sixty-nine percent (69%) of NPDES violations occurred in 1998 and all NPDES violations were reported in 1997 and 1998. All conventional parameter violations, with the exception of ammonia-N, were reported in 1998.

One acute bioassay event, conducted by Ohio EPA in the late winter of 1997, using *C. dubia* and *P. promelas,* revealed toxicity to *P. promelas* in effluents from 001. Fish mortality was greatest with the first day grab. The effluent composite sample toxicity for *P. promelas* was at 75%. All surviving fish exposed to the second day effluent grab and composite sample were lethargic with loss of equilibrium. Toxicity persisted into the mixing zone where 20% mortality and 5% adverse effects in *P. promelas* were noted. No fish died in upstream or control waters. No *C. dubia* mortality was observed in effluents or ambient waters. Survival in laboratory controls was >95% for *C. dubia.* Entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* in one testing event (48-hour) in 1996. Test results revealed no acute toxicity to *C. dubia or P. promelas* for the October, 1996 testing event.

Ninety-fifth percentile flow from 1989 were typically greater than the 3.00 MGD average design capacity for a ten year period (Figure 19). Plant performance may be periodically disrupted by excessive in-fluent loads, evidenced by annual flows greater than plant capacity during the time. The city is currently discussing an expansion to an average design flow of 6.00 MGD. Annual 95th ammonia-N loads were erratic and generally many times the median values. Elevated and erratic 95th percentiles often are indicative of inconsistent plant performance. Increasing conventional parameter loads were demonstrated during 1996-1998 by median loads for TSS (ranging from 26-39 kg/day) and $cBOD_5$ ( 25-32 kg/day). The Lebanon WWTP median ammonia-N load for 1998 comprised 32% of the aggregate load of the five facilities (four are majors) evaluated discharging directly to the Little Miami River.

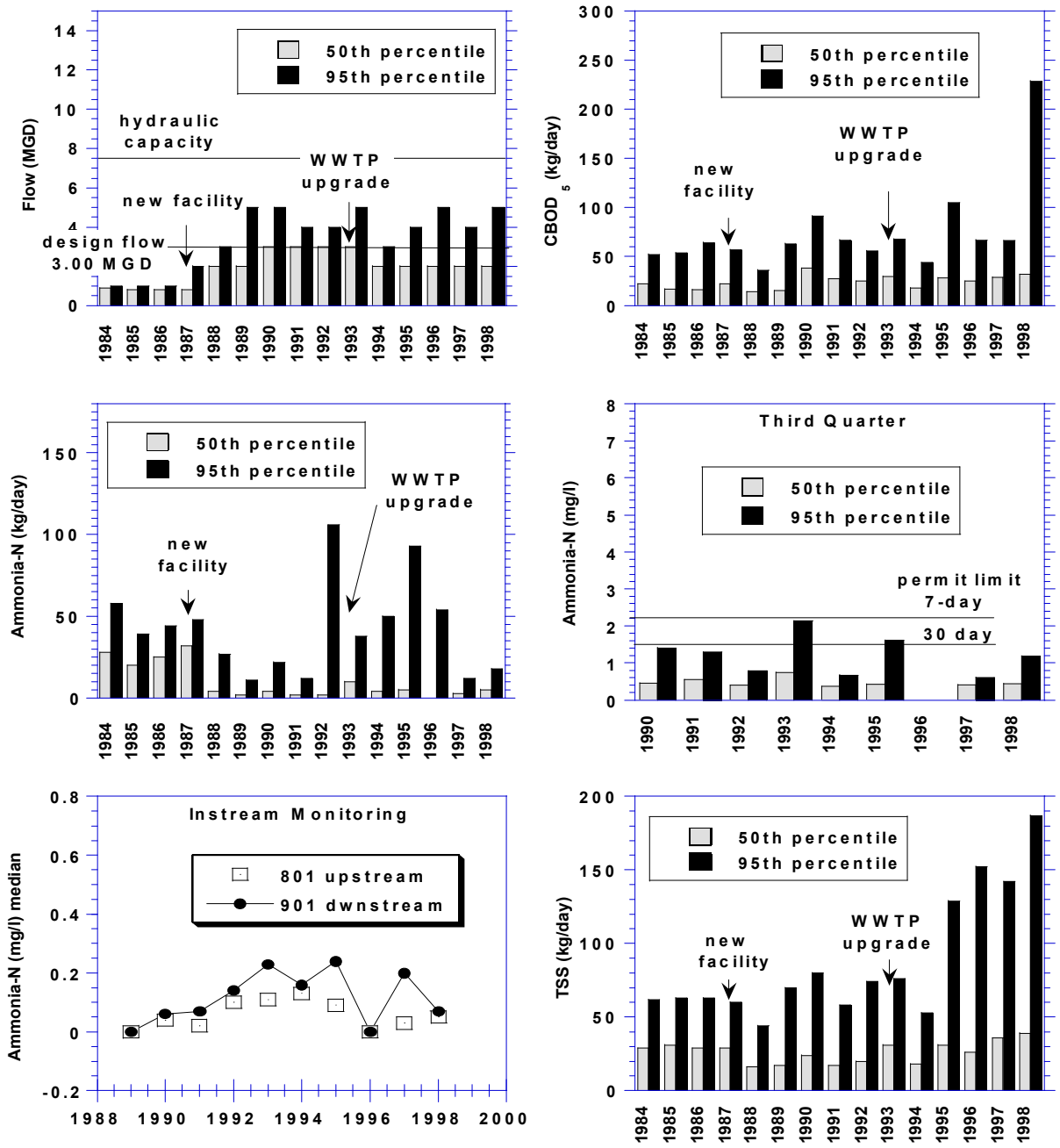



Figure 19. Median and 95th percentile effluent flows and loadings of carbonaceous oxygen demand, ammonia-nitrogen, third quarter ammonia-nitrogen, mean instream ammonia-nitrogen concentrations, and total suspended solids from the Lebanon WWTP for the period of record indicated.

**City of Mason WWTP (RM 3.24)**

Constructed in 1962 , a major upgrade in 1989 and expansion in 1997, the Mason WWTP is a secondary treatment plant consisting of an oxidation ditch, final settling and ultraviolet light disinfection. The collection system is separate (an SSO exist) and utilizes 12 lift stations. Eighty-five percent (85%) of the service area is sewered and serves a population of 11,000. Three aging ?Can Stations" (older prefabricated metal lift stations with essentially needed technology missing to handle overflows) on the collection system have been problematic and are currently being evaluated. The facility discharge is directly to Muddy Creek with a design flow of 4.95 MGD (2.50 MGD historically) and a peak design of 9.90 MGD. Excessive inflow and infiltration and other concerns have resulted in the need for flow equalization basins, along with new pretreatment facilities, clarifiers, sludge press, sludge digester and ultraviolet disinfection. Construction on some treatment phases have begun while other phases are currently in review. A Consent Order signed June 1991 contained a schedule for the city to upgrade the plant, meet NPDES limits and eliminate a separate sewer overflow by September 1995. Immediate requirements of the Consent Order include handling and disposing of sludge in accordance with an approved management plan and infiltration and inflow reduction. Construction on the project's final phase has commenced and detailed plans for the complete upgrade have been received and reviewed by Ohio EPA.

In 1993, a project to equalize facility in-fluent flows was initiated and online in May, 1994. Project improvements included: installation of new outlet and inlet siphon chambers and an inverted siphon along SR 42 (which eliminated overflows). A new 30" trunk sewer extending to the treatment facility was constructed as well as a distribution chamber. Equalization basins with two chambers @ 1.375 million gallons each and four floating aerators with guides were also constructed. An overflowing manhole was corrected with a sealed manhole lid underlayment.

In spring and early summer of 1995, rain events and human error prompted equalization basin overflows. This resulted in an unknown quantity of minimally treated waste being discharged to Muddy Creek. In 1996, spring rain events overloaded the equalization basins resulting in approximately 17,000 million gallons (MG) of waste being discharged to Muddy Creek. Additional weather related occurrences in January 27, 1997, resulted in sewer backups and basement flooding in the Snider Road area (Trunk sewer #42). In this overflow event, Mason WWTP experienced a solids washout of the secondary clarifiers resulting in 12.0 MGD bypassing and several NPDES violations. No other critical treatment facility equipment failures or bypass events were reported in 1997. In April, 1998 Mason bypassed approximately 2.0 MGD while working to isolate a broken clarifier and continued bypassing for the next couple days due to 4-5" rain event. Recent evaluation by the City of Mason of equalization basin problems has resulted in rethinking the ?operation" protocol of the equalization basins.

A 1998 water quality survey conducted by Ohio EPA documented obvious pin floc in the water column at and downstream of the facility. Field notes throughout the survey also disclosed that two locations downstream of Mason's final outfall and at the final outfall had notable quantities of visible foam. Currently Mason is investigating the foam problem and stated they suspect a polyphosphate additive at the water plant.

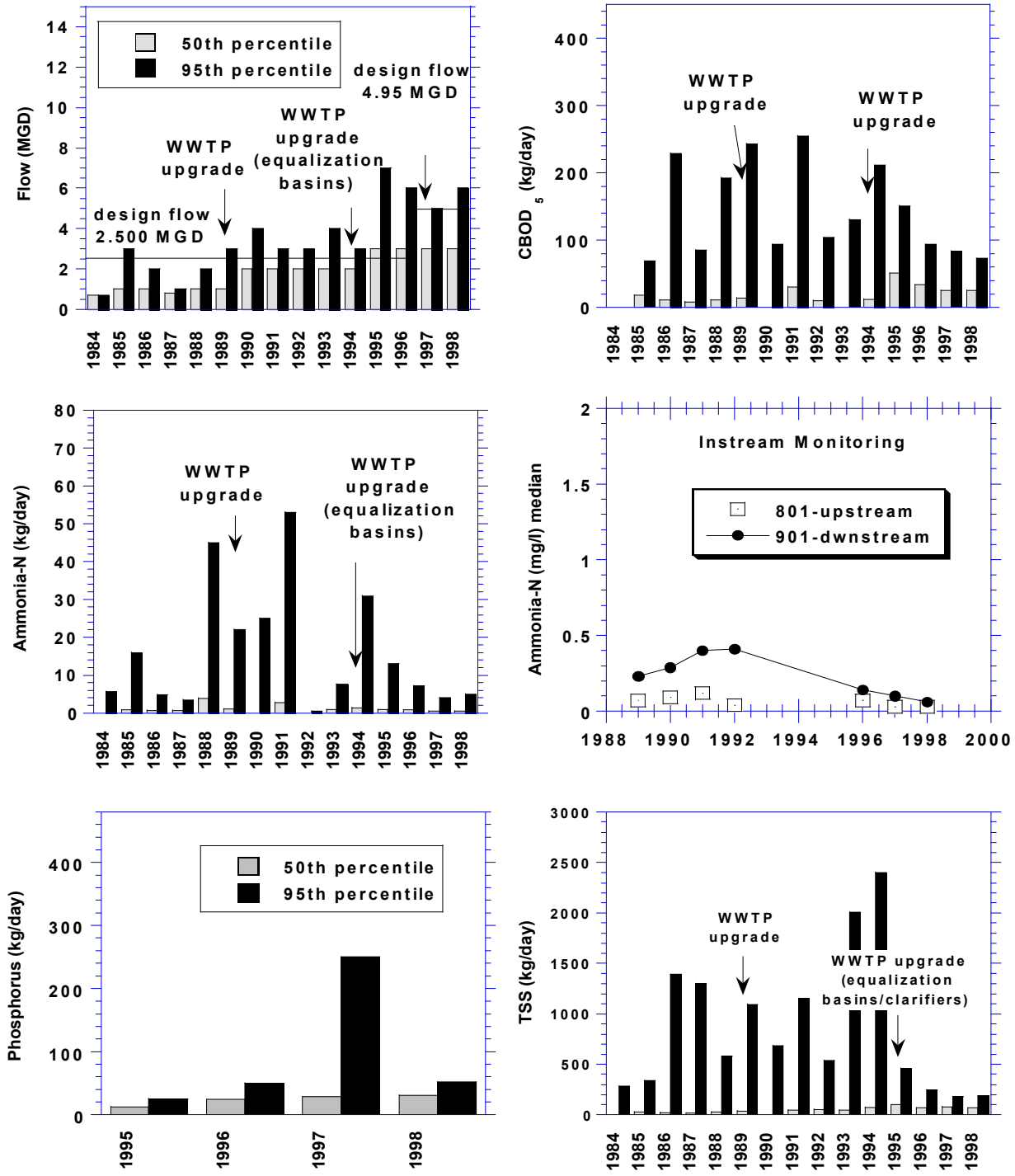



Figure 20. Median and 95th perentile effluent flows and loadings of five-day biochemical oxygen demand, ammonia-nitrogen, mean instream ammonia nitrogen concentrations, total phosphorus, and total suspended solids from Mason WWTP for the period of record indicated.

Industrial contributions comprise approximately 47% of the total inflow volume. Mason WWTP has seven permitted indirect dischargers and seven Significant Industrial Users (SIU) in their pretreatment program. Contributors include Cincinnati Electronics (radar systems warfare equipment), Mitsubishi Electric Automotive America Inc (automotive component parts), Worthington Custom Plastics, Reliance Medical Products (medical equipment), A-Mold, Bernefield Containers and Portion Pac Company. Cincinnati Electronics reported several pretreatment violations of cadmium and zinc (1997-1999). Mitsubishi Electric Automotive America, Inc reported violations of molybdenum (1996-1999), cadmium (1996, 1998 and 1999) and zinc (1996, 1999) and one violation of mercury (1999). Worthington Custom Plastics reported violations of cadmium (1998, 1999), copper and molybdenum (1996,1997) and mercury in 1996 and 1999. Makino reported violations of mercury (1999), cadmium (1998, 1999) copper (1996, 1998) and molybdenum and zinc in 1998. Reliance Medical Products reported violation of arsenic and cadmium (1997, 1998) copper and lead (1997) mercury (1999) and molybdenum (1996, 1997). A-Mold reported violations of cadmium (1996,1998) zinc (1996,1998) chromium in 1996 and hexavalent chromium (1997). Bernefield Containers reported violations of oil and grease and zinc (1997) and molybdenum (1996-1997). Portion Pac Company reported a violation of cyanide in 1996.

Nine (9) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to four parameters: fecal coliform, TSS, pH and dissolved oxygen (D.O). The NPDES violations were allocated nearly equitably between years, 1996 and 1997 and were most frequently TSS and fecal coliform. Preliminary data for 1999 exhibit NPDES violations of copper and ammonia-N. Pretreatment records for Mason, from January 1996 to 1999, denote several companies in violation of pretreatment copper standards as well as numerous other pretreatment violations. Ohio EPA sediment results, just downstream of the Mason WWTP outfall 001, indicate a presence of chromium , barium and nickel at elevated and highly elevated levels. Sewer overflows upstream, of the final outfall, 001 could be contributing to the presence of these metals in sediments.

One acute bioassay event, conducted by Ohio EPA in the winter, 1997 revealed no acute toxicity to either *C. dubia* or *P. promelas* in effluent samples or ambient waters. An acute bioassay event, conducted by Ohio EPA in the late summer, 1998 revealed toxicity to *C. dubia* in effluents at 001 only. *Ceriodaphnia dubia* mortality was 75% (within 48 hours of exposure) in the mixing zone sample. Mortality in effluents to *C. dubia* on the first day was >50%, however first day effluent (grab & composite) mortality was questionable due to excessive mortality in the reconstituted water control. Absence of mortality in the, upstream Muddy Creek samples, validated tests performed on the first day of sampling.

Entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* in one testing event (48-hour) during 1996. Test results revealed that 45% of both test organisms were adversely affected in 100% effluent. The acute AET for Mason WWTP is 30% affected organisms (0.3 TUA) in 100% effluent.

Annual median flow was typically below the design capacity until 1995-1998, after the addition of

equalization basins (Figure 20). An 11 to 20% increase in flow was predicted by Mason WWTP to occur from 1998-2000. An upgrade or expansion is planned to handle the increase to the facility. Notable reductions in percentile variance for conventional parameters were evident following the addition of clarifiers and equalization basins in 1994. The Mason WWTP median ammonia-N load for 1998 comprised 1% of the aggregate load of 10 major dischargers evaluated in the Little Miami River Watershed.

**Montgomery County Eastern Regional WWTP (RM 4.58)**

Constructed in 1953 and expanded in 1958, 1970 and 1988 (upgraded in 1993), the Montgomery County Eastern Regional WWTP is a secondary treatment plant utilizing secondary clarification and activated sludge. A major modification in 1988 included flow equalization tanks, secondary clarifiers, aerated channels, dechlorination, post-aeration and the removal of 42 overflows from the collection system. Currently, the wastewater collection system contains 17 lift stations with no reported overflows or bypasses. The treatment facility has a design flow of 13.0 MGD and discharges directly to the Little Beaver Creek. The latest population census is reported at 120,000, with saturated growth. The facility is served by separate sewers with all of the service area sewered. The extent of inflow/infiltration (I&I) has not been quantified and the need for a study has been examined. Headwall work in the Little Beaver Creek completed in 1997-1998 was the only upgrade to the facility since 1993. Odor and sewage complaints continue to be documented by Ohio EPA field personnel, however field presence to validate these complaints has revealed nothing substantial. Since 1996, at least one report annually is documented by Ohio EPA concerning collection system overflows and bypasses resulting in basement sewage.

The plant receives 15% industrial input consisting of waste streams from Delphi-Chassis (formerly General Motors-Delco), Kodak Co. and a dairy processing facility. From 1996-1998 no industries in Montgomery Counties Pretreatment program were in significant non-compliance (SNC). One incident of an accidental discharge of NaOCl on November 17, 1997 at the Scitex Digital Printing Company resulted in SNC. This created a situation of endangerment of treatment facility personnel but no environmental impact to the Little Beaver Creek was documented. Recently a Toxic Reduction Evaluation (TRE) was completed resulting in the discovery of an in-plant polymer as the source of toxicity. Three (3) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations were limited to three parameters: fecal coliform, free cyanide and ammonia-N. Permit violations occurred from 1996-1998.

Two acute bioassay events, conducted by Ohio EPA in the summer, 1993 and spring 1998, revealed no acute toxicity to either *C. dubia* or *P. promelas* test organisms in effluent samples or ambient waters. No other adverse effects or mortality were noted. Laboratory survivorship was at least 95% for both species. Entity conducted bioassays were performed utilizing *C. dubia* in three testing events over two years (December 1995, June 1997 and November 1997). Results revealed no significant toxicity to the test organism in the three, 48-hour acute or chronic toxicity tests.

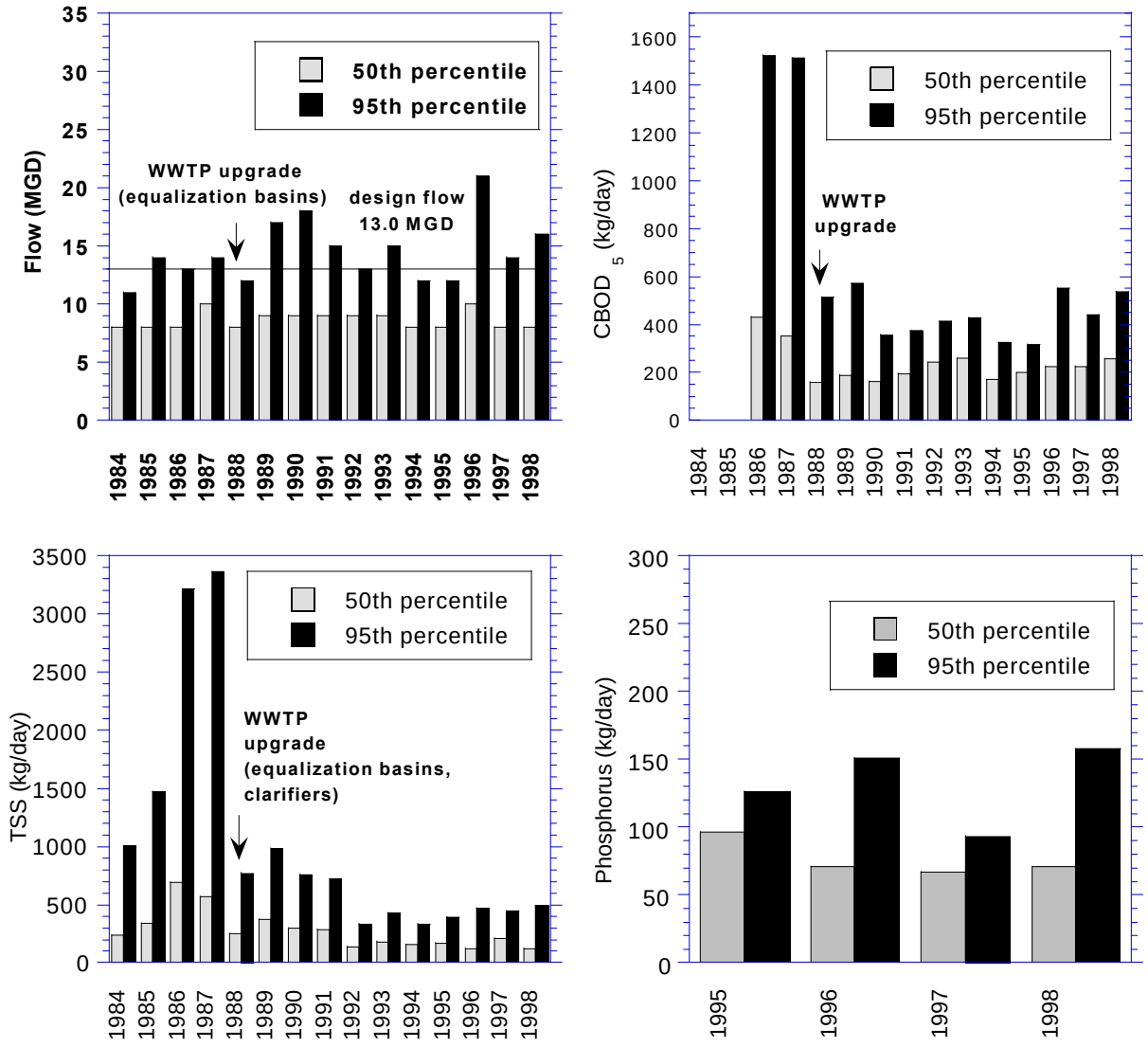



Figure 21. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, and total phosphorus from the Montgomery County Eastern Regional WWTP for the periods of record indicated.

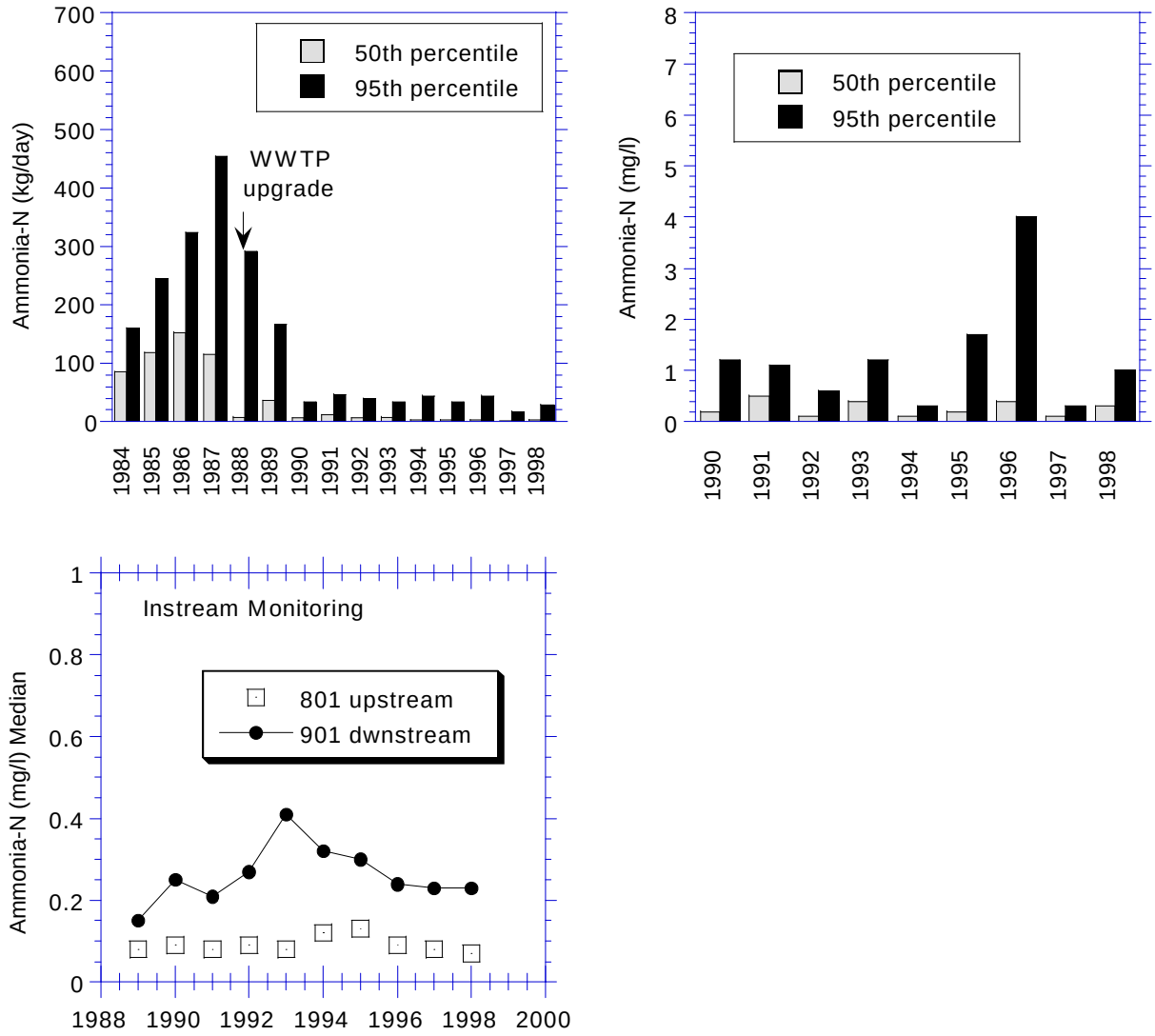



Figure 22. Median and 95th percentile effluent loadings of ammonia-nitrogen, third quarter ammonia-nitrogen, and mean instream ammonia-nitrogen concentrations from the Montgomery County Eastern Regional WWTP for the periods of record indicated.

Ninety-fifth percentile flows were greater than the 13.00 MGD design capacity in half of the years examined. These resulted in bypasses or overloaded sewers reported during 1996-1998 (Figures 21 and 22). Annual median and 95th percentile flows have not increased significantly or shown increasing variation, and that suggests consistent plant performance. Montgomery County Eastern Regional WWTP median ammonia-N load for 1998 comprised 8% of the aggregate load of 10 major dischargers evaluated in the Little Miami River Watershed (Figure 36).

**Village of South Charleston WWTP (RM 1.40)**

Initially constructed in 1938 and later expanded in 1969, the South Charleston's WWTP utilizes secondary treatment which includes aeration, settling, chlorination and aerobic sludge digestion. Flow equalization was added in 1990 along with additional clarifiers. The facility discharges to Gilroy Ditch at a design flow of 0.24 MGD. The latest census estimated the population at 1,600. Separate sewers that contain three lift stations (one lift station has an overflow) serve 98-99% of the village. An aging collection system has created excessive inflow and infiltration to the WWTP and has become a major problem for the facility. South Charleston is in the process of obtaining finances for a recommended treatment facility upgrade to address deficiencies within the existing sewer collection system. Since 1993 treatment upgrades at South Charleston WWTP consist solely of UV disinfection. Improvements to the collection system included a manhole rehabilitation project completed in 1996. The rehabilitation project included patching and waterproofing 95 manholes, resetting castings, reconstructing the chimney portion of 13 manholes, installing 50 stainless steel inserts beneath the lids (to catch surface inflow) and redirection of storm water. In-fluent flows coinciding with a storm event, immediately following the completion of the project, revealed drastic reductions in water volume to the facility. Since 1993 connections to the collection system have been limited to one subdivision of approximately 50 homes. Three reported bypass incidences of primary treated sewage occurred at the facility in January and May, (1996) and one in April, (1998) discharging directly to Gilroy Ditch. Possible causes were reported as weather related power outages and human error.

Industrial contributions are made is by a significant discharger, Yotek (a metal finisher) and minor discharger, Land Mark (chemical fertilizer). Yotek, contributes unacceptable oil and grease loads to South Charleston WWTP and the Village of South Charleston has given a directive to Yotek to remediate the problem.

Sixty-one (61) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to six parameters: $cBOD_5$, fecal coliform, ammonia-N, TSS, dissolved oxygen (D.O) and pH. Forty-nine percent (49%) of NPDES violations occurred repeatedly and were divided equally between years, 1998, 1997 and 1994. Thirty-nine percent (39%) of the NPDES violations were divided equally between 1993 and 1996. Over half (52%) of the NPDES violations occurred between 1996 and 1998 with ammonia-N and fecal coliform the most recurrent parameter exceeded.

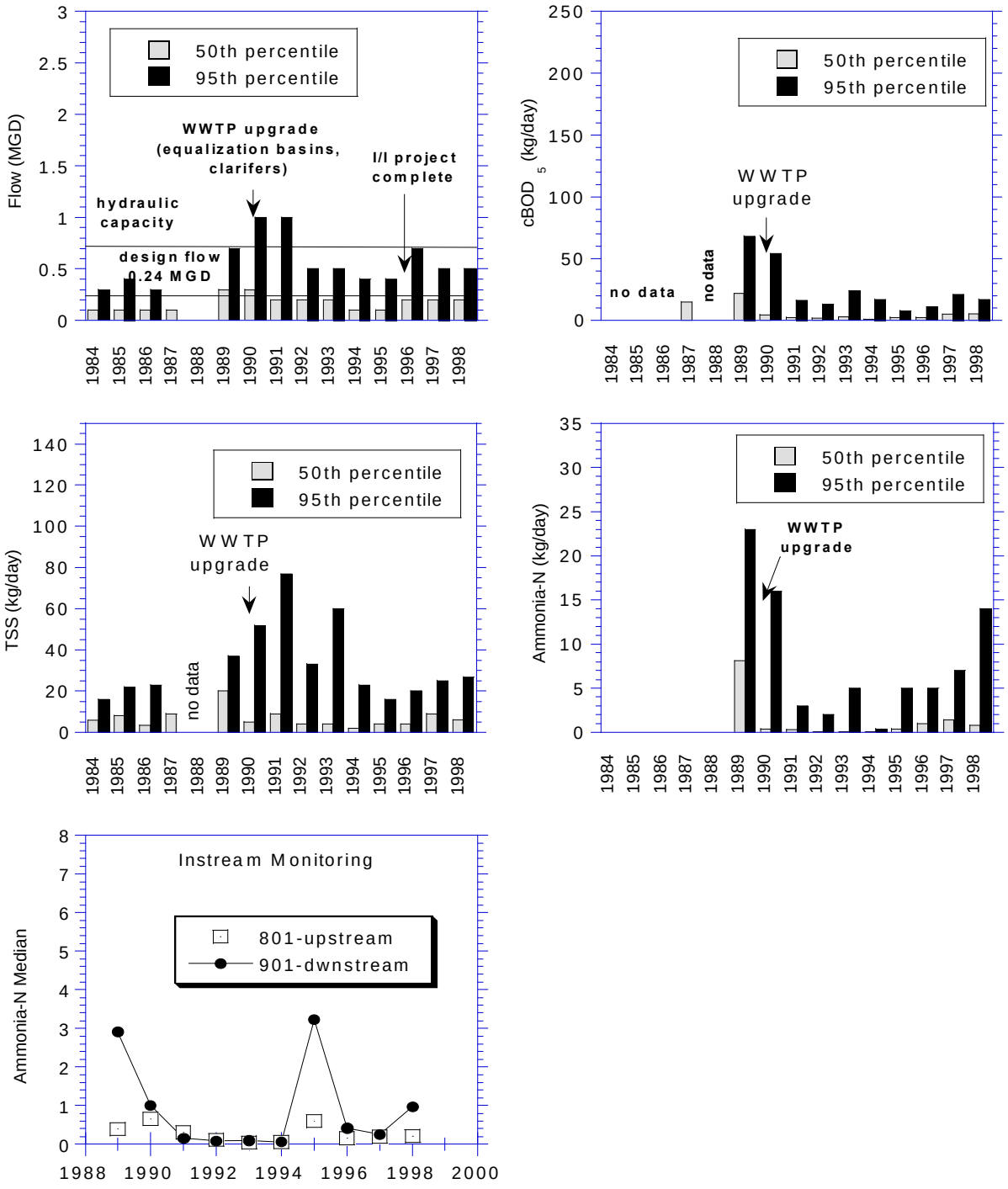



Figure 23. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and mean instream ammonia-nitrogen concentrations from the South Charleston WWTP for the period of record indicated.

Modified NPDES permit conditions for final effluent requires that by 2004, composite sampling for ammonia-nitrogen occur and in-fluent sampling be altered from grab to composite. The mercury limit was also reduced five to seven times that of the previous permit modification. Sampling upstream and downstream monitoring stations (801/901) no longer will require analyses of TSS and chlorine.

Reduction in median flows and percentile variance were notable after the facility upgrade of 1990 and remained within predictable ranges (Figure 23). Ninety-fifth percentile flows were typically greater than the 0.2400 MGD average design flow, indicating the need for a plant expansion. Following the Inflow and Infiltration (I&I) Project, completed in 1996, slight reductions in 95th percentile flow and percentile variance were noted. Annual 95th percentile ammonia-N loads generally increased from 1995-1998 while other conventional parameters remained fairly unchanged. The South Charleston WWTP median ammonia-N load for 1998 comprised 1% of the aggregate load of 19 dischargers evaluated discharging in the Little Miami River Watershed (Figure 36).

**Totes Inc. WWTP (RM 22.2)**

Totes Incorporated manufactures yellow and black latex boots utilizing processes such as latex dips, mold cleaning, mixing/curing and compounding. Production proceeds twenty-four hours, five days a week, with peak production between January and September. October through December production ceases and distribution begins. Wastewater volume is approximated at 30,000 gallons per day and consist of non-contact cooling water, second-stage $Cl_2$ wash treatment tank and stormwater. Treatment processes employ, activated sludge, settling, sand filters and chlorination. In 1996, OEPA conducted a Compliance Evaluation (C.E.) of Tote's wastewater facility and documented general poor upkeep of the work areas and grounds. In October, 1997 OEPA conducted a multimedia inspection of the plant and observed atypically large volumes of wastewater at the final outfall (001). The inspection occurred during Totes distribution month (Oct-Dec.) when wastewater production is at its lowest. The Totes operator could not account for the volume of water. The water appeared clear however it had an **?**antifreeze odor", similar to what was noted inside the industry. Ohio EPA inspectors left the facility and then returned a couple hours later to find the appearance of the **?**water" and volume unchanged however the associated odor had discontinued.

Permit violations for oil and grease, $BOD_5$, and TSS were commonly reported throughout 1994, 1995 and 1996. Storm water (primarily parking lot runoff) mixing with the final effluent has been mentioned as the cause of the oil and grease violations. Flow from non-contact cooling water, storm drains and the treatment plant combine prior to the outfall and are measured at the flume.

Two acute bioassay events, conducted by Ohio EPA in summer, 1998 and spring of 1998, exhibited slightly mixed toxicity results. Testing conducted in March, 1998 concluded the absence of acute toxicity to either test species in effluent samples. August 1998, testing revealed insignificant mortality to *C. dubia* in the effluent grab sample. No other mortality or adverse effects were observed to the fish and daphnia in the effluent and stream waters. Laboratory control survival was 95% or greater for both species.

As of July, 1999 Totes Inc. WWTP eliminated its direct discharge to the Little Miami River. Totes Inc.'s wastewater currently discharges to MSD Polk Run WWTP.

**Warren Co.-Lower Little Miami River WWTP (RM 0.14)**

Constructed in 1981 and upgraded in 1992, the Lower Little Miami River WWTP is a secondary treatment plant consisting of vertical loop reactor, extended aeration, secondary clarification and dechlorination. The collection system is separate with 100% of the service area sewered and 83 lift stations on the system. Population is approximately 36,500 with a population equivalent of 38,700 serving the City of Harrison, a portion of the Village of Morrow and Deerfield Twp. The WWTP discharges to Simpson Creek with a treatment plant flow design is 3.64 MGD with a recent doubled hydraulic capacity from 3.64 to 7.20 MGD. Upgrades since 1993 include two Vertical Loop Reactors and two clarifiers. The facility recently completed this upgrade and expansion however the facility is again in the design phase to double design capacity as development pressures continue for that area.

Numerous plant, lift station, manhole bypasses, and overflows were reported from 1993 to 1998. Foster Road Lift Station has had frequent bypasses and is in need of an upgrade as well as lift stations at Seilcrest Road and Carriage Gate Road Manhole overflows occurred repeatedly over six years at Socialville-Foster Rd, Columbia Rd , Walnut and Kings Mill Rd's. Most incidences were weather related and were reported due to equipment failure and human error. Most events were discovered between 700 a.m and 10 a.m.

The plant receives approximately 6% industrial input from two significant users, Sumitomo Sitex Silicon (semi-conductor devices) and Proctor and Gamble. Proctor and Gamble and Sumitomo Sitex Silicon are the only permitted industries on this system. Proctor and Gamble, a research and product development facility, currently monitors for several metals. There are no pretreatment limits for their metals and results reveal very low concentrations. Sumitomo Sitex pretreatment inflow is minimal and has not exceeded their pretreatment limits. Minor contributions occur seasonally ( sanitary wastewater) from Kings Island Amusement Park.

Ten (10) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to five parameters: $cBOD_5$, copper (total), total residual chlorine, fecal coliform and TSS. Total copper and $cBOD_5$ accounted equally for 60% of NPDES violations for all years. Ninety percent (90%) of the NPDES violations occurred from 1996 to 1998, exhibiting a general decreasing trend toward 1999.
Three acute bioassay events, conducted by Ohio EPA in the spring and early summer, 1990 revealed acute toxicity to *C. dubia* only. March, 1990 testing was technically invalid due to excessive mortality in control waters. April and May, 1990 first day grabs only, were acutely toxic and adversely effected motility in nearly all *C. dubia* exposed.

Entity conducted Whole Effluent Toxicity (WET) acute bioassay's (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* in 13 testing events (48-hour) over two separate years in 1993 and 1998. Results revealed acute toxicity to *C. dubia* for the test conducted in

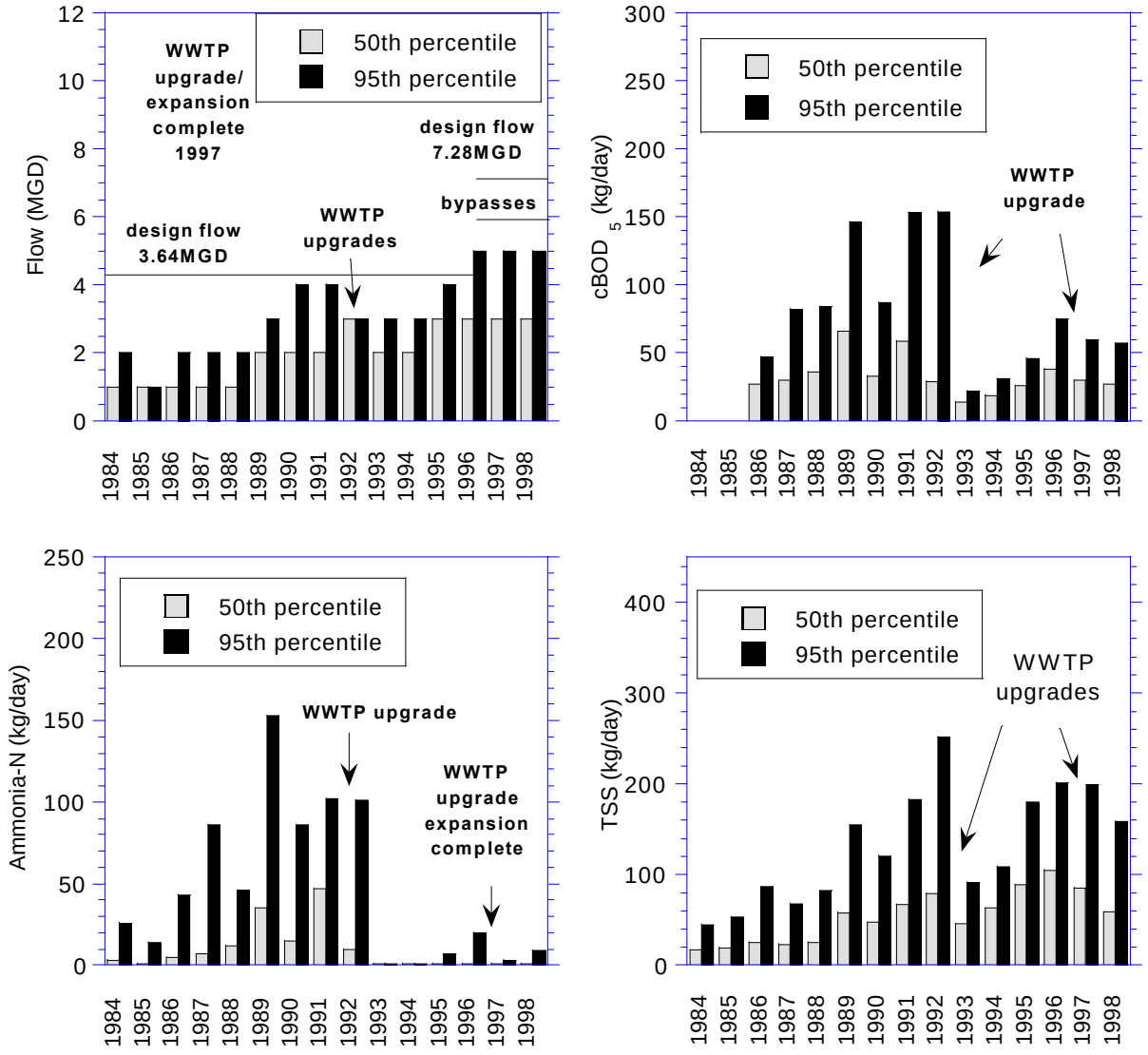



Figure 24. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, ammonia-nitrogen and total suspended solids from the Warren County Lower Little Miami WWTP for the period of record indicated.

November of 1993. Entity conducted Whole Effluent Toxicity (WET) tests, for 7-day chronic bioassays (a chronic effect can be measured in lethality, growth or reduced reproduction) were performed utilizing *P. promelas* and *C. dubia* in four testing events in 1993. *Ceriodaphnia dubia* populations exhibited chronic effects (above the AET limit) in reproduction and survival for toxicity testing conducted in December, 1993.

Annual median and 95th percentile flow exhibited a general increasing trend following the upgrade in 1992 (Figure 24). Although percentiles remained below plant design capacity many plant bypasses were reported from 1993-1998. Annual median and 95th percentile loadings for ammonia-N and $cBOD_5$ appeared similar to that of annual conduit flow behavior reflecting consistent loads. Median and 95th percentile TSS loads reacted independently of flows revealing no clear trend and suggesting slightly higher variability in effluent quality than the other conventional parameters. The Warren County Lower Little Miami River WWTP median ammonia-N load for 1998 comprised 3% of the aggregate load of 10 major dischargers evaluated in the Little Miami River Watershed.

**Village of Waynesville WWTP (RM 53.79)**

Constructed in 1962 with a major modification in 1983 the Waynesville WWTP is a secondary treatment plant consisting of flow equalization, fixed film reactor (RBC) extended aeration, lime stabilization and chlorination. The WWTP discharges to the Little Miami River and has design flow of 0.710 MGD. Collection sewers serve Harveysburg, Corwin and Caesar Creek Lake District and are currently maintained by the Warren County Sewer District. Seven lift stations exist, two inside and seven outside of the Village of Waynesville. The population is 1,969 with moderate to rapid growth predicted for the area. Service area has separate sewers and 100% of the area is sewered. Industrial contributions from a minor industrial user comprises <1% of the total inflow.

In April, 1998 Ohio EPA conducted an unannounced toxicity sampling event. Approximately four feet of solids were noted in the final effluent channel. Bypasses at the facility have been reported on numerous occasions since the previous survey in 1993. In winter and summer of 1997, partial bypasses occurred at the plant due to excessive flows and equalization lagoons filled to capacity. Waynesville WWTP reported automatic sampler failure at the time of the reported bypass events and could not sample at those times. In spring of 1996, several NPDES violations occurred due to numerous influences such as weather related flows and off-line RBCs. In 1995, excessive weather induced flows again caused bypassing of solids from the clarifier. In May, 1995 hydraulic overloading occurred 16 of 31 days with a reportable 8” of rain for the month. During the 16 days in-fluent flows were bypassed to the Little Miami River with minimum settling in the equalization lagoon.

Waynesville WWTP is currently seeking improvements to the existing facility to ensure compliance by the year, 2000. These improvements will include adding clarifiers, converting to total aeration, improving grit and mechanical screening and converting primary treatment tanks to sludge holding areas.

Eighteen (18) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to five parameters: TSS, dissolved oxygen (D.O), ammonia-N, fecal coliform and total residual chlorine. Seventy-two percent (72%) of NPDES violations occurred between years, 1993-1995. Permit violation records revealed a steady decline over the six years (1993-1998) with reductions primarily occurring from 1996-1998 when 27% of the total violations were reported These were dominated by TSS violations. Third quarter loadings for ammonia-N graphically exceeded 30-day NPDES limits (Figure 25) from 1996-1997 verifiably correlating with NPDES database violations reported in August and September of 1997.

One acute bioassay event, conducted by Ohio EPA in the winter, 1997 revealed no acute toxicity to either *C. dubia* or *P. promelas* in effluent samples or ambient waters. No other adverse effects or mortality were noted. Survival in the laboratory controls was 100% for both test organisms.

Annual median flow was typically below the design capacity for eight of fifteen (15) years, exhibiting a slight increase due possibly to greater volumes from population growth or an aging system (inflow and infiltration (I&I)) or both (Figure 25). Ninety-fifth percentile flow exceeded design flow near the end of record as treatment irregularities became apparent. due to reported excessive weather induced flows. Annual 95th percentile for TSS, $cBOD_5$ and ammonia-N were dramatically higher than 50th percentile after 1993. Percentiles were generally two to three times greater than the variability observed earlier in the record period due to overloaded equalization lagoons and reported excessive flows. Annual loadings of ammonia-N, based on 50th percentile values, declined from 0.4 kg/day in 1988 to 0.3 kg/day in 1998. This decreasing trend resulted in 25% reduction in ammonia-N loadings to the Little Miami River. The Waynesville WWTP median ammonia-N load for 1998 comprised 1% of the aggregate load of the 19 dischargers evaluated in the Little Miami River.

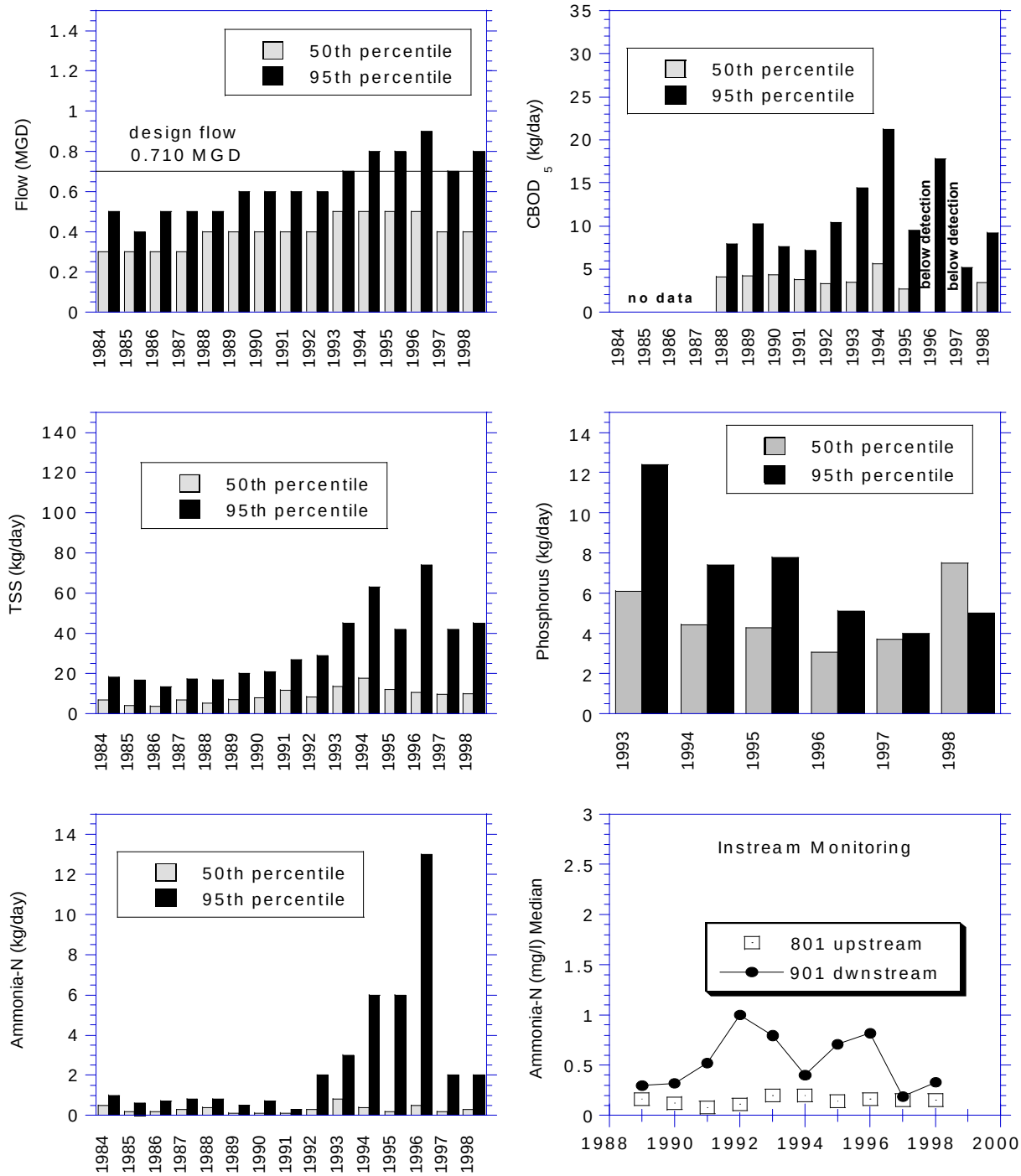



Figure 25. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, total suspended solids, phosphorus, ammonia-nitrogen and instream ammonia-nitrogen concentrations from the Waynesville WWTP for the period of record indicated.

**Wilmington WWTP (RM 6.83)**

Wilmington WWTP is a secondary treatment plant utilizing grit removal, primary settling, trickling filter towers, solids aeration, secondary settling and UV disinfection. Plant design flow is 3.0 MGD with a discharge to Lytle Creek. The WWTP was constructed in 1937 with improvements implemented in 1954, 1961, and a major modification in 1988. The population is 11,431 and the service area on 100% separate sewers. Administrative orders were issued against The City of Wilmington in September, 1996 for unapproved sludge test methods, land application of sludge and arsenic ceiling concentration exceedences. Industrial contributors include a metal finisher, electroplating, foundry, semiconductor manufacturer and a bag printer and manufacturer.

Twelve (12) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to six parameters: cBOD5, zinc (total), TSS, ammonia-N, oil and grease and dissolved oxygen (D.O). Zinc and $cBOD_5$ accounted for 50% of the total NPDES violations occurring with no apparent trend of frequency from 1994-1998. Over half (67%) of the NPDES violations occurred from 1993 through 1995. Zinc and dissolved oxygen (D.O) continued to exceed NPDES limits in 1998.

Ten acute bioassay events, conducted by Ohio EPA in the summer and spring from 1981-1998, exhibited mixed toxicity results. All mortality and adverse effects occurred in earlier bioassay events (1980's). The March 1986, July 1981 and June 1984 tests were the most toxic to both test organisms. Excessive mortality in definitive tests indicated upstream dilution water made it impossible to calculate lethal concentration for *C. affinis and C. dubia*. Summer testing events in 1993 (two events) and 1998 (one event) exhibited no toxicity to either *C. dubia* or *P. promelas* test organisms in effluent samples or ambient waters.

Ninety-fifth percentile flow exceeded design capacity for 67% of the flow record occurring primarily in the 1990's (Figure 26) with slight variability evident (1996 statewide high precipitation year). Conventional parameters were stable for the entire record suggesting consistent plant performance. The Wilmington WWTP median ammonia-N load for 1998 comprised 1% of the aggregate load of 10 major dischargers evaluated Little Miami River Watershed (Figure 36).

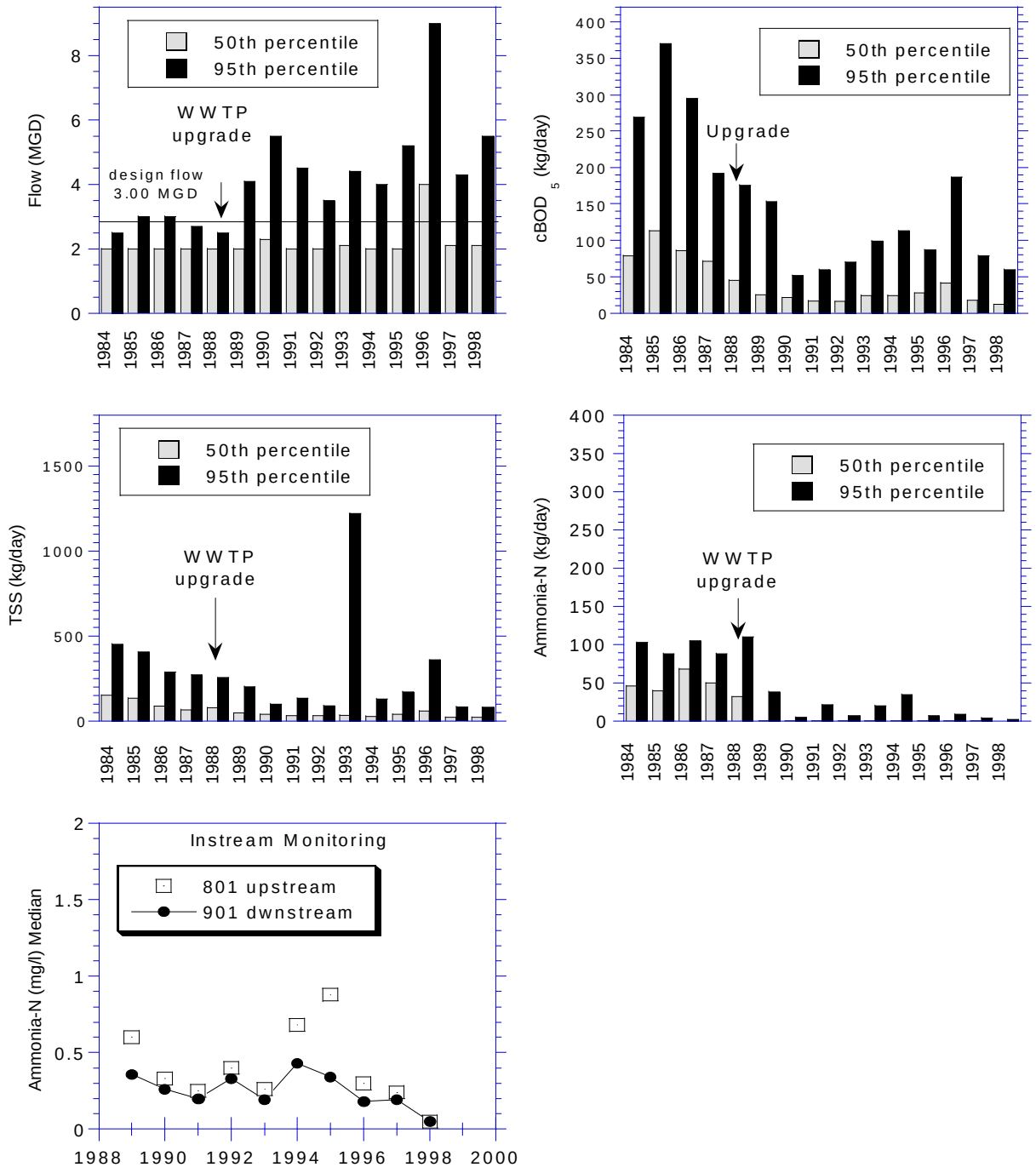



Figure 26. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and mean instream ammonia-nitrogen concentrations from the Wilmington WWTP for the period of record indicated.

**City of Xenia-Ford Rd WWTP (RM 77.03)**

Constructed in 1969 and upgraded in 1988, the Xenia-Ford Rd facility is an advanced secondary treatment plant consisting of secondary clarifiers, flow equalization, final clarification and dechlorination. The WWTP discharges directly to the Little Miami River with a design capacity of 3.60 MGD and a peak daily flow of 7.50 MGD. The city has discussed expansion of peak hydraulic capacity from 7.5-12.0 MGD. The existing design flow of 3.60 MGD will remain unchanged. The design capacity of the plant is not currently being exceeded however the hydraulic loading capacity is overloading the Inflow Retention Basin. Three lift stations exists on the collection system none of which are considered problematic. Xenia -Ford Rd WWTP serves northern Xenia and nearly all of the service area is sewered with separate sewers. The latest population census is 25,000, with no reported population equivalent or expected growth.

Improvements since 1993 include sludge processing, dewatering and lime stabilization. Future upgrades proposed include the installation of new screening devices, raw wastewater pumping modifications, construction of a new grit removal facility, construction of new secondary clarifiers and the conversion of existing clarifiers to aerobic digesters for sludge holding. The Xenia-Ford Rd WWTP median ammonia-N load for 1998 comprised 22% of the aggregate load of 10 major dischargers evaluated in the Little Miami River Watershed.

Various efforts are currently on-going to reduce inflow/infiltration in the Xenia-Ford Rd WWTP collection system. Relatively few overflows are reported occurring at the equalization basins at Xenia-Ford Road One chronic overflow, reported by the City of Xenia and occurring for numerous years, is the intermittent pumping from a manhole in the collection system directly to Shawnee Creek during heavy precipitation events. This practice has been greatly reduced except during extreme wet weather. Many facility bypasses exceeded 24 hours and nearly a million gallons of partially treated wastewater has discharged to the Little Miami River since 1993. One such incident in 1994 at the Pinecrest pump station, bypassed for 168 hours, dumping over a million gallons of untreated sewage to the river. In 1996, rain and melting snow prompted the reporting of six incidences of bypassing at the facility. Other overflow events in 1997 involved a manhole at N. West St. (debris obstruction) and two incidences of sewer backups into basements at California St.

Industrial contribution to the plant is approximately 5% of the inflow. Pretreatment records indicate three Significant Industrial Users (SIU) are on the WWTP's collection system. Pretreatment records for 1996-1999 document that the File Sharpening Company (file sharpening), violated oil and grease once in 1998. Central State University violated pretreatment standards for copper and mercury on numerous occasions in April-June 1999 (pretreatment records denote Central State University has been in non-compliance a few times for mercury from 1998-1999). In the spring of 1993 several plant bypasses were reported with ammonia concentrations of 5-6 mg/l detected.

Four (4) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations were limited to four parameters: TSS, ammonia-N, chromium (total)

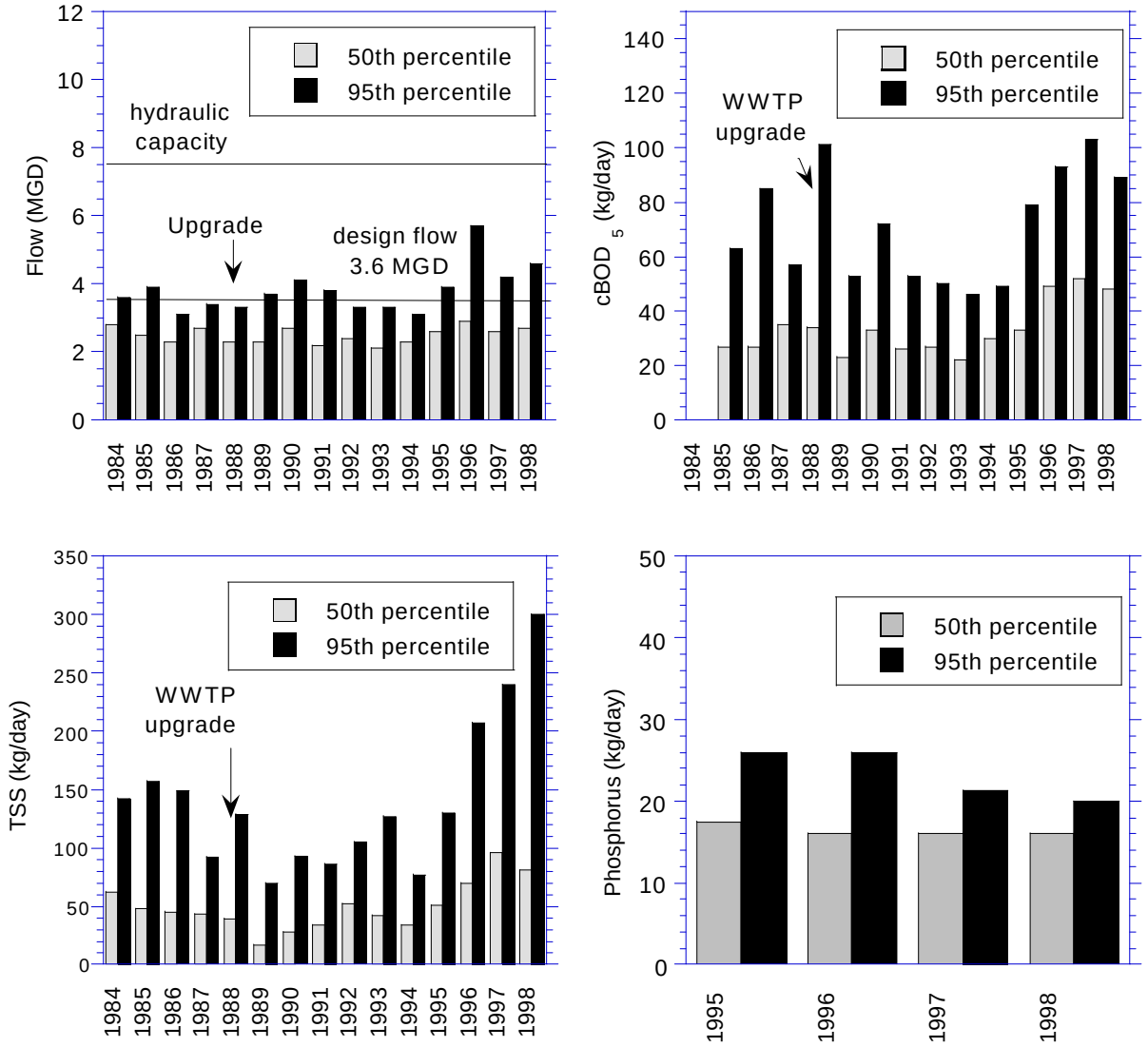



Figure 27. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, total suspended solids, and phosphorus from the Xenia-Ford Road WWTP for the period of record indicated.

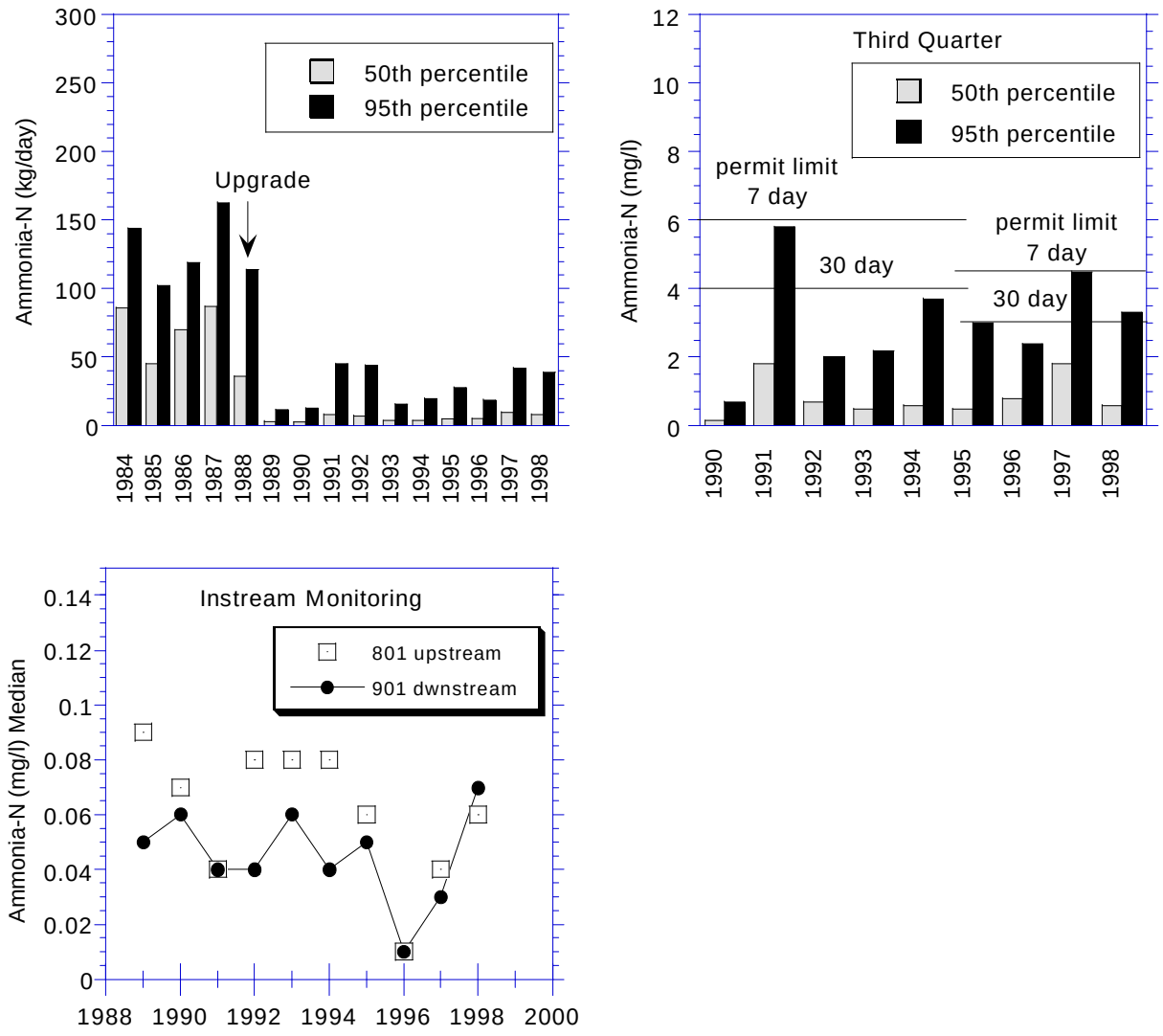



Figure 28. Median and 95th percentile loadings of ammonia-nitrogen, third quarter ammonia-nitrogen, and mean instream ammonia-nitrogen concentrations from the Xenia-Ford Road WWTP for the period of record indicated.

and $cBOD_5$. Total residual chlorine accounted for 69% of notifications by the entity (occurring primarily in 1996-1998), however concentrations remained below the Practical Quantification Level (PQL) for the facility and therefore were considered to be in compliance with the NPDES limit. Preliminary data for 1999 indicate chlorine discharges continued for the facility. Ninety-two percent (92%) of the NPDES violations occurred between 1996 and 1998.

Two acute bioassay events, conducted by Ohio EPA in the summer and winter of 1997 revealed no acute toxicity to either *C. dubia* or *P. promelas* in effluent samples or ambient waters. Mortality to *P. promelas* and *C. dubia* were <10% in ambient, effluent, composite and laboratory control waters.

Ninety-fifth percentiles for flows were greater than the design capacity (3.60 MGD) from 1995-1998. This indicates overloaded design and hydraulic loading capacities resulting in the overflow of the in-fluent retention basins (Figure 27). Median and 95th percentile $cBOD_5$ and TSS loads reacted independently of flows, exhibiting a general increasing trend and suggesting slightly higher variability in effluent quality than for the other conventional parameters. Annual median ammonia-N loads increased slightly following the facility upgrade of 1988 while percentile variance remained negligible. Graphing suggested predictable nitrification occurring in plant. Wastewater improvements, completed in 1988, resulted in notable declines overall for ammonia-N. Annual loadings of ammonia-N, based on 50th percentile values, declined from 36 kg/day in 1988 to 8.4 kg/day in 1998. Median ammonia-N loads from 1993-1998 doubled (4.0-8.4 kg/day) comprising 53% of the aggregate load from all five mainstem WWTP's discharging directly to the Little Miami River (four majors). Reduced NPDES limits from 1995 to 1998 demonstrate 95th percentiles exceeding 30-day limits twice as often (50%) as NPDES limits expired in 1995 (Figure 28). This decreasing trend resulted in an approximate 77% reduction in ammonia-N loadings over the years, to the Little Miami River. However, from 1993 until 1998 a general increasing trend and percentile variability in ammonia-N is evident and is most attributable to nitrate variances (incomplete nitrification) probably linked to operational controls. The increase in the ammonia-N load increases the potential for increased ammonia toxicity and oxygen demand downstream from the WWTP with nitrification occurring in the stream rather than in the WWTP. In addition the flow in the stream is effluent dominated during the summer months exacerbating the effects of nutrient loadings from the WWTP.

**City of Xenia Glady Run WWTP (RM 4.93)**

Constructed in 1959 with a major modification in 1988 and 1996, Xenia-Glady Run WWTP is an advanced secondary treatment plant consisting of activated sludge, settling and anaerobic digestion. The WWTP has a design capacity of 4.00 MGD with one lift station (not problematic) on the collection system. Discharge is directly to a small creek, Glady Run. Historically the plant discharged to a drainage swale of Glady Run. Glady Run recently merged with the swale. The estimated population is a minimum 25,000 in the southern section of the City of Xenia which is served by this plant. The entire service area is sewered.

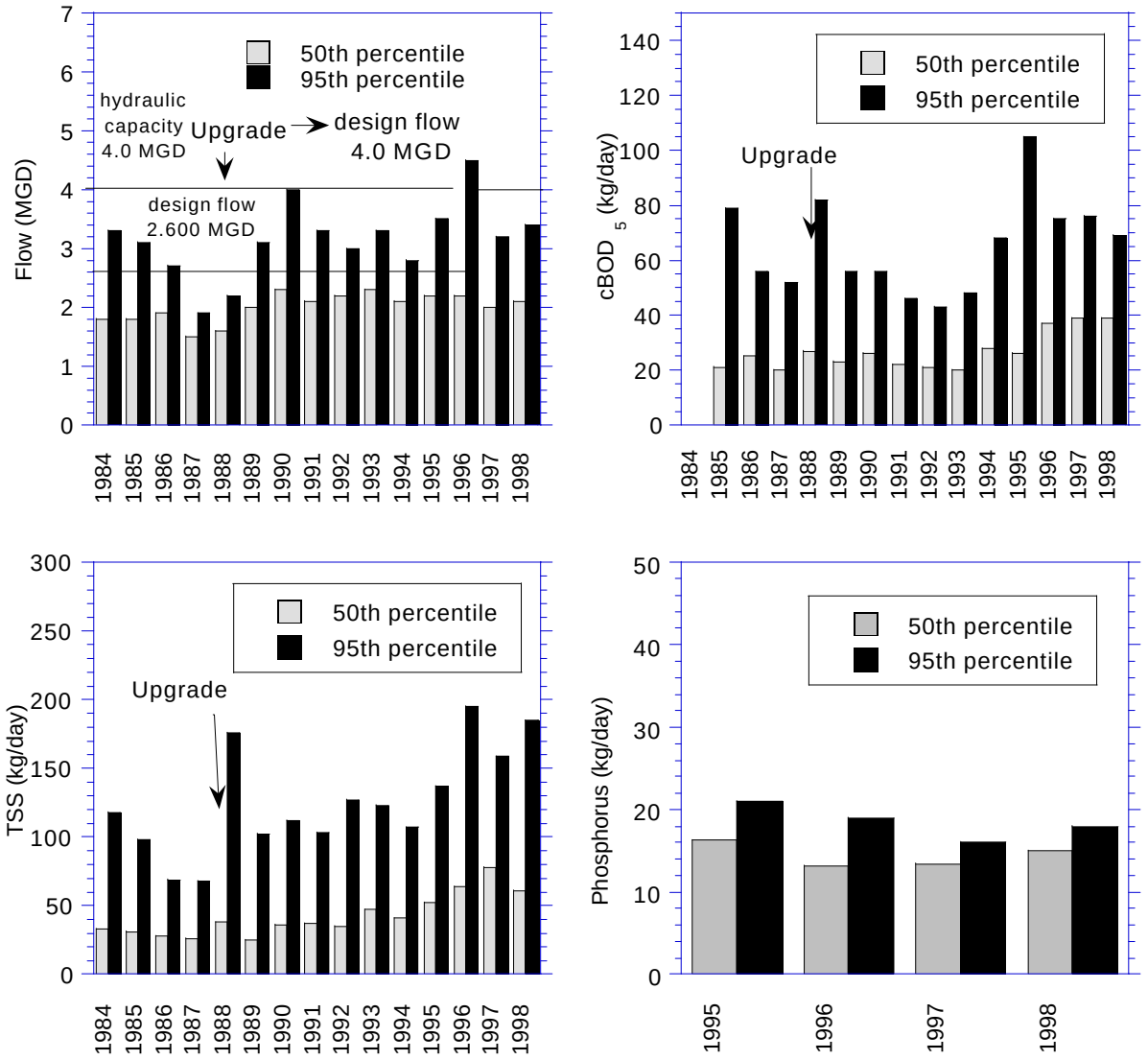



Figure 29. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, total suspended solids, and phosphorus concentrations from the Xenia-Glady Run WWTP for the period of record indicated.

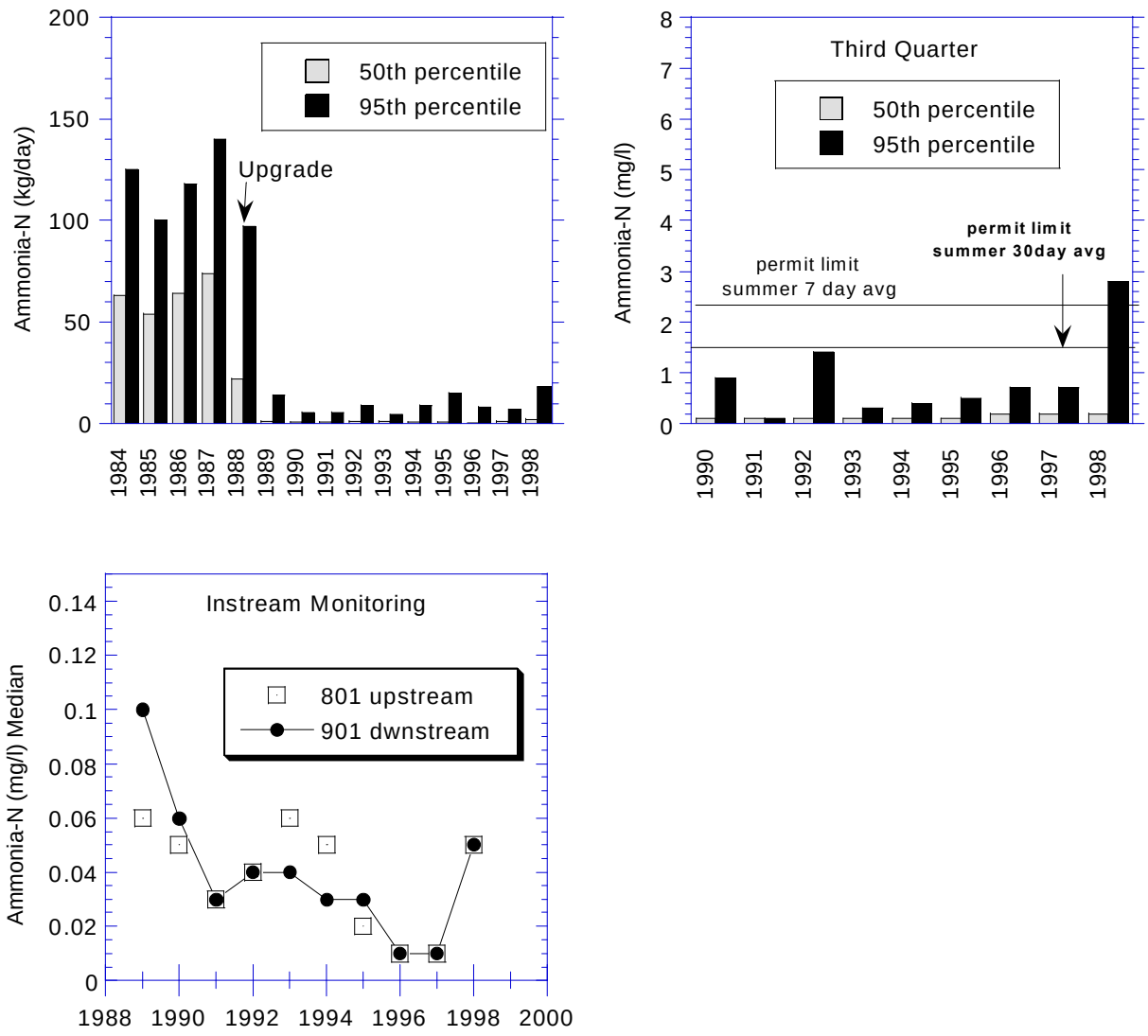



Figure 30. Median and 95th loadings of ammonia-nitrogen, third quarter ammonia-nitrogen, and mean instream ammonia-nitrogen concentrations from the Xenia-Glady Run WWTP for the period of record indicated.

The facilities in-fluent pumping capacity and relatively shallow final clarifiers have hindered its ability to handle peak flows. In 1996 the City prepared a facilities plan to address future growth and improvements needed at the plant. In 1997 improvements included the expansion of the disinfection systems and a new Sludge Processing Facility instituted at the Xenia-Ford Rd plant designed to serve both plants. In 1998 dechlorination, sludge processing, dewatering and lime stabilization went online. The City is continuing a program to evaluate its sewer system by repairing and removing sources of inflow and infiltration as they are identified. The City is utilizing smoke testing, televising and placing flow monitors in the collection system to aid in identifying the I&I problems.

In the spring months of 1993, 1994, 1995 and 1996 facility bypassing occurred for several hours reportedly caused by weather related excessive flows Ammonia levels were detected on the average of 5-6 mg/l during this bypass. The Pinecrest Relief Sewer was completed in 1995 and intended to eliminate facility bypass problems. Glady Run bypasses do not mix with final effluent in the plant. The design treatment capacity of the plant has not been exceeded. However, the hydraulic loading capacity is routinely exceeded filling the Inflow Retention Basin and overflowing during certain storm events. Overloaded collection systems, through March of 1998, occasionally resulted in Bob Evans Farm's facility (located on Birch Rd.) waste overflowing at a constricted region of the sewer line near Rt 35, downtown Xenia, where raw in-fluent would spill into the creek through a perforated manhole. This facility is a slaughterhouse and sausage production operation. In March of 1998 Bob Evan's Farm installed a significant pretreatment system capable of reducing BOD and oil and grease discharges to the City. This has eliminated the overflow occurrences at the downtown location.

Planned improvements at the Xenia Glady Run facility commenced in 1999 and include conversion of the existing activated sludge treatment process to Biological Nutrient Removal (BNR) process. Two new BNR tanks will be added. The existing grit removal facility will convert to a raw sewage pumping facility. Two new clarifiers will be instituted to handle a peak hydraulic flow of 12.0 MGD. The project will provide the needed improvements through the design year of 2015. When the expansion is complete the City of Xenia will increase the average treatment capacity of the WWTP from 2.6 to 4.0 MGD and the peak hydraulic capacity from 4.6 to 12.0 MGD.

In 1997 the City instituted a pretreatment program for both WWTPs although most of the industrial flow is received by the Glady Run WWTP. No indirect pretreatment dischargers exist however five significant industrial users are on the system. Pretreatment records indicate Modern Technologies Corporation violated hexavalent chromium and cyanide one time during 1998. Bob Evans Farms and Twist, Inc. were in violation of cyanide one time each in 1999. Vii Craft violated their copper limit once in 1999.

Two (2) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations were limited to two parameters: ammonia-N and hexavalent chromium. Total mercury accounted for 50% of notifications by the entity (occurring primarily in 1995 and 1996), however concentrations remained below the Practical Quanitification Level (PQL) for the facility and therefore were considered to be in compliance with the NPDES limit.

Two acute bioassay events, conducted by Ohio EPA in the spring, 1998 and summer of 1998 revealed no acute toxicity to either *C. dubia* or *P. promelas* test organisms in effluent samples or ambient waters. Survival in the laboratory controls was 100% for both test organisms.

Entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute is measured in lethality) were performed utilizing *C. dubia* and *P. promelas* in one testing event (48-hour) in 1994. Test results for both organisms were inconclusive due to failed testing endpoints and an AET of <1.0 TUA.

Plant design flow capacity increased to 4.00 MGD by 1996 and currently the plant is under additional expansion (Figures 29 and 30). Projected annual percent inflow increase to the WWTP for 2000 is 10%. Low variance in ammonia-N percentiles and in loading quantities suggest correlation with reduced median conduit flows noted in 1997 and 1998. Ninety-fifth percentiles for TSS were generally three to five times median loads for the majority of the record. Median and 95th percentile for ($cBOD_5$) did not change appreciably, remaining fairly consistent throughout the period of record. This was indicative of predictable plant performance for this parameter. The Xenia Glady Run WWTP median ammonia-N load for 1998 comprised 5% of the aggregate load of 10 major dischargers evaluated in the Little Miami River Watershed.

**Village of Yellow Springs WWTP (RM 4.4)**

Constructed in 1961, the Yellow Springs WWTP operates as secondary treatment consisting of extended aeration, secondary clarification, chlorination, and aerobic sludge digestion. The Yellow Springs WWTP effluent flows through a series of high gradient cascading falls Glen Helen Preserve before splitting into several channels that enter Yellow Springs Creek over a 100 meter segment. An upgrade to the WWTP in July of 1988 resulted in a design flow of 0.600 MGD. The service area consists of separate sewers with 90% of the area sewered. The most recent census, incorporating the Antioch College session, estimates the population at 3,772 with a population equivalent of 3,973 and stagnant growth predicted. One lift station with an overflow exists, however overflow incidences rarely occur due to recent upgrades. Elimination of the lift station overflow is planned with the future upgrade of the plant. An upgrade to the internal bypass was recently approved which should provide more accurate flow readings and reduce or prevent solids washouts during high flows. Replacement and rehabilitation of the Dayton Street trunk sewer line trunk line was completed in 1998. The project was initiated due to inflow and infiltration problems in an aging collection system resulting in volumes hydraulic overload of the system collection during wet weather events.

Industrial input from Vernay Labs, Inc. (print shop), Yellow Springs Instruments (environmental instruments) and Antioch Publishing Company (publishing company) comprises 2-4% of the WWTP inflow. Yellow Springs WWTP has no significant industrial users and is not required to implement an industrial pretreatment program at this time.

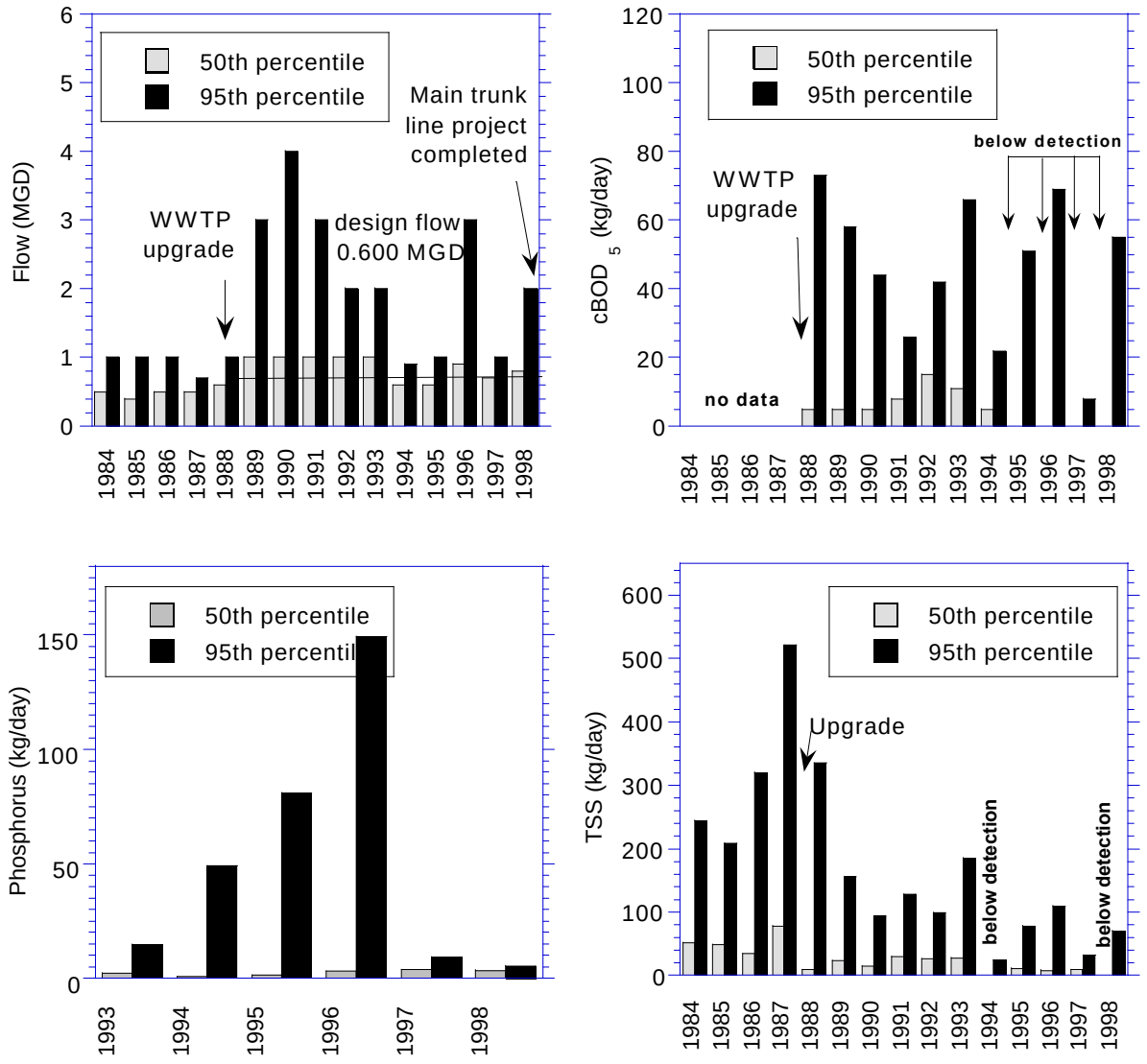



Figure 31. Median and 95th percentile effluent flows, and loadings of five-day biochemical oxygen demand, phosphorus, and total suspended solids from the Yellow Springs WWTP for the period of record indicated.

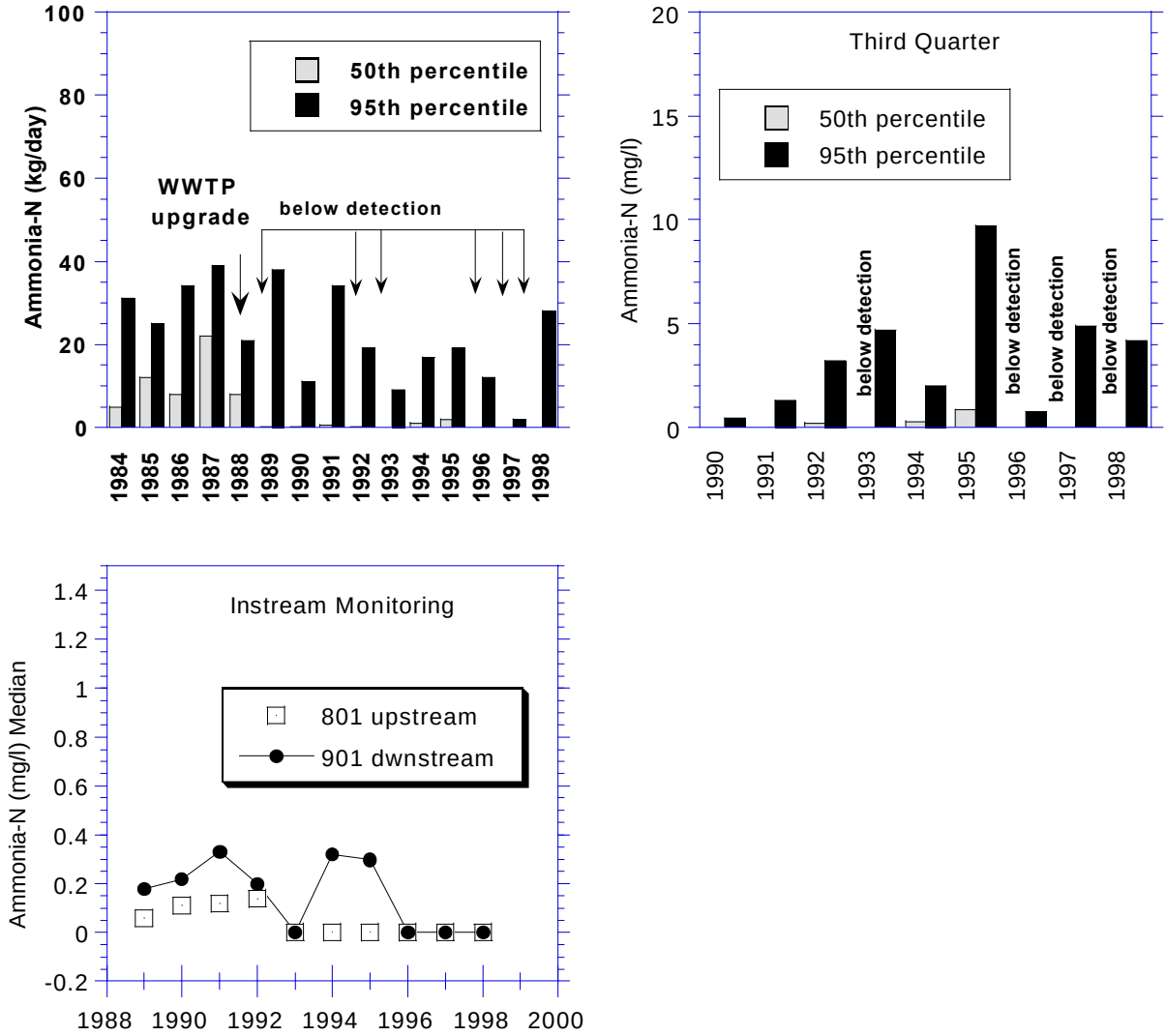



Figure 32. Median and 95th percentile loadings of ammonia-nitrogen, third quarter ammonia-nitrogen and mean instream ammonia-nitrogen concentrations from the Yellow Springs WWTP for the period of record indicated.

Seventy-seven (77) violations of the NPDES permit were reported to Ohio EPA for outfall 001 between 1993-1998. The violations, in declining order of frequency, were limited to three parameters: $cBOD_5$, fecal coliform and TSS. Carbonaceous biochemical oxygen demand ($cBOD_5$) accounted for 39% of NPDES violations and occurred continually from 1993-1998. Fecal coliform and $cBOD_5$, combined, accounted for 83% of the total NPDES violations. Fifty percent (50%) of the NPDES violations occurred between 1996 and 1998 (Dayton street trunkline project ongoing 1997-1998). Preliminary data for 1999 indicate notable reductions in NPDES violations for all of the aforementioned conventional parameters.

Two acute bioassay events, conducted by Ohio EPA in the fall and winter, 1992 revealed no acute toxicity to either *C. dubia* or *P. promelas* in effluent samples. October, 1992 samples revealed ten percent mortality to *C. dubia* in Yellow Springs Creek upstream water after 48-hr exposure, insufficient to describe the upstream receiving water as acutely toxic. Bioassay tests, from December 1992, indicated ten percent mortality in *C. dubia* not sufficient to describe the end point as acutely toxic.

Annual median flows began exceeding average design flow in 1989 (exception-1994-1995) and continued throughout the period of record. Possible causes for exceedences are I&I , flow meter inaccuracies or capacity concerns. Annual median loads for the conventional parameters correlated with flow, generally decreasing in trend however for ammonia-N and $cBOD_5$ 95th percentile variability remained high demonstrating the considerable instability of effluent quality. Median percentiles for TSS showed reductions of nearly 200% from the early 1990's (Figures 31 and 32). The Yellow Springs WWTP median ammonia-N load for 1998 comprised 1% of the aggregate load of 22 dischargers evaluated in the Little Miami River Watershed (Figures 33 and 34).

**NPDES Summary**- From 1993 to 1998, 29 facilities were evaluated that discharge within the entire Little Miami River Watershed. For purposes of this report 22 dischargers were evaluated that discharge directly or indirectly to the Little Miami River, and six that discharge directly or indirectly to the East Fork Little Miami River. Twenty-six percent (26%) of the 22 dischargers to the entire Little Miami River watershed had discharges of mercury (total). The appearance of mercury could originate from various sources such as dental offices, universities, hospitals and industry. All of the occurrences of mercury were below the Practical Quantification Level's (PQL) for the respective facility and therefore were considered to be in compliance with the issue NPDES permit. Thirty-three percent (33%) of six dischargers to the East Fork Little Miami River had discharges of total mercury in the past six years (1993-1998). All of the occurrences of mercury were below the Practical Quantification Level's (PQL) for the respective facility and therefore the facilities were considered to be in compliance. Twenty-four percent (24%) of 29 facilities, in the entire Little Miami River watershed, discharged metals, other than total mercury to the waterways at violations above their NPDES limits. All discharges of the metals in violation status were to the Little Miami River watershed (seven entities) and accounted for 30% of all discharges to that watershed. Other than total mercury the most common metals discharged to the LMR watershed were total copper and total zinc respectively.

A minimum of 430 monthly incidences of parameters violating NPDES limits were totaled while evaluating 23 direct and indirect dischargers to the Little Miami River, from 1993 to 1998 (parameters with daily maximums and monitoring requirements such as total residual chlorine, pH and dissolved oxygen (D.O) account for even greater numbers of NPDES violation incidences and could promote these parameters to a higher frequently status). Exact numbers for those parameters are beyond the scope of this report. The most frequent parameter exceeding NPDES limits on a total monthly basis from 1993-1998, in declining order of frequency, were $cBOD_5$, TSS, ammonia-N, fecal coliform, total residual chlorine, all metals, dissolved oxygen (D.O), oil and grease and pH.

The five leading classified major (> 1.0 MGD) dischargers, with the most numerous NPDES violations (from 1993-1998) in descending order of frequency, were Yellow Springs WWTP, South Charleston WWTP, Hamilton County MSD Sycamore WWTP, Greene County Sugar Creek WWTP and Lebanon WWTP. Greene County Sugar Creek and Lebanon WWTP had equal number of NPDES violations. The ten leading dischargers of NPDES violations from 1993-1998 of all 29 facilities (majors and minors), discharging directly or indirectly to the entire Little Miami River basin, in descending order of frequency, were Yellow Springs WWTP, Clermont County Batavia, South Charleston WWTP, Blanchester WWTP, Hamilton County MSD Sycamore WWTP, Jamestown WWTP, Lynchburg WWTP, Greene County Cedarville WWTP, Waynesville WWTP and Greene County Sugar Creek. The three leading dischargers of six facilities (majors and minors), with NPDES violations, discharging directly or indirectly to the East Fork of the Little Miami River basin in descending order of frequency, were Clermont County Batavia, Milford WWTP and Middle East Fork WWTP.

**Toxicity Summary**

Evaluating Ohio EPA conducted toxicity tests of 15 facilities in the Little Miami River Watershed showed acute toxicity in approximately 50% of the tests for following facilities: Cedarville WWTP, Lebanon WWTP, Mason WWTP, Hamilton County MSD Polk Run WWTP, Clermont County Lower East Fork WWTP and Warren County Lower Little Miami River WWTPs. Entity conducted acute and chronic toxicity test results (1993 to 1998) of eleven facilities in the Little Miami watershed showed toxicity at five of eleven facilities, (City of Mason, MSD Polk Run, Clermont County Lower East Fork WWTP, Warren County Lower Little Miami River WWTPs and Hamilton County Sycamore Creek WWTPs).

Ohio EPA conducted toxicity screening tests, from 1993-1998, for six facilities in the upper LMR (headwaters to Caesar Creek), revealed toxicity at one facility (Cedarville WWTP, 100% of screening tests). Entity conducted acute and chronic toxicity tests (1993-1998) for three facilities in the upper LMR (headwater to Caesar Creek), showed no toxicity. Seven the nine facilities in the lower reach (Caesar Creek to mouth) exhibited some level of acute and or chronic toxicity in their discharge in Ohio EPA tests. Of entity conducted tests at eight facilities in the lower reach (Caesar Creek to mouth), five exhibited some level of acute and or chronic toxicity in their discharge.

**Flow Summary (001 outfall)**
A slight increase in the amount of treated wastewater effluent, discharged by five *mainstem* facilities to the Little Miami River is a result of expansion of at lease two facilities between 1993 and 1998 (Figure 33). The cumulative total average annual flow increased three percent from 15.0 MGD in 1993 to 15.5 MGD in 1998. Greene County Sugar Creek and Xenia-Ford Rd WWTPs accounted for the majority of the increase.

In evaluating 22 dischargers (minors and majors) during 1998, the cumulative annual (median) effluent flow to the watershed totaled 59.0 MGD, an increase of 6.0 MGD from the compilation of 22 dischargers in 1993 (Figure 34). Three dischargers, in the upper watershed (headwater to Waynesville) accounted for 35% of the total flow to the watershed (Montgomery County Eastern Regional, Greene County Beaver Creek and Sugar Creek WWTPs). Development pressures increasing volume to the collection system increased inflow and infiltration problems, increased numbers of aging collection systems introducing greater accuracy of flow reporting, amongst other reasons, are all factors that would account for increases observed over five years.

**Ammonia-N Loadings Summary (001 outfall)**
The 200% reduction in final effluent annual median ammonia-N loads discharged by *mainstem* dischargers (five WWTPs), to the Little Miami River for the past five years, is not attributable to any significant upgrade of a facility (Figure 35). Improvements appear to be a result of increased effort to implement minor pollution controls, reduce I&I and improve operational management of the WWTP's. By 1998 Lebanon WWTP reduced annual ammonia-N load (median) to the watershed by 100% However, Lebanon WWTP still contributed 32% of the ammonia-N load, ranking fourth of five in discharge quantity while exhibiting a slight reduction in flow over 1993. Xenia-Ford Rd WWTP contributed over half of the ammonia-N load for mainstem dischargers; increasing ~110% over 1993 loads with a 29% increase in flow. The second largest contributor of flow to the mainstem, MSD Polk Run WWTP, contributed insignificant ammonia-N loads for 1993 and 1998.

The 1993 annual median ammonia-N loading from 18 dischargers to the Little Miami River watershed was 85 kg/day compared to median loadings observed in 1998 of 52 kg/day, a 58% reduction in ammonia-N (Figure 36). In 1993, Greene County Sugar Creek WWTP was the largest contributor of ammonia-N load was in the upper watershed (headwater to Waynesville) contributing nearly half of the ammonia-N load. In 1998, WWTPs in the lower watershed composed nearly 54% of the ammonia-N load to the watershed. In 1993 the upper watershed facilities discharged 66% of the ammonia-N load compared to 46% in 1998.

**Ammonia-N Summary for 801/901 (entity monitoring)**
Of five major dischargers to the Little Miami River mainstem only Greene County Sugar Creek WWTP and Xenia Ford WWTP have upstream monitoring data (801) that reveal average ammonia-N values greater than downstream values (Polk Run WWTP upstream and downstream values were similar in average concentration). Xenia-Ford WWTP upstream values were 5% higher than those detected at Greene County Sugar Creek WWTP (approximately 15 river miles apart). Nearly 50% of Greene County Sugar Creek WWTP's upstream concentrations were greater than or equaled those

detected downstream. Waynesville WWTP and Xenia-Ford WWTP exhibited the greatest variance between 801 and 901 concentrations for 40-50% of their data. Xenia-Ford Road and Greene County Sugar Creek WWTP's (most northern direct dischargers) upstream ammonia-N concentrations for were analogous at 0.06 mg/l..

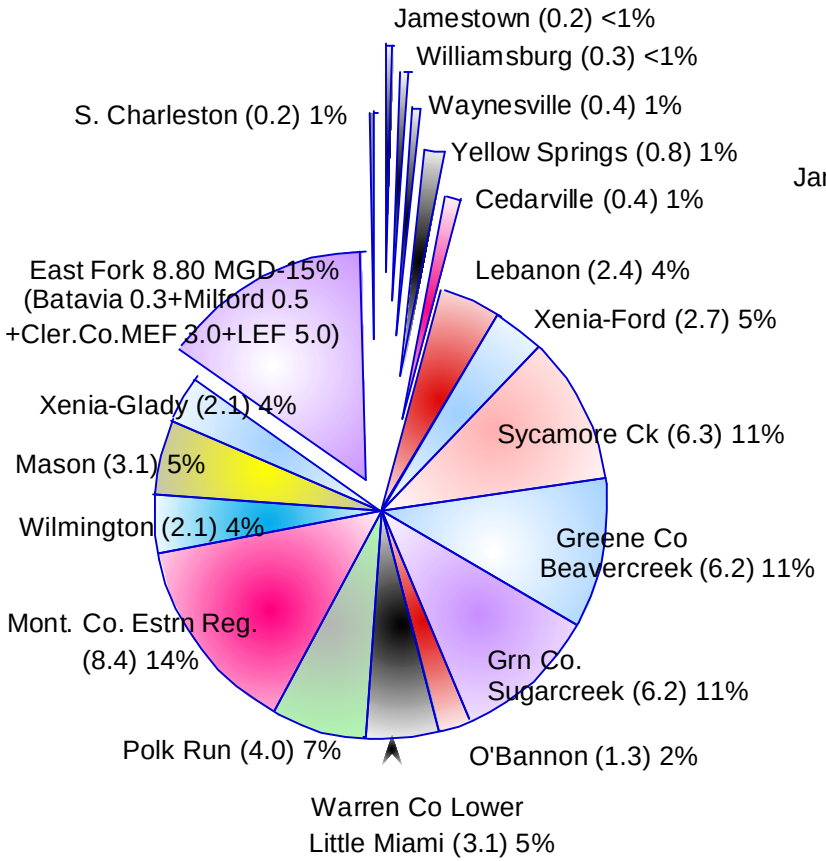
Upstream (801) average ammonia-N concentrations for *mainstem* dischargers ranged from 0.06-0.15 mg/l from 1989-1999. The upper watershed results averaged 0.06 mg/l, while the lower watershed mainstem results (Polk Run and Lebanon) revealed an average upstream (801) concentration of 0.08 mg/l. The Waynesville area produced the highest average upstream concentration of 0.15 mg/l. Overall upstream average 801 results, for the mainstem, were 0.09 mg/l for the five mainstem dischargers evaluated.

Four other dischargers within the watershed were evaluated (Mason, Beaver Creek, Montgomery County Eastern Regional and Wilmington WWTP's) for upstream and downstream ammonia-N monitoring concentrations (801/901). Of the four dischargers, only Wilmington WWTP had upstream concentrations that exceeded downstream levels typically 150% times greater than downstream. Sources for the elevated ammonia-N concentrations observed upstream could be attributed to two known dischargers; Airborne Express Airport (historical deicing compounds) and Randall Textron Incorporated (primarily metals and oil and grease constituents).

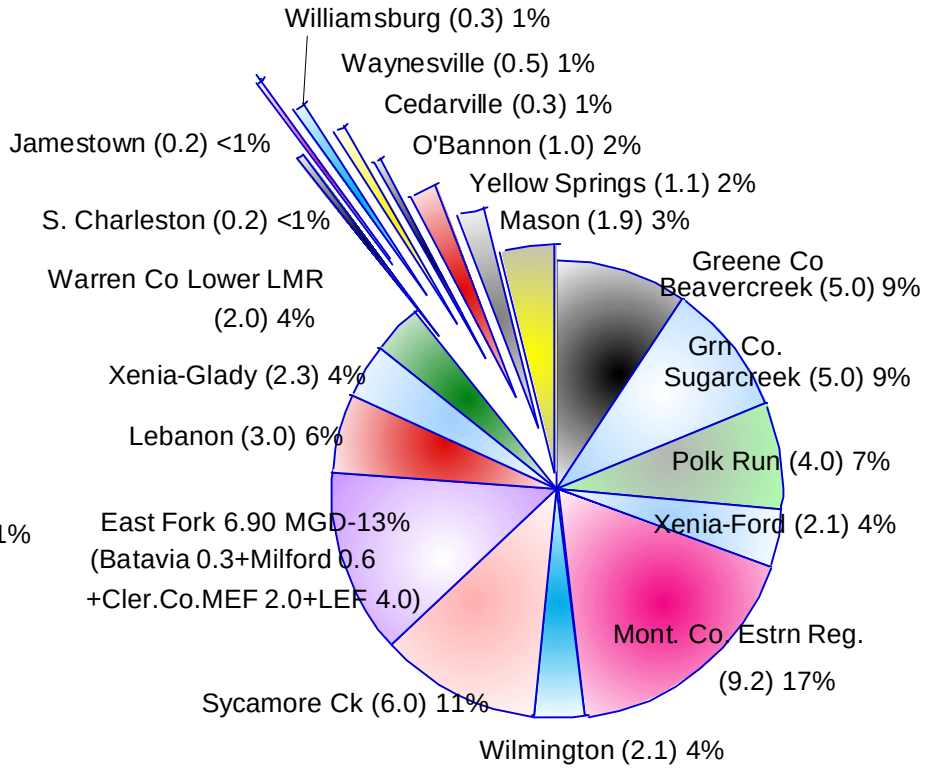
**Phosphorus Loadings Summary (001 outfall)**

During 1998, the largest contributor to the Little Miami River basin of cumulative annual total phosphorus load, was the Montgomery County Eastern Regional WWTP (Figure 37), also the largest discharger of volume on the mainstem. The upper and lower watersheds were evenly divided in total phosphorus load contribution, however the upper watershed sustained nearly 60% of the direct discharge to the mainstem.

Annual median phosphorus loadings, for five major (> 1.0 MGD) *mainstem* dischargers, between 1996 and 1998, demonstrated a 4% reduction in load to the mainstem. Greatest reductions in phosphorus loadings were noted at Greene County Sugar Creek WWTP which reduced their loading contribution of total phosphorus by 14% over three years. A 117% increase in total phosphorus loadings to the mainstem was noted for Waynesville WWTP from 1996 to 1998 demonstrating the need for an upgrade or operational shift in precipitant choice to this aging plant.




1998 Annual Median Flow
22 Dischargers
Total Flow=59 MGD




1993 Annual Median Flow
22 Dischargers
Total Flow=53 MGD

Figure 33. Proportional effluent loads in 1998 compared to 1993 for the same twenty-two dischargers in the Little Miami River Basin.

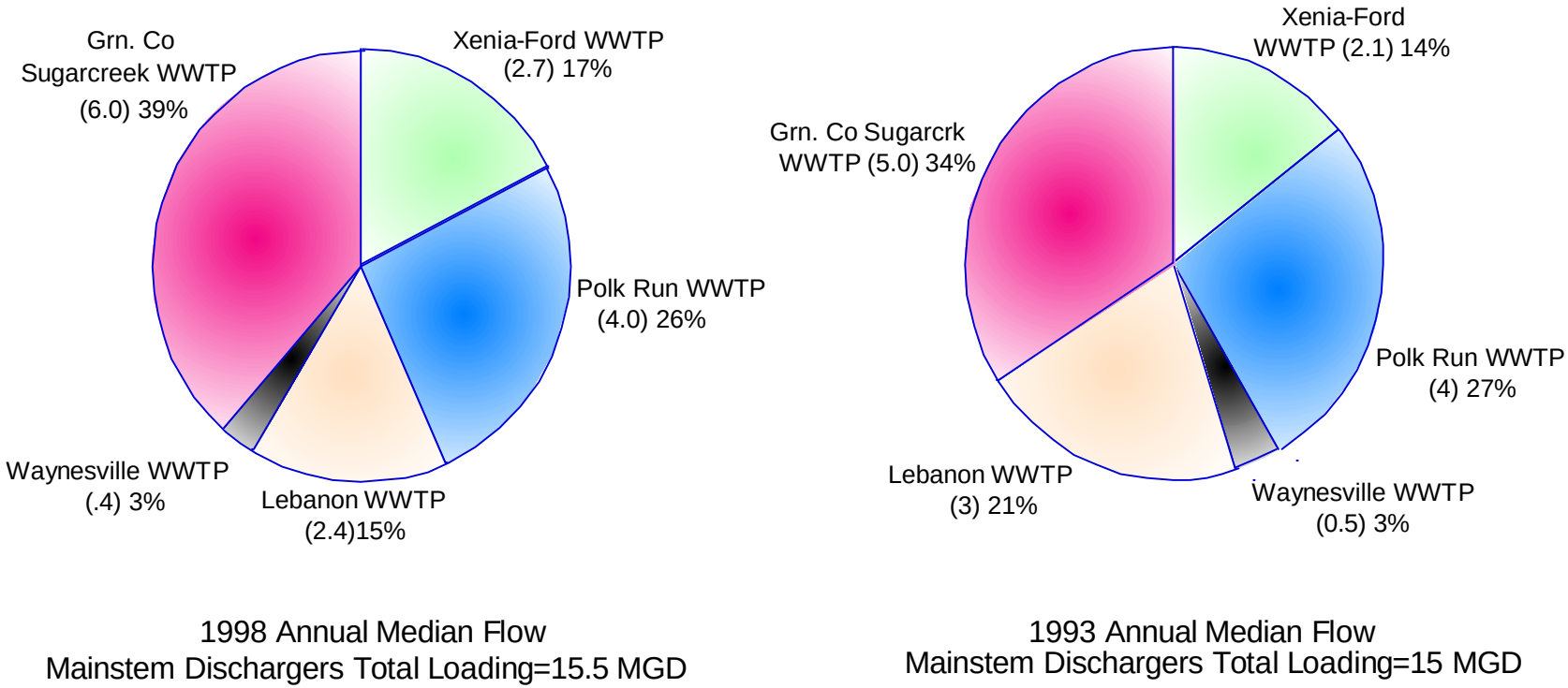
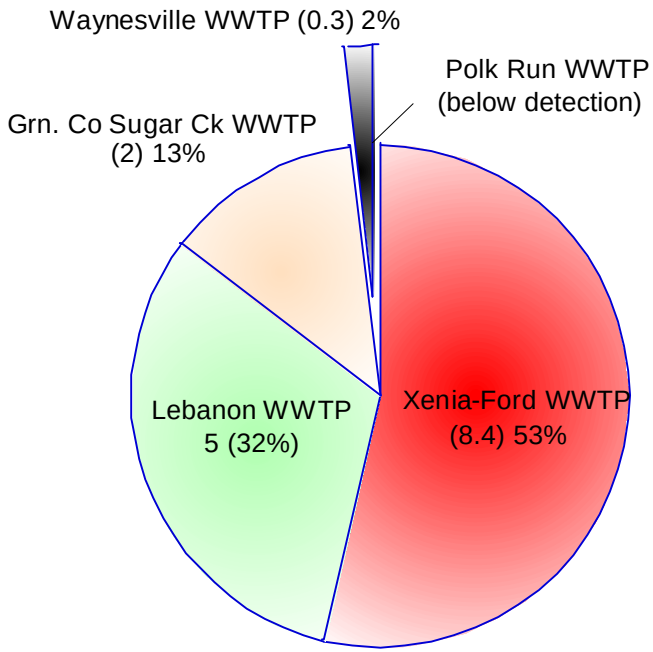
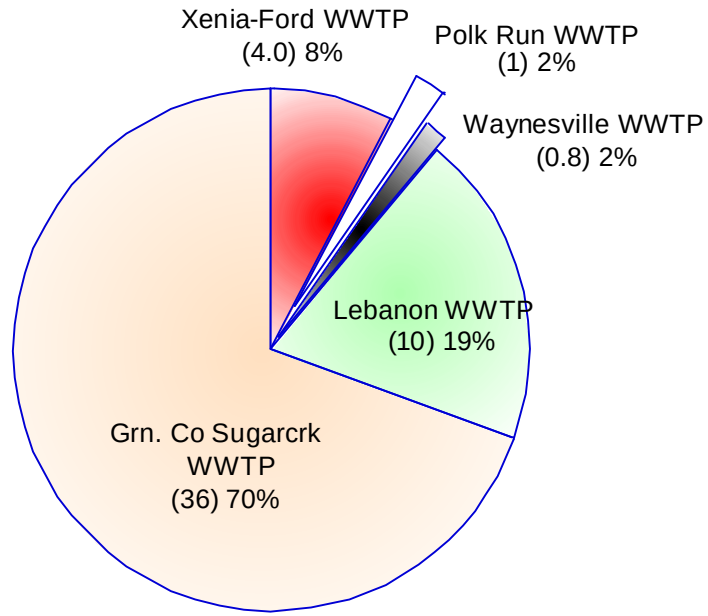



Figure 34. Proportional effluent loadings for the mainstem dischargers shown, 1998 and 1993.

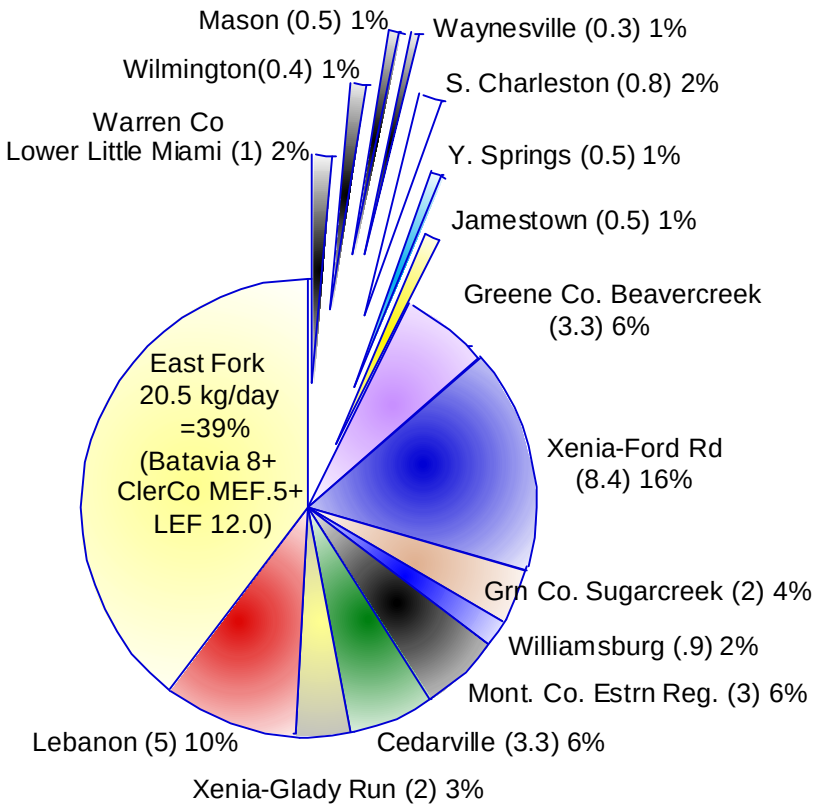



1998 Annual Median Ammonia-N
Mainstem dischargers
Total Loading=16 kg/day

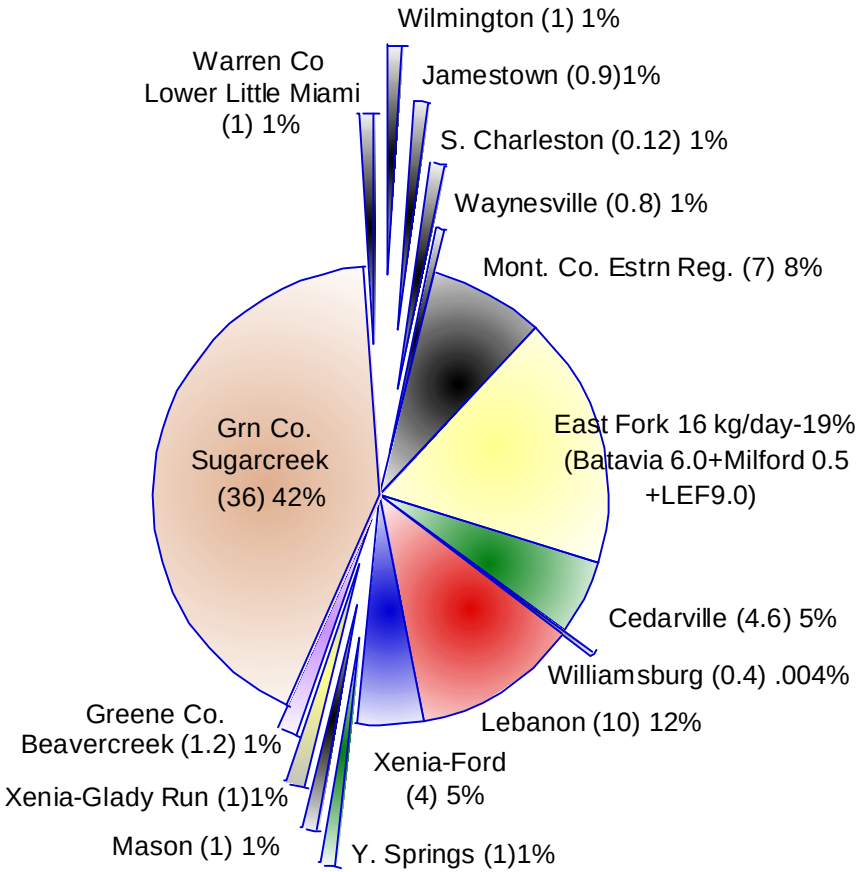



1993 Annual Median Ammonia-N
Mainstem dischargers
Total Loading= 52 kg/day

Figure 35. Relative proportion of ammonia-nitrogen loads in 1998 compared to 1993 for the mainstem dischargers shown.

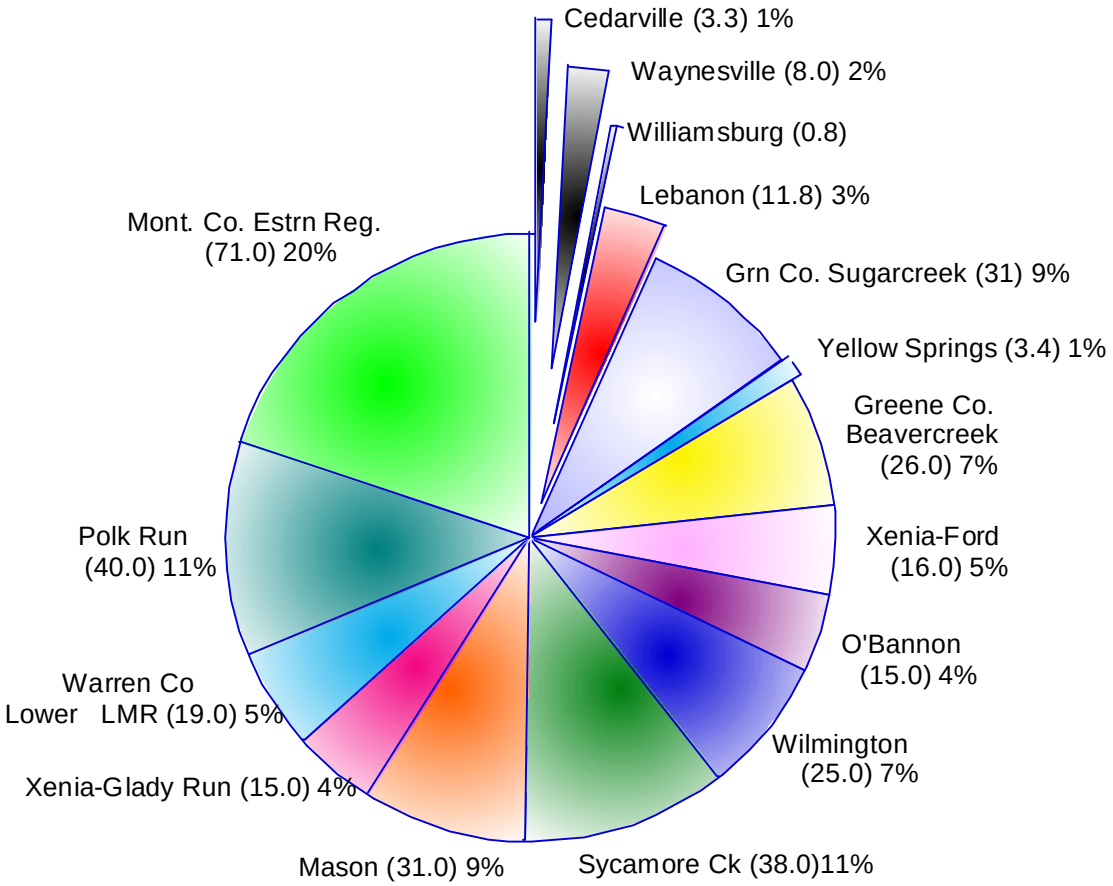



1998 Annual Median Ammonia-N
18 Dischargers Total Loading= 52 kg/day




1993 Annual Median Ammonia-N
18 Dischargers Total Loading= 86 kg/day

Figure 36. Proportional effluent loads of ammonia-nitrogen in 1998 compared to 1993 for the same eighteen dischargers shown in the Little Miami River basin.




1998 Annual Median Phosphorus
16 Dischargers Total Loading= 354 kg/day

Figure 37. Proportional phosphorus loads to the Little Miami River Basin relative to the total for the sixteen dischargers shown, 1998.

**Spills, Overflows, and Unauthorized Releases**

Pollutant discharges from spills, overflows, permit violations and other unauthorized releases are a significant source of lethal and sublethal stresses to aquatic communities in the Little Miami River drainage area. Appendix Table 2 is from Ohio EPA Emergency Response spill reports from 1994 to 1998. Spill report data was very incomplete for the time period evaluated. Spill data was determined to be useable if it could be located in the study area and the spill material could be identified. Quantities of materials spilled in the study area were not well documented. No quantity was reported in 59% ( 201/338) of the useable spills reported during the period from 1994 to 1998. There were 338 documented spill events into the Little Miami River and its tributaries in the years from 1994 to 1998.

Sewage, wastewater, and petroleum discharges made up the majority of reported spills to the Ohio EPA. Sewage spills accounted for 176 events with the majority of discharges resulting from bypasses from Hamilton County Metropolitan Sewer District (84 events), Clermont County WWTP (49 events), Warren County WWTP (15 events) and Xenia Ford Road WWTP (6 events). Industrial wastewater accounted for 36 events with General Motors Delphi facility discharging 15 times into Little Beaver Creek. Petroleum related material was discharged on 75 occurrences from numerous source areas in the basin. The Little Miami River mainstem experienced the most number of spills (95 events) documented during the reporting period. Sycamore Creek (27 events) and Little Beaver Creek (25 events) also had significant numbers of spills recorded during the same period.

**Fish Kills**

Nine fish kills were documented in the study area since 1993. Seven of the nine kills occurred in streams with impaired biological communities and help to corroborate sources and causes of impairment. Specifically, manure spills accounted for 3 of 4 fish kills in Anderson Fork or its tributaries, propylene glycol releases from Airborne Express resulted in 1 fish kill in both Indian and Lytle Creeks, and low dissolved oxygen in Little Beaver Creek upstream from the Montgomery County East Regional WWTP resulted in a kill.

Table 7. Reported fish kills in the Little Miami study area, 1994 - 1998.

| Date | Creek | Pollutant/Cause | Location |
|---|---|---|---|
| 6-3-94 | Indian Camp Creek | Unknown | RM 2.2 - 1.4 |
| 8-15-98 | Little Beaver Creek | Low D.O. | RM 6.8 |
| 7-25-95 | Second Creek | Sewage | Dst. Blanchester WWTP |
| 2-9-98 | Indian Run | Propylene Glycol | Dst. ABX |
| 2-8-98 | Lytle Creek | Propylene Glycol | Dst. ABX |
| 5-23-97 | Anderson Fork | Unknown | RM 14.5 - 14.3 |
| 8-19-95 | Anderson Fork+Trib. | Manure | Paintersville Rd. |
| 9-5-98 | Trib. to Anderson Fork | Manure | Irvin Rd. |
| 5-31-94 | Grog Run (Anderson Fork trib) | Manure | RM 3.0 - 0.2 |

**Surface Water Quality**

*[Many of the graphs included with the following summaries include dotted lines representing the 90th percentile concentration from least impacted regional reference sites of similar size (Ohio EPA 1999). Statistical data were segregated by ecoregion and further stratified by four ranges of stream and river size for these analyses as follows: headwater streams (0-20 sq. mi.); wadeable streams (> 20-200 sq. mi.); small rivers (> 200-1000 sq mi.); and large rivers (> 1000 sq. mi.).]*

*[Additionally, given that much of the bacteriological data (fecal coliform and E. coli) collected during the 1998 survey were not analyzed within the required holding time, it should be noted that discussions of bacteriological results in the following summaries are included only with the intent of gauging the potential for impacts on the receiving streams.]*

*Little Miami River*

Stream flows from May through September 1998 (Figure 38) as measured by two USGS gage stations in the Little Miami River exceeded the $7Q_{10}$ values but dropped below the 80% duration exceedence flows at both sites in September (USGS 1981 and 1999). Flows were above normal in May and June, reflecting above average precipitation. With the exception of peaks caused by localized storms in the lower basin during the third week of July and again in late September, subsequent stream flows generally followed a seasonal pattern, steadily declining from July through September. On specific water chemistry sampling days in the mainstem and the upper basin during the 1998 survey, the two gage stations (RMs 80.63 and 13.07) recorded lows on September 3 with respective mean daily flows of 21 cfs and 175 cfs. Corresponding highs of 103 cfs and 1600 cfs, respectively, were recorded on July 7 and July 21.

Datasonde continuous monitors recorded hourly dissolved oxygen (D.O.) concentration, D.O. percent saturation, temperature, pH and conductivity in 1998 at 38 sites (RMs 106.95-20.60) in the Little Miami River mainstem (Figures 39 - 43, Table 10). The lowest D.O. measurements of the entire survey were recorded in the uppermost reaches of the mainstem (RMs 106.95 and 106.35), with all concentrations well below the EWH minimum criterion of 5.0 mg/l and median percent saturations at both sites less than 15%. (Relative saturation, expressed as a percentage, is the relation of the existing oxygen solubility to the equilibrium content of the gas expected at the same temperature and partial pressure.) Sites downstream (RMs 103.10-93.50) continued to experience depressed D.O. values with numerous concentrations below EWH minimum criteria. Additionally, several sites in this section (RMs 104.88, 101.30, and 98.98) experienced significant diurnal fluctuation with the greatest range in D.O. concentrations (1.65 mg/l - 15.95 mg/l) in the mainstem occurring downstream of Gilroy Ditch and Lisbon Fork at RM 98.98 (Dolly Varden Road). Greater variation in diurnal pH was also measured in this reach with the widest fluctuation again recorded at RM 98.98 (7.17 SU - 8.37 SU). The wide fluctuations in D.O. and pH were directly caused by the significant algal growth observed by

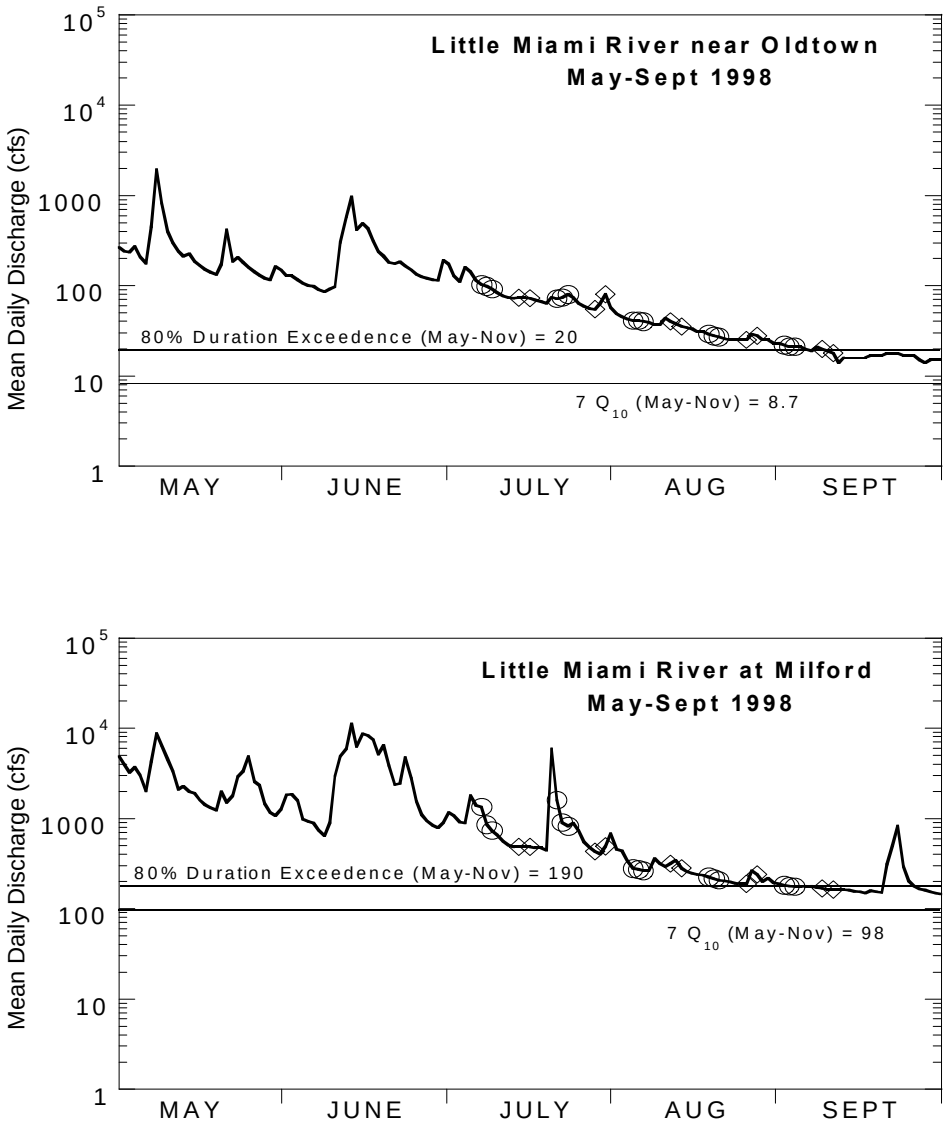



Figure 38. May through September, 1998 flow hydrographs for the Little Miami River near Oldtown (Rm 80.63) and the Little Miami River near Milford (Rm 13.07). Low flow conditions ($7Q_{10}$) and 80% duration exceedence flows for Oldtown and Milford are based on USGS stations #03240000 (period of record 1952-1998) and #03245500 (period of record 1938-1998), respectively. Open circles indicate river discharge on water chemistry sampling days in the Little Miami River mainstem and upper basin while diamonds indicate discharge on water chemistry sampling days in tributaries in the lower basin.

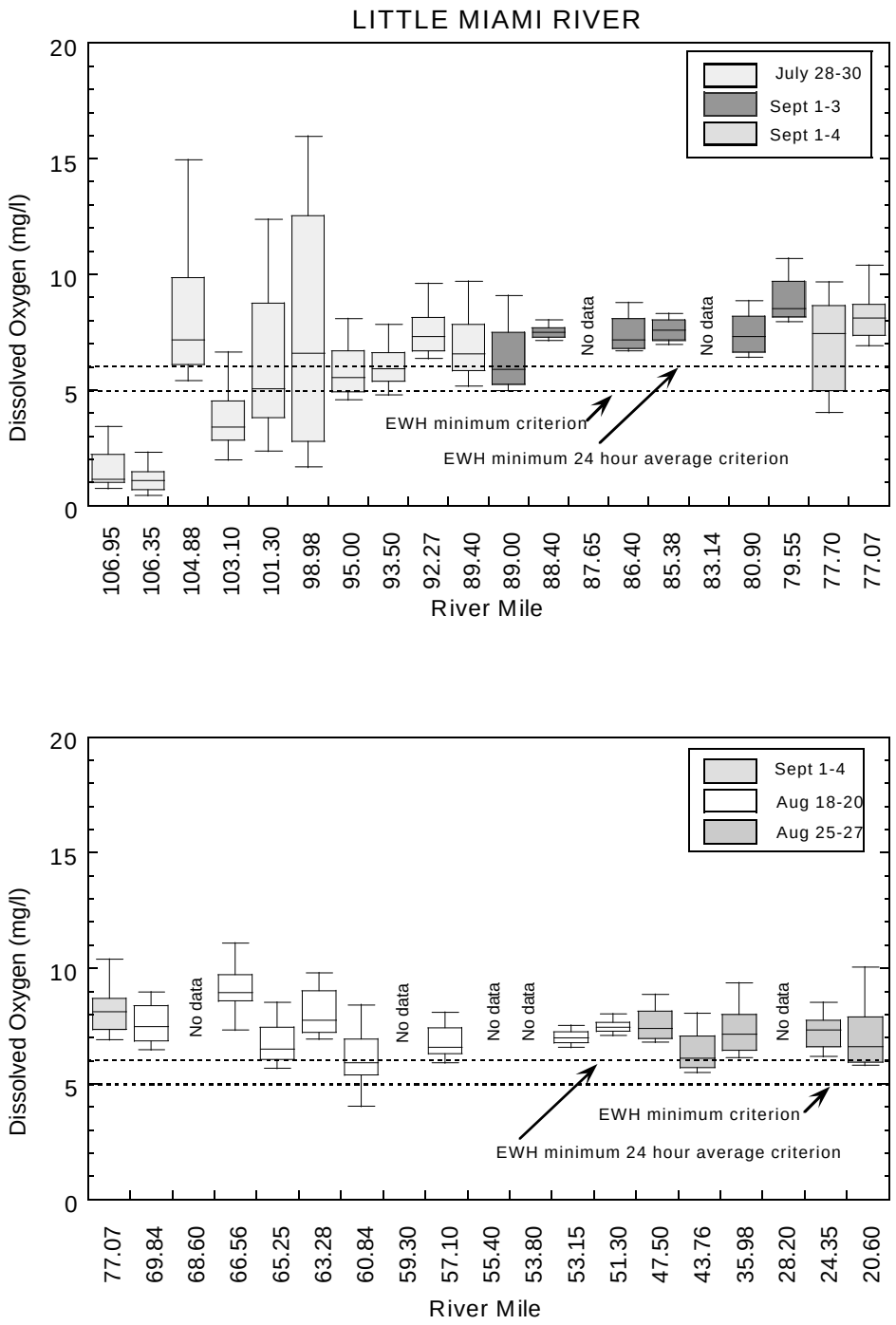
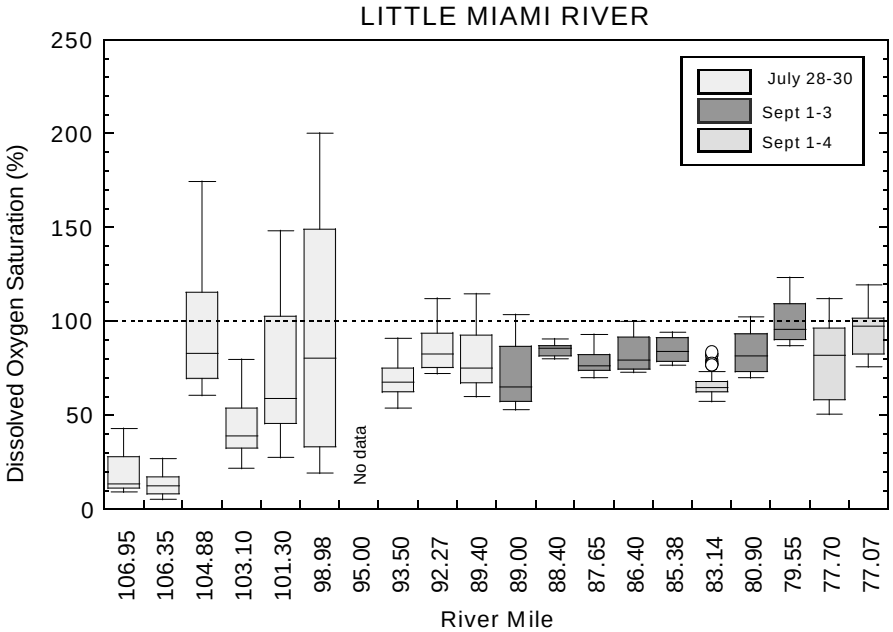



Figure 39. Distributions of dissolved oxygen concentrations recorded hourly over a 48 h period in the Little Miami River, 1998. Dates of observations are shown in the figure legends. Water Quality Standards criteria are shown as dashed horizontal lines.



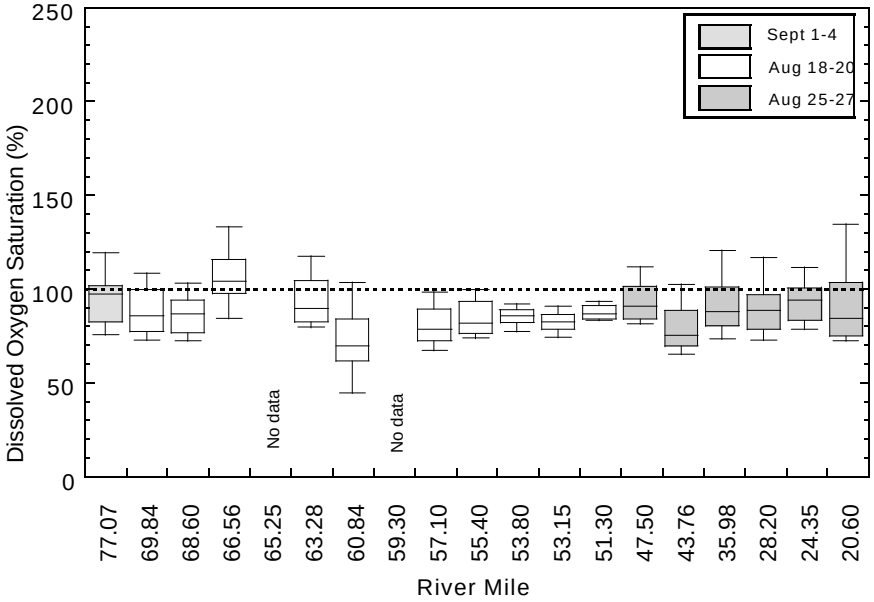




Figure 40. Distributions of percent dissolved oxygen saturation recorded hourly over a 48 h period in the Little Miami River, 1998. Dates of observations are shown in the figure legends.

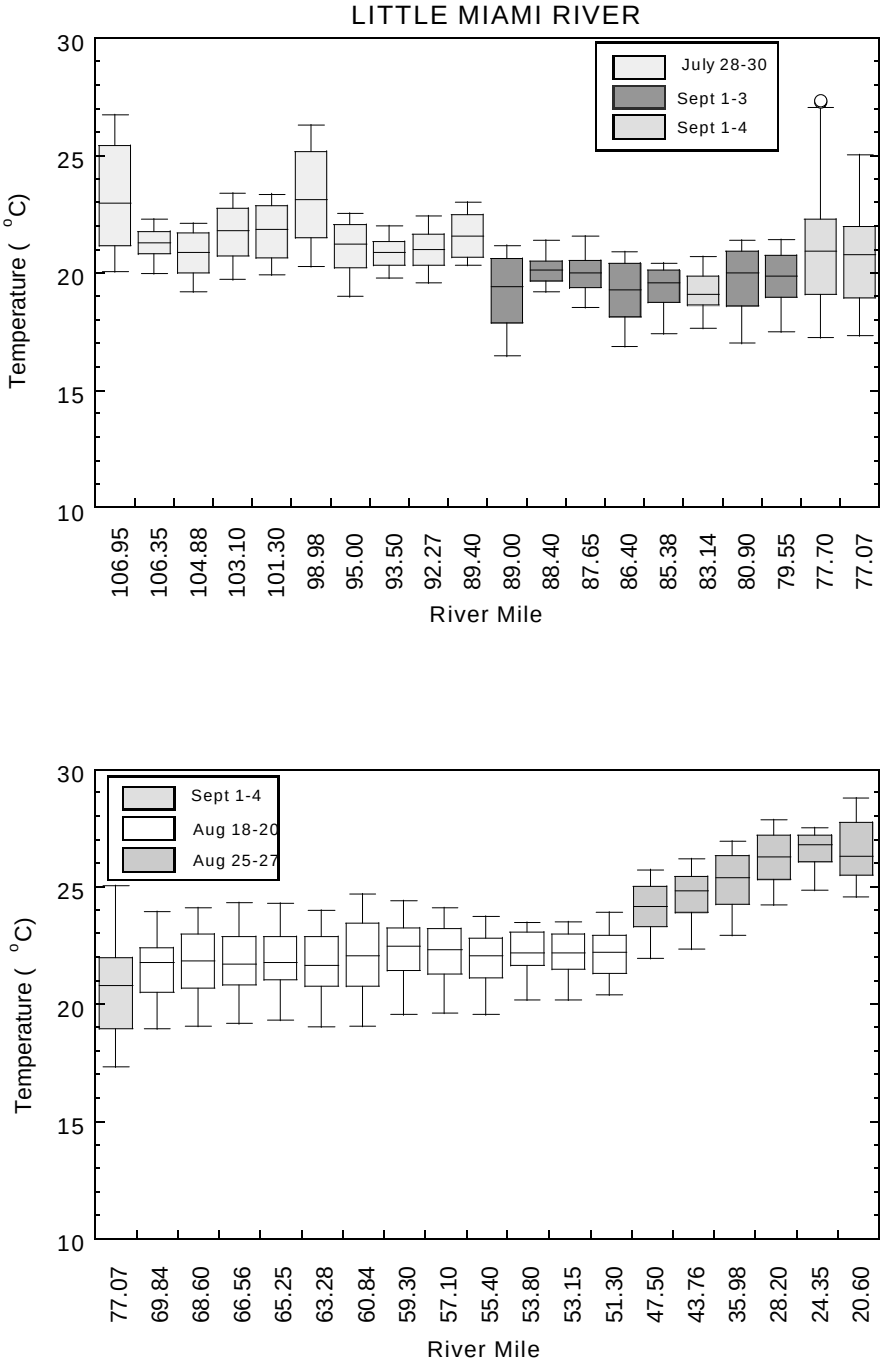
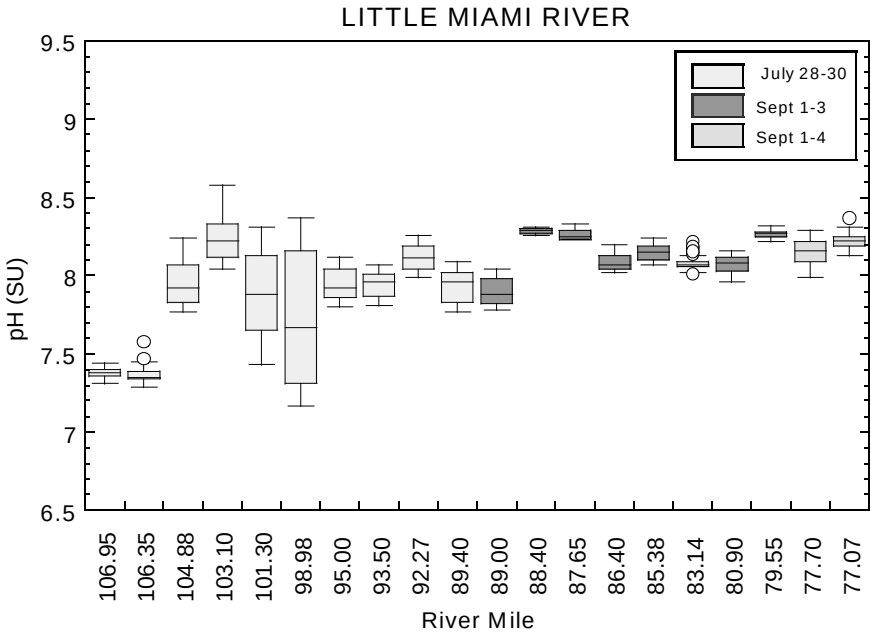



Figure 41. Distributions of temperature in degrees Celsius recorded hourly over a 48 h period in the Little Miami River, 1998. Dates of observations are shown in the figure legends.



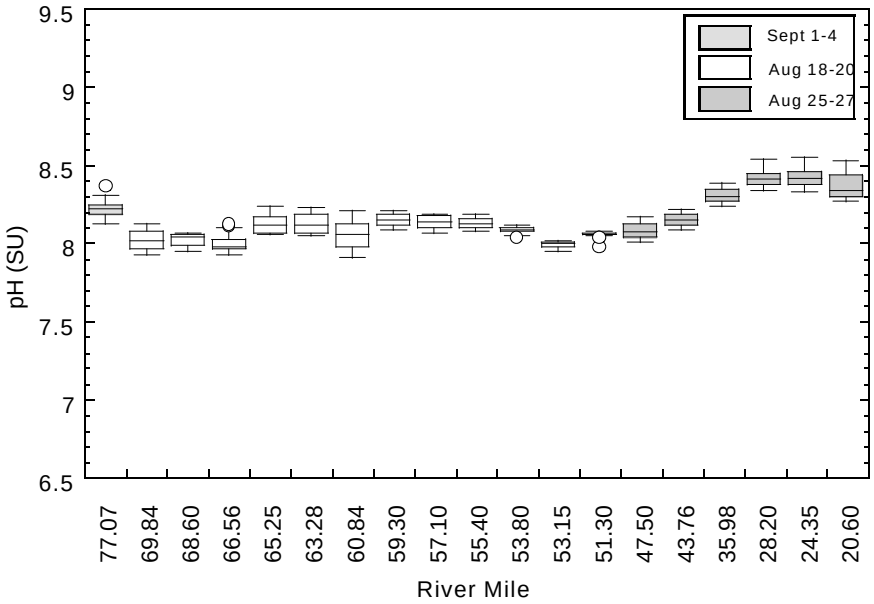
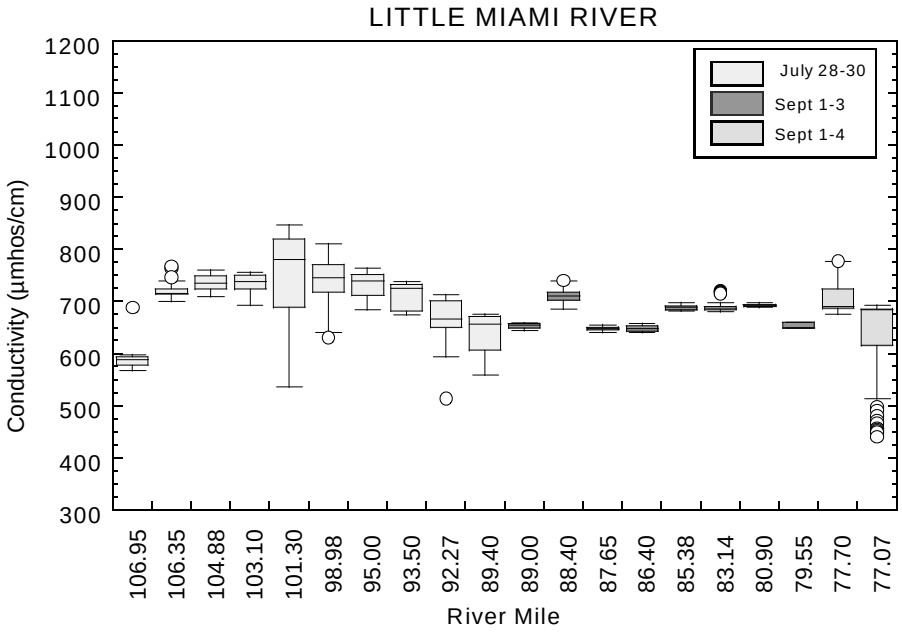




Figure 42. Distributions of pH recorded hourly over a 48 h period in the Little Miami River, 1998. Dates of observations are shown in the figure legends.



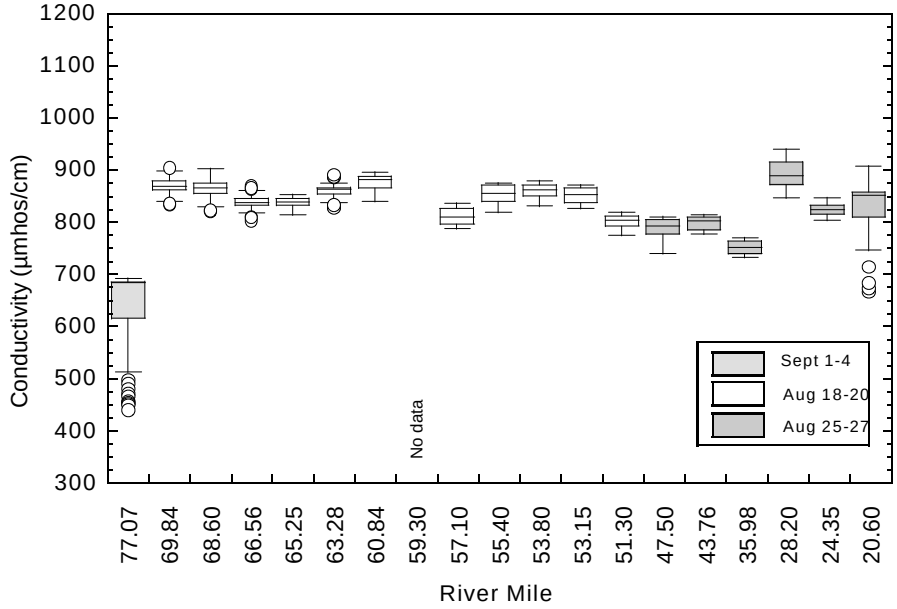




Figure 43. Distributions of conductivity recorded hourly over a 48 h period in the Little Miami River, 1998. Dates of observations are shown in the figure legends.

field crews in this headwater region. Lower flows in this upper reach exacerbate the impacts of nutrient loading from the Paygro facility and the South Charleston WWTP (discharge to Gilroy Ditch) as well as from habitat modification and agricultural runoff. Numerous dissolved oxygen measurements dropped below EWH minimum criteria further downstream at RM 77.70 (Fairgrounds Road) and at RM 60.84 (Roxanna-New Burlington Road). Median temperatures remained relatively stable depending on the sampling time period with the most variation apparent at sites measured from August 25-27 where median values increased longitudinally from 24.18°C (RM 47.50) to 26.81°C (RM 24.35). Excluding the uppermost sites (RMs 106.95-98.98) median pH values were also relatively stable with values ranging from 7.88 SU (RM 89.00) to 8.42 SU (RMs 28.20 and 24.35). The majority of conductivity measurements remained fairly constant depending on the sampling period with medians ranging from 588 $\mu$mhos/cm (RM 106.95) to 890 $\mu$mhos/cm (RM 28.20).

Water chemistry grab samples were collected every other week (five times) at 37 sites in the Little Miami River mainstem and analyzed for a variety of parameters. (Given that flows at RMs 106.95 and 104.88 diminished as the summer progressed, samples could not be collected at these sites during the last two sampling periods of the survey.) Comparable to the Datasonde results, the lowest D.O. concentrations and percent saturations were again recorded in the headwaters at RMs 106.95 and 106.35 with all but one concentration below the EWH minimum criterion of 5.0 mg/l (Figure 44, Table 8). Dissolved oxygen percent saturations, relatively stable throughout the rest of the mainstem, fluctuated widely in this headwater region with medians ranging from 24% at RM 106.95 to 105% at RM 98.98 where accelerated algal growth and excessive photosynthesis frequently pushed dissolved oxygen concentrations to supersaturated levels. Further downstream, D.O. dropped below the EWH minimum 24-hour average criterion of 6.0 mg/l on one occasion at RM 55.25.

While the majority (88%) of five-day biochemical oxygen demand ($BOD_5$) concentrations in the mainstem (Figure 45) were equal to or less than the minimum detection limit (MDL) of 2.0 mg/l, the highest values for the entire survey were recorded in the headwaters at RM 106.95 (28 mg/l) and RM 106.35 (12 mg/l). The highest median concentration (4.0 mg/l) was measured at RM 106.35 where values consistently exceeded the 90$^{th}$ percentile concentration (3.4 mg/l) for headwater reference sites in the Eastern Corn Belt Plains (ECBP) ecoregion.

While seventy-three percent (73%) of ammonia-N values recorded in the mainstem were equal to or less than the MDL of 0.05 mg/l, one exceedence (0.6 mg/l) of water quality criterion was reported downstream of Simpson Creek at RM 28.00 on September 1 (Figure 46, Table 8). Field investigators, observing raw sewage in Simpson Creek, tracked the source to an overflowing manhole on Socialville-Foster Road. No other elevated ammonia-N concentrations were observed at this site during the survey. The highest median ammonia-N value in the mainstem (0.14 mg/l) was recorded at RM 106.35 with 60% of values exceeding the 90$^{th}$ percentile concentration (0.1 mg/l) for headwater reference sites in the ECBP ecoregion.

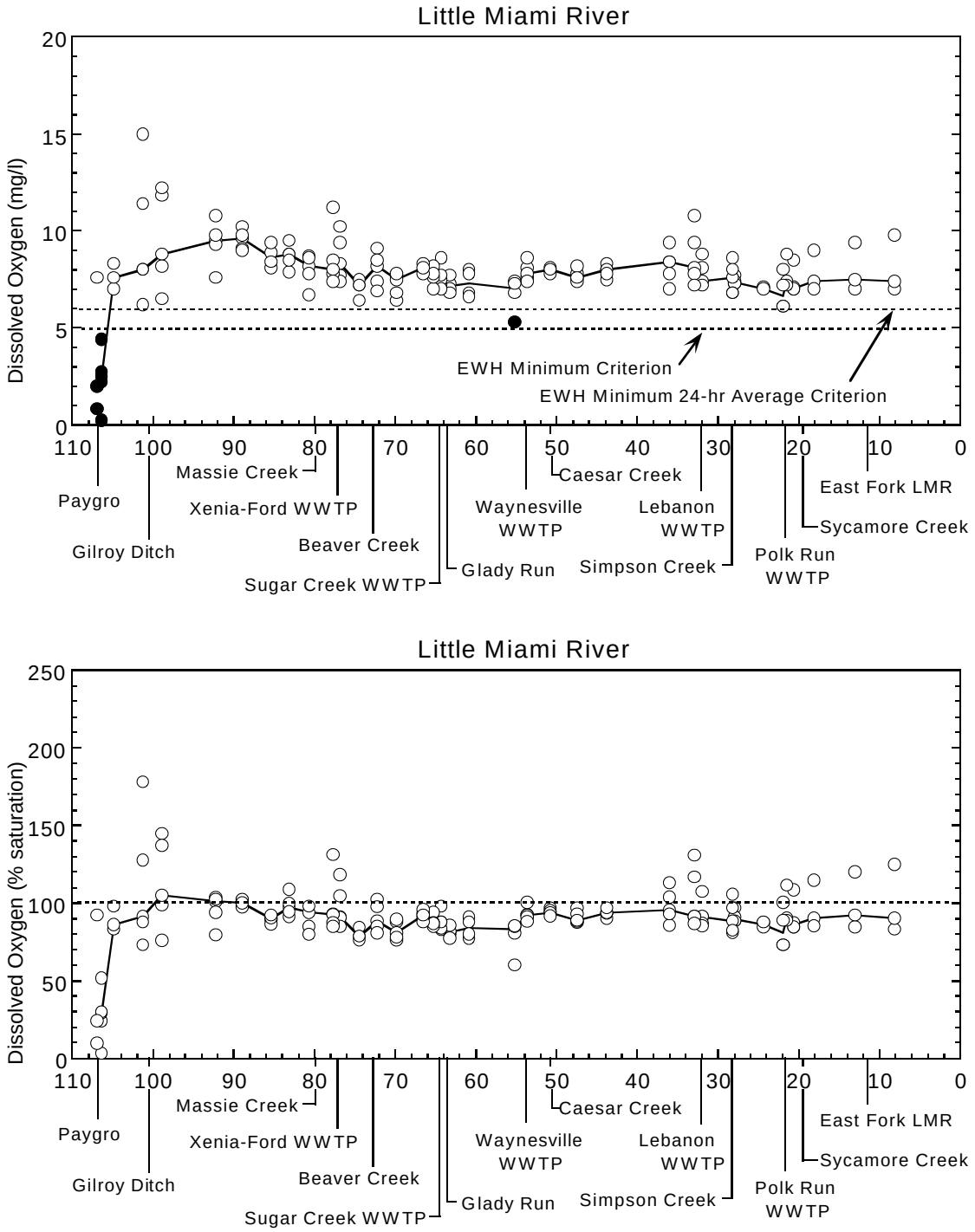



Figure 44. Longitudinal summary of dissolved oxygen concentrations (upper figure) and percent saturation (lower figure) in the Little Miami River during the 1998 survey. The solid line depicts the median value at each river mile sampled. Values below the water quality criteria are indicated by solid dots.

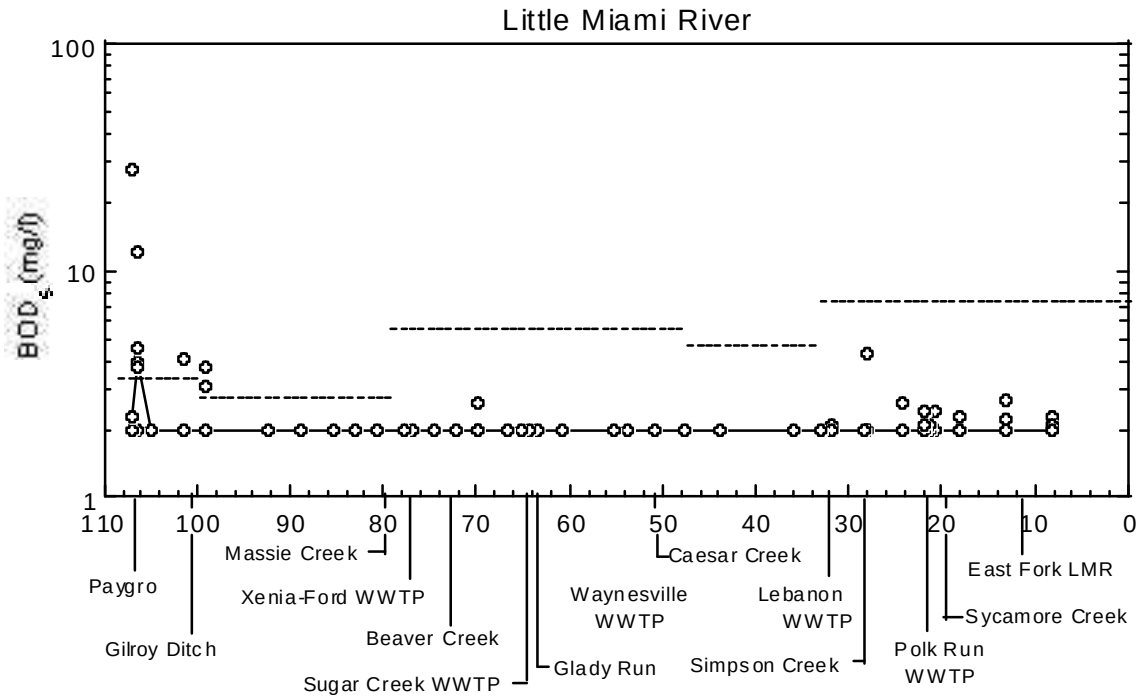



Figure 45. Longitudinal summary of $BOD_5$ concentrations in the Little Miami River during the 1998 survey (MDL is 2 mg/l). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion (upstream of Rm 48.0) and the Interior Plateau (IP) ecoregion (RMS 48.0 - 33.1). (ECBP ecoregion statistics were also utilized in the lower section (RMs 33.1 to the mouth) given the small IP sample size available for large rivers.)

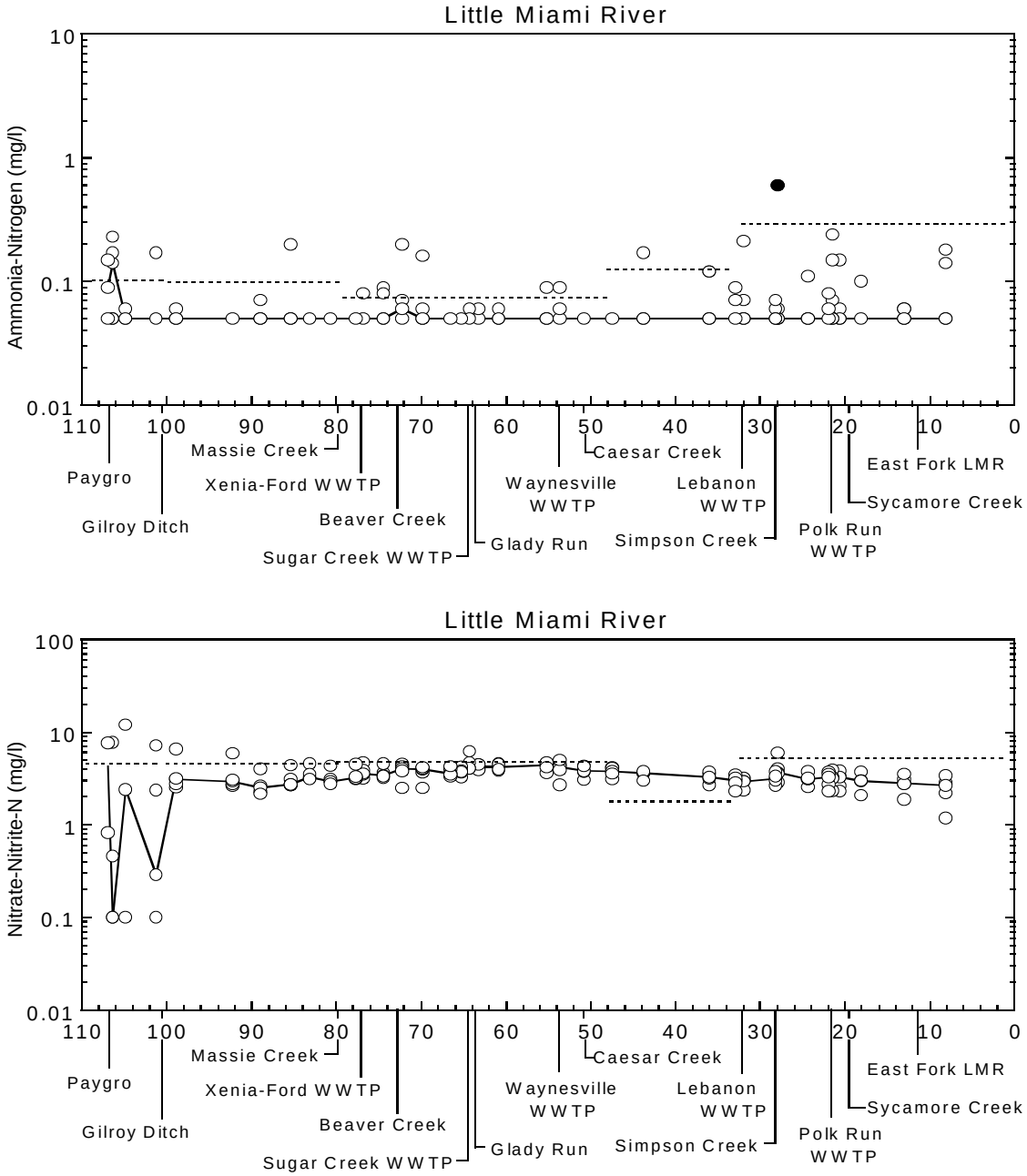



Figure 46. Longitudinal summary of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in the Little Miami River during the 1998 survey (MDL is 0.05 mg/l for $NH_3$-N and 0.1 mg/l or $NO_3$-$NO_2$-N). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90$^{th}$ percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion (upstream of Rm 48.0) and the Interior Plateau (IP) ecoregion (RMs 48.0 - 33.1). (ECBP ecoregion statistics were also utilized in the lower section (RMs 33.1 to the mouth) given the small IP sample size available for large rivers.) Values above water quality criteria are indicated by solid dots.

The mainstem generally experienced relatively stable levels of nitrate-nitrite-N (Figure 46) with a median of 3.30 mg/l calculated for all concentrations. While the highest median concentration (4.40 mg/l) was recorded downstream of the Sugar Creek WWTP at RM 64.28, the most fluctuation occurred in the headwaters with individual values ranging from less than the MDL of 0.1 mg/l (RMS 106.35, 104.88, and 101.30) to 12 mg/l, the highest value measured in the mainstem, at RM 104.88.

Virtually all total phosphorus concentrations (96%) were greater than the MDL of 0.05 mg/l with a median concentration of 0.34 mg/l for all values recorded in the mainstem (Figure 47). Reflecting the combined influence of habitat modification as well as runoff from Paygro and non-point sources, a median of 0.4 mg/l was calculated for sites in the uppermost headwater region (RMS 106.95 - 101.30) with individual maximum values of 3.23 mg/l (RM 106.95) and 3.06 mg/l (RM 106.35). Concentrations decreased downstream (RMS 98.98-74.46) to an overall median of 0.1 mg/l before climbing markedly downstream of the confluence with Beaver Creek (RM 72.74). Consistent with the increased nutrient loading from numerous point sources, values remained at these higher levels with an overall median concentration of 0.39 mg/l recorded for the remainder of the mainstem (RMS 72.30 -8.14).

Median concentrations of total suspended solids (TSS) (Figure 47) in the upper reaches of the mainstem decreased longitudinally from 26 mg/l (RM 106.95) to 5 mg/l (RMS 101.30, 98.98, and 92.27) before climbing again to 15 mg/l at RM 89.00, downstream of the Clifton WWTP. Values continued to increase longitudinally with the highest median values recorded in the lower mainstem at RM 24.35 (49 mg/l) and at RM 21.93 (39 mg/l). Typically, the highest individual concentrations tended to coincide with days of higher flow (July 7 and 21). (It should be noted that while an extremely high TSS concentration (970 mg/l) was recorded on August 6 at RM 106.95, this result may be somewhat compromised given that the site experienced minimal flow on this day and samplers may have inadvertently disturbed the substrate, thus introducing sediments into the sample. The site also experienced exceedences of water quality criteria for copper (35 µg/l), iron (36400 µg/l), and manganese (4660 µg/l) as well as the highest mainstem concentrations of the survey for aluminum (22700 µg/l), arsenic (17 µg/l), barium (378 µg/l), cadmium (0.9 µg/l), lead (24 µg/l), and zinc (338 µg/l) on this day. Concentrations of these parameters on the two previous sampling days, July 9 and July 23, were not elevated.)

Ninety-six percent (96%) of fecal coliform concentrations and 73% of *E. coli* concentrations measured in the mainstem were less than the applicable Average Recreation criteria (Figure 48, Table 9) with respective median concentrations of 220 colonies/100ml and 60 colonies/100ml calculated for the entire mainstem. The highest median fecal coliform and *E. coli* values (2500 colonies/100ml and 1150 colonies/100 ml, respectively) were recorded at RM 101.30 with all concentrations at the site greater than the maximum recreation criteria. Consistently elevated values may be attributed to runoff from an adjacent cow pasture. The highest fecal coliform and *E. coli* values (58000 colonies/100ml and 37500 colonies/100 ml, respectively) in the entire basin were recorded on September 1 downstream of Simpson Creek at RM 28.00. As discussed previously, an overflowing manhole on Socialville-Foster Road discharging raw sewage to Simpson Creek was the source.

Manganese and iron were elevated above water quality criteria in 4% and 13%, respectively, of samples analyzed in the mainstem (Table 8). Additionally, strontium concentrations in the water column were elevated in the upper reaches of the mainstem with the highest median values measured at RM 101.30 (10100 µg/l) and RM 98.98 (4950 µg/l). The median value for all concentrations measured in the mainstem was 378 µg/l. These results, similar to sediment sampling results in this section of the river, are associated with outwash from glacial deposits high in celestite ($SrSO_4$) found in the area. No other elevated metals were detected in the water column of the mainstem.

Seventeen of the 37 water chemistry sites in the mainstem were sampled for organic compounds (volatiles, semivolatiles, pesticides and PCBs) twice during the 1998 survey (Table 8). Pesticides accounted for virtually all (99%) of the compounds detected. Dieldrin, an insecticide no longer manufactured in the U.S., was the most frequently detected pesticide, exceeding water quality criteria in all samples. Concentrations of aldrin, endrin, and endosulfan II exceeded water quality criteria on several occasions. Polychlorinated biphenyls (PCBs) were not detected in the water column at any site (mainstem or tributary) during the 1998 survey.

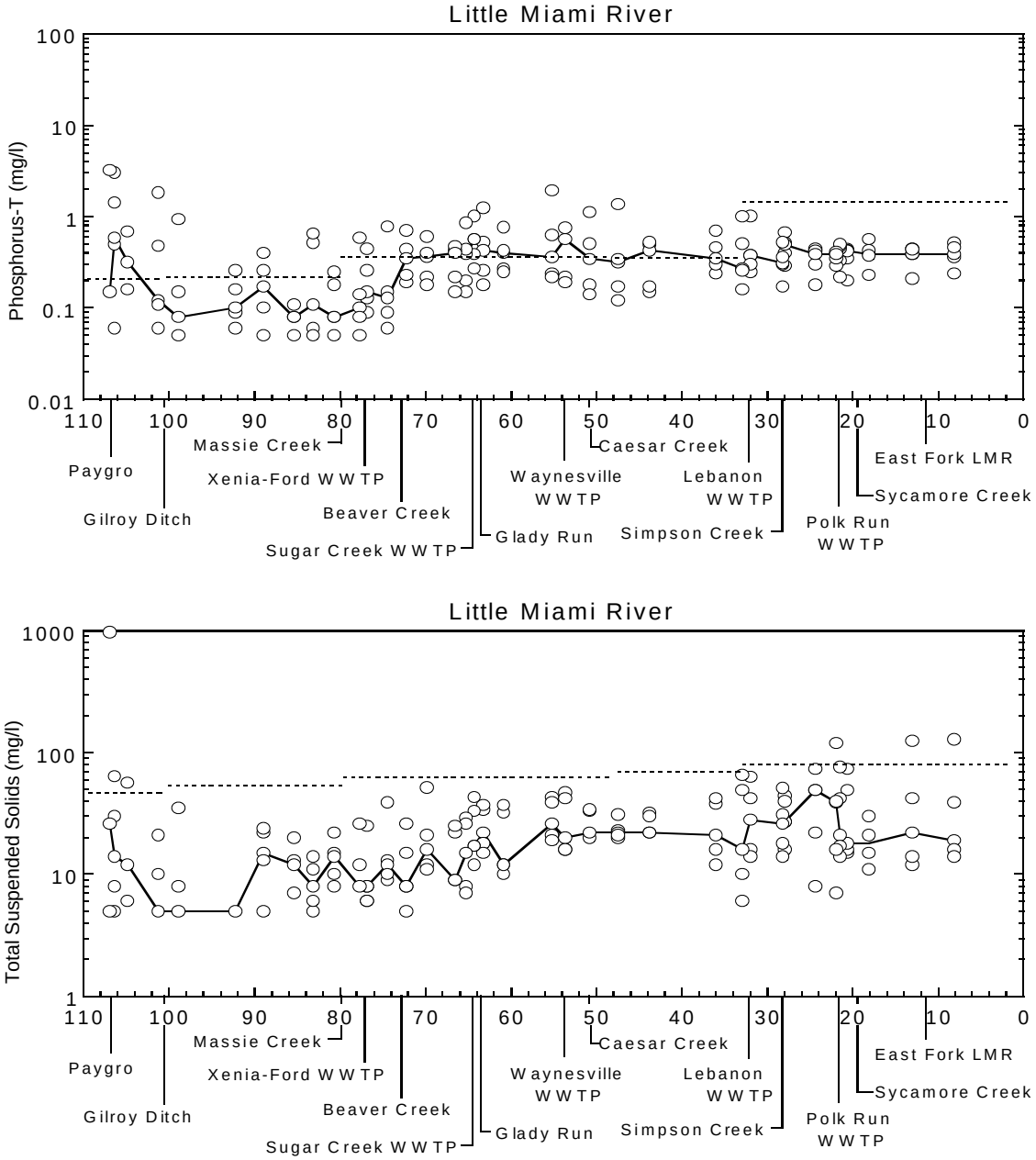



Figure 47. Longitudinal summary of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in the Little Miami River during the 1998 survey (MDL is 0.05 mg/l for TP, and 5 mg/l for TSS). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90$^{th}$ percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion (upstream of Rm 48.0) and the Interior Plateau (IP) ecoregion (RMs 48.0 - 33.1). (ECBP ecoregion statistics were also utilized in the lower section (RMs 33.1 to the mouth) given the small IP sample size available for large rivers.)

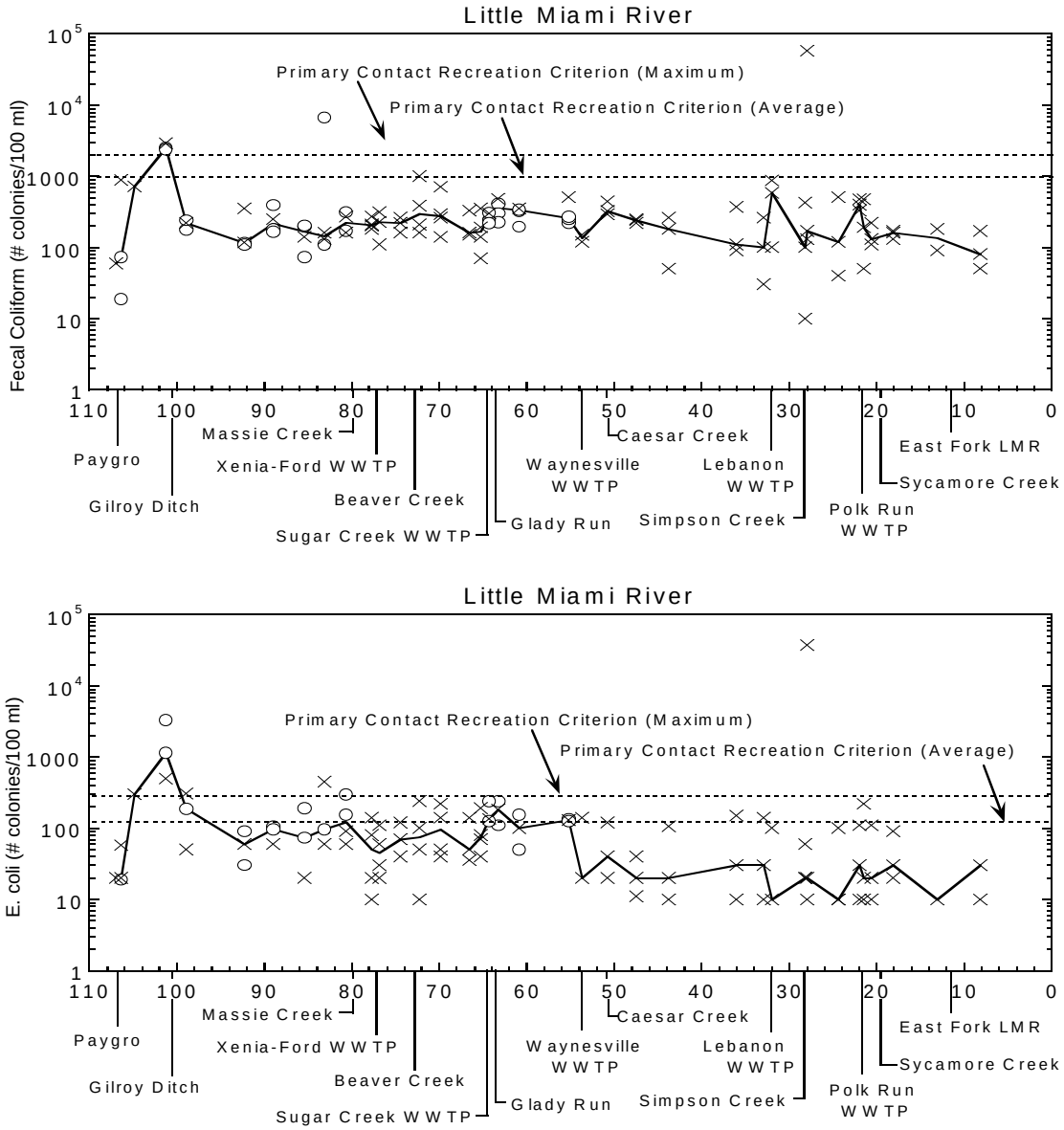



Figure 48. Longitudinal summary of fecal coliform concentrations (top) and *E. coli* concentrations (bottom) in the Little Miami River during the 1998 survey (MDL is 10 colonies/100 ml). The solid line depicts the median value at each river mile sampled. Dashed horizontal lines indicate applicable Water Quality Standards criteria. (Bacteriological data analyzed within the required holding time are depicted by an open circle while data which were not analyzed within the required holding time are depicted by an 'X'.)

Table 8. Concentrations ($\mu$g/l) of organic compounds detected in water samples collected in the Little Miami River study area during 1998.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Little Miami River*** | | |
| **RM 106.35** (Huntington Rd.) | | |
| Parameter* | 7/23/98 | 8/20/98[A] |
| Aldrin | 0.0031[J] | -- |
| alpha-Hexachlorocyclohexane | 0.0021 | -- |
| gamma-Hexachlorocyclohexane | -- | 0.0060 |
| Dieldrin | 0.0042 | 0.0078 |
| Endrin | -- | 0.0047 |
| 4,4'-DDT | -- | 0.0072 |
| Heptachlor Epoxide | -- | 0.012 |
| Atrazine | 0.23 | -- |
| TICs† (number detected) | 8 | 4 |
| | | |
| **RM 104.88** (SR 41) | | |
| Parameter* | 7/23/98 | 8/20/98 |
| delta-Hexachlorocyclohexane | 0.0021 | ** |
| gamma-Hexachlorocyclohexane | 0.003 | ** |
| Dieldrin | 0.0076 | ** |
| Heptachlor Epoxide | 0.0027 | ** |
| Atrazine | 0.36 | ** |
| Metolachlor | 0.34 | ** |
| TICs† (number detected) | 2 | ** |
| | | |
| **RM 98.98** (Dolly Varden Rd.) | | |
| Parameter* | 7/23/98 | 8/20/98 |
| alpha-Hexachlorocyclohexane | -- | 0.014 |
| delta-Hexachlorocyclohexane | 0.0043 | -- |
| gamma-Hexachlorocyclohexane | -- | 0.0062 |
| Dieldrin | 0.0051 | 0.0060 |
| Heptachlor epoxide | -- | 0.0061 |
| Atrazine | 0.76 | -- |
| Cyanazine | 0.22 | -- |
| Metolachlor | 3.0 | -- |
| TICs† (number detected) | 10 | 2 |

Table 8. Continued.

| ***Stream*** **River Mile** (Location) | -------Date Sample Collected------- | |
|---|---|---|
| ***Little Miami River (continued)*** | | |
| **RM 89.00** (Wilberforce Clifton Rd.) | | |
| Parameter* | 7/23/98 | 8/20/98 |
| Dieldrin | 0.0053 | 0.0053[J] |
| Atrazine | 0.26 | -- |
| Metolachlor | 0.45 | -- |
| TICs† (number detected) | 2 | 1 |
| **RM 83.14** (Jacoby Rd.) | | |
| Parameter* | 7/23/98 | 8/20/98 |
| Dieldrin | 0.0054 | 0.0056 |
| delta-Hexachlorocyclohexane | -- | 0.0081 |
| **RM 80.63** (US 68) | | |
| Parameter* | 7/23/98 | 8/20/98 |
| Dieldrin | 0.0029 | 0.0059 |
| Heptachlor Epoxide | -- | 0.0032 |
| TICs† (number detected) | 1 | -- |
| **RM 76.90** (Dst. Xenia Ford WWTP) | | |
| Parameter* | 7/23/98 | 8/20/98 |
| gamma-Hexachlorocyclohexane | 0.0025 | 0.0068 |
| Dieldrin | 0.006 | 0.0061 |
| Endosulfan II | -- | 0.0034 |
| Endrin | -- | 0.0050 |
| Heptachlor epoxide | -- | 0.0038 |
| Atrazine | 0.34 | -- |
| TICs† (number detected) | 2 | 2 |
| **RM 72.30 (Indian Ripple Rd.)** | | |
| Parameter* | 7/23/98 | 8/20/98 |
| delta-Hexachlorocyclohexane | -- | 0.0099 |
| gamma-Hexachlorocyclohexane | 0.0034 | 0.0063 |
| Dieldrin | 0.0039 | 0.0075 |
| Endosulfan II | -- | 0.0036 |
| Endrin | -- | 0.0061 |
| Heptachlor Epoxide | -- | 0.0033 |
| TICs† (number detected) | 3 | – |

Table 8. Continued.

| ***Stream*** **River Mile** (Location) | -------Date Sample Collected------- | |
|---|---|---|
| ***Little Miami River (continued)*** | | |
| **RM 66.56** (Lower Bellbrook Rd.) | | |
| Parameter* | 7/22/98 | 8/19/98 |
| delta-Hexachlorocyclohexane | -- | 0.0093 |
| gamma-Hexachlorocyclohexane | 0.003 | 0.0071 |
| Dieldrin | 0.0035 | 0.0061 |
| Endosulfan II | -- | 0.0033 |
| Endrin | -- | 0.0054 |
| Heptachlor | 0.0027 | -- |
| Heptachlor Epoxide | -- | 0.0035 |
| Atrazine | 0.24 | -- |
| TICs† (number detected) | 11 | -- |
| **RM 64.28** (Dst. Sugar Creek WWTP) | | |
| Parameter* | 7/21/98 | 8/18/98 |
| gamma-Hexachlorocyclohexane | 0.0097 | 0.0076[J] |
| Dieldrin | 0.0057 | 0.0083[J] |
| Endosulfan II | -- | 0.0032 |
| Endrin | -- | 0.0056 |
| Heptachlor Epoxide | -- | 0.0042 |
| **bis(2-Ethylhexyl)phthalate** | -- | 0.71 |
| Atrazine | 0.54 | -- |
| TICs† (number detected) | 4 | 2 |
| **RM 63.28** (Dst. Glady Run) | | |
| Parameter* | 7/21/98 | 8/18/98 |
| gamma-Hexachlorocyclohexane | 0.0089 | 0.0074 |
| Dieldrin | 0.0055 | 0.0074 |
| Endosulfan II | -- | 0.0036 |
| Endosulfan sulfate | 0.02 | -- |
| Endrin | -- | 0.0054 |
| Heptachlor Epoxide | -- | 0.0033 |
| Atrazine | 0.49 | -- |
| Metolachlor | 0.2 | -- |
| TICs† (number detected) | 4 | 3 |

Table 8. Continued.

| ***Stream*** **River Mile** (Location) | -------Date Sample Collected------- | |
|---|---|---|
| ***Little Miami River (continued)*** | | |
| **RM 60.84** (Roxanna-New Burlington Rd.) | | |
| Parameter* | 7/21/98 | 8/18/98 |
| Aldrin | 0.003 | -- |
| delta-Hexachlorocyclohexane | -- | 0.010 |
| gamma-Hexachlorocyclohexane | 0.0055 | 0.0076 |
| Dieldrin | 0.0068 | 0.0056 |
| Endosulfan II | -- | 0.0032 |
| Endrin | -- | 0.0051 |
| Heptachlor Epoxide | -- | 0.0034 |
| Atrazine | 0.31 | -- |
| Metolachlor | 0.23 | -- |
| TICs† (number detected) | 2 | 1 |
| **RM 55.25** (Adj. New Burlington Rd.) | | |
| Parameter* | 7/21/98 | 8/18/98 |
| delta-Hexachlorocyclohexane | -- | 0.0099 |
| gamma-Hexachlorocyclohexane | 0.0033 | 0.0085 |
| Dieldrin | 0.0065 | 0.0080 |
| Endosulfan II | -- | 0.0032 |
| Endrin | -- | 0.0052 |
| Heptachlor Epoxide | -- | 0.0061 |
| Atrazine | 0.22 | -- |
| TICs† (number detected) | 3 | 1 |
| **RM 53.69** (Dst. Waynesville WWTP) | | |
| Parameter* | 7/21/98 | 8/18/98 |
| gamma-Hexachlorocyclohexane | 0.0022 | 0.0082 |
| Dieldrin | 0.0049 | 0.0091 |
| Endosulfan II | -- | 0.0038 |
| Endosulfan sulfate | 0.021 | -- |
| Endrin | -- | 0.0057 |
| Heptachlor Epoxide | -- | 0.0033 |
| TICs† (number detected) | 1 | 2 |

Table 8. Continued.

| ***Stream*** **River Mile** (Location) | -------Date Sample Collected------- | |
|---|---|---|
| ***Little Miami River (continued)*** | | |
| **RM 31.96** (Dst. Lebanon WWTP) | | |
| Parameter* | 7/21/98 | 8/18/98 |
| Aldrin | 0.0032 | -- |
| delta-Hexachlorocyclohexane | -- | 0.0085 |
| gamma-Hexachlorocyclohexane | 0.0078 | 0.0079 |
| Dieldrin | 0.0083 | 0.0073 |
| Endosulfan II | -- | 0.0037 |
| Heptachlor Epoxide | -- | 0.0033 |
| Hexachlorobenzene | 0.0041 | -- |
| Atrazine | 1.3 | 0.66[J] |
| Cyanzine | 0.46 | -- |
| Metolachlor | 0.62 | -- |
| Simazine | 0.2 | -- |
| TICs† (number detected) | 3 | 2 |
| **RM 21.45** (Branch Hill New Guinea Rd.) | | |
| Parameter* | 7/21/98[B] | 8/18/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0073 |
| delta-Hexachlorocyclohexane | -- | 0.0092 |
| gamma-Hexachlorocyclohexane | 0.0074 | 0.0086 |
| Dieldrin | 0.01 | 0.0066 |
| Heptachlor Epoxide | -- | 0.0038 |
| Hexachlorobenzene | 0.0025 | -- |
| Atrazine | -- | 0.59 |
| TICs† (number detected) | 2 | 1 |
| **RM 8.14** (Newtown Rd.) | | |
| Parameter* | 7/21/98[B] | 8/18/98 |
| Aldrin | 0.0042 | -- |
| delta-Hexachlorocyclohexane | -- | 0.0099 |
| gamma-Hexachlorocyclohexane | 0.011 | 0.0065 |
| Dieldrin | 0.011 | 0.0070 |
| Endrin | -- | 0.0067 |
| Endrin aldehyde | 0.007 | -- |
| Heptachlor Epoxide | -- | 0.0038 |
| Atrazine | -- | 0.86[J] |
| Cyanazine | -- | 0.32 |
| Metolachlor | -- | 0.39[J] |
| TICs† (number detected) | 3 | 1 |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Gilroy Ditch*** | | |
| **RM 0.50** (Dst. South Charleston WWTP) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| Dieldrin | 0.0080[J] | -- |
| alpha-Hexachlorocyclohexane | -- | 0.011 |
| delta-Hexachlorocyclohexane | -- | 0.012 |
| Heptachlor epoxide | 0.0060[J] | 0.0023 |
| TICs† (number detected) | 11 | 4 |
| ***North Fork Little Miami River*** | | |
| **RM 0.37** (North River Rd.) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| Heptachlor epoxide | 0.0027[J] | -- |
| TICs† (number detected) | 1 | 1 |
| ***Yellow Springs Creek*** | | |
| **RM 0.10** (Grinnel Rd.) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| gamma-Hexachlorocyclohexane | 0.0059[J] | -- |
| Dieldrin | 0.0060[J] | -- |
| TICs† (number detected) | 2 | -- |
| ***Massie Creek*** | | |
| **RM 7.71** (Tarbox Cemetary Rd.) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0072 |
| delta-Hexachlorocyclohexane | -- | 0.011 |
| gamma-Hexachlorocyclohexane | -- | 0.0060 |
| Dieldrin | 0.0064[J] | -- |
| Heptachlor epoxide | 0.0034[J] | -- |
| TICs† (number detected) | 3 | -- |
| **RM 0.26** (Ust. US 68, Ust. Oldtown Creek) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0072 |
| gamma-Hexachlorocyclohexane | -- | 0.0055 |
| Dieldrin | 0.0062[J] | 0.0032 |
| Endosulfan II | 0.0034 | -- |
| Heptachlor epoxide | 0.0033[J] | -- |
| TICs† (number detected) | 2 | 1 |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***North Fork Massie Creek*** | | |
| **RM 1.17** (James Barber Rd.) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0081 |
| Dieldrin | 0.0058[J] | 0.0026 |
| Heptachlor epoxide | 0.0034[J] | -- |
| TICs† (number detected) | 2 | -- |
| ***Ludlow Creek*** | | |
| **RM 0.25** (Hilltop Rd.) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| TICs† (number detected) | 1 | 1 |
| ***Shawnee Creek*** | | |
| **RM 0.65** (Hawkins Rd.) | | |
| Parameter* | 8/6/98 | 9/3/98 |
| Dieldrin | 0.0056[J] | 0.0020 |
| Heptachlor epoxide | 0.0033[J] | -- |
| TICs† (number detected) | 2 | 1 |
| ***Beaver Creek*** | | |
| **RM 1.57** (Dayton-Xenia Rd.) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| TICs† (number detected) | 1 | 2 |
| **RM 0.20** (Dst. Beaver Creek WWTP) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| gamma-Hexachlorocyclohexane | 0.0078 | 0.013 |
| Dieldrin | -- | 0.0052 |
| 4,4'-DDD | 0.0083 | -- |
| Endrin aldehyde | 0.0064 | -- |
| Hexachlorobenzene | -- | 0.0028 |
| TICs† (number detected) | 5 | 5 |
| ***Little Beaver Creek*** | | |
| **RM 4.62** (Ust. Montgomery Co. Eastern Regional WWTP) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0043 |
| Endosulfan I | -- | 0.0068 |
| Endosulfan sulfate | -- | 0.024 |
| Heptachlor epoxide | 0.0027 | – |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Little Beaver Creek (continued)*** | | |
| **RM 4.40** (Dst. Montgomery Co. Eastern Regional WWTP) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| *Chloroform* | 0.500 | -- |
| gamma-Hexachlorocyclohexane | 0.0092 | 0.015 |
| Dieldrin | 0.010 | -- |
| Endrin | 0.0063 | -- |
| Endrin aldehyde | 0.014 | -- |
| **bis(2-Ethylhexyl)phthalate** | 1.0 | 0.66 |
| TICs† (number detected) | 7 | 10 |
| | | |
| **RM 0.05** (Factory Rd.) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| gamma-Hexachlorocyclohexane | 0.0094 | 0.012 |
| 4,4'-DDD | 0.012 | -- |
| 4,4'-DDE | 0.010 | -- |
| Dieldrin | 0.0074 | -- |
| Hexachlorobenzene | -- | 0.0032 |
| TICs† (number detected) | 6 | 4 |
| | | |
| ***Sugar Creek*** | | |
| **RM 0.40** (Penewit Rd.) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| Dieldrin | 0.0055 | -- |
| alpha-Hexachlorocyclohexane | -- | 0.0039 |
| gamma-Hexachlorocyclohexane | -- | 0.0030 |
| Heptachlor | -- | 0.0055 |
| TICs† (number detected) | 3 | 2 |
| | | |
| ***Glady Run*** | | |
| **RM 4.08** (Hedges Rd.) | | |
| Parameter* | 8/5/98 | 9/2/98 |
| gamma-Hexachlorocyclohexane | 0.020 | 0.030 |
| 4,4'-DDD | 0.0095 | -- |
| Dieldrin | -- | 0.0064 |
| Endrin | 0.0059 | -- |
| Endrin aldehyde | 0.0060 | -- |
| Heptachlor epoxide | 0.0039 | -- |
| TICs† (number detected) | 6 | 5 |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Caesar Creek*** | | |
| **RM 23.10** (Stone Rd.) | | |
| Parameter* | 8/4/98 | 9/1/98 |
| Heptachlor epoxide | 0.0039 | -- |
| alpha-Hexachlorocyclohexane | -- | 0.0049 |
| Atrazine | 0.74 | 0.41 |
| Cyanazine | 0.21 | -- |
| TICs† (number detected) | 1 | 1 |
| | | |
| **RM 16.52** (Spring Valley-Paintersville Rd.) | | |
| Parameter* | 8/4/98 | 9/1/98 |
| Dieldrin | 0.006 | -- |
| Heptachlor epoxide | 0.0029 | -- |
| Atrazine | 0.53 | 0.27[J] |
| TICs† (number detected) | 5 | 2 |
| | | |
| ***South Branch Caesar Creek*** | | |
| **RM 2.10** (Hoop Rd.) | | |
| Parameter* | 8/4/98 | 9/1/98 |
| *Methylene chloride* | -- | 2.85 |
| alpha-Hexachlorocyclohexane | -- | 0.0072 |
| gamma-Hexachlorocyclohexane | -- | 0.0063 |
| Heptachlor epoxide | 0.0036 | -- |
| Hexachlorobenzene | -- | 0.0022 |
| Atrazine | 2.0 | 0.70 |
| Cyanazine | -- | 0.26 |
| TICs† (number detected) | 3 | 2 |
| | | |
| ***Anderson Fork*** | | |
| **RM 13.87** (Port William Rd.) | | |
| Parameter* | 8/4/98 | 9/1/98 |
| Dieldrin | 0.0091 | 0.0066 |
| Atrazine | 1.0 | 2.0 |
| Metolachlor | 0.49 | 0.86 |
| TICs† (number detected) | 4 | 1 |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Anderson Fork (continued)*** | | |
| **RM 4.90** (Old Winchester Trail) | | |
| Parameter* | 8/4/98 | 9/1/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0047 |
| gamma-Hexachlorocyclohexane | 0.0056 | -- |
| Dieldrin | 0.0076 | 0.0030 |
| Heptachlor epoxide | 0.0037 | -- |
| Atrazine | 0.76 | 0.54 |
| Metolachlor | 0.23 | -- |
| TICs† (number detected) | 2 | 3 |
| | | |
| ***Todd Fork*** | | |
| **RM 19.50** (US 22/3) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0070 |
| gamma-Hexachlorocyclohexane | 0.0054 | -- |
| Dieldrin | 0.0066 | -- |
| Heptachlor epoxide | 0.0038 | -- |
| Atrazine | 0.72 | 0.30 |
| | | |
| **RM 15.17** (Spring Hill Rd.) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| delta-Hexachlorocyclohexane | 0.0081 | -- |
| gamma-Hexachlorocyclohexane | 0.0068 | 0.010 |
| Dieldrin | 0.0078 | -- |
| Hexachlorobenzene | -- | 0.0060 |
| Atrazine | 2.4 | 0.46 |
| Cyanazine | 0.53 | -- |
| Metolachlor | 0.57 | -- |
| Simazine | 0.23 | -- |
| TICs† (number detected) | 2 | 2 |
| | | |
| **RM 0.14** (US 22/3 @ Morrow) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| alpha-Hexachlorocyclohexane | 0.0068 | -- |
| Dieldrin | 0.0070 | -- |
| Heptachlor epoxide | 0.0033 | -- |
| Atrazine | 0.73 | 0.51 |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| **RM 0.14** (US 22/3 @ Morrow)-continued. | | |
| Parameter* | 8/13/98 | 9/10/98 |
| Cyanazine | 0.22 | -- |
| Metolachlor | 0.33 | -- |
| | | |
| ***Lytle Creek*** | | |
| **RM 9.25** (Adj. Townsend Field) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| Aldrin | -- | 0.0031[J] |
| alpha-Hexachlorocyclohexane | 0.0074 | -- |
| beta-Hexachlorocyclohexane | 0.0031 | -- |
| delta-Hexachlorocyclohexane | 0.010 | 0.0076[J] |
| 4,4'-DDE | 0.0075 | -- |
| Heptachlor epoxide | 0.0042 | -- |
| Atrazine | 0.44 | 0.33 |
| Metolachlor | 0.52 | 0.31 |
| TICs† (number detected) | 2 | 3 |
| | | |
| **RM 7.01** (Nelson Rd.) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| *1,1-Dichloroethane* | 0.600 | 1.01 |
| *cis-1,2-Dichloroethene* | 1.54 | 1.54 |
| *1,1,1-Trichloroethane* | 1.02 | 0.960 |
| *Trichloroethene* | 1.02 | 0.570 |
| alpha-Hexachlorocyclohexane | 0.0070 | -- |
| beta-Hexachlorocyclohexane | 0.0026 | -- |
| delta-Hexachlorocyclohexane | 0.0095 | -- |
| 4,4'-DDE | 0.0075 | -- |
| Heptachlor epoxide | 0.0040 | -- |
| Atrazine | 0.42 | 0.29 |
| Metolachlor | 0.53 | 0.24 |
| TICs† (number detected) | 3 | 1 |
| | | |
| **RM 5.94** (Buffalo farm off US 22/3) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| delta-Hexachlorocyclohexane | 0.018 | -- |
| gamma-Hexachlorocyclohexane | 0.021 | 0.021[J] |
| Dieldrin | 0.017 | 0.012[J] |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| **RM 5.94** (Buffalo farm off US 22/3)-continued. | | |
| Parameter* | 8/13/98 | 9/10/98 |
| Heptachlor | 0.0028 | -- |
| Heptachlor epoxide | 0.0059 | 0.0040[J] |
| Atrazine | 0.86 | 0.78 |
| TICs† (number detected) | 5 | 11 |
| | | |
| ***Cowan Creek*** | | |
| **RM 13.20** (Jenkins Rd., Ust. Indian Run & ABX ) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0079 |
| delta-Hexachlorocyclohexane | 0.0072 | -- |
| Dieldrin | 0.0086 | -- |
| Heptachlor epoxide | 0.0074 | -- |
| Atrazine | 0.52 | 0.71 |
| TICs† (number detected) | 3 | -- |
| | | |
| ***Cowan Creek*** | | |
| **RM 12.45** (Adj. Jenkins Rd., Dst. Indian Run) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| Aldrin | -- | 0.0035[J] |
| Dieldrin | 0.0079 | -- |
| Heptachlor epoxide | 0.0096 | -- |
| Atrazine | 0.46 | 0.30 |
| TICs† (number detected) | 2 | 2 |
| | | |
| **RM 1.34** (Adj. Cowan Creek Rd.) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| gamma-Hexachlorocyclohexane | 0.0082 | ** |
| Atrazine | 5.8 | ** |
| Cyanazine | 0.83 | ** |
| Metolachlor | 1.0 | ** |
| Simazine | 0.38 | ** |
| TICs† (number detected) | 3 | ** |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Indian Run*** | | |
| **RM 0.10** (Near mouth, Dst. ABX) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| *Toluene* | -- | 1.03 |
| alpha-Hexachlorocyclohexane | 0.0078 | -- |
| delta-Hexachlorocyclohexane | 0.0091 | 0.0058[J] |
| gamma-Hexachlorocyclohexane | 0.0061 | -- |
| 4,4'-DDE | 0.0072 | -- |
| Dieldrin | 0.0073 | -- |
| Heptachlor epoxide | 0.0098 | -- |
| TICs† (number detected) | 2 | 2 |
| ***East Fork Todd Fork*** | | |
| **RM 1.60** (SR 132 ) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| alpha-Hexachlorocyclohexane | -- | 0.0075 |
| delta-Hexachlorocyclohexane | 0.0089 | -- |
| Dieldrin | 0.0079 | -- |
| Endosulfan II | 0.0038 | -- |
| Heptachlor epoxide | 0.0062 | -- |
| Atrazine | 0.41 | 0.76 |
| TICs† (number detected) | 1 | – |
| ***Muddy Creek*** | | |
| **RM 2.50** (Mason-Morrow Rd., Dst. Mason WWTP) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| delta-Hexachlorocyclohexane | -- | 0.0065[J] |
| gamma-Hexachlorocyclohexane | 0.0071 | -- |
| 4,4'-DDD | 0.0093 | -- |
| Dieldrin | 0.0089 | -- |
| Endrin | 0.0068 | -- |
| Heptachlor epoxide | 0.012 | -- |
| Hexachlorobenzene | 0.0033[J] | -- |
| TICs† (number detected) | 2 | 3 |

Table 8. Continued.

| ***Stream*** | | |
|---|---|---|
| **River Mile** (Location) | -------Date Sample Collected------- | |
| ***Simpson Creek*** | | |
| **RM 0.01** (Adj. Foster Rd., Dst. Lower LMR WWTP) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| *Bromodichloromethane* | 0.930 | -- |
| *Chloroform* | 1.02 | -- |
| *Dibromochloromethane* | 0.610 | -- |
| alpha-Hexachlorocyclohexane | 0.0089[J] | -- |
| delta-Hexachlorocyclohexane | 0.018 | -- |
| gamma-Hexachlorocyclohexane | 0.0090[J] | -- |
| Endrin | -- | 0.0078 |
| Heptachlor epoxide | -- | 0.0061 |
| Atrazine | 0.26 | -- |
| TICs† (number detected) | 6 | 5 |
| ***O'Bannon Creek*** | | |
| **RM 1.84** (O'Bannonville Rd., Dst. O'Bannon WWTP) | | |
| Parameter* | 8/13/98 | 9/10/98 |
| *Bromodichloromethane* | -- | 0.540 |
| *Chloroform* | 0.940 | 1.37 |
| alpha-Hexachlorocyclohexane | 0.0078 | -- |
| gamma-Hexachlorocyclohexane | 0.031 | 0.015[J] |
| Endrin | -- | 0.043 |
| Heptachlor epoxide | -- | 0.013[J] |
| Atrazine | 0.87 | 1.6 |
| Cyanazine | 0.26 | 0.46 |
| Metolachlor | 0.55 | 0.78 |
| TICs† (number detected) | 2 | 5 |
| ***Sycamore Creek*** | | |
| **RM 0.20** (Dst. Sycamore Creek WWTP) | | |
| Parameter* | 8/11/98 | 9/8/98 |
| *Bromodichloromethane* | -- | 2.40 |
| *Chloroform* | 0.740 | 3.02 |
| *Dibromochloromethane* | -- | 0.890 |
| Aldrin | 0.0074 | -- |
| delta-Hexachlorocyclohexane | 0.014 | 0.016 |
| gamma-Hexachlorocyclohexane | 0.0059 | 0.010 |
| Dieldrin | 0.0090 | -- |

Table 8. Continued.

| ***Stream*** **River Mile** (Location) | -------Date Sample Collected------- | |
|---|---|---|
| ***Sycamore Creek*** | | |
| RM 0.20 (Dst. Sycamore Creek WWTP) | | |
| Parameter* | 8/11/98 | 9/8/98 |
| Endosulfan II | 0.0036 | -- |
| Endrin aldehyde | 0.010 | -- |
| TICs† (number detected) | 4 | 1 |

* Only compounds that were detected at least once are listed. Parameters in plain type are pesticides; parameters in italic type are *volatile organic compounds*; and parameters in bold type are **semivolatile organic compounds**. No polychlorinated biphenyls (PCBs) were detected at any site.

** No sample taken due to inadequate flow.

-- Compound not detected or below the method detection limit.

† TICs (Tentatively Identified Compounds)--Analysis indicates the presence of an analyte (non-priority pollutant) that has been "tentatively identified".

Qualifiers:

J Analyte is detected. Analyte result is estimated due to not meeting quality control criteria for the sample.

*Gilroy Ditch*

Gilroy Ditch enters the Little Miami River at RM 100.65 and receives discharge from the South Charleston WWTP at RM 1.40. Hourly dissolved oxygen (concentration and percent saturation), temperature, pH and conductivity were measured by Datasonde continuous monitors at three sites (RMS 1.45, 0.50, and 0.01) from July 28-30 (Figure 49). Numerous D.O. concentrations were below the WWH minimum criterion of 4.0 mg/l at all three locations (Table 9), and significant diurnal fluctuations were documented at both sites downstream of the South Charleston WWTP with the greatest range in values of the entire survey (0.43 mg/l-16.54 mg/l) occurring at RM 0.50. Median D.O. percent saturations increased from 56% at RM 1.45 to 105% at RM 0.50. Greater variation in diurnal pH was also apparent at downstream sites with the widest fluctuation again recorded at RM 0.50 (7.35 SU - 8.88 SU). The extensive algal growth observed at both RMs 0.50 and 0.01 by field crews and the corresponding flux in D.O. and pH reflect the impact of nutrient loading from the South Charleston WWTP. Median conductivity measurements increased longitudinally from 726 $\mu$mhos/cm (RM 1.45) to 888 $\mu$mhos/cm (RM 0.01). Temperatures did not vary significantly, ranging from 21.4$^{o}$ C to 23.2$^{o}$ C, reflecting significant groundwater influence.

Water chemistry daytime grab samples were collected every other week (five times) upstream (RM 1.45) and downstream (RM 0.50) of the South Charleston WWTP (Figures 50 and 51). Similar to Datasonde results, D.O. concentrations increased to supersaturated levels at RM 0.50 with a median percent saturation of 181%, the highest of any site in the entire survey. $BOD_5$ concentrations, all less than the MDL (2 mg/l) at RM 1.45, increased minimally downstream at RM 0.05 where one value (4.2 mg/l) exceeded the 90$^{th}$ percentile concentration (3.4 mg/l) for headwater reference sites in the ECBP ecoregion. While concentrations of ammonia-N were generally comparable at the two sites, one value exceeded WWH water quality criterion on August 6 downstream of the South Charleston WWTP at RM 0.50 with the highest value (3.37 mg/l) of the entire survey. Median concentrations of nitrate-nitrite-N and total phosphorus increased longitudinally from 0.24 mg/l and 0.12 mg/l, respectively, at RM 1.45 to 3.61 mg/l and 0.64 mg/l, respectively, at RM 0.50. Concentrations of TSS remained stable with medians ranging from 5 mg/l at RM 1.45 to 8 mg/l at RM 0.50. All concentrations of fecal coliform and *E. coli* remained below secondary contact recreation criteria at both sites.

The highest lead and zinc concentrations of the survey were recorded downstream of the South Charleston WWTP at RM 0.50 on August 6 (10 µg/l and 117 µg/l, respectively), August 20 (18 µg/l and 159 µg/l, respectively), and September 3 (24 µg/l and 301 µg/l, respectively). The highest strontium concentrations were recorded in Gilroy Ditch (median values of 25400 µg/l (RM1.45) and 7840 µg/l (RM 0.50)), and were associated with outwash from glacial deposits high in celestite ($SrSO_4$). No other elevated metal concentrations were recorded in Gilroy Ditch.

Water samples from RM 0.50 were analyzed for organic compounds twice during the 1998 survey (Table 8), revealing various organochlorine pesticides and one exceedence of water quality criterion for Dieldrin (Table 8).

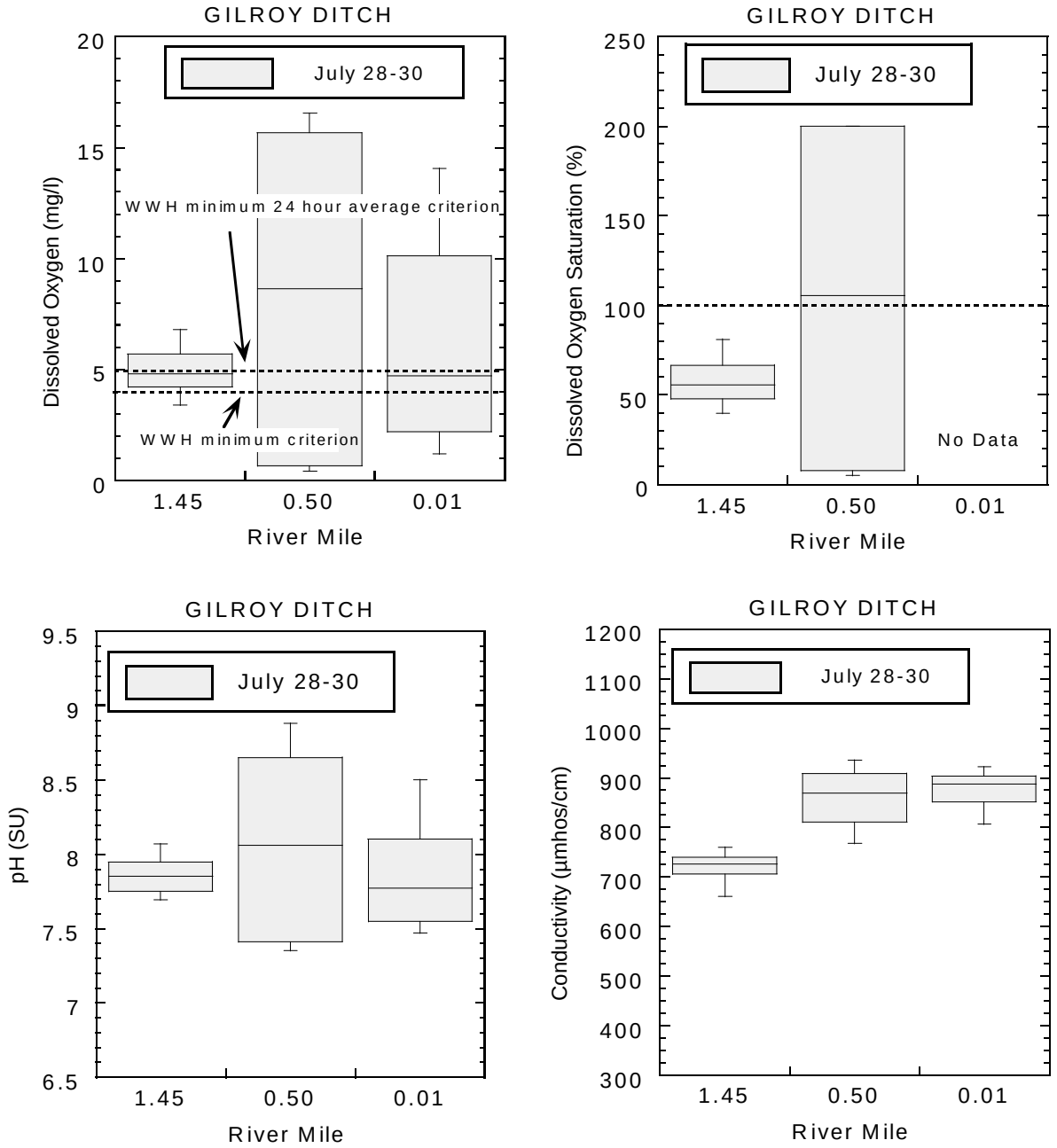



Figure 49. Clockwise from top left: Distributions of dissolved oxygen concentration, percent saturation, conductivity, and pH recorded hourly over a 48 h period in Gilroy Ditch, 1998. Dates of observations are shown in the figure legends. Water Quality Standards criteria for dissolved oxygen are shown as dashed horizontal lines.

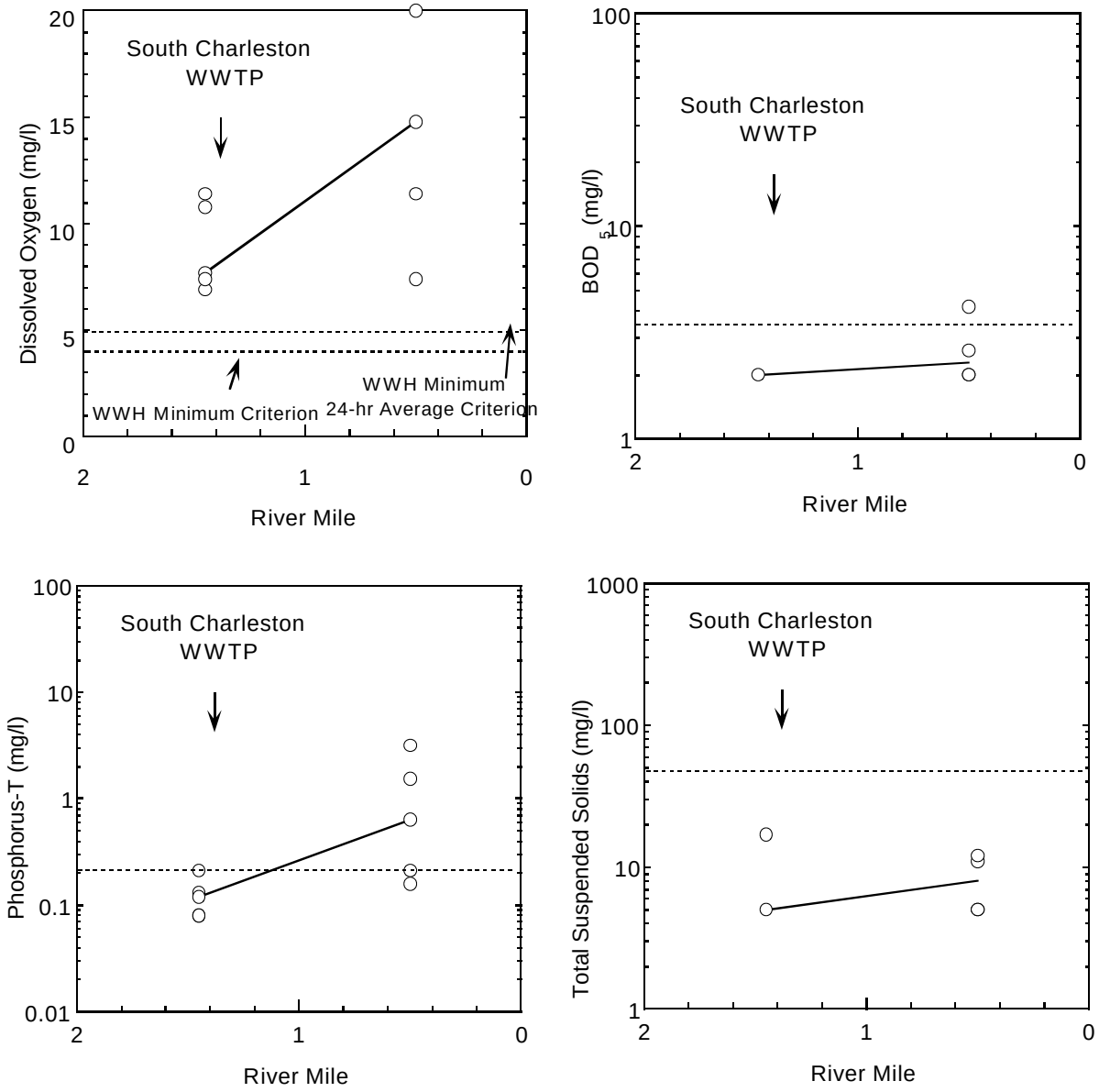



Figure 50. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Gilroy Ditch, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

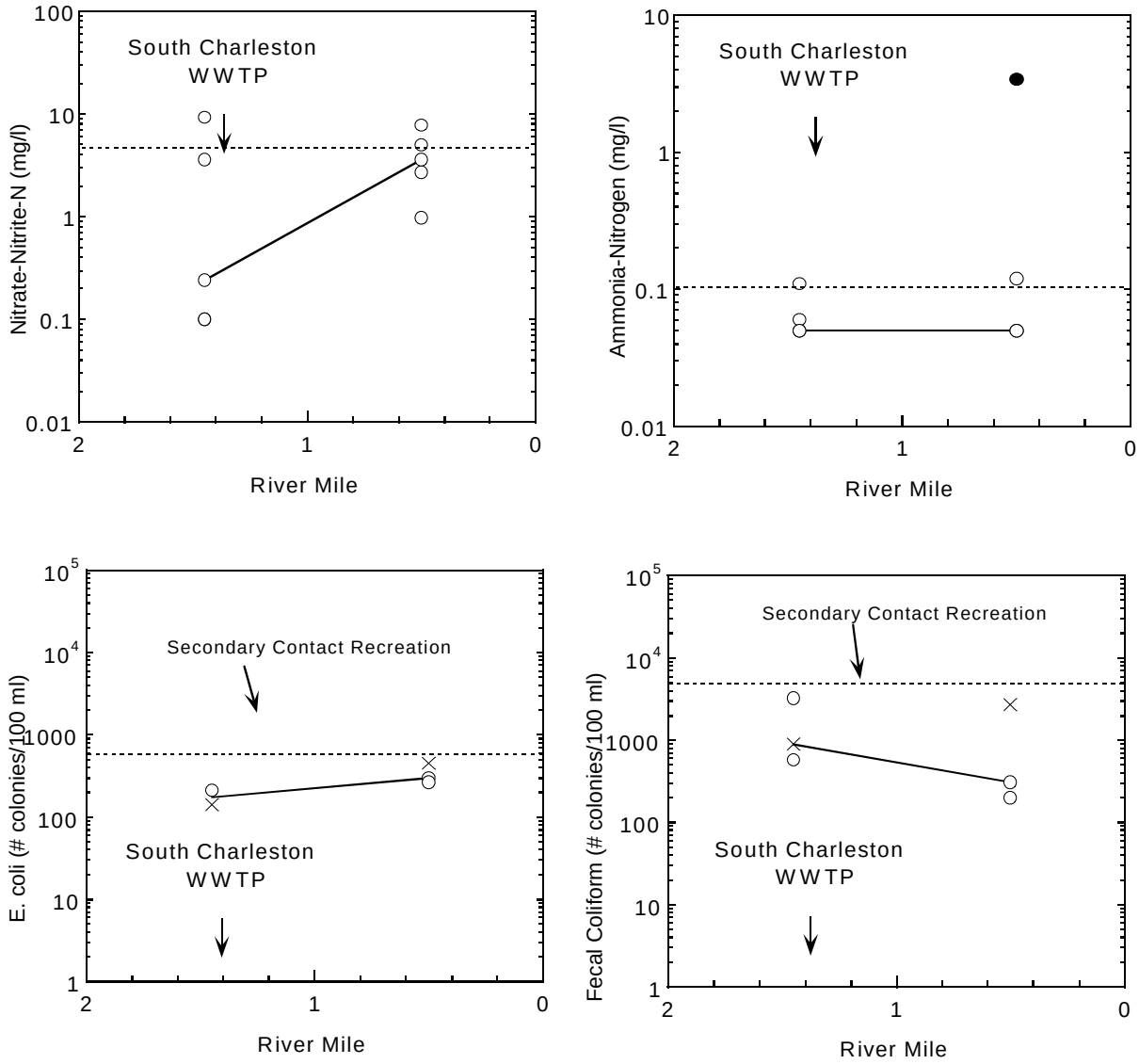



Figure 51. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Gilroy Ditch, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. The solid line depicts the median value at each river mile sampled. The solid point in the ammonia-nitrogen plot represents an exceedence of the Water Quality Standards. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen.

*Lisbon Fork*

Lisbon Fork enters the Little Miami River at RM 100.00. In addition to Datasonde monitoring at RM 0.40 from July 28-30 (Figure 52, Table 10), water chemistry daytime grab samples were collected every other week at the site (Figures 53 and 54). While Datasonde D.O. concentration data were unavailable, percent saturations ranged from 31% to 86% with a median value of 49%. (Field notes indicate that the monitor was placed at the downstream edge of a deep pool which may account for the lower values.) Temperature, pH, and conductivity values as measured by Datasonde monitors remained relatively stable with respective medians of 21.57°C, 7.93 SU, and 668 $\mu$mhos/cm.

Daytime grab samples collected at the site generally indicate good water quality. Dissolved oxygen concentrations ranged from 5.3 mg/l to 9.5 mg/l with a median percent saturation of 81%. While all $BOD_5$ concentrations were less than the MDL of 2 mg/l, all values of ammonia-N and nitrate-nitrite-N recorded were less than applicable 90$^{th}$ percentile concentrations for headwater reference sites in the ECBP ecoregion with respective medians of less than 0.05 mg/l and 1.69 mg/l. Phosphorus and TSS concentrations also remained low with median values of 0.085 mg/l and 6.5 mg/l, respectively. While all fecal coliform values recorded were below Primary Contact Recreation criteria, concentrations of *E. coli* exceeded the Primary Contact Recreation criteria on August 20 (260 colonies/100ml) and September 3 (380 colonies/100ml) (Table 8). With the exception of one exceedence of water quality criterion for manganese (106 µg/l), no other elevated parameters were observed in this tributary.

*North Fork Little Miami River*

The North Fork Little Miami River enters the mainstem Little Miami River at RM 91.64. While Datasonde continuous monitors measured hourly dissolved oxygen, temperature, pH and conductivity at RM 0.37 from July 28-30 (Figure 52 ), water chemistry daytime grab samples were collected every other week (five times) at RM 7.15 and RM 0.37 (Figure 55). All D.O. concentrations measured by Datasonde monitors at RM 0.37 remained above WWH criteria while percent saturations ranged from 68% to 98%. Temperature, pH, and conductivity values at the site remained relatively stable with respective medians of 20.53°C, 7.87 SU, and 684 $\mu$mhos/cm.

Water chemistry daytime grab samples collected at RM 7.15 and RM 0.37 reveal good water quality with only minimal variation in results observed between the two sites (Figure 55). The median D.O. concentration at both sites was 7.8 mg/l while median percent saturations approached 80%. All $BOD_5$ concentrations were less than the MDL of 2 mg/l. Additionally, the majority (80%) of all ammonia-N concentrations were equal to or less than the MDL (0.05 mg/l) with only one value (0.12 mg/l at RM 0.37) above the 90$^{th}$ percentile concentration (0.096 mg/l) for wadeable reference sites in the ECBP ecoregion. Median nitrate-nitrite-N concentrations decreased longitudinally from 2.03 mg/l (RM 7.15) to 1.24 mg/l (RM 0.37) while corresponding total phosphorus medians decreased from 0.11 mg/l to 0.05 mg/l. While all TSS concentrations at RM 7.15 were less than the MDL of 5 mg/l, values at RM 0.37 ranged from 7 mg/l to 27 mg/l. (Field crews, noting turbidity at this downstream site on two occasions (July 9 and July 23), were unable to determine the cause. Additionally, while RM 0.37 is downstream of the confluence with Goose Creek (RM 1.09), all TSS concentrations recorded in Goose Creek were also equal to or less than the MDL.) All fecal coliform

concentrations remained below Primary Contact Recreation criteria with median values decreasing longitudinally from 265 colonies/100ml (RM 7.15) to 100 colonies/100ml (RM 0.37). While *E. coli* values remained relatively stable at both sites with median values approaching 85 colonies/100ml, one concentration recorded at RM 7.15 (248 colonies/100ml) exceeded the average Primary Contact Recreation criterion. With the exception of one exceedence of water quality criterion for iron (2120 µg/l at RM 0.37), no other elevated parameters were noted in the North Fork Little Miami River. Organic water analyses detected heptachlor epoxide at RM 0.37, the only site sampled for organic compounds (Table 8).

*Goose Creek*

Daytime grab water chemistry samples were collected at one site, RM 0.92, in this tributary of the North Fork Little Miami River (confluence at RM 1.09) during the 1998 survey (Figures 53 and 54). Dissolved oxygen concentrations at the site ranged from 7 mg/l to 8.8 mg/l with a median percent saturation of 77%. All concentrations of $BOD_5$ and TSS were equal to or less than MDLs (2 mg/l and 5 mg/l, respectively). Additionally, concentrations of ammonia-N and total phosphorus remained low with recorded medians less than MDLs (0.05 mg/l for both parameters), while a median of 1.29 mg/l was recorded for nitrate-nitrite-N. Although all fecal coliform values were below Primary Contact Recreation criteria, all concentrations of *E. coli* exceeded Primary Contact Recreation criteria at the site (Table 9). Manganese concentrations exceeded water quality criterion on three occasions. No other elevated parameters were observed in this tributary.

*Yellow Springs Creek*

Yellow Springs Creek receives the discharge from the Yellow Springs WWTP at RM 0.43 before entering the Little Miami River at RM 85.17. In addition to hourly Datasonde monitoring of D.O., temperature, pH, and conductivity at RM 0.10 from September 1-3 (Figure 52), water chemistry daytime grab samples were collected every other week at the site (Figures 53 and 54).
All Datasonde D.O. concentrations were above EWH minimum water quality criteria while percent saturations ranged from 83% to 111%. Datasonde temperature, pH, and conductivity values remained relatively stable with respective medians of 16.92°C, 8.08 SU, and 834 $\mu$mhos/cm.

Results of daytime grab water chemistry sampling generally indicate good water quality. Medians of 9.1 mg/l and 95% were calculated for D.O. concentration and percent saturation, respectively. While all $BOD_5$ concentrations were less than the MDL of 2 mg/l, concentrations of ammonia-N at the site were also consistently low with four of five values below the MDL of 0.05 mg/l. Nitrate-nitrite-N (4.22 mg/l) and total phosphorus (0.18 mg/l) medians approached 90$^{th}$ percentile concentrations for headwater reference sites in the ECBP ecoregion. Additionally, the majority (80%) of TSS values were less than the MDL (5 mg/l). All fecal coliform concentrations remained below Primary Contact Recreation criteria. *E. coli* values exceeded the average Primary Contact Recreation criterion on August 20 (210 colonies/100ml) and September 3 (177 colonies/100ml). Organic water analyses detected gamma-hexachlorocyclohexane (Lindane) and one exceedence of water quality criterion for Dieldrin (Table 8). No other elevated parameters were noted.

*Jacoby Branch*

Hourly D.O., temperature, pH and conductivity were measured by a Datasonde continuous monitor from September 1-3 at RM 0.50 of Jacoby Branch, a headwater tributary entering the Little Miami River at RM 82.55 (Figure 52). All D.O. concentrations were above WWH minimum criteria while percent saturations at the site ranged from 84% to 121%. Median concentrations of temperature, pH, and conductivity were 17.13°C, 8.04 SU, and 668 $\mu$mhos/cm, respectively. Results of daytime grab water chemistry sampling at the site generally indicate good water quality (Figures 53 and 54). Dissolved oxygen concentrations were above WWH minimum criteria with minimal variation in percent saturations recorded (89% to 105%). Additionally, all concentrations of $BOD_5$ and ammonia-N were less than applicable MDLs. All values of nitrate-nitrite-N were below the 90$^{th}$ percentile concentration for headwater reference sites in the ECBP ecoregion with concentrations ranging from 0.91 mg/l to 2.77 mg/l. Concentrations of total phosphorus and TSS also remained low with the majority (80% for each parameter) of values recorded less than the applicable MDLs. Values above the Primary Contact Recreation criteria were measured for both fecal coliform and *E. coli* at the site (Table 9). (Field notes indicate that the site may be impacted by runoff from an upstream residence harboring waterfowl and a variety of animals.) No other parameters were elevated.

*Conner Branch*

One site (RM 0.16) on Conner Branch, a headwater tributary entering the Little Miami River at RM 81.45, was evaluated during the 1998 survey. Results of hourly monitoring of D.O. concentration, D.O. percent saturation, temperature, pH and conductivity by a Datasonde continuous monitor from September 1-3 reflect minimal variation in diurnal values for all parameters with respective median concentrations of 8.55 mg/l, 87%, 15.29°C, 8.06 SU, and 691 $\mu$mhos/cm (Figure 52). Results of water chemistry daytime grab samples collected at the site every other week during the survey (Figures 53 and 54) indicate generally good water quality with all D.O. concentrations above WWH minimum criteria and percent saturations ranging from 91% to 108%. All $BOD_5$ and TSS concentrations were less than the applicable MDLs. Concentrations of ammonia-N were also low with the majority (80%) of values less than the MDL of 0.05 mg/l. Nitrate-nitrite-N concentrations at the site remained stable (median 3.62 mg/l) while phosphorus levels ranged from less than the MDL (0.05 mg/l) to 0.47 mg/l with a median of 0.08 mg/l. Fecal coliform concentrations were below Primary Contact Recreation criteria . *E. coli* exceeded the average Primary Contact Recreation criterion on one occasion (330 colonies/100ml)(Table 9). No other elevated parameters were documented in this tributary.

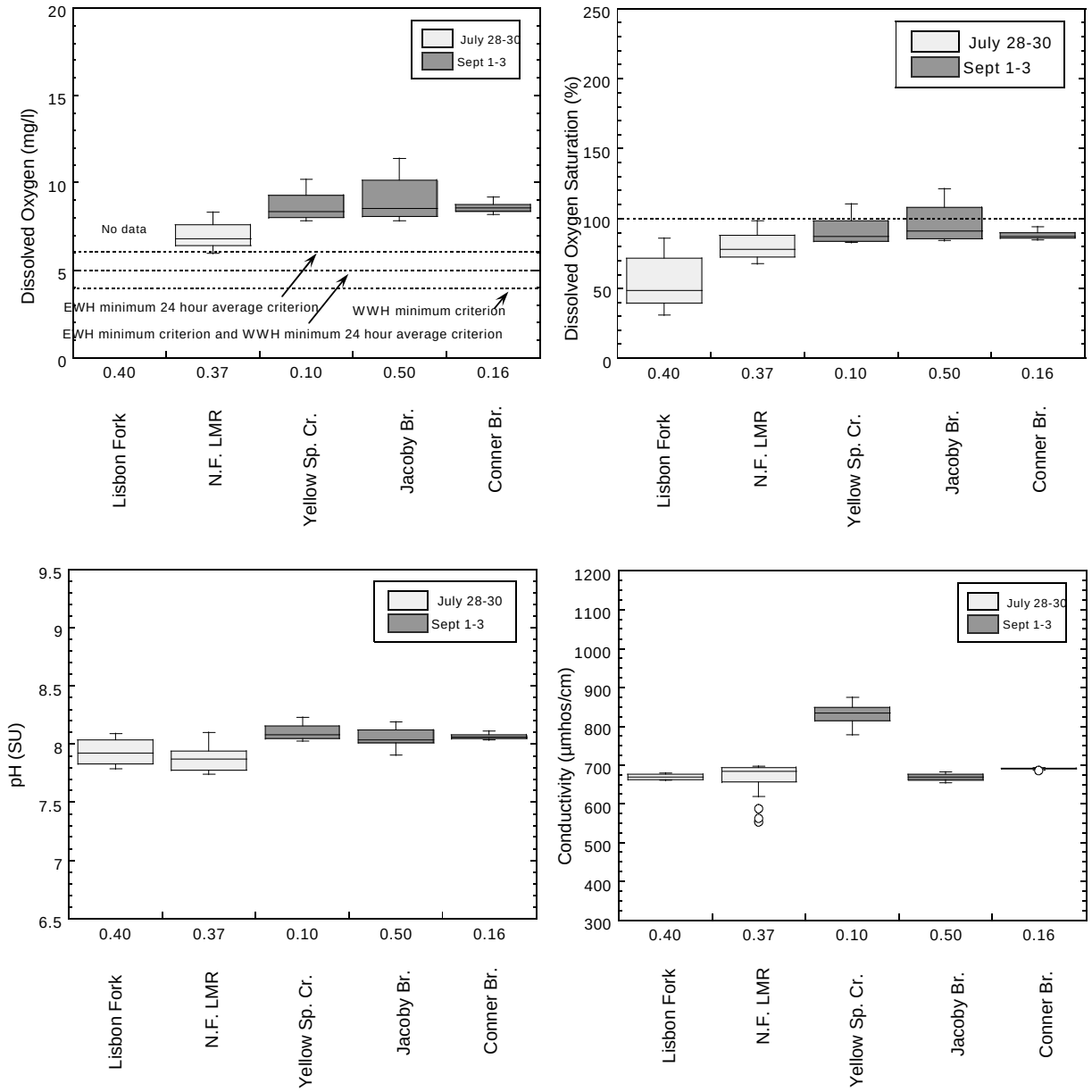



Figure 52. Clockwise from top left: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, conductivity, and pH recorded hourly over a 48 h period in Lisbon Fork, North Fork Little Miami River, Yellow Springs Creek, Jacoby Branch, and Conner Branch, 1998. Dates of observations are shown in the figure legends. Water Quality Standards criteria for dissolved oxygen are shown as dashed horizontal lines.

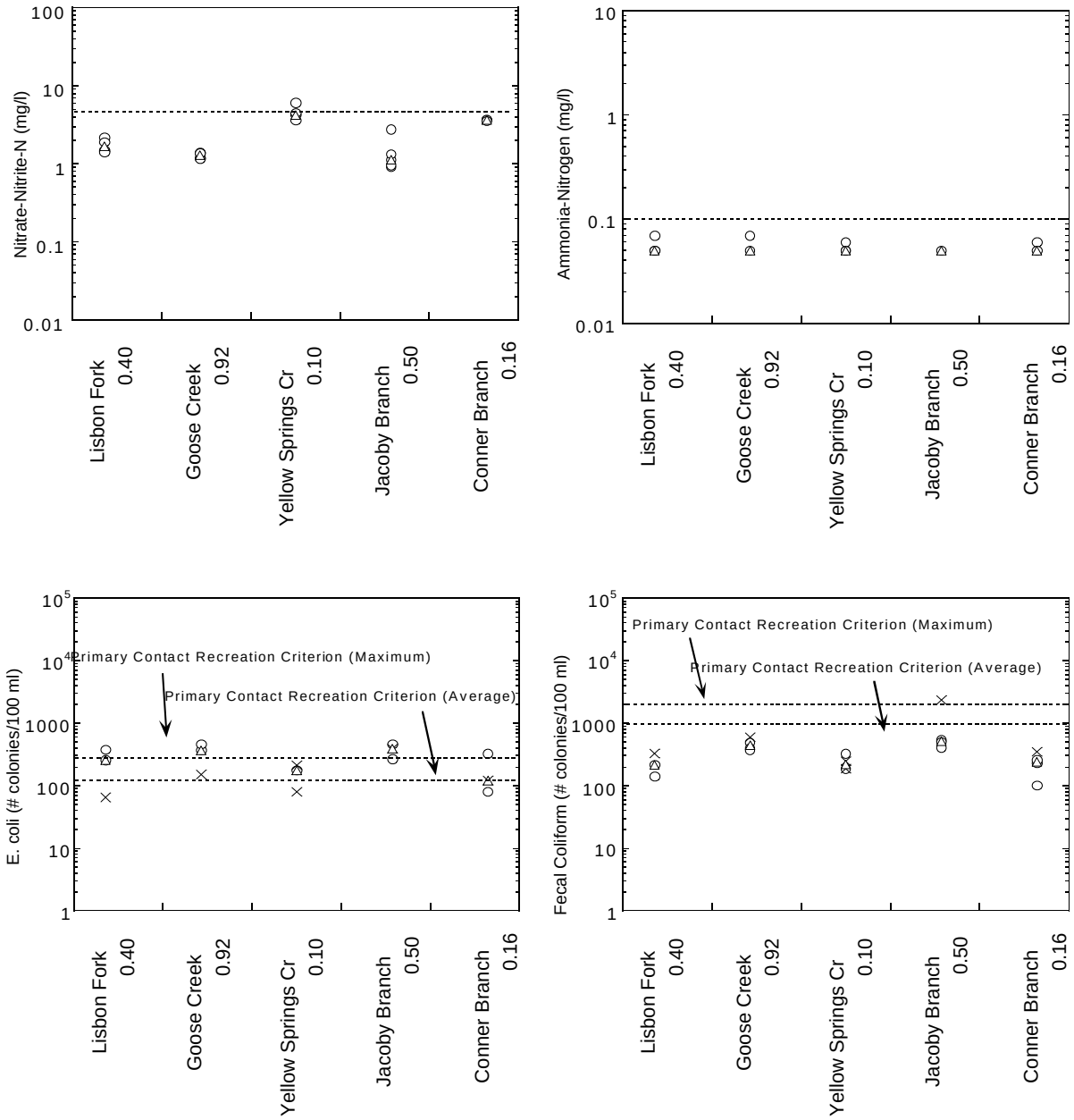



Figure 53. Scatter plots of water column chemistry results (daytime grabs) in Lisbon Fork, Goose Creek, Yellow Springs Creek, Jacoby Branch and Conner Branch 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. Triangles depict the median value at each location. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen.

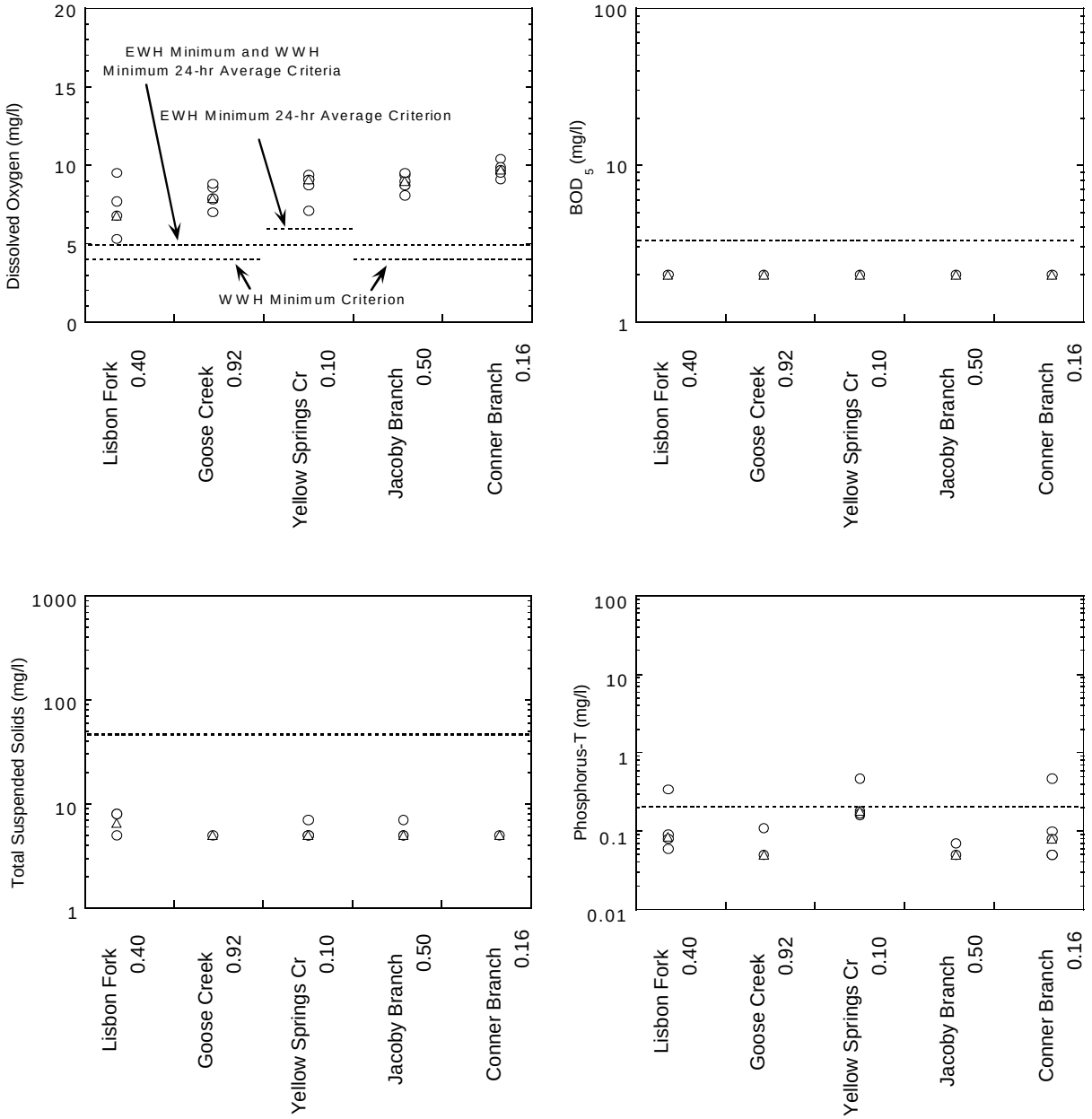



Figure 54. Scatter plots of water column chemistry results (daytime grabs) in Lisbon Fork, Goose Creek, Yellow Springs Creek, Jacoby Branch and Conner Branch 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total phosphorus, and total suspended solids. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

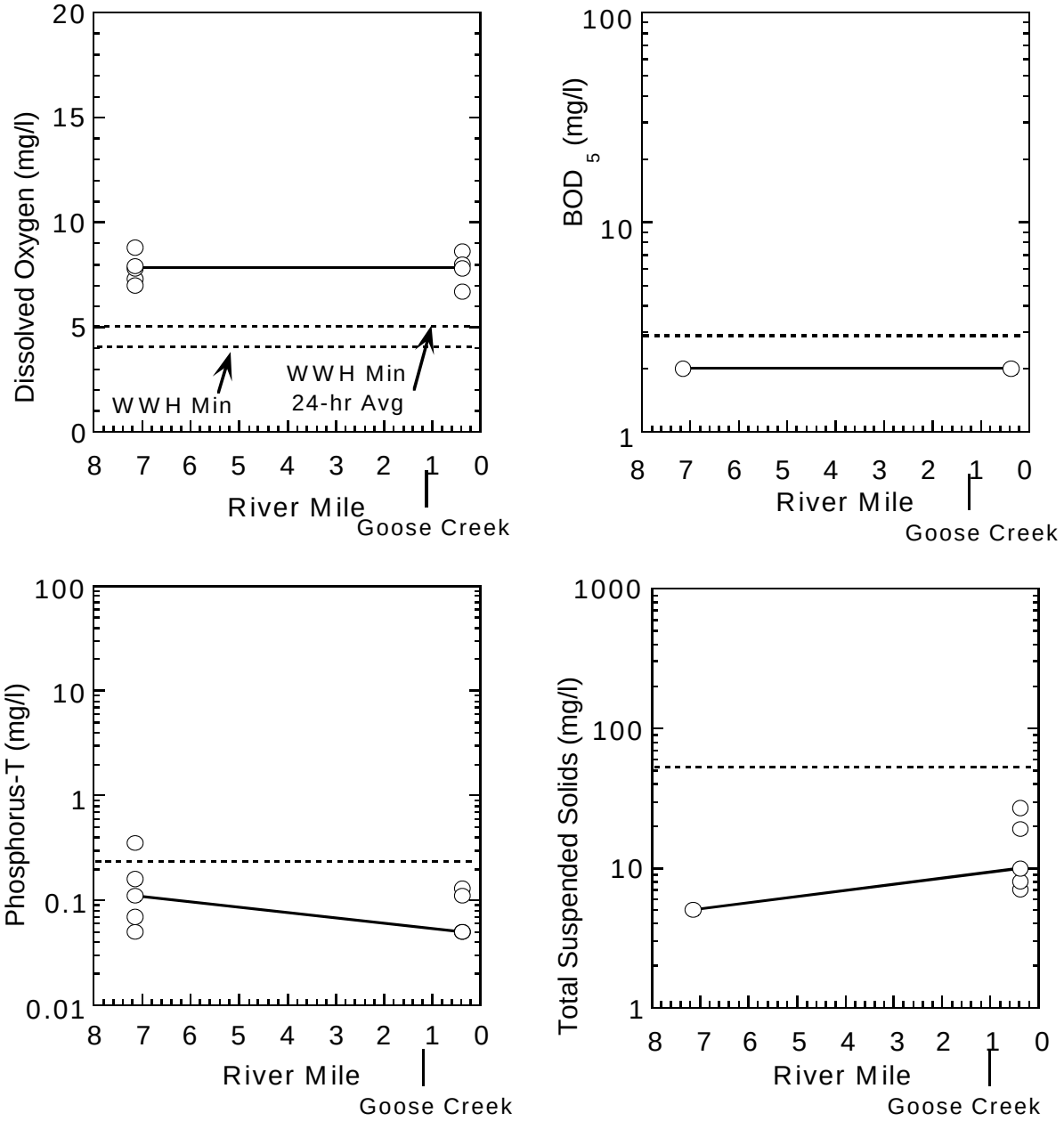



Figure 55. Longitudinal scatter plots of water column chemistry results (daytime grabs) in the North Fork Little Miami River, 1998. Clockwise from top: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen polt, or the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

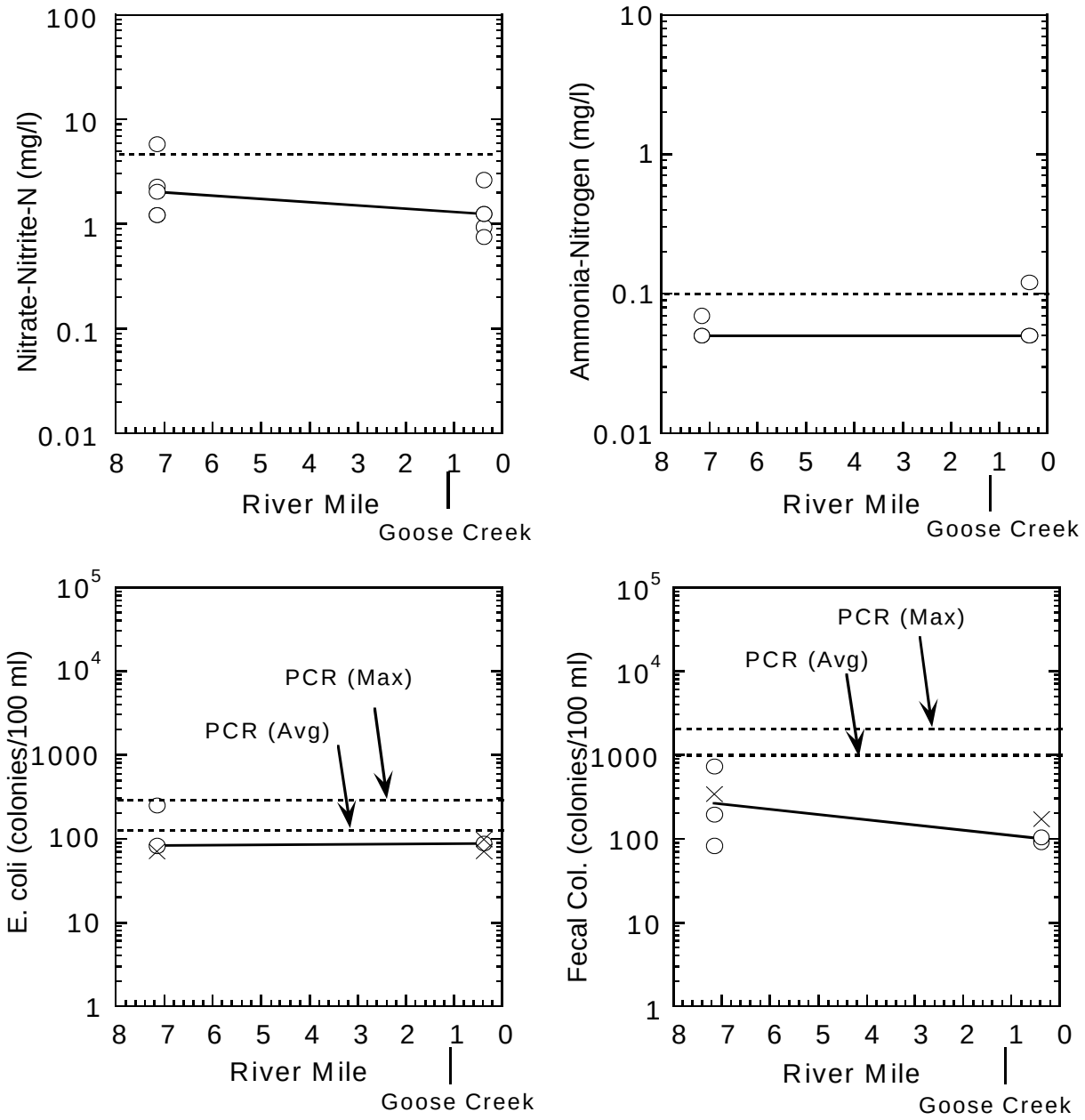



Figure 56. Longitudinal scatter plots of water column chemistry results (daytime grabs) in the North Fork Little Miami River, 1998. Clockwise from top: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliformbacteria, and *Escherichia coli*. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict applicable Water Quality Standards in the fecal coliform and *E. coli* plots, or the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

*Massie Creek*

Massie Creek, entering the Little Miami River at RM 79.54, receives the discharge from the Cedarville WWTP at RM 8.95. Stream flow from May through September 1998 (Figure 56) as measured by a USGS gage station in Massie Creek at Wilberforce (RM 4.38) exceeded 7 $Q_{10}$ values but dropped below the 80% duration exceedence flows in September (USGS 1981 and 1999). Peak flows for the period were recorded in May and June. With the exception of peaks caused by localized storms during the third week of July and again in the second week of August, subsequent stream flows steadily declined from July through September. On specific water chemistry sampling days in Massie Creek during the 1998 survey, the gage recorded a mean daily low on September 3 of 5 cfs and a mean daily high of 51 cfs on July 23.

Hourly dissolved oxygen (concentration and percent saturation), temperature, pH and conductivity were measured by Datasonde continuous monitors at one site (RM 0.20) from September 1-3 and at eight sites (RMS 8.96, 8.25, 7.16, 5.58, 4.38, 2.75, 1.20, and 0.05) from September 30 - October 2 (Figure 57). Dissolved oxygen measurements were relatively stable longitudinally from RM 5.58 through RM 0.05 with all concentrations above WWH minimum criteria and median percent saturations ranging from 75% to (RM 2.75) to 85% (RM 1.20), except that significant diurnal fluctuation was observed at RM 7.16. Dissolved oxygen concentrations (and percent saturations) at the site ranged from 3.51 mg/l (38%) to 16.32 mg/l (182%) with seven of the 47 measured concentrations less than the WWH minimum criterion of 4.0 mg/l. The combined impact of nutrient loading from the Cedarville WWTP and non-point sources was evidenced by the algal growth observed by field crews. Conditions for excessive algal growth were exacerbated by the open canopy. Diel pH variation was correspondingly high with values ranging from 7.81 SU to 8.76 SU. Temperatures were relatively stable depending on the sampling period with median values measured from September 30-October 2 ranging from 16.00°C (RM 0.05) to 17.94°C (RM 8.96). The highest conductivities were measured at RMS 8.25 and 7.16, downstream of the Cedarville WWTP, with median values of 981 $\mu$mhos/cm and 899 $\mu$mhos/cm, respectively.

Water chemistry daytime grab samples were collected at four sites (RMS 7.71, 4.38, 1.20, and 0.26) in Massie Creek during the 1998 survey (Figures 58 and 59). All D.O. concentrations remained above WWH minimum criteria. The majority (94% for each parameter) of $BOD_5$ and ammonia-N concentrations recorded were less than applicable MDLs (2 mg/l and 0.05 mg/l, respectively). Minimal longitudinal variation was observed in concentrations of nitrate-nitrite-N with medians ranging from 2.60 mg/l (RM 7.71) to 3.74 mg/l (RM 1.20). While the majority (72%) of total phosphorus concentrations remained below the $90^{th}$ percentile concentration (0.22 mg/l) for wadeable reference sites in the ECBP ecoregion, maximum values of 0.87 mg/l and 0.56 mg/l, respectively, were measured at RM 4.38 and RM 0.26. With the exception of peak values recorded on July 23 (the highest flow day of the survey in the basin), TSS concentrations were less than or equal to the MDL of 5 mg/l. All fecal coliform concentrations were below Primary Contact Recreation criteria with median values increasing longitudinally from RM 7.71 (227 colonies/100ml) to RM 0.26 (420 colonies/100ml). Concentrations of *E. coli* at RM 0.26 exceeded the average Primary Contact Recreation criterion on two occasions, and values exceeded the maximum Primary Contact Recreation criterion at all sites on August 20 with exceptionally high concentrations

measured at RM 7.71 (7900 colonies/100ml) and RM 4.38 (8670 colonies/100ml). *E. coli* concentrations measured at RM 0.14 in the South Fork Massie Creek (confluence at RM 9.95) minimally exceeded the Average Primary Contact criterion, however final effluent fecal coliform concentrations on August 20 at the Cedarville WWTP (RM 8.95) were below the minimum detection limit, so the source of the contamination was unconfirmed. With the exception of manganese (106 µg/l) and iron (2770 µg/l) water quality criteria exceedences at RM 4.38 (Table 9), no other elevated conventional parameters were recorded in Massie Creek. Water samples from RMS 7.71 and 0.26 were analyzed for organic compounds twice during the 1998 survey (Table 8), revealing exceedences of water quality criteria for Dieldrin and Endosulfan II.

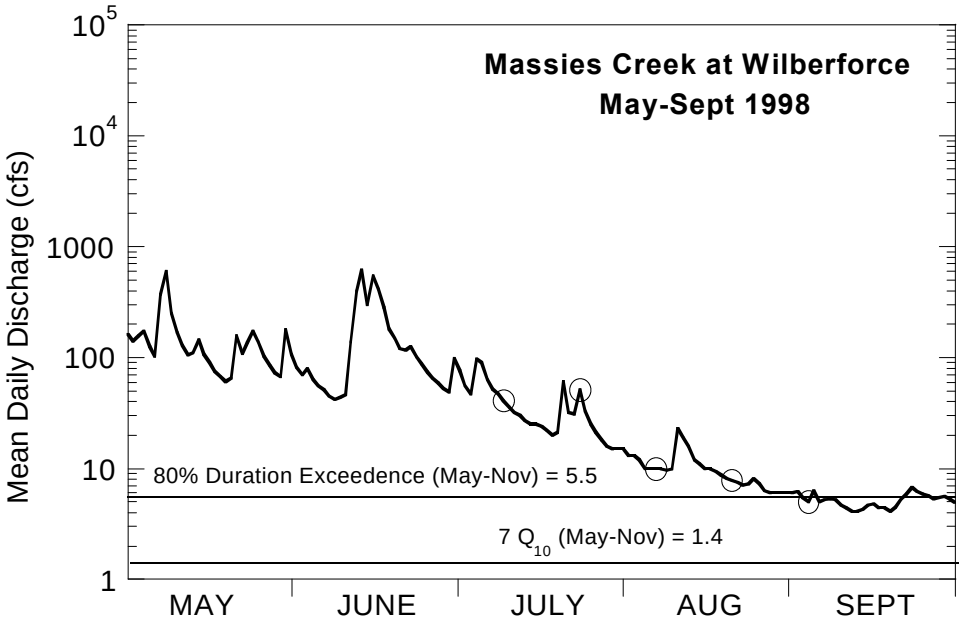



Figure 57. May through September, 1998 flow hydrograph for Massie Creek at Wilberforce (Rm 4.38). Low flow conditions ($7Q_{10}$) and 80% duration exceedence flow is based on USGS station #03241500 (period of record 1952-1998). Open circles indicate river discharge on water chemistry sampling days in Massie Creek.

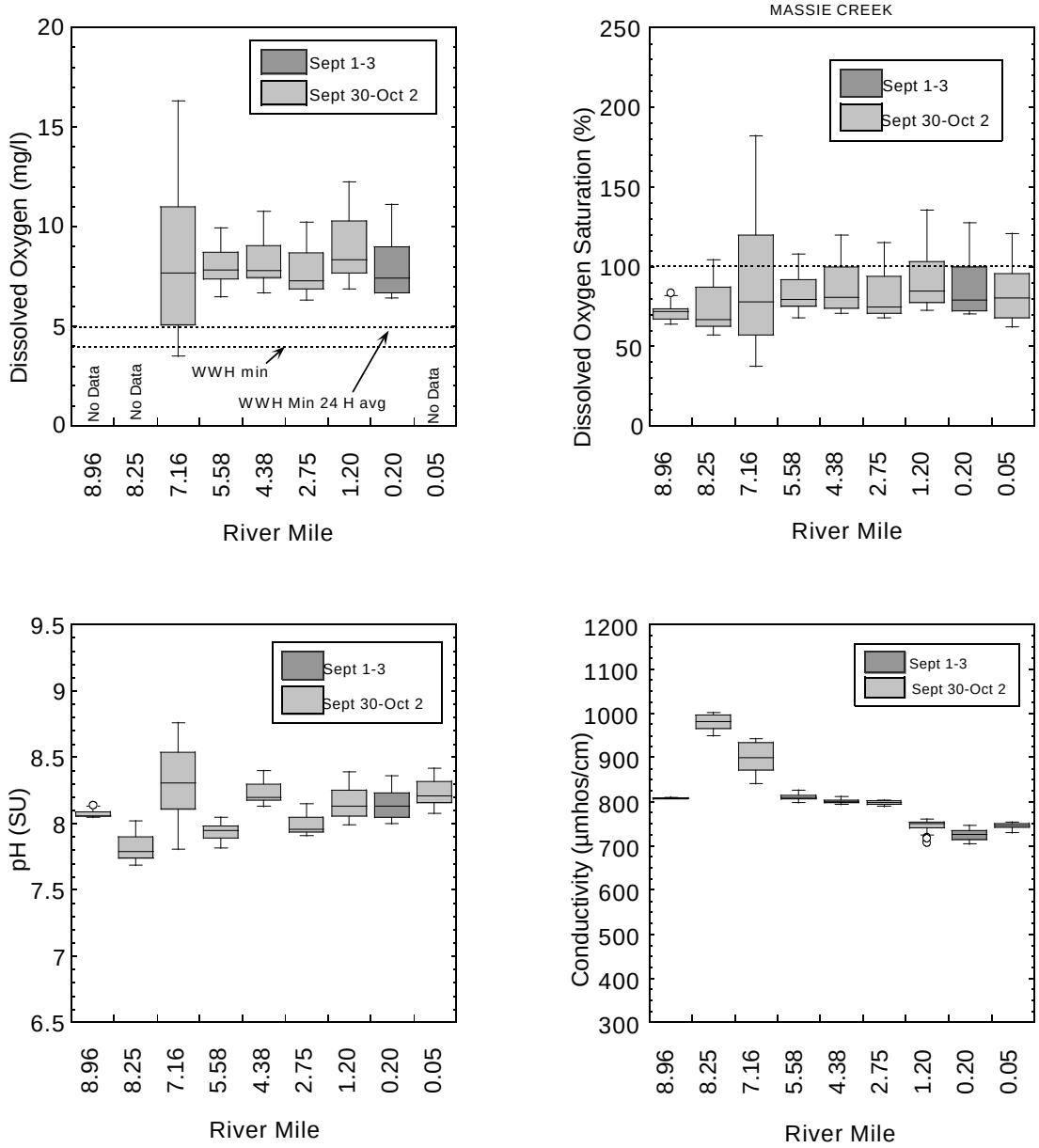



Figure 58. Clockwise from top left: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, conductivity, and pH recorded hourly over a 48 h period in Massie Creek, 1998. Dates of observations are shown in the figure legends.

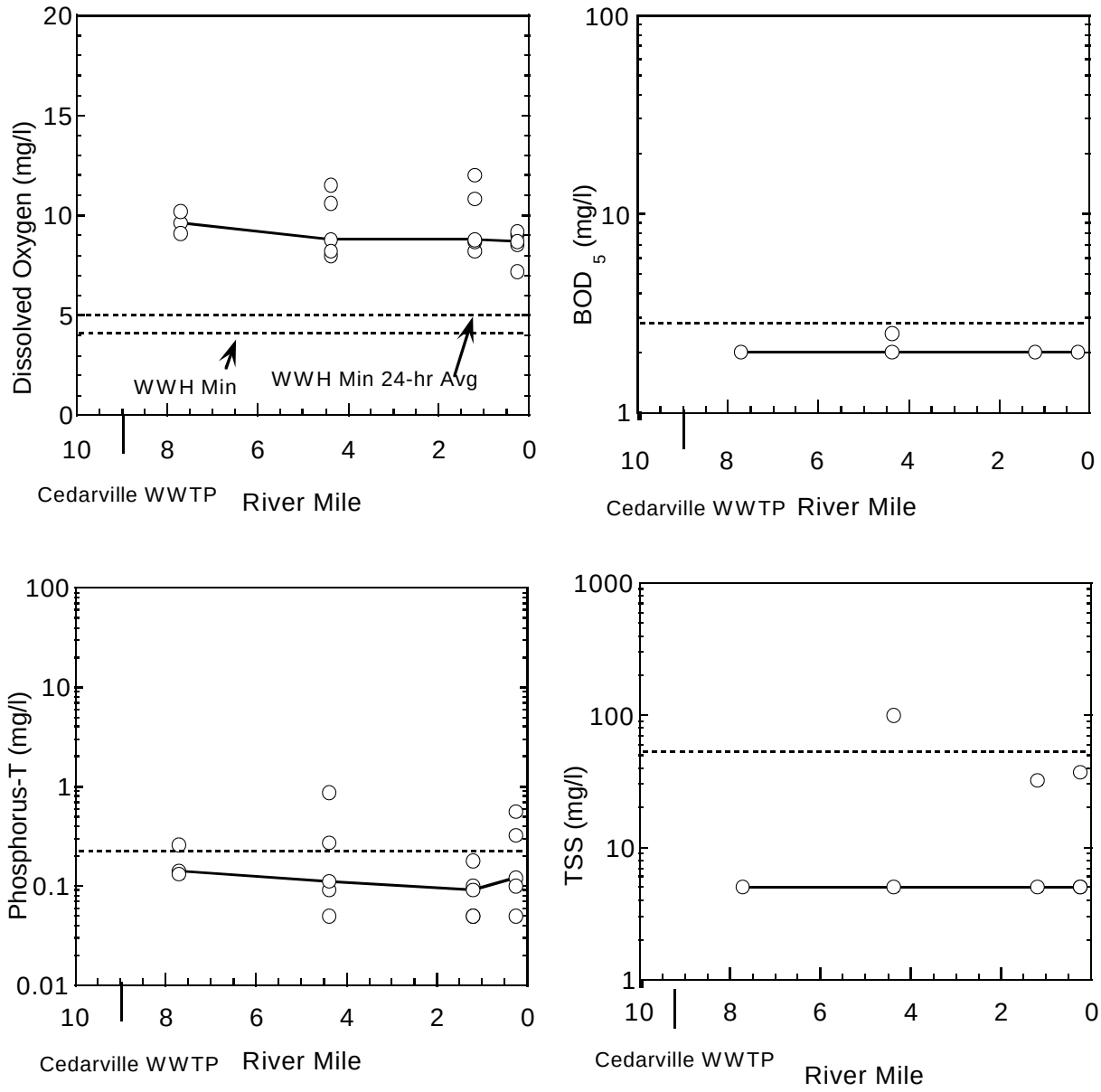



Figure 59. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Massie Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

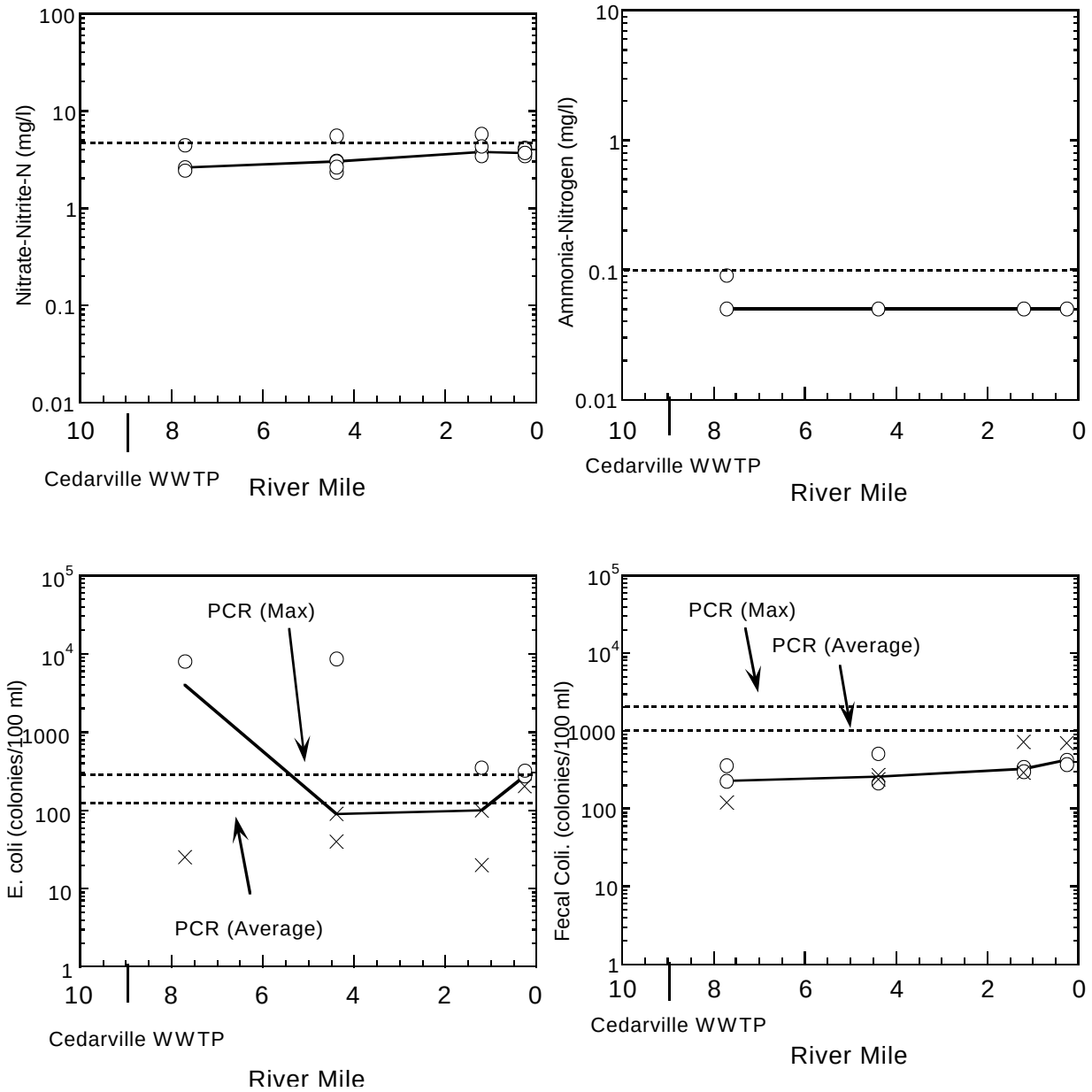



Figure 60. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Massie Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

*North Fork Massie Creek*

Daytime grab water chemistry samples were collected at RMS 7.95 and 1.17 in this tributary of Massie Creek (confluence at RM 9.96) during the 1998 survey (Figures 60 and 61). Reflecting the minimal flow at this site throughout the summer, D.O. concentrations at RM 7.95 were typically lower than those measured downstream at RM 1.17, with the concentration falling below the WWH minimum 24-hour average criterion of 5.0 mg/l on September 3. In contrast, as the summer progressed and flows continued to decrease, concentrations downstream at RM 1.17 frequently reached supersaturated levels with peak percent saturations occurring on August 20 (132 %) and September 3 (195%). Algal mats blanketed much of the stream surface at this site late in the survey, reflecting the impact of non-point runoff in this agricultural basin exacerbated by the open canopy and minimal riparian at the site. All $BOD_5$ concentrations recorded at both sites were less than the MDL (2 mg/l). Ammonia-N concentrations remained low with all values measured at RM 1.17 less than or equal to the MDL (0.05 mg/l) and all but one value (0.12 mg/l) recorded at RM 7.95 less than or equal to the $90^{th}$ percentile concentration (0.1 mg/l) for headwater reference sites in the ECBP ecoregion. Higher nitrate-nitrite-N concentrations were generally recorded at the downstream site with median values increasing from 0.18 mg/l (RM 7.95) to 1.31 mg/l (RM 1.17). Only one phosphorus value (0.68 mg/l at RM 7.95) exceeded the $90^{th}$ percentile concentration (0.206 mg/l) for headwater reference sites in the ECBP ecoregion. While respective median and maximum TSS concentrations at RM 1.17 were 5 mg/l and 15 mg/l, consistently higher values were recorded at RM 7.95 with values ranging from 16 mg/l to 30 mg/l. (Field crews noted turbidity at this site throughout the survey but were unable to determine the cause.) All fecal coliform concentrations were below Primary Contact Recreation criteria with median values decreasing longitudinally from RM 7.95 (520 colonies/100ml) to RM 1.17 (112 colonies/100ml). Concentrations of *E. coli* followed a similar longitudinal pattern, with one value (200 colonies/100ml) exceeding the average Primary Contact Recreation criterion at RM 7.95. Manganese and iron concentrations frequently exceeded water quality criteria at RM 7.95. Water samples from RM 1.17 were analyzed for organic compounds twice during the 1998 survey (Table 8), revealing various organochlorine pesticides and exceedences of water quality criteria for Dieldrin (Table 9).

*South Fork Massie Creek*

Daytime grab water chemistry samples were collected at RMS 2.15 and 0.14 in this tributary of Massie Creek (confluence at RM 9.95) every other week (five times) during the 1998 survey (Figures 62 and 63). While all D.O. concentrations remained above WWH minimum criteria and median values remained relatively stable longitudinally, a significant increase in percent saturations was observed at both sites as the summer progressed and flows continued to decrease. While D.O. percent saturations at RM 2.15 ranged from 70% to 90% during the first three sampling events (July 9, July 23, and August 6), values increased to 120% and 123%, respectively, on August 20 and September 3. Values at RM 0.14 followed a similar pattern with recorded percent saturations ranging from 85% to 97% during the first three sampling periods before increasing to 108% and 139%, respectively, on August 20 and September 3. As observed in other tributaries in the upper Little Miami River basin, the effect of nutrient loading exacerbated by low flow conditions was evidenced by the significant amount of algae observed at both sites late in the survey and the corresponding supersaturated daytime dissolved oxygen values.

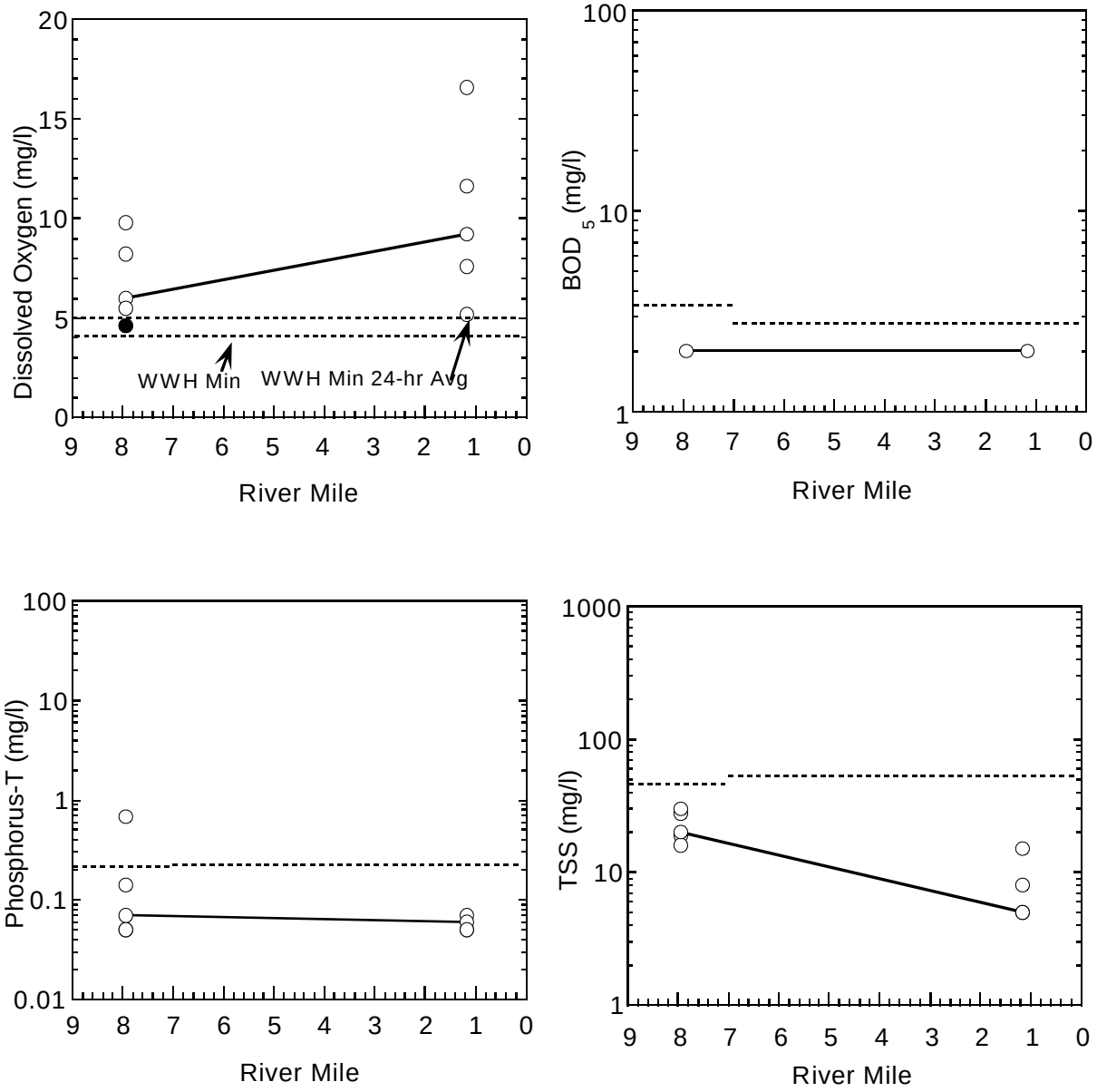



Figure 61. Longitudinal scatter plots of water column chemistry results (daytime grabs) in the North Fork Massie Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. The solid lines depict medians at each location. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

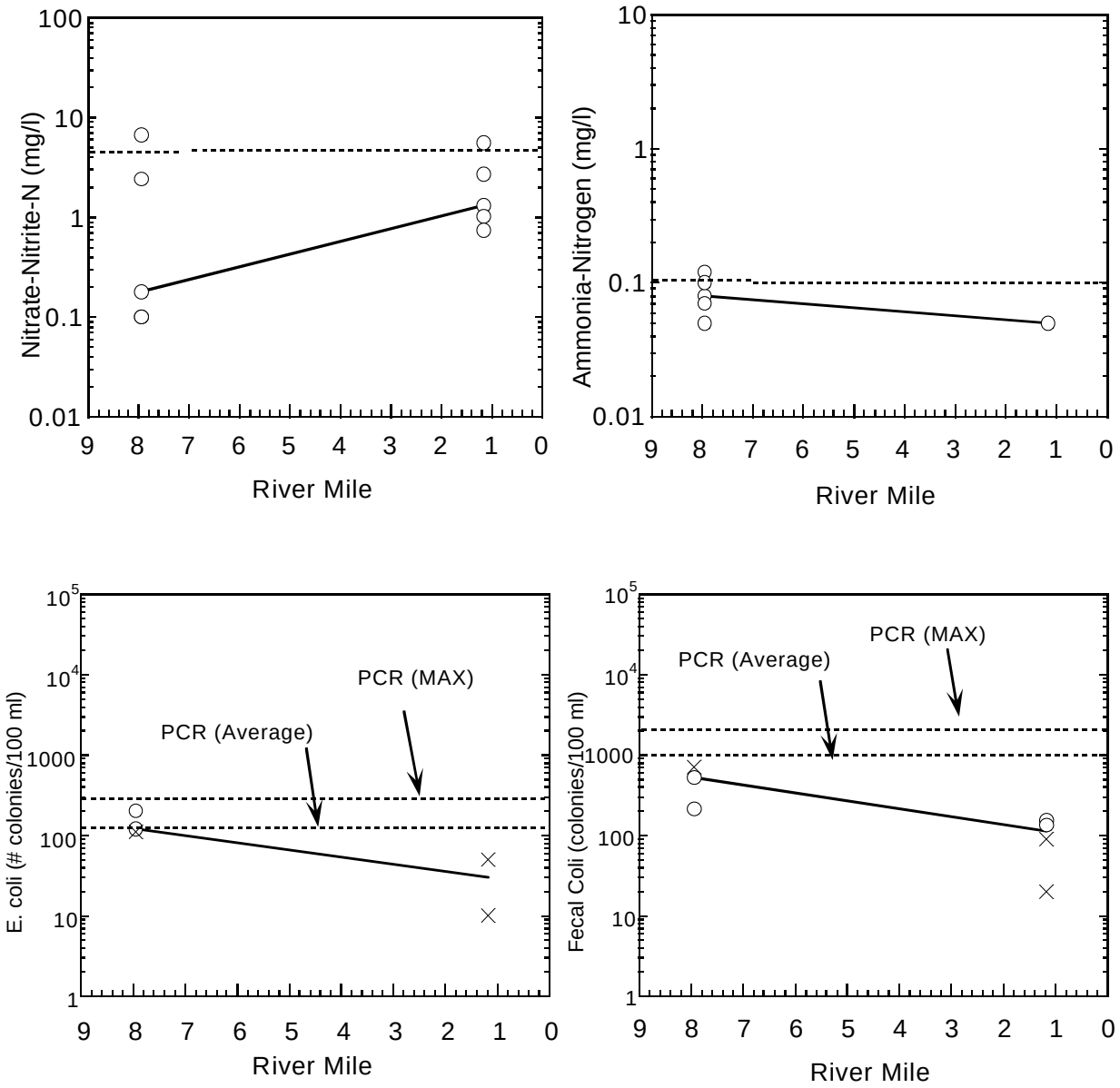



Figure 62. Longitudinal scatter plots of water column chemistry results (daytime grabs) in the North Fork of Massie Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

While all $BOD_5$ concentrations were less than the MDL of 2 mg/l, ammonia-N and total phosphorus concentrations also remained low with all values recorded less than applicable 90$^{th}$ percentile concentrations (0.1 mg/l and 0.206 mg/l, respectively) for headwater reference sites in the ECBP ecoregion. Respective median and maximum nitrate-nitrite-N concentrations decreased from 1.70 mg/l and 7.66 mg/l at RM 2.15 to 0.65 mg/l and 6.72 mg/l at RM 0.14. TSS concentrations during the survey ranged from less than the MDL of 5 mg/l to 11 mg/l with little variation observed between sites. While all fecal coliform concentrations were below Primary Contact Recreation criteria, *E. coli* exceeded the average Primary Contact Recreation criterion at RM 0.14 on one occasion. With the exception of one exceedence of water quality criterion for manganese at RM 2.15, no other elevated metal concentrations were recorded in this tributary.

*Tributary to Massie Creek @ RM 5.31*

Water chemistry daytime grab samples were collected at RM 0.65 of this Massie Creek tributary. Given that this tributary did not have an aquatic life use designation during the 1998 survey, water quality criteria identified for the limited resource water (LRW) use designation apply (OAC rule 3745-1-07). Analyses of water samples collected at the site generally indicate good water quality. All D.O. concentrations measured were well above LRW (as well as WWH) minimum criteria with values ranging from 7.4 mg/l to 8.6 mg/l and a median percent saturation of 88%. While four of five $BOD_5$ concentrations recorded were less than the MDL of 2 mg/l, one value (4.3 mg/l) minimally exceeded the 90$^{th}$ percentile concentration (3.4 mg/l) for headwater reference sites in the ECBP ecoregion. Ammonia-N concentrations remained low with the majority (80%) of values measured less than or equal to the MDL (0.05 mg/l). While nitrate-nitrite-N values ranged from 1.06 mg/l to 4.95 mg/l, concentrations of total phosphorus ranged from 0.08 mg/l to 0.22 mg/l. TSS concentrations were typically low (median of 6 mg/l) with the highest value (32 mg/l) coinciding with the highest flow day (July 23) in the basin. Bacteriological sampling revealed consistently elevated concentrations of fecal coliform (2300 to 15300 colonies/100ml) and *E. coli* (150 to 923 colonies/100ml) at the site with values exceeding maximum recreation criteria applicable to all waters once for each parameter. While this tributary primarily drains agricultural land, the site may also be impacted by local on-site sewage systems (especially given that bacteriological samples were only collected in this tributary during August and September on days of no precipitation and minimal stream flow). This situation requires further investigation. No other elevated parameters were observed in this tributary.

*Clark Run*

Clark Run enters Massie Creek at RM 2.38. Water chemistry daytime grab samples collected at one site, RM 0.44, during the 1998 survey (Figures 64 and 65) indicate generally good water quality. Dissolved oxygen measurements at the site were relatively stable throughout the summer with concentrations ranging from 7.8 mg/l to 8.5 mg/l with a median percent saturation of 91%. All $BOD_5$ and TSS concentrations were less than applicable MDLs. While all concentrations of ammonia-N and total phosphorus were below applicable 90$^{th}$ percentile concentrations (0.1 mg/l and 0.206, respectively) for headwater reference sites in the ECBP ecoregion, nitrate-nitrite-N concentrations at the site consistently exceeded the headwater reference site 90$^{th}$ percentile concentration (4.60 mg/l) with values ranging from 5.67 mg/l to 8.16 mg/l. Fecal coliform

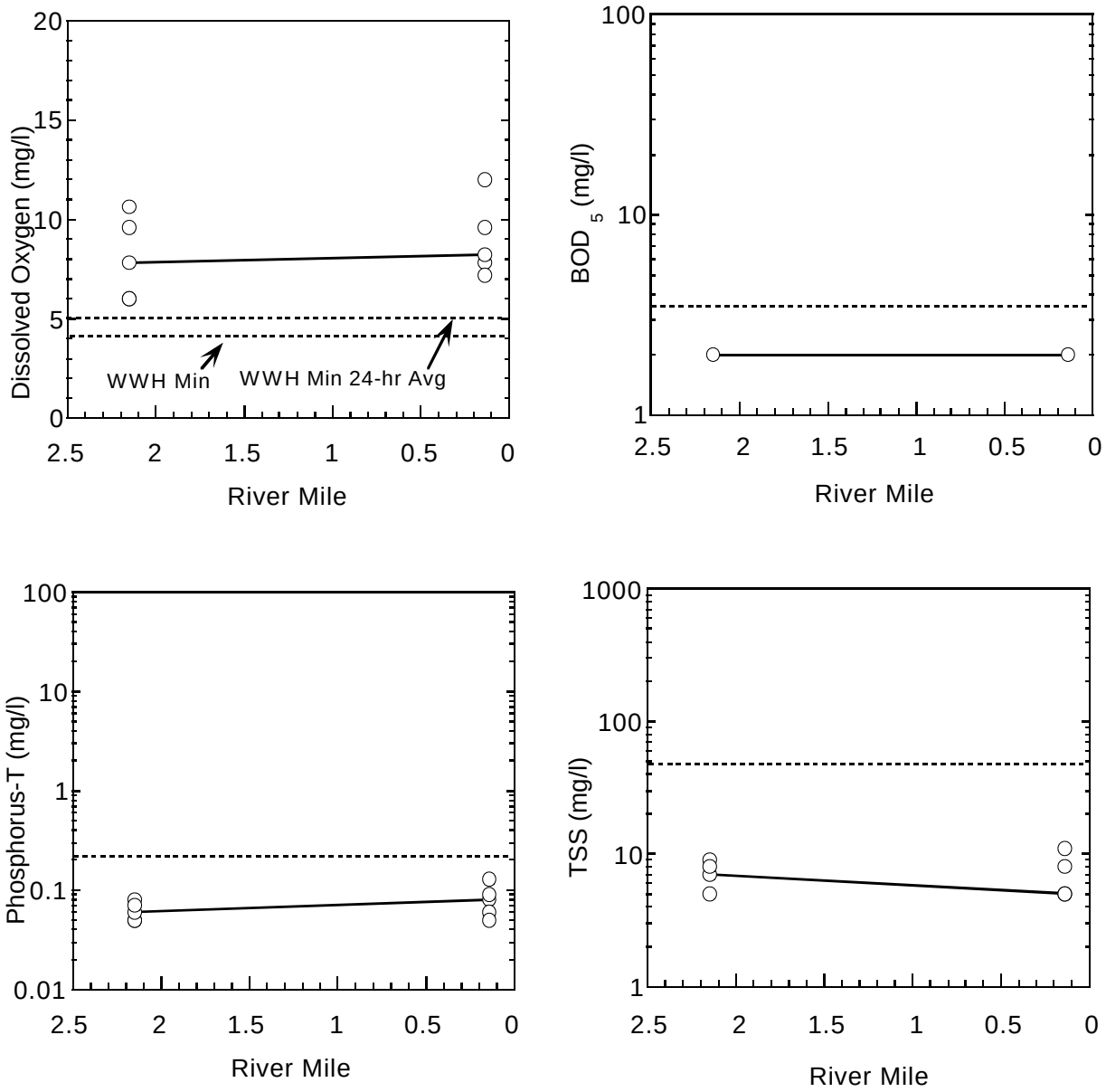



Figure 63. Longitudinal scatter plots of water column chemistry results (daytime grabs) in the South Fork of Massie Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

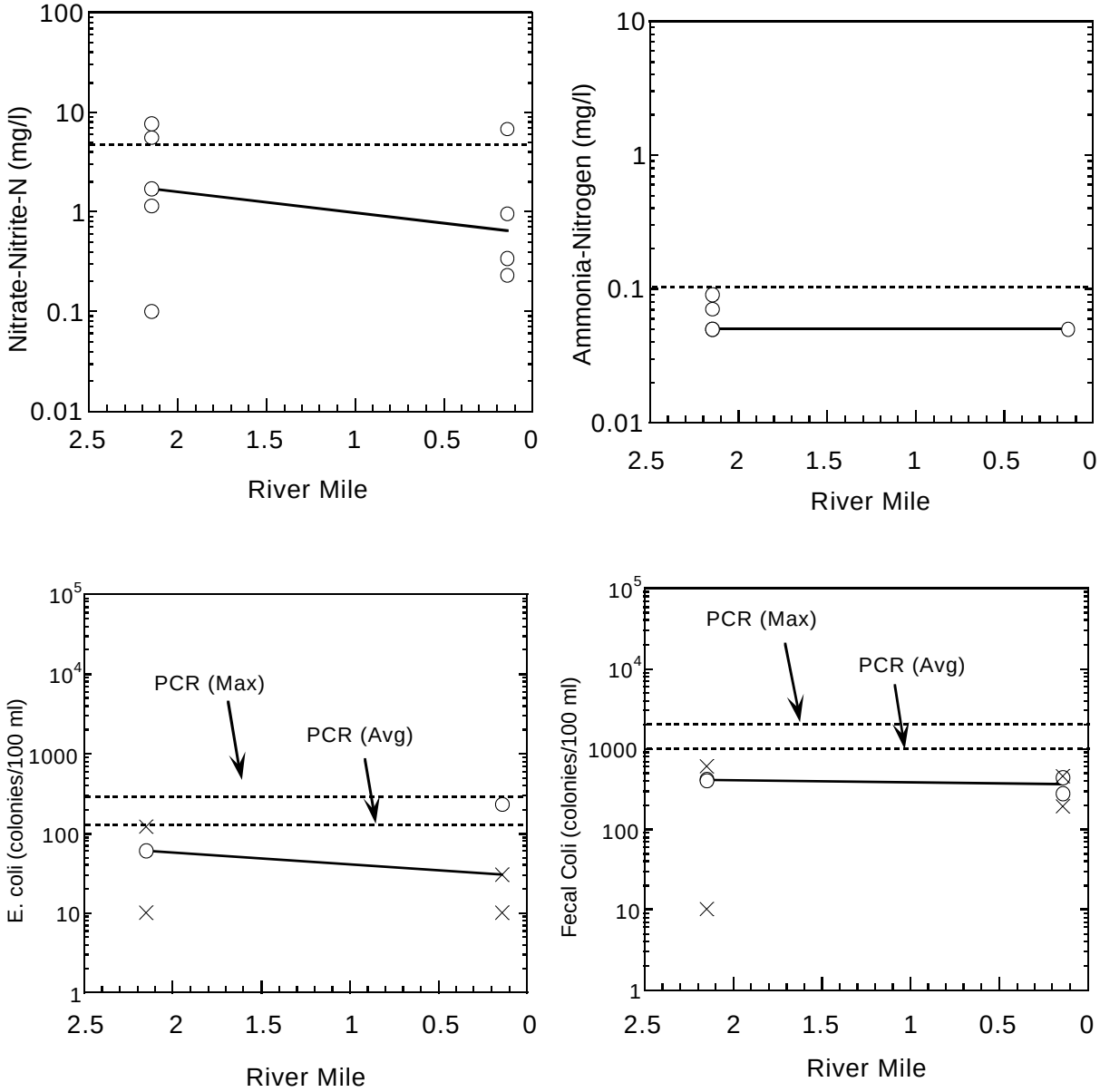



Figure 64. Longitudinal scatter plots of water column chemistry results (daytime grabs) in the South Fork of Massie Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

concentrations recorded were well below Primary Contact Recreation criteria while *E. coli* values exceeded average Primary Contact Recreation criterion on one occasion (240 colonies/100ml). No other elevated parameters were recorded in Clark Run.

*Oldtown Creek*

Daytime grab water chemistry samples were collected near the mouth (RM 0.10) of this tributary to Massie Creek (confluence at RM 0.25) during the 1998 survey (Figures 64 and 65). Dissolved oxygen concentrations, well above WWH minimum criteria, ranged from 8.1 mg/l to 9.5 mg/l with a median percent saturation of 97%. All ammonia-N and four of five $BOD_5$ concentrations were less than applicable MDLs (0.05 mg/l and 2 mg/l, respectively). Nitrate-nitrite-N values at the site (median and maximum values of 5.65 mg/l and 7.08 mg/l, respectively) generally exceeded the 90$^{th}$ percentile concentration (4.60 mg/l) for headwater reference sites in the ECBP ecoregion while concentrations of total phosphorus ranged from 0.05 mg/l to 0.45 mg/l with a median value of 0.10 mg/l. While four of five TSS concentrations were less than the MDL of 5 mg/l, a concentration of 123 mg/l was recorded at the site on July 23, the highest flow day of the survey in this basin. Although all fecal coliform values were below Primary Contact Recreation criteria, concentrations of *E. coli* exceeded Primary Contact Recreation criteria in all samples with values ranging from 150 to 630 colonies/100 ml. With the exception of one exceedence of water quality criterion for iron (1850 µg/l), no other elevated parameters were observed in this tributary.

*Ludlow Creek*

Ludlow Creek enters the Little Miami River at RM 76.63, approximately 0.40 miles downstream of the Xenia Ford Road WWTP discharge to the mainstem. Results of water chemistry daytime grab sampling at RM 0.25 of this tributary during the 1998 survey (Figures 64 and 65) generally indicate good water quality. Dissolved oxygen measurements were stable throughout the survey with median concentration and percent saturation values of 8.6 mg/l and 93%, respectively. All $BOD_5$ and ammonia-N concentrations recorded at the site were less than applicable MDLs. While concentrations of nitrate-nitrite-N remained stable with respective median and maximum values of 3.12 mg/l and 3.26 mg/l, total phosphorus concentrations ranged from 0.06 mg/l to 0.43 mg/l with a median value of 0.1 mg/l. TSS concentrations in this tributary were consistently higher than the MDL with values ranging from 7 mg/l to 30 mg/l and a median of 14 mg/l. (Field crews frequently observed light turbidity but were unable to pinpoint the source.) Two of four *E. coli* values exceeded the average Primary Contact Recreation criterion at the site while all fecal coliform concentrations remained below Primary Contact Recreation criteria. No other elevated conventional parameters were recorded at the site. Additionally, while water samples from the site were analyzed for organic compounds twice during the survey (Table 8), no priority pollutants were detected.

*Shawnee Creek*

Shawnee Creek flows through the city of Xenia before entering the Little Miami River at RM 76.42, approximately 0.20 miles downstream from Ludlow Creek's confluence with the mainstem. Water chemistry samples were collected at RM 0.65 of this tributary during the 1998 survey (Figures 64 and 65). Dissolved oxygen concentrations were above WWH minimum criteria at the site with percent saturations ranging from 91% to 116%. Additionally, all concentrations of $BOD_5$ and

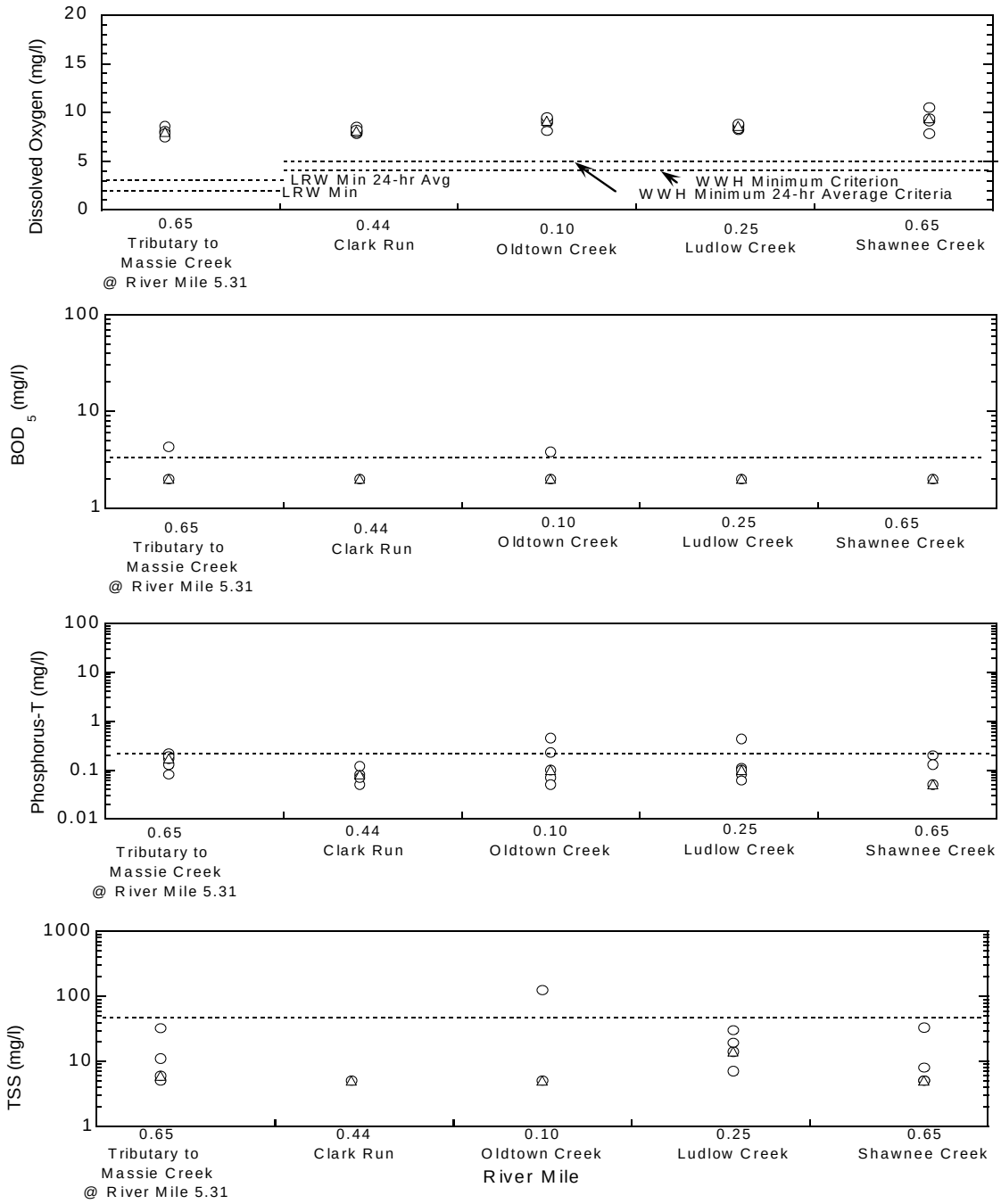



Figure 65. Scatter plots of water column chemistry results (daytime grabs) for an unnamed tributary to Massie Cr., Clark Run, Oldtown Cr., Ludlow Cr., and Shawnee Cr., 1998. From the top: dissolved oxygen, 5-day biochemical oxygen demand, total phosphorus, and total suspended solids (TSS). Triangles show the medians at each sampling location. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

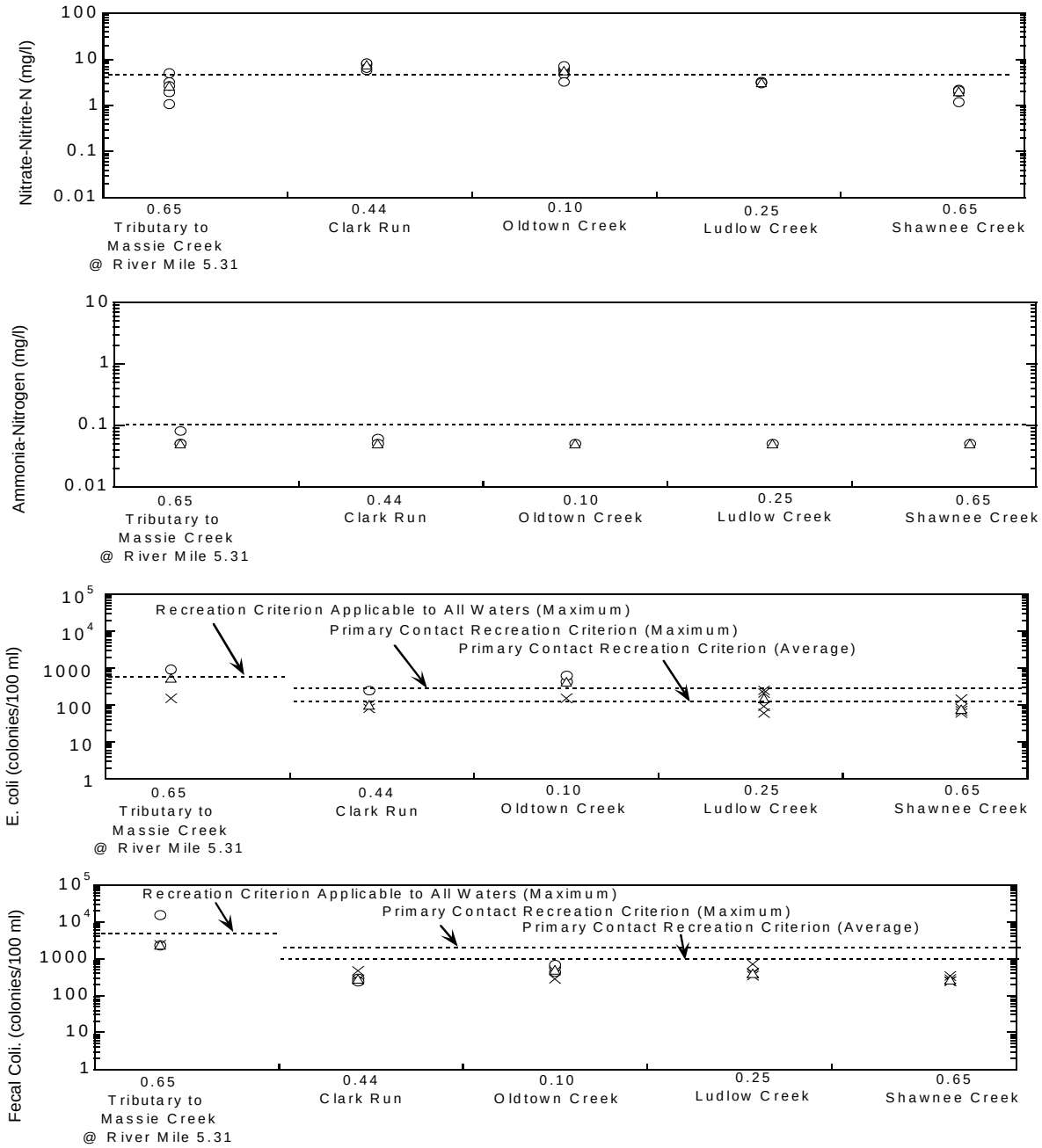



Figure 66. Scatter plots of water column chemistry results (daytime grabs) for an unnamed tributary to Massie Cr., Clark Run, Oldtown Cr., Ludlow Cr., and Shawnee Cr., 1998. From the top: nitrate-nitrite-nitrogen, ammonia-nitrogen, *Escherichia coli* colonies/100ml, and fecal coliform bacterial colonies/100ml. Triangles depict the median value at each river mile sampled. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

*Beaver Creek*

ammonia-N were less than applicable MDLs (2 mg/l and 0.05 mg/l, respectively) while all values of nitrate-nitrite-N and total phosphorus were less than applicable 90$^{th}$ percentile concentrations for headwater reference sites in the ECBP ecoregion (4.60 mg/l and 0.206 mg/l, respectively). Concentrations of TSS were generally low with the highest value (33 mg/l) recorded on July 23, a day of higher flows due to recent precipitation. While all fecal coliform values remained below Primary Contact Recreation criteria, *E. coli* concentrations exceeded the average Primary Contact Recreation criterion on one occasion (140 colonies/100 ml). With the exception of one exceedence of water quality criterion for iron (1660 µg/l), no other conventional parameters were elevated in this tributary. Organic water analyses detected heptachlor epoxide at the site and two exceedences of water quality criteria for Dieldrin (Table 9).

Beaver Creek, entering the Little Miami River at RM 72.74, receives the discharge from the Beaver Creek WWTP at RM 0.40. Water chemistry daytime grab samples were collected at five sites (RMS 6.30, 3.86, 1.57, 0.50 and 0.20) in this tributary during the 1998 survey (Figures 66 and 67).

All D.O. concentrations in this tributary remained above WWH minimum criteria. Values recorded in the upper reach (RMS 6.30 and 3.86) where the gradient is lower tended to be lower with median concentrations at both sites of 6.8 mg/l. Values increased at downstream sites with median concentrations ranging from 8.1 mg/l at RM 1.57 to 8.8 mg/l at RM 0.50. All concentrations of $BOD_5$ were less than or equal to the MDL of 2 mg/l. Concentrations of ammonia-N also remained low with the majority (75%) of concentrations less than or equal to the MDL (0.05 mg/l) and only two values minimally exceeding the 90$^{th}$ percentile concentrations for ECBP ecoregion reference sites. Minimal longitudinal variation was observed in concentrations of nitrate-nitrite-N at sites upstream of the Little Beaver Creek confluence at RM 1.12 (RMS 6.30, 3.86, and 1.57) with values in this reach ranging from 1.33 mg/l to 2.13 mg/l and an overall median for all concentrations of 1.72 mg/l. Downstream concentrations increased substantially at RM 0.50 (median and maximum values of 3.81 mg/l and 4.20 mg/l) and again downstream of the Beaver Creek WWTP at RM 0.20 (median and maximum values of 5.34 mg/l and 7.34 mg/l). The majority (67%) of total phosphorus concentrations exceeded the 90$^{th}$ percentile concentrations for ECBP ecoregion reference sites, with concentrations recorded upstream from Little Beaver Creek significantly lower than those obtained downstream from it (Figure 66) demonstrating that the phosphorus loads from the Montgomery County Eastern Regional WWTP are conserved and delivered to the Little Miami River mainstem. Additionally, concentrations of numerous parameters including potassium, sodium, chloride, sulfate, total dissolved solids, and conductivity increased significantly at RM 0.50, downstream of the Little Beaver Creek confluence, and remained elevated at RM 0.20.

TSS concentrations measured at RM 0.20 ranged from less than the MDL of 5 mg/l to 14 mg/l. Values recorded at sites upstream from Little Beaver were higher than those downstream with median values ranging from 14 mg/l at RM 1.57 to 18 mg/l at RM 3.86. Concentrations at all sites were highest during high flow (July 8 and July 22), except that the highest concentration (44 mg/l) recorded occurred at Fairgrounds Road (RM 3.86) on August 5 and was caused by installation of a water line crossing.

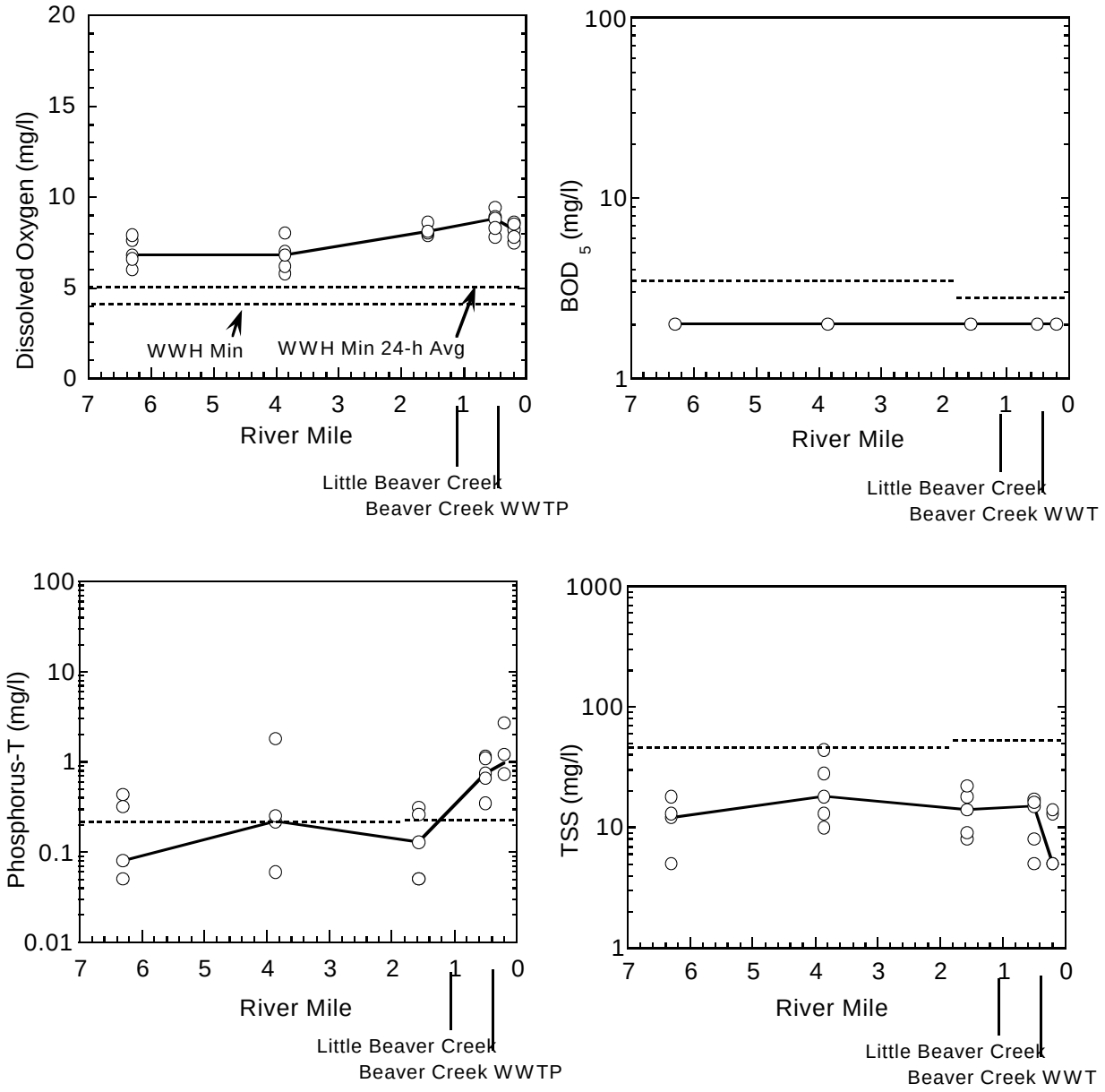



Figure 67. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Beaver Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots. Medians for each location are joined by a solid line.

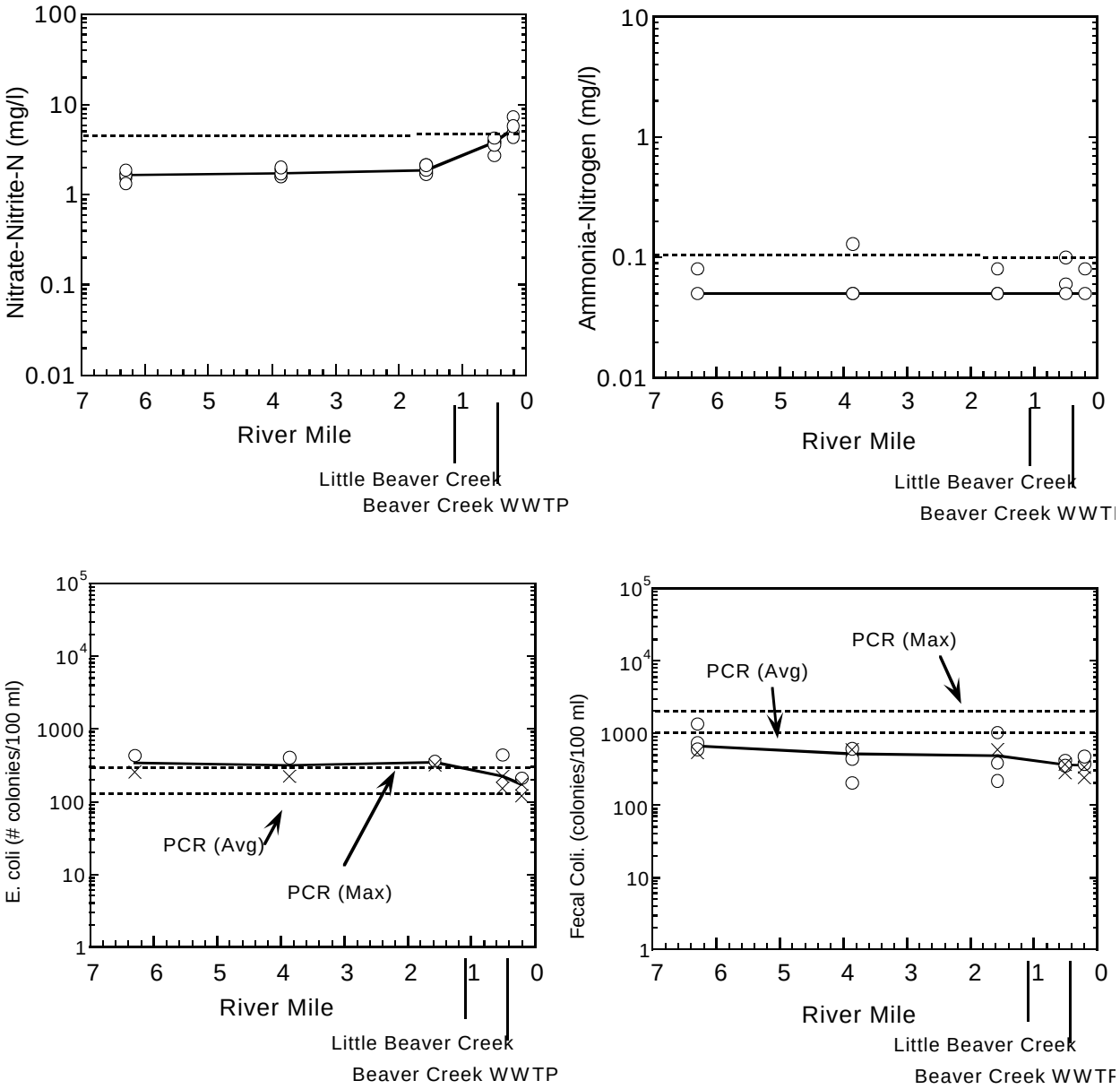



Figure 68. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Beaver Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacteria, and *Escherichia coli*. Medians at each location are joined by solid lines. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

Fecal coliform concentrations at RM 6.30 exceeded the average Primary Contact Recreation criterion on one occasion (1330 colonies/100 ml). Median values decreased longitudinally from RM 6.30 (661 colonies/100 ml) to RM 0.20 (353 colonies/100 ml). The majority (92%) of *E. coli* concentrations exceeded Primary Contact Recreation criteria with median values ranging from 170 colonies/100 ml at RM 0.20 to 340 colonies/100 ml at RM 1.57. One exceedence of water quality criterion for iron was recorded at RM 3.86 (2240 µg/l), and concentrations of manganese frequently exceeded water quality criterion at both RMS 6.30 and 3.86.

Water samples from RMS 1.57 and 0.20 were analyzed for organic compounds twice during the 1998 survey (Table 8). While no priority pollutants were detected at RM 1.57, various organochlorine pesticides were recorded downstream of the Beaver Creek WWTP at RM 0.20 including exceedences of water quality criteria for Dieldrin and gamma-hexachlorocyclohexane (Table 9).

*Little Beaver Creek*

Little Beaver Creek, flowing through the communities of Kettering and Beavercreek, receives the discharge from the Montgomery County Eastern Regional WWTP at RM 4.58 before entering Beaver Creek at RM 1.12. Water chemistry daytime grab samples were collected at six sites (RMS 6.23, 4.62, 4.40, 3.47, 1.95 and 0.05) in Little Beaver Creek during the 1998 survey (Figures 68 and 69). All D.O. concentrations remained above WWH minimum criteria, however values generally decreased longitudinally from RM 6.23 through RM 1.95 with median concentrations (and percent saturations) ranging from 8 mg/l (90%) at RM 6.23 to 6.7 mg/l (73%) at RM 1.95. This pattern was inversely related to the concentrations of $BOD_5$. $BOD_5$ values were elevated above the 90$^{th}$ percentile downstream from the Montgomery County Eastern Regional WWTP. (Additionally, chemical oxygen demand (COD) concentrations in this tributary were frequently elevated above the MDL of 10 mg/l with the highest value of the survey (113 mg/l) recorded at RM 4.62 on August 19.)

The majority (66%) of ammonia-N concentrations were greater than the MDL of 0.05 mg/l with an overall median of 0.12 mg/l calculated for all concentrations in this subbasin. While ammonia-N values were consistently elevated downstream of the Montgomery County Eastern Regional WWTP at RM 4.40 (median and maximum values of 0.37 mg/l and 0.84 mg/l) and RM 3.47 (median and maximum values of 0.18 mg/l and 0.74 mg/l), concentrations above the applicable 90$^{th}$ percentile concentrations for reference sites were frequently observed throughout the basin with the highest concentration (1.03 mg/l) recorded at RM 1.95 on September 2.

All nitrate-nitrite-N concentrations in samples collected upstream from the WWTP (RMS 6.23 and 4.62) remained below the 90$^{th}$ percentile ECBP reference range with an overall median of 0.8 mg/l. Concentrations increased sharply at RM 4.40, downstream from the Montgomery County Eastern Regional WWTP, and remained elevated longitudinally through RM 0.05 with values ranging from 2.48 mg/l to 8.07 mg/l and an overall median for all concentrations in this lower reach of 5.96 mg/l.

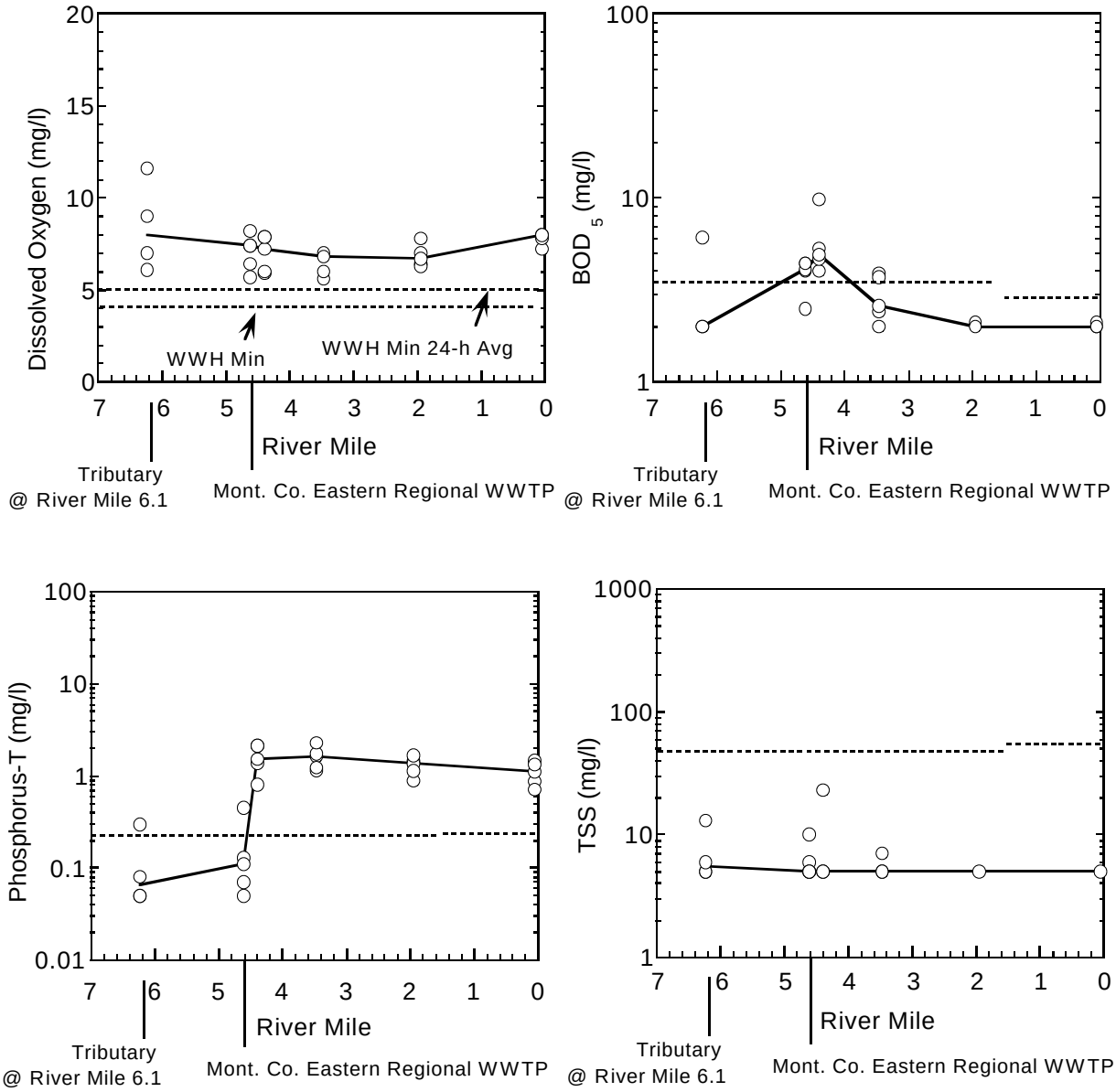



Figure 69. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Little Beaver Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

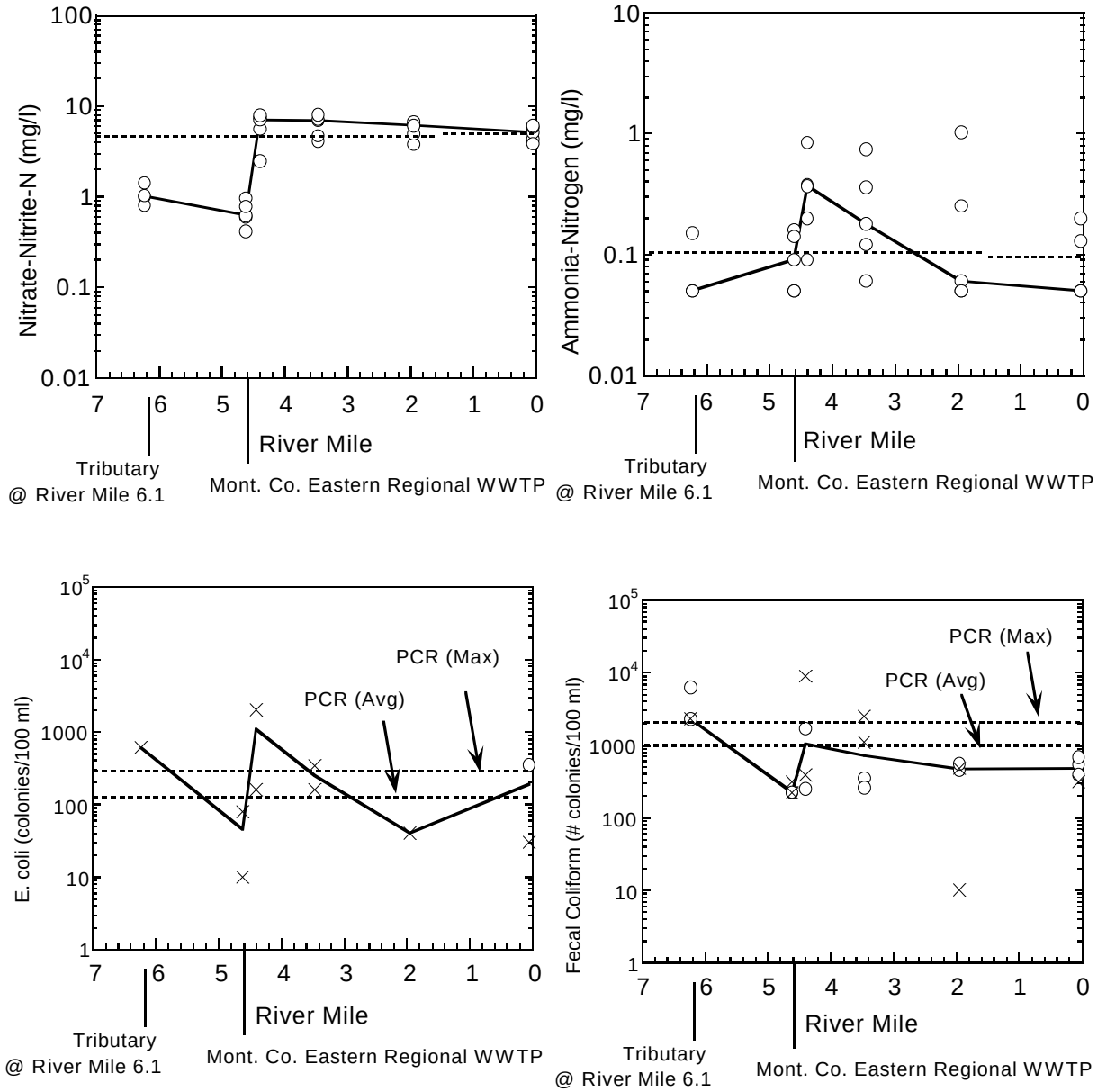



Figure 70. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Little Beaver Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacteria, and *Escherichia coli*. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

Concentrations of total phosphorus followed a similar pattern with an overall median of 0.08 mg/l for upper sites (RMS 6.23 and 4.62) before increasing sharply downstream from the WWTP, and remaining elevated through RM 0.05 with values ranging from 0.71 mg/l to 2.28 mg/l and an overall median of 1.37 mg/l. Additionally, concentrations of numerous parameters including potassium, sodium, chloride, sulfate, zinc, total dissolved solids, and conductivity increased significantly at RM 4.40 and remained at these higher levels through RM 0.05 and into Beaver Creek. While Little Beaver Creek is impacted by non-point runoff, the overwhelming impact on this small headwater tributary results from the Montgomery County Eastern Regional WWTP discharge as evidenced by the sustained levels of nutrients and other compounds found downstream of the facility.

Concentrations of TSS were low with the majority (79%) of values less than or equal to the MDL of 5 mg/l and the highest concentrations generally coinciding with higher flow days. Although the majority (70%) of fecal coliform concentrations were below Primary Contact Recreation criteria, numerous exceedences of criteria were recorded at RMS 6.23, 4.40, and 3.47. Concentrations of *E. coli* exceeded Primary Contact Recreation criteria at RMS 6.23, 4.40, 3.47, and 0.05. Bacteriological results reflect the combined impact of point source and non-point runoff.

Water samples from RMS 4.62, 4.40, and 0.05 were analyzed for organic compounds twice during the 1998 survey (Table 8), revealing various organochlorine pesticides at all three sites including exceedences of water quality criteria for endosulfan I (RM 4.62), Dieldrin (RMS 4.40 and 0.05), endrin (RM 4.40), and gamma-hexachlorocyclohexane (RMS 4.40 and 0.05). Low concentrations of chloroform and bis(2-ethylhexyl)phthalate were also detected at RM 4.40.

*Tributary to Little Beaver Creek @ RM 6.1*

This tributary receives non-contact cooling water from General Motors Delphi Chassis Systems before entering the Little Beaver Creek at RM 6.1. Water chemistry daytime grab samples were collected at one site (RM 0.15) approximately 0.5 miles downstream of the General Motors facility during the 1998 survey . All D.O. concentrations measured at the site were above WWH minimum criteria with values ranging from 6.0 mg/l to 8.4 mg/l. Four of five $cBOD_5$ concentrations recorded were less than the MDL of 2 mg/l, the other (4.4 mg/l) minimally exceeded the $90^{th}$ percentile concentration (3.4 mg/l) for ECBP headwater reference sites. Ammonia-N concentrations were low with the majority (80%) of values less than or equal to the MDL (0.05 mg/l). Nitrate-nitrite-N values ranged from 0.73 mg/l to 1.14 mg/l. With the exception of concentrations measured on August 19 (0.64 mg/l) and September 2 (0.19 mg/l), total phosphorus values at the site were less than the MDL (0.05 mg/l). All TSS concentrations were less than or equal to the MDL of 5 mg/l. Fecal coliform concentrations exceeded the maximum secondary contact recreation criterion on one occasion (9670 colonies/100 ml), bacteriological sampling revealed consistently elevated concentrations of fecal coliform (median of 3350 colonies/100 ml) and *E. coli* (median of 510 colonies/100 ml) at the site reflecting the impact of non-point source runoff. No other elevated parameters were observed in this tributary.

*Sugar Creek*

Sugar Creek enters the Little Miami River at RM 65.61, approximately 1.20 miles upstream of the Sugar Creek WWTP discharge to the mainstem. Daytime grab water chemistry samples were collected at two sites (RMS 2.13 and 0.40) in this tributary (Figures 70 and 71). All D.O. concentrations remained above WWH minimum criteria with median concentrations and percent saturations at both sites approaching 7.0 mg/l and 80%, respectively. All $BOD_5$ concentrations were less than the 90$^{th}$ percentile concentration (2.90 mg/l) for wadeable reference sites in the ECBP ecoregion. While all ammonia-N concentrations measured at RM 0.40 were less than the MDL of 0.05 mg/l, respective median and maximum values of 0.06 mg/l and 0.12 mg/l were recorded at RM 2.13. Higher concentrations of both nitrate-nitrite-N and total phosphorus were typically measured at RM 0.40, downstream of the Little Sugar Creek confluence. Concentrations of nitrate-nitrite-N, while remaining low, increased longitudinally from RM 2.13 (median and maximum values of 0.22 mg/l and 0.71 mg/l) to RM 0.40 (median and maximum values of 0.49 mg/l and 1.03 mg/l). While total phosphorus concentrations followed a similar pattern with medians increasing from 0.16 mg/l at RM 2.13 to 0.25 mg/l downstream at RM 0.40, concentrations above the 90$^{th}$ percentile concentration (0.220 mg/l) for wadeable reference sites were documented at both sites. Concentrations of total suspended solids remained low with the majority (80%) of values equal to or less than the MDL (5 mg/l). While median fecal coliform concentrations increased longitudinally from RM 2.13 (320 colonies/100 ml) to RM 0.40 (455 colonies/100 ml) with all values recorded below Primary Contact Recreation criteria, all concentrations of *E. coli* exceeded Primary Contact Recreation criteria with median values decreasing longitudinally from RM 2.13 (230 colonies/100 ml) to RM 0.40 (180 colonies/100 ml). With the exception of one exceedence of water quality criterion for manganese (103 µg/l at RM 0.40), no other elevated conventional parameters were noted in Sugar Creek. Water samples from RM 0.40 analyzed for organic compounds revealed various organochlorine pesticides and exceedences of water quality criteria for Dieldrin and heptachlor (Tables 7 and 8).

*Little Sugar Creek*

Little Sugar Creek enters Sugar Creek at RM 1.55. Results of water chemistry daytime grab sampling at RM 0.45 of this tributary during the 1998 survey generally indicate good water quality (Figures 70 and 71). Dissolved oxygen measurements ranged from 8.2 mg/l to 11.0 mg/l with a median percent saturation of 102%. All $BOD_5$, ammonia-N, and TSS concentrations were less than applicable MDLs. Concentrations of nitrate-nitrite-N also remained low throughout the survey with values ranging from 0.60 mg/l to 1.25 mg/l. While three of five concentrations of total phosphorus measured at the site were less than the MDL of 0.05 mg/l, one value (0.30 mg/l on August 19) exceeded the 90$^{th}$ percentile concentration (0.206 mg/l) for headwater reference sites in the ECBP ecoregion. Reflecting the impact of non-point runoff, fecal coliform concentrations exceeded the average Primary Contact Recreation criterion on one occasion (1200 colonies/100 ml) while two *E. coli* values (270 colonies/100 ml and 750 colonies/100 ml) exceeded criteria. No other elevated parameters were recorded in Little Sugar Creek.

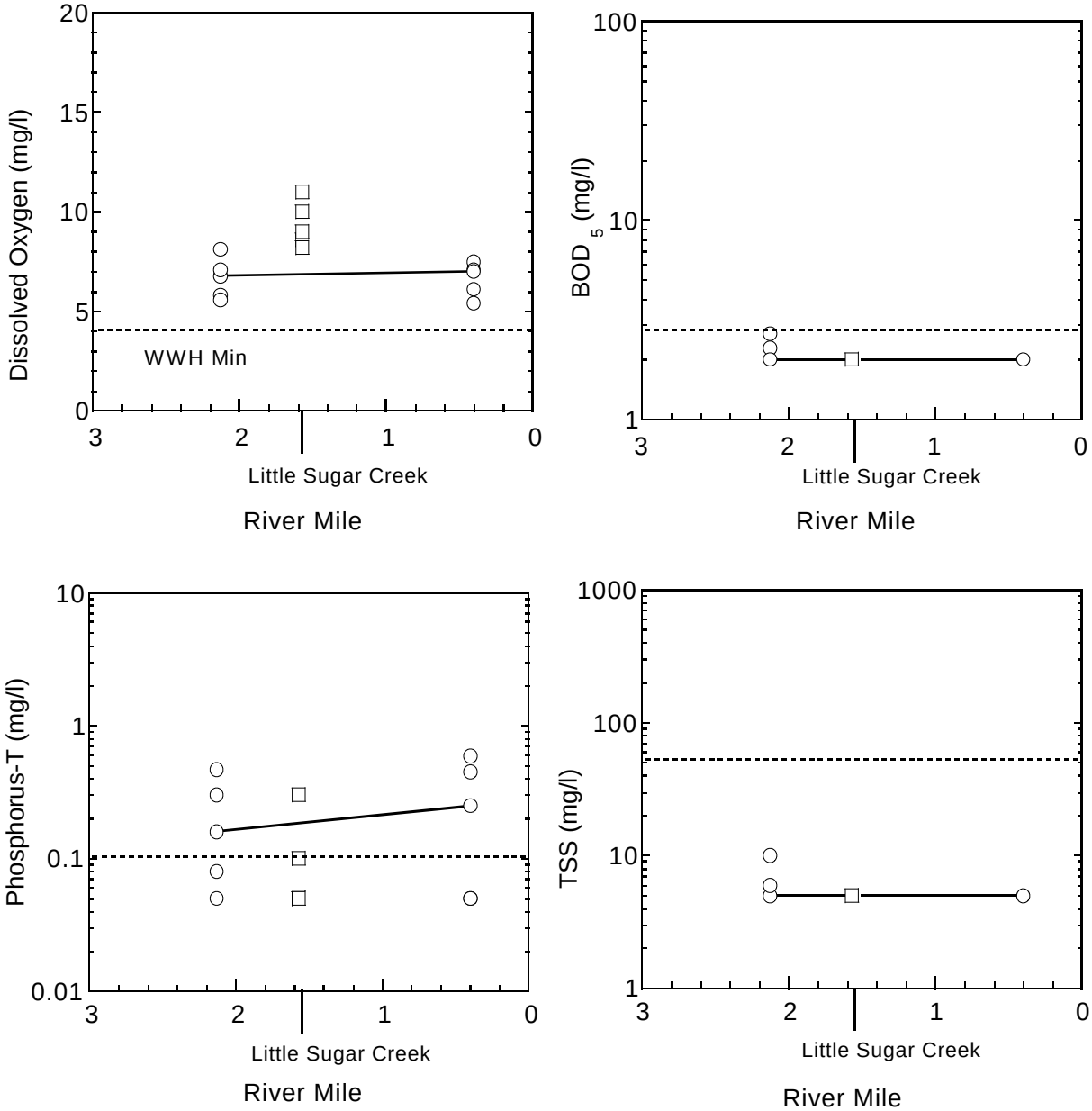



Figure 71. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Sugar Creek and Little Sugar Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, and total phosphorus. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from wadable reference sites in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots.

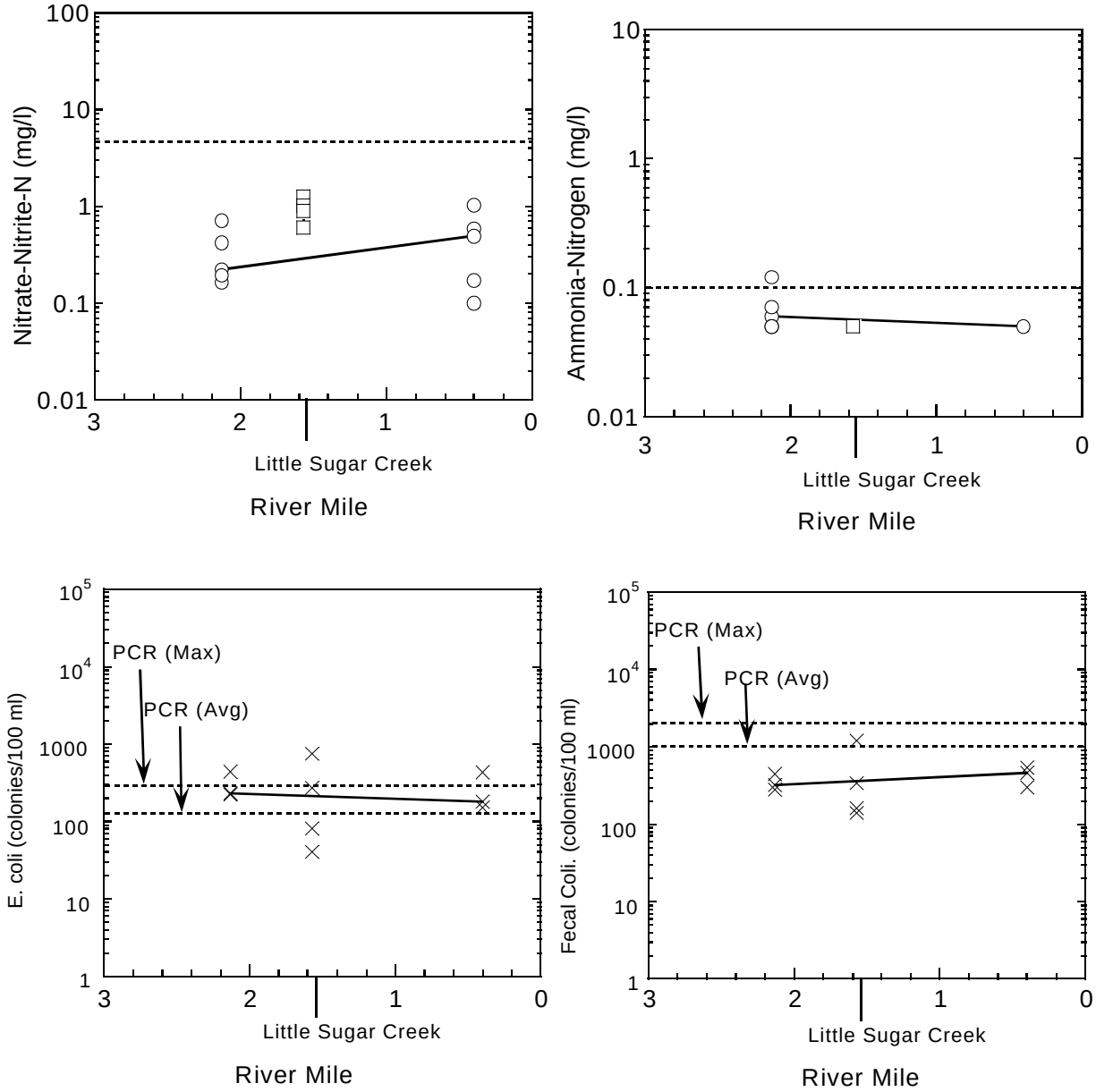



Figure 72. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Sugar Creek and Little Sugar Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

*Tributary to Little Miami River @ RM 69.85*

Water chemistry daytime grab samples were collected at RM 0.10 in this tributary of the Little Miami River (Figures 72 and 73). Given that this stream did not have an aquatic life use designation during the 1998 survey, water quality criteria identified for the limited resource water (LRW) use designation apply (OAC rule 3745-1-07). All D.O. concentrations measured were well above LRW (as well as WWH) minimum criteria with values ranging from 6.2 mg/l to 11.3 mg/l. Concentrations of $BOD_5$ and ammonia-N were less than applicable MDLs. Nitrate-nitrite-N and total phosphorus concentrations also remained low with median values of 0.67 mg/l and 0.05 mg/l, respectively. The majority of TSS concentrations (four of five) were less than the MDL of 5 mg/l. Concentrations of fecal coliform ranged from 10 to 2200 colonies/100 ml with a median of 70 colonies/100 ml while *E. coli* concentrations recorded at the site ranged from less than the MDL (10 colonies/100 ml) to 80 colonies/100 ml. No other elevated parameters were observed in this tributary.

*Tributary to Little Miami River @ RM 62.01*

Water chemistry daytime grab samples were collected at RM 0.55 of this tributary (Figures 72 and 73). Water quality criteria identified for the limited resource water (LRW) use designation apply (OAC rule 3745-1-07) given that this stream did not have an aquatic life use designation during the 1998 survey. Dissolved oxygen concentrations, well above LRW (as well as WWH) minimum criteria, ranged from 7.3 mg/l to 9.3 mg/l with a median percent saturation of 87%. All $BOD_5$ and ammonia-N concentrations recorded were less than applicable MDLs (2 mg/l and 0.05 mg/l, respectively). Nitrate-nitrite-N values at the site varied only from 1.12 mg/l to 1.94 mg/l. Total phosphorus concentrations ranged from less than the MDL (0.05 mg/l) to 0.24 mg/l with a median of 0.09 mg/l. Total suspended solids concentrations were typically low (median of 6 mg/l), with higher values observed on September 1 (30 mg/l) and August 18 (18 mg/l). (Field notes indicate that sediment may have inadvertently been introduced into the sample thus somewhat compromising TSS results on these two dates.) Bacteriological sampling revealed concentrations of fecal coliform ranging from 420 to 2400 colonies/100 ml and *E. coli* values ranging from 150 to 440 colonies/100 ml at the site. No other elevated parameters were observed in this tributary.

*Tributary to Little Miami River @ RM 60.50*

Water chemistry daytime grab samples were collected at one site (RM 0.20) in this tributary during the 1998 survey (Figures 72 and 73). Given that this tributary did not have an aquatic life use designation during the 1998 survey, water quality criteria identified for the limited resource water (LRW) use designation apply (OAC rule 3745-1-07). All D.O. concentrations were above LRW (as well as WWH) minimum criteria with values ranging from 5.7 mg/l to 8.2 mg/l and corresponding percent saturations ranging from 62% to 96%. All $BOD_5$ and ammonia-N concentrations recorded were less than applicable MDLs. Nitrate-nitrite-N values remained below the ECBP ecoregion headwater reference site $90^{th}$ percentile concentration (4.60 mg/l) with values ranging from 3.03 mg/l to 4.50 mg/l.

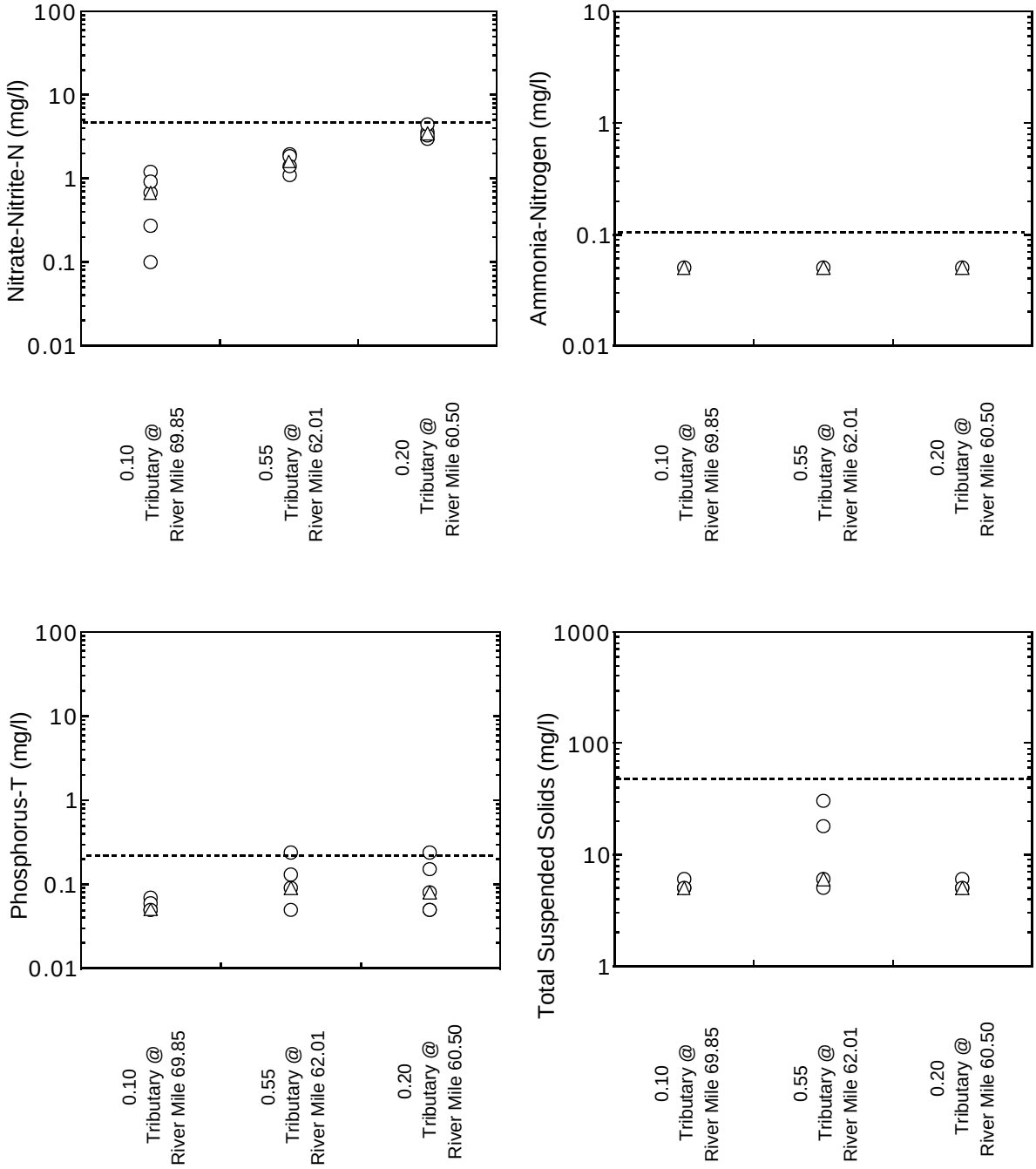



Figure 73. Scatter plots of water column chemistry results (daytime grabs) from three unnamed tributaries to the Little Miami River, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, total suspended solids, and total phosphorus. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. Medians for each location are shown as triangles.

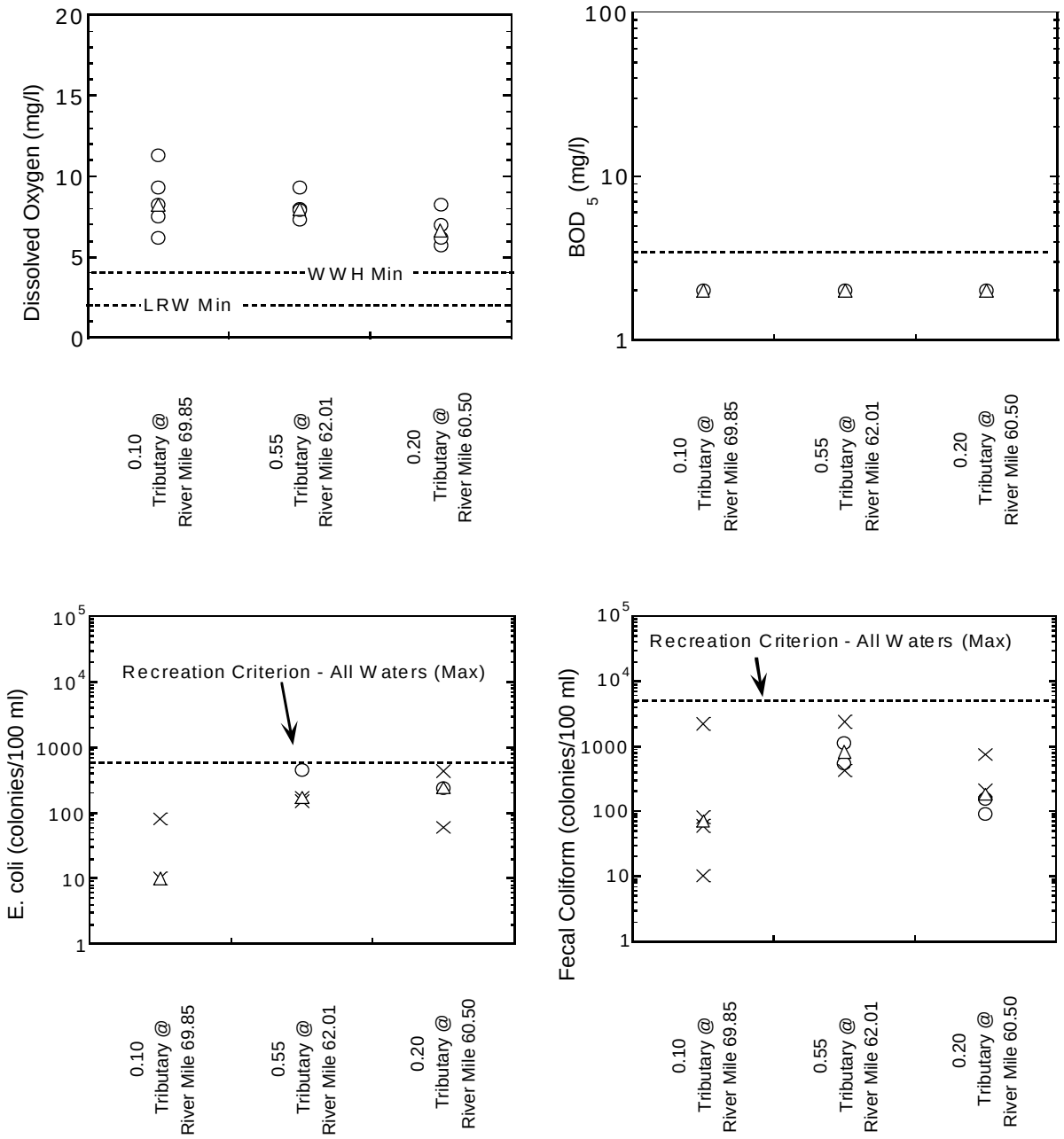



Figure 74. Scatter plots of water column chemistry results (daytime grabs) from three unnamed tributaries to the Little Miami River, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, fecal coliform bacteria, and *Escherichia coli*. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and Recreation Contact Water Quality Standards (all waters) are shown for the bacteria plots. The 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion is shown for the $BOD_5$ plot. Medians for each location are shown as triangles

Concentrations of total phosphorus ranged from less than the MDL of 0.05 mg/l to 0.24 mg/l with a median of 0.08 mg/l. Total suspended solids concentrations remained low with four of five values less than or equal to the MDL of 5 mg/l. While fecal coliform concentrations ranged from 91 to 745 colonies/100 ml, *E. coli* values ranged from 60 to 430 colonies/100 ml. No other elevated parameters were observed in this tributary.

*Glady Run*

Glady Run receives the discharge from the Xenia Glady Run WWTP at RM 4.93 before entering the Little Miami River at RM 63.72 near the community of Spring Valley. Water chemistry daytime grab samples were collected at three sites (RMS 4.99, 4.08, and 2.08) in this tributary during the 1998 survey (Figures 74 and 75). Dissolved oxygen values, relatively stable longitudinally, remained above WWH minimum criteria with median concentrations (and percent saturations) ranging from 7.5 mg/l (85%) at RM 4.08 to 8.6 mg/l (92%) at RM 2.08. Concentrations of $BOD_5$ remained low with all values less than the MDL of 2 mg/l at RMS 4.99 and 2.08 and only one value (3.8 mg/l) at RM 4.08 exceeding the ECBP 90$^{th}$ percentile concentration (3.4 mg/l) for headwater reference sites. While the majority (80%) of ammonia-N concentrations were less than or equal to the ECBP headwater reference site 90$^{th}$ percentile concentration (0.1 mg/l), values exceeded WWH water quality criterion downstream of the Xenia Glady Run WWTP on September 2 at RM 4.08 (0.81 mg/l) and RM 2.08 (1.20 mg/l). (Per the entity's monthly operating report, while ammonia-N was not analyzed on September 2, the final effluent concentration (2.78 mg/l) on September 1 was elevated.)

While nitrate-nitrite-N concentrations at RM 4.99 remained low (median of 1.70 mg/l), median concentrations increased downstream of the Xenia Glady Run WWTP at RM 4.08 (8.91 mg/l), and remained elevated at RM 2.08 (6.74 mg/l). Similarly, while the majority (87%) of total phosphorus concentrations recorded in Glady Run exceeded the 90$^{th}$ percentile concentration (0.206 mg/l) for ECBP headwater reference sites, significantly higher values were measured at sites downstream of the Xenia Glady Run WWTP with median values increasing longitudinally from RM 4.99 (0.23 mg/l) to RM 4.08 (1.10 mg/l) and remaining elevated at RM 2.08 (0.94 mg/l).

Concentrations of TSS remained low (generally less than 9 mg/l) with the highest concentration recorded (15 mg/l at RM 2.08) coinciding with a day of higher flows. All fecal coliform and *E. coli* concentrations were below Secondary Contact Recreation criteria. Median fecal coliform concentrations increased longitudinally from 270 colonies/100 ml at RM 4.99 to 540 colonies/100 ml at RM 2.08 while *E. coli* medians decreased longitudinally from 220 colonies/100 ml at RM 4.99 to 120 colonies/100 ml at RM 2.08.

Water samples from RM 4.08, analyzed for organic compounds twice during the 1998 survey (Table 8), revealed various organochlorine pesticides at the site including exceedences of water quality criteria for Dieldrin, endrin, and gamma-hexachlorocyclohexane (Table 9).

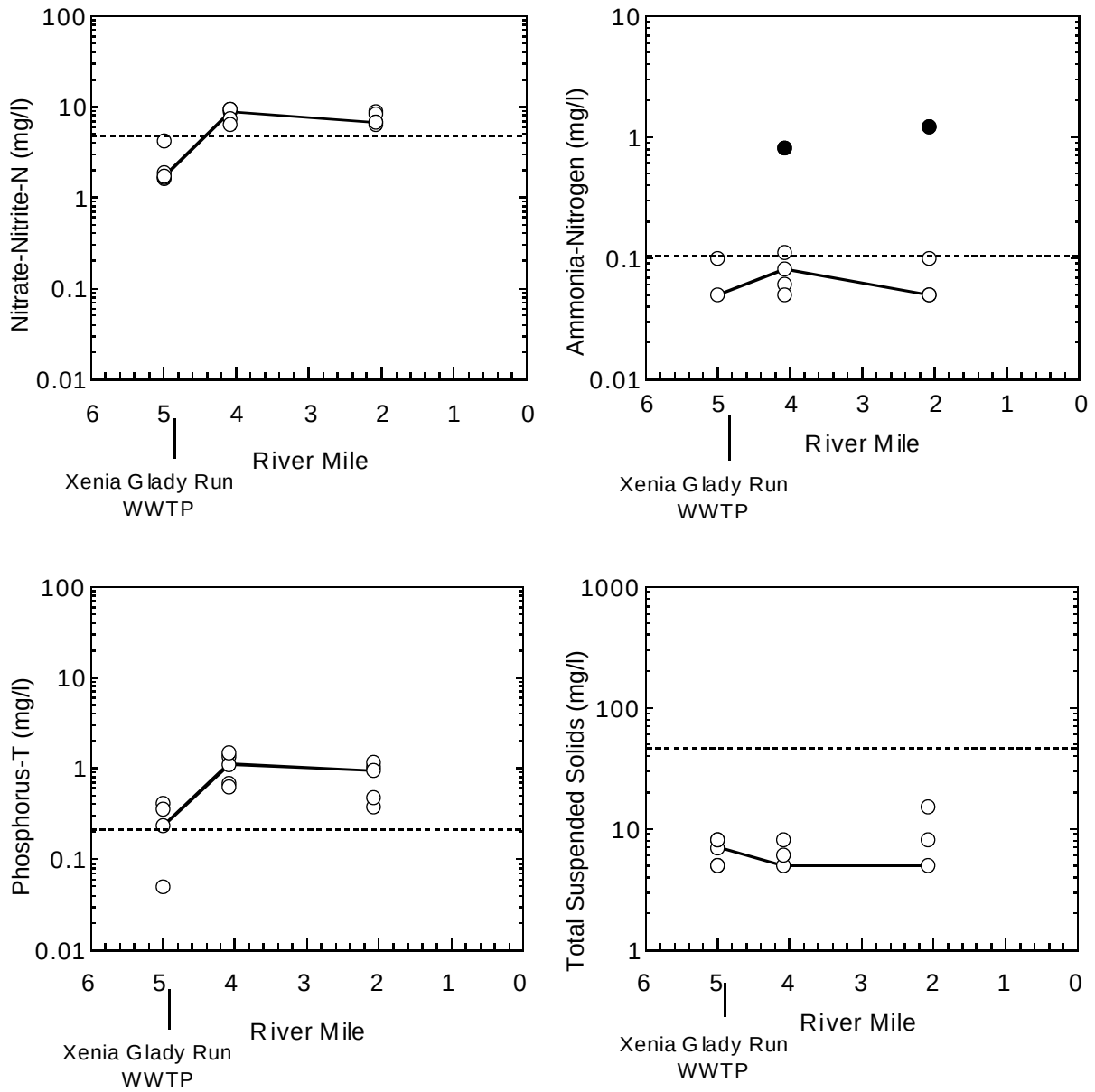



Figure 75. Longitudinal scatter plots of water column chemistry results (daytime grabs) from Glady Run, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, total suspended solids, and total phosphorus. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. Exceedences of Water Quality Standards for ammonia-nitrogen concentrations are shown as solid circles. Median for each location are joined by solid lines.

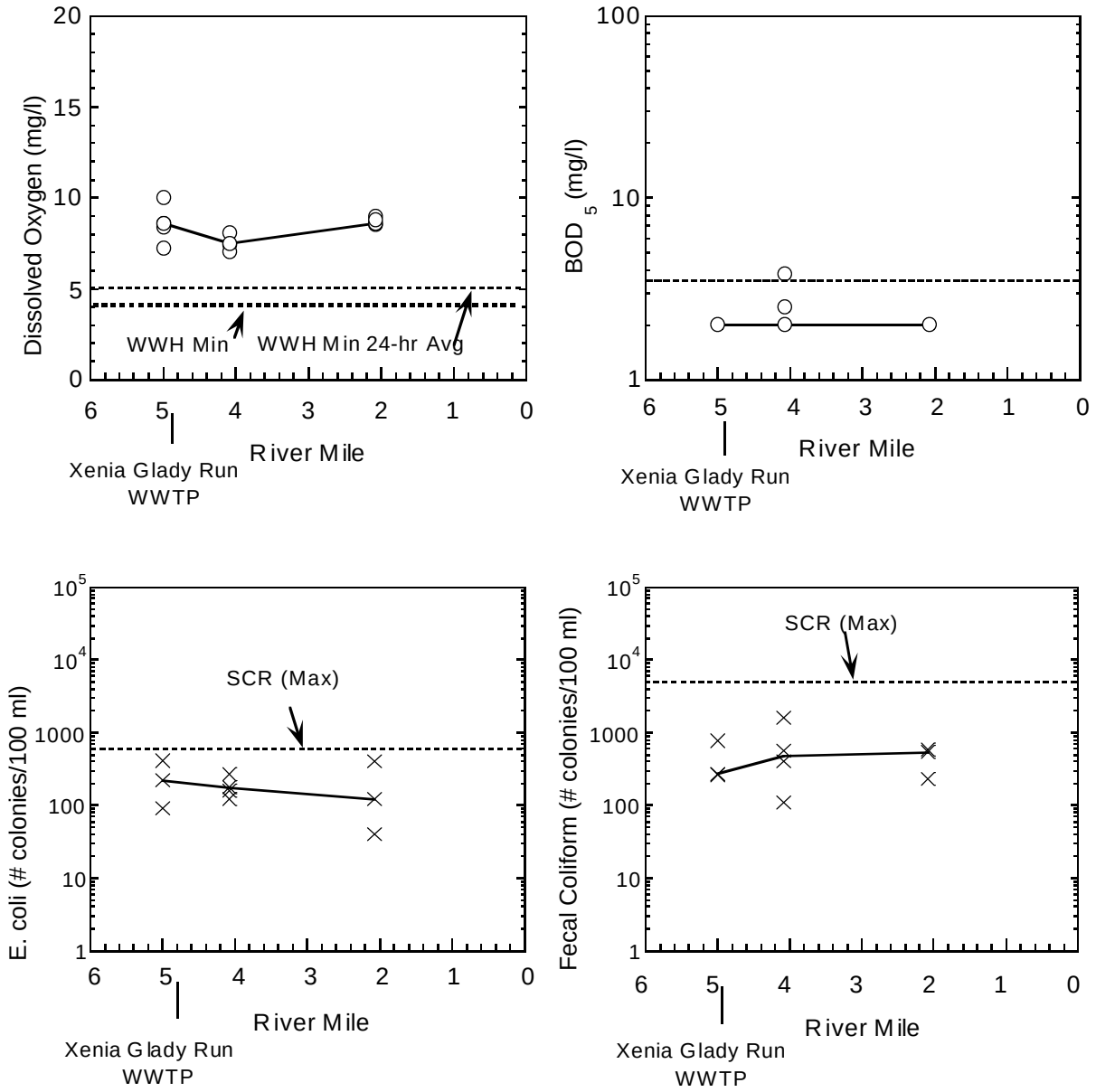



Figure 76. Longitudinal scatter plots of water column chemistry results (daytime grabs) from Glady Run, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, fecal coliform bacteria, and *Escherichia coli*. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and Secondary Contact Water Quality Standards (SRC) are shown for the bacteria plots. The 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion is shown for the $BOD_5$ plot. Medians for each location are joined by a solid line.

*Mill Run*

Mill Run joins the Little Miami River upstream of Waynesville at RM 55.44. Daytime grab water chemistry samples were collected at RM 1.74 during the 1998 survey. Given that flows in this tributary continuously diminished as the summer progressed, samples could not be collected at the site during the last week of the survey. Consequently, D.O. concentrations were low compared to other tributaries, but remained above Water Quality Standards. All $BOD_5$ and ammonia-N concentrations were less than the respective MDLs of 2 mg/l and 0.05 mg/l. Nitrate-nitrite-N concentrations ranged from less than the MDL of 0.10 mg/l to 1.52 mg/l, and total phosphorus values ranged from less than the MDL of 0.05 mg/l to 0.19 mg/l. The majority (75%) of TSS concentrations measured at the site were less than the MDL of 5 mg/l while all concentrations of fecal coliform and *E. coli* remained below Primary Contact Recreation criteria. With the exception of one exceedence of water quality criterion for manganese (174 µg/l), no other elevated parameters were observed in this tributary.

*Newman Run*

Newman Run enters the Little Miami River at RM 53.12, approximately 0.7 miles downstream of the Waynesville WWTP discharge to the mainstem. Flows gradually diminished such that no samples could be collected during the last week of the survey. Results of four water chemistry daytime grab samples collected at RM 0.27 indicate relatively good water quality. Dissolved oxygen concentrations ranged from 6.7 mg/l to 7.8 mg/l with a median percent saturation of 86%. All $BOD_5$ and ammonia-N concentrations recorded were less than applicable MDLs. Concentrations of nitrate-nitrite-N ranged from 1.00 mg/l to 2.86 mg/l, and total phosphorus concentrations ranged from 0.06 mg/l to 0.29 mg/l with a median value of 0.17 mg/l. Only one TSS concentration exceeded the MDL of 5 mg/l. Concentrations of *E. coli* exceeded the Primary Contact Recreation criteria at the site while all fecal coliform concentrations remained below Primary Contact Recreation criteria. No other elevated parameters were recorded at the site.

*Caesar Creek*

Caesar Creek enters the Little Miami River at RM 50.92. (During the 1998 survey the EWH aquatic life use designation and water quality criteria applied from the headwaters of this stream to the confluence with Anderson Fork (RM 13.92) while the WWH aquatic life use designation applied from RM 13.92 to the mouth.) Hourly dissolved oxygen (concentration and percent saturation), temperature, pH and conductivity were measured by Datasonde continuous monitors at two sites (RMS 16.52 and 2.70) from August 25-27 (Figure 77). Dissolved oxygen concentrations upstream of Caesar Creek Lake at RM 16.52 ranged from 4.27 mg/l to 7.98 mg/l with numerous values (13 of 48 measurements) dropping below the EWH minimum criterion of 5.0 mg/l. While above WWH minimum criteria, concentrations measured downstream of the lake at RM 2.70 were also low, ranging from 5.36 mg/l to 6.82 mg/l with a median value of 5.65 mg/l. Percent saturations at RM 16.52 ranged from 49% to 99% while values downstream at RM 2.70 varied only from 67% to 88%. (Water released from the bottom of the reservoir by the Army Corps of Engineers to augment natural downstream low-flow conditions is typically lower

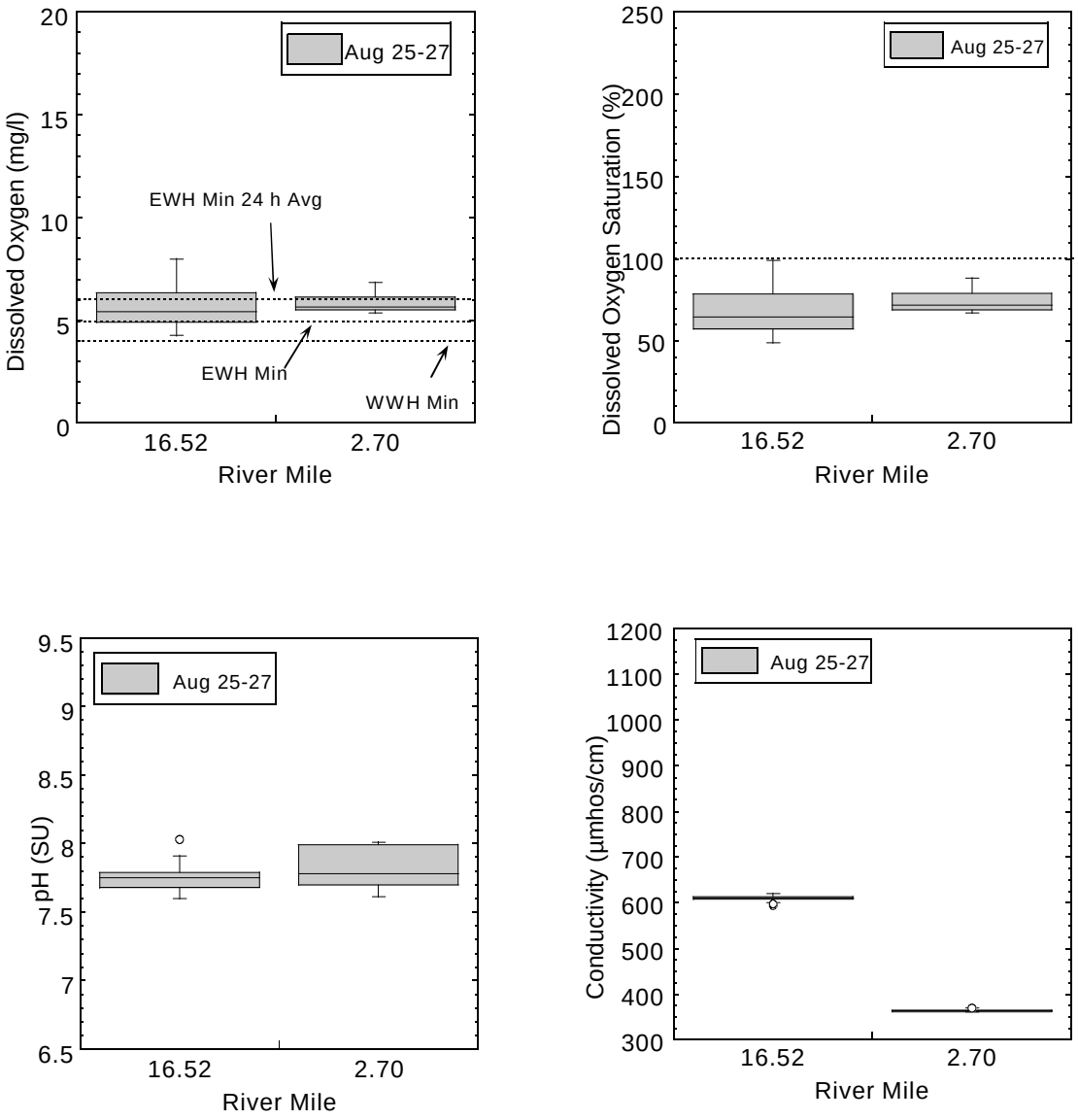



Figure 77. Clockwise from top left: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, conductivity, and pH recorded hourly over a 48 h period in Caesar Creek, 1998. Dates of observations are shown in the figure legends. Water Quality Standards criteria are shown as dashed horizontal lines in the dissolved oxygen plot.

in oxygen and may account for the lower values recorded at RM 2.70 while lower values at RM 16.52 may be attributable to the lower flows observed at this site later in the summer.) Temperatures at RM 2.70 were generally higher with respective median and maximum values of 25.67°C and 27.23°C compared to corresponding values of 22.68°C and 25.15°C recorded upstream at RM 16.52. While pH values remained stable with values at both sites ranging from 7.6 SU to 8.0 SU and medians approaching 7.7 SU, a significant longitudinal decrease in conductivities was observed with median values dropping from 611 $\mu$mhos/cm (RM 16.52) to 364 $\mu$mhos/cm (RM 2.70).

Water chemistry daytime grab samples (Figures 78 and 79) were collected upstream of Caesar Creek Lake at three sites (RMS 26.50, 23.10, and 16.52) and downstream of the lake near the mouth (RM 0.15). Concentrations of dissolved oxygen measured at the two uppermost sites remained above EWH minimum criteria with median concentrations (and percent saturations) increasing longitudinally from 7.2 mg/l (85%) at RM 26.50 to 8.8 mg/l (106%) downstream of South Branch Caesar Creek at RM 23.10. Similar to Datasonde results, values decreased downstream at RM 16.52 (median concentration and percent saturation of 7.3 mg/l and 76%, respectively) with one concentration (5.6 mg/l on September 1) dropping below the EWH minimum 24-hour average criterion of 6.0 mg/l. Median D.O. concentrations and percent saturations measured near the mouth at RM 0.15 increased to 9.1 mg/l and 92%. The majority of $BOD_5$ (90%) and ammonia-N (84%) concentrations recorded were less than or equal to applicable MDLs (2 mg/l and 0.05 mg/l, respectively) with all values for both parameters below applicable 90$^{th}$ percentile reference site concentrations.

Median values of 2.62 mg/l and 0.11 mg/l, respectively, were calculated for all concentrations of nitrate-nitrite-N and total phosphorus measured in Caesar Creek. Respective median and maximum concentrations of nitrate-nitrite-N increased from 1.33 mg/l and 3.63 mg/l at RM 26.50 to 2.62 mg/l and 6.47 mg/l at RM 23.10, downstream of South Branch Caesar Creek. Subsequent downstream nitrate-nitrite-N measurements remained relatively stable with medians of 2.34 mg/l and 3.25 mg/l recorded at RMS 16.52 and 0.15, respectively. Following a similar pattern, concentrations of total phosphorus increased from RM 26.50 (median and maximum values of 0.09 mg/l and 0.50 mg/l) to RM 23.10 (median and maximum values of 0.28 mg/l and 0.68 mg/l), downstream of the South Branch Caesar Creek confluence and remained at these higher levels at RM 16.52 (median and maximum values of 0.23 mg/l and 0.77 mg/l). While several total phosphorus concentrations at sites upstream of Caesar Creek Lake exceeded the 90$^{th}$ percentile concentration (0.22 mg/l) for wadeable reference sites, lower values were recorded at RM 0.15 with values ranging from less than the MDL of 0.05 mg/l to 0.10 mg/l. Higher nutrient levels in the upper reaches may be attributed to the additional cumulative nutrient load from both the North Branch Caesar Creek and South Branch Caesar Creek as well as general non-point runoff.

Concentrations of total suspended solids were low at RM 0.15 as most values were less than or equal to the MDL of 5 mg/l. Concentrations were frequently elevated at sites upstream of Caesar

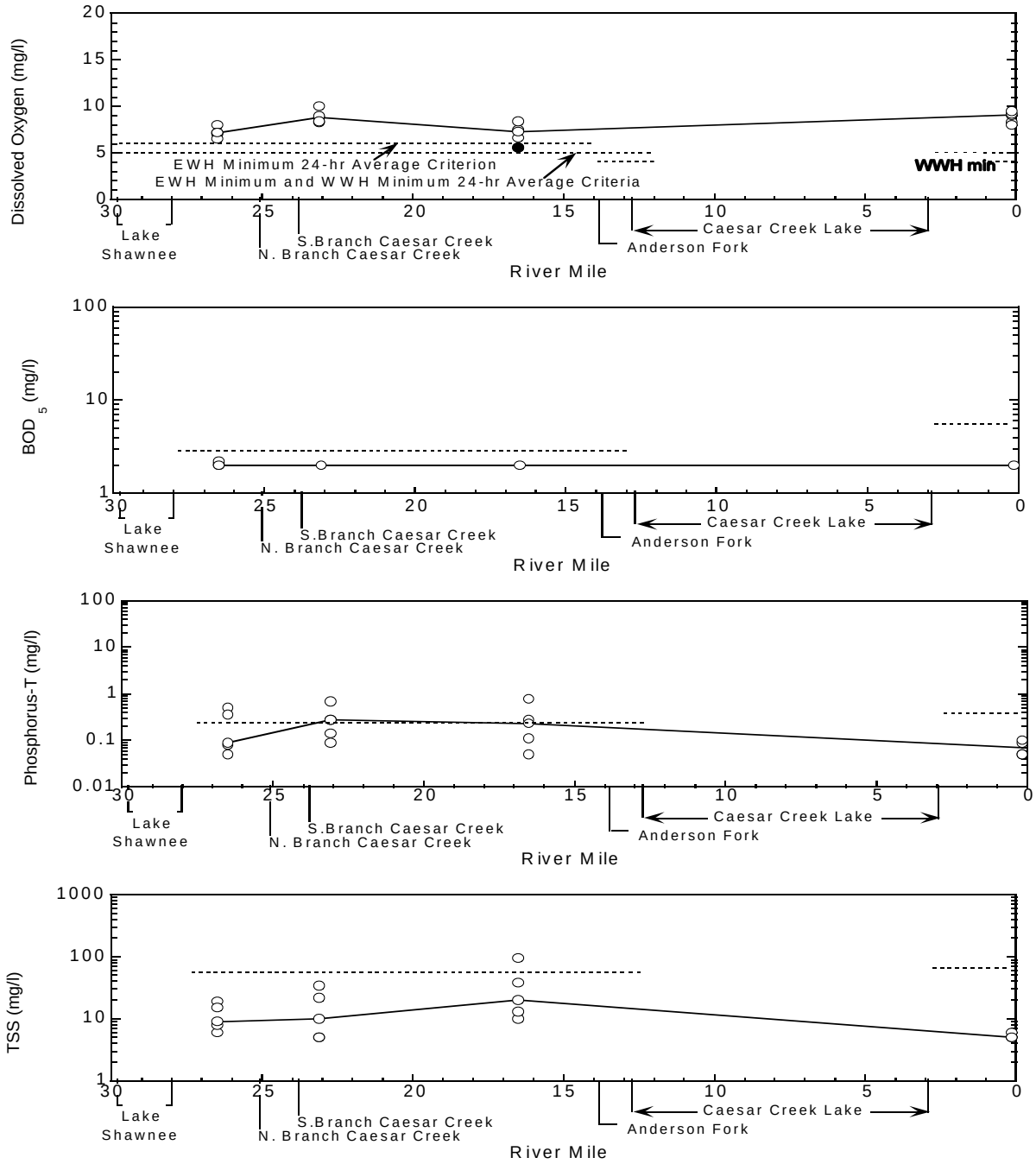



Figure 78. Longitudinal scatter plots of water column chemistry results (daytime grabs) for Caesar Creek., 1998. From the top: dissolved oxygen, 5-day biochemical oxygen demand, total phosphorus, and total suspended solids (TSS). Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots. Medians for each location are joined by a solid line.

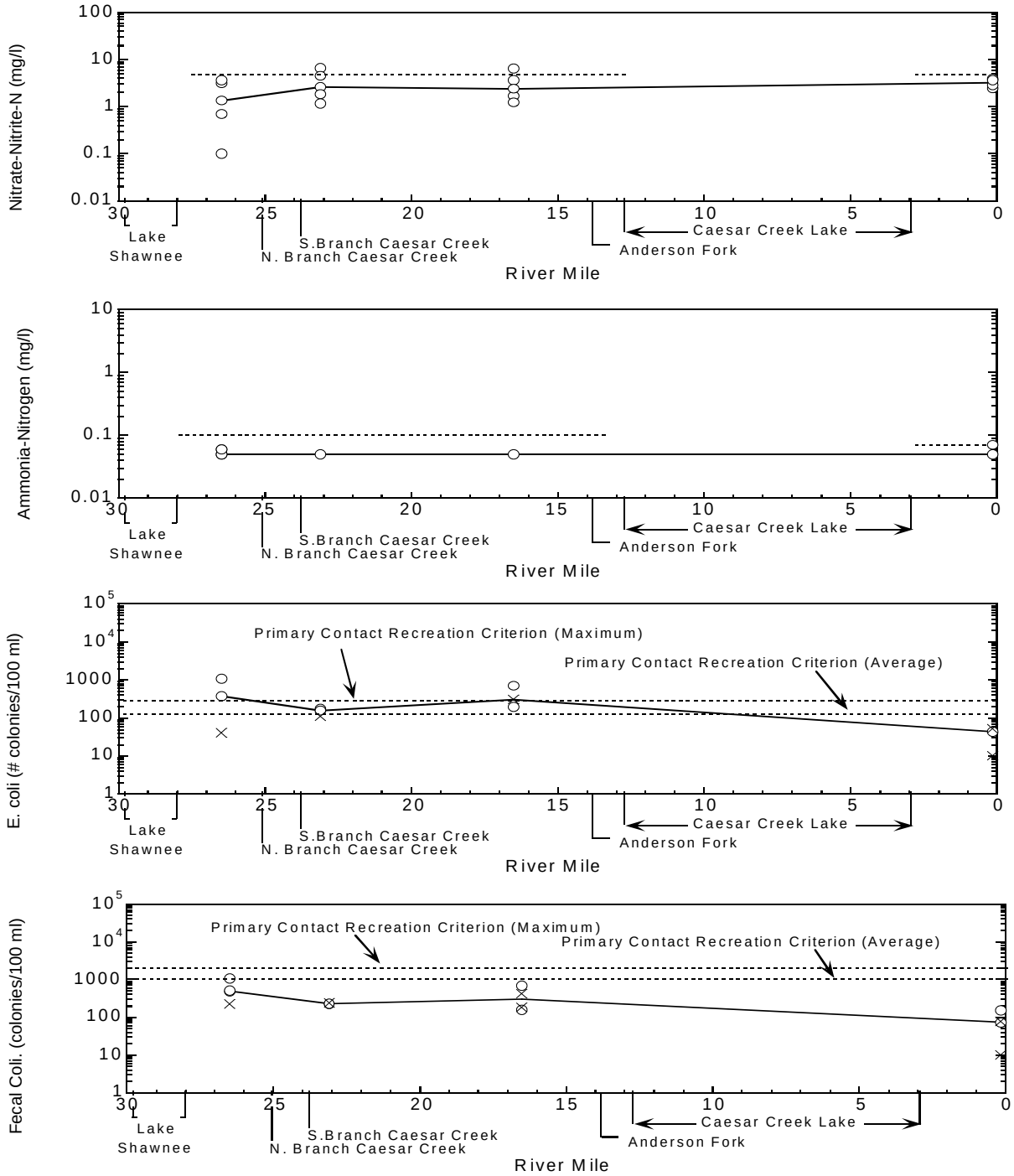



Figure 79. Longitudinal scatter plots of water column chemistry results (daytime grabs) for Caesar Creek, 1998. From the top: nitrate-nitrite-nitrogen, ammonia-nitrogen, *Escherichia coli* colonies/100ml, and fecal coliform bacterial colonies/100ml. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

Creek Lake with respective median (and maximum values) increasing longitudinally from 9 mg/l (19 mg/l) at RM 26.50 to 20 mg/l (94 mg/l) at RM 16.52. While the highest values coincided with higher flow days, field crews frequently observed light turbidity at upstream sites throughout the survey. Increased values may be partly attributable to inadequate sediment control practices at a construction site (Sebastian Hills golf course) adjacent to the most upstream site (RM 26.50) as well as the combined sediment load from the North Branch Caesar Creek and South Branch Caesar Creek.

Fecal coliform exceeded the average Primary Contact Recreation criterion at RM 26.50 on one occasion (1080 colonies/100 ml on August 18). All other concentrations measured in the basin were below criteria with median values ranging from 75 colonies/100 ml at RM 0.15 to 499 colonies/100 ml at RM 26.50. Concentrations of *E. coli* upstream of Caesar Creek Lake exceeded Primary Contact Recreation criteria in 78% of the samples. In addition to general non-point agricultural runoff, upstream sites may be impacted by livestock and local on-site sewage systems from Shawnee Hills subdivision on Shawnee Lake.

An elevated chemical oxygen demand (COD) concentration (73 mg/l) was recorded at RM 26.50 on July 21. Water samples from RMS 23.10 and 16.52 were analyzed for organic compounds twice during the 1998 survey (Table 8), revealing various organochlorine pesticides at both sites. One concentration of Dieldrin (0.006 µg/l) recorded at RM 16.52 exceeded water quality criteria.

*North Branch Caesar Creek*

Daytime grab water chemistry samples were collected at RMS 6.66 and 1.23 (Figures 80 and 81). Dissolved oxygen at RM 1.23 remained relatively stable with concentrations ranging from 7.2 mg/l to 9.5 mg/l and a median percent saturation of 96%; D.O. concentrations at RM 6.66 frequently reached supersaturated levels as the summer progressed. Algal mats observed on the stream surface were responsible for the variation and reflect the impact of non-point nutrients. Field crews noted livestock access, and a thin riparian zone with minimal shading.

Although concentrations of $BOD_5$ and ammonia-N exceeded 90$^{th}$ percentile ECBP reference site concentrations once at RM 6.66, values recorded in this tributary for both parameters were typically low with the majority (80% and 90%, respectively) less than applicable MDLs. Values of nitrate-nitrite-N at both sites exceeded the 90$^{th}$ percentile ECBP reference site concentrations on July 7 and July 21, and higher concentrations were generally recorded at the downstream site with median values increasing from 1.67 mg/l (RM 6.66) to 4.69 mg/l (RM 1.23). Respective median total phosphorus concentrations of 0.17 mg/l and 0.12 mg/l were measured at RM 6.66 and RM 1.23, while maximum values at each site (0.28 mg/l and 0.6 mg/l, respectively) exceeded applicable 90$^{th}$ percentile ECBP reference site concentrations.

While TSS concentrations at RM 6.66 ranged from less than the MDL of 5 mg/l to 11 mg/l, consistently higher values were recorded downstream at RM 1.23 with the highest concentrations at the site measured on July 7 (39 mg/l) and July 21 (42 mg/l), days of higher flow. Concentrations of fecal coliform (2400 colonies/100 ml) and *E. coli* (370 colonies/100 ml) exceeded maximum Primary Contact Recreation criteria at RM 6.66 on July 7 while all concentrations of *E. coli* recorded

at RM 1.23 exceeded the average Primary Contact Recreation criterion. Additionally, while iron concentrations recorded at RM 1.23 on July 7 (2080 µg/l) and July 21 (1540 µg/l) exceeded water quality criterion, concentrations of aluminum on these days (1660 µg/l and 1170 µg/l, respectively) were also elevated.

*South Branch Caesar Creek*

The South Branch Caesar Creek receives the discharge from the Jamestown WWTP at RM 9.00 before entering Caesar Creek at RM 23.78. Daytime grab water chemistry samples were collected at two sites (RMS 8.23 and 2.10) in this tributary during the 1998 survey (Figures 82 and 83). While D.O. concentrations remained above WWH minimum criteria, percent saturations at both sites were somewhat depressed with all values less than 100%. Dissolved oxygen remained relatively stable longitudinally with median concentrations (and percent saturations) of 6.8 mg/l (79%) recorded at RM 8.23 versus 7.1 mg/l (87%) at RM 2.10. Concentrations of $BOD_5$ exceeded the 90$^{th}$ percentile ECBP headwater reference site concentration (3.4 mg/l) at RM 8.23 twice (4 mg/l and 6.1 mg/l) while values recorded at RM 2.10 remained low with the majority (four of five) less than the MDL of 2 mg/l.

Ammonia-N concentrations were frequently elevated downstream of the Jamestown WWTP at RM 8.23, exceeding WWH water quality criterion on August 4 (1.07 mg/l). Median ammonia-N concentrations decreased from 0.24 mg/l at RM 8.23 to less than the MDL of 0.05 mg/l at RM 2.10. Nitrate-nitrite-N concentrations, elevated at RM 8.23 (median and maximum values of 5.64 mg/l and 9.74 mg/l), decreased downstream at RM 2.10 (median and maximum values of 1.00 mg/l and 4.66 mg/l). While the majority (90%) of total phosphorus concentrations recorded in this tributary exceeded the 90$^{th}$ percentile ECBP headwater reference site concentration (0.206 mg/l), higher values were generally recorded at RM 8.23 downstream of the Jamestown WWTP. Total phosphorus concentrations at RM 8.23 ranged from 0.21 mg/l to 1.78 mg/l with a median of 1.16 mg/l while values recorded downstream at RM 2.10 ranged from 0.20 mg/l to 1.07 mg/l with a median of 0.23 mg/l. Additionally, concentrations of numerous parameters including conductivity, total dissolved solids, strontium, barium, sodium, and chloride were frequently elevated at RM 8.23 downstream of the Jamestown WWTP.

Relatively stable longitudinally, TSS concentrations remained low with median and maximum values of 8 mg/l and 14 mg/l recorded at RM 8.23 while corresponding values of 6 mg/l and 11 mg/l were measured at the downstream site (RM 2.10). Bacteriological sampling at RM 8.23, downstream of the Jamestown WWTP, revealed consistently elevated concentrations of both fecal coliform and *E. coli* with all values exceeding applicable Primary Contact Recreation criteria. Fecal coliform concentrations at the site ranged from 1620 to 17000 colonies/100 ml while *E. coli* concentrations ranged from 923 to 33000 colonies/100 ml. While concentrations of

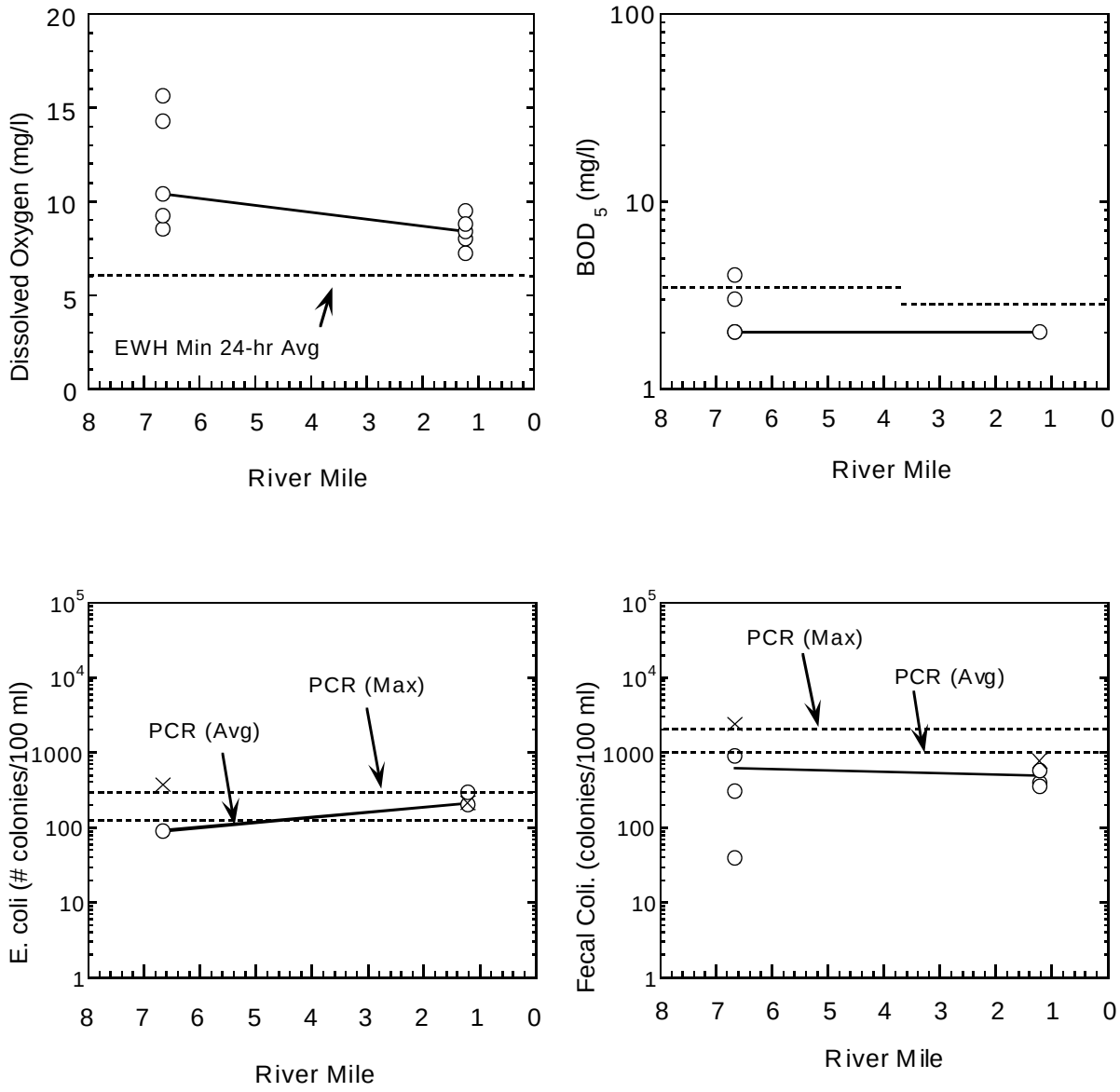



Figure 80. Longitudinal scatter plots of water column chemistry results (daytime grabs) from the North Branch Caesar Creek, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and Primary Recreation Contact Water Quality Standards (PCR) are shown for the bacteria plots. The 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion is shown for the $BOD_5$ plot. Medians for each location are joined by a solid line.

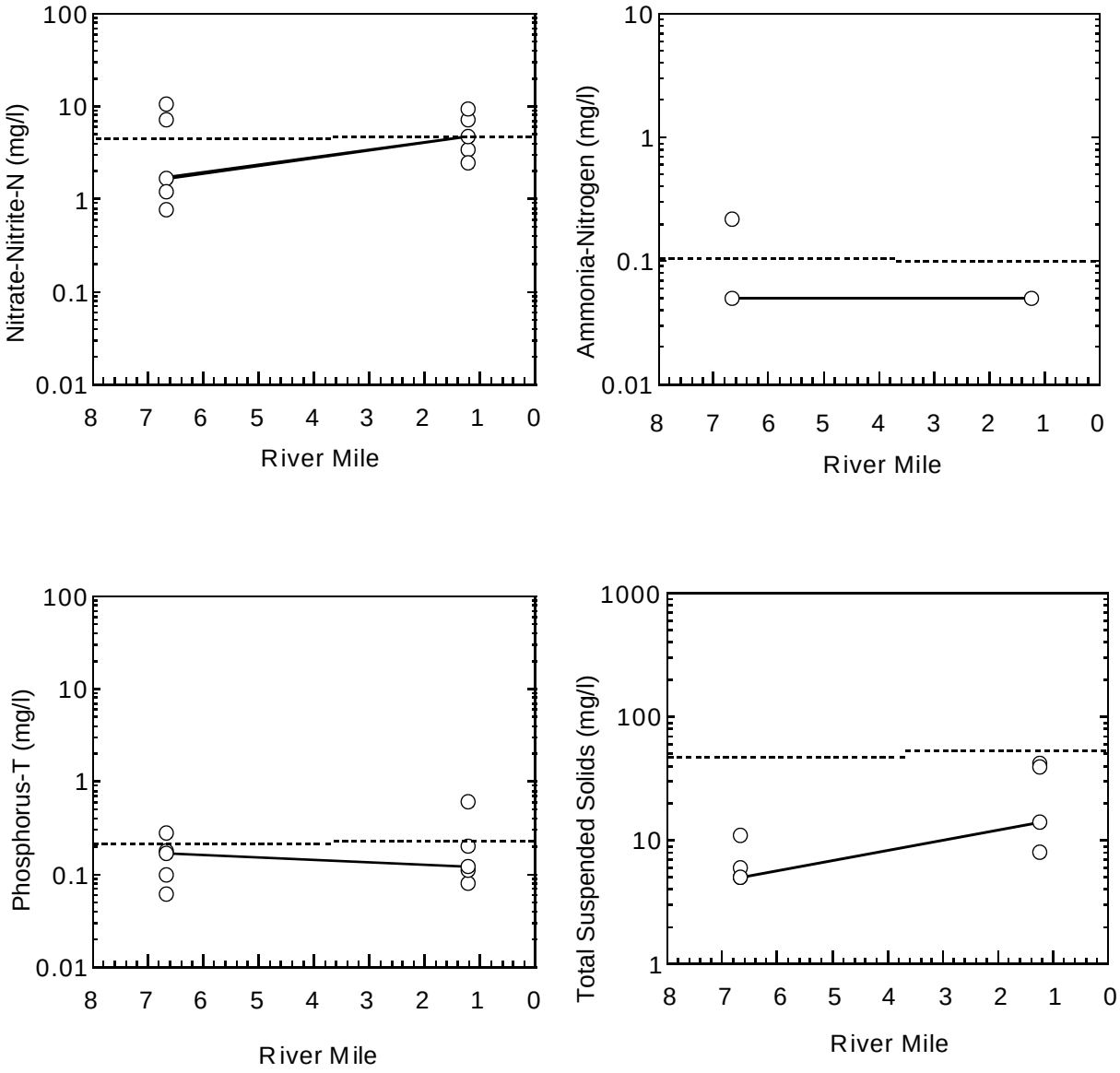



Figure 81. Longitudinal scatter plots of water column chemistry results (daytime grabs) from the North Branch Caesar Creek, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, total suspended solids, and total phosphorus. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. Medians for each location are joined by a solid line.

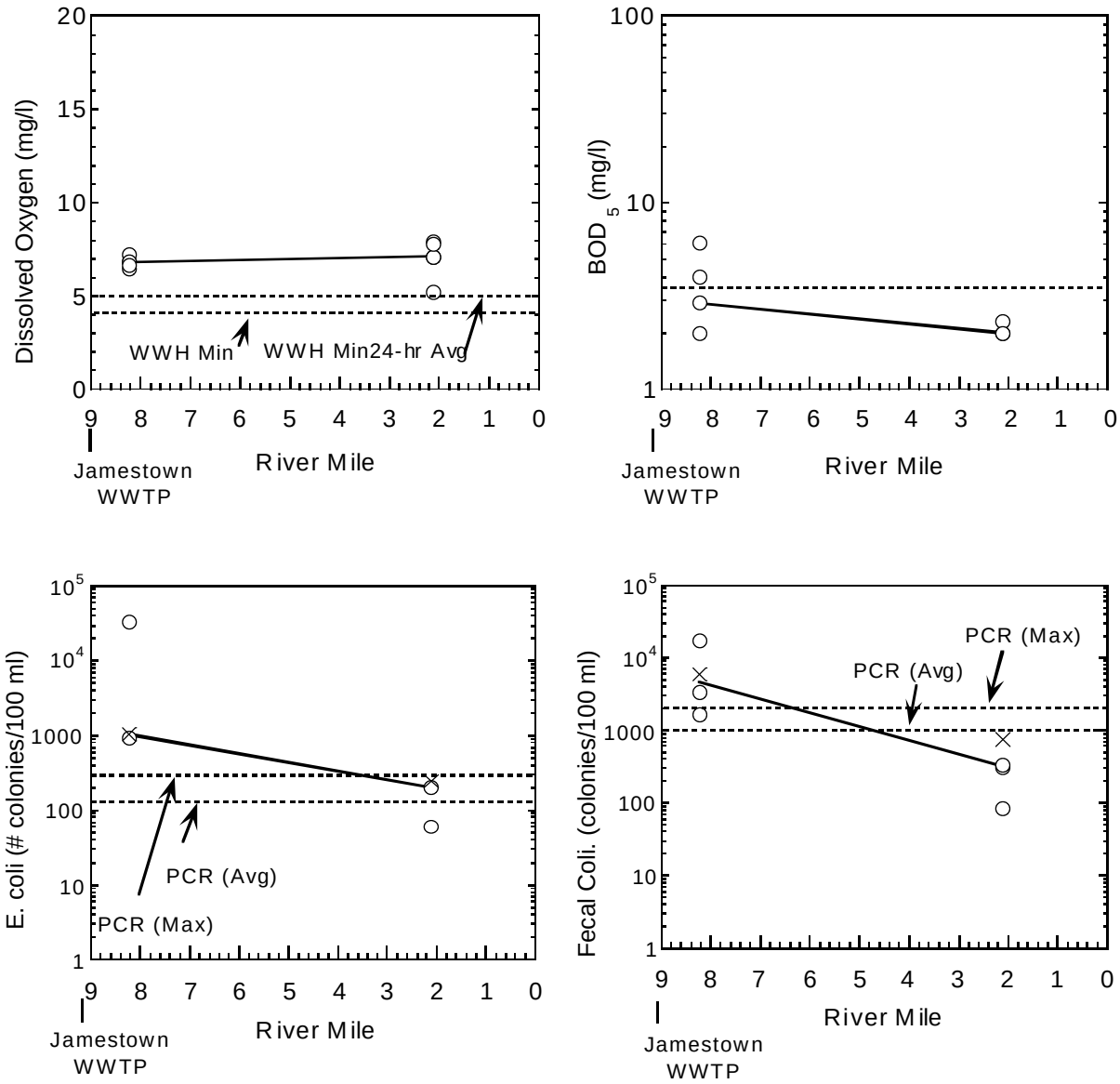



Figure 82. Longitudinal scatter plots of water column chemistry results (daytime grabs) from the South Branch Caesar Creek, 1998, in relation to the Jamestown WWTP. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, fecal coliform bacterial colonies/100ml, and *Escherichia coli* colonies/100ml. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and Primary Contact Recreation Water Quality Standards (PCR) are shown for the bacteria plots. The 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion is shown for the $BOD_5$ plot. Medians for each location are joined by a solid line.

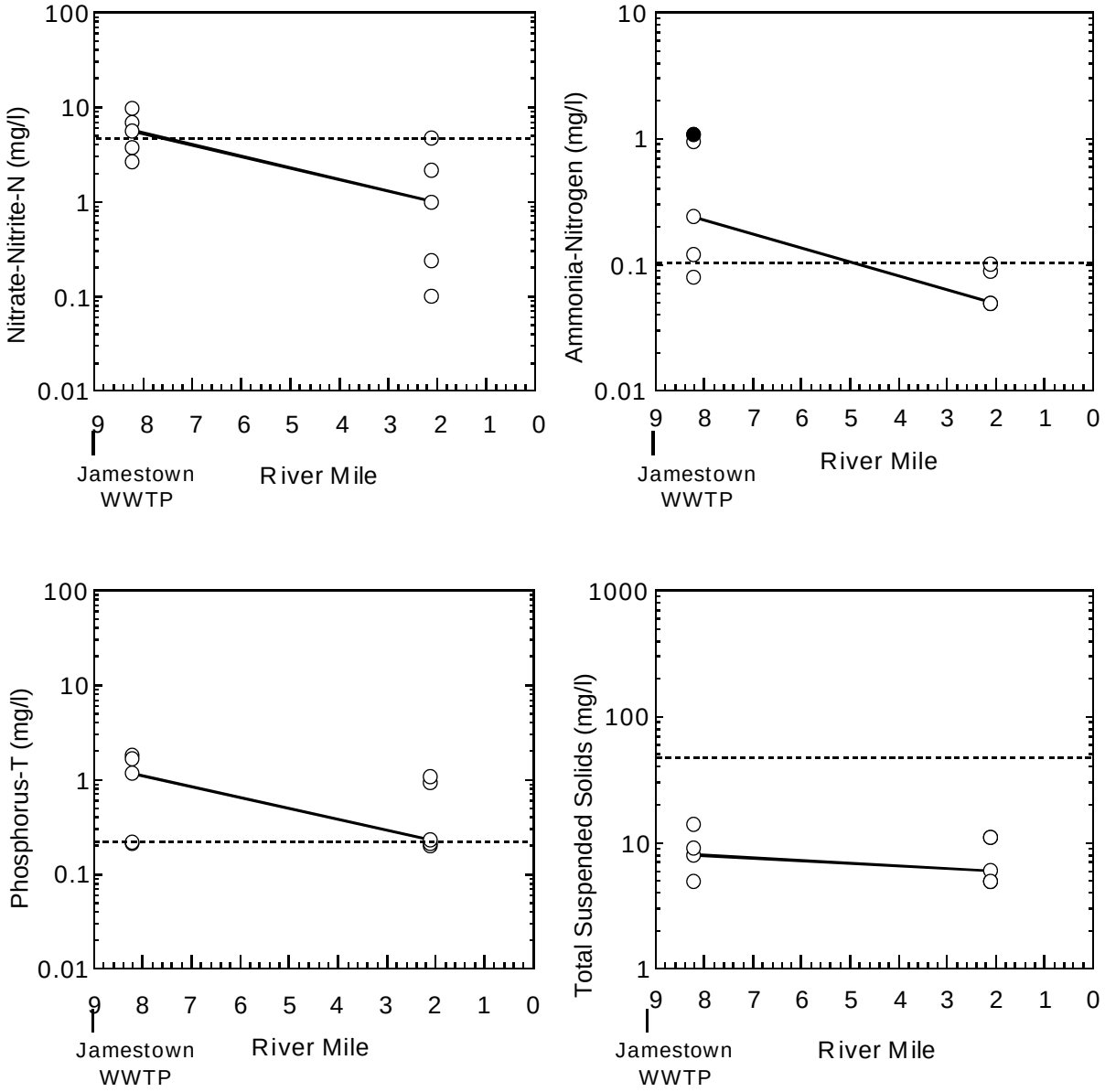



Figure 83. Longitudinal scatter plots of water column chemistry results (daytime grabs) from the South Branch of Caesar Creek, 1998 in relation to the Jamestown WWTP. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, total suspended solids, and total phosphorus. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. Exceedences of Water Quality Standards for ammonia-nitrogen are shown as solid circles.

fecal coliform at RM 2.10 remained below recreation criteria, *E. coli* concentrations exceeded average Primary Recreation Criterion on two occasions (200 colonies /100 ml and 240 colonies/100 ml). Water samples from RM 2.10 were analyzed for organic compounds twice during the 1998 survey (), revealing low concentrations of various pesticides as well as methylene chloride (a volatile organic compound).

*Anderson Fork*

Water chemistry daytime grab samples were collected at four sites (RMS 18.80, 13.87, 9.45, and 4.90) in Anderson Fork, a tributary of Caesar Creek (confluence at RM 13.92) during the 1998 survey (Figure 84). Water quality criteria identified for the WWH use designation apply in this tributary from the headwaters to the Grog Run confluence (RM 11.02) while the EWH use designation applies from RM 11.02 to the mouth. Median D.O. concentrations (and percent saturations) increased longitudinally from 5.5 mg/l (67%) at RM 18.80 to 8.0 mg/l (84%) at RM 4.90. Reflecting the diminished flow observed in this tributary as the summer progressed, concentrations recorded on September 1 at RM 18.80 (4.90 mg/l) and RM 9.45 (5.60 mg/l) dropped below minimum 24-hour average criteria. Both $BOD_5$ and ammonia-N remained low with 90% of $BOD_5$ concentrations less than the MDL of 2 mg/l and 90% of ammonia-N values less than the $90^{th}$ percentile concentration (0.096 mg/l) for ECBP wadeable reference sites.

Minimal longitudinal variation was observed in nitrate-nitrite-N concentrations with medians ranging from 1.22 mg/l (RM 18.80) to 2.23 mg/l (RM 4.90). Values measured on July 7 and July 21 (higher flow days) frequently exceeded the $90^{th}$ percentile concentration (4.84 mg/l) for ECBP wadeable reference sites with maximum values ranging from 7.96 mg/l (RM 4.90) to 8.96 mg/l (RM 18.80). An overall median of 0.23 mg/l was calculated for all concentrations of total phosphorus recorded in Anderson Fork with 50% of concentrations exceeding the $90^{th}$ percentile concentration (0.22 mg/l) for ECBP wadeable reference sites. Median concentrations of total phosphorus ranged from 0.20 mg/l (RM 18.80) to 0.32 mg/l (RM 13.87), and maximums ranged from 0.27 mg/l (RM 18.80) to 0.84 mg/l (RM 9.45).

High flows on July 7 and July 21 accounted for the highest concentrations of total suspended solids, but concentrations were consistently elevated throughout the survey with median values ranging from 18 mg/l (RM 13.87) to 32 mg/l (RM 4.90). All fecal coliform concentrations were below Primary Contact Recreation criteria with median values ranging from 320 colonies/100 ml at RM 9.45 to 494 colonies/100 ml at RM 13.87. Concentrations of *E. coli* frequently exceeded Primary Contact Recreation criteria at all sites (8 of 12 values) with medians ranging from 100 colonies/100 ml (RM 9.45) to 190 colonies/100 ml (RM 13.87).

In addition to concentrations of iron (2540 to 5300 µg/l) above water quality criterion at all four sites on July 21, elevated concentrations of aluminum (2170 to 4280 µg/l) were recorded at all sites on this day. Concentrations of both iron (1440 µg/l) and manganese (212 µg/l) exceeded criteria at RM 18.80 on September 1. Additionally, the highest sulfate concentrations (median of

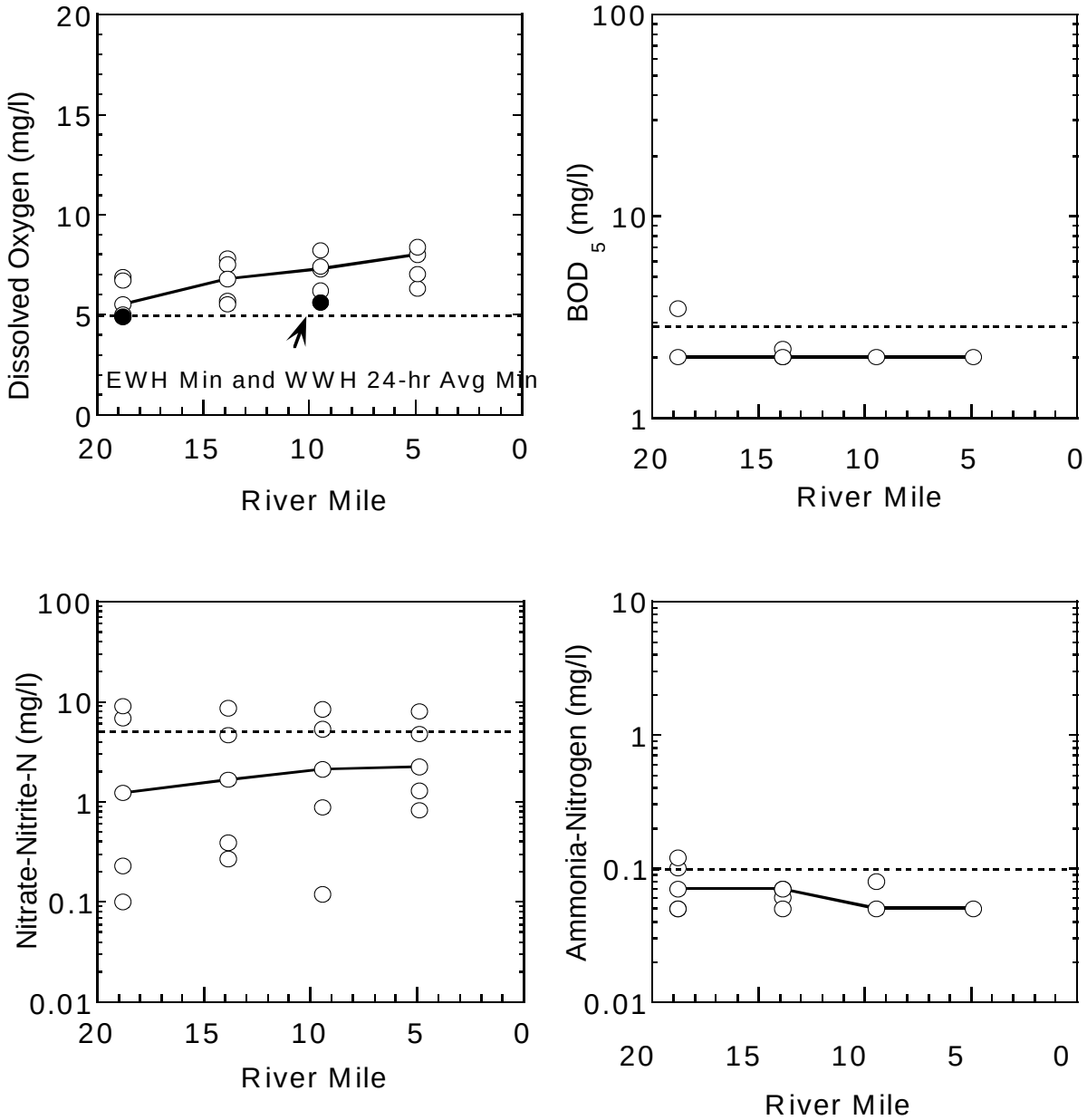



Figure 84. Longitudinal scatter plots of water column chemistry results (daytime grabs) for dissolved oxygen, 5-day biochemical oxygen demand, nitrate-nitrite-nitrogen, and ammonia-nitrogen from Anderson Fork, 1998. Dashed horizontal lines depict Water Quality Standars in the dissolved oxygen plot, otherwise they show the 90th percentile concentrations from reference sites of similar size in the Eastern Cornbelt Plains (ECBP) ecoregion. Medians at each location are joined by solid lines. Values below the Water Quality Criteria for dissolved oxygen are shown as shaded dots.

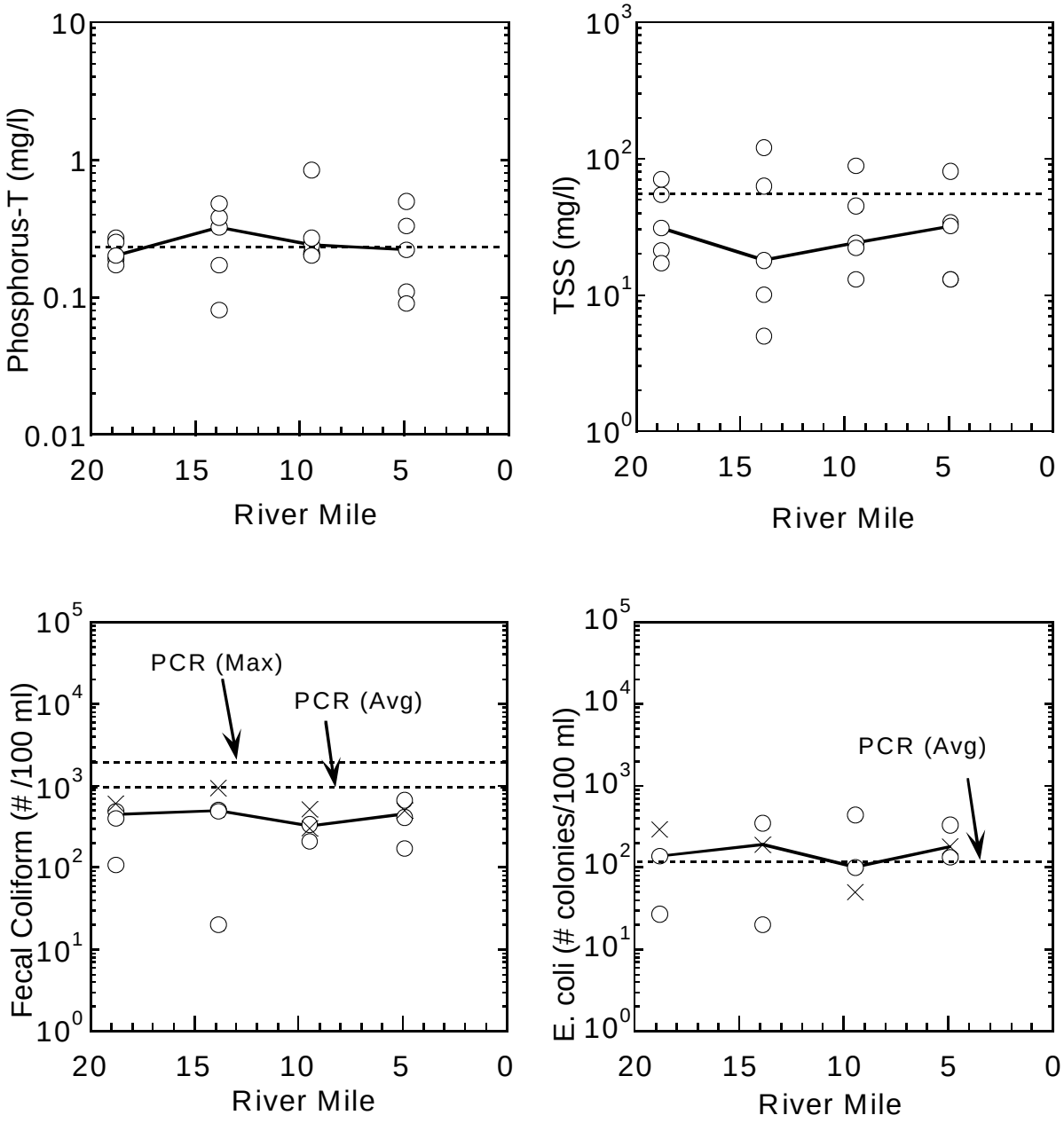



Figure 85. Longitudinal scatter plots of water column chemistry results (daytime grabs) for total phosphorus, total suspended solids (TSS), fecal coliform bacteria, and *E. coli* from Anderson Fork, 1998. Dashed horizontal lines depict Water Quality Standars in the bacterial plots, otherwise they show the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Cornbelt Plains (ECBP) ecoregion. Medians at each location are joined by solid lines.

137 mg/l) of the entire survey were recorded at RM 18.80. Water samples from RMS 13.87 and 4.90, analyzed for organic compounds twice during the 1998 survey (Table 8), revealed various organochlorine pesticides and exceedences of water quality criteria for Dieldrin (Table 9).

*Painters Creek*

Water chemistry daytime grab samples were collected at one site (RM 0.43) in this tributary of Anderson Fork (confluence at RM 5.93) during the 1998 survey (Figures 85 and 86). Dissolved oxygen concentrations, ranging from 5.0 mg/l to 9.0 mg/l with a median percent saturation of 60%, dropped below the EWH minimum 24-hour average criterion on August 4 (5.4 mg/l) and August 18 (5.0 mg/l). The majority of $BOD_5$ concentrations (four of five) and all concentrations of ammonia-N recorded were less than applicable MDLs (2 mg/l and 0.05 mg/l, respectively). While three of five values recorded for nitrate-nitrite-N were less than the MDL (0.1 mg/l), higher concentrations were measured on July 7 (7.55 mg/l) and July 21 (3.08 mg/l), days of higher flow in the basin. Concentrations of total phosphorus ranged from less than the MDL of 0.05 mg/l to 1.43 mg/l with a median value of 0.13 mg/l. With the exception of the concentration measured on July 21 (17 mg/l), the highest flow day in the basin, all TSS concentrations were less than the MDL of 5 mg/l. While fecal coliform concentrations remained below Primary Contact Recreation criteria, *E. coli* concentrations exceeded recreation criteria in all samples with values ranging from 230 colonies/100 ml to 370 colonies/100 ml. Additionally, while iron exceeded water quality criterion on one occasion, concentrations of manganese frequently exceeded criterion. No other elevated parameters were observed in this tributary.

*Buck Run*

Buck Run, draining primarily agricultural land, empties directly to Caesar Creek Lake. Water chemistry daytime grab samples were collected at RM 1.18 of this tributary during the 1998 survey (Figures 85 and 86). Dissolved oxygen measurements, somewhat depressed, ranged from 5.9 mg/l to 8.8 mg/l with a median percent saturation of 63%. All $BOD_5$ and ammonia-N concentrations measured at the site were less than applicable MDLs. While concentrations of nitrate-nitrite-N ranged from less than the MDL of 0.1 mg/l to 4.77 mg/l, total phosphorus concentrations ranged from 0.07 mg/l to an exceptionally elevated 4.76 mg/l. Total suspended solids ranged from 8 mg/l to 17 mg/l with a median of 12 mg/l. Fecal coliform concentrations remained below Primary Contact Recreation criteria with values ranging from 83 colonies/100 ml to 664 colonies/100 ml while *E. coli* values exceeded recreation criteria on July 7 (270 colonies/100 ml) and August 18 (367 colonies/100 ml). Concentrations of manganese exceeded water quality criterion on two occasions (118 µg/l and 112 µg/l). No other elevated parameters were recorded in Buck Run.

*Trace Run*

Trace Run drains directly to Caesar Creek Lake. Daytime grab water chemistry samples were collected at RM 1.83 of this tributary during the 1998 survey (Figures 85 and 86). Dissolved oxygen concentrations measured at the site ranged from 7.4 mg/l to 9.5 mg/l with a median percent saturation of 87%. All $BOD_5$ and ammonia-N concentrations were less than applicable MDLs (2 mg/l and 0.05 mg/l, respectively). Nitrate-nitrite-N concentrations ranged from less than the MDL of 0.10 mg/l to 6.11 mg/l with a median of 0.73 mg/l. While three of five total phosphorus

measurements were less than the MDL of 0.05 mg/l, two values (1.15 mg/l on August 4 and 1.08 mg/l on August 18) exceeded the 90th percentile ECBP headwater reference site concentration (0.206 mg/l). Concentrations of TSS remained low throughout the survey at the site with four of five values less than the MDL of 5 mg/l and a maximum concentration of 6 mg/l. While concentrations of fecal coliform and *E. coli* generally remained low, concentrations recorded on August 18 (2630 colonies/100 ml and 250 colonies/100 ml, respectively) exceeded Primary Contact Recreation criteria. No other elevated parameters were observed in this tributary.

*Jonahs Run*

One site (RM 1.32) was sampled in Jonahs Run, a tributary draining directly to Caesar Creek Lake (Figures 85 and 86). (Given that flows in this tributary became interstitial as the summer progressed, samples could not be collected at the site during the last week of the survey.) Concentrations of D.O. remained relatively stable ranging from 7.2 mg/l to 9.3 mg/l with a median percent saturation of 90% while all $BOD_5$ and ammonia-N concentrations recorded at the site were less than applicable MDLs. While concentrations of nitrate-nitrite-N remained low with values ranging from 0.1 mg/l to 2.48 mg/l, total phosphorus concentrations ranged from 0.11 mg/l to 1.39 mg/l with a median value of 0.55 mg/l. Total suspended solids concentrations were generally low (median of 9 mg/l). Concentrations of *E. coli* exceeded the average Primary Contact Recreation criterion on one occasion (170 colonies/100 ml on July 7) while all fecal coliform concentrations remained below Primary Contact Recreation criteria. Concentrations of iron (1330 µg/l) exceeded water quality criterion on July 21. No other elevated parameters were recorded at the site.

*Flat Fork*

Flat Fork drains directly to Caesar Creek Lake. Daytime grab water chemistry samples were collected at RM 1.70 of this tributary during the 1998 survey (Figures 86 and 87). All D.O. concentrations remained above WWH minimum criteria, ranging from 6.5 mg/l to 10.2 mg/l with a median percent saturation of 83%. Concentrations of $BOD_5$ and ammonia-N remained less than applicable 90th percentile ECBP headwater reference site concentrations (3.4 mg/l and 0.1 mg/l, respectively). While concentrations of nitrate-nitrite-N remained relatively low with values ranging from 0.15 mg/l to 4.49 mg/l, four of five total phosphorus concentrations exceeded the 90th percentile ECBP headwater reference site concentration (0.206 mg/l). Generally low, the maximum TSS concentration recorded at the site (25 mg/l) occurred on July 21, the highest flow day in this basin during the survey. All concentrations of fecal coliform and *E. coli* remained below applicable Primary Contact Recreation criteria. Concentrations of iron (1300 µg/l) and manganese (2130 µg/l) exceeded water quality criteria on separate occasions. No other elevated parameters were observed in Flat Fork.

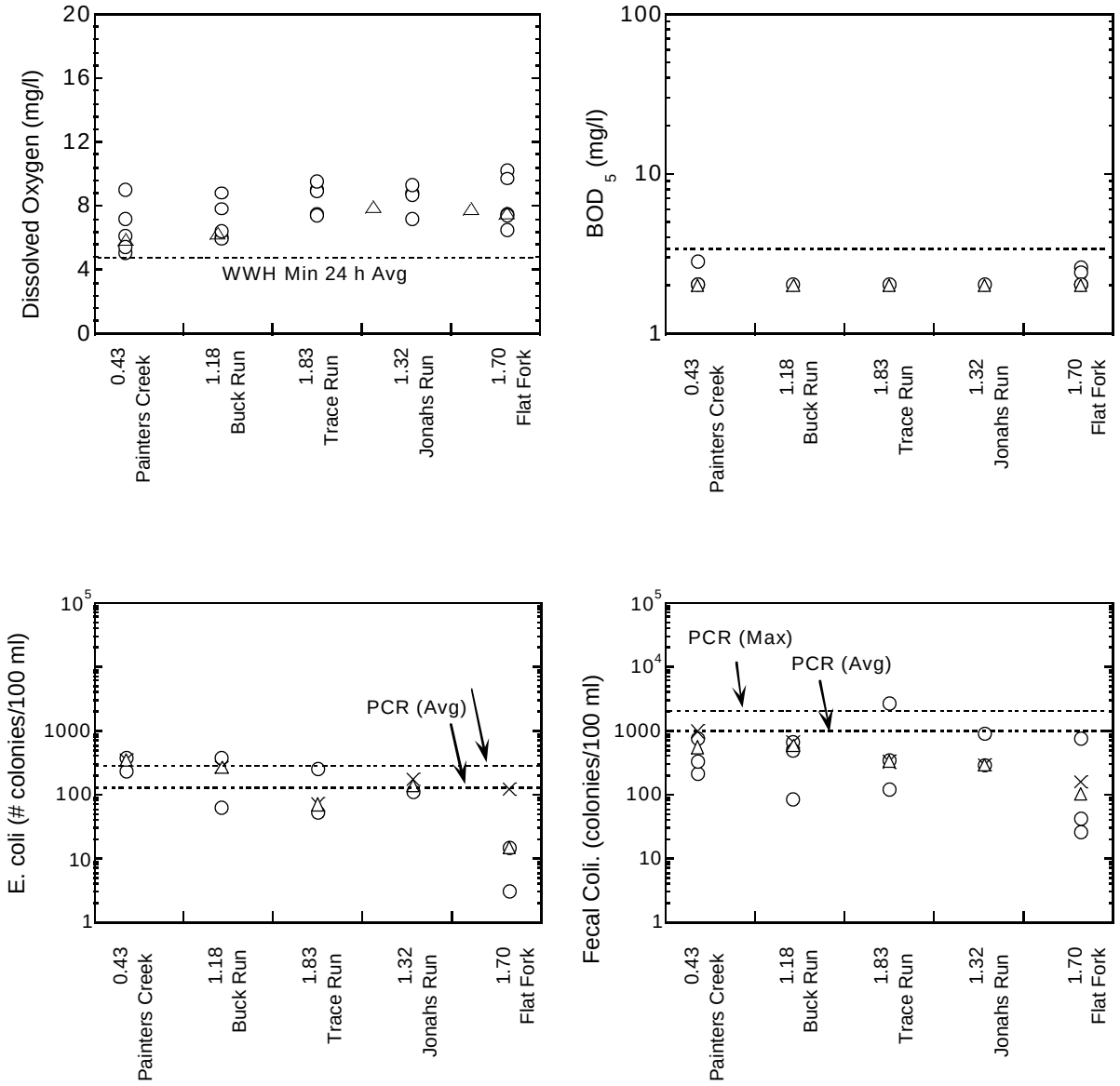



Figure 86. Scatter plots of water column chemistry results (daytime grabs) from Painters Cr., Buck Run, Trace Run, Jonahs Run, and Flat Fork, 1998. Clockwise from top left: dissolved oxygen, 5-day biochemical oxygen demand, fecal coliform bacteria, and *Escherichia coli*. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and Primary Recreation Contact criteria (PCR) are shown for the bacteria plots. The 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion is shown for the $BOD_5$ plot. Medains for each location are shown as a triangle.

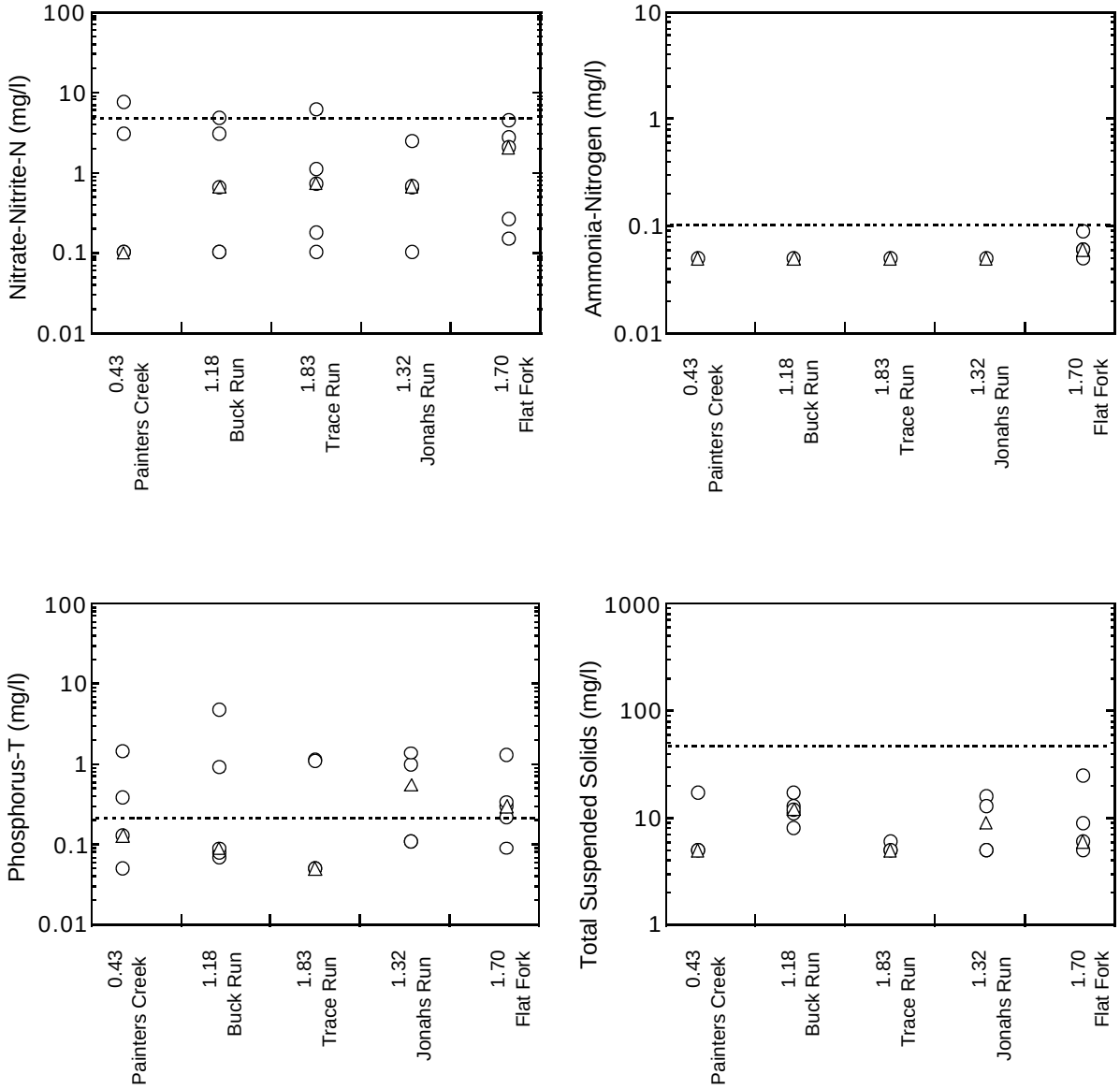



Figure 87. Scatter plots of water column chemistry results (daytime grabs) from Painters Cr., Buck Run, Trace Run, Jonahs Run, and Flat Fork, 1998. Clockwise from top left: nitrate-nitrite-nitrogen, ammonia-nitrogen, total suspended solids, and total phosphorus. Dashed horizontal lines depict the 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. Triangles show medians for each location.

*Todd Fork*

The water quality of Todd Fork is strongly influenced by nutrient loadings from the Wilmington WWTP. Nitrate-nitrogen and total phosphorus increased in Todd Fork downstream from Lytle Creek from concentrations within background levels for the ecoregion to concentrations either approaching or exceeding the 90$^{th}$ percentile of reference sites of similar size in the ecoregion (Figure 88). Impacts to water quality and the fish community were realized in the lower 5 miles of Todd Fork. The impacts were caused by algal production and respiration as inferred by the assimilation of nutrients, and variable and supersaturating dissolved oxygen concentrations occurring in that reach (Figure 88).

*Lytle and Cowan Creeks*

Lytle and Cowan Creeks receive discharge from the ABX airport, and Lytle Creek receives treated wastewater from the Wilmington WWTP. ABX uses propylene glycol as a deicer for aircraft, and discharges the spent propylene glycol via a series of outfalls directly to Lytle Creek and Indian Run, and indirectly to Cowan Creek via Indian Run. Propylene glycol is degraded by biological processes, consequently biological oxygen demand is a major concern. Current loadings of propylene glycol result in frequent anoxia in Lytle Creek and occasional anoxia in Indian Run. Residual contamination from discontinued urea-based deicers results in measurable loadings of ammonia-N to Lytle Creek and Indian Run. Those loadings have decreased in each of the last 3 years, and did not adversely impact water quality measured during the summer low-flow period in 1998. However, peak loadings during wet weather in winter may result in high instream concentrations of ammonia given that the 95th percentile effluent concentration at the 002 outfall in 1998 was 5.33 mg/l. Ammonia-N concentrations in sediments collected in Lytle Creek at RM 9.4 were nearly three times higher than in sediments collected at reference locations, possibly reflecting residual contamination from urea-based deicing compounds, but ammonia concentrations in the water column were within normal ranges. Phosphorus was also highly elevated in sediments collected at RM 9.4, but the source was unidentified.

Regardless of the source, loadings of nutrients to the headwaters of Lytle Creek resulted in elevated concentrations of nitrogen and phosphorus (Figure 89), that in turn, stimulated algal production and respiration as inferred by nutrient assimilation, and wide variation and supersaturation of dissolved oxygen concentrations (see Figures 89 and 90, upstream from the Wilmington WWTP). Loadings of nitrogen and phosphorus by the Wilmington WWTP resulted in a nearly two order of magnitude increase in nutrient concentrations. Those nutrients were conserved and delivered to Todd Fork (Figure 88). Lytle Creek was also contaminated with *E. coli* and fecal coliform bacteria upstream from the Wilmington WWTP. A failing sewer collection system is a possible source of contamination.

Loadings of propylene glycol to Cowan Creek via Indian Run did not result in measurable water quality impacts during the summer-fall low flow sampling period. However, low or intermittent flow in Cowan Creek resulted in critically low dissolved oxygen concentrations (Figure 90).

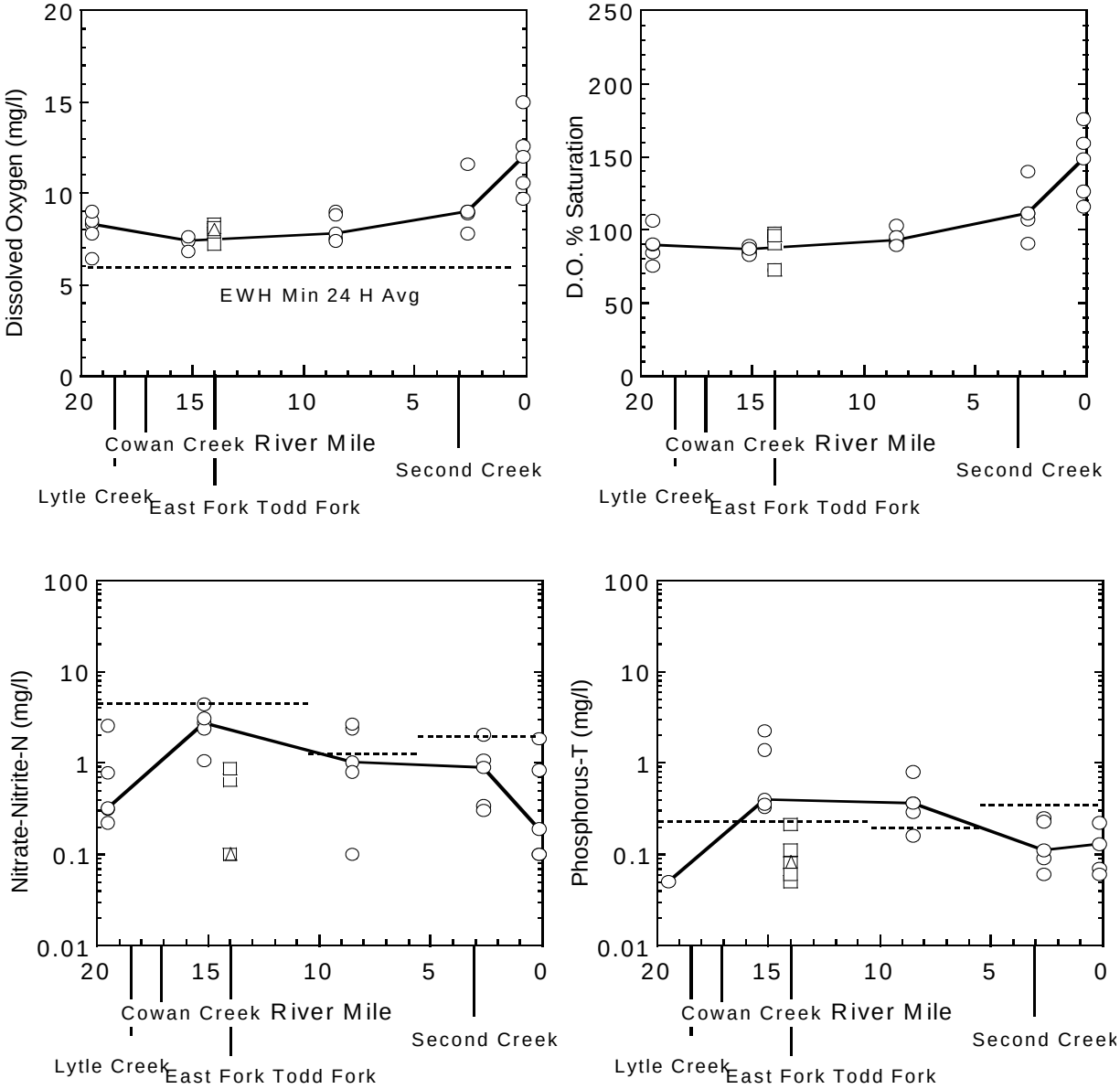



Figure 88. Longitudinal scatter plots of water column chemistry results (daytime grabs) in Todd Fork and East Fork Todd Fork (squares), 1998. Clockwise from top left: dissolved oxygen, dissolved oxygen percent saturation, nitrate-nitrite-nitrogen, and total phosphorus. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, and 90$^{th}$ percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for the other plots. Medians for each Todd Fork location are connected by solid lines; the medians for East Fork Todd Fork are shown as triangles.

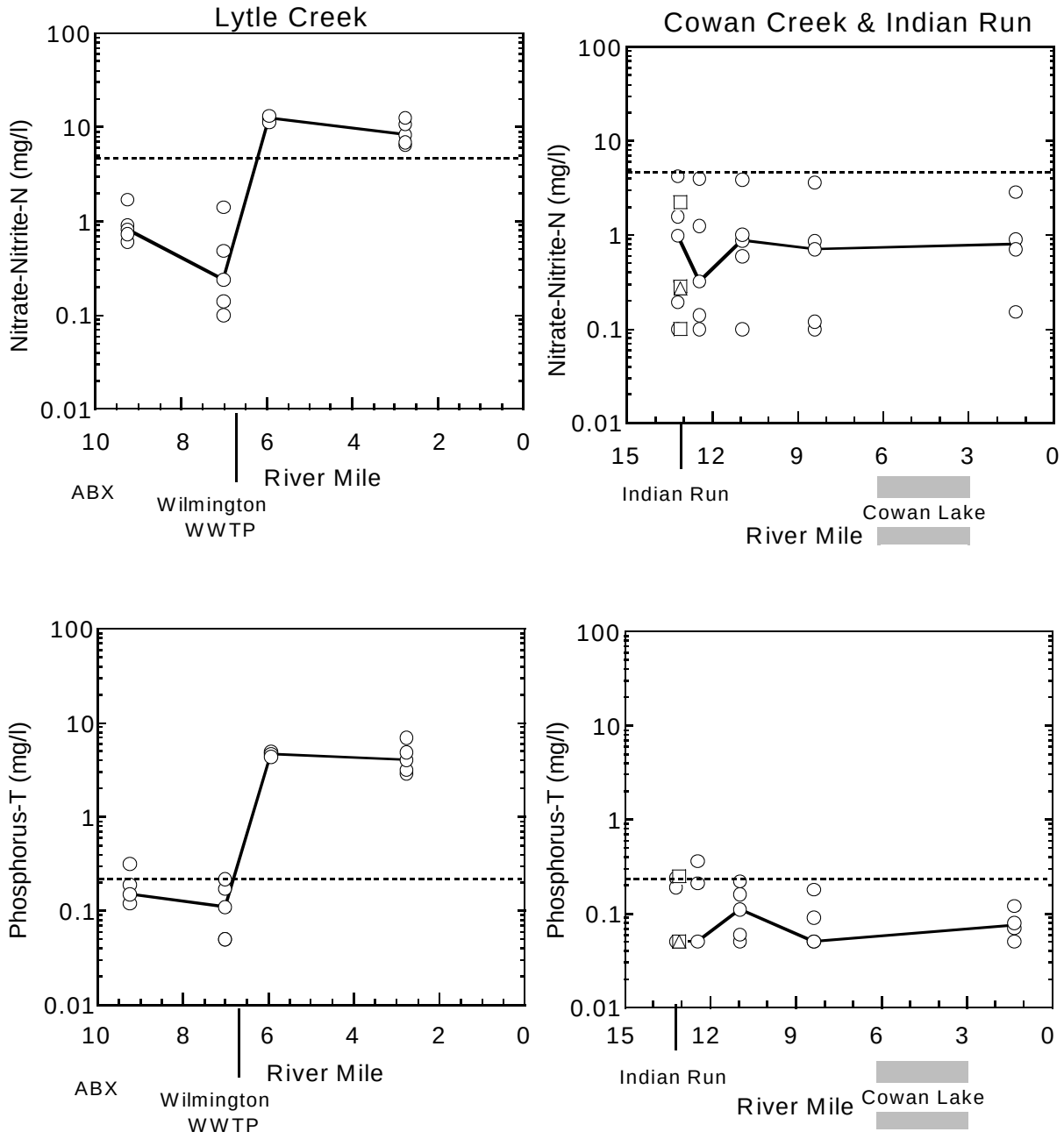



Figure 89. Longitudinal scatter plots of nitrate-nitrite nitrogen and total phosphorus for Lytle Creek, Cowan Creek and Indian Run, 1998. Dashed horizontal lines depict 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains ecoregion. Medians at each location in Lytle and Cowan Creeks are joined by solid lines; those for Indian Run are shown a triangles.

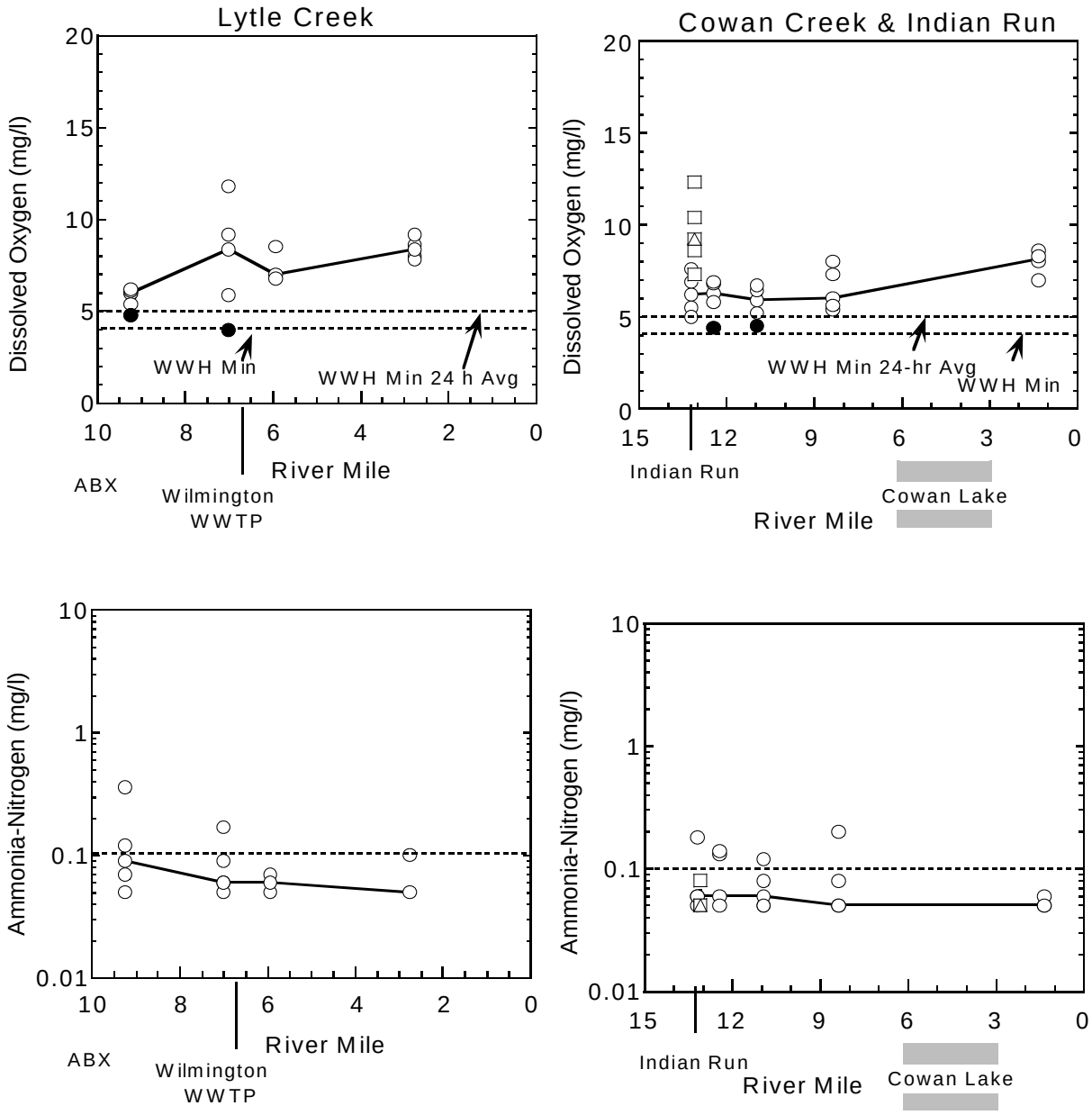



Figure 90. Longitudinal scatter plots of water column chemistry results (daytime grabs) for dissolved oxygen, and ammonia-nitrogen in Lytle Creek, Cowan Creek and Indian Run, 1998. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. Medians for locations sampled in Lytle and Cowan Creeks are joined by solid lines, and those for Indian Run are shown as triangles. Dissolved oxygen concentrations below WQS are shown as filled circles.

*Muddy Creek*

Nitrogen and phosphorus concentrations increase by nearly two orders of magnitude downstream from the Mason WWTP (Figure 91). Again, nutrient enrichment appears to have impaired water quality by stimulating algal production. However, unlike in Todd Fork, and in Lytle Creek upstream from the WWTP, the inferential evidence was not so clear, given that little assimilation of the nutrients occurred, and supersaturating D.O. concentrations were not pronounced. A critically low concentration of dissolved oxygen was recorded in one of the daytime grab samples collected downstream from the WWTP at RM 0.7. An alternate hypothesis is that the low dissolved oxygen was attributable to organic enrichment as ammonia-nitrogen, and *E. coli* levels increased downstream from the WWTP relative to upstream (Figure 91).

*O Bannon Creek*

Following suit, nitrogen and phosphorus concentrations increased by an order or two of magnitude downstream from the Clermont County O'Bannon Creek WWTP. Algal productivity was clearly stimulated by the nutrient enrichment as masses of filamentous algae were observed at the downstream most site. Dissolved oxygen superstaturation and variation were pronounced (Figure 92), and though only measured in daytime grab samples, suggest that concentrations were likely falling to critical levels at night. Otherwise, water quality was not negatively influenced by the WWTP given that fecal coliform and *E. coli* levels, and ammonia-nitrogen, $BOD_5$ and total suspended solid concentrations were similar and not elevated at sites upstream and downstream from the plant (see Appendix xx).

*Simpson Creek and Sycamore Creek*

No water quality impairments to Simpson Creek by the Warren County Lower Little Miami WWTP were evident in the water quality grab samples. However, an overflowing sewer contaminated the stream with raw sewage on at least one date, as observed by field crews, and caused an exceedence of the ammonia-nitrogen WQS in the Little Miami River.

Fecal coliform and *E. coli* levels in grab samples were elevated downstream from the Hamilton County Sycamore Creek WWTP relative to upstream. However, the samples were kept past QA/QC holding times, and are only used for comparative purposes (Figure 93). No other water quality parameter indicated a problem with the plant.

The Warren County Lower Little Miami River WWTP and the Hamilton County Sycamore Creek WWTP respectively discharge to Simpson Creek and Sycamore Creek within several hundred meters of each creek's confluence with the Little Miami River. Both plants raise the concentration of nitrogen and phosphorus by at least an order of magnitude in their respective receiving streams, but secondary water quality impacts from nutrient enrichment are not likely to be manifest in so short a reach.

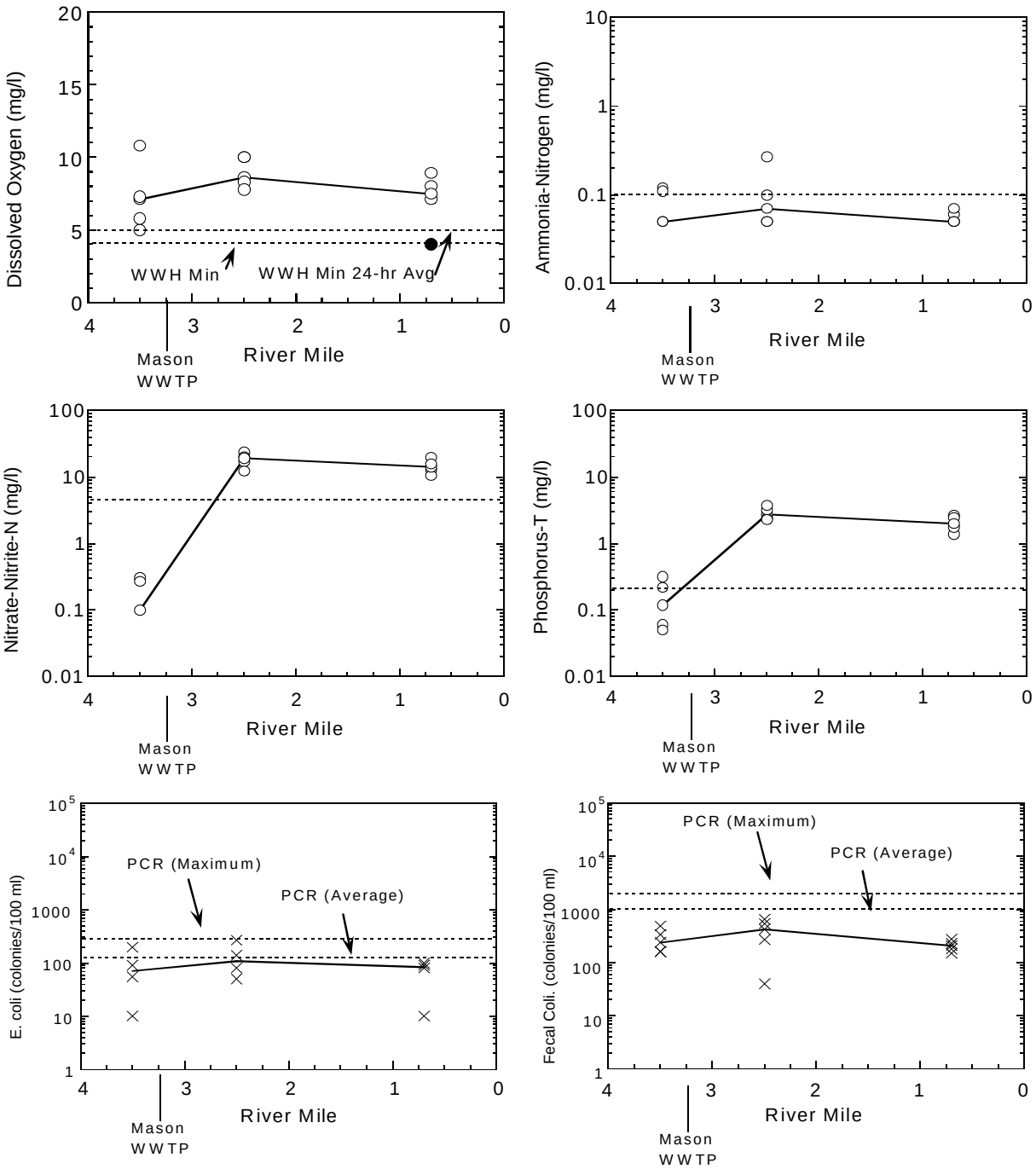



Figure 91. Longitudinal scatter plots of water column chemistry results (daytime grabs) for Muddy Creek, 1998. Left to right from the top: dissolved oxygen, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, *Escherichia coli* colonies/100ml, and fecal coliform bacterial colonies/100ml. The solid line depicts the median value at each river mile sampled. Dashed horizontal lines depict the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion for nitrate-nitrite-nitrogen, total phosphorus and ammonia-nitrogen. Primary Contact Recreation (PCR) Water Quality Standards are shown for the bacteria plots.

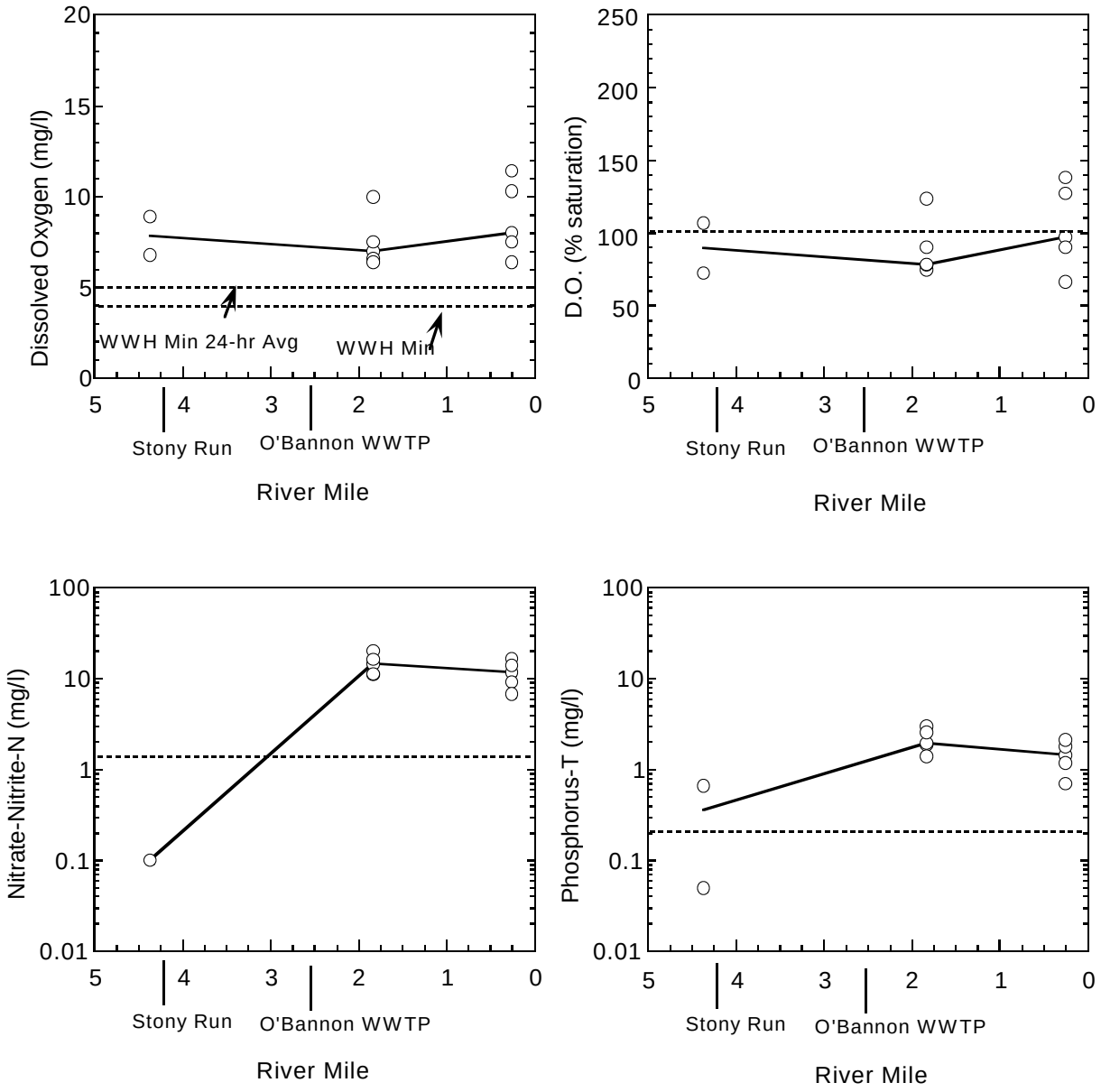



Figure 92. Longitudinal scatter plots of water column chemistry results (daytime grabs) in O'Bannon Creek, 1998. Clockwise from top left: dissolved oxygen, dissolved oxygen percent saturation, total phosphorus and nitrate-nitrite-nitrogen. Dashed horizontal lines depict applicable Water Quality Standards in the dissolved oxygen plot, 100% D.O. saturation, and 90th percentile concentrations from reference sites of similar size in the Interior Plateau ecoregion for the total phosphorus and nitrate-nitrogen plots.

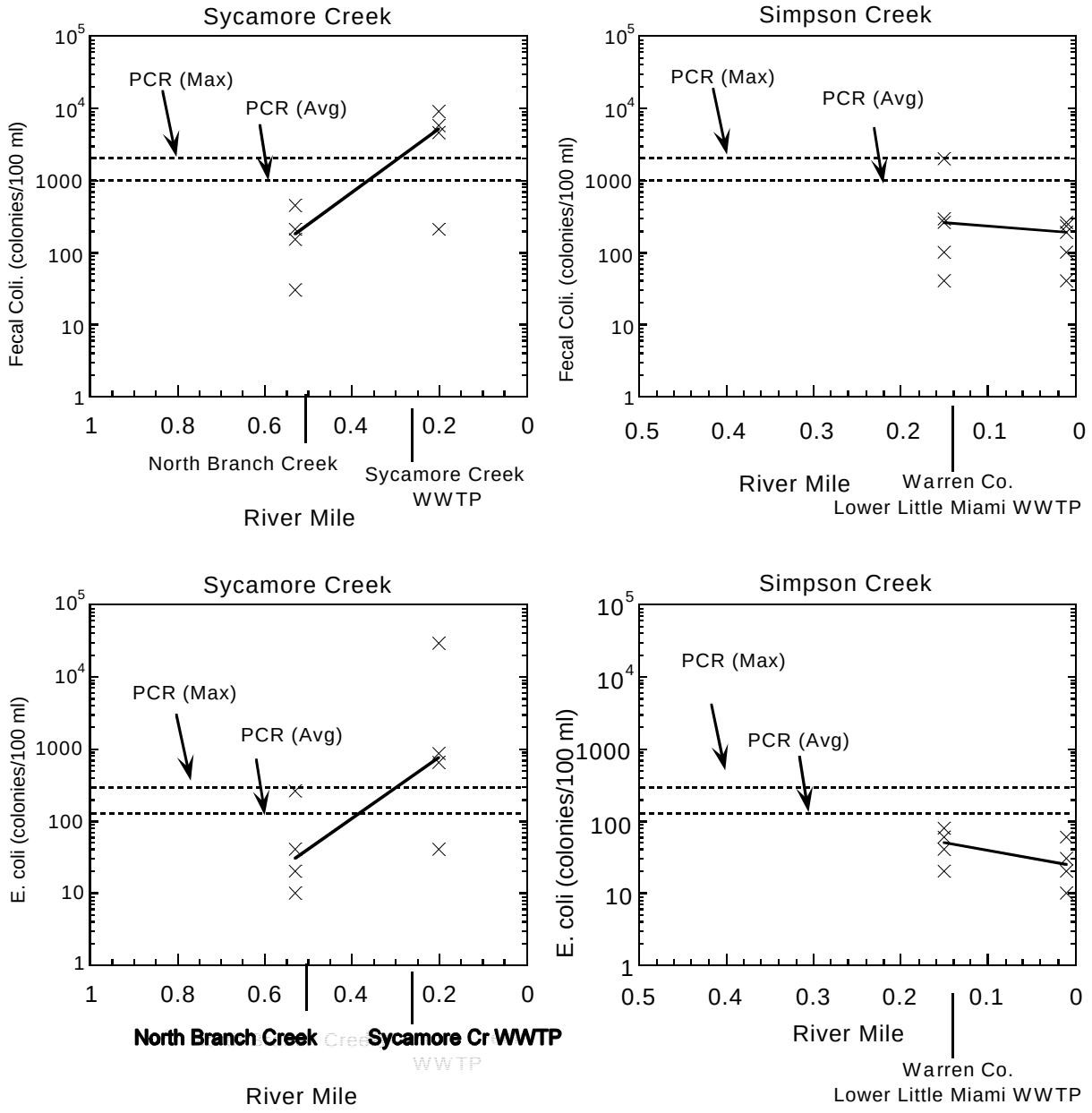



Figure 93. Longitudinal scatter plots of fecal coliform bacteria, and *Escherichia coli* in water quality samples (daytime grab) from Sycamore Creek, and Simpson Creek, 1998. Dashed horizontal lines depict the Primary Contact Recreation (PCR) Water Quality Standards.

Table 9. Exceedences of Ohio EPA water quality criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Little Miami River study area during 1998 (units are $\mu$g/l for metals and organics, µmhos/cm for conductivity, #colonies/100ml for fecal coliform and *E. coli*, and mg/l for all other parameters).

| Stream (use designation[a]) | River Mile | Parameter (value) |
|---|---|---|
| Little Miami River<br>(EWH, PCR, AWS) | 106.95 | Copper-T (35*)<br>D.O. (2.0[‡‡], 0.8[‡‡])<br>Iron-T (36400*[∞])<br>Manganese-T (4660***) |
| | 106.35 | D.O. (4.4[‡‡], 2.5[‡‡], 0.25[‡‡], 2.2[‡‡], 2.7[‡‡])<br>Iron-T (1280*, 2080*)<br>Manganese-T (931*, 246*, 357*)<br>Aldrin (0.0031[# J])<br>Dieldrin (0.0042[#], 0.0078*[#])<br>Endrin (0.0047*)<br>4,4'-DDT (0.0072*[#]) |
| | 104.88 | *E. coli* (*300*[″″])<br>Manganese-T (166*)<br>Dieldrin (0.0076*[#]) |
| | 101.30 | *E. coli* (1150[◊◊], 3300[◊◊], *500*[″″])<br>Fecal coliform (2500[◊◊], 2400[◊◊], *2900*[″″])<br>Manganese-T (113*) |
| | 98.98 | *E. coli* (187[◊], *308*[″″])<br>Dieldrin (0.0051*[#], 0.0060*[#]) |
| | 89.00 | Dieldrin (0.0053*[#], 0.0053*[# J]) |
| | 85.38 | *E. coli* (190[◊]) |
| | 83.14 | *E. coli* (*445*[″″])<br>Fecal coliform (6620[◊◊])<br>Dieldrin (0.0054*[#], 0.0056*[#]) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Little Miami River (continued) (EWH, PCR, AWS) | 80.63 | *E. coli* (300[◊◊], 155[◊])<br>Dieldrin (0.0029[#], 0.0059*[#]) |
| | 77.70 | *E. coli* (*140*[″])<br>Iron-T (1030*) |
| | 76.90 | Dieldrin (0.006*[#], 0.0061*[#])<br>Endosulfan II (0.0034*)<br>Endrin (0.0050*) |
| | 72.30 | *E. coli* (*240*[″])<br>Dieldrin (0.0039[#], 0.0075*[#])<br>Endosulfan II (0.0036*)<br>Endrin (0.0061*) |
| | 69.84 | *E. coli* (*140*[″], *220*[″])<br>Iron-T (1230*) |
| | 66.56 | *E. coli* (*140*[″])<br>Dieldrin (0.0035[#], 0.0061*[#])<br>Endosulfan II (0.0033*)<br>Endrin (0.0054*)<br>Heptachlor (0.0027*) |
| | 65.25 | *E. coli* (*190*[″]) |
| | 64.28 | *E. coli* (240[◊], 127[◊], *135*[″])<br>Iron-T (1220*)<br>Dieldrin (0.0057*[#], 0.0083*[# J])<br>Endosulfan II (0.0032*)<br>Endrin (0.0056*) |
| | 63.28 | *E. coli* (240[◊], *180*[″])<br>Iron-T (1060*)<br>Dieldrin (0.0055*[#], 0.0074*[#])<br>Endosulfan II (0.0036*)<br>Endrin (0.0054*) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Little Miami River (continued) (EWH, PCR, AWS) | 60.84 | *E. coli* (155◊)<br>Iron-T (1130*)<br>Aldrin (0.003#)<br>Dieldrin (0.0068*#, 0.0056*#)<br>Endosulfan II (0.0032*)<br>Endrin (0.0051*) |
| | 55.25 | D.O. (5.3‡)<br>*E. coli* (127◊, 136◊, *130″*)<br>Iron-T (1240*)<br>Dieldrin (0.0065*#, 0.0080*#)<br>Endosulfan II (0.0032*)<br>Endrin (0.0052*) |
| | 53.69 | *E. coli* (*140″*)<br>Dieldrin (0.0049#, 0.0091*#)<br>Endosulfan II (0.0038*)<br>Endrin (0.0057*) |
| | 35.98 | *E. coli* (*150″*)<br>Iron-T (1510*) |
| | 32.95 | *E. coli* (*140″*)<br>Iron-T (2110*) |
| | 31.96 | Iron-T (2060*)<br>Aldrin (0.0032#)<br>Dieldrin (0.0083*#, 0.0073*#)<br>Endosulfan II (0.0037*) |
| | 28.20 | Iron-T (1960*) |
| | 28.00 | Ammonia-N (0.60*L)<br>*E. coli* (*37500″″*)<br>Fecal coliform (*58000″″*)<br>Iron-T (1520*) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Little Miami River (continued) (EWH, PCR, AWS) | 24.35 | Iron-T (1170*, 2180*) |
| | 21.93 | Iron-T (1020*, 2060*) |
| | 21.45 | *E. coli* (*220*[″])<br>Iron-T (2550*)<br>Dieldrin (0.01*[#], 0.0066*[#]) |
| | 20.60 | Iron-T (2440*) |
| | 18.14 | Iron-T (1060*, 2400*) |
| | 13.07 | Iron-T (4100*)<br>Manganese-T (141*) |
| | 8.14 | Iron-T (7060*[∞])<br>Manganese-T (306*)<br>Aldrin (0.0042[#])<br>Dieldrin (0.011*[#], 0.0070*[#])<br>Endrin (0.0067*)<br>gamma-Hexachlorocyclohexane (0.011*) |
| Gilroy Ditch (WWH, SCR, AWS) | 0.50 | Ammonia-N (3.37*[B])<br>Dieldrin (0.0080*[# J]) |
| Lisbon Fork (WWH, PCR, AWS) | 0.40 | *E. coli* (260[◊], 380[◊◊])<br>Manganese-T (106*) |
| N.F. Little Miami River (WWH, PCR, AWS) | 7.15 | *E. coli* (248[◊]) |
| | 0.37 | Iron-T (2120*[M]) |
| Goose Creek (WWH, PCR, AWS) | 0.92 | *E. coli* (461[◊◊], 370[◊◊], *150*[″])<br>Manganese-T (212*, 184*, 132*) |
| Yellow Springs Creek (EWH, PCR, AWS) | 0.10 | *E. coli* (177[◊], *210*[″])<br>Dieldrin (0.0060*[# J]) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Jacoby Branch (WWH, PCR, AWS) | 0.50 | *E. coli* (270[◊], 460[◊◊], *395*[″″]) Fecal coliform (*2350*[″″]) |
| Conner Branch (WWH, PCR, AWS) | 0.16 | *E. coli* (330[◊◊]) |
| Massie Creek (WWH, PCR, PWS, AWS) | 7.71 | *E. coli* (7900[◊◊]) Dieldrin (0.0064*[# J]) |
| | 4.38 | *E. coli* (8670[◊◊]) Iron-T (2770*) Manganese-T (106*) |
| | 1.20 | *E. coli* (350[◊◊]) |
| | 0.26 | *E. coli* (320[◊◊], 270[◊], *200*[″]) Dieldrin (0.0062*[# J], 0.0032[#]) Endosulfan II (0.0034*) |
| North Fork Massie Creek (WWH, PCR, AWS) | 7.95 | D.O. (4.6[‡]) *E. coli* (200[◊]) Iron-T (1190*, 1130*) Manganese-T (214*, 173*, 120*) |
| | 1.17 | Dieldrin (0.0058*[# J], 0.0026[#]) |
| South Fork Massie Creek (WWH, PCR, AWS) | 2.15 | Manganese-T (319*) |
| | 0.14 | *E. coli* (230[◊]) |
| Tributary to Massie Creek @ RM 5.31 (undesignated) | 0.65 | *E. coli* (923[◊◊◊◊]) Fecal coliform (15300[◊◊◊◊]) |
| Clark Run (WWH, PCR, AWS) | 0.44 | *E. coli* (240[◊]) |
| Oldtown Creek (WWH, PCR, AWS) | 0.10 | *E. coli* (430[◊◊], 630[◊◊], *150*[″]) Iron-T (1850*) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Ludlow Creek (WWH, PCR, AWS) | 0.25 | *E. coli* (*250*[″], *210*[″]) |
| Shawnee Creek (WWH, PCR, AWS) | 0.65 | *E. coli* (*140*[″])<br>Iron-T (1660*)<br>Dieldrin (0.0056*[# J], 0.0020[#]) |
| Beaver Creek (WWH, PCR, AWS) | 6.30 | *E. coli* (420[◊◊], *250*[″])<br>Fecal coliform (1330[◊])<br>Manganese-T (116*, 103*, 166*, 118*) |
| | 3.86 | *E. coli* (400[◊◊], *220*[″])<br>Iron-T (2240*)<br>Manganese-T (134*, 146*, 117*, 118*, 109*) |
| | 1.57 | *E. coli* (360[◊◊], *320*[″″]) |
| | 0.50 | *E. coli* (430[◊◊], *150*[″], *220*[″]) |
| | 0.20 | *E. coli* (206[◊], *170*[″])<br>Dieldrin (0.0052*[#])<br>gamma-Hexachlorocyclohexane (0.013*) |
| Little Beaver Creek (WWH, PCR, AWS) | 6.23 | *E. coli* (*610*[″″])<br>Fecal coliform (6310[◊◊], 2300[◊◊], *2300*[″″]) |
| | 4.62 | Endosulfan I (0.0068*) |
| | 4.40 | *E. coli* (*160*[″], *2000*[″″])<br>Fecal coliform (1700[◊], *8900*[″″])<br>Dieldrin (0.010*[#])<br>Endrin (0.0063*)<br>gamma-Hexachlorocyclohexane (0.015*) |
| | 3.47 | *E. coli* (*160*[″], *340*[″″])<br>Fecal coliform ( *2500*[″″], *1100*[″]) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Little Beaver Cr.(Cont.) | 0.05 | *E. coli* (350◊◊)<br>Dieldrin (0.0074*#)<br>gamma-Hexachlorocyclohexane (0.012*) |
| Tributary<br>to Little Beaver Creek<br>@ RM 6.1 (WWH, SCR, AWS) | 0.15 | Fecal coliform (9670◊◊◊) |
| Sugar Creek<br>(WWH, PCR, AWS) | 2.13 | *E. coli* (*230*", *440*"", *220*") |
| | 0.40 | *E. coli* (*180*", *150*", *430*"")<br>Manganese-T (103*)<br>Dieldrin (0.0055*#)<br>Heptachlor (0.0055*#) |
| Little Sugar Creek<br>(WWH, PCR, AWS) | 0.45 | *E. coli* (*270*", *750*"")<br>Fecal coliform (*1200*") |
| Glady Run<br>(WWH, SCR, AWS) | 4.08 | Ammonia-N (0.81*F)<br>Dieldrin (0.0064*#)<br>Endrin (0.0059*)<br>gamma-Hexachlorocyclohexane (0.020*, 0.030*) |
| | 2.08 | Ammonia-N (1.20*B) |
| Mill Run<br>(WWH, PCR, AWS) | 1.74 | Manganese-T (174*) |
| Newman Run<br>(WWH, PCR, AWS) | 0.27 | *E. coli* (330◊◊, *130*") |
| Caesar Creek<br>(EWH, PCR, AWS-headwaters to RM 13.92)<br>(WWH, PCR, AWS-RM 13.92 to mouth) | 26.50 | *E. coli* (1080◊◊, 380◊◊)<br>Fecal coliform (1080◊)<br>Manganese-T (190*) |
| | 23.10 | *E. coli* (173◊, 155◊)<br>Iron-T (1560*) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Caesar Creek (continued) | 16.52 | D.O. (5.6[‡])<br>*E. coli* (195[◊◊], 700[◊◊], *310*[˝˝])<br>Iron-T (1290*, 3360*)<br>Dieldrin (0.006*[#]) |
| North Branch Caesar Creek<br>(EWH, PCR, AWS) | 6.66 | *E. coli* (*370*[˝])<br>Fecal coliform (*2400*[˝˝]) |
| | 1.23 | *E. coli* (204[◊], 290[◊], *210*[˝])<br>Iron-T (2080*, 1540*) |
| South Branch Caesar Creek<br>(WWH, PCR, AWS) | 8.23 | Ammonia-N (1.07*[L])<br>*E. coli* (923[◊◊], 33000[◊◊], *1040*[˝˝])<br>Fecal coliform (3300[◊◊], 1620[◊], 17000[◊◊], *5900*[˝˝]) |
| | 2.10 | *E. coli* (200[◊], *240*[˝]) |
| Anderson Fork<br>(WWH, PCR, AWS-headwaters to RM 11.02)<br>(EWH, PCR, AWS-RM 11.02-mouth) | 18.80 | D.O. (4.90[‡])<br>*E. coli* (136[◊], *290*[˝])<br>Iron-T (2540*, 1440*)<br>Manganese-T (212*) |
| | 13.87 | *E. coli* (350[◊◊], *190*[˝])<br>Iron-T (5300*[∞])<br>Dieldrin (0.0091*[#], 0.0066*[#]) |
| | 9.45 | D.O. (5.60[‡])<br>*E. coli* (440[◊◊])<br>Iron-T (3340*) |
| | 4.90 | *E. coli* (333[◊◊], 133[◊], *180*[˝])<br>Iron-T (3210*)<br>Dieldrin (0.0076*[#], 0.0030[#]) |
| Painters Creek<br>(EWH, PCR, AWS) | 0.43 | D.O. (5.4[‡], 5.0[‡])<br>*E. coli* (230[◊], 370[◊◊], *345*[˝˝])<br>Iron-T (1130*)<br>Manganese-T (153*, 159*, 136*) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Buck Run (WWH, PCR, AWS) | 1.18 | *E. coli* (367◊◊, *270*″) |
| | | Manganese-T (118*, 112*) |
| Trace Run (WWH, PCR, AWS) | 1.83 | *E. coli* (250◊) |
| | | Fecal coliform (2630◊◊) |
| Jonahs Run (WWH, PCR, AWS) | 1.32 | *E. coli* (*170*″) |
| | | Iron-T (1330*) |
| Flat Fork (WWH, PCR, AWS) | 1.70 | Iron-T (1300*) |
| | | Manganese-T (213*) |
| Todd Fork (EWH, PCR, AWS) | 19.50 | Dieldrin (0.0066*#) |
| | 15.17 | Dieldrin (0.0078*#) |
| | 0.14 | Dieldrin (0.0070*#) |
| Lytle Creek (WWH, PCR, AWS) | 9.25 | D.O. (4.80‡) |
| | | Copper-T (38**) |
| | | *E. coli* (*320*″″, *230*″) |
| | | Fecal coliform (*2200*″″) |
| | | Aldrin (0.0031#J) |
| | 7.01 | D.O. (4.00‡) |
| | | *E. coli* (*350*″″, *460*″″, *210*″) |
| | | Fecal coliform (*3300*″″) |
| | | Manganese-T (125*, 148*, 267*, 129*) |
| | 5.94 | Arsenic-T (175*∞, 101∞) |
| | | gamma-Hexachlorocyclohexane (0.021*, 0.021*J) |
| | | Dieldrin (0.017*#, 0.012*#J) |
| | | Heptachlor (0.0028*) |
| | 2.76 | *E. coli* (*390*″″) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Cowan Creek (WWH, PCR, AWS) | 13.20 | *E. coli* (*210*[″]) |
| | | Dieldrin (0.0086*[#]) |
| | 12.45 | D.O. (4.40[‡]) |
| | | *E. coli* (*230*[″], *240*[″]) |
| | | Fecal coliform (*5000*[″″]) |
| | | Iron-T (1530*) |
| | | Manganese-T (109*) |
| | | Aldrin (0.0035[#J]) |
| | | Dieldrin (0.0079*[#]) |
| | 10.95 | D.O. (4.50[‡]) |
| | | *E. coli* (*400*[″″]) |
| | | Iron-T (1630*) |
| | 8.38 | *E. coli* (*200*[″], *135*[″]) |
| | | Iron-T (1180*) |
| Indian Run (WWH, PCR, AWS) | 0.10 | Manganese-T (124*) |
| | | Dieldrin (0.0073*[#]) |
| East Fork Todd Fork (WWH, PCR, AWS) | 1.60 | Manganese-T (144*) |
| | | Dieldrin (0.0079*[#]) |
| | | Endosulfan II (0.0038*) |
| Muddy Creek (WWH, PCR, AWS) | 3.50 | *E. coli* (*200*[″]) |
| | | Manganese-T (682*) |
| | 2.50 | Conductivity (2480*) |
| | | *E. coli* (*270*[″], *140*[″]) |
| | | Dieldrin (0.0089*[#]) |
| | | Endrin (0.0068*) |
| | 0.70 | D.O. (4.00[‡]) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|
| Simpson Creek (WWH, PCR, AWS) | 0.15 | Fecal coliform (*2000*[″]) |
| | | Manganese-T (142*) |
| | 0.01 | Total Dissolved Solids (1530*) |
| | | Conductivity (2690*) |
| | | Endrin (0.0078*) |
| O'Bannon Creek (WWH, SCR, AWS) | 4.37 | Manganese-T (130*) |
| | 1.84 | gamma-Hexachlorocyclohexane (0.031*, 0.015*[J]) |
| | | Endrin (0.043*) |
| | 0.26 | pH (9.01[Δ]) |
| Sycamore Creek (WWH, PCR, AWS) | 0.53 | *E. coli* (260[◊]) |
| | 0.20 | *E. coli* (*29000*[″″], *650*[″″], *860*[″″]) |
| | | Fecal coliform (*4600*[″″], *5800*[″″], *9100*[″″]) |
| | | Aldrin (0.0074[#]) |
| | | Dieldrin (0.0090*[#]) |
| | | Endosulfan II (0.0036*) |

Table 9. Continued.

| Stream (use designation) | River Mile | Parameter (value) |
|---|---|---|

* exceedence of numerical criteria for prevention of chronic toxicity (CAC).
** exceedence of numerical criteria for prevention of acute toxicity (AAC).
*** exceedence of numerical criteria for prevention of lethality (FAV).
\# exceedence of numerical criteria for the protection of human health (non-drinking).
‡ value is below the minimum 24-hour average warmwater habitat dissolved oxygen (D.O.) criterion (5.0 mg/l) or value is below the minimum 24-hour average exceptional warmwater habitat D.O. criterion (6.0 mg/l) as applicable.
‡‡ value is below the minimum warmwater habitat D.O. criterion (4.0 mg/l) or value is below the minimum exceptional warmwater habitat D.O. criterion (5.0 mg/l) as applicable.
◊ value is above the average Primary Contact Recreation (PCR) criteria (See note *b* below). (fecal coliform 1000/100ml; *E. coli* 126/100ml)
◊◊ value is above the maximum Primary Contact Recreation (PCR) criteria (See note *b* below). (fecal coliform 2000/100ml; *E. coli* 298/100ml)
◊◊◊ value is above maximum Secondary Contact Recreation (SCR) criteria (See note *b* below) (fecal coliform 5000/100ml; *E. coli* 576/100ml)
◊◊◊◊ value is above maximum criteria applicable to all waters (See note *b* below) (fecal coliform 5000/100ml; *E. coli* 576/100ml)
Δ exceedence of the pH criteria (6.5-9.0).
∞ exceedence of agricultural water supply criterion.
J Analyte result is estimated due to not meeting quality control criteria for the sample.
B Ammonia exceedence is based on both field and laboratory analyzed pH.
F Ammonia exceedence is based on field field analyzed pH.
L Ammonia exceedence is based on laboratory analyzed pH.
M Modeling water chemistry grab samples.

Notes:

*a* Use designations:

| Aquatic Life Habitat | Water Supply | Recreation |
|---|---|---|
| EWH - exceptional warmwater habitat | AWS - agricultural water supply | PCR - primary contact |
| WWH - warmwater habitat | | SCR - secondary contact |

*b* Bacteriological data (fecal coliform, *E. coli*) are shown only to gauge the potential for impacts to the receiving stream and do not represent actual exceedences of criteria. Actual exceedences of the average recreational criteria (PCR) are based on a geometric mean of not less than five samples within a thirty-day period whereas maximum criteria (PCR and SCR) represent the values that are not to be exceeded in more than ten percent of the samples in a thirty-day period. Requriments associated with the criteria applicable to all waters include: ata least two or more samples must exceed criteria when five or fewer samples are collected, or criteria must be exceeded in more than twenty percent of the samples when more than five samples are taken. [Additionally, italicized values indicate samples that were not analyzed within required holding time, and are included to only to gauge potential for impacts.

Table 10. Number of exceedences of Ohio EPA water quality criteria (OAC 3745-1) for dissolved oxygen (D.O.), and minimum D.O. values measured by Datasondes® during hourly diel sampling of the Little Miami River basin, 1998.

| Stream (Use Designation[1]) | RM | Number of Measurements Below Minimum at Any Time Criteria† | Minimum D.O. Value Recorded |
|---|---|---|---|
| Little Miami River | 106.95 | 45† | 0.74 |
| (EWH, PCR, AWS) | 106.35 | 48† | 0.45 |
| | 103.10 | 44† | 1.95 |
| | 101.30 | 23 | 2.35 |
| | 98.98 | 19 | 1.65 |
| | 95.00 | 17 | 4.56 |
| | 93.50 | 6 | 4.76 |
| | 89.00 | 1 | 4.96 |
| | 77.70 | 18 | 4.02 |
| | 60.84 | 9 | 4.02 |
| Gilroy Ditch | 1.45 | 10 | 3.40 |
| (WWH, SCR, AWS) | 0.50 | 19† | 0.43 |
| | 0.01 | 21 | 1.19 |
| Massie Creek | 7.16 | 7 | 3.51 |
| (WWH, PCR, PWS, AWS) | | | |
| Caesar Creek | 16.50 | 13 | 4.27 |
| (EWH, PCR, AWS-headwaters to RM 13.92) | | | |
| Lytle Creek | 7.01 | 28† | 2.84 |
| (WWH, PCR, AWS) | | | |
| Cowan Creek | 13.20 | 31† | 2.21 |
| (WWH, PCR, AWS) | 12.45 | 24 | 2.44 |

† Represents an exceedence of the use specific minimum 24-hour average WQS criteria.
[1] See Table 9 for explanation of abbreviations.

**Chemical Water Quality Changes**

*Little Miami River*

Nineteen years (1980-1998) of monthly ambient monitoring conducted in the Little Miami River at US 68 (RM 80.63) as part of the National Ambient Water Quality Monitoring Network (NAWQMN) is summarized for six parameters in Figure 94. All dissolved oxygen concentrations (daytime grabs) recorded during the period were above EWH minimum criteria. Concentrations of ammonia-N were generally low throughout the period with 80% of values at or below the minimum detection limit of 0.05 mg/l and an overall median of 0.05 mg/l. Maximum ammonia-N values were recorded in November of 1980 (2.15 mg/l) and March of 1997 (1.00 mg/l). While the majority (70%) of nitrate-nitrite values recorded at the site were less than or equal to the 90$^{th}$ percentile concentration (4.84 mg/l) for wadeable reference sites in the ECBP ecoregion, somewhat higher values were recorded in latter years compared to earlier years with overall medians increasing from 3.73 mg/l (1980-1988) to 4.31 mg/l (1989-1998). Phosphorus concentrations at the site have generally remained low with an overall median of 0.09 mg/l recorded for the nineteen year period and the majority (90%) of values less than or equal to the 90$^{th}$ percentile concentration (0.22 mg/l) for wadeable reference sites in the ECBP ecoregion. Median total suspended solids (TSS) at the site ranged from less than the MDL of 5 mg/l (1987, 1992, and 1995) to 15 mg/l in 1981 with higher concentrations typically coinciding with high flow days, indicative of impacts associated with non-point runoff in the basin. Additionally, concentrations of fecal coliform measured at the site were generally low with 84% of values less than the maximum Primary Contact Recreation criterion (2000 colonies/100 ml).

Ohio EPA previously conducted an intensive biological and water quality study of the mainstem Little Miami River in 1993. May through September stream flows for 1998 and 1993 as measured by USGS gage stations in the Little Miami River near Oldtown (RM 80.63) and at Milford (RM 13.07) are compared in Figure 95. While 1998 mean daily flows from May through most of June generally exceeded 1993 flows for the same period in both the upper and lower basins, several significant storm events in the upper basin pushed 1993 flows well above average in late June and throughout July with levels measured at the Oldtown gage on water chemistry sampling days ranging from 70 to 340 cfs (median 123 cfs) compared to 1998 values ranging from 71 to 103 cfs (median 86 cfs) for the same period. Flows measured in the lower basin at the Milford gage in 1993 on sampling days for this same period ranged from 293 to 2500 cfs (median 634 cfs) compared to 1998 values ranging from 735 to 1600 cfs (median 874 cfs). Subsequent flows moderated in August and September with mean monthly flows dropping below average in both 1993 and 1998 at both gages. Mean daily flows at the Oldtown gage on sampling days during this latter period were similar during the two survey years, ranging from 18 to 40 cfs (median 24 cfs) in 1993 compared to 1998 values ranging from 21 to 41 cfs (median 28 cfs). Flows measured in the lower basin at the Milford gage on sampling days in August and September were generally higher in 1998 with values ranging from 175 to 281 cfs (median 217 cfs) compared to 1993 values ranging from 128 to 199 cfs (median 171 cfs).

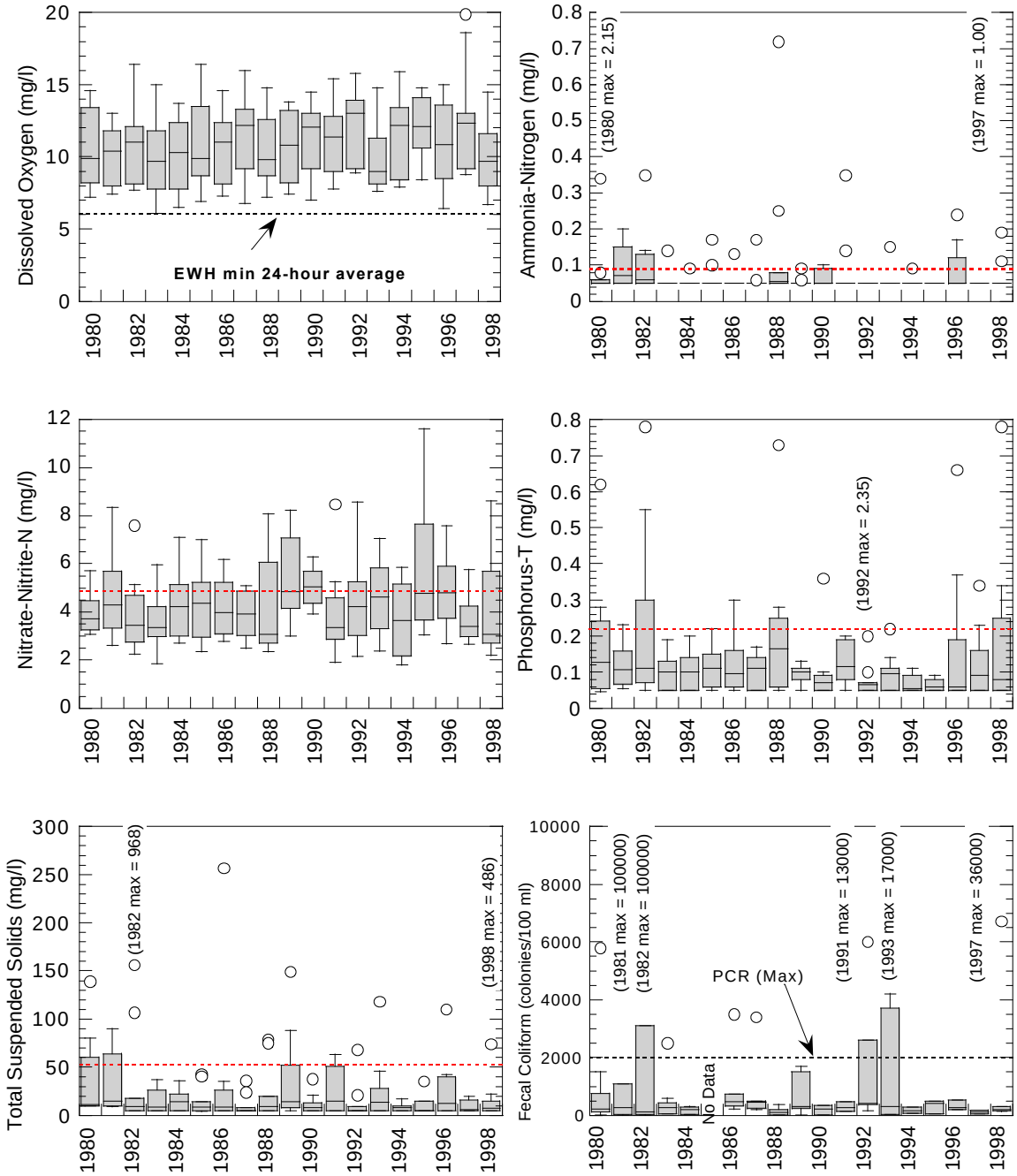



Figure 94. Yearly distributions of water quality parameters from monthly ambient monitoring at the US 68 NAWQMN station. Left to right from the top: dissolved oxygen, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, total suspended solids, and fecal coliform bacteria. Dashed horizontal lines show 90$^{th}$ percentile reference ranges for the Eastern Corn Belt Plain ecoregion unless otherwise indicated.

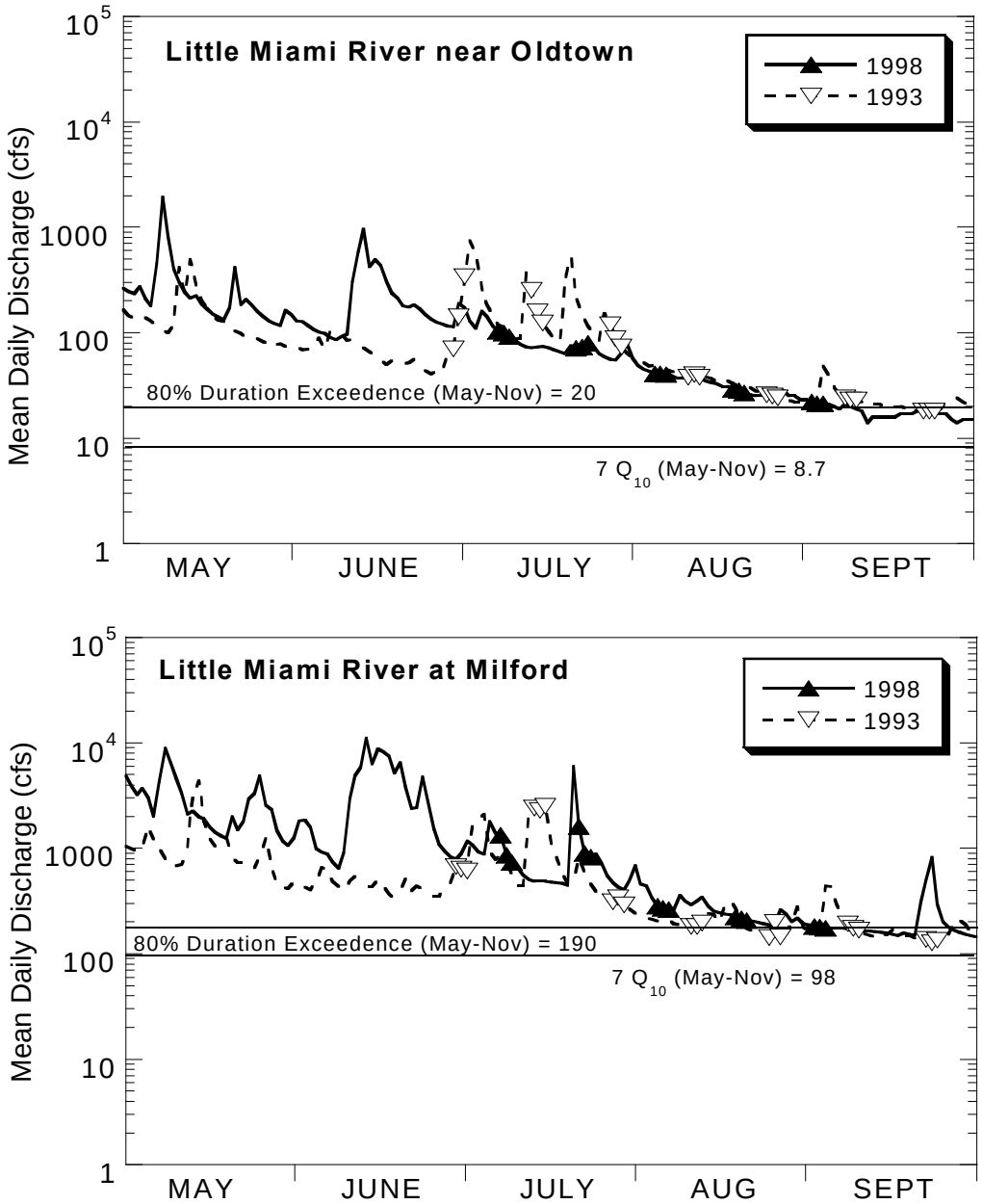



Figure 95. Flow hydrographs for the Little Miami River, 1998 and 1993, from the USGS gauging stations at Oldtown (upper panel) and Milford (lower panel). Markers show water chemistry sampling dates.

A comparison of 1998 and 1993 water chemistry results for select parameters is presented in Figures 96 and 97. Water samples were collected at thirty-seven (37) sites in the mainstem during the 1998 survey compared to thirty-four (34) sites in the 1993 survey with twenty-one (21) sites common to both surveys.

Most dissolved oxygen concentrations (daytime grabs) were above EWH criteria during both surveys. The lowest values in both 1993 and 1998 were measured in the headwater region. Higher 1998 median concentrations (8.0 mg/l and 8.8 mg/l, respectively) were measured upstream (RM 101.30) and downstream (RM 98.98) of the Gilroy Ditch confluence compared to 1993 values (4.65 mg/l and 6.5 mg/l, respectively). With the exception of this uppermost reach (RMs 106.95 - 98.98), D.O. concentrations were relatively comparable with median values ranging from 7.1 mg/l to 9.2 mg/l in 1993 and from 6.7 mg/l to 9.6 mg/l in 1998.

Excluding 1993 wastewater treatment plant mixing zone sites, concentrations of ammonia-N recorded during both surveys were relatively comparable with medians at most sites approaching the MDL of 0.05 mg/l. Median ammonia-N concentrations downstream of the Sugarcreek WWTP (RM 64.28) decreased from 0.09 mg/l in 1993 to 0.05 mg/l in 1998 while median values downstream of the Lebanon WWTP (RM 31.96) dropped from 0.11 mg/l to 0.05 mg/l. The highest median ammonia-N concentration (0.14 mg/l) for either survey (non-mixing zone) was measured downstream of Paygro at RM 106.35 during the 1998 survey.

Median concentrations of both nitrate-nitrite-N and total phosphorus at common sites in the upper basin (RMs 101.30-63.28) were generally lower in 1998 compared to 1993. The reverse held true of common sites in the lower basin (RMs 47.50-8.14) with 1998 medians typically greater than 1993 values. The median nitrate-nitrite-N and total phosphorus concentrations recorded at the ten sites common to both surveys in the upper basin (RMs 101.30-63.28) were not significantly different (Figures 96 and 97). Conversely, 1998 overall nitrate-nitrite-N and total phosphorus medians recorded at the remaining eleven (11) common sites in the lower basin (RMs 47.50-8.14) increased (from 2.84 mg/l to 3.16 mg/l, and 0.31 mg/l to 0.39 mg/l, for $NO_x$ and TP, respectively). Consistent with the cumulative impact of nutrient loading from numerous point sources, total phosphorus increased markedly downstream of the confluence with Beaver Creek in both survey years and persisted at these higher levels throughout the remainder of the mainstem.

Median 1998 concentrations of total suspended solids, generally lower than 1993 values at sites common to both surveys from RMs 101.30-47.50, increased above 1993 levels from RMs 43.76-28.00 before again declining below 1993 median levels in the remainder of the mainstem (RMs 21.45-8.14). Elevated individual concentrations typically coincided with higher flow days in both years. The overall median for all TSS concentrations recorded at the twenty-one (21) common sites in the mainstem declined from 23 mg/l in 1993 to 17 mg/l in 1998.

Median concentrations of both fecal coliform and *E. coli* were generally significantly lower at common sites during the 1998 survey compared to 1993. The most notable decreases occurred upstream of Gilroy Ditch at Clifton Road (RM 101.30), upstream of Yellow Springs Creek at

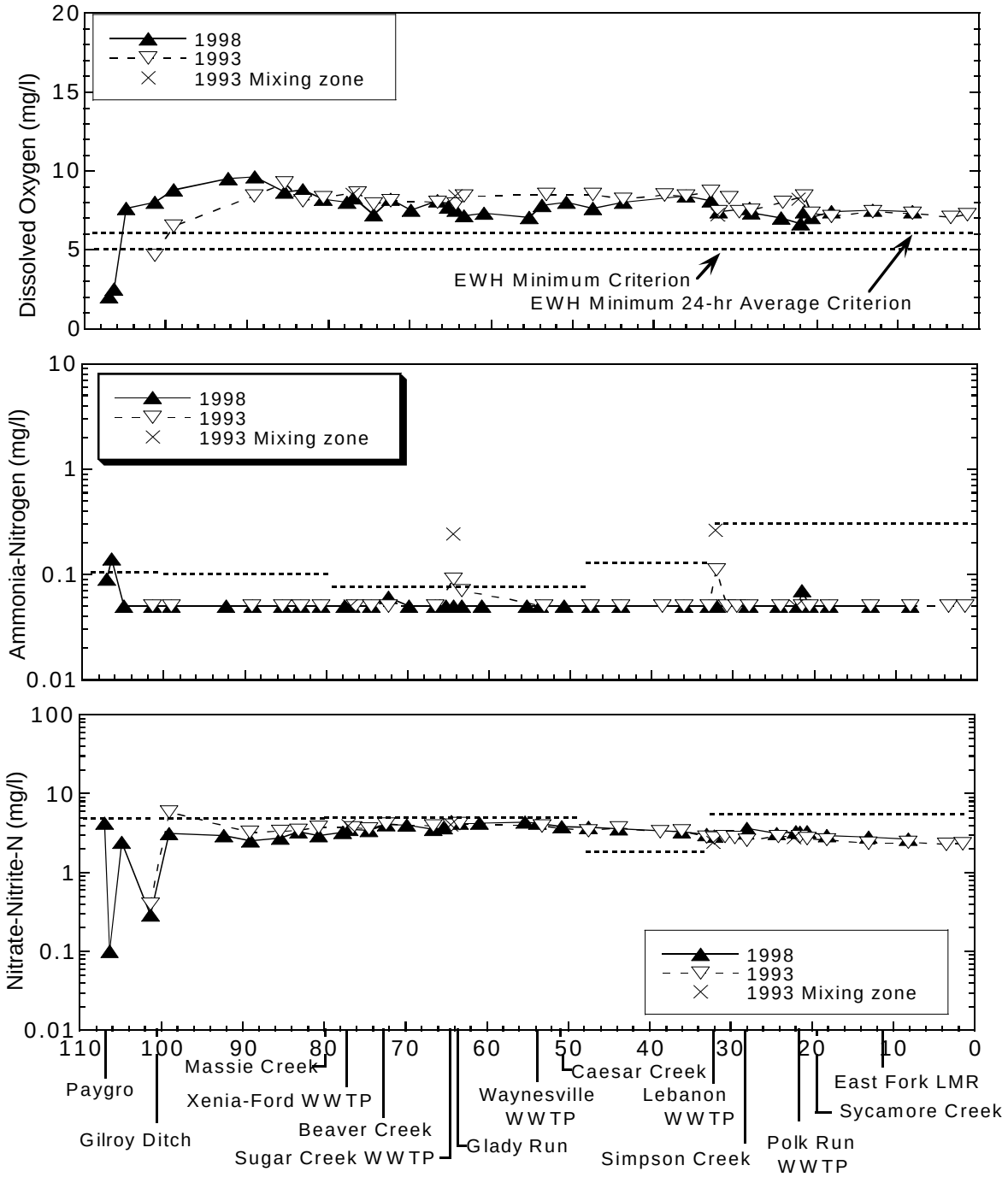



Figure 96. Median concentrations of dissolved oxygen, ammonia-nitrogen, and nitrate-nitrogen in the Little Miami River, 1998 and 1993). Dashed horizontal lines show the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plain ecoregion unless otherwise noted.

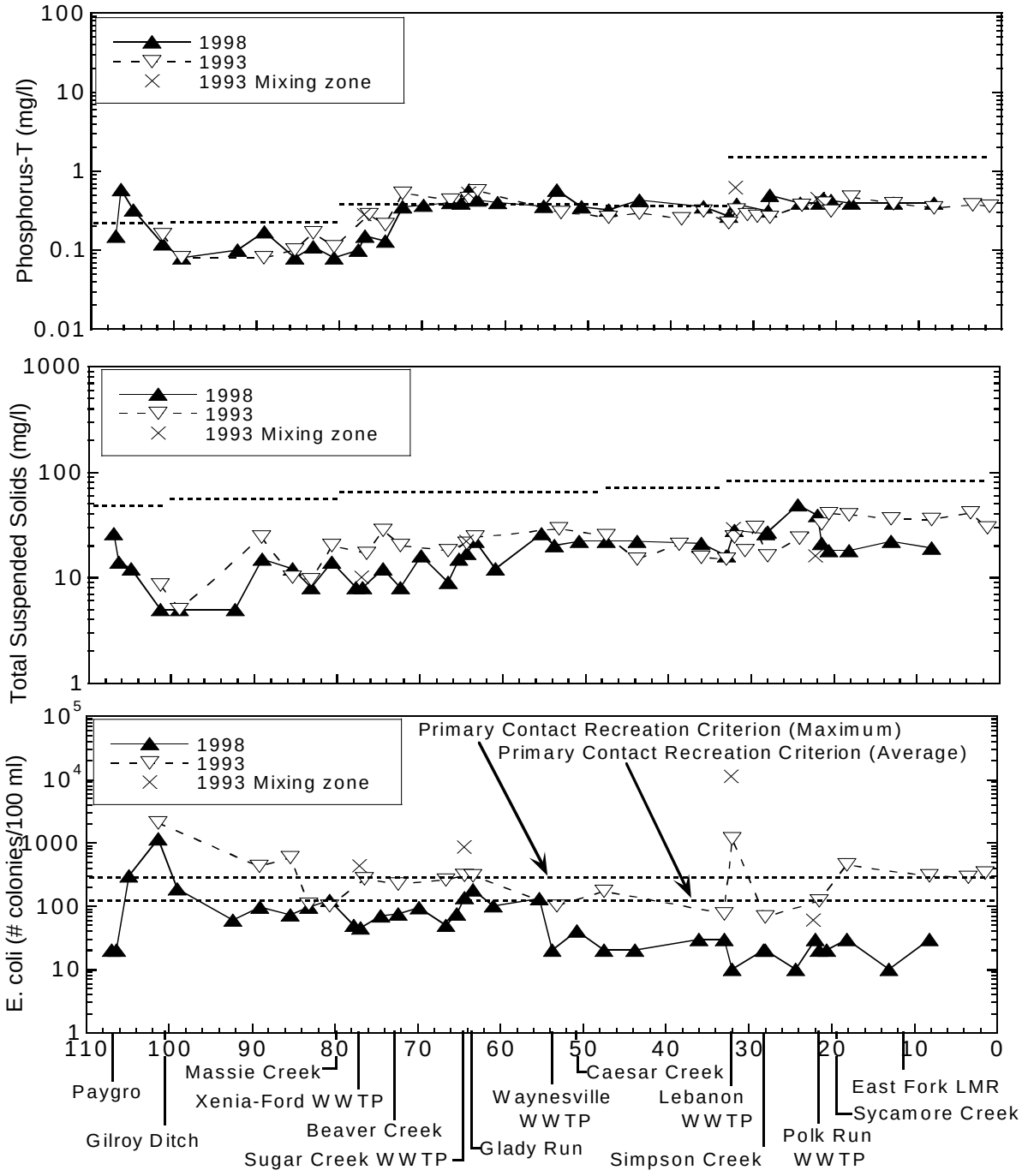



Figure 97. Median concentrations of total phosphorus and total suspended solids, and number of *Esterichia coli* colonies in the Little Miami River, 1998 and 1993. Dashed horizontal lines show the 90th percentile concentrations from reference sites of similar size in the Eastern Corn Belt Plain ecoregion unless otherwise noted.

Grinnel Road (RM 85.38 ), and downstream of the Lebanon WWTP (RM 31.96). The overall median for all fecal coliform concentrations recorded at common sites in the mainstem declined from 340 colonies/100 ml in 1993 to 197 colonies/100 ml in 1998 while the corresponding overall median for all *E. coli* concentrations dropped from 240 colonies/100 ml to 60 colonies/100 ml.

*Yellow Springs Creek*

Water chemistry samples, collected at RM 0.10 in Yellow Springs Creek during both the 1998 and 1993 intensive biological and water quality surveys (Figure 98), indicate minimal variation in most parameter median concentrations. Median dissolved oxygen at the site approached 9.0 mg/l in both years while ammonia-N and TSS medians remained below applicable MDLs (0.05 mg/l and 5 mg/l, respectively). While nitrate-nitrite-N concentrations remained relatively stable with respective 1998 and 1993 medians of 4.22 mg/l and 4.35 mg/l, a significant improvement was observed in phosphorus levels with the 1998 median concentration declining to 0.18 mg/l from 0.415 mg/l measured in 1993. Higher median concentrations of both fecal coliform and *E. coli* were measured in 1998 (219 and 177 colonies/100 ml, respectively) compared to 1993 (145 and 98 colonies/100 ml, respectively).

*Oldtown Creek*

One site (RM 0.10) was sampled in this tributary during both the 1998 and 1993 surveys (Figure 98). Dissolved oxygen concentrations remained well above WWH minimum criteria in both years with respective 1998 and 1993 median values of 9.1 mg/l and 9.8 mg/l while median concentrations of ammonia-N and TSS at the site remained below applicable MDLs (0.05 mg/l and 5 mg/l, respectively). Nitrate-nitrite-N medians increased from 3.82 mg/l in 1993 to 5.65 mg/l in 1998 while median total phosphorus increased from 0.05 mg/l to 0.10 mg/l. Bacteriological results (fecal coliform and *E. coli*) were also typically higher in 1998 compared to 1993 levels with fecal coliform medians increasing from 155 to 495 colonies/100 ml and *E coli* medians increasing from 155 to 430 colonies/100 ml.

*Beaver Creek*

Water samples were collected at five sites in this tributary during the 1998 survey compared to four sites (including one mixing zone) during the 1993 survey (Figure 99). Two sites (RMs 1.57 and 0.20) were common to both surveys. Median concentrations of dissolved oxygen at the two common sites, upstream of the Little Beaver Creek at RM 1.57 and downstream of the Beaver Creek WWTP at RM 0.20, were comparable, approximating 8 mg/l while median ammonia-N remained less than the MDL of 0.05 mg/l in both survey years.

Concentrations of nitrate-nitrite-N recorded in 1998 at common sites generally mirrored 1993 values with medians at RM 1.57 decreasing from 1.92 mg/l in 1993 to 1.87 mg/l in 1998 while values downstream at RM 0.20 declined from 5.75 mg/l to 5.34 mg/l. While the 1998 median concentration of total phosphorus at RM 1.57 (0.13 mg/l) was marginally higher compared to 1993 (0.07 mg/l), median values downstream of the Beaver Creek WWTP at RM 0.20 approached 1.0 mg/l in both survey years.

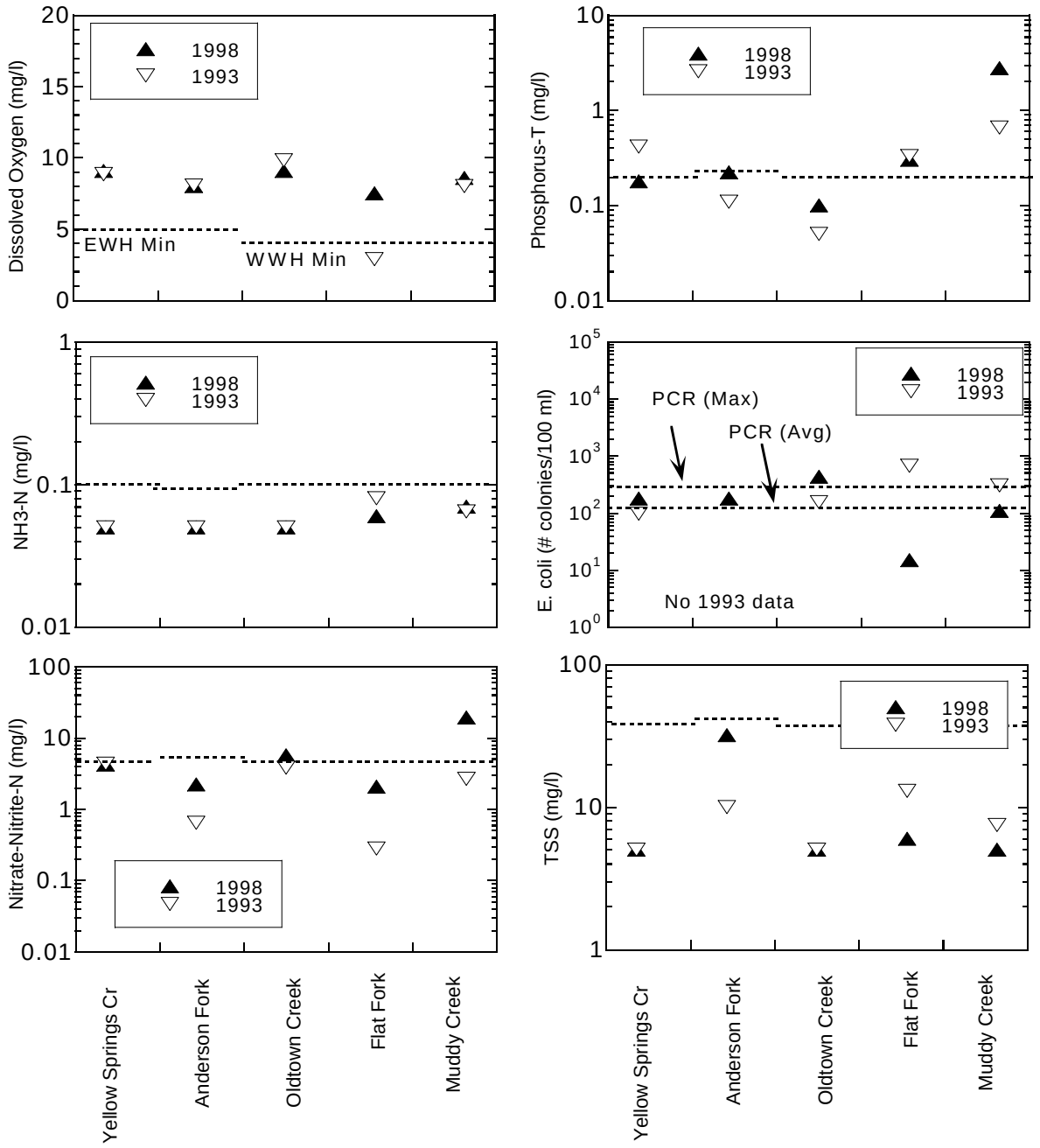



Figure 98. Median concentrations of dissolved oxygen, total phosphorus, ammonia-nitrogen, *E. coli*, nitrate-nitrate-nitrogen, and total suspended solids in selected small streams in the Little Miami River catchment, 1998 and 1993. Dashed horizontal lines show the 90th percentile concentration for ecoregion reference sites of similar size unless otherwise noted.

Median TSS concentrations upstream of the Little Beaver Creek at RM 1.57 ranged from 12 mg/l in 1993 to 14 mg/l in 1998 while medians downstream at RM 0.20 decreased from 8 mg/l in 1993 to 5 mg/l in 1998. While bacteriological sampling at common sites generally indicated lower values in 1998 compared to 1993, median fecal coliform concentrations measured at RM 0.20 increased from 170 to 353 colonies/100 ml from 1993 to 1998. *E. coli* medians at the site, however, decreased from 200 to 170 colonies/100 ml from 1993 to 1998. Fecal coliform medians at RM 1.57 decreased from 520 to 480 colonies/100 ml from 1993 to 1998 while *E. coli* medians at the site decreased from 530 to 340 colonies/100 ml.

*Little Beaver Creek*

Water samples were collected from five sites (including one mixing zone) in 1993 in Little Beaver Creek and six sites in 1998 (Figure 100). Three locations (RMs 4.62, 1.95, and 0.05) were common to both surveys. With the exception of RM 1.95 where median D.O. concentrations remained constant at 6.7 mg/l during both survey years, D.O. values at common sites decreased in 1998 with medians upstream of the Montgomery County Eastern Regional WWTP (RM 4.62) falling from 10.6 mg/l in 1993 to 7.4 mg/l in 1998 and medians near the mouth (RM 0.05) declining from 8.5 mg/l to 8.0 mg/l.

Ammonia-N medians recorded at common sites downstream (RMs 1.95 and 0.05) approached 0.05 mg/l during both survey years and medians at RM 4.62 increased from 0.05 mg/l in 1993 to 0.09 mg/l in 1998. The highest median ammonia-N concentration (0.37 mg/l) for either survey was measured downstream of Montgomery County Eastern Regional WWTP at RM 4.40 during the 1998 survey. Nitrate-nitrite-N and total phosphorus, similar longitudinally, increased downstream of the Montgomery County Eastern Regional WWTP and remained elevated through RM 0.05 in both survey years. Median nitrate-nitrite-N upstream of the WWTP at RM 4.62 decreased from 0.73 mg/l in 1993 to 0.62 mg/l in 1998. Higher nitrate-nitrite-N values were measured in 1998 at common sites downstream with medians at RMs 1.95 increasing from 4.64 mg/l in 1993 to 6.06 mg/l in 1998 and RM 0.05 medians increasing from 4.68 mg/l to 5.18 mg/l. Longitudinally, 1998 phosphorus medians generally mirrored those recorded in the previous survey. Median phosphorus at common sites ranged from 0.07 mg/l (RM 4.62) to 1.15 mg/l (RMs 1.95 and 0.05) in 1993 while 1998 medians ranged from 0.11 mg/l (RM 4.62) to 1.36 mg/l (RM 1.95).

Median total suspended solids concentrations remained below the MDL of 0.05 mg/l at all three common sites during both surveys. Bacteriological medians at sites sampled only in 1998 (RMs 6.23, 4.40, and 3.47) were generally elevated with fecal coliform ranging from 725 to 2300 colonies/100 ml and *E. coli* medians of 250 to1080 colonies/100 ml. These values at common sites were generally somewhat lower in 1998 compared to 1993. Median fecal coliform at common sites ranged from 223 colonies/100 ml (RM 4.62) to 473 colonies/100 ml (RM 0.05) in 1998 compared to 1993 values ranging from 310 colonies/100 ml (RM 4.62) to 540 colonies/100 ml (RM 0.05). Similarly, 1998 median *E. coli* values at common sites ranged from 45 colonies/100 ml (RM 4.62) to 190 colonies/100 ml (RM 0.05). Medians in 1993 ranged from 210 colonies/100 ml (RM 4.62) to 390 colonies/100 ml (RM 0.05).

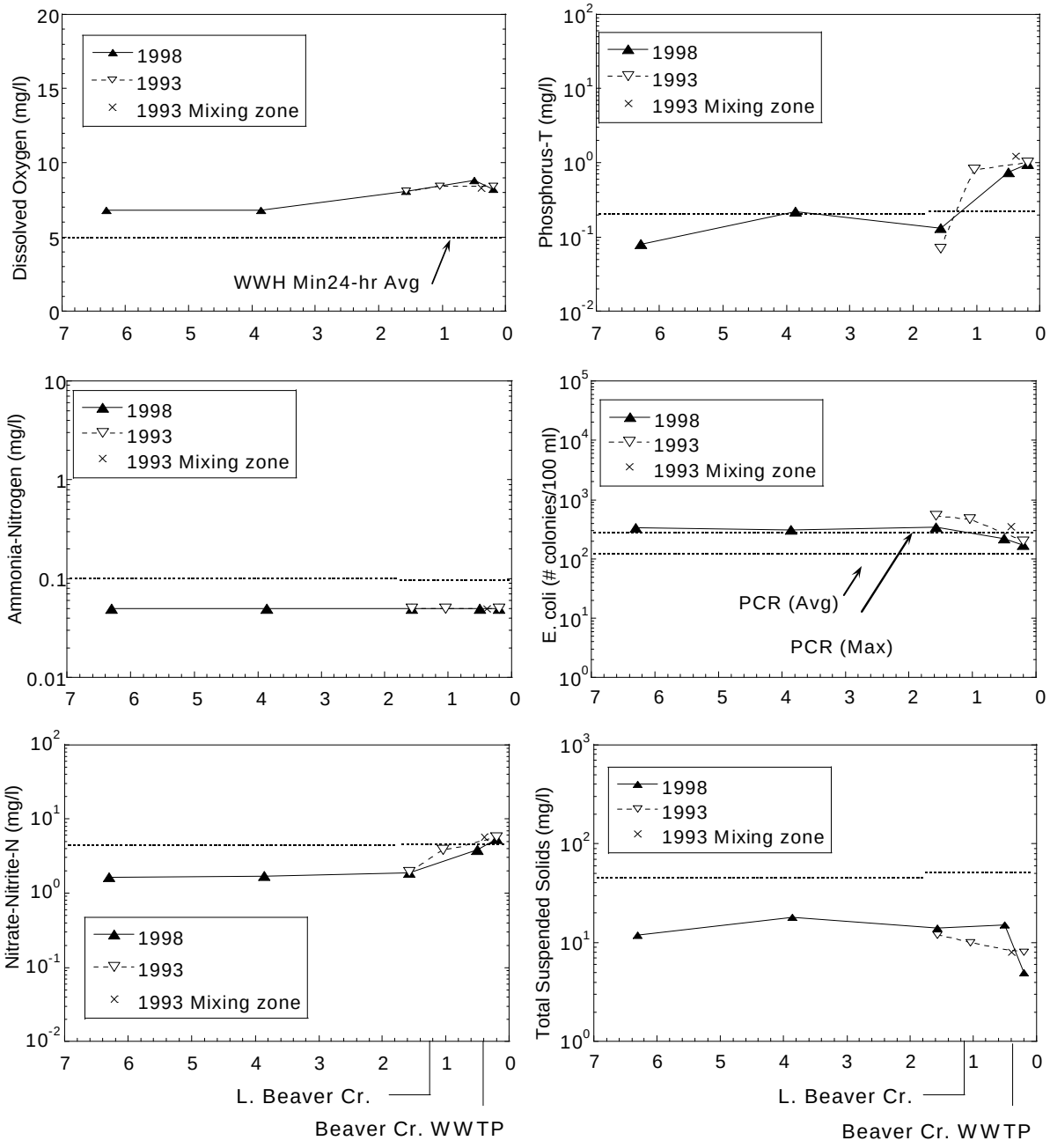



Figure 99. Median concentrations of dissolved oxygen, total phosphorus, ammonia-nitrogen, *E. coli*, nitrate-nitrate-nitrogen, and total suspended solids in Beaver Creek, 1998 and 1993, in relation to the confluence of Little Beaver Creek and the Greene County Beaver Creek WWTP. Dashed horizontal lines show the 90th percentile concentration for ecoregion reference sites of similar size unless otherwise noted.

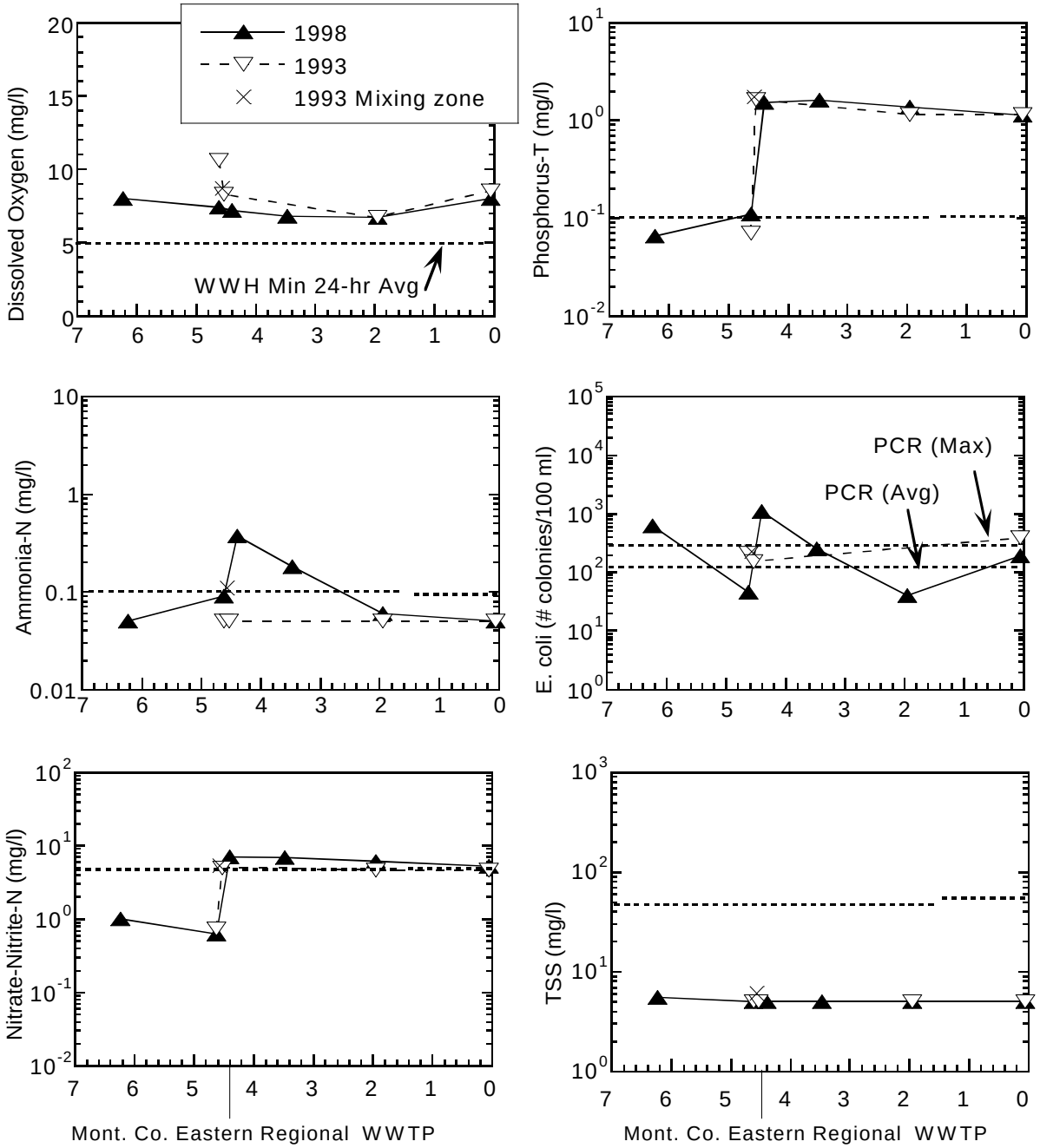



Figure 100. Median concentrations of dissolved oxygen, total phosphorus, ammonia-nitrogen, *E. coli*, nitrate-nitrate-nitrogen, and total suspended solids in Little Beaver Creek, 1998 and 1993, in relation to the Montgomery County Eastern Regional WWTP. Dashed horizontal lines show the 90th percentile concentration for ecoregion reference sites of similar size unless otherwise noted.

*Glady Run*

Water samples were collected at three sites (RMs 4.99, 4.08, and 2.08) in this tributary during the 1998 survey compared to two sites (RMs 4.75 and 0.60) in 1993 (Figure 101). Dissolved oxygen concentrations remained above WWH minimum criteria at all sites during both surveys with 1998 median concentrations ranging from 7.5 mg/l (RM 4.08) to 8.6 mg/l (RMs 4.99 and 2.08) and 1993 medians of 7.3 mg/l and 10.5 mg/l measured at RMs 4.75 and 0.60, respectively.

Median ammonia-N concentrations remained low during both surveys with the highest value (0.08 mg/l) recorded downstream of the Xenia Glady Run WWTP at RM 4.08 in 1998. Median concentrations of nitrate-nitrite-N and total phosphorus at sites downstream of the WWTP were elevated during both surveys. Respective 1998 nitrate-nitrite-N and total phosphorus medians decreased from 8.91 mg/l and 1.1 mg/l at RM 4.08 to 6.74 mg/l and 0.94 mg/l at RM 2.08. Similarly, 1993 respective medians for nitrate-nitrite-N and total phosphorus decreased from 8.85 mg/l and 1.05 mg/l at RM 4.75 to 6.79 mg/l and 0.56 mg/l at RM 0.60.

Total suspended solids concentrations remained low during both survey years with the highest median values reported in 1993 (8 mg/l at both RMs 4.75 and 0.60). Fecal coliform and *E. coli* medians remained below secondary contact recreation criteria in both 1998 and 1993. Median fecal coliform ranged from 270 to 540 colonies/100 ml in 1998 compared to medians ranging from 228 to 540 colonies in 1993. *E. coli* medians ranged from 120 to 220 colonies/100 ml in 1998 compared to 1993 medians ranging from 270 to 490 colonies/100 ml.

*Caesar Creek*

This tributary to the Little Miami River was sampled in 1998 at four sites (RMs 26.50, 23.10, 16.52, and 0.15). Two of these locations (RMs 16.52 and 0.15) were also sampled during the 1993 survey (Figure 102). Dissolved oxygen at common sites increased longitudinally from RM 16.52 to 0.15 in both survey years with respective medians ranging from 7.3 mg/l to 9.1 mg/l in 1998 and from 7.2 mg/l to 8.3 mg/l in 1993. (Individual D.O. concentrations dropped below EWH minimum criteria at RM 16.52 during both the 1998 and 1993 surveys.)

Median ammonia-N concentrations remained below the MDL of 0.05 mg/l at all sites during both survey years. Nitrate-nitrite-N and total phosphorus medians generally increased in 1998 over 1993 values at common sites. Nitrate-nitrite-N medians of 2.34 mg/l and 3.25 mg/l were measured in 1998 at RMs 16.52 and 0.15, respectively, compared to 1993 medians of 1.85 mg/l and 3.04 mg/l. Total phosphorus medians at RM 16.52 increased from 0.11 mg/l in 1993 to 0.23 mg/l in 1998 while medians remained relatively stable at RM 0.15 with 0.06 mg/l measured at the site in 1993 compared to 0.07 mg/l in 1998. Total suspended solids concentrations were significantly higher at RM 16.52 during the 1998 survey with median concentrations increasing from 6.5 mg/l in 1993 to 20 mg/l in 1998. Median TSS measured at RM 0.15 remained less than the MDL of 5 mg/l during both survey years. Fecal coliform medians at RM 16.52 increased from 80 colonies/100 ml in 1993 to 301 colonies/100 ml in 1998. Similarly, *E. coli* medians at the site increased from 90 colonies/100 ml in 1993 to 310 colonies/100 ml in 1998. (Bacteriological samples were not collected at RM 0.15 in 1993.)

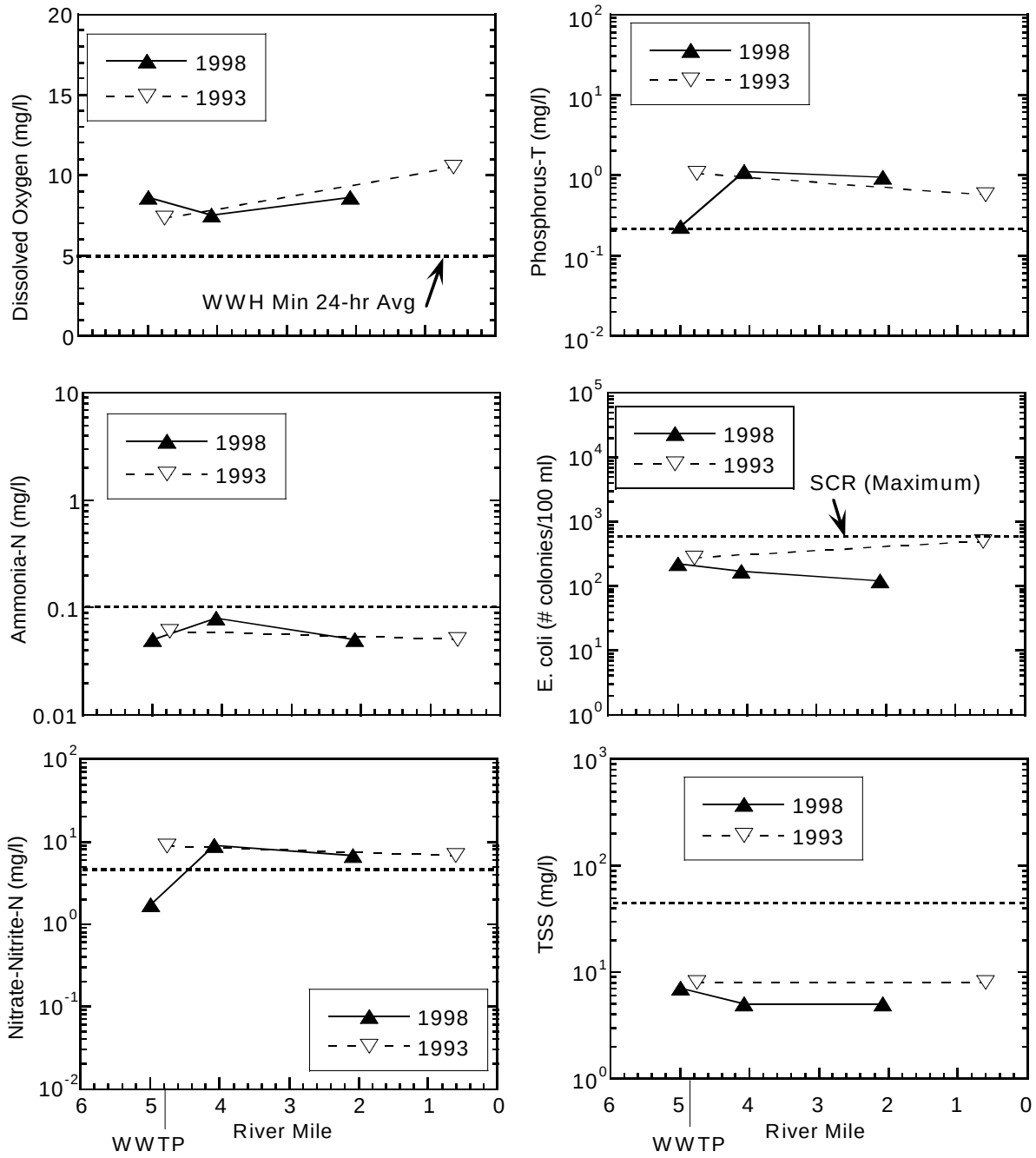



Figure 101. Median concentrations of dissolved oxygen, total phosphorus, ammonia-nitrogen, *E. coli*, nitrate-nitrate-nitrogen, and total suspended solids in Glady Run, 1998 and 1993, in relation to the Xenia-Glady Run WWTP. Dashed horizontal lines show the 90th percentile concentration for ecoregion reference sites of similar size unless otherwise noted.

*Anderson Fork*

Anderson Fork was sampled at RM 4.90 during both the 1993 and 1998 surveys (Figure 98). Concentrations of D.O. and ammonia-N were similar between years with respective medians of 8.0 mg/l and 0.05 mg/l. Median 1998 concentrations of nitrate-nitrite-N (2.23 mg/l), total phosphorus (0.22 mg/l), and TSS (32 mg/l) increased over 1993 levels (0.645 mg/l, 0.11 mg/l, and 10 mg/l, respectively).

*Flat Fork*

Water chemistry samples collected at RM 1.70 of this tributary during the 1998 survey generally indicate improved water quality since the 1993 survey (Figure 98). Dissolved oxygen medians at the site increased from 2.9 mg/l in 1993 to 7.5 mg/l in 1998 while median ammonia-N decreased from 0.08 mg/l to 0.06 mg/l. Similarly, respective TSS, fecal coliform, and *E. coli* medians decreased from 13 mg/l, 780 colonies/100 ml, and 670 colonies/100 ml in 1993 to 6 mg/l, 101 colonies/100 ml, and 15 colonies/100 ml, respectively, in 1998. Median concentrations of nitrate-nitrite-N increased to 2.08 mg/l in 1998 from 0.28 mg/l in 1993. While median phosphorus values decreased minimally from 0.33 mg/l in 1993 to 0.30 mg/l in 1998, values remained elevated above the 90$^{th}$ percentile ECBP headwater reference site concentration (0.206 mg/l) in both survey years, reflecting the continued agricultural impact on the basin.

*Muddy Creek*

Water chemistry samples were collected at RM 2.50, downstream of the Mason WWTP (discharge at RM 3.24), during both the 1998 and 1993 water quality surveys (Figure 98). Median D.O. concentrations, comparable for the two periods, ranged from 8.0 mg/l in 1993 to 8.6 mg/l in 1998 while median ammonia-N approximated 0.07 mg/l in both years. A significant increase in phosphorus levels was observed at the site during the latest survey with medians increasing from 0.66 mg/l in 1993 to 2.76 mg/l in 1998. Additionally, median nitrate-nitrite-N increased from 2.67 mg/l in 1993 to the exceptionally elevated level of 19.2 mg/l in 1998. Lower 1998 median concentrations of TSS (5 mg/l), fecal coliform (420 colonies/100 ml), and *E. coli* (110 colonies/100 ml) were measured at the site compared to 1993 median values (7.5 mg/l, 598 colonies/100 ml, and 305 colonies/100 ml, respectively).

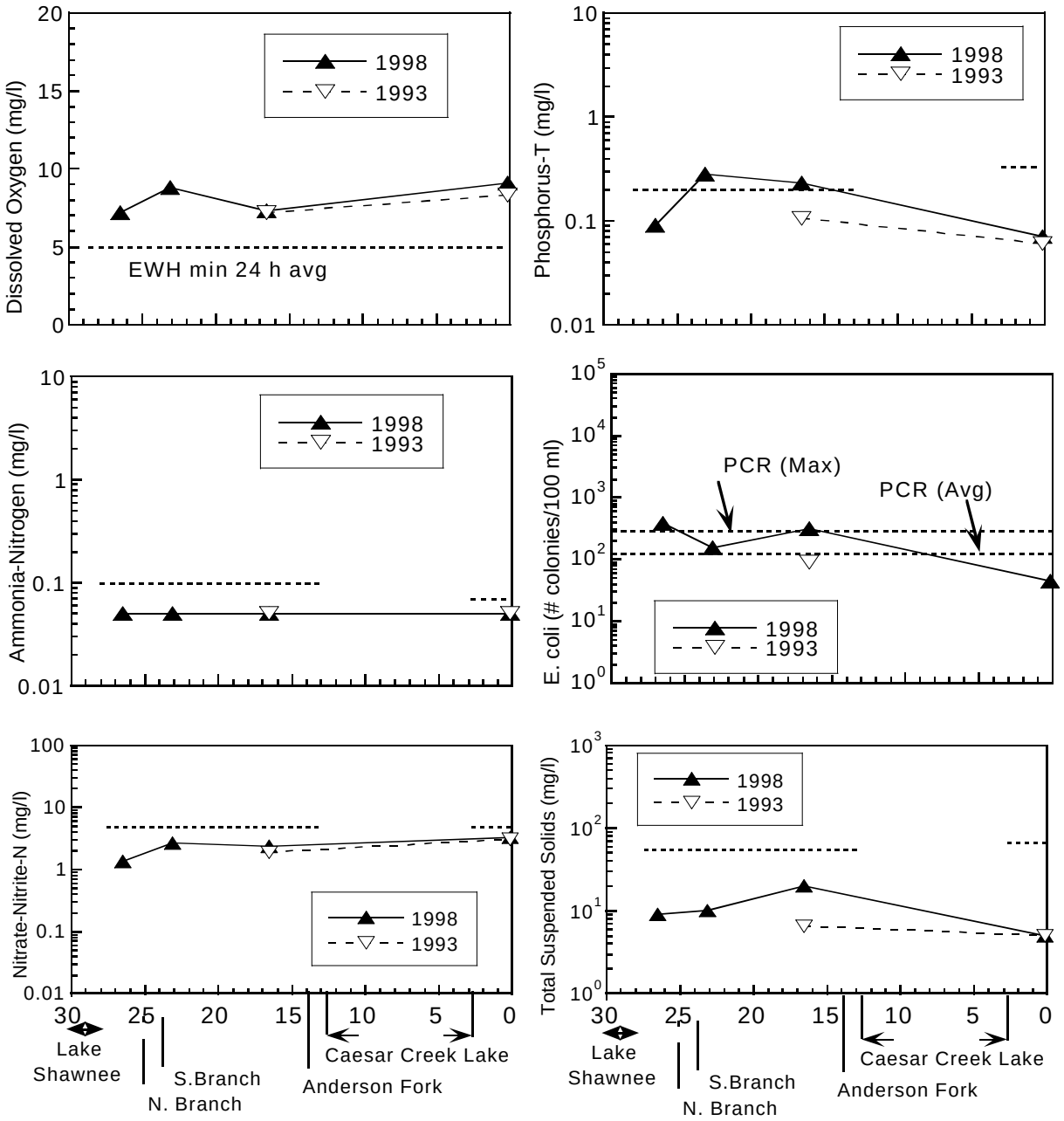



Figure 102. Median concentrations of dissolved oxygen, total phosphorus, ammonia-nitrogen, *E. coli*, nitrate-nitrate-nitrogen, and total suspended solids in Caesar Creek, 1998 and 1993, in relation to major tributaries and instream impoundments. Dashed horizontal lines show the 90th percentile concentration for ecoregion reference sites of similar size unless otherwise noted.

*Sycamore Creek*

Water samples were collected at RMs 0.53 and 0.20 in 1998 compared to RMs 0.40 and 0.05 in 1993 (Figure 103). (The mixing zone (RM 0.25) of Sycamore Creek WWTP was also sampled during the 1993 survey.)

Dissolved oxygen medians remained stable in 1998 with a median of 8.0 mg/l recorded at both sites compared to 1993 medians which decreased from 9.6 mg/l upstream of the Sycamore Creek WWTP (RM 0.40), to 7.3 mg/l near the mouth (RM 0.05). Median ammonia-N remained low during both surveys with the highest median value (0.09 mg/l) recorded in 1993 at RM 0.05.

Nitrate-nitrite-N and total phosphorus levels increased downstream of the Sycamore Creek WWTP during both surveys. Nitrate-nitrite-N medians in 1998 increased from 0.10 mg/l at RM 0.53 to 2.43 mg/l at RM 0.20. In 1993, nitrate-nitrite-N medians ranged from 0.14 mg/l (RM 0.40) to 2.82 mg/l (RM 0.05). Similarly, 1998 total phosphorus medians ranged from 0.08 mg/l (RM 0.53) to 0.39 mg/l (RM 0.20) compared to 1993 values ranging from 0.09 mg/l (RM 0.40) to 2.43 mg/l (RM 0.05).

With the exception of RM 0.05 where a median of 17.5 mg/l was measured in 1993, median concentrations of total suspended solids remained less than the MDL of 5 mg/l. Fecal coliform and *E. coli* levels increased at sites downstream of the Sycamore Creek WWTP during both survey years. Median fecal coliform increased longitudinally from 180 to 5200 colonies/100 ml in 1998 compared to an increase from 175 to 12820 colonies/100 ml in 1993. Similarly, *E. coli* medians increased longitudinally from 30 to 755 colonies/100 ml in 1998 compared to an increase in 1993 from 300 to 3383 colonies/100 ml.

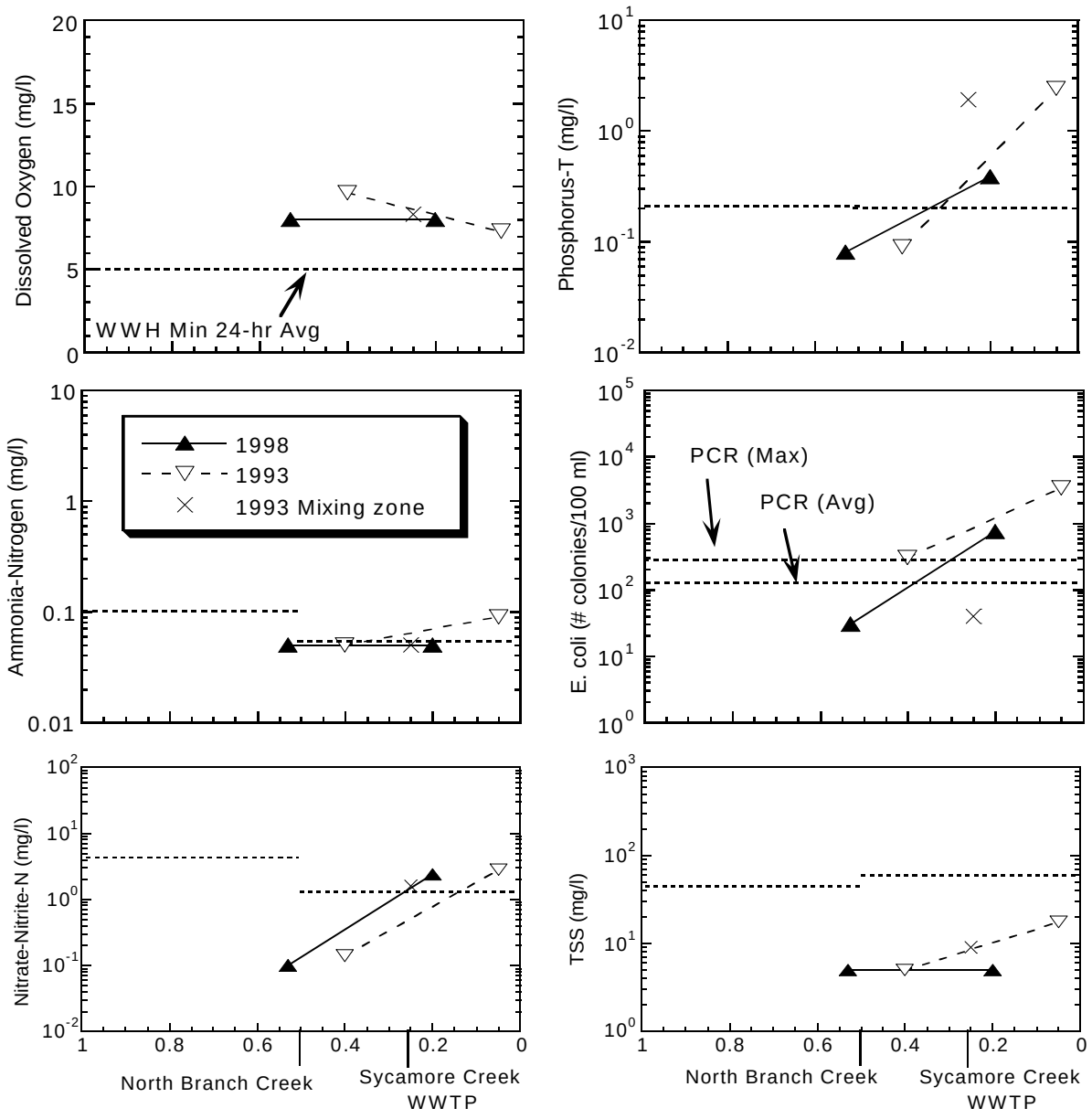



Figure 103. Median concentrations of dissolved oxygen, total phosphorus, ammonia-nitrogen, *E. coli*, nitrate-nitrate-nitrogen, and total suspended solids in Sycamore Creek, 1998 and 1993, in relation to the confluence of North Branch Creek and the Hamilton County MSD Sycamore Creek WWTP. Dashed horizontal lines show the 90th percentile concentration for ecoregion reference sites of similar size unless otherwise noted.

**Sediment Quality**

Sediment samples were collected in 63 locations in the 1998 study area to assess levels of contaminants present in stream sediments. In addition to particle size, sediments were typically analyzed for 18 metals, 59 volatile organic compounds (VOC's), 93 semivolatile organic compounds, 19 organochlorine pesticides and 7 PCB (polychlorinated biphenyl) compounds. Whenever possible, composite samples from a cross-section of the stream channel were collected with silts and clays comprising at least 30% of the sample. Sediments composed of sand and larger sized particles (>60 microns) are often stable inorganic silicate minerals and not usually associated with contaminants. Given that the finer grained silts and clays (<60 microns) are much more chemically, physically and biologically interactive, collection efforts were biased toward collecting these types of sediments.

Select parameters were ranked based upon stream sediment classification guidelines developed by Kelly and Hite (1984), the Persuad (1994), and Ohio EPA. Both Kelly and Hite and Ohio EPA address relative concentrations rather than direct toxicity, statistically ranking pollutant concentrations from non-elevated to extremely elevated. Kelly and Hite developed a five-tier classification of Illinois stream sediments for constituents for which adequate data was available (select metals, pesticides and PCB's), based upon one, two, four and eight standard deviations from background means. Ohio EPA metal guidelines, based upon ecoregion reference sites, are derived from median value plus one, two, four and eight inter-quartile range values.

Utilizing biologically based guidelines to protect sediment-dwelling organisms, the Ontario system establishes three ecotoxic effect levels: No Effect Level, Lowest Effect Level (LEL), and the Sever Effect Level (SEL). Concentrations above the LEL are expected to affect sediment use by some benthic organisms, while levels which exceed the SEL are expected to detrimentally affect the majority of benthic organisms. (Given differences in background levels for heavy metals in Ohio versus the Ontario Great Lakes watershed, only the SEL was used for heavy metals analysis in this report.)

Sediment quality in the mainstem and tributaries was generally very good. Thirty six percent (8/22) of the sediment sites on the mainstem exhibited exceptional sediment quality, with all metal detections below the Ohio non elevated guidelines and no organic compounds detected in the sediment. Tributary sites had 15% (6/41) of sites with exceptional sediment quality. This was broken down to 7.7% (2/26) in the upper tributaries (north of Oregonia) and 27% (4/15) in the lower tributaries.

Acetone was detected in 29% (18/63) of sediment samples including some sites listed as having no quantifiable organic contamination. This chemical is used to clean sampling equipment and is a residual from cleaning and not considered being in the environment.

**Sediment Metals**

*Little Miami River (RMs 106.35-8.14)*
Eighteen metals were analyzed in the sediment samples taken in the Little Miami River and its tributaries. Of the eighteen metals, 12 were evaluated by Ohio guidelines, Illinois guidelines (Kelly & Hite) or the Ontario Guidelines. Six of the eighteen metals ( Ca, Mg, Na, K, Se, and Sr) were not evaluated by any of the three guidelines.

There were 63 sediment samples collected in the study area of the Little Miami Basin. Mainstem sites accounted for 22 of the sediment sites, LMR tributaries (north of Oregonia) had 26 sediment sites and lower tributaries had 15 sediment sites. Of the 12 metals included in the various sediment classifications, the majority (86%) of concentrations recorded at the 22 mainstem sites were ranked "non-elevated" or "slightly elevated" by all applicable guidelines. Barium, manganese and aluminum (54%, 32%, and 23%) were the metals most frequently ranked "elevated" or higher per Ohio EPA guidelines.

Historical sediment metal results (1993 survey) analyzed for nine different metals. The 1998 survey was expanded to 12 metals. Comparison between the two surveys for the 9 metals indicated very little difference in sediment metal values between years. The exception was a sediment zinc increase at RM 28.0 (LMR downstream of Simpson Creek) from 4.2 mg/kg (Ohio "non-elevated") in 1993 to 29.1 mg/kg (Ohio "highly elevated") in 1998. The sites on the mainstem with the highest metal contamination in 1998 were RM's (50.75, 28.00 and 106.35).

River mile 50.75, downstream of Caesar Creek, recorded 92% (11/12) of the evaluated metals in the "extremely elevated" or "highly elevated" category per the Ohio EPA guidelines. In addition arsenic, iron, and manganese were classified as in the "Severe Effect Level" by the Ontario guidelines. (Table 11) Metal contamination at this site appears to be associated with the dumping of domestic trash, metal parts and fill for bank stabilization. Unrecognizable metal parts can be observed in the river bed.

River mile 28.00, downstream of Simpson Creek, documented 25% (3/12) of the evaluated metals in the "extremely elevated" or "highly elevated" category per the Ohio EPA guidelines. (Table 11). In addition manganese was classified as in the "Severe Effect Level" by the Ontario guidelines.

River mile 106.35, at the headwaters, recorded 25% (3/12) of the evaluated metals in the "highly elevated" category per the Ohio EPA guidelines. This area is upstream of the Pay Gro facility in South Charleston.

Thirty two percent of the sites on the mainstem (7/22) recorded all of the evaluated metals in the "non elevated" category. These sites were RMs 98.98, 60.84, 55.25, 53.69, 43.76, 35.98, and 20.60.

Table 11. Concentrations (mg/kg) of metals in sediment samples collected in the Little Miami River study area during 1998. Parameter concentrations were evaluated based on Ohio EPA sediment reference sites, the Kelly and Hite (1984) stream sediment classification system and the Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (1993).

| **Stream** | ----------**Sediment Concentration (mg/kg dry weight)**---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Al-T**** | **As-T** | **Ba-T**** | **Ca-T*** | **Cd-T** | **Cr-T** | **Cu-T** | **Fe-T** | **Pb-T** |
| **Little Miami River** | | | | | | | | | |
| 106.35 | **28200$^{D}$** | ***17.4$^{Cd}$*** | *208$^{C}$* | 45700 | 0.336$^{Aa}$ | *30.2$^{Cc}$* | 18.1$^{Aa}$ | ***37900$^{Cd}$*** | <34.5$^{Aa-b}$ |
| 98.98 | 9660$^{A}$ | 8.53$^{Ab}$ | 79.5$^{A}$ | 85800 | 0.262$^{Aa}$ | <15.7$^{Aa}$ | 10.5$^{Aa}$ | 13000$^{Aa}$ | <20.9$^{Aa}$ |
| 85.38 | *18700$^{C}$* | 6.92$^{Aa}$ | *189$^{C}$* | 57000 | 0.468$^{Aa}$ | *<30.5$^{Aa-Cc}$* | 20.4$^{Ba}$ | 15600$^{Aa}$ | *<40.7$^{Aa-c}$* |
| 80.63 | 12000$^{B}$ | 4.52$^{Aa}$ | *160$^{C}$* | 131000 | 0.298$^{Aa}$ | *<28.9$^{Aa-Cc}$* | 10.6$^{Aa}$ | 11900$^{Aa}$ | *<38.5$^{Aa-c}$* |
| 76.90 | 11500$^{A}$ | 3.3$^{Aa}$ | 118$^{B}$ | 42300 | 0.159$^{Aa}$ | <19.8$^{Aa-b}$ | 10.6$^{Aa}$ | 9070$^{Aa}$ | <26.4$^{Aa}$ |
| 72.30 | 13400$^{B}$ | 5.12$^{Aa}$ | *137$^{C}$* | 59700 | 0.31$^{Aa}$ | *<23.2$^{Aa-Bc}$* | 17$^{Aa}$ | 13100$^{Aa}$ | 31$^{Ab}$ |
| 66.56 | 15000$^{B}$ | 5.37$^{Aa}$ | *157$^{C}$* | 84100 | 0.42$^{Aa}$ | *<26.8$^{Aa-Cc}$* | 17.9$^{Aa}$ | 14600$^{Aa}$ | <35.8$^{Aa-b}$ |
| 65.25 | *16600$^{C}$* | 5.4$^{Aa}$ | *166$^{C}$* | 125000 | 0.347$^{Aa}$ | ***<38.6*** $^{Aa-Cd}$ | 14.1$^{Aa}$ | 19200$^{Ab}$ | *<51.4$^{Aa-Bc}$* |
| 64.28 | 11500$^{A}$ | 5.51$^{Aa}$ | *142$^{C}$* | 184000 | 0.305$^{Aa}$ | *<35.2$^{Aa-Cc}$* | <11.7$^{Aa}$ | 15600$^{Aa}$ | *<46.9$^{Aa-Bc}$* |
| 63.28 | *18500$^{C}$* | 8.32$^{Ab}$ | *160$^{C}$* | 81200 | 0.452$^{Aa}$ | *<30.8$^{Aa-Cc}$* | 16.4$^{Aa}$ | 21200$^{Ab}$ | *<41.1$^{Aa-c}$* |
| 60.84 | 7360$^{A}$ | 2.66$^{Aa}$ | 70.4$^{A}$ | 66500 | 0.128$^{Aa}$ | <14.8$^{Aa}$ | 5.42$^{Aa}$ | 8880$^{Aa}$ | <19.7$^{Aa}$ |
| 55.25 | 9350$^{A}$ | 3.63$^{Aa}$ | 80.3$^{A}$ | 59400 | 0.17$^{Aa}$ | <16.5$^{Aa-b}$ | 10.4$^{Aa}$ | 10300$^{Aa}$ | <22.0$^{Aa}$ |
| 53.69 | 8420$^{A}$ | 3.92$^{Aa}$ | 71.2$^{A}$ | <955 | 0.134$^{Aa}$ | <14.3$^{Aa}$ | 8.12$^{Aa}$ | 9660$^{Aa}$ | <19.1$^{Aa}$ |
| 50.75 | **36300$^{D}$** | **49.9$^{EeΔ}$** | **283$^{D}$** | 42600 | *1.08$^{Cc}$* | **56.1$^{Dd}$** | ***82.1$^{Ec}$*** | **76200$^{EeΔ}$** | ***103*** $^{Ce}$ |
| 47.50 | 16400$^{B}$ | 5.62$^{Aa}$ | *102$^{C}$* | 36400 | 0.134$^{Aa}$ | 17.1$^{Ab}$ | 10.7$^{Aa}$ | 14700$^{Aa}$ | <21.4$^{Aa}$ |
| 43.76 | 11000$^{A}$ | 3.18$^{Aa}$ | 77.4$^{A}$ | 63000 | 0.119$^{Aa}$ | <14.9$^{Aa}$ | 5.96$^{Aa}$ | 10600$^{Aa}$ | <19.8$^{Aa}$ |
| 35.98 | 8620$^{A}$ | 3.17$^{Aa}$ | 56.3$^{A}$ | 47800 | <0.100$^{Aa}$ | <15.1$^{Aa}$ | 6.04$^{Aa}$ | 9600$^{Aa}$ | <20.1$^{Aa}$ |
| 31.96 | 13300$^{A}$ | 4.35$^{Aa}$ | 83.1$^{B}$ | 41100 | 0.1$^{Aa}$ | 15.3$^{Aa}$ | 6.69$^{Aa}$ | 12800$^{Aa}$ | <19.1$^{Aa}$ |
| 28.00 | 20300$^{B}$ | 6.22$^{Aa}$ | **136$^{D}$** | 14600 | 0.251$^{Aa}$ | *23.1$^{Bc}$* | 11$^{Aa}$ | *28500$^{Ac}$* | <20.1$^{Aa}$ |
| 24.35 | 13700$^{A}$ | 3.86$^{Aa}$ | 86.2$^{B}$ | 46000 | 0.164$^{Aa}$ | 16.9$^{Ab}$ | 9.52$^{Aa}$ | 12200$^{Aa}$ | <21.2$^{Aa}$ |
| 20.60 | 7940$^{A}$ | 3.68$^{Aa}$ | 54$^{A}$ | 51200 | 0.104$^{Aa}$ | <12.0$^{Aa}$ | 5.2$^{Aa}$ | 10200$^{Aa}$ | <16.0$^{Aa}$ |
| 8.14 | 16100$^{B}$ | 4.36$^{Aa}$ | *93.1$^{C}$* | 28500 | 0.111$^{Aa}$ | 18.3$^{Ab}$ | 8.46$^{Aa}$ | 13100$^{Aa}$ | <17.8$^{Aa}$ |
| **Gilroy Ditch** | | | | | | | | | |
| 0.50 | 12200$^{B}$ | 8.14$^{Ab}$ | 105$^{B}$ | 85000 | 0.198$^{Aa}$ | <18.0$^{Aa-b}$ | 11.4$^{Aa}$ | 14000$^{Aa}$ | <24.0$^{Aa}$ |
| **North Fork Little Miami River** | | | | | | | | | |
| 0.37 | **23300$^{D}$** | *11$^{Bc}$* | *196$^{C}$* | 34200 | 0.483$^{Aa}$ | *29$^{Cc}$* | 14.9$^{Aa}$ | *23700$^{Bc}$* | *38.6$^{Ac}$* |
| **Yellow Springs Creek** | | | | | | | | | |
| 0.10 | *21000$^{C}$* | 6.87$^{Aa}$ | **217$^{D}$** | 76600 | 0.585$^{Bb}$ | *<33.8$^{Aa-Cc}$* | **48.4$^{Db}$** | 15600$^{Aa}$ | *<45.0$^{Aa-c}$* |

Table 11. Continued.

| Stream | ----------Sediment Concentration (mg/kg dry weight)---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Mg-T*** | **Mn-T** | **Hg-T*** ** | **Na-T*** | **Ni-T#** | **K-T*** | **Se-T*** | **Sr-T*** | **Zn-T** |
| **Little Miami River (continued)** | | | | | | | | | |
| 106.35 | 19000 | *524*$^{Ca}$ | 0.0589$^{a}$ | <4310 | <34.5$^{A-B}$ | 8630 | 1.9 | 99.2 | *111*$^{Bc}$ |
| 98.98 | 27700 | 288$^{Aa}$ | <0.0322$^{a}$ | <2620 | <20.9$^{A}$ | 1570 | 1.05 | 266 | 54.9$^{Aa}$ |
| 85.38 | 10200 | 280$^{Aa}$ | <0.0638$^{a}$ | <5090 | *<40.7*$^{A-C}$ | 4070 | 2.34 | 192 | 84.5$^{Ab}$ |
| 80.63 | 15400 | 374$^{Ba}$ | *0.152*$^{c}$ | <4810 | <38.5$^{A-B}$ | 2890 | <1.92 | 268 | 53.9$^{Aa}$ |
| 76.90 | 5290 | 328$^{Ba}$ | 0.0746$^{b}$ | <3300 | <26.4$^{A}$ | 2640 | <1.32 | 99.2 | 55.5$^{Aa}$ |
| 72.30 | 17800 | 350$^{Ba}$ | 0.0881$^{b}$ | <3880 | <31.0$^{A-B}$ | 3100 | <1.55 | 80.6 | *106*$^{Bc}$ |
| 66.56 | 16100 | *496*$^{Ca}$ | <0.0489$^{a}$ | <4470 | <35.8$^{A-B}$ | 3580 | <1.79 | 122 | 85.9$^{Ab}$ |
| 65.25 | 27000 | *716*$^{Ca}$ | <0.0714$^{a-b}$ | <6430 | *<51.4*$^{A-C}$ | 3860 | <2.57 | 140 | 99$^{Ab}$ |
| 64.28 | 32800 | *619*$^{Ca}$ | <0.0724$^{a-b}$ | <5860 | *<46.9*$^{A-C}$ | 2350 | <2.35 | 178 | 58.6$^{Aa}$ |
| 63.28 | 19500 | *704*$^{Ca}$ | <0.0547$^{a}$ | <5140 | *<41.1*$^{A-C}$ | 3080 | <2.05 | 98.6 | 89.4$^{Ab}$ |
| 60.84 | 14300 | 322$^{Aa}$ | <0.0341$^{a}$ | <2460 | <19.7$^{A}$ | 1480 | <0.985 | 77.8 | 48.2$^{Aa}$ |
| 55.25 | 14300 | 326$^{Aa}$ | <0.0279$^{a}$ | <2750 | <22.0$^{A}$ | 2200 | <1.10 | 74.3 | 57.2$^{Aa}$ |
| 53.69 | 11900 | 285$^{Aa}$ | <0.0266$^{a}$ | <2390 | <19.1$^{A}$ | 1910 | <0.955 | 65.9 | 43$^{Aa}$ |
| 50.75 | 9360 | **1130**$^{DaΔ}$ | <0.0593$^{a}$ | <5200 | *57.2*$^{C}$ | 7280 | 6.96 | 109 | **300**$^{De}$ |
| 47.50 | 9630 | 508$^{Aa}$ | 0.0461$^{a}$ | <2680 | *<21.4*$^{A-C}$ | 3210‡ | <1.07 | 61.5 | 47.6$^{Aa}$ |
| 43.76 | 12900 | 396$^{Aa}$ | 0.0323$^{a}$ | <2480 | <19.8$^{A-B}$ | 2980 | <0.992 | 90.8 | 42.2$^{Aa}$ |
| 35.98 | 10600 | 305$^{Aa}$ | 0.0317$^{a}$ | <2510 | *<20.1*$^{A-C}$ | 2510 | <1.00 | 76.4 | 29.7$^{Aa}$ |
| 31.96 | 8120 | 414$^{Aa}$ | <0.0204$^{a}$ | <2390 | *<19.1*$^{A-C}$ | 2870 | <0.956 | 74.5 | 44$^{Aa}$ |
| 28.00 | 5020 | ***2020***$^{DcΔ}$ | <0.0294$^{a}$ | <2510 | **29.1**$^{D}$ | 5020 | <1.00 | 49.2 | 55.2$^{Aa}$ |
| 24.35 | 10000 | 375$^{Aa}$ | 0.0569$^{a}$ | <2640 | *<21.2*$^{A-C}$ | 3170 | <1.06 | 86.2 | 49.2$^{Aa}$ |
| 20.60 | 8000 | 402$^{Aa}$ | <0.0285$^{a}$ | <2000 | <16.0$^{A-B}$ | 2000 | <0.800 | 94 | 40$^{Aa}$ |
| 8.14 | 7570 | 397$^{Aa}$ | *0.102*$^{c}$ | <2230 | *<17.8*$^{A-C}$ | 4010 | <0.891 | 61.5 | 42.3$^{Aa}$ |
| **Gilroy Ditch (continued)** | | | | | | | | | |
| 0.50 | 31100 | 208$^{Aa}$ | 0.0596$^{a}$ | <2990 | <24.0$^{A}$ | 2990 | 1.2 | 720 | 63.5$^{Aa}$ |
| **North Fork Little Miami River (continued)** | | | | | | | | | |
| 0.37 | 13200 | *646*$^{Ca}$ | 0.0834$^{b}$ | <4390 | <35.1$^{A-B}$ | 4390 | <1.76 | 57.9 | 86$^{Ab}$ |
| **Yellow Springs Creek (continued)** | | | | | | | | | |
| 0.10 | 14600 | 341$^{Ba}$ | *0.1*$^{c}$ | <5630 | *<45.0*$^{A-C}$ | 4500 | <2.25 | 67.5 | *126*$^{Bc}$ |

Table 11. Continued.

| Stream | ----------Sediment Concentration (mg/kg dry weight)---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Al-T**** | **As-T** | **Ba-T**** | **Ca-T*** | **Cd-T** | **Cr-T** | **Cu-T** | **Fe-T** | **Pb-T** |
| **Massie Creek** | | | | | | | | | |
| 7.71 | *19100*$^{C}$ | 7.14$^{Aa}$ | *149*$^{C}$ | 41500 | 0.282$^{Aa}$ | *<26.5*$^{Aa\text{-}Cc}$ | 15.9$^{Aa}$ | 15600$^{Aa}$ | <35.3$^{Aa\text{-}b}$ |
| 0.26 | 12900$^{B}$ | 5.02$^{Aa}$ | 110$^{B}$ | 65100 | 0.233$^{Aa}$ | <17.9$^{Aa\text{-}b}$ | 11.4$^{Aa}$ | 11100$^{Aa}$ | <23.9$^{Aa}$ |
| **Ludlow Creek** | | | | | | | | | |
| 0.25 | *16600*$^{C}$ | 5.09$^{Aa}$ | 109$^{B}$ | 35300 | 0.224$^{Aa}$ | 17.4$^{Ab}$ | 10.6$^{Aa}$ | 14800$^{Aa}$ | <22.4$^{Aa}$ |
| **Shawnee Creek** | | | | | | | | | |
| 0.65 | 15200$^{B}$ | 6.64$^{Aa}$ | 120$^{B}$ | 35400 | 0.177$^{Aa}$ | 19.4$^{Ab}$ | 15.5$^{Aa}$ | 13200$^{Aa}$ | *48.7*$^{Bc}$ |
| **Beaver Creek** | | | | | | | | | |
| 6.30 | 7320$^{A}$ | 6.73$^{Aa}$ | 56.8$^{A}$ | 40100 | 0.122$^{Aa}$ | <16.7$^{Aa\text{-}b}$ | 6.68$^{Aa}$ | 10700$^{Aa}$ | <22.3$^{Aa}$ |
| 0.50 | 14200$^{B}$ | 5.7$^{Aa}$ | 115$^{B}$ | 57000 | 0.19$^{Aa}$ | 20.8$^{Bb}$ | 14.7$^{Aa}$ | 14000$^{Aa}$ | <24.5$^{Aa}$ |
| 0.20 | 13700$^{B}$ | 5.55$^{Aa}$ | 116$^{B}$ | 56100 | 0.305$^{Aa}$ | 20.5$^{Bb}$ | 12.8$^{Aa}$ | 12700$^{Aa}$ | <22.2$^{Aa}$ |
| **Little Beaver Creek** | | | | | | | | | |
| 4.62 | *15800*$^{C}$ | 7.3$^{Aa}$ | 121$^{B}$ | 51500 | 0.254$^{Aa}$ | <23.0$^{Aa\text{-}Bb}$ | 12.3$^{Aa}$ | 14000$^{Aa}$ | <30.7$^{Aa\text{-}b}$ |
| 4.40 | 8560$^{A}$ | 5.24$^{Aa}$ | 101$^{B}$ | 31700 | 0.401$^{Aa}$ | 22$^{Bb}$ | *28.4*$^{Ca}$ | 8470$^{Aa}$ | <25.8$^{Aa}$ |
| 3.54 | 14400$^{B}$ | 5.53$^{Aa}$ | *138*$^{C}$ | 50300 | 0.41$^{Aa}$ | *26*$^{Bc}$ | *27.6*$^{Ca}$ | 13700$^{Aa}$ | <33.5$^{Aa\text{-}b}$ |
| 3.47 | 11600$^{A}$ | 7.01$^{Aa}$ | 92.6$^{A}$ | 48000 | **3.09**$^{Ed}$ | 16.7$^{Ab}$ | 15.7$^{Aa}$ | 11800$^{Aa}$ | *54.9*$^{Bc}$ |
| 0.05 | 9980$^{A}$ | 3.73$^{Aa}$ | 89.8$^{A}$ | 45900 | 0.216$^{Aa}$ | <19.6$^{Aa\text{-}b}$ | 15.1$^{Aa}$ | 10300$^{Aa}$ | <26.2$^{Aa}$ |
| **Sugar Creek** | | | | | | | | | |
| 0.40 | 10500$^{A}$ | 4.9$^{Aa}$ | 77.3$^{A}$ | 55400 | 0.208$^{Aa}$ | <17.3$^{Aa\text{-}b}$ | 12.1$^{Aa}$ | 11900$^{Aa}$ | <23.1$^{Aa}$ |
| **Little Sugar Creek** | | | | | | | | | |
| 0.45 | *17000*$^{C}$ | 5.72$^{Aa}$ | 127$^{B}$ | 72900 | 0.252$^{Aa}$ | <18.9$^{Aa\text{-}b}$ | 14.5$^{Aa}$ | 14900$^{Aa}$ | <25.2$^{Aa}$ |
| **Glady Run** | | | | | | | | | |
| 4.08 | 12300$^{B}$ | 3.66$^{Aa}$ | 99.3$^{A}$ | 28500 | 0.267$^{Aa}$ | <17.4$^{Aa\text{-}b}$ | 22.1$^{Ba}$ | 12500$^{Aa}$ | <23.2$^{Aa}$ |
| **Newman Run** | | | | | | | | | |
| 0.27 | 14500$^{B}$ | 5.07$^{Aa}$ | 76.8$^{A}$ | 54800 | 0.128$^{Aa}$ | <15.4$^{Aa}$ | 9.22$^{Aa}$ | 13800$^{Aa}$ | <20.5$^{Aa}$ |
| **Caesar Creek** | | | | | | | | | |
| 26.50 | 11000$^{A}$ | 4.94$^{Aa}$ | 68.7$^{A}$ | 22000 | 0.17$^{Aa}$ | <16.5$^{Aa\text{-}b}$ | 8.79$^{Aa}$ | 11400$^{Aa}$ | <22.0$^{Aa}$ |
| 16.52 | *15700*$^{C}$ | 6.27$^{Aa}$ | 93.1$^{A}$ | 28600 | 0.19$^{Aa}$ | 16.4$^{Ab}$ | 11.1$^{Aa}$ | 13800$^{Aa}$ | <21.2$^{Aa}$ |
| 0.15 | 10200$^{A}$ | 4.5$^{Aa}$ | 63.1$^{A}$ | 33500 | <0.134$^{Aa}$ | <20.1$^{Aa\text{-}b}$ | 9.39$^{Aa}$ | 12100$^{Aa}$ | <26.8$^{Aa}$ |

Table 11. Continued.

| Stream | ----------Sediment Concentration (mg/kg dry weight)---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Mg-T*** | **Mn-T** | **Hg-T*** ** | **Na-T*** | **Ni-T#** | **K-T*** | **Se-T*** | **Sr-T*** | **Zn-T** |
| **Massie Creek (continued)** | | | | | | | | | |
| 7.71 | 11500 | *655*$^{Ca}$ | <0.0427$^{a}$ | <4410 | <35.3$^{A-B}$ | 4410 | <1.76 | 99.7 | 76.7$^{Aa}$ |
| 0.26 | 12500 | 322$^{Aa}$ | <0.0384$^{a}$ | <2990 | <23.9$^{A}$ | 2990 | <1.19 | 131 | 60.9$^{Aa}$ |
| **Ludlow Creek (continued)** | | | | | | | | | |
| 0.25 | 11200 | 456$^{Ba}$ | <0.0302$^{a}$ | <2800 | <22.4$^{A}$ | 2800 | <1.12 | 34.7 | 58.8$^{Aa}$ |
| **Shawnee Creek (continued)** | | | | | | | | | |
| 0.65 | 12200 | 353$^{Ba}$ | *0.138*$^{c}$ | <2770 | <22.1$^{A}$ | 3320 | <1.11 | 48.7 | 64.8$^{Aa}$ |
| **Beaver Creek (continued)** | | | | | | | | | |
| 6.30 | 15000 | 323$^{Aa}$ | <0.0302$^{a}$ | <2780 | <22.3$^{A}$ | 1670 | <1.11 | 31.7 | 46.2$^{Aa}$ |
| 0.50 | 20200 | *511*$^{Ca}$ | 0.067$^{a}$ | <3070 | <24.5$^{A}$ | 3680 | <1.23 | 64.4 | 75.4$^{Aa}$ |
| 0.20 | 17800 | 420$^{Ba}$ | 0.0673$^{a}$ | <2780 | <22.2$^{A}$ | 3330 | <1.11 | 48.8 | 57.2$^{Aa}$ |
| **Little Beaver Creek (continued)** | | | | | | | | | |
| 4.62 | 20000 | 445$^{Ba}$ | <0.0397$^{a}$ | <3840 | <30.7$^{A-B}$ | 3070 | <1.54 | 51.5 | 79.9$^{Aa}$ |
| 4.40 | 11600 | 200$^{Aa}$ | **0.222**$^{d}$ | <3230 | <25.8$^{A}$ | 1940 | <1.29 | 50.4 | *108*$^{Bc}$ |
| 3.54 | 19300 | 392$^{Ba}$ | 0.0581$^{a}$ | <4190 | <33.5$^{A-B}$ | 3350 | <1.68 | 66.2 | *121*$^{Bc}$ |
| 3.47 | 18100 | 292$^{Aa}$ | 0.0364$^{a}$ | <2450 | <19.6$^{A}$ | 2450 | <0.980 | 51 | 78.9$^{Aa}$ |
| 0.05 | 17700 | 346$^{Ba}$ | <0.0366$^{a}$ | <3280 | <26.2$^{A}$ | 2620 | <1.31 | 49.8 | 68.8$^{Aa}$ |
| **Sugar Creek (continued)** | | | | | | | | | |
| 0.40 | 14400 | 453$^{Ba}$ | <0.0327$^{a}$ | <2880 | <23.1$^{A}$ | 2310 | <1.15 | 49.6 | 51.9$^{Aa}$ |
| **Little Sugar Creek (continued)** | | | | | | | | | |
| 0.45 | 13800 | 449$^{Ba}$ | <0.0318$^{a}$ | <3140 | <25.2$^{A}$ | 5030 | <1.26 | 67.3 | 69.2$^{Aa}$ |
| **Glady Run (continued)** | | | | | | | | | |
| 4.08 | 9870 | *476*$^{Ca}$ | <0.0421$^{a}$ | <2900 | <23.2$^{A}$ | 2900 | <1.16 | 42.4 | 81.3$^{Ab}$ |
| **Newman Run (continued)** | | | | | | | | | |
| 0.27 | 11800 | 404$^{Ba}$ | <0.0309$^{a}$ | <2560 | <20.5$^{A}$ | 3580 | <1.02 | 82 | 35.8$^{Aa}$ |
| **Caesar Creek (continued)** | | | | | | | | | |
| 26.50 | 9890 | 260$^{Aa}$ | <0.0292$^{a}$ | <2750 | <22.0$^{A}$ | 2750 | <1.10 | 80.8 | 37.9$^{Aa}$ |
| 16.52 | 13800 | 319$^{Aa}$ | <0.0306$^{a}$ | <2640 | <21.2$^{A}$ | 3170 | <1.06 | 48.7 | 52.9$^{Aa}$ |
| 0.15 | 8050 | **751**$^{Da}$ | <0.0356$^{a}$ | <3350 | <26.8$^{A}$ | 2680 | <1.34 | 67.8 | 47$^{Aa}$ |

Table 11. Continued.

| Stream | ----------Sediment Concentration (mg/kg dry weight)---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Al-T**** | **As-T** | **Ba-T**** | **Ca-T*** | **Cd-T** | **Cr-T** | **Cu-T** | **Fe-T** | **Pb-T** |
| **North Branch Caesar Creek** | | | | | | | | | |
| 1.23 | 12400$^{B}$ | 5.69$^{Aa}$ | 72.4$^{A}$ | 28700 | 0.185$^{Aa}$ | 14.6$^{Aa}$ | 7.94$^{Aa}$ | 11400$^{Aa}$ | <17.6$^{Aa}$ |
| **South Branch Caesar Creek** | | | | | | | | | |
| 2.10 | 15100$^{B}$ | 7.63$^{Aa}$ | 90.3$^{A}$ | 33300 | 0.246$^{Aa}$ | 15$^{Aa}$ | 12.6$^{Aa}$ | 14000$^{Aa}$ | <19.3$^{Aa}$ |
| **Anderson Fork** | | | | | | | | | |
| 9.45 | 11500$^{A}$ | 4.72$^{Aa}$ | 67.5$^{A}$ | 23300 | 0.142$^{Aa}$ | <15.2$^{Aa}$ | 7.61$^{Aa}$ | 11200$^{Aa}$ | <20.3$^{Aa}$ |
| 4.90 | **23600$^{D}$** | 8.17$^{Ab}$ | *139$^{C}$* | 26100 | 0.243$^{Aa}$ | **39.4$^{Dd}$** | *32.4$^{Ca}$* | 17000$^{Aa}$ | *44$^{Ac}$* |

| | ----------Sediment Concentration (mg/kg dry weight)---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mg-T*** | **Mn-T** | **Hg-T***** | **Na-T*** | **Ni-T#** | **K-T*** | **Se-T*** | **Sr-T*** | **Zn-T** |
| **North Branch Caesar Creek (continued)** | | | | | | | | | |
| 1.23 | 11500 | 293$^{Aa}$ | <0.0301$^{a}$ | <2210 | <17.6$^{A}$ | 3090 | <0.882 | 44.1 | 39.7$^{Aa}$ |
| **South Branch Caesar Creek (continued)** | | | | | | | | | |
| 2.10 | 14500 | 377$^{Ba}$ | <0.0350$^{a}$ | <2420 | <19.3$^{A}$ | 3860 | <0.966 | 98 | 54.6$^{Aa}$ |
| **Anderson Fork (continued)** | | | | | | | | | |
| 9.45 | 10100 | 223$^{Aa}$ | <0.0348$^{a}$ | <2540 | <20.3$^{A}$ | 2540 | <1.01 | 57.3 | 44.1$^{Aa}$ |
| 4.90 | 6950 | 279$^{Aa}$ | <0.0386$^{a}$ | <2900 | 24.3$^{A}$ | 6950 | <1.16 | 130 | *128$^{Bc}$* |

* Not evaluated by Ohio EPA, Kelly and Hite (1984) or Ontario (1993).
** Not evaluated by Kelly and Hite (1984) or Ontario (1993).
*** Not evaluated by Ohio EPA.
# Not evaluated by Kelly and Hite (1984).
† Additional sample collected (this site was not originally part of the survey).
‡ Estimated value.

Ohio EPA Guidelines:
- A Non-elevated
- B Slightly elevated
- *C Elevated*
- **D Highly elevated**
- **E <u>Extremely elevated</u>**

Kelly and Hite Guidelines:
- a Non-elevated
- b Slightly elevated
- *c Elevated*
- **d Highly elevated**
- **e <u>Extremely elevated</u>**

Ontario Guidelines:
- **<u>severe effect level (SEL)</u>**

§ Ohio EPA sediment guidelines are based on ecoregions. River miles 47.50 - 8.14 of the Little Miami River mainstem are evaluated based on guidelines for the Interior Plateau (IP) ecoregion; remaining sites are evaluated based on guidelines for the Eastern Corn Belt Plain (ECBP) ecoregion. (Aluminum concentrations for sites in the IP ecoregion were evaluated based on Ohio EPA statewide guidelines.)

*Upper Little Miami River tributaries (North of Oregonia)*
Of the 12 metals included in the various sediment classifications, the majority (91%) of concentrations recorded at the 26 tributary sites were ranked "non-elevated" or "slightly elevated" by all applicable guidelines. Forty-six percent (12/26) of all tributary sites had all metal detections in the "non elevated" category. Barium, manganese and aluminum (19%, 19%, and 31%) were the metals most frequently ranked "elevated" or higher per Ohio EPA guidelines.

A total of 23% ( 6 /26) of the tributary sites documented sediment metals in the "highly elevated" or "extremely elevated" category as evaluated by the Ohio guidelines. Little Beaver Creek (RM 3.47) downstream of the old Lammars barrel factory detected Cadmium at 3.09 mg/kg, the only tributary site in the survey detecting an Ohio "extremely elevated" guideline designation. Little Beaver Creek (RM 4.40) detected Mercury in the "highly elevated" range at 0.222 mg/kg, the highest Mercury value in the entire survey.

Strontium in the sediments of Gilroy Ditch (720 mg/kg) and mainstem (RM 98.98-266 mg/kg) (RM 80.63-268 mg/kg) was noticeably higher than at the remaining sediment sites. These sites are located in glacial deposits appearing to be high in Celestite ($SrSO_4$). High levels of sediment strontium and dissolved strontium were associated with the outwash sand and gravels of the buried valley near South Charleston. Gilroy Ditch, Lisbon Fork, and the upper mainstem documented the highest dissolved strontium levels when groundwater recharge dominated stream flow. Strontium has not been evaluated by any of the three guidelines but has chemical characteristics similar to that of calcium.

*Lower Little Miami River tributaries (South of Oregonia)*
Of the 12 metals included in the various sediment classifications, the majority (92%) of concentrations recorded at the 15 tributary sites were ranked "non-elevated" or "slightly elevated" by all applicable guidelines. Forty-seven percent (7/15) of all tributary sites had all metal detections in the "non elevated"or "slightly elevated" category.

There were no sites with metal concentrations in the "extremely elevated" range and only three sites with metals in the "highly elevated" range. Muddy Creek (RM 2.50) recorded Barium (168 mg/kg) and Nickel (29.2 mg/kg) in the "highly elevated" range. The other two sites recording "highly elevated" metal results were Cowan Creek (RM 1.34) recorded Aluminum at 35,800 mg/kg and Simpson Creek (RM 0.01) recording Barium at 134 mg/kg.

Table 12. Concentrations (mg/kg) of metals in sediment samples collected from tributaries in the lower Little Miami River study area during 1998. Parameter concentrations were evaluated based on Ohio EPA sediment reference sites, the Kelly and Hite (1984) stream sediment classification system and the Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (1993).

| **Stream** | **----------Sediment Concentration (mg/kg dry weight)----------** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Al-T**** | **As-T** | **Ba-T**** | **Ca-T*** | **Cd-T** | **Cr-T** | **Cu-T** | **Fe-T** | **Pb-T** |
| **Todd Fork** | | | | | | | | | |
| 15.17 | 11200$^{A}$ | 4.18$^{Aa}$ | 60.7$^{‡A}$ | 26900$^{‡}$ | 0.169$^{Aa}$ | <14.9$^{Aa}$ | 9.46$^{Aa}$ | 10700$^{‡Aa}$ | <19.9$^{Aa}$ |
| 0.14 | 11000$^{A}$ | 3.53$^{Aa}$ | 65.6$^{A}$ | 27500 | 0.131$^{Aa}$ | 12.7$^{Aa}$ | 6.97$^{Aa}$ | 10900$^{Aa}$ | 30.8$^{Bb}$ |
| **Lytle Creek** | | | | | | | | | |
| 9.25 | 13000$^{B}$ | 4.65$^{Aa}$ | 74$^{‡A}$ | 29100$^{‡}$ | 0.301$^{Aa}$ | 18.5$^{Ab}$ | 21.7$^{Ba}$ | 12500$^{‡Aa}$ | 27$^{Aa}$ |
| 7.01 | *17700*$^{C}$ | 7.33$^{Aa}$ | 125$^{B}$ | 31700 | *0.803*$^{Cb}$ | *26.1*$^{Bc}$ | 25.4$^{Ba}$ | 16000$^{Aa}$ | 36.6$^{Ab}$ |
| 5.94 | 13300$^{B}$ | 5.64$^{Aa}$ | 90.2$^{‡A}$ | 23900$^{‡}$ | 0.417$^{Aa}$ | 19.6$^{‡Ab}$ | 21.5$^{Ba}$ | 12300$^{‡Aa}$ | 30.7$^{Ab}$ |
| **Cowan Creek** | | | | | | | | | |
| 13.20 | 14800$^{B}$ | 5.43$^{Aa}$ | 82.7$^{‡A}$ | 12600$^{‡}$ | 0.202$^{Aa}$ | <18.9$^{Aa-b}$ | 12.6$^{Aa}$ | 14000$^{‡Aa}$ | <25.2$^{Aa}$ |
| 12.45 | *21900*$^{C}$ | 5.5$^{Aa}$ | 132$^{‡B}$ | 15600$^{‡}$ | 0.346$^{Aa}$ | *24.4*$^{‡Bc}$ | 14.9$^{Aa}$ | 15700$^{‡Aa}$ | <27.2$^{Aa}$ |
| 8.38 | 10400$^{A}$ | 5.17$^{Aa}$ | 60.8$^{A}$ | 13700 | 0.174$^{Aa}$ | <13.7$^{Aa}$ | 8.69$^{Aa}$ | 11900$^{Aa}$ | <18.3$^{Aa}$ |
| 1.34 | **35800**$^{D}$ | 5$^{Aa}$ | *145*$^{C}$ | 35000 | <0.0999$^{Aa}$ | *33.5*$^{Cc}$ | 12$^{Aa}$ | *23600*$^{Bc}$ | <20.0$^{Aa}$ |
| **Indian Run** | | | | | | | | | |
| 0.10 | *15600*$^{C}$ | 6.01$^{Aa}$ | 111$^{‡B}$ | 40100$^{‡}$ | 0.426$^{Aa}$ | 21.3$^{‡Bb}$ | 14.9$^{Aa}$ | 14500$^{‡Aa}$ | <25.8$^{Aa}$ |
| **East Fork Todd Fork** | | | | | | | | | |
| 1.60 | 13600$^{B}$ | 3.83$^{Aa}$ | 78.7$^{A}$ | 12300 | 0.148$^{Aa}$ | <15.3$^{Aa}$ | 11.8$^{Aa}$ | 11700$^{Aa}$ | <20.4$^{Aa}$ |
| **Muddy Creek** | | | | | | | | | |
| 2.50 | *33400*$^{C}$ | 8.93$^{Bb}$ | **168**$^{D}$ | 50800 | 0.23$^{Aa}$ | *32.3*$^{Cc}$ | 15$^{Aa}$ | *29200*$^{Ac}$ | 20.8$^{Aa}$ |
| **Simpson Creek** | | | | | | | | | |
| 0.01 | *23700*$^{C}$ | 5.13$^{Aa}$ | **134**$^{D}$ | 30600 | <0.218$^{Aa}$ | *<32.8*$^{Aa-Cc}$ | *42.6*$^{Cb}$ | 20600$^{Ab}$ | *<43.7*$^{Aa-Cc}$ |
| **O Bannon Creek** | | | | | | | | | |
| 0.26 | 15300$^{B}$ | 5.48$^{Aa}$ | *93.7*$^{C}$ | 36500 | 0.152$^{Aa}$ | <18.2$^{Aa-b}$ | 9.13$^{Aa}$ | 15900$^{Aa}$ | <24.3$^{Aa-B}$ |
| **Sycamore Creek** | | | | | | | | | |
| 0.20 | 11300$^{A}$ | 4.25$^{Aa}$ | 66.2$^{A}$ | 40500 | 0.192$^{Aa}$ | <15.2$^{Aa}$ | 8.6$^{Aa}$ | 13600$^{Aa}$ | <20.2$^{Aa}$ |

Table 12. Continued.

| Stream | ----------Sediment Concentration (mg/kg dry weight)---------- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River Mile | **Mg-T*** | **Mn-T** | **Hg-T*** ** | **Na-T*** | **Ni-T#** | **K-T*** | **Se-T*** | **Sr-T*** | **Zn-T** |
| **Todd Fork (continued)** | | | | | | | | | |
| 15.17 | 11000 | 273[Aa] | <0.0379[a] | <2490 | <19.9[A] | 2490 | <0.996 | 40.3 | 49.3[Aa] |
| 0.14 | 6560 | 385[Aa] | <0.0294[a] | <2050 | <16.4[A-B] | 2460 | <0.820 | 54.1 | 43.9[Aa] |
| **Lytle Creek (continued)** | | | | | | | | | |
| 9.25 | 13200 | 258[Aa] | <0.0298[a] | <2640 | <21.1[A] | 3700 | <1.06 | 42.3 | 87.2[Ab] |
| 7.01 | 13400 | 320[Aa] | 0.0418[a] | <3520 | <28.2[A-B] | 4230 | <1.41 | 53.5 | *148*[Cc] |
| 5.94 | 10400 | 356[Ba] | <0.0360[a] | <3070 | <24.5[A] | 3680 | <1.23 | 49.7 | 99.4[Ab] |
| **Cowan Creek (continued)** | | | | | | | | | |
| 13.20 | 6940 | 317[Aa] | <0.0342[a] | <3150 | <25.2[A] | 2520 | <1.26 | 48 | 50.5[Aa] |
| 12.45 | 6790 | 371[Ba] | <0.0401[a] | <3390 | <27.2[A] | 4750 | <1.36 | 74.7 | 65.2[Aa] |
| 8.38 | 5950 | 221[Aa] | <0.0293[a] | <2290 | <18.3[A] | 1830 | <0.915 | 25.6 | 58.6[Aa] |
| 1.34 | 13000 | 446[Ba] | <0.0268[a] | <2500 | 21.5[A] | 14500 | <0.999 | 64.9 | 57.4[Aa] |
| **Indian Run (continued)** | | | | | | | | | |
| 0.10 | 9690 | 280[Aa] | <0.0389[a] | <3230 | <25.8[A] | 3230 | <1.29 | 196 | 75[Aa] |
| **East Fork Todd Fork (continued)** | | | | | | | | | |
| 1.60 | 4090 | *488*[Ca] | 0.0459[a] | <2560 | <20.4[A] | 3580 | <1.02 | 26.6 | 61.3[Aa] |
| **Muddy Creek (continued)** | | | | | | | | | |
| 2.50 | 11000 | 583[Aa] | <0.0309[a] | <2210 | **29.2[D]** | 8840 | 0.928 | 118 | 73.4[Aa] |
| **Simpson Creek (continued)** | | | | | | | | | |
| 0.01 | 7650 | 1000[Ba] | <0.0584[a] | <5460 | **<43.7[A-D]** | 6550 | <2.18 | 87.4 | *129*[Cc] |
| **O Bannon Creek (continued)** | | | | | | | | | |
| 0.26 | 5480 | 550[Aa] | <0.0271[a] | <3040 | *<24.3*[A-C] | 3650 | <1.22 | 91.3 | 59.6[Aa] |
| **Sycamore Creek (continued)** | | | | | | | | | |
| 0.20 | 5560 | 478[Aa] | <0.0315[a] | <2530 | *<20.2*[A-C] | 3030 | <1.01 | 84 | 53.1[Aa] |

Table 12. Continued

* Not evaluated by Ohio EPA, Kelly and Hite (1984) or Ontario (1993).
** Not evaluated by Kelly and Hite (1984) or Ontario (1993).
*** Not evaluated by Ohio EPA.
[#] Not evaluated by Kelly and Hite (1984).
[‡] Estimated value.

| Ohio EPA Guidelines: | Kelly and Hite Guidelines: | Ontario Guidelines: |
|---|---|---|
| [A] Non-elevated | [a] Non-elevated | **severe effect level (SEL)** |
| [B] Slightly elevated | [b] Slightly elevated | |
| *[C] Elevated* | *[c] Elevated* | |
| **[D] Highly elevated** | **[d] Highly elevated** | |
| **[E] Extremely elevated** | **[e] Extremely elevated** | |

[§] Ohio EPA sediment guidelines are based on ecoregions. Muddy Creek, Simpson Creek, O'Bannon Creek, Sycamore Creek and river mile 0.14 on Todd Fork are evaluated based on guidelines for the Interior Plateau (IP) ecoregion; remaining sites are evaluated based on guidelines for the Eastern Corn Belt Plain (ECBP) ecoregion. (Aluminum concentrations for sites in the IP ecoregion were evaluated based on Ohio EPA statewide guidelines.)

**Sediment Organics**

Organic compounds detected in sediment samples were are divided into two groups. One group of compounds which have quantifiable values (compounds detected are compared to a known standard at five different concentrations) and the second group are compounds whose peaks match the computer's spectral database but are not compared to a known standard. The latter group of reported compounds is called tentatively identified compounds (TIC). Tentatively identified compound information is not as reliable as quantifiable compound information. The computer is approximately 80% accurate on TIC identification and concentrations can be off as much as 100%.

*Mainstem*

Sediments from the mainstem documented 68% (15/22) of the locations without any quantifiable organic compounds Table 13. The upper part of the mainstem (RM 98.98 to RM 63.28) recorded 100% (7/7) of the locations with quantifiable organic compounds. Results from the lower part of the mainstem (RM 60.84 to RM 8.14) did not detect any quantifiable organic compounds present in the 12 sediment locations. Historical results from the 1993 survey indicated that 75% (3/12) of the mainstem sites did not have any quantifiable organic compounds..

Polynuclear aromatic hydrocarbons (PAH) were detected in 18% (4/22) of the mainstem sites with Fluoranthene common at all four sites. PAH's are often associated with urban activities. They are found in coal piles, runoff from asphalt, downstream of sewage treatment facilities and are the products of incomplete combustion such as from diesel and automobile exhaust.

The most contaminated quantifiable organic sediment site on the mainstem was at RM 63.28 (total PAHs 6.73 mg/kg), downstream from Glady Run (also contaminated with PAH's). Benzo(a)pyrene, Benzo(k)fluoranthene, Chrysene, Fluoranthene, Phenanthrene, and Pyrene were detected in levels greater than the lowest effect level (LEL) established by the Ontario guidelines. Sediment results from the 1993 survey detected Chrysene, Fluoranthene, Phenanthrene, and Pyrene at almost identical concentrations documented in 1998. Benzo(a)pyrene was a compound newly detected in 1998. Benzo(a)anthracene was detected in 1993 but not detected in the 1998 sample results. Benzo(b&k)fluoranthene was listed in laboratory results as two separate compounds in 1998.

Ontario "Lowest Effect Level"guidelines were also exceeded at Dolly Varden Road (RM 98.98) (Dieldrin 16.6 $\mu$g/kg) and at Indian Ripple Road (RM 72.3) (Fluoranthene(1.5 mg/kg) and (Pyrene 1.1 mg/kg).

Also detected but not evaluated by any of the established guidelines was 3&4 Methylphenol at RM 80.63 (U.S. 68) and RM 76.90 (downstream of Xenia Ford Road WWTP). The compounds 3- Methylphenol (meta-cresol) and 4- Methylphenol (para-cresol) are found in coal tar and petroleum and have been used as a wood preservative in railroad ties and telephone poles. The 1993 report did not evaluate RM 80.63 and found no compounds detected at RM 76.90.

Nineteen different tentatively identified compounds were detected in the sediments of the mainstem. The majority of compounds detected were in the single digit part per million (mg/kg) range and were not evaluated by any of the guidelines. The most common compounds detected were: Nonacosane ($C_{29}H_{60}$) found in 86% (19/22) of samples, Heptacosane ($C_{27}H_{56}$) found in 82% (18/22) of samples, gamma-Sitosterol found in 68% (15/22) of samples, Pentacosane ($C_{25}H_{52}$) found in 64% (14/22) of samples, and Hexadecanoic Acid ($C_{16}H_{32}O_2$) found in 32% (7/22) of samples. The majority of these compounds can be associated with the degradation of organic products such as plant material and sewage sludge.

Table 13. Sediment concentrations (mg/kg) of semi-volatile, volatile, pesticide, and PCB compounds (priority pollutant scan) detected in the Little Miami River study area during 1998. Individual compounds were evaluated by the Kelly-Hite (1984) Stream Sediment Classification System and the Ontario Aquatic Sediment Quality Guidelines. (Persuad 1993).

| Landmark River Mile | Analysis Performed | Compound Detected | Result |
|---|---|---|---|
| **#1B Little Miami River** Pay Gro Bridge RM 106.35 | 1) VOC | Acetone | 0.123 mg/kg |
| | 2) BNA | | BDL |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#3 Little Miami River** Dolly Varden Road RM 98.98 | 1) VOCs | | BDL |
| | 2) BNA | | BDL |
| | 3) Pesticides | Dieldrin £ | 16.6 $\mu$g/kg |
| | 4) PCBs | | BDL |
| **#7 Little Miami River** Grinnel Road RM 85.38 | 1) VOCs | | BDL |
| | 2) BNA | | BDL |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#9 Little Miami River** U.S. 68 RM 80.63 | 1) VOCs | Acetone | 0.124 mg/kg |
| | 2) BNA | 3&4 Methylphenol * | 1.4 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#11 Little Miami River** dst. Xenia Ford Rd. WWTP RM 76.90 | 1) VOCs | Acetone | 0.129 mg/kg |
| | 2) BNA | 3&4 Methylphenol * | 3.4 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#13 Little Miami River** Indian Ripple Rd. RM 72.30 | 1) VOCs | Acetone | 0.0878 mg/kg |
| | 2) BNA | Flouranthene £ | 1.5 mg/kg |
| | | Pyrene £ | 1.1 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |

Table 13. Continued.

| Landmark River Mile | Analysis Performed | Compound Detected | Result |
|---|---|---|---|
| **#15 Little Miami River** Lower Bellbrook Rd. RM 66.56 | 1) VOCs | | BDL |
| | 2) BNA | Fluoranthene | 0.64 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#16 Little Miami River** dst. SR 725 & Sugar Ck. RM 65.25 | 1) VOCs | | BDL |
| | 2) BNA | Fluoranthene | 0.59 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#17 Little Miami River** dst. Sugar Ck. WWTP RM 64.28 | 1) VOCs | | BDL |
| | 2) BNA | | BDL |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#18 Little Miami River** LMR dst. Glady Run RM 63.28 | 1) VOCs | | BDL |
| | 2) BNA | Benzo(a)pyrene £ | 0.61 mg/kg |
| | | Benzo(k)Fluoranthene £ | 0.59 mg/kg |
| | | Chrysene £ | 0.73 mg/kg |
| | | Fluoranthene £ | 1.8 mg/kg |
| | | Phenanthrene £ | 1.6 mg/kg |
| | | Pyrene £ | 1.4 mg/kg |
| | | Total PAH | 6.73 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#19 Little Miami River** Roxanna New Burlington RM 60.84 | 1) VOCs | | BDL |
| | 2) BNA | | BDL |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#20 Little Miami River** adj.N.Burlington Rd. RM 55.25 | 1) VOCs | Acetone | 0.0769 mg/kg |
| | 2) BNA | | BDL |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |

Table 13. Continued.

| Landmark River Mile | Analysis Performed | Compound Detected | Result |
|---|---|---|---|
| **#21 Little Miami River** dst. Waynesville WWTP RM 53.69 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#22 Little Miami River** adj.Waynesville Rd. RM 50.75 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#23 Little Miami River** Oregonia Rd. RM 47.50 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#84 Little Miami River** SR 350 RM 43.76 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#84A Little Miami River** dst. Stubbs Mill Rd. RM 35.98 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#86 Little Miami River** Dst. Lebanon WWTP RM 31.96 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | Acetone | 0.0536 mg/kg<br>BDL<br>BDL<br>BDL |
| **#88 Little Miami River** Dst. Simpson Creek RM 28.00 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | Acetone | 0.0771 mg/kg<br>BDL<br>BDL<br>BDL |
| **#89 Little Miami River** Ust. O'Bannon Ck. RM 24.35 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |

Table 13. Continued.

| | | |
|---|---|---|
| **#92 Little Miami River** Lake Isabella RM 20.60 | 1) VOCs | BDL |
| | 2) BNA | BDL |
| | 3) Pesticides | BDL |
| | 4) PCBs | BDL |
| **#94A Little Miami River** Newtown Rd. RM 8.14 | 1) VOCs | BDL |
| | 2) BNA | BDL |
| | 3) Pesticides | BDL |
| | 4) PCBs | BDL |

1) Volatile Organic Compounds (VOC) U.S .EPA Method 8260
2) Base Neutral & Acid Extractibles (BNA) U.S. EPA Method 8270
3) Pesticides U.S. EPA Method 8081/8082A
4) Polychlorinated biphenyls (PCBs) U.S. EPA Method 8081/8082A

| Kelly-Hite Classification System | Ontario Sediment Guidelines |
|---|---|
| a non elevated < lowest effect level | |
| b slightly elevated | £> lowest effect level |
| c elevated | ▲ > severe effect level |
| **d highly elevated** | |
| **e extremely elevated** | |

* not evaluated by Kelly-Hite or Ontario
BDL Below Detection Limit

This chemical is used to clean sampling equipment and is believed to be residual from cleaning.

*Upper Tributaries*

Sediment organics in the upper tributaries are more influenced by urban activities than was the mainstem. No quantifiable organic compounds were detected in 46% (12/26) of the tributary locations. Polycyclic aromatic hydrocarbons (PAHs) were detected in 46% (12/26) of the tributary locations. All of those locations documenting PAHs in the sediments were in Greene County. Little Beaver Creek (5 sites), Beaver Creek (3 sites) , Glady Run(1 site), Shawnee Creek (1 site), Sugar Creek (1 site), and Little Sugar Creek (1 site) all recorded PAH compounds.

PAHs are released to the environment through natural and man- made sources with emissions largely to the atmosphere. Natural sources include emissions from volcanoes and forest fires. Man-made sources provide a much greater release volume than natural sources; the largest single source is burning of wood in homes. Automobile and truck emissions are also major sources of PAHs. PAHs enter surface water through atmospheric deposition, either by dry deposition or through precipitation. Industrial effluents, municipal wastewater, improper disposal of waste motor oil and coal pile runoff are some additional PAH sources to surface water. Due to their high $K_{ow}$ (octanal-water partition coefficient), PAHs will tend to accumulate in stream sediments. Rain appears to be a major vector for pollutant transfer. Larger particles emitted from urban sources tend to settle onto streets and when combined with road leaching, make up to 74% of the PAH transfer to surface water through urban runoff. Atmospheric washout due to rain events has been estimated as the other 26% of the PAH loading to surface water. (Ollivon, 1998)

The work of Ireland (1995) and Ankley (1994) has demonstrated the phototoxicity of PAH compounds. Many higher molecular weight PAH's can absorb energy from solar ultraviolet radiation, resulting in excited states that exhibit far more toxicity than the parent molecule. This phenomena would be most noticeable in clear streams with little riparian cover.

*Little Beaver Creek*

Sediments in the Little Beaver Creek documented the most significant organic contamination in the entire study area. It is not surprizing that the Invertebrate Community Index (ICI) of Little Beaver Creek documents a significant impact upon the Benthic community. Little Beaver Creek RM 4.40 (36.7 mg/kg total PAH) ranks as one of the more PAH contaminated streams in the Southwestern Ohio. Of the streams sampled by Ohio EPA, only the Great Miami River RM 51.3 (Butler County) (472.0 mg/kg total PAH), Dick's Creek RM 2.51 (Butler County) (50.2 mg/kg total PAH), Mill Creek RM 5.2 (Hamilton County) (48.1 mg/kg total PAH ), and Wolf Creek RM 16.61 (39.9 mg/kg total PAH) have worse PAH contamination. In addition to PAH's, PCB's, volatile organics, and pesticides were also detected in the sediments of Little Beaver Creek. All locations on Little Beaver Creek (5) recorded Benzo(a)pyrene, Chrysene, Fluoranthene, Phenanthrene, and Pyrene exceeded the "lowest effect level" established in the Ontario guidelines. Benzo(g,h,i)perylene and Benzo(k)fluoranthene exceeded the Ontario "lowest effect level" at 3 of 5 sites. Benzo(b)fluoranthene was detected at all sites but was not evaluated by any of the two organic guidelines.

Sediment samples taken at RM 4.62 upstream from the Montgomery County Eastern Regional

WWTP documented Benzo(a)pyrene (0.75 mg.kg), Chrysene (0.97 mg/kg), Fluoranthene (1.8 mg/kg), Phenanthrene (0.99 mg/kg), and Pyrene (1.4 mg/kg) all exceeded the Ontario "lowest effect level". Benzo(b)fluoranthene (0.97 mg/kg) and bis (2-Ethylhexyl)phthalate (1.3 mg/kg) were also detected but there are no guidelines established. No organic contamination was detected at this location in the 1993 survey.

Potential sources of PAHs could be due to urban runoff, industrial stormwater runoff from the Delphi Chassis Systems and sediment contamination from Gentile Air Force Depot (Defense Electronics Supply Center), which is presently under remediation for metal and PAH contamination.

The site at RM 4.40, downstream of the Montgomery County Eastern Regional WWTP, has significantly increased sediment PAHs. Also, total Chlordane (57.0 $\mu$g/kg), trans- Nonachlor (20.2 $\mu$g/kg), and PCB-1254 (140 $\mu$g/kg)were detected. Chlordane exceeded the Ontario "lowest effect level" and "extremely elevated" by the Kelly-Hite guidelines. PCB-1254 exceeded the Ontario "lowest effect level" and "elevated" by the Kelly-Hite guidelines. Trans-Nonachlor was not evaluated by any of the two guidelines. Total PAH concentration increased to 36.7 mg/kg with Benzo(a)pyrene , Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Fluoranthene, Indeno(1,2,3-cd) pyrene Phenanthrene, and Pyrene all exceeded Ontario "lowest effect level". Sewage sludge entering the stream from WWTP plant upsets as well as urban run off are known sources of PAHs.

The same group of 15 chemicals was present at sampling location RM 3.6, upstream of the old Lammars Barrel factory. Sediment contamination at RM 3.6 generally decreased but still exceeded the Kelly-Hite and Ontario guidelines. Total PAH levels decreased to 17.7 mg/kg. PCB- 1254 increased to 147$\mu$g/mg. In addition to being an urbanized watershed, several small businesses are located in the immediate riparian of the stream.

Location RM 3.47 was downstream of the Lammars barrel factory. This site was the location of an October 31,1969 fire that destroyed the entire barrel and solvent recycling operation. Contamination from past operations and the fire has been investigated by Ohio EPA and U.S.EPA. No remediation has taken place but is in the remedial investigation phase.

Ten additional volatile organic compounds and one new PCB were detected at the site adjacent to the Lammars barrel factory. None of the volatile organic compounds present are evaluated by any of the two guidelines, the total of 10 volatile organics was 1.21 mg/kg. Total PAHs decreased in concentration (7.41 mg/kg) from the upstream site. The same 8 PAHs evaluated by the Ontario guidelines still exceeded the "lowest effect level". Polychlorinated Biphenyl concentrations increased in the sediment with PCB-1254 increasing to 306$\mu$g/kg and PCB-1248 being detected for the first time at 109$\mu$g/kg. Total PCBs exceeded the "lowest effect level" by the Ontario guidelines and in the "highly elevated" range by the Kelly-Hite guidelines.

Little Beaver Creek at RM 0.05 documented Benzo(a)pyrene (0.80 mg/kg),Benzo(k)fluoranthene (0.91 mg/kg), Chrysene (1.0 mg/kg) Fluoranthene (2.1 mg/kg) and Pyrene (1.6 mg/kg) at levels

exceeding the Ontario "lowest effect level" guidelines. Total chlordanes were 20.4$\mu$g/kg, which was also over the Ontario "lowest effect level". A trend in decreasing PAH contamination in sediment occurs downstream of RM 4.40 (downstream of the WWTP).

*Beaver Creek*

Polycyclic aromatic hydrocarbons make up most the contamination detected in the three sites on Beaver Creek. The headwater site at RM 6.30 (near New Germany-Trebein) reported the most PAHs (6.46 mg/kg total) and highest concentrations of all three sites. This location is part of the Beavercreek wetlands geologic formation and the sediments are characteristic of wetland soils. Sediment organics included Benzo(k)fluoranthene (0.65 mg/kg), Chrysene (0.91 mg/kg), Fluoranthene (1.9 mg/kg), Phenanthrene (0.92 mg/kg) and Pyrene (1.4 mg/kg) exceeded the Ontario "lowest effect level" guidelines. Benzo(b)fluoranthene was also detected at 0.68 mg/kg, but was not evaluated by any of the two organic guidelines. Possible sources of PAH contamination could be due in part to the boom in new construction in the drainage area. In addition a great deal of asphalt resurfacing has been conducted in the watershed.

Sampling locations at RM 0.50 (3.94 mg/kg total PAH) and 0.20 (1.57 mg/kg total PAH) bracket the Beavercreek WWTP. Upstream of the WWTP (RM 0.50), (Chrysene (0.73 mg/kg), Fluoranthene (1.4 mg/kg), and Pyrene (1.1 mg/kg) were detected at levels exceeding the Ontario "lowest effect level" guidelines. In addition, Bis(2-ethylhexyl)phthalate (0.82 mg/kg) and Benzo(b)fluoranthene (0.71 mg/kg) were also detected. These compounds were not evaluated. The downstream site (RM 0.20) detected Fluoranthene (0.90) and Pyrene (0.67 mg/kg) at levels exceeding the Ontario "lowest effect level".

*Glady Run*

Glady Run (RM 4.08) documented seven of the characteristic urban PAHs present in sediments (9.99 mg/kg total PAH). Sediment organics included Benzo (a)pyrene (0.98 mg/kg), Benzo(k)fluoranthene (1.1 mg/kg), Chrysene (1.2 mg/kg), Fluoranthene (2.7 mg/kg), Phenanthrene (0.91 mg/kg) and Pyrene (2.0 mg/kg) exceeding the Ontario "lowest effect level". Bis (2-ethylhexyl)phthalate (2.5 mg/kg) and Benzo(b)fluoranthene (1.1 mg/kg) were also detected but not evaluated by any of the two guidelines. This tributary, receives drainage from Xenia and is subject to urban runoff from new construction, existing housing, industrial and commercial properties and discharges from the Glady Run WWTP.

Historical organic sediment analysis from the 1993 survey indicated that Glady Run (RM 4.75)(downstream of the WWTP) detected Fluoranthene (2.1 mg/kg), Chrysene (1.2 mg/kg), Pyrene (1.7 mg/kg) and Bis(2-ethylhexyl)phthalate (2.7 mg/kg). Analysis in 1993 from RM 4.82 (upstream of the WWTP) did not detect any organic compounds. The 1998 survey (RM 4.08) detected seven PAHs present, four more than was reported in 1993. The PAHs common to both surveys were at relatively the same concentrations in both years.

*Shawnee Creek* (RM 0.65)

Nine of the characteristic urban PAHs were present in Shawnee Creek,[ Benzo(a)pyrene (1.9 mg.kg), Benzo(g,h,i)perylene (1.0 mg/kg), Benzo(k)fluoranthene (1.9 mg/kg), Chrysene (2.3 mg/kg), Fluoranthene (3.6 mg/kg),Indeno(1,2,3,cd)pyrene (1.0), Phenanthrene (1.2 mg/kg), and Pyrene (3.0 mg/kg)] exceeding the Ontario "lowest effect level" guidelines. Benzo(b)fluoranthene (1.6 mg/kg.) was also present but not evaluated by the guidelines. Total PAHs were at 17.5 mg/kg . Potential sources are from urban runoff, sewage overflows into Shawnee Creek from the Ford Road WWTP collection system, Kilcare drag strip, Tom's Auto Parts upstream of the site, and major asphalt paving of Hawkins and Dayton-Xenia Roads in the area.

*Sugar Creek*

One organic compound, (Fluoranthene 0.76 mg/kg),was found in the sediments of Sugar Creek. This PAH exceeded the Ontario "lowest effect level".

*Little Sugar Creek* (RM 0.45)

This site documented Fluoranthene (1.0 mg/kg) and Pyrene (0.76 mg/l) exceeding the Ontario "lowest effect level". Di-n-butylphthalate (2.3 mg/kg) and 3&4 Methylphenol (2.2 mg/kg) were detected but were not evaluated by any of the guidelines.

Agricultural chemicals were found at 23% (6/26) of the upper tributary sites. Four of the six sites were associated with the Little Beaver Creek downstream of the Montgomery County Eastern Regional WWTP where Alpha-Chlordane, gamma Chlordane and trans-Nonachlor were present. Anderson Fork (RM 4.90) had Dieldrin at 8.01 $\mu$g/kg which exceeded the Ontario "lowest effect level" and elevated by the Kelly-Hite guidelines. Gilroy Ditch (RM 0.5) had a-BHC (14.5 mg/kg) and total chlordanes (16.5 mg/kg)exceeded Ontario "lowest effect level".

Twenty-five different tentatively identified compounds were detected in the sediments of the 26 upper tributary sites. The majority of compounds detected were in the single part per million (mg/kg) range and were not evaluated by any of the guidelines. The most common compounds detected are: Nonacosane ($C_{29}H_{60}$) found in 96% (25/26) of samples, Heptacosane ($C_{27}H_{56}$) found in 96% (25/26) of samples, gamma-Sitosterol found in 85% (22/26) of samples, Pentacosane ($C_{25}H_{52}$) found in 68% (18/26) of samples, and Hexadecanoic Acid ($C_{16}H_{32}O_2$) found in 62% (16/26) of samples. The majority of these compounds can be associated with the degradation of organic products such as plant material and sewage sludge.

*Lower Tributaries*

Sediment organics contamination in the lower tributaries were similar to the mainstem. No quantifiable organic compounds were detected in 67% (10/15) of the tributary locations. Organic contamination was detected at 33% ( 5/15) locations. Polycyclic aromatic hydrocarbons (PAHs) were detected in 27% (4/15) of the tributary locations.

*Lytle Creek*

All three sediment sites on Lytle Creek had organic contamination. Lytle Creek ranks as the second most contaminated drainage way in the entire survey, only Little Beaver Creek was more contaminated. The Invertebrate Community Index (ICI) of Lytle Creek documents a significant impact upon the Benthic community.

Lytle Creek (RM 9.25) (adjacent Townsend Field) is downstream from Airborne Express and detected nine of the characteristic urban PAH's [ Benzo(a)pyrene (0.89mg/kg), Benzo(g,h,i)perylene (0.69 mg/kg), Benzo(k)fluoranthene (0.78 mg/kg), Chrysene (1.1 mg/kg), Fluoranthene (2.3 mg/kg), Indeno(1,2,3,cd)pyrene (0.64 mg/kg), Phenanthrene (1.2 mg/kg), and Pyrene (1.8 mg/kg)] for a total of 10.23 mg/kg. Eight of the nine PAH's were above the Ontario "Lowest Effect Level" . Benzo(b)Fluoranthene (0.83 mg/kg) was the only PAH not evaluated by the Ontario guidelines.

Lytle Creek (RM 7.01) (Nelson Road) was one of the more contaminated sediment site on the entire survey. The survey area is influenced by Randall Textron's outfall, stormwater runoff and air deposition into the creek. In 1993, Ohio EPA issued Director's Findings and Orders to Randall Textron for air contaminant issues. The case was settled in 1996 . A new Director's Findings and Orders was issued in 1999 for different air contaminant issues. Ohio EPA also documented NPDES violations by Randall Textron into Lytle Creek. The survey area is also impacted by untreated sewage discharging into Lytle Creek from a manhole of the Wilmington WWTP's collection system. Sediments downstream from Randall Textron had an oily sheen to them. The same nine PAH's detected upstream at were present but at higher levels (25.33 mg/kg total PAH's) at RM 7.01. All of the same eight PAH's exceeded the Ontario "Lowest Effect Level". A new contaminant, PCB-1254 (181 mg/kg) was present at levels exceeding the Ontario "Lowest Effect Level"and " elevated" by the Kelly-Hite guidelines. An increase in PAH levels and the presence of a new contaminant ( PCB-1254) suggests a new source area. Lytle Creek (RM 5.94) is downstream of the Wilmington WWTP and the old Wilmington landfill. The stream bed is covered with a layer of sewage sediment. Sediment PAH levels have dropped to a total of 4.07 mg/kg for four of the same PAH's detected upstream. All four PAH's detected exceeded the Ontario "Lowest Effect Level". PCB-1254 levels decreased to 104 mg/kg but were still over the Ontario "Lowest Effect Level" and Kelly-Hite "elevated" level.

*Cowan Creek*

Cowan Creek (RM 12.45)(Jenkins Road) was the only organic contaminant site without PAH's present. Dieldrin was detected at 7.79 mg/kg which exceeded the Ontario "Lowest Effect Level" and Kelly-Hite "elevated" level.

Sixteen different tentatively identified compounds were detected in the sediments of the 15 lower tributary sites. The majority of compounds detected were in the single part per million (mg/kg) range and were not evaluated by any of the guidelines. The most common compounds detected are: Nonacosane ($C_{29}H_{60}$) found in 93% (14/15) of samples, Heptacosane ($C_{27}H_{56}$) found in 93% (14/15) of samples, gamma-Sitosterol found in 87% (13/15) of samples, Hexadecanoic Acid ($C_{16}H_{32}O_2$) found in 73%(11/15) of samples , and Pentacosane ($C_{25}H_{52}$) found in 67% (10/15) of samples. The

majority of these compounds can be associated with the degradation of organic products such as plant material and sewage sludge.

*Sycamore Creek*

Polycyclic aromatic hydrocarbons represented the majority of organic compound contamination detected at RM 0.2. Seven different PAH's totaling 7.77 mg/kg were found in the sediments downstream of the Hamilton County WWTP. All PAH's were characteristic of urban activity in types of PAH detected and concentrations present. Six of the seven PAH's exceeded the Ontario "Lowest Effect Level". Benzo(b)Fluoranthene was the only PAH not evaluated by the Ontario guidelines. Toluene was detected at 0.06 mg/kg and was not evaluated by any of the two guidelines. Particle size distribution was 83.1% sand or greater which suggests that organic contamination would have been higher if more fine grain material had been collected.

Table 14. Sediment concentrations (mg/kg) of semi-volatile, volatile, pesticide, and PCB compounds (priority pollutant scan) detected in the Little Miami River study area during 1998. Individual compounds were evaluated by the Kelly-Hite (1984) Stream Sediment Classification System and the Ontario Aquatic Sediment Quality Guidelines. (Persuad 1993).

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| **#24 Newman s Run** | 1) VOC | | BDL |
| U.S. 42 | 2) BNA | | BDL |
| RM 0.3 | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#28 Glady Run** | 1) VOCs | | BDL |
| Hedges Road | 2) BNA | Benzo(a) pyrene £ | 0.98 mg/kg |
| RM 4.08 | | Benzo(b)Fluoranthene £ | 1.1 mg/kg |
| | | Benzo(k)Fluoranthene £ | 1.1 mg/kg |
| | | bis (2-Ethylhexyl)phthalate * | 2.5 mg/kg |
| | | Chrysene £ | 1.2 mg/kg |
| | | Fluoranthene £ | 2.7 mg/kg |
| | | Phenanthrene £ | 0.91 mg/kg |
| | | Pyrene £ | 2.0 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#31 Sugar Creek** | 1) VOCs | | BDL |
| Penewit Road | 2) BNA | Fluoranthene £ | 0.76 mg/kg |
| RM 0.4 | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#32 Little Sugar Creek** | 1) VOCs | | BDL |
| Maple Dr. | 2) BNA | Di-n-butylphthalate * | 2.3 mg/kg |
| RM 0.45 | | Fluoranthene £ | 1.0 mg/kg |
| | | 3&4 Methylphenol * | 2.2 mg/kg |
| | | Pyrene £ | 0.76 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| **#33 Beaver Creek** | 1) VOCs | | BDL |
| New Germany Trebein | 2) BNA | Benzo(b)Fluoranthene * | 0.68 mg/kg |
| RM 6.30 | | Benzo(k)Fluoranthene £ | 0.65 mg/kg |
| | | Chrysene £ | 0.91 mg/kg |
| | | Fluoranthene £ | 1.9 mg/kg |
| | | Phenanthrene £ | 0.92 mg/kg |
| | | Pyrene £ | 1.4 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **# 36 Beaver Creek** | 1) VOCs | Acetone ∮ | 0.118 mg/kg |
| ust. Beaver Creek WWTP | 2) BNA | Benzo(b)Fluoranthene * | 0.71 mg/kg |
| RM 0.50 | | bis (2-Ethylhexyl)phthalate * | 0.82 mg/kg |
| | | Chrysene £ | 0.73 mg/kg |
| | | Fluoranthene £ | 1.4 mg/kg |
| | | Pyrene £ | 1.1 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **# 37 Beaver Creek** | 1) VOCs | Acetone ∮ | 0.0756 mg/kg |
| dst. WWTP | 2) BNA | Fluoranthene £ | 0.90 mg/kg |
| RM 0.20 | | Pyrene £ | 0.67 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#39 Little Beaver Creek** | 1) VOCs | | BDL |
| ust. Mont. Co. Regional WWTP | 2) BNA | Benzo(a) pyrene £ | 0.75 mg/kg |
| RM 4.62 | | Benzo(b)Fluoranthene * | 0.97 mg/kg |
| | | bis (2-Ethylhexyl)phthalate * | 1.3 mg/kg |
| | | Chrysene £ | 0.97 mg/kg |
| | | Fluoranthene £ | 1.8 mg/kg |
| | | Phenanthrene £ | 0.99 mg/kg |
| | | Pyrene £ | 1.4 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| **#39A Little Beaver Ck.** dst. Mont. Co. WWTP RM 4.40 | 1) VOCs | | BDL |
| | 2) BNA | Benzo(a) pyrene £ | 3.0 mg/kg |
| | | Benzo(b)Fluoranthene * | 3.4 mg/kg |
| | | Benzo(g,h,i)perylene £ | 2.4 mg/kg |
| | | Benzo(k)Fluoranthene £ | 3.3 mg/kg |
| | | bis (2-Ethylhexyl)phthalate* | 6.6 mg/kg |
| | | Chrysene £ | 4.0 mg/kg |
| | | Fluoranthene £ | 8.2 mg/kg |
| | | Indeno(1,2,3-cd) pyrene £ | 2.2 mg/kg |
| | | 3&4 Methylphenol * | 6.2 mg/kg |
| | | Phenanthrene £ | 3.9 mg/kg |
| | | Pyrene £ | 6.3 mg/kg |
| | 3) Pesticides | Alpha-Chlordane | 25.2 μg/kg |
| | | Gamma-Chlordane | 31.8 μg/kg |
| | | Total Chlordane £ e | 57.0 μg/kg |
| | 4) PCBs | trans-Nonachlor * | 20.2 μg/kg |
| | | PCB-1254 £ c | 140 μg/kg |
| **Ex Little Beaver Creek** Grange Hall Rd. Ust. Lammars Barrel RM 3.6 | 1) VOCs | Acetone ∮ | 0.0922 mg/kg |
| | 2) BNA | Benzo(a) pyrene £ | 1.7 mg/kg |
| | | Benzo(b)Fluoranthene * | 2.0 mg/kg |
| | | Benzo(g,h,i)perylene £ | 1.4 mg/kg |
| | | Benzo(k)Fluoranthene £ | 1.6 mg/kg |
| | | bis (2-Ethylhexyl)phthalate * | 3.0 mg/kg |
| | | Chrysene £ | 2.1 mg/kg |
| | | Fluoranthene £ | 4.2 mg/kg |
| | | Indeno(1,2,3-cd) pyrene £ | 1.3 mg/kg |
| | | 3&4 Methylphenol * | 0.79 mg/kg |
| | | Phenanthrene £ | 1.9 mg/kg |
| | | Pyrene £ | 3.2 mg/kg |
| | 3) Pesticides | Alpha-Chlordane | 18.7 μg/kg |
| | | Gamma-Chlordane | 25.6 μg/kg |
| | | Total Chlordane £ | 44.3 μg/kg |
| | | trans-Nonachlor * | 13.0 μg/kg |
| | 4) PCBs | PCB-1254 £ c | 147 μg/kg |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| **#40 Little Beaver Creek** Grange Hall Road dst. Lammars Barrel RM 3.47 | 1) VOCs | n-Butylbenzene * | 0.0538 mg/kg |
| | | tert-Butylbenzene * | 0.0634 mg/kg |
| | | Ethylbenzene * | 0.0495 mg/kg |
| | | Naphthalene * | 0.0480 mg/kg |
| | | n-Propylbenzene * | 0.0668 mg/kg |
| | | 1,2,3-Trimethylbenzene* | 0.445 mg/kg |
| | | 1,2,5-Trimethylbenzene * | 0.143 mg/kg |
| | | o-Xylene * | 0.0793 mg/kg |
| | | m&p-Xylene * | 0.258 mg/kg |
| | 2) BNA | Benzo(a) pyrene £ | 0.62 mg/kg |
| | | Benzo(b)Fluoranthene * | 0.64 mg/kg |
| | | Benzo(g,h,i)perylene £ | 0.53 mg/kg |
| | | Benzo(k)Fluoranthene £ | 0.61 mg/kg |
| | | bis (2-Ethylhexyl)phthalate * | 1.0 mg/kg |
| | | Chrysene £ | 0.75 mg/kg |
| | | Fluoranthene £ | 1.6 mg/kg |
| | | Indeno(1,2,3-cd) pyrene £ | 0.57 mg/kg |
| | | Phenanthrene £ | 0.79 mg/kg |
| | | Pyrene £ | 1.2 mg/kg |
| | 3) Pesticides | Gamma-Chlordane | 17.7 $\mu$g/kg |
| | | Total Chlordane £ | 17.7 $\mu$g/kg |
| | 4) PCBs | PCB-1248 £ | 109 $\mu$g/kg |
| | | PCB-1254 £ | 306 $\mu$g/kg |
| **#42 Little Beaver Ck.** @ Factory Road RM 0.05 | 1) VOCs | | BDL |
| | 2) BNA | Benzo(a) pyrene £ | 0.80 mg/kg |
| | | Benzo(b)Fluoranthene * | 0.92 mg/kg |
| | | Benzo(k)Fluoranthene £ | 0.91 mg/kg |
| | | bis (2-Ethylhexyl)phthalate* | 1.4 mg/kg |
| | | Chrysene £ | 1.0 mg/kg |
| | | Fluoranthene £ | 2.1 mg/kg |
| | | 3&4 Methylphenol* | 1.3 mg/kg |
| | | Phenanthrene £ | 0.91 mg/kg |
| | | Pyrene £ | 1.6 mg/kg |
| | 3) Pesticides | Alpha-Chlordane | 9.50 $\mu$g/kg |
| | | Gamma-Chlordane | 10.9 $\mu$g/kg |
| | | Total Chlordane £ | 20.4 $\mu$g/kg |
| | 4) PCBs | | BDL |
| **#44 Ludlow Creek** @Hilltop Road RM 0.2 | 1) VOCs | | BDL |
| | 2) BNA | | BDL |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| ***#47* Yellow Springs Creek** @Grinnel Road RM | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#49 N.Fk. Little Miami River** North River Road RM 0.37 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#52 Gilroy Ditch** @Bearchet Farm RM 0.5 | 1) VOCs<br>2) BNA<br>3) Pesticides<br><br>4) PCBs | <br><br>a-BHC £<br>Gamma-Chlordane<br>Total Chlordane £ | BDL<br>BDL<br>14.5 $\mu$g/kg<br>16.5 $\mu$g/kg<br>16.5 $\mu$g/kg<br>BDL |
| **#53 Shawnee Creek** Hawkins Road RM 0.65 | 1) VOCs<br>2) BNA<br><br><br><br><br><br><br><br>3) Pesticides<br>4) PCBs | Acetone ∮<br>Benzo(a) pyrene £<br>Benzo(b)Fluoranthene *<br>Benzo(g,h,i)perylene £<br>Benzo(k)Fluoranthene £<br>Chrysene £<br>Fluoranthene £<br>Indeno(1,2,3-cd) pyrene £<br>Phenanthrene £<br>Pyrene £ | 0.07 mg/kg<br>1.9 mg/kg<br>1.6 mg/kg<br>1.0 mg/kg<br>1.9 mg/kg<br>2.3 mg/kg<br>3.6 mg/kg<br>1.0 mg/kg<br>1.2 mg/kg<br>3.0 mg/kg<br>BDL<br>BDL |
| **#54 Caesar Creek** New Jasper -Paintersville RM 26.5 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#56 Caesar Creek** Spring Valley -Paintersville RM 16.52 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| **#57 Caesar Creek**<br>Corwin Road<br>RM 0.15 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#64 Anderson Fork**<br>U.S. 68<br>RM 9.45 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#65 Anderson Fork**<br>Winchester Trail<br>RM 4.90 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | <br><br>Dieldrin £ | BDL<br>BDL<br>8.01 $\mu$g/kg<br>BDL |
| **#68S. Branch Caesar Cr.**<br>@Hoop Road<br>RM 2.10 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#70 N. Branch Caesar Creek**<br>Jasper Road<br>RM 1.23 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#71 Massie Creek**<br>Tarbox Cemetery Rd.<br>RM 7.71 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |
| **#74 Massie Creek**<br>US 68 ust Old Town Ck.<br>RM 0.26 | 1) VOCs<br>2) BNA<br>3) Pesticides<br>4) PCBs | | BDL<br>BDL<br>BDL<br>BDL |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** |
|---|---|---|---|
| **#96 Sycamore Creek** | 1) VOC | Toluene | 0.06 mg/kg |
| dst. Hamilton Co. WWTP | 2) BNA | Benzo(a)pyrene £ | 0.67 mg/kg |
| RM 0.2 | | Benzo(b)Fluoranthene | 0.72 mg/kg |
| | | Benzo(k)Fluoranthene £ | 0.62 mg/kg |
| | | Chrysene £ | 0.86 mg/kg |
| | | Fluoranthene £ | 2.0 mg/kg |
| | | 3&4 Methylphenol* | 0.65 mg/kg |
| | | Phenanthrene £ | 1.4 mg/kg |
| | | Pyrene £ | 1.5 mg/kg |
| | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#99 O Bannon Creek** | 1) VOC | | BDL |
| S.R. 48 | 2) BNA | | BDL |
| RM 2.6 | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#101 Simpson Creek** | 1) VOC | | BDL |
| dst. Lower LMR WWTP | 2) BNA | | BDL |
| RM 0.15 | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#103 Muddy Creek** | 1) VOC | | BDL |
| Mason Road | 2) BNA | | BDL |
| dst. Mason WWTP | 3) Pesticides | | BDL |
| RM 2.50 | 4) PCBs | | BDL |
| **#106 Todd Fork** | 1) VOC | Acetone ∮ | 0.0784 mg/kg |
| Spring Hill Road | 2) BNA | | BDL |
| RM 15.17 | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#107 Todd Fork** | 1) VOC | | BDL |
| US 22/3@Morrow | 2) BNA | | BDL |
| RM 0.14 | 3) Pesticides | | BDL |
| | 4) PCBs | | BDL |
| **#108 Cowan Creek** | 1) VOC | Acetone ∮ | 0.0895 mg/kg |
| Jenkins Rd. | 2) BNA | 3&4 Methylphenol * | BDL |
| ust. Indian Run & ABX | 3) Pesticides | Dieldrin | BDL |
| RM 13.20 | 4) PCBs | | BDL |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** | |
|---|---|---|---|---|
| **#109 Cowan Creek** | 1) VOC | | 0.109 | mg/kg |
| adj. Jenkins Road | 2) BNA | | 1.5 | mg/kg |
| dst. Indian Run & ABX | 3) Pesticides | | 7.79 | $\mu$g/kg |
| RM 12.45 | 4) PCBs | | BDL | |
| **#111 Cowan Creek** | 1) VOC | | BDL | |
| Cuba Rd. | 2) BNA | | BDL | |
| RM 8.38 | 3) Pesticides | | BDL | |
| | 4) PCBs | | BDL | |
| **#112 Cowan Creek** | 1) VOC | | BDL | |
| adj. Cowan Creek Rd. | 2) BNA | | BDL | |
| Dst. Cowan Lake | 3) Pesticides | | BDL | |
| RM 1.34 | 4) PCBs | | BDL | |
| **#113 Indian Run** | 1) VOC | Acetone ∮ | 0.0914 | mg/kg |
| @ mouth dst. ABX | 2) BNA | | BDL | |
| RM 0.10 | 3) Pesticides | | BDL | |
| | 4) PCBs | | BDL | |
| **#114 Lytle Creek** | 1) VOC | Acetone ∮ | 0.0721 | mg/kg |
| adj. Townsend Field | 2) BNA | Benzo(a)pyrene £ | 0.89 | mg/kg |
| dst. ABX | | Benzo(b)Fluoranthene | 0.83 | mg/kg |
| RM 9.25 | | Benzo(g,h,i)perylene | 0.69 | mg/kg |
| | | Benzo(k)Fluoranthene £ | 0.78 | mg/kg |
| | | Chrysene £ | 1.1 | mg/kg |
| | | Fluoranthene £ | 2.3 | mg/kg |
| | | Indeno(1,2,3-cd)pyrene | 0.64 | mg/kg |
| | | Phenanthrene £ | 1.2 | mg/kg |
| | | Pyrene | 1.8 | mg/kg |
| | 3) Pesticides | | BDL | |
| | 4) PCBs | | BDL | |

| Table 14. Continued. **Landmark River Mile** | **Analysis Performed** | **Compound Detected** | **Result** | |
|---|---|---|---|---|
| **#115 Lytle Creek** | 1) VOC | | BDL | |
| Nelson Rd. | 2) BNA | Benzo(a)pyrene £ | 1.3 | mg/kg |
| RM 7.01 | | Benzo(b)Fluoranthene | 1.5 | mg/kg |
| | | Benzo(g,h,i)perylene | 1.1 | mg/kg |
| | | Benzo(k)Fluoranthene £ | 1.2 | mg/kg |
| | | bis(2-Ethylhexyl)phthalate* | 1.4 | mg/kg |
| | | Chrysene £ | 1.7 | mg/kg |
| | | Fluoranthene £ | 3.3 | mg/kg |
| | | Indeno(1,2,3-cd)pyrene | 1.0 | mg/kg |
| | | Phenanthrene £ | 1.4 | mg/kg |
| | | Pyrene £ | 2.6 | mg/kg |
| | 3) Pesticides | | BDL | |
| | 4) PCBs | PCB-1254 £ c | 181 | mg/kg |
| **#116 Lytle Creek** | 1) VOC | Acetone ∮ | 0.0936 | mg/kg |
| @Buffalo Farm | 2) BNA | Benzo(a)pyrene £ | 0.68 | mg/kg |
| dst. Wilmington WWTP | | bis(2-Ethylhexyl)phthalate* | 1.1 | mg/kg |
| RM 5.94 | | Chrysene £ | 0.79 | mg/kg |
| | | Fluoranthene £ | 1.4 | mg/kg |
| | | Pyrene £ | 1.2 | mg/kg |
| | 3) Pesticides | | BDL | |
| | 4) PCBs | PCB-1254 £ c | 104 | mg/kg |
| **#118 E. Frk. Todd** | 1) VOC | | BDL | |
| **Frk.** | 2) BNA | | BDL | |
| SR 132 | 3) Pesticides | | BDL | |
| RM 1.60 | 4) PCBs | | BDL | |

1) Volatile Organic Compounds (VOC) U.S .EPA Method 8260
2) Base Neutral & Acid Extractibles (BNA) U.S. EPA Method 8270
3) Pesticides U.S. EPA Method 8081/8082A
4) Polychlorinated biphenyls (PCBs) U.S. EPA Method 8081/8082A

| Kelly-Hite Classification System | Ontario Sediment Guidelines |
|---|---|
| a non elevated | < lowest effect level |
| b slightly elevated | £> lowest effect level |
| c elevated | ▲ > severe effect level |
| **d highly elevated** | |
| **e extremely elevated** | |

* not evaluated by Kelly-Hite or Ontario
BDL Below Detection Limit
This chemical is used to clean sampling equipment and is believed to be residual from cleaning.

## Habitat Quality for Aquatic Life

*Little Miami River*

Two patterns in the matrix of habitat attributes for the Little Miami River are apparent (Table 15). First, the headwaters upstream from Clifton, including the North Fork and Lisbon Fork, posses a greater number of anthropogenically derived habitat attributes than natural attributes. Row crop agriculture strongly influences in that part of the basin. The Qualitative Habitat Evaluation Index (QHEI) scores for the four sites sampled upstream from Clifton suggest that the potential to achieve EWH is limited by the number of modified habitat attributes (mean QHEI = 53 ± 10 SD). High influence modified habitat attributes (i.e., those strongly associated with impaired biological performance (Rankin 1995) encountered in the reach upstream from Clifton included sparse cover, no sinuosity, and channelization. An accumulation of two high influence attributes is likely to preclude fish communities from meeting WWH, and only rarely allow the fish community to meet EWH. Moderate influence attributes, by definition, have less effect on the fish community, such that five to six moderate influence attributes can sometimes be present without precluding a WWH fish community, especially when the influence extends to only a small reach. The four sites sampled upstream from Clifton each had four to eight moderate influence attributes, with riffle and substrate embeddedness, fair to poor channel development and low sinuosity being common to nearly all of the sites.

The other pattern evident in the QHEI matrix is that all the riffles are at least moderately embedded with fine gravel, sand and silt. These two patterns are related as the practices resulting in modified habitat attributes in the headwaters and tributaries result in the bedload of sediment that infiltrates the riffles throughout the mainstem. Two other pervasive sources of sediment loads affecting the mainstem are eroding banks, especially where the riparian buffers have been removed, and suburban development. In and downstream from Clifton, the habitat is otherwise capable of supporting EWH communities, with the habitat characterized by natural features derived from a free flowing channel interacting with glacial till and a mature riparian corridor. A free-flowing river allows for channel development (*i.e.*, riffle-pool-run sequences and sinuosity), glacial till provides a variety of substrate sizes, and woody debris augment structural complexity and cover. These characteristics generally exist downstream from Clifton as evidenced by the uniform pattern in the QHEI matrix. One feature not evident in the QHEI matrix is the transition between the ECBP and IP ecoregion. Functionally the change has little consequence for habitat quality or the fish community with one exception; as the river enters the IP, the riffles tend to become wider, longer and shallower, and the gradient increases slightly offering a favorable habitat for the mountain madtom, a State Endangered species.

*Tributaries*

Habitat quality was evaluated at 75 locations in 39 tributaries to the Little Miami River (Table 15). Of the 75 locations sampled, 52 had more positive habitat attributes than negative ones; the converse was true for the remaining 23 sites. Positive habitat attributes, referred to as WWH attributes in Table 15, are those attributes that are associated with high quality biological assemblages. And, as discussed for the Little Miami mainstem, negative habitat attributes (*i.e.*, modified attributes) are those that have a deleterious effect on the stream community. Having twice as many stream segments

with intact habitat compared to segments with degraded habitat indicates that the watershed, as a whole, is intact. This is especially true when one considers that the degraded stream segments are clustered in four main areas, and that subbasins subject to high levels of anthropogenic stress are sampled more intensively (*e.g.*, the Beaver Creek subbasin). The four clusters with degraded habitat are the entire Beaver Creek subbasin, the headwaters of Massie Creek, Anderson Fork, and the headwater tributaries of the Little Miami River (Lisbon Fork, Gilroy Ditch, North Fork LMR, Goose Creek). The common thread running through these groups is that they have either been channelized, are subjected to poor agricultural landuse practices, or both. With respect to the Little Miami River mainstem, the Beaver Creek subbasin and the headwater LMR tributaries are likely the greatest sources of sediment (excluding mainstem bank erosion), and therefore should be the focus of remedial action. Caesar Creek Reservoir acts as a sediment sink for Anderson Fork.

Ludlow Creek is the only other tributary sampled in the upper LMR watershed that stands out as having the potential to export high sediment loads. Ludlow Creek drains the rapidly developing eastern suburbs of Dayton.

Massie Creek is a good example of how high quality instream habitat and mature riparian buffers can help help mitigate adverse affects from upstream and assimilate pollutant loadings. Massie Creek drains intensively farmed land, and the North and South Branches of Massie are channelized and contain a heavy sediment load. However, substrates in Massie Creek are relatively clean. This is accomplished because the flood plain and stream channel are not disconnected by channelization, and the wooded flood plain filters and sequesters sediments during runoff and flood events. Massie Creek also demonstrates that agricultural landuse in close proximity to the stream can be sustained if certain practices are followed. The stream habitat at RM 1.2 was excellent, showing no modified traits and having a QHEI score of 80.5; despite flowing through a dairy farm with row crops. Here, the landowner, Dave Linkhart, practices good stewardship by fencing his cows out of the stream, and maintaining a wooded buffer along the margins.

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecoli) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-001) Little Miami River | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 104.9 | **47.5** | 8.33 | ■ | | | | | ■ | | | ■ | | | 3 | ● | | ● | ● | | 3 | ♦ | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 7 | 1.00 | 2.75 |
| 101.3 | **44.5** | 6.58 | ■ | ■ | | | | | | | ■ | | | 3 | | | ● | ● | | 2 | ♦ | ♦ | | | ♦ | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 8 | 0.75 | 2.75 |
| 98.3 | **54.0** | 8.33 | ■ | | | | ■ | | | | ■ | | | 3 | | | | ● | | 1 | ♦ | | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 6 | 0.50 | 2.00 |
| 92.2 | **67.0** | 5.59 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | | | | ♦ | | | | | ♦ | ♦ | ♦ | | 4 | 0.13 | 0.63 |
| 85.9 | **68.0** | 4.90 | ■ | | | | | | | ■ | ■ | ■ | | 4 | | | | ● | | 1 | ♦ | | | | ♦ | ♦ | | | | | ♦ | ♦ | | 5 | 0.40 | 1.40 |
| 83.1 | **81.5** | 25.00 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.10 | 0.20 |
| 80.6 | **79.0** | 2.96 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.10 | 0.20 |
| 76.8 | **79.5** | 5.13 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | | 2 | 0.11 | 0.33 |
| 72.3 | **82.0** | 4.78 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 69.3 | **79.0** | 3.06 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 65.6 | **77.0** | 2.60 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | ♦ | | | | | | | | | | ♦ | | 2 | 0.11 | 0.33 |
| 64.2 | **74.5** | 2.60 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | ♦ | | | | | | | | | ♦ | ♦ | | 3 | 0.11 | 0.44 |
| 63.3 | **78.0** | 2.60 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | | 2 | 0.11 | 0.33 |
| 59.8 | **77.0** | 4.44 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | ♦ | | | | | | | | | | ♦ | | 2 | 0.11 | 0.33 |
| 54.0 | **76.5** | 3.28 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | | 2 | 0.11 | 0.33 |
| 53.6 | **65.0** | 3.28 | ■ | | | | ■ | ■ | | | ■ | ■ | | 5 | | | | | | 0 | | | | | ♦ | | | | | ♦ | | ♦ | | 3 | 0.17 | 0.67 |
| 51.2 | **85.5** | 4.57 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 45.7 | **78.5** | 5.03 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | ● | | 1 | | | | ♦ | | | | | | | | ♦ | | 2 | 0.22 | 0.44 |
| 43.8 | **82.0** | 4.50 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 38.5 | **81.0** | 4.22 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 33.6 | **81.0** | 2.79 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 32.0 | **84.0** | 2.79 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 28.3 | **80.5** | 3.56 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 27.9 | **81.5** | 4.95 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 23.9 | **82.5** | 3.98 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| 21.9 | **76.5** | 4.65 | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | 7 | | | | ● | | 1 | | ♦ | | | ♦ | | | | | ♦ | | ♦ | | 4 | 0.25 | 0.75 |
| 21.1 | **81.5** | 3.85 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | ● | | 1 | | | | | | | | | | | | ♦ | | 1 | 0.22 | 0.33 |
| 18.5 | **79.0** | 6.58 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | ● | | 1 | | | | | | | | | | | | ♦ | | 1 | 0.22 | 0.33 |
| 13.5 | **81.0** | 5.52 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | | 2 | 0.10 | 0.30 |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecol) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-001) Little Miami River | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.9 | **84.5** | 4.98 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | | 9 | | | | | | 0 | | | | | | | | | | | ♦ | | 1 | 0.10 | 0.20 |
| 3.5 | **75.5** | 5.62 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | | | | | | | | | ♦ | ♦ | | 2 | 0.13 | 0.38 |
| (11-007) Sycamore Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.4 | **70.5** | 13.89 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | | 8 | | | | ● | | 1 | | | | ♦ | ♦ | | | | | ♦ | ♦ | | 4 | 0.22 | 0.67 |
| 0.2 | **63.5** | 13.89 | ■ | ■ | | ■ | ■ | | | ■ | | | ■ | 6 | | | | ● | | 1 | ♦ | | | | | | | | | ♦ | ♦ | | 3 | 0.29 | 0.71 |
| (11-010) O'Bannon Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.3 | **72.0** | 10.10 | ■ | ■ | | ■ | ■ | | | | ■ | ■ | | 6 | | | | ● | | 1 | | | | ♦ | | | | | | ♦ | ♦ | | 3 | 0.29 | 0.71 |
| 2.4 | **69.5** | 43.48 | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | | | 0 | | | | | | | ♦ | | | | | | 1 | 0.10 | 0.20 |
| 0.3 | **56.5** | 28.90 | ■ | | ■ | ■ | ■ | | | ■ | ■ | ■ | | 7 | | | | ● | | 1 | | | | ♦ | | | | | | | ♦ | | 2 | 0.25 | 0.50 |
| (11-017) Simpson Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.9 | **65.5** | 111.1 | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | ● | | 1 | | | | | | | | | | | | | 0 | 0.20 | 0.20 |
| 0.1 | **57.0** | 125.0 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | ● | | 1 | | | | | | | | | | | ♦ | | 1 | 0.20 | 0.30 |
| (11-020) Muddy Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.5 | **75.0** | 14.29 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | 2 | 0.11 | 0.33 |
| 2.5 | **69.5** | 38.46 | ■ | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 7 | | | | | | 0 | | | | | | | | | | | ♦ | | 1 | 0.13 | 0.25 |
| 0.7 | **73.5** | 22.73 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | 2 | 0.11 | 0.33 |
| (11-021) Turtle Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.3 | **70.5** | 10.42 | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | | 7 | | | | ● | | 1 | | | | | | | | | | | ♦ | ♦ | 2 | 0.25 | 0.50 |
| (11-030) Newman Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.3 | **61.5** | 41.67 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | ■ | 8 | | | | ● | | 1 | | | | | | | | | | ♦ | | | 1 | 0.22 | 0.33 |
| (11-031) Mill Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.9 | **61.5** | 22.99 | ■ | ■ | | ■ | ■ | ■ | | | ■ | | | 6 | | | | ● | ● | 2 | | | | | | | ♦ | | | ♦ | | ♦ | 3 | 0.43 | 0.86 |

Key QHEI Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | Total WWH Attributes | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | Total H.I. MWH Attributes | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecoli) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | Total M.I. MWH Attributes | (MWH H.I.+1)/(WWH+1) Ratio | (MWH M.I.+1)/(WWH+1) Ratio |
| (11-032) Glady Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.8 | 51.5 | 12.66 | ■ | | | | | | | | ■ | | ■ | 3 | | | ● | ● | ● | 3 | ♦ | | | | ♦ | ♦ | | | ♦ | | | | 4 | 1.00 | 2.00 |
| 4.0 | 66.5 | 26.32 | ■ | ■ | | ■ | | | ■ | ■ | | | ■ | 6 | | | ● | ● | | 2 | | | | | | ♦ | | | | ♦ | ♦ | | 3 | 0.43 | 0.86 |
| 2.1 | 67.5 | 37.04 | ■ | ■ | | ■ | ■ | ■ | ■ | | | | ■ | 7 | | | | | | 0 | | | | | ♦ | | ♦ | | | ♦ | ♦ | | 4 | 0.13 | 0.63 |
| (11-033) Sugar Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.4 | 71.5 | 9.43 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | | | | | | | | ♦ | ♦ | ♦ | | 3 | 0.13 | 0.50 |
| 0.4 | 71.5 | 8.13 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | | | | | | | | ♦ | | ♦ | | 2 | 0.13 | 0.38 |
| (11-034) Little Sugar Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.5 | 56.5 | 33.33 | ■ | ■ | | ■ | ■ | ■ | | | | | | 5 | | | | ● | ● | 2 | | | | | ♦ | | | | ♦ | ♦ | ♦ | | 4 | 0.50 | 1.17 |
| (11-035) Beaver Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.1 | 35.0 | 10.10 | | | | | | ■ | | | | ■ | | 2 | ● | ● | ● | ● | | 4 | | ♦ | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | ♦ | 7 | 1.67 | 4.00 |
| 3.9 | 37.5 | 4.29 | | | | | | | | | | ■ | | 1 | | ● | ● | ● | | 3 | ♦ | ♦ | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 2.00 | 5.50 |
| 1.6 | 57.0 | 5.21 | | ■ | | | ■ | ■ | ■ | | | ■ | | 5 | | | | ● | | 1 | ♦ | ♦ | | | ♦ | | | | | ♦ | ♦ | | 5 | 0.33 | 1.17 |
| 0.5 | 76.0 | 15.38 | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | | 7 | | | | | | 0 | | ♦ | | | ♦ | | | | | ♦ | ♦ | | 4 | 0.13 | 0.63 |
| 0.3 | 70.5 | 7.25 | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | | 7 | | | | | | 0 | | ♦ | | | ♦ | | | | | ♦ | ♦ | | 4 | 0.13 | 0.63 |
| (11-036) Little Beaver Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.7 | 58.5 | 16.13 | | ■ | | ■ | | | | | | ■ | | 3 | | | ● | ● | | 2 | ♦ | ♦ | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 0.75 | 2.50 |
| 3.5 | 60.0 | 15.63 | | ■ | | ■ | | ■ | ■ | | | ■ | | 5 | | | ● | ● | | 2 | ♦ | | | | ♦ | ♦ | | | | ♦ | ♦ | | 5 | 0.50 | 1.33 |
| 0.1 | 62.0 | 15.38 | | ■ | | | | ■ | | | | ■ | | 3 | | | | | | 0 | ♦ | | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 6 | 0.25 | 1.75 |
| (11-037) Ludlow Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.2 | 42.5 | 8.70 | | ■ | | | | | | | | ■ | | 2 | ● | | ● | ● | | 3 | ♦ | ♦ | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 1.33 | 3.67 |
| (11-038) Conner Branch | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.1 | 76.5 | 26.32 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | ♦ | ♦ | | 2 | 0.11 | 0.33 |
| (11-039) Jacoby Branch | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecol) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-039) Jacoby Branch | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.3 | **67.5** | 50.00 | ■ | ■ | | | ■ | ■ | ■ | | | ■ | ■ | 8 | | | | | | 0 | | ♦ | | | | | | | | ♦ | ♦ | ♦ | | 4 | 0.11 | 0.56 |
| (11-040) Yellow Springs Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.1 | **70.5** | 35.71 | ■ | ■ | | | ■ | ■ | ■ | | | | ■ | 6 | | | | | | 0 | | | | | | | | | | ♦ | ♦ | ♦ | | 3 | 0.14 | 0.57 |
| (11-041) North Fork Little Miami River | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.1 | **54.0** | 6.45 | ■ | ■ | | | | | ■ | | | | ■ | 4 | | | | | | 0 | ♦ | ♦ | | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 0.20 | 1.60 |
| 2.6 | **43.0** | 6.41 | | ■ | | | | | ■ | | | ■ | ■ | 4 | ● | | | ● | | 2 | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | ♦ | ♦ | ♦ | | 8 | 0.60 | 2.20 |
| (11-043) Lisbon Fork | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.4 | **52.0** | 10.20 | ■ | ■ | | | | ■ | | | | ■ | | 4 | | | ● | ● | ● | 3 | | ♦ | | | | ♦ | ♦ | ♦ | | ♦ | ♦ | ♦ | | 7 | 0.80 | 2.20 |
| (11-044) Gilroy Ditch | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.5 | **62.0** | 19.23 | | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 6 | | | ● | | | 1 | ♦ | ♦ | | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 0.29 | 1.29 |
| 1.3 | **59.0** | 22.73 | | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | ● | | | 1 | ♦ | | | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 6 | 0.25 | 1.00 |
| 0.5 | **49.0** | 11.63 | | ■ | | | ■ | | | | ■ | | | 3 | | | ● | ● | ● | 3 | ♦ | | | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 6 | 1.00 | 2.50 |
| (11-045) Shawnee Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.7 | **85.5** | 15.38 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | | | ♦ | | 1 | 0.11 | 0.22 |
| (11-053) Trib. to Little Miami R. (RM 60.50) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.2 | **71.0** | 62.50 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | ■ | 8 | | | ● | | | 1 | | | | | | | ♦ | | | ♦ | | | | 2 | 0.22 | 0.44 |
| (11-054) Trib. to Little Miami R. (RM 62.01) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.6 | **67.0** | 34.48 | ■ | ■ | | | ■ | ■ | | | ■ | | ■ | 6 | | | | | ● | 1 | | | | | | ♦ | | | | ♦ | | | | 2 | 0.29 | 0.57 |
| (11-101) Hall Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.5 | **56.0** | 58.82 | | ■ | | ■ | | | | ■ | ■ | | ■ | 5 | | | ● | ● | ● | 3 | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | | | | | 5 | 0.67 | 1.50 |
| 0.2 | **63.5** | 40.00 | | ■ | | ■ | | | | ■ | ■ | ■ | ■ | 6 | | | ● | ● | | 2 | ♦ | | | | | ♦ | ♦ | | | | | | | 3 | 0.43 | 0.86 |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecol) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-104) Sugarcamp Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.2 | **64.0** | 66.67 | ■ | ■ | | | ■ | | ■ | ■ | ■ | ■ | | 7 | | | ● | ● | | 2 | | | | ♦ | ♦ | | | | | | | | 2 | 0.38 | 0.63 |
| (11-105) Shayler Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.1 | **64.0** | 26.67 | ■ | | | ■ | | | | ■ | ■ | ■ | | 5 | | | ● | ● | | 2 | | | | ♦ | ♦ | | | | ♦ | | | | 3 | 0.50 | 1.00 |
| 1.7 | **64.0** | 29.85 | | ■ | | | | | ■ | ■ | ■ | ■ | | 5 | | | ● | ● | | 2 | ♦ | | | ♦ | ♦ | | | | | | | | 3 | 0.50 | 1.00 |
| (11-107) Stonelick Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17.7 | **60.5** | 7.09 | ■ | ■ | | | ■ | ■ | | | ■ | | | 5 | | | ● | | | 1 | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 6 | 0.33 | 1.33 |
| 9.8 | **57.0** | 18.87 | ■ | | | ■ | | | | ■ | ■ | ■ | | 5 | | | | ● | | 1 | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | | | 5 | 0.33 | 1.17 |
| 1.0 | **73.0** | 7.58 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | ♦ | | | | | | ♦ | | | 2 | 0.10 | 0.30 |
| (11-116) Lucy Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.0 | **45.5** | 55.56 | ■ | | | | | | | ■ | | ■ | | 3 | | | ● | ● | ● | 3 | ♦ | | | ♦ | ♦ | | | | ♦ | | | | 4 | 1.00 | 2.00 |
| 1.9 | **62.0** | 55.56 | | ■ | | ■ | | ■ | ■ | | ■ | | | 5 | | | ● | | | 1 | ♦ | ♦ | | | | ♦ | | | | ♦ | ♦ | | 5 | 0.33 | 1.17 |
| 0.2 | **60.0** | 60.61 | | | | ■ | | ■ | ■ | | ■ | | | 4 | | | ● | ● | | 2 | ♦ | ♦ | | ♦ | ♦ | | | | | ♦ | ♦ | | 6 | 0.60 | 1.80 |
| (11-120) Slabcamp Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.6 | **52.0** | 38.46 | ■ | ■ | | | ■ | | | ■ | | | | 4 | | | | ● | ● | 2 | | | | ♦ | | | ♦ | ♦ | | | | ♦ | 4 | 0.60 | 1.40 |
| (11-131) Cabin Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3 | **70.0** | 50.00 | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | ♦ | | | 1 | 0.11 | 0.22 |
| (11-133) Todd Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.0 | **61.5** | 47.62 | ■ | | | ■ | | ■ | | ■ | ■ | | | 6 | | | ● | ● | | 2 | ♦ | | | | ♦ | | | | ♦ | ♦ | ♦ | | 5 | 0.43 | 1.14 |
| (11-137) Pleasant Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.0 | **37.0** | 13.89 | ■ | | | | ■ | | | | | | | 2 | | ● | | ● | ● | 3 | ♦ | | | ♦ | | | | | ♦ | ♦ | ♦ | | 5 | 1.33 | 3.00 |
| 2.5 | **62.0** | 11.49 | ■ | ■ | | ■ | ■ | ■ | | | ■ | | | 6 | | | | | | 0 | ♦ | | | | | | | | ♦ | ♦ | ♦ | ♦ | 5 | 0.14 | 0.86 |
| 1.3 | **66.0** | 14.71 | ■ | ■ | | | ■ | ■ | | | ■ | | | 5 | | | | ● | | 1 | ♦ | | | ♦ | | | | | ♦ | ♦ | ♦ | | 5 | 0.33 | 1.17 |
| 0.5 | **62.5** | 25.00 | ■ | | | | | ■ | | | | | | 2 | | | ● | | ● | 2 | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 6 | 1.00 | 3.00 |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal Cobble, Gravel Substrates | Silt Free Substrates | Good, Excellent Substrates | Moderate, High Sinuosity | Extensive, Moderate Cover | Fast Current, Eddies | Low-Normal Overall | Riffle Embeddedness | Max Depth > 40 cm | Low-Normal Riffle Embeddedness | Total WWH Attributes | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | Total H.I. MWH Attributes | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecoli) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | Total M.I. MWH Attributes | (MWH H.I.+1)/(WWH+1) Ratio | (MWH M.I.+1)/(WWH+1) Ratio |
| (11-138) Fivemile Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.5 | 56.5 | 4.92 | ■ | | | ■ | | ■ | | | ■ | | | 4 | | | ● | ● | | 2 | ♦ | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | | 6 | 0.60 | 1.80 |
| (11-150) West Fork East Fork Little Miami River | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.2 | 71.0 | 8.67 | ■ | ■ | | ■ | ■ | ■ | ■ | | ■ | | | 7 | | | | ● | | 1 | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | | | 5 | 0.25 | 0.88 |
| (11-151) Dodson Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.2 | 47.0 | 5.68 | ■ | | | | | ■ | | | ■ | | | 3 | | | | ● | | 1 | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | ♦ | 7 | 0.50 | 2.25 |
| (11-154) Turtle Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.4 | 61.5 | 26.32 | ■ | ■ | | ■ | ■ | ■ | | | | | ■ | 6 | | | ● | | ● | 2 | ♦ | | | | ♦ | | | ♦ | ♦ | | | | 4 | 0.43 | 1.00 |
| 1.7 | 65.5 | 17.86 | ■ | | | | | ■ | ■ | | ■ | | | 4 | | | ● | | | 1 | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | | | 5 | 0.40 | 1.40 |
| (11-161) Trib. to Shayler Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.9 | 56.5 | 17.39 | ■ | ■ | | | ■ | | | | ■ | | | 4 | | | | ● | | 1 | ♦ | | | ♦ | | | | | ♦ | ♦ | ♦ | | 5 | 0.40 | 1.40 |
| 0.8 | 56.5 | 17.54 | | ■ | | ■ | | | | | ■ | | | 3 | | | ● | ● | | 2 | ♦ | ♦ | | | ♦ | | | | ♦ | ♦ | ♦ | | 6 | 0.75 | 2.25 |
| (11-200) Todd Fork | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20.3 | 76.0 | 9.35 | ■ | ■ | | ■ | | | ■ | ■ | ■ | | | 7 | | | | | | 0 | ♦ | | | | ♦ | | | | ♦ | ♦ | | | 4 | 0.13 | 0.63 |
| 19.5 | 67.5 | 20.41 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | ♦ | | ♦ | | 2 | 0.11 | 0.33 |
| 15.2 | 79.0 | 10.20 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | | | | | | | | ♦ | | 1 | 0.10 | 0.20 |
| 5.6 | 79.0 | 10.10 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | | | 0 | | | | | | | | | | | | | 0 | 0.10 | 0.10 |
| 2.6 | 78.0 | 14.71 | ■ | | | ■ | ■ | ■ | ■ | ■ | ■ | | | 8 | | | | ● | | 1 | | | | | | | | | | | ♦ | | 1 | 0.22 | 0.33 |
| 0.3 | 67.5 | 12.05 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | | 8 | | | | ● | | 1 | | | | | ♦ | | | | | | ♦ | | 2 | 0.22 | 0.44 |
| (11-209) Cowan Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.9 | 73.5 | 5.38 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | ♦ | | | | | | | | ♦ | | ♦ | | 3 | 0.13 | 0.50 |
| 1.2 | 63.0 | 43.48 | ■ | ■ | | | ■ | ■ | | | ■ | ■ | ■ | 7 | | | | | | 0 | | | | | ♦ | | ♦ | | ♦ | | | | 3 | 0.13 | 0.50 |
| Year: | 96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13.3 | 58.5 | 4.85 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | ♦ | | | | ♦ | | | | ♦ | | | ♦ | 4 | 0.13 | 0.63 |
| 12.4 | 71.5 | 7.14 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | ♦ | | | | | | | | ♦ | | | ♦ | 3 | 0.13 | 0.50 |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecoli) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-209) Cowan Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.9 | **62.5** | 5.38 | ■ | | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | | | ♦ | | ♦ | | | | ♦ | | ♦ | | 4 | 0.13 | 0.63 |
| 8.5 | **64.0** | 8.47 | ■ | | | ■ | ■ | ■ | | | ■ | ■ | ■ | 7 | | | | | | 0 | | | | ♦ | ♦ | | | | | ♦ | | | | 3 | 0.13 | 0.50 |
| 6.9 | **65.0** | 5.62 | ■ | | | ■ | ■ | ■ | | | ■ | ■ | | 6 | | | | | | 0 | | | | ♦ | ♦ | | | | | ♦ | | ♦ | | 4 | 0.14 | 0.71 |
| (11-211) Indian Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.4 | **35.5** | 4.20 | | ■ | | | | | | | | | | 1 | | | ● | ● | ● | 3 | ♦ | | | | ♦ | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 2.00 | 5.50 |
| (11-212) Lytle Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.2 | **48.5** | 13.16 | ■ | ■ | | | ■ | | | | | ■ | | 4 | | | | ● | | 1 | | | | | ♦ | | | | | ♦ | ♦ | | ♦ | 4 | 0.40 | 1.20 |
| 8.8 | **55.0** | 12.50 | ■ | ■ | | ■ | | | | | ■ | ■ | | 5 | | | ● | ● | | 2 | | | | | ♦ | ♦ | | | | ♦ | ♦ | | ♦ | 5 | 0.50 | 1.33 |
| 8.1 | **49.0** | 16.67 | | ■ | | | | | | | ■ | | | 2 | | | ● | ● | ● | 3 | ♦ | | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 6 | 1.33 | 3.33 |
| 7.0 | **65.5** | 15.38 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | ● | | | 1 | ♦ | | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 6 | 0.25 | 1.00 |
| 6.0 | **71.5** | 7.35 | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | | 7 | | | | | | 0 | | | | | | | | | | | ♦ | ♦ | | 2 | 0.13 | 0.38 |
| 2.9 | **57.5** | 12.66 | ■ | | | ■ | ■ | | | ■ | ■ | ■ | | 7 | | | ● | ● | | 2 | | ♦ | | | ♦ | ♦ | | | | | ♦ | ♦ | | 5 | 0.38 | 1.00 |
| 1.4 | **76.5** | 20.83 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | ♦ | | ♦ | | 2 | 0.11 | 0.33 |
| 0.6 | **57.5** | 31.25 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | ● | ● | | 2 | | | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | | 5 | 0.38 | 1.00 |
| (11-217) East Fork Todd Fork | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.2 | **79.5** | 7.63 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | ♦ | | | | | | | ♦ | ♦ | | 3 | 0.10 | 0.40 |
| (11-300) Caesar Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26.5 | **65.5** | 12.66 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | ♦ | | | ♦ | | | | | ♦ | ♦ | ♦ | | 5 | 0.13 | 0.75 |
| 23.1 | **70.5** | 13.70 | ■ | | | ■ | ■ | ■ | | | ■ | ■ | ■ | 7 | | | | | | 0 | | | | | | | | | | ♦ | | | | 1 | 0.13 | 0.25 |
| 16.6 | **72.0** | 5.21 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | ■ | 8 | | | | | | 0 | | | | | | | | | | ♦ | | | | 1 | 0.11 | 0.22 |
| 0.2 | **95.0** | 8.20 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | | | 0 | | | | | | | | | | | | | | 0 | 0.10 | 0.10 |
| (11-301) Flat Fork | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.7 | **44.0** | 31.25 | ■ | | | | ■ | | | | ■ | | | 3 | | | | ● | ● | 2 | | | | | ♦ | | ♦ | ♦ | ♦ | ♦ | | | ♦ | 6 | 0.75 | 2.25 |
| (11-302) Jonahs Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecoli) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-302) Jonahs Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.3 | **40.5** | 32.35 | ■ | | | | | | | | | | | 1 | | | ● | ● | ● | 3 | | | | | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | | ♦ | 7 | 2.00 | 5.50 |
| (11-303) Trace Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.8 | **67.0** | 33.33 | ■ | ■ | | ■ | ■ | ■ | | ■ | | ■ | 7 | | | | | ● | 1 | | | | | ♦ | | | ♦ | ♦ | | | | 3 | 0.25 | 0.63 |
| (11-305) Buck Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.6 | **73.5** | 27.78 | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | | 7 | | | | | | 0 | | | | | | | | | | ♦ | ♦ | ♦ | | 3 | 0.13 | 0.50 |
| (11-306) Anderson Fork | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18.8 | **46.5** | 3.55 | ■ | ■ | | ■ | ■ | | | | | | 4 | | ● | | | ● | ● | 3 | ♦ | | | | ♦ | | | | ♦ | ♦ | ♦ | | 5 | 0.80 | 1.80 |
| 13.9 | **64.0** | 6.94 | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | | 8 | | | | | | 0 | ♦ | | | | | ♦ | | | | ♦ | ♦ | ♦ | | 5 | 0.11 | 0.67 |
| 9.4 | **74.5** | 13.16 | ■ | ■ | | ■ | ■ | ■ | | | ■ | | 6 | | | | | | 0 | ♦ | | | | | | | | | ♦ | ♦ | ♦ | | 4 | 0.14 | 0.71 |
| 5.0 | **63.0** | 7.35 | ■ | ■ | | ■ | ■ | ■ | | | ■ | | 6 | | | | ● | | 1 | ♦ | | | | | ♦ | | | | ♦ | ♦ | ♦ | | 5 | 0.29 | 1.00 |
| (11-307) Painters Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.4 | **64.5** | 18.52 | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | ♦ | | ♦ | | 2 | 0.11 | 0.33 |
| (11-311) South Branch Caesar Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 | **67.0** | 9.43 | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | | 8 | | | | ● | | 1 | | | | | | ♦ | ♦ | | | ♦ | | ♦ | | 4 | 0.22 | 0.67 |
| (11-312) North Branch Caesar Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.1 | **61.0** | 32.26 | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | | 7 | | | | | | 0 | ♦ | ♦ | | | | ♦ | | | | ♦ | ♦ | | ♦ | 6 | 0.13 | 0.88 |
| 1.2 | **56.0** | 12.66 | | ■ | | | | | | | ■ | | 3 | ● | | | ● | | 2 | ♦ | ♦ | | | | ♦ | ♦ | | | ♦ | ♦ | ♦ | | 7 | 0.75 | 2.50 |
| (11-400) Massies Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.7 | **88.0** | 11.76 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | | | 0 | | | | | | | | | | | | | | 0 | 0.10 | 0.10 |
| 5.6 | **82.5** | 11.24 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | 9 | | | | | | 0 | | | | | | | | | | | | | ♦ | 1 | 0.10 | 0.20 |
| 4.3 | **88.0** | 10.75 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | | | 0 | | | | | | | | | | | | | | 0 | 0.10 | 0.10 |
| 1.2 | **80.5** | 11.11 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 9 | | | | | | 0 | | | | | | | | | | | | | | 0 | 0.10 | 0.10 |

Key
QHEI
Components

| | | | WWH Attributes | | | | | | | | | | | | MWH Attributes | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | *High Influence* | | | | | *Moderate Influence* | | | | | | | | | | | | | | | | | | |
| River Mile | QHEI | Gradient (ft/mile) | No Channelization or Recovered | Equal 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-Normal Riffle Embeddedness | **Total WWH Attributes** | Channelized or No Recovery | Silt/Muck Substrates | No Sinuosity | Sparse/No Cover | Max Depth < 40 cm (MC, HW) | **Total H.I. MWH Attributes** | Recovering Channel | Heavy/Moderate Silt Cover | Sand Substrates (Ecal) | Hardpan Substrate Origin | Fair/Poor Development | Low Sinuosity | Only 1-2 Cover Types | Intermittent and Poor Pools | No Fast Current | High/Mod. Overall Embeddedness | High/Mod. Riffle Embeddedness | No Riffle | **Total M.I. MWH Attributes** | **(MWH H.I.+1)/(WWH+1) Ratio** | **(MWH M.I.+1)/(WWH+1) Ratio** |
| (11-401) Oldtown Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.1 | **61.5** | 17.24 | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | | 8 | | | ● | | | 1 | ♦ | | | | ♦ | ♦ | | | | ♦ | ♦ | | 5 | 0.22 | 0.78 |
| (11-402) Clark Run | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.5 | **74.0** | 50.00 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 8 | | | | | | 0 | | | | | | | | | | ♦ | | ♦ | | 2 | 0.11 | 0.33 |
| (11-403) North Fork Massies Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.9 | **33.5** | 5.26 | | | | | | | | | | | | 0 | ● | ● | | ● | ● | 4 | ♦ | ♦ | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | 7 | 5.00 | *.** |
| 1.2 | **63.5** | 7.04 | ■ | ■ | | ■ | ■ | ■ | | | ■ | ■ | | 7 | | | | | | 0 | | | | | ♦ | | | | | ♦ | ♦ | ♦ | 4 | 0.13 | 0.63 |
| (11-404) South Fork Massies Creek | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year: | 98 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 | **44.5** | 5.81 | | | ■ | | | | | | | ■ | | 2 | ● | | ● | ● | | 3 | ♦ | | | | ♦ | ♦ | | | | ♦ | ♦ | ♦ | 6 | 1.33 | 3.33 |
| 0.3 | **56.0** | 23.81 | ■ | | | | | | | | ■ | ■ | ■ | 4 | | | | ● | | 1 | | | | | ♦ | ♦ | | | | ♦ | | | 3 | 0.40 | 1.00 |

**Macroinvertebrate Communities**

*Little Miami River*

Macroinvertebrate communities were evaluated at 40 stations along the Little Miami River from the headwaters (RM 106.8) to near the mouth (RM 3.4) (Figure 104, Table 16). The Invertebrate Community Index (ICI) ranged from 56 (exceptional) downstream from US 42 (RM 63.0) and upstream from Roxanna-New Burlington Road (RM 60.9) to a low of 18 (fair) upstream from Clifton Road (RM 101.8). The stations with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT), a measure of the diversity of pollution sensitive taxa, were upstream from US 35 (RM 74.6) and upstream from Foster-Maineville Road (RM 29.2) with 23 taxa. Overall, the macroinvertebrate communities were evaluated as very good or exceptional at 30 sites, marginally good or good at three sites, fair at three sites (two of them mixing zone sites), and very poor or poor at four sites (two of them mixing zone sites).

Macroinvertebrate taxa collected in the Little Miami River that are indicative of high quality streams in Ohio included the mayflies *Acerpenna pygmaeus* at RM 98.8, *Paracloeodes* sp. 2 at RMs 54.3, 36.0, and 8.8, *Plauditus dubius/virile* at 12 sites between RMs 50.7 and 3.4, and *Ephoron album* at RMs 29.2 and 28.0; the stoneflies *Agnetina capitata* complex at six sites between RMs 43.9 and 24.2 and *Neoperla clymene* complex at RM 19.1; the caddisflies *Psychomyia flavida* at RM 43.9 and *Protoptila* sp. at RMs 43.9 and 21.9; and the midges *Rheotanytarsus distinctissimus* at 22 sites between RMs 98.8 and 21.9, and *Sublettea coffmani* at eight sites between RMs 85.3 and 64.5. Seventeen species of freshwater mussels (Unionidae) were found as live or fresh-dead specimens in the mainstem of the Little Miami River during this study. The threehorn wartyback (*Obliquaria reflexa*), found at RM 24.2, is state listed as a threatened species and the wavy-rayed lampmussel (*Lampsilis fasciola*), found at RMs 83.1 and 77.1, is state listed as a special interest species. Hoggarth (1992) found 30 species of freshwater mussels to be extant in the Little Miami River mainstem.

Zebra mussels (*Dreissena polymorpha*) were not found during the current study. However, they were found on the artificial substrates at RM 13.1 during the 1993 study. Zebra mussels apparently have not dispersed widely in the Little Miami River basin. Zebra mussel distribution within the free flowing rivers of Ohio has been verified in the Scioto River from Circleville to downstream from Chillicothe in 1997 and in Alum Creek downstream from the Alum Creek Reservoir to its mouth in 1996.

Macroinvertebrate communities in the upper portion of the Little Miami River (defined *ad hoc* as upstream from Mathers Mill, RM 45) showed a similar longitudinal trend compared to the 1993 sampling with evaluations generally in the very good to exceptional range. Community performance declined in 1998 upstream from the confluence of Gilroy Ditch (at RM 101.8) and downstream from Clifton (at RMs 85.3 and 83.1).

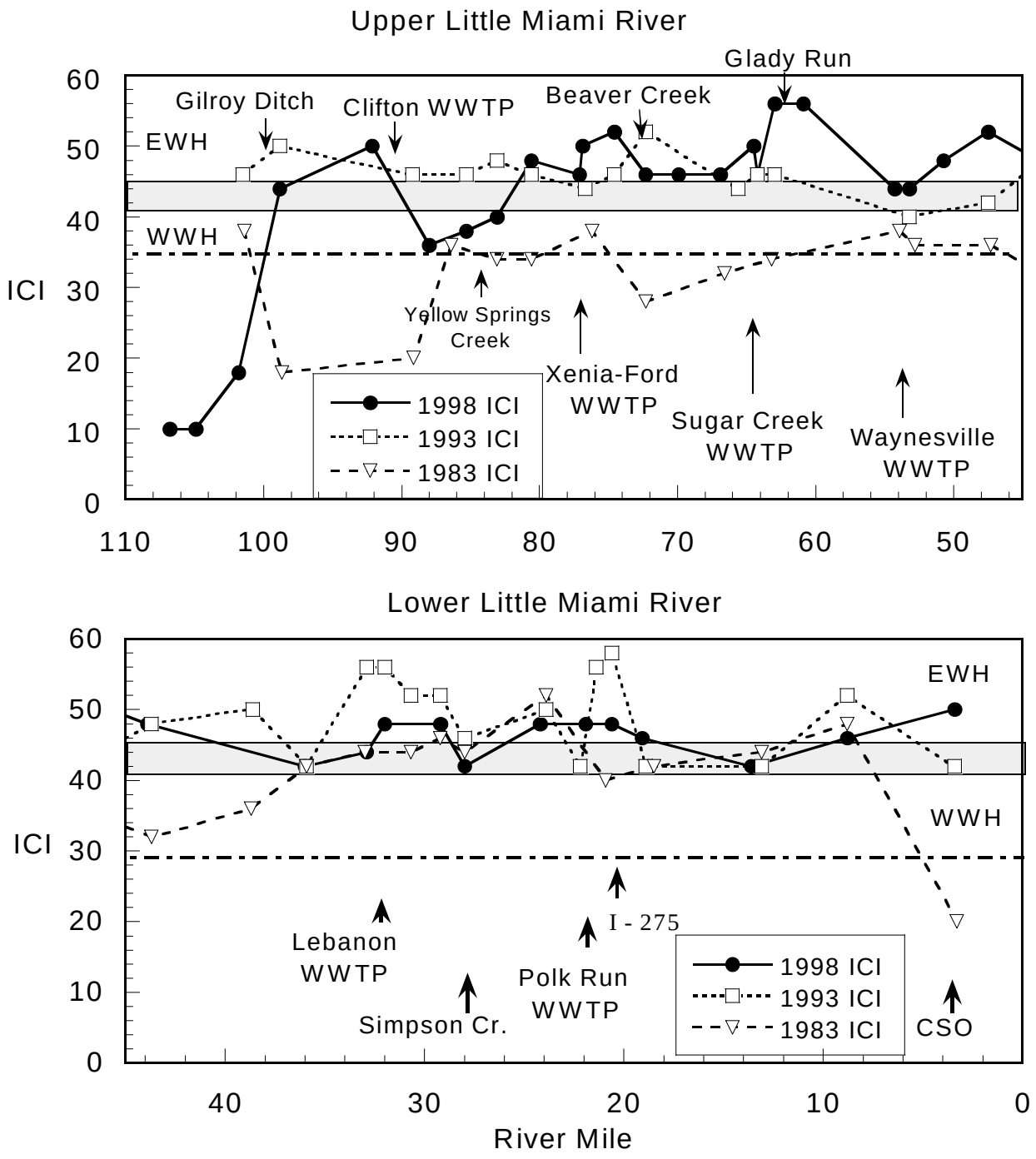



Figure 104. Longitudinal plots of ICI scores from the upper Little Miami River (top panel) and lower Little Miami River (bottom panel), 1983, 1993 and 1998, in relation to point source dischargers.

The macroinvertebrate sampling stations bracketing PayGro were impacted primarily by intermittent stream flow conditions and probably nutrient enrichment and low D.O. concentrations. The upstream site (RM 106.8) was also maintained in a channelized condition. Both communities were evaluated as poor with low EPT diversity and were predominated by facultative and tolerant organisms. No impact could be attributed directly to PayGro.

The macroinvertebrate community was not substantially impacted by the confluence of Gilroy Ditch (RM 100.65, S. Charleston WWTP at RM 1.4). The upstream station was performing in the fair range (ICI=18 at RM 101.8) with low densities and diversity (EPT=4) of most organisms and with snails of the genus *Elimia* predominant. The habitat at this site was good except for low flows. This station performed substantially better in 1993 when it was evaluated as exceptional (EPT=13 with hydropsychid caddisflies, riffle beetles, and baetid mayflies predominant). There was no obvious evidence of pollution. Low diel D.O. concentrations were probably a contributing factor to the low community performance. The community downstream from Gilroy Ditch (downstream from Dolly Varden Road at RM 98.8) improved to the very good range with an ICI value of 44. However, relatively high numbers of midges and the freshwater coelenterate *Hydra* at this site were an indication of organic enrichment from Gilroy Ditch. The station downstream from Pitchin Road (RM 92.1) improved into the exceptional range (ICI=50) with little or no indication of continued organic enrichment.

Macroinvertebrate community performance declined into the good range downstream from the Clifton WWTP within the Clifton Gorge area of the John Bryan State Park (RM 88.0). Diversity declined (EPT=11 compared to 16 at RM 92.1) and organism density was low on most substrates. To what extent the Clifton WWTP discharge was contributing to this decline is not clear. Community performance gradually improved at the next two downstream sites with no apparent impact from the confluence of Yellow Springs Creek (RM 85.17). The community improved into the exceptional range by US 68 (ICI=48 at RM 80.6).

The Xenia-Ford Road WWTP discharge was not significantly impacting the macroinvertebrate community. Within the mixing zone (RM 77.0) diversity declined (EPT=6 & 14 compared to 19 at RM 77.1) and midges were predominant. There was no indication of significant toxicity. The community downstream from the WWTP was performing in the exceptional range (ICI=50 at RM 76.9); however, high numbers of filter-feeding midges of the *Rheotanytarsus exiguus* group (2654/ft$^2$ compared to 385 at RM 80.6, overall density=4050 orgs./ft$^2$ compared to 777 at RM 80.6) was an indication of mild organic enrichment. Organism densities recovered to near background conditions by US 35 (RM 74.6) with 1799 orgs./ft$^2$ and Indian Ripple Rd. (RM 72.3) with 998 orgs./ft$^2$.

The Green County Sugar Creek WWTP discharge (RM 64.43) was not significantly impacting the macroinvertebrate community. Within the mixing zone diversity declined (EPT=5 & 12 compared to 15 at RM 64.5) and midges were predominant, however, there was no indication of significant toxicity. Communities downstream from the WWTP were performing in the exceptional range.

Macroinvertebrate communities were not significantly impacted by the confluence of Beaver Creek (RM 72.7), Glady Run (RM 63.7), or the Waynesville WWTP (RM 53.75). Community performance remained in the exceptional or very good range throughout the lower part of the upper Little Miami River. Macroinvertebrate communities in the lower Little Miami River demonstrated a similar longitudinal trend compared to the 1993 sampling with evaluations generally in the very good to exceptional range.

The Lebanon WWTP discharge (RM 32.12) was not significantly impacting the macroinvertebrate community. Within the mixing zone diversity declined (EPT=7 & 12 compared to 18 at RM 36.0) without tolerant organisms becoming predominant. There was no indication of significant toxicity. Communities downstream from the WWTP were performing in the exceptional range.

The Hamilton County MSD Polk Run WWTP discharge (RM 21.8, 0.1) was not significantly impacting the macroinvertebrate community. Within the mixing zone diversity declined (EPT=7 & 2 compared to 11 at RM 21.9) with tolerant and facultative midges predominant. There was no indication of significant toxicity. Communities downstream from the WWTP were performing in the exceptional range.

High numbers of filter-feeding midges of the *Rheotanytarsus exiguus* group (2140/ft$^2$, organism density=3391/ft$^2$) at Beechmont Ave. (RM 3.4) was an indication of organic enrichment. Otherwise, this station supported a high diversity of aquatic organisms (total EPT=21) with an ICI value of 50 (exceptional).

*Upper Little Miami River Tributaries*

Macroinvertebrate communities were sampled in 34 tributaries at 61 locations (plus three mixing zones) in the upper Little Miami River basin. Of the 61 locations sampled, 25 were performing in the very good or exceptional range, 26 were performing in the marginally good or good range, seven were exhibiting fair communities, and three were evaluated as poor. Fifteen stations were not achieving their aquatic life use designation or recommended aquatic life use if the stream was undesignated. Of the 10 stations not achieving the assigned Warmwater Habitat (WWH) use, six were impacted by municipal WWTP discharges (Gilroy Ditch at RMs 1.3, 0.4; L. Beaver Cr. at RMs 3.5, 2.0, 0.1; and Glady Run at RM 4.0), three were probably most impacted by urban run-off [L. Beaver Cr. at RMs 6.1, 4.7; and tributary to L. Beaver Cr. (RM 6.1) at RM 0.3], and the community at one station was limited by low gradient conditions caused by past channelization and natural wetland conditions (Beaver Cr. at RM 6.1). The five stations which were not achieving the assigned Exceptional Warmwater Habitat (EWH) use were apparently most limited by poor land use practices including riparian vegetation removal, unrestricted livestock access to the stream channel, and siltation (Caesar Cr. at RMs 26.5, 23.1; N. Br. Caesar Cr. at RMs 6.7, 1.2; and Anderson Frk. at RM 9.5). Conner Branch which is currently designated WWH should be redesignated CWH due to the high number (9) and prominence of cool-water taxa present.

*Gilroy Ditch*

The macroinvertebrate communities in Gilroy Ditch were impaired by the South Charleston WWTP discharge (RM 1.4). Downstream from the WWTP discharge (RM 1.3) the predominant organisms shifted from more intolerant types (various caddisflies, baetid mayflies, and riffle beetles) at RM 1.5 to more tolerant types (*Elimia* snails, hydroptilid caddisflies, and flatworms). Thick growth of *Elodea* and green filamentous algae appeared downstream from the WWTP. The community changes observed downstream from the WWTP were consistent with an enrichment/D.O. type impact. Further downstream at RM 0.4 the community continued to be predominated by more tolerant organisms (snails of the genus *Elimia* and flatworms) and there was a decline in diversity (qualitative sample EPT=2). Algae continued to be prolific. This station was also potentially impacted by poor land use practices including the removal of the woody riparian corridor and unrestricted livestock access to the stream channel. The communities in 1983 were similar with the upstream station evaluated as good (EPT=7) at RM 1.5 and the downstream station evaluated as fair (EPT=3) at RM 0.5. The stream apparently has improved since 1979 when a fair community (EPT=3 at RM 1.5) was collected upstream from the WWTP compared to poor communities (EPT=0 at RM 1.3, EPT=1 at RM 0.1) downstream.

*Lisbon Fork*

Lisbon Fork was supporting an exceptional macroinvertebrate community at Old Springfield Road (RM 0.4) with 17 EPT taxa and mostly intolerant taxa predominant. However, fairly high densities of green filamentous algae present at this site was an indication of mild nutrient enrichment.

*North Fork Little Miami River*

Macroinvertebrate communities sampled in the North Fork Little Miami River were fairly diverse at Mitchell Road (RM 7.1) with 12 EPT taxa and at North River Rd. (RM 0.3) with 19 EPT taxa. Various caddisflies were predominant at both sites with mayflies scarcer than expected. The relative scarcity of mayflies may have something to do with travertine encrusting the tops of the larger substrates at both sites. Other Ohio sites with travertine encrustations have reduced mayfly populations.

*Goose Creek*

Goose Creek at Jackson Road (RM 0.8) was a channelized, slow moving, silt and muck bottomed stream with a lot of watercress and relatively cool water (17 C). The poor habitat conditions were probably the primary factor limiting the macroinvertebrate community (7 EPT taxa).

*Yellow Springs Creek*

Yellow Springs Creek upstream from Grinnel Road (RM 0.1) was supporting a high quality macroinvertebrate community (ICI=50). The only evidence of possible enrichment from the Yellow Springs WWTP was the observation of higher than expected numbers of red midges collected from some of the natural substrates. Community performance in 1998 was slightly higher than 1993 when a station at RM 0.3 scored an ICI of 46 (exceptional) and included 12 EPT taxa (compared to 16 in 1998) collected from the natural substrates.

*Jacoby Branch*
The macroinvertebrate community in Jacoby Branch at US 68 (RM 0.5) was meeting the expectations of an exceptional warmwater habitat stream. Twenty taxa of mayflies and caddisflies were collected with caddisflies, mayflies, and riffle beetles predominant.

*Conner Branch*
Conner Branch was supporting an exceptional macroinvertebrate community including the coolwater stonefly genera *Leuctra* sp. and *Amphinemura* sp.; caddisflies *Dolophilodes distinctus* and *Ceratopsyche slossonae*; and midge taxa *Parametriocnemus*, *Polypedilum aviceps*, *Micropsectra* sp., and *Paratanytarsus* n. sp. 1. This stream is meeting the proposed community attributes for a coldwater habitat stream which are that at least four coolwater macroinvertebrate taxa must be present in the community (combination of artificial and natural substrate samples) and that the coolwater taxa compose at least 9% of the sample (artificial substrates) or, in the absence of quantitative data, at least some of the coolwater taxa are observed to be prominent in the community based on natural substrate sampling. The proposed requirement for the fish community is that coolwater species should make up at least 11% of the sample and, if there is no macroinvertebrate sample for corroboration, at least two coolwater fish species must be present in the community.

*Massie Creek*
Macroinvertebrate communities in Massie Creek were achieving very good or exceptional ICI scores (44-46) throughout its length. There was no indication of significant impact from Cedarville or Wilberforce. Community performance has improved since 1993 when the community at RM 0.3 was evaluated as good (EPT=9) and 1983 when three stations were evaluated as good (EPT=7 at RM 9.7, EPT=12 at RM 7.7, EPT=10 at RM 0.2). EPT taxa richness at four stations sampled in 1998 ranged from 17 to 20.

*North Fork Massie Creek*
Macroinvertebrate communities in the Forth Fork Massie Creek were performing in the good range at Selma-Jamestown Road (EPT=10 at RM 7.9) and exceptional at James-Barber Road (EPT=20 at RM 1.1). The stream bed at both sites was composed primarily of fine gravel, sand, and silt which may be an indication of sedimentation within this sub-basin. High amounts of green filamentous algae at the downstream site were an indication of mild nutrient enrichment.

*South Fork Massie Creek*
The macroinvertebrate communities collected from the South Fork Massie Creek were performing in the exceptional range at Weimer Road (EPT=19 at RM 2.1) and very good at RM 0.2 (EPT=15) despite the channelized stream channel and signs of nutrient enrichment present at the upstream station; high amounts of filamentous green algae were present at RM 2.1. Community performance was similar in 1993 with evaluations of exceptional at RM 2.1 (EPT=16) and very good at RM 1.1 (EPT=13).

*Tributary to Massie Creek (RM 5.3)*
The tributary to Massie Creek sampled at RM 0.3 was a small, high quality stream with total and EPT taxa richness of 46 and 17, respectively.

*Clark Run*
Clark Run at Stevenson Road (RM 0.5) was supporting a relatively diverse mayfly and caddisfly assemblage (EPT=17). However, organism density on the natural substrates was relatively low and mayfly and caddisfly taxa had lower than expected predominance. These negative community attributes may be due to natural travertine encrustations on the larger substrates reducing the habitat's suitability for macroinvertebrates.

*Oldtown Creek*
Oldtown Creek at Brush Row Road (RM 0.4) was supporting a good macroinvertebrate community (EPT=12). However, lower than expected diversity (5 taxa) and predominance of mayflies may be due to concreted substrates and fairly heavy siltation. Community performance was similar in 1993 and 1983; both were evaluated as good.

*Ludlow Creek*
The macroinvertebrate community in Ludlow Creek was evaluated as good (EPT=12). However, lower than expected diversity and abundance of mayflies (6 taxa) may be due to travertine encrustations on the substrates and fairly heavy siltation.

*Shawnee Creek*
Shawnee Creek at Hawkins Road (RM 0.7) was supporting a good macroinvertebrate community (total taxa=49, EPT=11).

*Beaver Creek*
Beaver Creek at New Germany-Trebien Road (RM 6.1) was a channelized, slow moving stream surrounded by wetland areas. The poor habitat conditions and possible associated low D.O. concentrations were probably the primary causes of the very limited macroinvertebrate community (EPT=3) collected in this area. Community performance improved at RMs 4.0 and 1.6 into the good range due to improved habitat conditions. The confluence of Little Beaver Creek at RM 1.12 was not significantly impacting the macroinvertebrate community. The ICI score increased to 48 (exceptional) at RM 0.5. The Beaver Creek WWTP effluent was moderately impacting the macroinvertebrate community performance. Within the mixing zone, diversity declined (EPT=4/3) and mayflies were eliminated altogether. The community response did not typify an acutely toxic condition, rather a combination of enrichment and mild toxicity. Community performance at the station downstream at RM 0.3 declined into the very good range (ICI=42) compared to exceptional upstream from the WWTP at RM 0.5 (ICI=48) due to declines in mayfly and dipteran diversities. Community response was similar in 1993 with no appreciable impact from the confluence of Little Beaver Creek (ICI=48 at both RMs 1.6 and 0.5) and a moderate impact from the Beaver Creek WWTP discharge (ICI=48 at RM 0.5 and a fair community at RM 0.2).

*Little Beaver Creek*

Little Beaver Creek macroinvertebrate communities sampled upstream from the Montgomery County Eastern Regional WWTP discharge were impacted by urban runoff and channelization. Diversity at the two stations was low (EPT=3 at RM 6.1 and 5 at RM 4.7) with primarily tolerant and facultative taxa predominant (19.8% tolerant organisms at RM 4.7). The community was further degraded downstream from the WWTP discharge. The sample collected within the WWTP mixing zone (RM 4.57) on July 7 was indicative of acutely toxic conditions (EPT=0 with the toxic tolerant midge taxon *Polypedilum illinoense* predominant). The community improved into the fair range by Grange Hall Road (RM 3.5) with an ICI score of 20. The community remained impacted for the remainder of the stream. The community response downstream from the WWTP discharge has improved since 1982 when the stream was degraded into the very poor or poor range all the way to the mouth (Figure 105). Sampling in 1993 found a toxic impact within the WWTP mixing zone similar to the current study. However, the community evaluations were higher upstream from the WWTP (ICI=40 at RM 4.7) and near the mouth (ICI=38 at RM 0.1).

*Tributary to Little Beaver Creek (RM 6.1)*

The poor macroinvertebrate community (EPT=3) collected from the tributary to Little Beaver Creek (RM 6.1) at RM 0.3 was probably limited by runoff from the surrounding urban area.

*Tributary to Little Miami River (RM 69.85)*

A high quality macroinvertebrate community (EPT=16) was collected from the tributary to Little Miami River (RM 69.85) adjacent to Upper Bellbrook Road (RM 0.1).

*Sugar Creek*

Macroinvertebrate communities sampled from Sugar Creek were evaluated as good. The station at Penewit Road (RM 0.3) had the highest mayfly and caddisfly diversity (EPT=16 compared to 12 at RM 2.2). However, the predominance of midges and blackflies in the riffle at this site was an indication of a mild enrichment impact.

*Little Sugar Creek*

The macroinvertebrate community in Little Sugar Creek at RM 0.5 was evaluated as good (EPT=13). However, moderate to heavy algal growth and relatively high macroinvertebrate organism density were indications of enrichment.

*Glady Run*

The Xenia Glady Run WWTP (RM 4.9) was severely impacting the macroinvertebrate community. The community sampled upstream from the WWTP was evaluated as marginally good (ICI=34 at RM 5.8). The mayfly and caddisfly diversity (EPT=6) was relatively low at this site and the proportion of other dipterans and non-insects (87.5%) and tolerant organisms (21.1%) were relatively high. These community attributes may be due to periodic low flows along with nutrient enrichment. However, the communities sampled within the WWTP mixing zone (RM 4.9) declined into the very poor range with very low diversity of mayflies and caddisflies (EPT=1 / 2); the site was predominated by high densities of tolerant midges of the *Chironomus riparius* group. The community response was

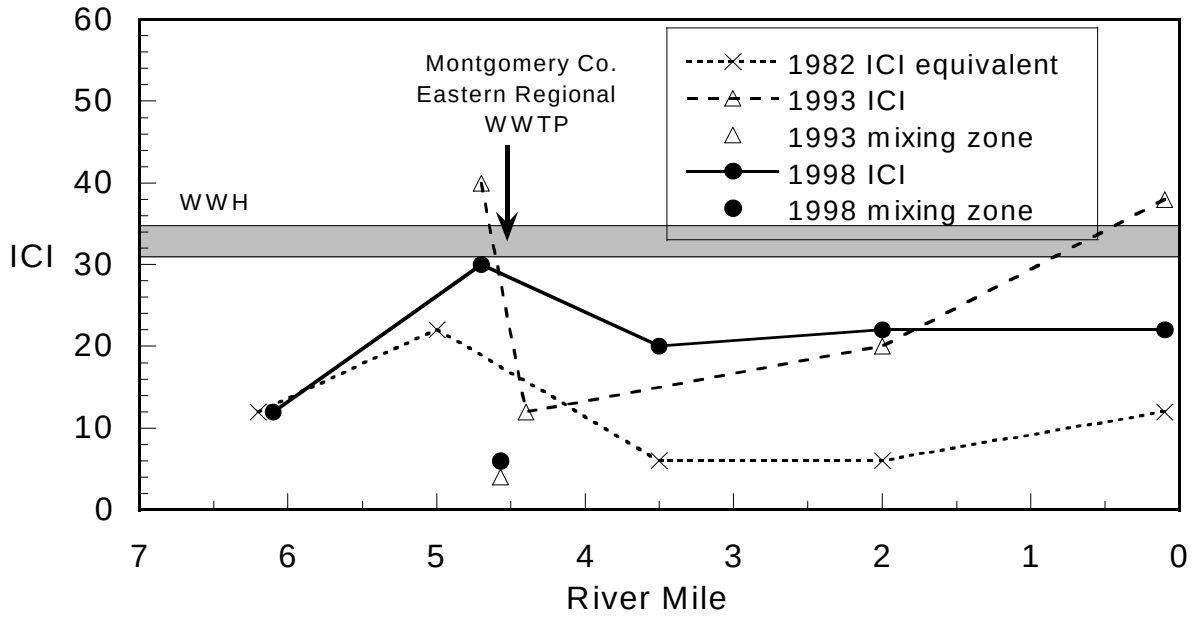



Figure 105. Longitudinal plot of ICI scores from Little Beaver Creek, 1982, 1993, and 1998, in relation to the Montgomery County Eastern Regional WWTP.

more indicative of a severe organic enrichment and low D.O. impact rather than acute toxicity. The community remained degraded at Hedges Road (ICI=28 at RM 4.0) and recovered to a very good condition by Schnebly Road (ICI=42 at RM 2.1). Coolwater midge taxa were well represented in Glady Run but did not constitute the required 9% of the community at two of the three stations evaluated using artificial substrates. Community response in 1993 was similar in that the community downstream from the WWTP discharge was degraded into the fair range (ICI= 28 at RM 4.7) compared to good upstream (ICI=36 at RM 4.9). However, in 1993 the community only recovered to the fair range (ICI=24) by RM 0.3.

*Tributary to Little Miami River (RM 62.01)*

The tributary to Little Miami River (RM 62.01) sampled at RM 0.5 was supporting a low good macroinvertebrate community (EPT=10). Relatively low organism density and only limited predominance of mayfly and caddisfly taxa indicated the community at this station was possibly limited by periodic low flow conditions.

*Tributary to Little Miami River (RM 60.5)*

The tributary to Little Miami River (RM 60.5) sampled at RM 0.2 was supporting a very good macroinvertebrate community (total taxa=46, EPT=14).

*Newman Run*
A very good macroinvertebrate community (EPT=14) was sampled in Newman Run at Pekin Road (RM 0.3). The communities in 1993 (EPT=4) and 1983 (EPT=5) were evaluated as fair. The low community performance in past years was probably due to periodic low flow conditions.

*Caesar Creek*
The macroinvertebrate communities collected from Caesar Creek stations at New Jasper-Paintersville Road (RM 26.5) and Stone Road (RM 23.1) were not meeting EWH use designation expectations for EPT diversity and predominance. Poor land use practices including the removal of the woody riparian vegetation and allowing livestock unrestricted access to the stream, both observed at the upstream site, were probably the principal causes of the lower then expected performances. The communities improved into the very good range at the two downstream stations on Caesar Creek. Community performance at Spring Valley-Paintersville Road (RM 16.5) was similar in 1993 with an evaluation of very good; however, the station at Corwin Road (RM 0.1) was only evaluated as fair (EPT=8). The flows at this station are highly modified and regulated by Caesar Creek Reservoir releases which were probably the strongest detrimental impact on community performance.

*North Branch Caesar Creek*
The macroinvertebrate communities collected from the North Branch Caesar Creek were not meeting EWH use designation expectations for EPT diversity and predominance. Flatworms (moderately pollution tolerant) were more numerous than expected for an unimpacted site. The upstream station at Junkin Road (RM 6.7) had denuded banks and unrestricted livestock access to the stream. The two sampled stations had fairly high amounts of instream silt. The North Branch Caesar Creek stations appeared impacted by poor land use practices which resulted in siltation, the negative habitat attributes associated with the removal of the woody riparian, and possibly nutrient enrichment.

*South Branch Caesar Creek*
The macroinvertebrate community collected from the South Branch Caesar Creek at Cemetery Road (RM 8.2) was meeting the minimal expectations for the WWH use designation. However, the abundances of midges, flatworms, and leeches, which are groups that tend to be moderately to highly pollution tolerant, were higher than expected for an unimpacted stream. The stream banks were denuded of their woody riparian vegetation at this station which, in association with silt and possible nutrient runoff, were threatening the community health in this stream. The macroinvertebrate community performance improved into the very good range by Hoop Road (RM 2.1).

*Anderson Fork*
Anderson Fork was supporting good macroinvertebrate communities from Haley Road (RM 18.8) to US 68 (RM 9.5). The woody riparian corridor was observed intact at all of the sampling stations. Relatively high amounts of silt on the natural substrates at RM 9.5 was the only noted potential source of impact. The macroinvertebrate community performance improved into the very good range (EPT=17) by Winchester Trail (RM 4.9). Community performance appears to have improved since 1993 when the community at RM 5.0 was evaluated as good (EPT=11).

*Painters Creek*
Painters Creek at Eleazer Road (RM 0.4) was supporting a very good macroinvertebrate community (EPT=16). No evidence of pollution or habitat degradation was observed at this site.

*Buck Run*
The macroinvertebrate community in Buck Run at SR 380 (RM 1.2) was meeting the expectations for the WWH use designation (total taxa=38, EPT=8). This station had an intact woody riparian corridor and there was no evidence of pollution. However, considering the small size of the stream at this station, it likely becomes intermittent during periods of low precipitation.

*Trace Run*
Trace Run at Brimstone-Mills Road (RM 1.8) was a small stream whose macroinvertebrate community was meeting the minimal expectations for the WWH use designation (total taxa=49, EPT=8).

*Jonahs Run*
Jonahs Run downstream from Oregonia Road (RM 2.1) was a small, mostly sand-bottomed stream which was supporting a marginally good macroinvertebrate community (EPT=6). The relatively low organism density and diversity at this site may be due to periodic low to intermittent stream flows during periods of low precipitation.

*Flat Fork*
Flat Fork at Oregonia Road (RM 1.7) was a small stream which was supporting a good macroinvertebrate community (EPT=9). Flat Fork in 1993 (RM 1.7) was sampled during intermittent flow conditions and yielded a very limited macroinvertebrate community (EPT=2). The macroinvertebrate community performance in Flat Fork is limited by periodic intermittent flow conditions.

*Lower Little Miami River Tributaries*
Macroinvertebrate communities were sampled in 11 tributaries at 28 ambient locations and 5 mixing zones in the lower Little Miami River basin. Of the 28 locations sampled, six were performing in the very good or exceptional range, 12 were performing in the marginally good or good range, and 10 were exhibiting fair communities; none were evaluated as poor. Twelve stations were not achieving their designated aquatic life use designation. Of the ten stations not achieving their WWH use, four were impacted by municipal WWTP discharges (Lytle Creek at RMs 6.1 and 2.6, Simpson Creek at RM 0.1, and Sycamore Creek at RM 0.1); two were probably most impacted by urban runoff and potentially sewer overflows and airport discharges (Lytle Creek at RMs 9.3 and 7.0); two were small stream locations limited by channelization, removal of the woody riparian corridor, and to some extent nutrient enrichment (Cowan Creek at RM 13.3, Indian Run at RM 0.2); and two were stations likely limited by flow variations (Simpson Creek at RM 0.2, O'Bannon Creek at RM 4.5). The two stations which were not achieving their designated EWH use were probably limited by siltation and nutrient enrichment (Todd Fork at RMs 19.6 and 8.6).

*Todd Fork*

Todd Fork was supporting mostly high quality macroinvertebrate communities from US 22 / SR 3 (RM 19.6) to adjacent to Morrow-Woodville Road (RM 0.4). Potential causes for the communities at some stations not meeting the EWH use expectations were siltation, observed at RMs 19.6 and 15.1, and nutrient enrichment noted at RM 19.6. The stations sampled had good instream habitat and intact woody riparian corridors. Community performance in 1984 was similar when very good communities were sampled upstream (ICI=42 at RM 19.5) and downstream (ICI=44 at RM 17.2) from the confluence of Lytle Creek.

*East Fork Todd Fork*

The East Fork Todd Fork at SR 132 (RM 1.6) was supporting a high quality macroinvertebrate community. Sixteen EPT taxa were collected with mostly pollution intolerant taxa predominant.

*Lytle Creek*

The macroinvertebrate communities in Lytle Creek were degraded into the fair range from adjacent to Townsend Field (RM 9.3) to Ogden Road (RM 2.6). Mayfly and caddisfly diversities were relatively low and tolerant to facultative organisms were more abundant than expected for an unimpacted stream. Historically, Wilmington has had problems with sanitary sewer overflows during moderate to high rain events. The Airborne Express Air Park discharges are another potential source for instream contamination upstream from the Wilmington WWTP. The community response within the Wilmington WWTP mixing zone (RM 6.7) was a reduction in organism diversity (20 taxa, 2 EPT) and an increase in the toxic tolerant midges *Polypedilum illinoense* and *Cricotopus bicinctus*, indicating mild toxicity from the WWTP discharge. The macroinvertebrate community response has demonstrated two trends since the 1951 sampling reported by Gaufin and Tarzwell (1952). First, the WWTP effluent quality has improved since 1984 and no longer creates a three mile zone of highly degraded communities (Figure 106). Secondly, the community health upstream from the WWTP discharge has declined since 1984. None of the sampling locations in 1996 and 1998 were meeting WWH use expectations. Additionally, downstream communities did not spatially recover as quickly as in 1952. These trends are best explained by improved treatment of oxygen depleting pollutants by the WWTP and an increase in other pollutants, especially upstream from the WWTP.

*Cowan Creek and Indian Run*

Cowan Creek was, for the most part, meeting WWH use expectations. No impact was detected downstream from the confluence of Indian Run. The only station that was not meeting WWH expectations was the most upstream site at Jenkins Road (RM 13.3). The stream at this station was small and channelized, and the woody vegetation was removed along its riparian corridor. The community response in 1996 was similar with a fair community at RM 13.2 and good communities from RMs 12.5 to 6.9.

The macroinvertebrate community in Indian Creek (RM 0.2) was not meeting WWH expectations. The mayfly and caddisfly diversity was relatively low (5) and tolerant to facultative organisms were predominant. This degree of community impairment could be caused by the existing stream habitat conditions (small stream size, channelized, and lack of woody riparian) and apparent nutrient

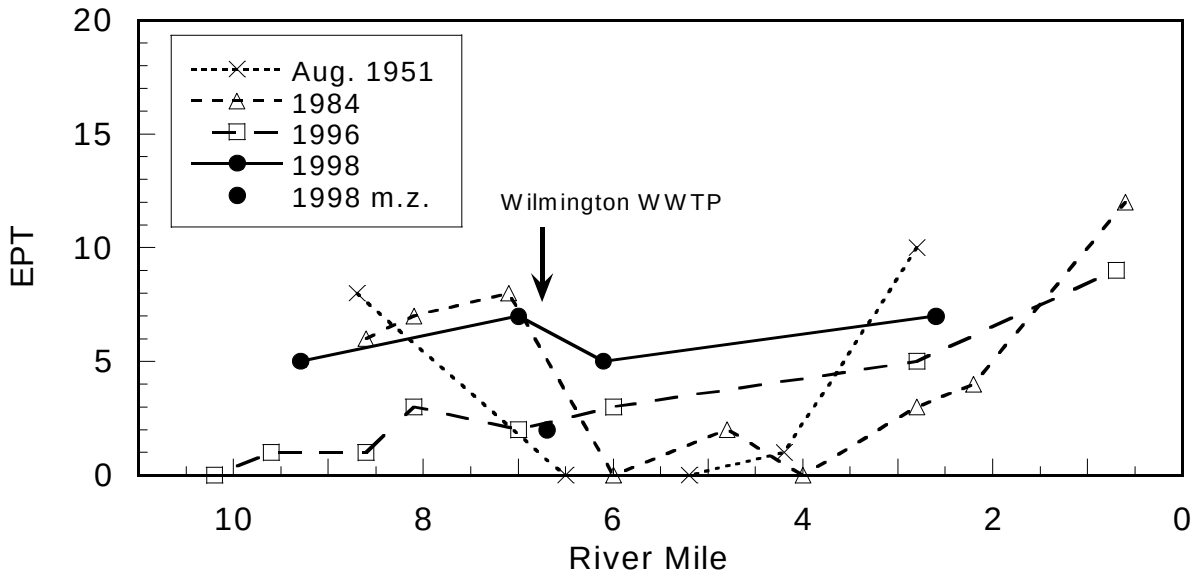



Figure 106. Longitudinal plot of the number of EPT taxa collected from natural substrates in Lytle Creek, 1951, 1984, 1996, and 1998, in relation to the Wilmington WWTP.

enrichment; thick growths of algae were an indication of nutrient enrichment. To what extent the Airborne Express Air Park discharges contributed to the community impairment was not clear. The community in 1996 was apparently performing at a slightly higher level with a marginally good evaluation (EPT=7).

*Turtle Creek*

The macroinvertebrate community in Turtle Creek downstream from SR 48 (RM 0.3) was achieving an ICI score (48) indicative of exceptional community performance. Community performance at this station was similar to sampling in 1989 (ICI=46) and 1990 (very good evaluation). Communities sampled in 1993 at RMs 0.6 and 0.5 were only performing at the level of non-significant departure from the Interior Plateau ecoregion biocriterion for WWH streams, apparently due to low flow conditions. Turtle Creek in 1983 was impacted by the Cincinnati Milacron discharge which has since been eliminated. Community performance declined from an ICI value of 36 (good) upstream from the discharge at RM 0.6 to 18 (fair) downstream at RM 0.4.

*Muddy Creek*

The Mason WWTP discharge (RM 3.24) was not significantly impacting the macroinvertebrate communities in Muddy Creek. Community performance was evaluated as good upstream and downstream from the discharge. However, a relatively high abundance of flatworms (moderately tolerant) at RM 0.7 was an indication that enrichment from the WWTP extended downstream to near the mouth. The community in the WWTP mixing zone (RM 3.24) was degraded and evaluated as fair. EPT diversity declined (5 compared to 8 at RM 3.3) and the tolerant midge taxa *Cricotopus bicinctus*, *Cricotopus sylvestris* group, and *Chironomus riparius* group increased in abundance.

Accumulation of sewage solids in areas outside of the current was observed at the mixing zone site. Acute toxicity was not indicated by this community response. Community responses in 1989, 1991, and 1993 were similar in that no significant impact downstream from the WWTP discharge was observed. Sampling in 1981 found a poor quality community (11 total taxa and EPT=1) immediately downstream from the discharge at RM 3.2. The community was partially recovered by RM 2.5 (fair community with 5 EPT taxa) and not fully recovered until RM 0.5 (marginally good community with 9 EPT taxa).

*Simpson Creek*

The Warren County Lower Little Miami River WWTP discharge (RM 0.14) was slightly impacting the macroinvertebrate communities in Simpson Creek. Community performance was evaluated as fair upstream and downstream from the discharge. Simpson Creek is a high gradient, boulder and bedrock stream. The community upstream from the WWTP discharge was not indicative of significant nutrient enrichment effects and appeared most limited by variations in stream flow. The community in the WWTP mixing zone was degraded into the poor range due mainly to a decrease in EPT diversity (EPT=4 compared to 6 at RM 0.2). Increased densities of filter feeding hydropsychid caddisflies and blackflies indicated an enrichment impact from the WWTP. The community response in 1983 was similar with a fair community (20 total taxa, EPT=6) at RM 0.1.

*O Bannon Creek*

The Clermont County O'Bannon Creek WWTP discharge (RM 2.57) was not significantly impacting the macroinvertebrate communities in O'Bannon Creek. Community performance was evaluated as fair upstream and good downstream from the discharge. The limited community sampled upstream from Gibson Road (RM 4.5) (25 total taxa, EPT=5) was likely affected by periodic low stream flow conditions. Communities sampled in the WWTP mixing zone (RM 2.57) and upstream from O'Bannonville Road (RM 1.9) had increased diversities which were meeting the expectations for a WWH stream. However, high organism density at both sites and higher than expected abundance of flatworms (moderately tolerant) at RM 1.9 were indications of mild nutrient enrichment from the WWTP. Large amounts of filamentous algae at the station near the mouth (RM 0.2) were also an indication of nutrient enrichment. The community response in 1990 was similar with very good communities upstream (RM 2.7) and downstream (RM 2.5) from the WWTP discharge.

*Stony Creek*

Stony Creek at Gibson Road (RM 0.2) is a small stream with an intact woody riparian corridor and a fairly diverse macroinvertebrate community (49 total taxa, EPT=13) and was meeting WWH expectations.

*Sycamore Creek*

The Hamilton County Sycamore Creek WWTP (RM 0.26) was impacting the macroinvertebrate community in Sycamore Creek. The community sampled upstream from the WWTP discharge was fairly diverse (48 taxa with 11 EPT taxa). However, relatively high abundance of mostly facultative midges was an indication of a mild impact from upstream sources. Within the WWTP mixing zone (RM 0.24) and at the downstream station (RM 0.1) the diversity declined (30 taxa with 6 EPT taxa

and 33 taxa with 7 EPT taxa, respectively) and the communities were predominated by high densities of blackflies of the genus *Simulium* (facultative primarily for organic pollution), the midges *Dicrotendipes neomodestus* and *Dicrotendipes fumidus* (facultative for organic pollution), and the midges *Cricotopus bicinctus* and *Polypedilum illinoense* (tolerant for toxic pollution). The community response was indicative of primarily an enrichment impact but with some indications of mild toxicity. Community performance upstream from the WWTP discharge has demonstrated gradual improvement since 1983 (fair community at RM 0.6, 18 total taxa with 4 EPT taxa) and 1993 (fair community at RM 0.5, 30 total taxa with 7 EPT taxa). The community response downstream from the WWTP discharge has improved since 1983 when the community was indicative of poorly treated effluent (low diversity, 10 total taxa with 0 EPT taxa and predominated by organic tolerant midges of the genus *Chironomus*).

Table 16. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Little Miami River study area, July to August, 1998.

| *Quantitative Evaluation* *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
|---|---|---|---|---|---|---|---|
| *Little Miami River* (11-001) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 106.8 | - | - | 20 | 0 | - | P* | Poor |
| 104.9 | - | - | 35 | 3 | - | P* | Poor |
| 101.8 | 564 | 26 | 37 | 4 | 4 | 18* | Fair |
| 98.8 | 719 | 55 | 54 | 11 | 16 | 44[ns] | Very Good |
| 92.1 | 335 | 41 | 60 | 16 | 21 | 50 | Exceptional |
| 88.0 | - | - | 34 | 11 | - | G* | Good |
| 85.3 | 521 | 36 | 66 | 14 | 15 | 38* | Good |
| 83.1 | 550 | 24 | 69 | 17 | 18 | 40* | Good |
| 80.6 | 777 | 36 | 83 | 20 | 22 | 48 | Exceptional |
| 77.1 | - | - | 67 | 19 | - | E | Exceptional |
| *77.0[d]* | - | - | *37/50* | *6/14* | - | *F/G* | *Fair/Good* |
| 76.9 | 4050 | 42 | 75 | 18 | 21 | 50 | Exceptional |
| 74.6 | 1799 | 37 | 71 | 21 | 23 | 52 | Exceptional |
| 72.3 | 998 | 35 | 44 | 14 | 19 | 46 | Exceptional |
| 69.9 | 1289 | 28 | 56 | 16 | 18 | 46 | Exceptional |
| 66.9 | 688 | 34 | 47 | 13 | 16 | 46 | Exceptional |
| 64.5 | 1017 | 29 | 63 | 15 | 18 | 50 | Exceptional |
| *64.4[d]* | - | - | *23/41* | *5/12* | - | *P/MG* | *Poor/Marg. Good* |
| 64.2 | 1338 | 29 | 59 | 15 | 17 | 46 | Exceptional |
| 63.0 | 1232 | 37 | 55 | 18 | 20 | 56 | Exceptional |
| 60.9 | 1039 | 38 | 56 | 17 | 19 | 56 | Exceptional |
| 54.3 | 234 | 48 | 54 | 16 | 18 | [40][c] | Very Good[ns] |
| 53.2 | 728 | 28 | 50 | 16 | 17 | 44[ns] | Very Good |
| 50.7 | 451 | 29 | 50 | 20 | 21 | 48 | Exceptional |
| Interior Plateau (EWH - Existing) | | | | | | | |
| 47.5 | 934 | 37 | 64 | 18 | 21 | 52 | Exceptional |
| 43.9 | 383 | 42 | 52 | 17 | 22 | 48 | Exceptional |
| 36.0 | 759 | 32 | 50 | 18 | 22 | 42[ns] | Very Good |
| 32.9 | 345 | 44 | 52 | 18 | 22 | [38][c] | Very Good[ns] |

Table 16. Continued

| *Quantitative Evaluation* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
| *Little Miami River* (11-001) Interior Plateau (EWH - Existing) | | | | | | | |
| *32.1*[d] | - | - | *33/41* | *7/12* | - | *F/MG* | *Fair/Marg. Good* |
| 32.0 | 741 | 41 | 49 | 17 | 22 | 48 | Exceptional |
| 29.2 | 534 | 35 | 46 | 17 | 23 | 48 | Exceptional |
| 28.0 | 724 | 45 | 60 | 19 | 22 | 42[ns] | Very Good |
| 24.2 | 766 | 42 | 53 | 14 | 19 | 48 | Exceptional |
| 21.9 | 524 | 53 | 43 | 11 | 21 | 48 | Exceptional |
| *21.8*[d] | - | - | *34/22* | *7/2* | - | *F/P* | *Fair/Poor* |
| 20.6 | 1988 | 38 | 50 | 15 | 17 | 48 | Exceptional |
| 19.1 | - | - | 56 | 20 | - | E | Exceptional |
| 13.6 | - | - | 47 | 17 | - | VG[ns] | Very Good |
| 8.8 | - | - | 55 | 21 | - | E | Exceptional |
| 3.4 | 3391 | 41 | 62 | 18 | 21 | 50 | Exceptional |
| *Gilroy Ditch* (11-044) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 1.5 | - | - | 47 | 8 | - | G | Good |
| 1.3 | - | - | 46 | 7 | - | F* | Fair |
| 0.4 | 872 | 35 | 31 | 2 | 4 | 28* | Fair |
| *Lisbon Fork* (11-043) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.4 | - | - | 70 | 17 | - | E | Exceptional |
| *North Fork Little Miami River* (11-041) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 7.1 | - | - | 60 | 12 | - | G | Good |
| 0.3 | - | - | 54 | 19 | - | E | Exceptional |
| *Goose Creek* (11-042) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.8 | - | - | 57 | 7 | - | MG[ns] | Marg. Good |
| *Yellow Springs Creek* (11-040) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 0.1 | 411 | 48 | 72 | 16 | 18 | 50 | Exceptional |

Table 16. Continued.

| *Quantitative Evaluation* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
| *Jacoby Branch* (11-039) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.5 | - | - | 74 | 20 | - | E | Exceptional |
| *Conner Branch* (11-038) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.1 | - | - | 57 | 15 | - | E | Exceptional |
| *Massie Creek* (11-400) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 7.7 | 652 | 45 | 78 | 17 | 19 | 46 | Exceptional |
| 5.5 | 1551 | 34 | 79 | 20 | 23 | 46 | Exceptional |
| 4.4 | 1037 | 37 | 73 | 19 | 22 | 44 | Very Good |
| 1.2 | 1115 | 28 | 72 | 19 | 23 | 46 | Exceptional |
| *North Fork Massie Creek* (11-403) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 7.9 | - | - | 59 | 10 | - | G | Good |
| 1.1 | - | - | 70 | 20 | - | E | Exceptional |
| *South Fork Massie Creek* (11-404) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 2.1 | - | - | 52 | 19 | - | E | Exceptional |
| 0.2 | - | - | 61 | 15 | - | VG | Very Good |
| *Tributary to Massie Creek (RM 5.3)* (11-405) Eastern Cornbelt Plains (No Existing Use) | | | | | | | |
| 0.3 | - | - | 46 | 17 | - | E | Exceptional |
| *Clark Run* (11-402) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.5 | - | - | 35 | 17 | - | VG | Very Good |
| *Oldtown Creek* (11-401) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.4 | - | - | 56 | 12 | - | G | Good |
| *Ludlow Creek* (11-037) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.2 | - | - | 36 | 12 | - | G | Good |

Table 16. Continued.

*Quantitative Evaluation*

| *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
|---|---|---|---|---|---|---|---|
| *Shawnee Creek* (11-045) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.7 | - | - | 49 | 11 | - | G | Good |
| *Beaver Creek* (11-035) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 6.1 | - | - | 18 | 3 | - | P* | Poor |
| 4.0 | 186 | 42 | 24 | 4 | 7 | 36 | Good |
| 1.6 | 431 | 35 | 49 | 8 | 9 | 36 | Good |
| 0.5 | 1473 | 38 | 37 | 8 | 11 | 48 | Exceptional |
| *0.39*[d] | - | - | *28/27* | *4/3* | - | *F/F* | *Fair/Fair* |
| 0.3 | 2146 | 25 | 35 | 5 | 9 | 42 | Very Good |
| *Little Beaver Creek* (11-036) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 6.1 | - | - | 25 | 3 | - | P* | Poor |
| 4.7 | 1286 | 33 | 32 | 5 | 6 | 30* | Fair |
| *4.57*[d] | - | - | *13/23* | *0/2* | - | *VP/P* | *V. Poor/Poor* |
| 3.5 | 362 | 35 | 26 | 1 | 4 | 20* | Fair |
| 2.0 | 499 | 33 | 24 | 5 | 6 | 22* | Fair |
| 0.1 | 322 | 31 | 38 | 5 | 5 | 22* | Fair |
| *Tributary to Little Beaver Creek (RM 6.1)* (11-056) Eastern Cornbelt Plains (No Existing Use) | | | | | | | |
| 0.3 | - | - | 15 | 3 | - | P* | Poor |
| *Tributary to Little Miami River (RM 69.85)* (11-055) Eastern Cornbelt Plains (No Existing Use) | | | | | | | |
| 0.1 | - | - | 38 | 16 | - | VG | Very Good |
| *Sugar Creek* (11-033) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 2.2 | - | - | 47 | 12 | - | G | Good |
| 0.3 | - | - | 52 | 16 | - | G | Good |
| *Little Sugar Creek* (11-034) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.5 | - | - | 54 | 13 | - | G | Good |

Table 16. Continued.

| *Quantitative Evaluation* *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
|---|---|---|---|---|---|---|---|
| *Glady Run* (11-032) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 5.8 | 355 | 42 | 35 | 6 | 7 | 34[ns] | Marg. Good |
| *4.9*[d] | - | - | *16/18* | *½* | - | *VP/VP* | *V. Poor/V. Poor* |
| 4.0 | 380 | 39 | 28 | 2 | 3 | 28* | Fair |
| 2.1 | 291 | 35 | 22 | 6 | 6 | 42 | Very Good |
| *Tributary to Little Miami River (RM 62.01)* (11-054) Eastern Cornbelt Plains (No Existing Use) | | | | | | | |
| 0.5 | - | - | 33 | 10 | - | G | Good |
| *Tributary to Little Miami River (RM 60.5)* (11-053) Eastern Cornbelt Plains (No Existing Use) | | | | | | | |
| 0.2 | - | - | 46 | 14 | - | VG | Very Good |
| *Newman Run* (11-030) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.3 | - | - | 54 | 14 | - | VG | Very Good |
| *Caesar Creek* (11-300) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 26.5 | - | - | 46 | 10 | - | G* | Good |
| 23.1 | - | - | 61 | 11 | - | G* | Good |
| 16.5 | 250 | 42 | 63 | 16 | 19 | 44[ns] | Very Good |
| (WWH - Existing) | | | | | | | |
| 0.2 | - | - | 56 | 19 | - | VG | Very Good |
| *North Branch Caesar Creek* (11-312) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 6.7 | - | - | 59 | 11 | - | G* | Good |
| 1.2 | - | - | 53 | 10 | - | G* | Good |
| *South Branch Caesar Creek* (11-311) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 8.2 | - | - | 57 | 10 | - | G | Good |
| 2.1 | - | - | 44 | 15 | - | VG | Very Good |
| *Anderson Fork* (11-306) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 18.8 | - | - | 46 | 11 | - | G | Good |
| 13.9 | - | - | 43 | 13 | - | G | Good |

Table 16. Continued.

*Quantitative Evaluation*

| *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
|---|---|---|---|---|---|---|---|
| *Anderson Fork* (11-306) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 9.5 | - | - | 50 | 13 | - | G* | Good |
| 4.9 | 361 | 37 | 44 | 17 | 23 | [36][c] | Very Good[ns] |
| *Painters Creek* (11-307) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 0.4 | - | - | 51 | 16 | - | VG[ns] | Very Good |
| *Buck Run* (11-305) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 1.2 | - | - | 38 | 8 | - | G | Good |
| *Trace Run* (11-303) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 1.8 | - | - | 49 | 8 | - | G | Good |
| *Jonahs Run* (11-302) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 2.1 | - | - | 24 | 6 | - | MG[ns] | Marginally Good |
| *Flat Fork* (11-301) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 1.7 | - | - | 42 | 9 | - | G | Good |
| *Todd Fork* (11-200) Eastern Cornbelt Plains (EWH - Existing) | | | | | | | |
| 19.6 | 973 | 46 | 62 | 14 | 15 | 36* | Good |
| 15.1 | 1010 | 29 | 59 | 18 | 18 | [30][c] | Very Good[ns] |
| 8.6 | - | - | 53 | 15 | - | G* | Good |
| 2.5 | 658 | 37 | 53 | 15 | 19 | 46 | Exceptional |
| 0.4 | - | - | 68 | 19 | - | VG[ns] | Very Good |
| *Lytle Creek* (11-212) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 9.3 | - | - | 28 | 5 | - | F* | Fair |
| 7.0 | - | - | 39 | 7 | - | F* | Fair |
| *6.7*[d] | - | - | *20* | *2* | - | *P* | *Poor* |
| 6.1 | - | - | 36 | 5 | - | F* | Fair |
| 2.6 | - | - | 39 | 7 | - | F* | Fair |

Table 16. Continued.

*Quantitative Evaluation*

| *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
|---|---|---|---|---|---|---|---|
| *Lytle Creek* (11-212) (1996) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 10.2 | - | - | 11 | 0 | - | VP* | Very Poor |
| 9.6 | - | - | 22 | 1 | - | P* | Poor |
| 8.6 | - | - | 26 | 1 | - | P* | Poor |
| 8.1 | - | - | 25 | 3 | - | P* | Poor |
| *Lytle Creek* (11-212) (1996) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 7.0 | - | - | 23 | 2 | - | P* | Poor |
| 6.0 | - | - | 33 | 3 | - | P* | Poor |
| 2.8 | - | - | 25 | 5 | - | F* | Fair |
| 0.7 | - | - | 53 | 9 | - | G | Good |
| *Tributary to Lytle Creek* (11-218) (1996) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.7 | - | - | 7 | 0 | - | VP* | Very Poor |
| *Cowan Creek* (11-209) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 13.3 | - | - | 47 | 7 | - | F* | Fair |
| 12.4 | - | - | 43 | 14 | - | G | Good |
| 10.9 | - | - | 50 | 12 | - | G | Good |
| 8.5 | - | - | 50 | 17 | - | VG | Very Good |
| 1.2 | - | - | 25 | 9 | - | G | Good |
| *Indian Run* (11-211) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.2 | - | - | 33 | 5 | - | F* | Fair |
| *Cowan Creek* (11-209) (1996) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 13.2 | - | - | 49 | 5 | - | F* | Fair |
| 12.5 | - | - | 47 | 7 | - | G | Good |
| 10.9 | - | - | 43 | 9 | - | G | Good |
| 8.4 | - | - | 46 | 7 | - | G | Good |
| 6.9 | - | - | 49 | 9 | - | G | Good |
| *Indian Run* (11-211) (1996) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 0.3 | - | - | 29 | 7 | - | MG[ns] | Marginally Good |

Table 16. Continued.

*Quantitative Evaluation*

| *Stream* River Mile | Density ( /ft$^2$) | Quant. Taxa | Qual. Taxa | Qual. EPT[a] | Total EPT | ICI | Evaluation[b] |
|---|---|---|---|---|---|---|---|
| *East Fork Todd Fork* (11-217) Eastern Cornbelt Plains (WWH - Existing) | | | | | | | |
| 1.6 | - | - | 58 | 16 | - | VG | Very Good |
| *Turtle Creek* (11-021) Interior Plateau (WWH - Existing) | | | | | | | |
| 0.3 | 410 | 47 | 48 | 11 | 14 | 48 | Exceptional |
| *Muddy Creek* (11-020) Interior Plateau (WWH - Existing) | | | | | | | |
| 3.3 | - | - | 29 | 8 | - | G | Good |
| *3.24*[d] | - | - | *36* | *5* | - | *F* | *Fair* |
| 2.5 | - | - | 36 | 8 | - | G | Good |
| 0.7 | 457 | 31 | 38 | 9 | 9 | [28][c] | Good |
| *Simpson Creek* (11-017) Interior Plateau (WWH - Existing) | | | | | | | |
| 0.2 | - | - | 19 | 6 | - | F* | Fair* |
| *0.14*[d] | - | - | *21* | *4* | - | *P* | *Poor* |
| 0.1 | 242 | 19 | 17 | 3 | 5 | 26* | Fair* |
| *O Bannon Creek* (11-010) Interior Plateau (WWH - Existing) | | | | | | | |
| 4.5 | - | - | 25 | 5 | - | F* | Fair* |
| *2.57*[d] | - | - | *45* | *11* | - | *G* | *Good* |
| 1.9 | - | - | 43 | 12 | - | G | Good |
| 0.2 | - | - | 36 | 11 | - | G | Good |
| *Stony Creek* (11-012) Interior Plateau (WWH - Existing) | | | | | | | |
| 0.2 | - | - | 49 | 13 | - | G | Good |
| *Sycamore Creek* (11-007) Interior Plateau (WWH - Existing) | | | | | | | |
| 0.5 | - | - | 48 | 11 | - | G | Good |
| *0.24*[d] | - | - | *30* | *6* | - | *F* | *Fair* |
| 0.1 | - | - | 33 | 7 | - | F* | Fair* |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *Little Miami River* (11-001) Eastern Corn Belt Plains (EWH - Existing) | | | | | |
| 106.8 | 20 | 0 | Moderate | Beetles, Mosquitos larvae, leeches | Poor |
| 104.9 | 35 | 3 | Low-Mod. | Physella snails, corixids, beetles | Poor |
| 88.0 | 34 | 11 | Low-Mod. | Hydropsychid caddisflies, blackflies, riffle beetles | Good |
| 77.1 | 67 | 19 | Moderate | Hydropsychid caddisflies, mayflies, midges | Exceptional |
| *77.0A[d]* | *37* | *6* | *Moderate* | *Midges* | *Fair* |
| *77.0B[d]* | *50* | *14* | *Moderate* | *Midges, hydropsychids, mayflies* | *Good* |
| *64.4A[d]* | *23* | *5* | *Low* | *Midges* | *Poor* |
| *66.4B[d]* | *41* | *12* | *Low* | *Midges* | *Marg. Good* |
| 54.3 | 54 | 16 | Low-Mod. | Hydropsychid caddisflies, baetid maylies | Very Good |
| *Little Miami River* Interior Plateau (EWH - Existing) | | | | | |
| 32.9 | 52 | 18 | Mod.-High | Hydropsychid caddisflies, baetid mayflies, riffle beetles | Very Good |
| *32.1A[d]* | *33* | *7* | *Low-Mod.* | *Riffle beetles, heptageniid mayflies* | *Fair* |
| *32.1B[d]* | *41* | *12* | *Low* | *Heptageniid mayflies, hydropsychid caddisflies, oligochaet worms* | *Marg. Good* |
| *21.8A[d]* | *34* | *7* | *Low-Mod.* | *Red midges* | *Fair* |
| *21.8B[d]* | *22* | *2* | *Low* | *Heptageniid mayflies,* red midges, bryozoans | Poor |
| 19.1 | 56 | 20 | Mod.-High | Hydropsychid caddisflies, bryozoans | Exceptional |
| 13.6 | 47 | 17 | Mod.-High | Hydropsychid caddisflies | Very Good |
| 8.8 | 55 | 21 | High | Hydropsychid caddisflies, baetid mayflies, midges | Exceptional |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *Gilroy Ditch* (11-044) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 1.5 | 47 | 8 | Low-Mod. | Caddisflies, baetid mayflies, riffle beetles | Good |
| 1.3 | 46 | 7 | Low-Mod. | *Elimia* snails, hydroptilid caddisflies, flatworms | Fair |
| *Lisbon Fork* (11-043) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.4 | 70 | 17 | Moderate | Caddisflies, mayflies, *Elimia* snails | Exceptional |
| *North Fork Little Miami River* (11-041) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 7.1 | 60 | 12 | Moderate | Caddisflies, riffle beetles, *Corbicula* clams | Good |
| 0.3 | 54 | 19 | Moderate | Caddisflies, *Elimia* snails | Exceptional |
| *Goose Creek* (11-042) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.8 | 57 | 7 | Moderate | Midges, *Pseudocloeon* mayflies, blackflies | Marg. Good |
| *Jacoby Branch* (11-039) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.5 | 74 | 20 | Moderate | Caddisflies, mayflies, Riffle beetles | Exceptional |
| *Conner Branch* (11-038) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.1 | 57 | 15 | Moderate | Hydropsychid caddisflies, Baetic mayflies, midges | Exceptional |
| *North Fork Massie Creek* (11-403) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 7.9 | 59 | 10 | Moderate | Hydropsychid caddisflies, midges | Good |
| 1.1 | 70 | 20 | Moderate | Caddisflies, riffle beetles | Exceptional |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *South Fork Massie Creek* (11-404) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 2.1 | 52 | 19 | Moderate | Caddisflies, *Elimia* snails, riffle beetles | Exceptional |
| 0.2 | 61 | 15 | Moderate | Caddisflies, riffle beetles, *Elimia* snails | Very Good |
| *Tributary to Massie Creek (RM 5.3)* (11-405) Eastern Corn Belt Plains (No Existing Use) | | | | | |
| 0.3 | 46 | 17 | Low-Mod. | Caddisflies, baetid mayflies, blackflies | Exceptional |
| *Clark Run* (11-402) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.5 | 35 | 17 | Low-Mod. | *Chimarra* caddisflies, midges, riffle beetles | Very Good |
| *Oldtown Creek* (11-401) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.4 | 56 | 12 | Moderate | Hydropsychid caddisflies, midges, blackflies | Good |
| *Little Beaver Creek* (11-036) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 6.1 | 25 | 3 | Low | Baetid mayflies, midges | Poor |
| *4.57A*[d] | *13* | *0* | *Low* | *Midges, flatworms, blackflies* | *Very Poor* |
| *4.57B*[d] | *23* | *2* | *Mod.-High* | *Blackflies, midges* | *Poor* |
| *Tributary to Little Beaver Creek (RM 6.1)* (11-056) Eastern Corn Belt Plains (No Existing Use) | | | | | |
| 0.3 | 15 | 3 | Low | Baetid mayflies, blackflies, flatworms | Poor |
| *Tributary to Little Miami River (RM 69.85)* (11-055) Eastern Corn Belt Plains (No Existing Use) | | | | | |
| 0.1 | 38 | 16 | Low | *Chimarra* caddisflies | Very Good |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *Sugar Creek* (11-033) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 2.2 | 47 | 12 | Moderate | Hydropsychid caddisflies | Good |
| 0.3 | 52 | 16 | Moderate | Midges, blackflies, hydropsychid caddisflies | Good |
| *Little Sugar Creek* (11-034) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.5 | 54 | 13 | High | Hydropsychid caddisflies | Good |
| *Glady Run* (11-032) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| *4.9A*[d] | *16* | *1* | *Mod.-High* | *Red midges* | *Very Poor* |
| *4.9B*[d] | *18* | *2* | *High* | *Red midges* | *Very Poor* |
| *Trib. to Little Miami River (RM 62.01)* (11-054) Eastern Corn Belt Plains (No Existing Use) | | | | | |
| 0.5 | 33 | 10 | Low-Mod. | Midges, Hydropsychid caddisflies | Good |
| *Tributary to Little Miami River (RM 60.5)* (11-053) Eastern Corn Belt Plains (No Existing Use) | | | | | |
| 0.2 | 46 | 14 | Low | Hydropsychid caddisflies | Very Good |
| *Newman Run* (11-030) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.3 | 54 | 14 | Low | Hydropsychid caddisflies, Blackflies | Very Good |
| *Caesar Creek* (11-300) Eastern Corn Belt Plains (EWH - Existing) | | | | | |
| 26.5 | 46 | 10 | Low-Mod. | Hydropsychid caddisflies, heptageniid mayflies, water penny beetles | Good |
| 23.1 | 61 | 11 | Moderate | Hydropsychid caddisflies, midges, riffle beetles | Good |
| (WWH - Existing) | | | | | |
| 0.2 | 56 | 19 | Moderate | Hydropsychid caddisflies, baetid mayflies | Very Good |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *North Branch Caesar Creek* (11-312) Eastern Corn Belt Plains (EWH - Existing) | | | | | |
| 6.7 | 59 | 11 | Low-Mod. | Caddisflies, midges, mayflies | Good |
| 1.2 | 53 | 10 | Low-Mod. | Midges, hydropsychid caddisflies, flatworms | Good |
| *South Branch Caesar Creek* (11-311) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 8.2 | 57 | 10 | Moderate | Midges, flatworms, leeches | Good |
| 2.1 | 44 | 14 | Moderate | Caddisflies, water penny beetles, midges | Very Good |
| *Anderson Fork* (11-306) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 18.8 | 46 | 11 | Low-Mod. | Hydropsychid caddisflies, riffle beetles, mayflies | Good |
| 13.9 | 43 | 13 | Mod.-High | Hydropsychid caddisflies, baetid mayflies, riffle beetles | Good |
| (EWH - Existing) | | | | | |
| 9.5 | 50 | 13 | Moderate | Hydropsychid caddisflies, riffle beetles, mayflies | Good |
| *Anderson Fork* (11-306) Eastern Corn Belt Plains (EWH - Existing) | | | | | |
| 4.9 | 44 | 17 | Moderate | Hydropsychid caddisflies, baetid mayflies, midges | Very Good |
| *Painters Creek* (11-307) Eastern Corn Belt Plains (EWH - Existing) | | | | | |
| 0.4 | 51 | 16 | Moderate | Hydropsychid caddisflies, baetid mayflies | Very Good |
| *Buck Run* (11-305) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 1.2 | 38 | 8 | Low-Mod. | Hydropsychid caddisflies, heptageniid mayflies, water penny beetles | Good |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *Trace Run* (11-303) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 1.8 | 49 | 8 | Low-Mod. | Hydropsychid caddisflies, midges | Good |
| *Jonahs Run* (11-302) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 2.1 | 24 | 6 | Low | Hydropsychid caddisflies, heptageniid mayflies | Marg. Good |
| *Flat Fork* (11-301) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 1.7 | 42 | 9 | Low-Mod. | Hydropsychid caddisflies, mayflies, riffle beetles | Good |
| *Todd Fork* (11-200) Eastern Corn Belt Plains (EWH - Existing) | | | | | |
| 15.1 | 59 | 18 | Moderate | Hydropsychid caddisflies, riffle beetles, midges | Very Good |
| 8.6 | 53 | 15 | Mod.-High | Caddisflies, midges, riffle beetles | Good |
| 0.4 | 68 | 19 | Moderate | Hydropsychid caddisflies, riffle beetles, baetid mayflies | Very Good |
| *Lytle Creek* (11-212) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 9.3 | 28 | 5 | Mod.-High | Blackflies, hydropsychid caddisflies, midges | Fair |
| 7.0 | 39 | 7 | High | Hydropsychid caddisflies, midges, *Physella* snails | Fair |
| *6.7*[d] | *20* | *2* | *High* | *Midges* | *Poor* |
| 6.1 | 36 | 5 | High | Midges, hydropsychid caddisflies, blackflies | Fair |
| 2.6 | 39 | 7 | Moderate | Hydropsychid caddisflies, midges | Fair |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| ***Lytle Creek (11-212) (1996)*** Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 10.2 | 11 | 0 | Mod.-High | Red midges | Very Poor |
| 9.6 | 22 | 1 | Low | Blackflies, oligochaetes, aquatic sowbugs | Poor |
| 8.6 | 26 | 1 | Low-Mod. | Hydropsychid caddisflies, aquatic sowbugs, scuds | Poor |
| 8.1 | 25 | 3 | Low | Hydropsychid caddisflies, oligochaetes, red midges | Poor |
| 7.0 | 23 | 2 | Low-Mod. | Blackflies, leeches | Poor |
| 6.0 | 33 | 3 | Low-Mod. | Hydropsychid caddisflies, blackflies | Poor |
| 2.8 | 25 | 5 | Low-Mod. | Hydropsychid caddisflies | Fair |
| 0.7 | 53 | 9 | Low-Mod. | Hydropsychid caddisflies, | |
| *Tributary to Lytle Creek* (11-218) (1996) Eastern Cornbelt Plains (WWH - Existing) | | | | | |
| 0.7 | 7 | 0 | Very High | Red midges | Very Poor |
| | | | | limpets, bryozoa | Good |
| *Cowan Creek* (11-209) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 13.3 | 47 | 7 | Mod.-High | Midges, riffle beetles, flat worms | Fair |
| 12.4 | 43 | 14 | Mod.-High | Midges, hydropsychid caddisflies, *Caenis* mayflies | Good |
| 10.9 | 50 | 12 | Mod.-High | Midges, hydropsychid caddisflies | Good |
| 8.5 | 50 | 17 | Moderate | Hydropsychid caddisflies, midges | Very Good |
| 1.2 | 25 | 9 | Low-Mod. | Hydropsychid caddisflies, riffle beetles, mayflies | Good |
| *Indian Run* (11-211) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.2 | 33 | 5 | Mod.-High | Midges, *Sphaerium* clams | Fair |

Table 16. Continued.

| *Qualitative Evaluation* *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *Cowan Creek* (11-209) (1996) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 13.2 | 49 | 5 | Low | Flatworms | Fair |
| 12.5 | 47 | 7 | Moderate | Caddisflies, mayflies | Good |
| 10.9 | 43 | 9 | Moderate | Hydropsychid caddisflies, mayflies, craneflies | Good |
| 8.4 | 46 | 7 | Moderate | Hydropsychid caddisflies, baetid mayflies | Good |
| 6.9 | 49 | 9 | Moderate | Hydropsychid caddisflies, | Good |
| *Indian Run* (11-211) (1996) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 0.3 | 29 | 7 | Low-Mod. | Flatworms, caddisflies, midges | Marginally Good |
| *East Fork Todd Fork* (11-217) Eastern Corn Belt Plains (WWH - Existing) | | | | | |
| 1.6 | 58 | 16 | Moderate | Caddisflies, baetid mayflies, *Petrophila* moths | Very Good |
| *Muddy Creek* (11-020) Interior Plateau (WWH - Existing) | | | | | |
| 3.3 | 29 | 8 | Mod.-High | Hydropsychid caddisflies, midges, riffle beetles | Good |
| *3.24[d]* | *36* | *5* | *High* | *Midges, hydropsychid caddisflies* | *Fair* |
| 2.5 | 36 | 8 | Mod.-High | Hydropsychid caddisflies, baetid mayflies, midges | Good |
| 0.7 | 38 | 9 | Mod.-High | Hydropsychid caddisflies, baetid mayflies, flatworms | Good |
| *Simpson Creek* (11-017) Interior Plateau (WWH - Existing) | | | | | |
| 0.2 | 19 | 6 | Low-Mod. | Water penny beetles, flatworms, riffle beetles | Fair |
| *0.14[d]* | *21* | *4* | *Mod.-High* | *Hydropsychid caddisflies, blackflies* | *Poor* |

Table 16. Continued.

*Qualitative Evaluation*

| *Stream* River Mile | No. Qual. Taxa | Qual. EPT[a] | Relative Density | Predominant Organisms | Narrative Evaluation |
|---|---|---|---|---|---|
| *O Bannon Creek* (11-010) Interior Plateau (WWH - Existing) | | | | | |
| 4.5 | 25 | 5 | Moderate | Riffle beetles | Fair |
| *2.57*[d] | *45* | *11* | *High* | *Hydropsychid caddisflies, baetid mayflies, riffle beetles* | *Good* |
| 1.9 | 43 | 12 | High | Riffle beetles, hydropsychid caddisflies, flatworms | Good |
| 0.2 | 36 | 11 | Mod.-High | Caddisflies, baetid mayflies, riffle beetles | Good |
| *Stony Creek* (11-012) Interior Plateau (WWH - Existing) | | | | | |
| 0.2 | 49 | 13 | Low | Caddisflies, water penny beetles | Good |
| *Sycamore Creek* (11-007) Interior Plateau (WWH - Existing) | | | | | |
| 0.5 | 48 | 11 | Moderate | Hydropsychid caddisflies, midges, baetid mayflies | Good |
| *0.24*[d] | *30* | *6* | *High* | *Blackflies, midges* | *Fair* |
| *Sycamore Creek* (11-007) Interior Plateau (WWH - Existing) | | | | | |
| 0.1 | 33 | 7 | High | Blackflies, midges | Fair |

Ecoregion Biocriteria: Invertebrate Community Index (ICI)

| | WWH | EWH | MWH |
|---|---|---|---|
| Eastern Corn Belt Plains | 36 | 46 | 22 |
| Interior Plateau | 30 | 46 | 22 |

[a] EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa richness.
[b] A qualitative narrative evaluation based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.
[c] The sampling location was located within an impoundment with non-detectable current speed.
[d] Mixing zone sampling location.
* Significant departure from applicable biological criterion (>4 ICI units), poor and very poor results are underlined.
[ns] Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

***Biological Assessment - Fish Communities***

*Little Miami River*

Fish communities in the upper portion of the Little Miami River (defined *ad hoc* as upstream from Mathers Mill, RM 45) showed similar longitudinal trends with respect to point source dischargers between 1993 and 1998. IBI and MIwb scores peaked through the reach downstream from Yellow Springs to the confluence with Beaver Creek, then decreased below the nonsignificant departure range of EWH downstream from Beaver Creek to Spring Valley coinciding with the increased wastewater loadings (Figures 107 and 108). The fish community recovered to near complete EWH performance upstream from the Waynesville WWTP, decreased to marginally meeting the WWH criteria downstream from it, then partially recovered upstream from the confluence with Caesar Creek. One difference between 1998 and 1993 was that the MIwb scores were lower in the reach between Yellow Springs and the confluence with Beaver Creek in 1998 compared to 1993 (Figure 107; Table 17). Coincidentally, the Datasondes® also recorded lower dissolved oxygen concentrations in this reach in 1998 compared to 1993. The suppressed MIwb scores and low dissolved oxygen concentrations are symptomatic of an overly stressed system. Though these results suggest that water quality deteriorated over the intervening period, systems that are stressed show greater interannual variation than unstressed systems, so the results may equally reflect an ongoing stress.

The incidence of either deformities, eroded fins, lesions or tumors (DELTs) on fish in 1998 was similar in frequency to 1993, and followed the same pattern where the incidence of DELTs was generally highest in the reach receiving point source pollutant loads (Figure 109). The dissolved oxygen regime in the upper LMR mainstem showed a cyclical pattern of variation and median concentrations (Figure 110). The reach having a high incidence of DELTs roughly corresponds with the trough of one of these cycles. The pattern of dissolved oxygen concentrations depicted in Figure 110, when interpreted as an indicator of the dissolved oxygen regime and not as a snap-shot of where an oxygen sag is likely to occur at any point in time, explains why the incidence of DELTs does not occur in perfect lock step with where the lowest oxygen concentrations were recorded. A different suite of rain events, loadings, and cloud cover prior to and during the Datasonde® deployment could produced a different pattern in dissolved oxygen concentrations.

Nutrient over-enrichment is implicated as the cause for the general malaise shown by the fish population in the EWH reach, as can be inferred by the performance of individual IBI metrics (Figure 111). The proportions of tolerant and omnivorous fishes increases within the reach receiving wastewater from Dayton and Xenia, but those proportions return to normal levels further downstream. Relatedly, the proportion of fish with DELTs increases, and, on average, several pollution intolerant species are lost within the reach subject to wastewater loadings. However, unlike the proportions of tolerant and omnivorous fishes, the DELT and Intolerant metrics do not recover to normal levels in the downstream reach. The increase in tolerant and omnivorous fishes with a corresponding loss of intolerant species suggests an acute effect from the cumulative loadings (*e.g.*, organic enrichment, frequent low dissolved oxygen, episodic toxicity). However, the return to a normal trophic structure, but suppressed numbers of intolerant species and elevated occurrence of DELTs, demonstrates a chronic stress such as infrequent and episodically low dissolved oxygen concentrations as described

in the preceding paragraph. Wide diel variation and episodically low dissolved oxygen concentrations are caused by high levels of algal productivity and respiration, which is stimulated, in turn, by high nutrient concentrations. Whether the observed dissolved oxygen regime or any other factor was responsible for causing the DELTs was untested. DELTs are positively associated with a variety of water quality indicators (*e.g.*, ammonia-nitrogen, metals, nitrate-nitrogen and phosphorus) in the Ohio EPA database including low dissolved oxygen. Assuming that DELTs were caused by a constituent of the wastewater or urban/suburban runoff, one would expect to see a pattern of impact and recovery in the frequency of DELTs with respect to the pollution source. In the absence of such a pattern, the widespread occurrence of DELTs throughout the mainstem, and the observed low dissolved oxygen concentrations, are collectively an indication that the system is overly stressed, and nutrient enrichment is the best explanation.

Site specific impacts to the upper LMR mainstem were observed at the site downstream from the Waynesville WWTP and at all sites upstream from Clifton. The sites upstream from Clifton were impacted by channelization and gross nutrient enrichment. Masses of filamentous algae were especially noted downstream from Gilroy Ditch (South Charleston WWTP) at RM 98.3 (Dolly Varden Road). The site was channelized and unshaded by riparian vegetation, thus exacerbating effects of nutrient enrichment. The site downstream from the Waynesville WWTP appeared impacted by organic enrichment, as intolerant species were absent and the proportion of omnivorous fishes increased compared to upstream.

The fish community in the lower half of the mainstem is also affected by nutrient over-enrichment. IBI and MIwb scores in 1998 were depressed in the reach between Caesar Creek and South Lebanon relative to 1993, and coincided with the highest incidence of DELTs. Again, in the absence of a direct pollution source, nutrient over-enrichment acting on an already taxed system best explains the difference between 1998 and 1993. The lower mainstem fish community is further impacted by additional pollutant loads coming from suburban Cincinnati. Starting at the site downstream from Simpson Creek (Warren County Lower LMR WWTP) the proportion of omnivorous fishes increases, whereas the proportion of round-bodied suckers, simple lithophils and insectivores decreases. The increased abundance of omnivores reflects increasing enrichment. However, the changes in the fish community suggest that point source pollution loads are not the only problem facing the lower mainstem. Starting at South Lebanon, residential homes and yards encroached on the riparian zone with increasing frequency, and in and downstream from Loveland the river valley was heavily suburbanized; the consequence being that additional sediment loads resulted in the loss of simple lithophils and reduced abundance of round-bodied suckers.

For the LMR mainstem on the whole, the fish populations and community structure were similar between 1993 and 1998. In 1993, 82 species of fish were collected versus 73 in 1998, the difference being that in 1993 the fish were sampled three times, as opposed to twice in 1998, and at later dates and under lower flows in 1993. Additional sampling passes typically yield more species electrofishing when the total number of passes is less than five (Paller, 1995). So the absence of blue sucker, tonguetied minnow, and variegated darter in 1998 does not necessarily indicate deteriorating water or habitat quality relative to 1993, rather their absence is more an indication of their rarity,

which, in turn, is another indication that the river has been, and continues to be, stressed. Metrics measuring trophic composition and the number of intolerant species were similar in 1993 and 1998; evidence that water quality, at least with respect to organic enrichment and toxicity, and habitat quality has been largely unchanged.

*Upper LMR Tributaries*

Thirty-one tributaries were sampled at 56 locations (plus three mixing zones) in the upper Little Miami River basin. Of those 56 locations sampled, 14 had IBI scores that were rated Very Good to Exceptional, 17 were rated Good, 10 were rated Marginally Good, 12 were rated Fair, and 3 rated Poor (Figure 112). Wastewater loads and habitat quality explained most of the separation by narrative range. Habitat quality was highest in the streams and sites rated Very Good and Exceptional, and was successively lower in the other narrative ranges. Variance within the QHEI scoring matrix increased with successively lower narrative ranges reflecting the wide variety of sources of habitat impairment, both natural and anthropogenic, affecting these streams. For example, the Caesar Creek sub-basin and Massie Creek had scattered localized impairment mainly due to channelization or sedimentation from agriculture. Flat Fork and Jonahs Run in the Caesar Creek basin were intermittent and nearly dry, and so were naturally limited. The site at RM 23.1 on Caesar Creek was also naturally limited because the habitat was dominated by shallow bedrock. Anderson Fork was impacted by sedimentation from agriculture and bank erosion. Caesar Creek Reservoir acts as a sink for sediment from Anderson Fork. The North Fork of Massie Creek is channelized and carries a heavy bedload of sediment. Ludlow Creek, and Beaver Creek upstream from the confluence with Little Beaver Creek were affected by both suburbanization and agriculture. The North Fork of the Little Miami River and Gilroy Ditch were previously channelized. Though the fish communities were only marginally impaired in both, the Little Miami River mainstem was significantly impaired downstream from both because of the exported sediments and nutrients. From the standpoint of the TMDL, the habitat quality in the Very Good and Exceptional streams obviously needs to be maintained, whereas degraded headwater reaches and tributaries need to be restored. The Beaver Creek sub-basin and Glady Run had widespread impairment (Figure 113). The Beaver Creek subbasin was impaired primarily by wastewater loads and poor habitat. Glady Run was impaired by wastewater. Because the Little Miami River mainstem is impaired downstream from the Beaver Creek basin and Glady Run, those two tributaries should receive attention during the TMDL process.

*Beaver Creek Subbasin and Glady Run*

Beaver Creek is impacted by channelization and other habitat alterations, and Little Beaver Creek and Glady Run are effluent dominated. Effluent domination as the cause for impairment in Glady Run is given by the fact that the habitat was generally good, yet tolerant fishes were disproportionately represented in the electrofishing samples. Although tolerant fishes were predominant, acute toxicity was not implicated as the root cause of impairment given pioneering fishes were not abnormally abundant. Rather the fish community suggested that the problem was chronic as sensitive species were rare. An indication of chronic stress was witnessed on the second electrofishing pass when elevated conductivity reduced electrofishing efficiency at RM 2.1 to the point that the sample was declared invalid. No fish kill was associated with the elevated conductivity. The adequacy of the habitat in Glady Run was evidenced by the strong populations of southern redbelly dace in the creek.

Little Beaver Creek, like Glady Run, is also effluent dominated, and also had a disproportionate number of tolerant fishes represented in the electrofishing samples. However, unlike Glady Run, the fish community in Little Beaver Creek was affected by toxicity as evidenced by an elevated incidence of DELTs, and a disproportionate abundance of pioneering species in the electrofishing samples. Little Beaver Creek is an urban steam subjected to urban runoff and associated pollutant loads that are likely a source of toxicity. Also, the habitat in Little Beaver Creek is constrained by a higher proportion of modified habitat attributes compared to Glady Run.

In contrast to Glady Run and Little Beaver Creek, fish populations in Beaver Creek were limited mainly by poor habitat. The entire length of Beaver Creek has been either directly subjected to channelization or suffers from the consequences of it, as evidenced by silt and sand embedding the substrates at all sites. Additionally, being near a large urban center, landuse in the drainage is intense, comprised of a mosaic of suburban development, nurseries, golf courses, dairy farms (cows were in the stream at RM 3.9), and row crops. The Beaver Creek WWTP did not adversely affect the fish community in Beaver Creek downstream from the plant relative to the impaired condition of the fish community upstream; however, the relative abundance of tolerant fishes increased downstream from the plant, and the abundance of darters and sculpins decreased. Curiously though, the abundance of darters and sculpins was highest in the mixing zone. This pattern suggests that toxicity, plant upsets, or bypasses are not problematic, rather the cumulative load to the creek is likely responsible for the increased abundance of tolerant fishes.

*Massie Creek*

The North Fork of Massie Creek was impaired primarily by sedimentation, channelization, and organic enrichment from livestock. Organic enrichment at RM 1.2 resulted in a fair IBI score, and was the difference between the marginally good score obtained upstream where habitat degradation was the limiting factor. The South Fork was similarly affected by habitat degradation, but lacked cows in the stream; consequently, the IBI met the WWH criterion.

The fish communities in the mainstem of Massie Creek were not commensurate with the excellent habitat present. The number of darter, sucker and sunfish species were lower than expected. Typically, this species composition would be associated with impaired habitat, but obviously that was not the case. The dissolved oxygen concentration at RM 7.2 (Tarbox Cemetery Rd.) had a wide diel variation with minimum concentrations falling below 4.0 mg/l, indicating nutrient enrichment. Toxicity of the Cedarville WWTP effluent and poor plant performance have been documented, however, whether that has influenced the fish community is uncertain given the high MIwb score downstream from the plant. What is certain is that the WWTP and nonpoint loadings are causing the nutrient enrichment.

*Caesar Creek Subbasin*

Local habitat quality explained about half the variation in IBI scores between sites within the Caesar Creek subbasin ($R^2 = 0.4956$). The relatively high correlation reflects the lack of wastewater loads, and that habitat within the subbasin is mostly intact. In Anderson Fork, the coefficient of correlation between the IBI and QHEI was 0.9778. This relationship illustrates the ability of a stream that has

not been channelized to assimilate and recover from nonpoint pollution loads. The most upstream site was heavily polluted with silt, but the natural habitat features through the reach helped assimilate the sediment load. Anderson Fork was moderately polluted with sediment at the other three sites due to agriculture and bank erosion, so it is unlikely that the fish community would have performed as well at the downstream sites if sediment export from upstream was expedited by channelization. In contrast to the Caesar Creek subbasin, the QHEI explained only 9 percent of the variation in IBI scores in the remaining tributaries within the upper LMR study area, further evidence of impairment from wastewater loads and nonpoint pollution (see the preceding discussions).

*Sycamore Creek*

The Hamilton County Sycamore Creek WWTP had no discernible impact on the fish community in Sycamore Creek. The fish community underperformed relative to the habitat quality present due to the fewer than expected number of sucker, darter and pollution intolerant species in the electrofishing samples (both upstream and downstream from the WWTP). The lack of these species groups was driven by habitat degradation due to suburbanization and urban runoff. Though overall habitat quality was good, the riffles were moderately embedded with silt and sand, few trees were in the riparian area, and bank erosion was moderate to heavy.

*O Bannon Creek*

The fish communities in O'Bannon Creek were limited by nutrient enrichment and suburbanization within the watershed. The riffles at the most downstream site (RM 0.3) were heavily embedded with silt and sand, likely as the result of residential development, and masses of filamentous algae were present indicating nutrient enrichment from the O'Bannon Creek WWTP. Bluntnose minnows were inordinately abundant in the mixing zone sample during the second pass, which may be symptomatic of organic enrichment. However, the impacts to the fish community from the O'Bannon Creek WWTP, aside from the effects of nutrient enrichment, were negligible in comparison to impacts from suburbanization as trophic structure was relatively intact but the proportion of simple lithophils and number of darter species were lower than expected.

*Simpson Creek*

An instream impoundment at RM 1.2 intercepts all the flow in Simpson Creek during the summer low flow period. Consequently, during low flow, the stream resumes with the Warren County Lower Little Miami River WWTP at RM 0.3, and flows down a hillside with a gradient of 125 ft/mi, effectively rendering the WWTP a point source to the LMR mainstem. Having only a short, high gradient, stream reach that lacks upstream connectivity is obviously a limiting factor for a resident headwater community. Accordingly, the fish community was composed mostly of transient fishes from the LMR mainstem, and therefore, is not an appropriate indicator of WWTP effluent quality.

*Muddy Creek*

The Mason WWTP had a minor impact on the fish community in Muddy Creek. The proportion of omnivores downstream from the plant was greater than upstream, and the reverse was true of insectivores. This shift in trophic structure is indicative of either organic or nutrient enrichment. Toxicity is not implicated because the IBI scored higher in the mixing zone that either upstream or

downstream, and was the same between passes. The upstream site was impacted by suburban and urban runoff as evidenced by poor performance of the sensitive, darter and simple lithophil species metrics.

*Todd Fork and East Fork Todd Fork*

Todd Fork has an Exceptional Warmwater Habitat aquatic life use designation. Fish communities sampled from Todd Fork did not fully meet expectations for the EWH use designation at any location except for RM 15.2 (Table 17). The number of sucker species, and the number of intolerant species metrics underperformed at all sites. These two metrics are sensitive to environmental disturbances, such as nutrient enrichment or sedimentation, near the "high end" of an aquatic health continuum. Coincidentally, the riffles at five of the six sites sampled were moderately embedded with sand and silt, and the riffle and channel substrates at the most upstream location (RM 20.3) were heavily embedded with sand. Also, a bed load of fine sand and gravel was noted on the QHEI field sheet for RM 15.2. The sources of the sediment were not identified, but were likely derived from nonpoint sources in the headwaters as riparian zones in the lower twenty miles of Todd Fork were generally intact, and bank erosion was minimal. Although EWH performance by the fish community was not realized, Todd Fork supported a full compliment of high quality indicator species (e.g., rosyface shiner, silver shiner, banded darter, stonecat madtom, black redhorse). So despite being marginalized by nonpoint sedimentation, the fish community has the potential to meet EWH performance with the implementation of nonpoint controls.

The East Fork of Todd Fork is currently undesignated in the Water Quality Standards. The fish community in the East Fork Todd Fork, similar to Todd Fork, was limited by a bedload of sand, and, consequently, performed consistent with expectations for a WWH stream. Like Todd Fork, the restoration potential for the East Fork to EWH is great.

*Lytle Creek, Cowan Creek and Indian Run*

Biological communities in Lytle Creek were adversely affected by frequent anoxia. No fish were found in Lytle Creek at RM 10.2 upstream from the tributary receiving discharge from the ABX 001 - 003 outfalls, nor in the receiving tributary; the difference being Lytle Creek at RM 10.2 was intermittent and had only one small pool ( 4 $m^2$) in a 150 m reach, whereas the tributary had continuous flow. Downstream from the receiving tributary, where flow in Lytle Creek was continuous and habitat was more than adequate to support a WWH headwater fish community (QHEI = 75), pioneering tolerant fishes composed 98% of the fish sampled, demonstrating that the fish community is periodically wiped out by toxicity or anoxia. The fish community was impaired in Lytle Creek by ABX at least to the Wilmington WWTP. Sediments collected in Lytle Creek at RM 9.4 did not contain unusually high concentrations of metals or organic pollutants, suggesting toxicity was limited to effects from deicing chemicals or anoxia. Ammonia-nitrogen concentrations were nearly three times higher than in sediments collected at reference locations, possibly reflecting residual contamination from urea-based deicing compounds, but ammonia concentrations in the water column were within normal ranges. Phosphorus was also highly elevated in sediments collected at RM 9.4, but the source was unidentified.

The Wilmington WWTP, though not negatively impacting the fish community relative to the degraded condition upstream, appears to delay recovery from the ABX impact (Figure 114). The delay is due to nutrient over-enrichment. Masses of filamentous algae were present downstream from the WWTP.

Cowan Creek receives only a fraction of the discharge from ABX that Lytle Creek does, consequently the fish and macroinvertebrate communities fair commensurately better. A minor longitudinal impact due to ABX was detectable in Cowan Creek in 1996. In 1998, IBI scores upstream and downstream from Indian Run were the same, however Cowan Creek upstream from Indian Run (RM 13.3) was intermittent, whereas downstream from Indian Run, the flow was continuous, suggesting that the potential for the fish community was greater downstream from Indian Run. The median dissolved oxygen concentration measured in 1998 upstream from Indian Run was 3.6 mg/l, and the median downstream, where flow was continuous, was 4.1 mg/l. IBI scores decreased by 12 points at RM 13.3 between 1996 and 1998 due largely to the loss of two sucker species and one sunfish species for unkown reasons. Nitrogen loadings from ABX to Indian Run resulted in measurably increased nitrate-nitrogen concentrations in Cowan Creek on 19 September 1996, demonstrating that loadings from ABX influence the water quality in Cowan Creek.

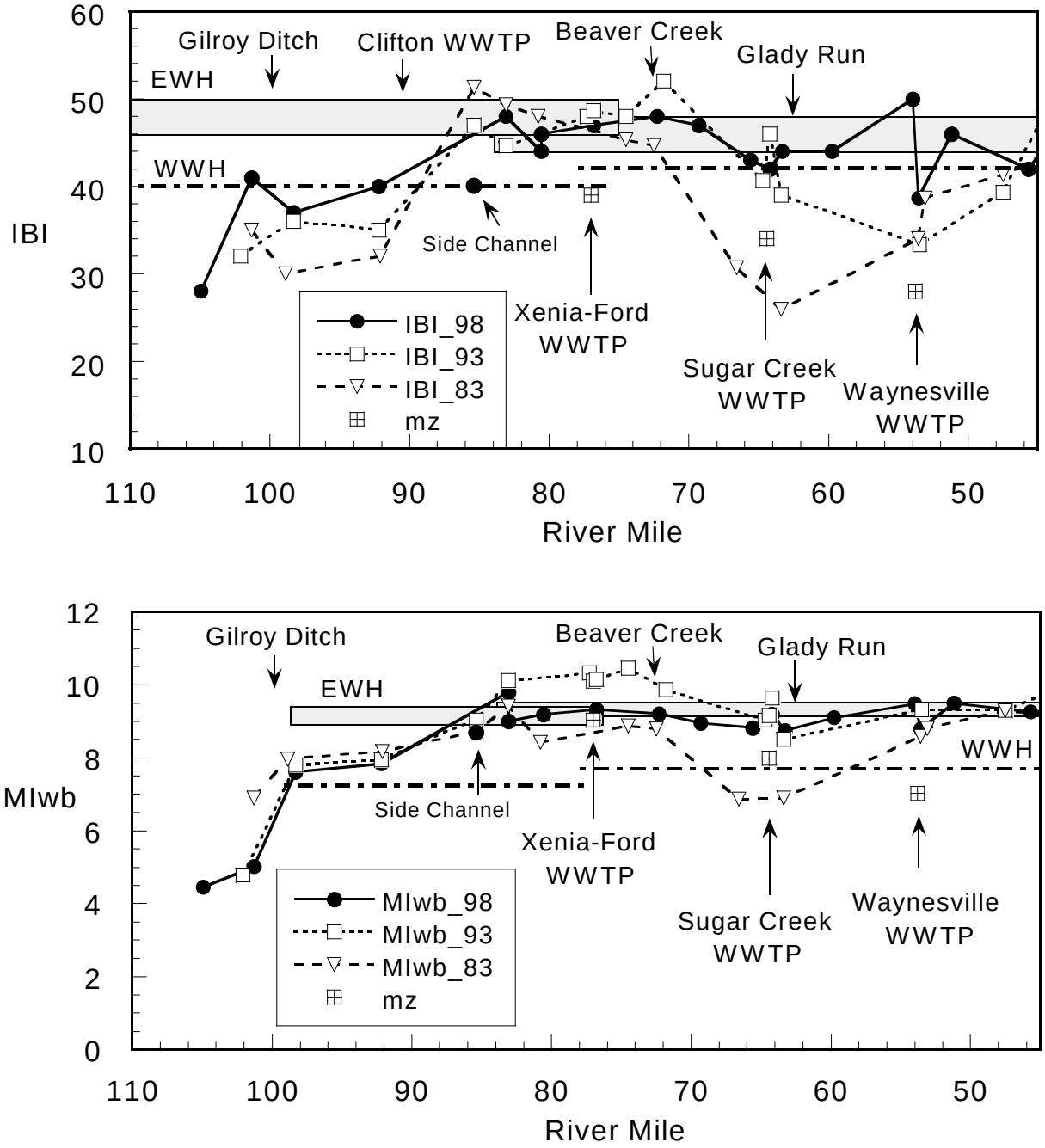



Figure 107. Plots of IBI (top panel) and MIwb (bottom panel) scores for the upper Little Miami River, 1983, 1993 and 1998 in relation to point source discharges and major tributaries.

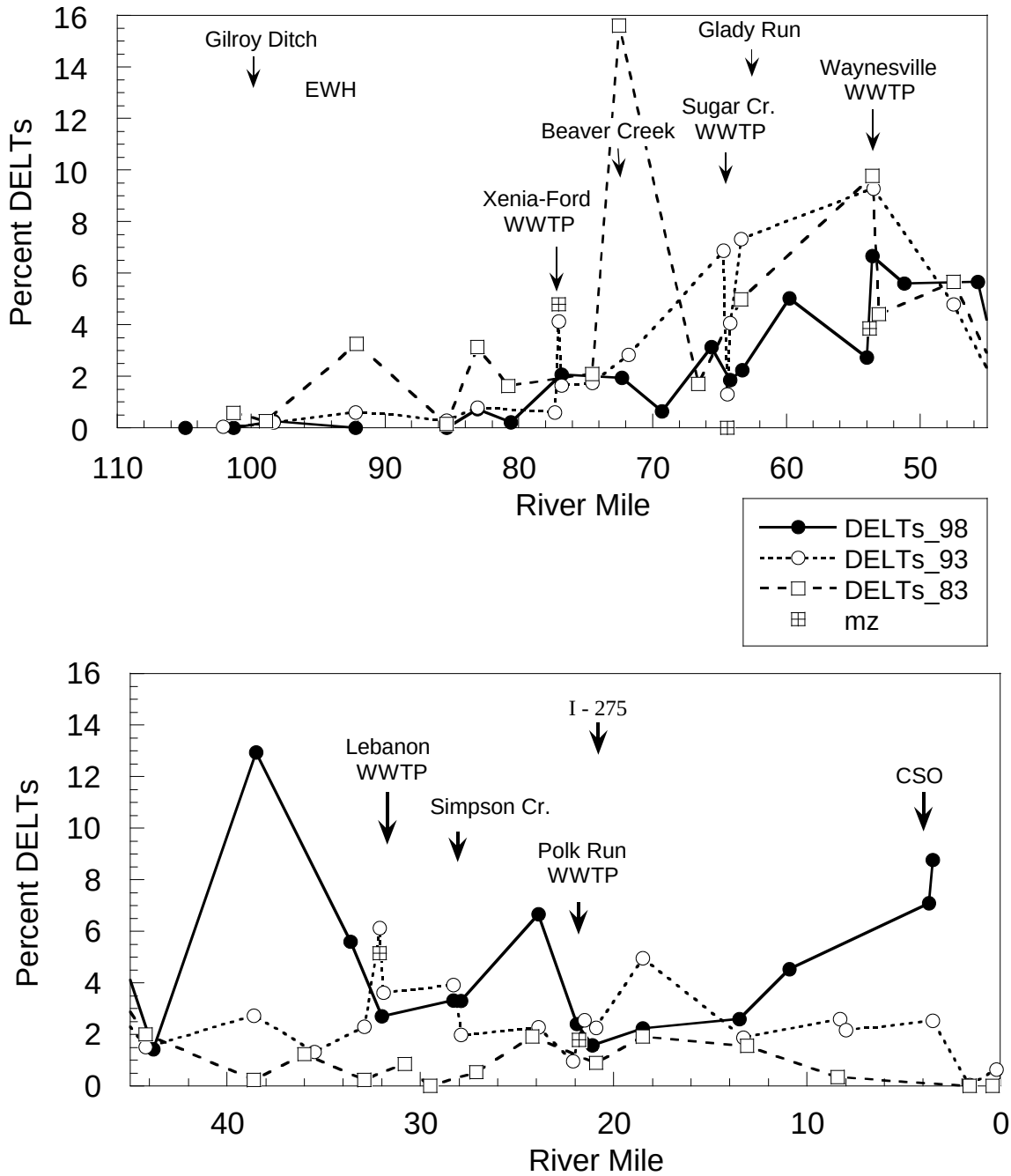



Figure 108. Percent of fish with anomalous deformities, eroded fins, lesions or tumors (DELT) in electrofishing samples from the upper (top panel) and lower (bottom panel) Little Miami River, 1983, 1993 and 1998 in relation to point source discharges and major tributaries.

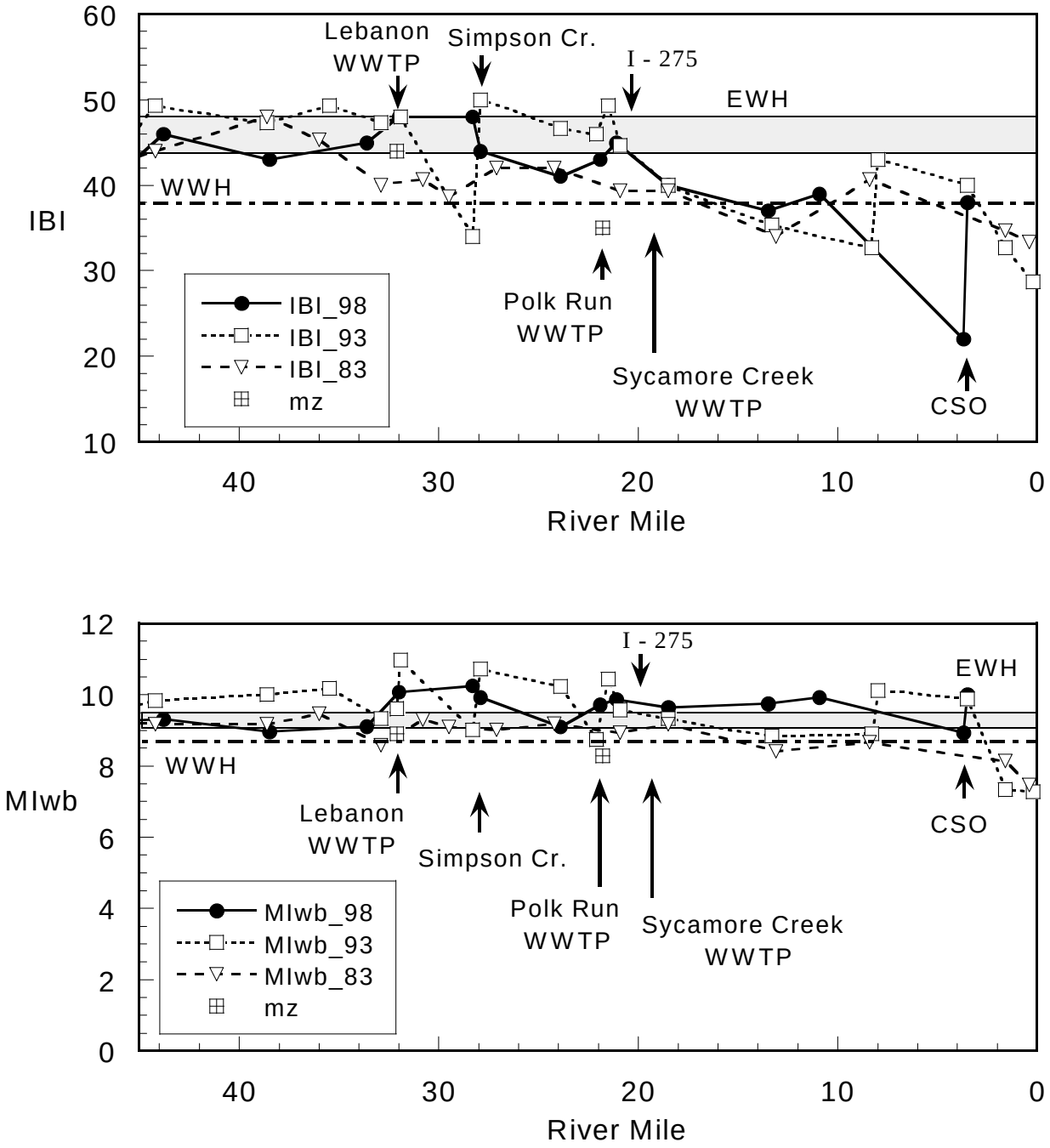



Figure 109. Plots of IBI (top panel) and MIwb (bottom panel) scores for the lower Little Miami River, 1983, 1993 and 1998 in relation to point source discharges and major tributaries.

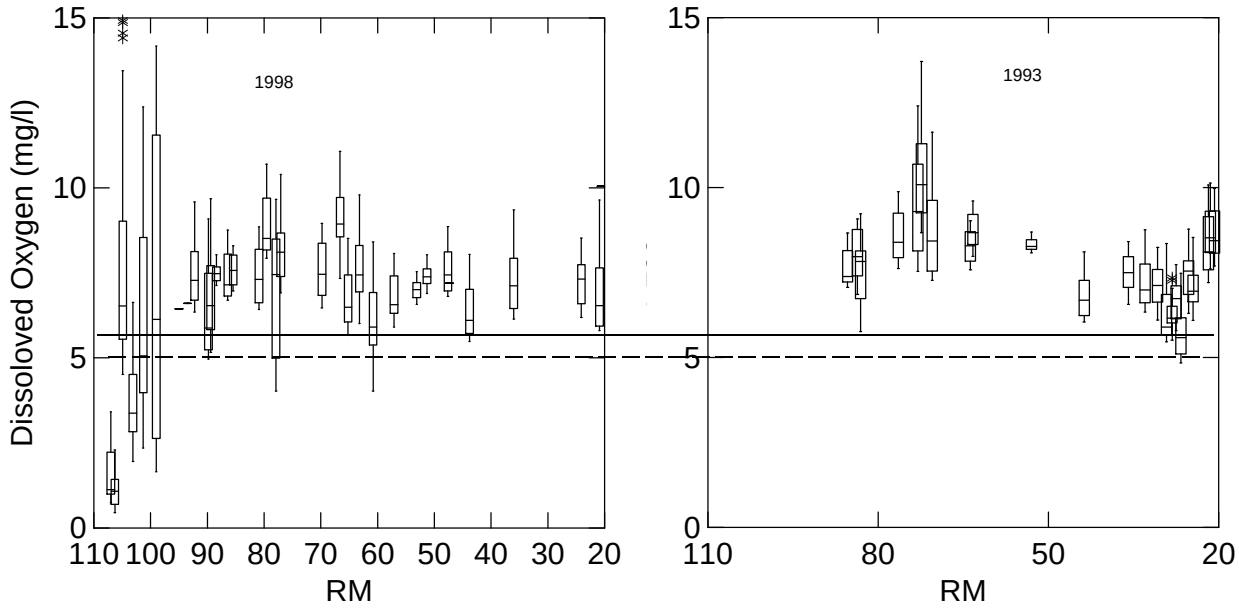



Figure 110. Distributions of dissolved oxygen concentrations sampled hourly over 48 h intervals in the Little Miami River, 1998 and 1993. Note that in either year not all data were collected on the same date, but all data were collected during the summer-fall low flow period .

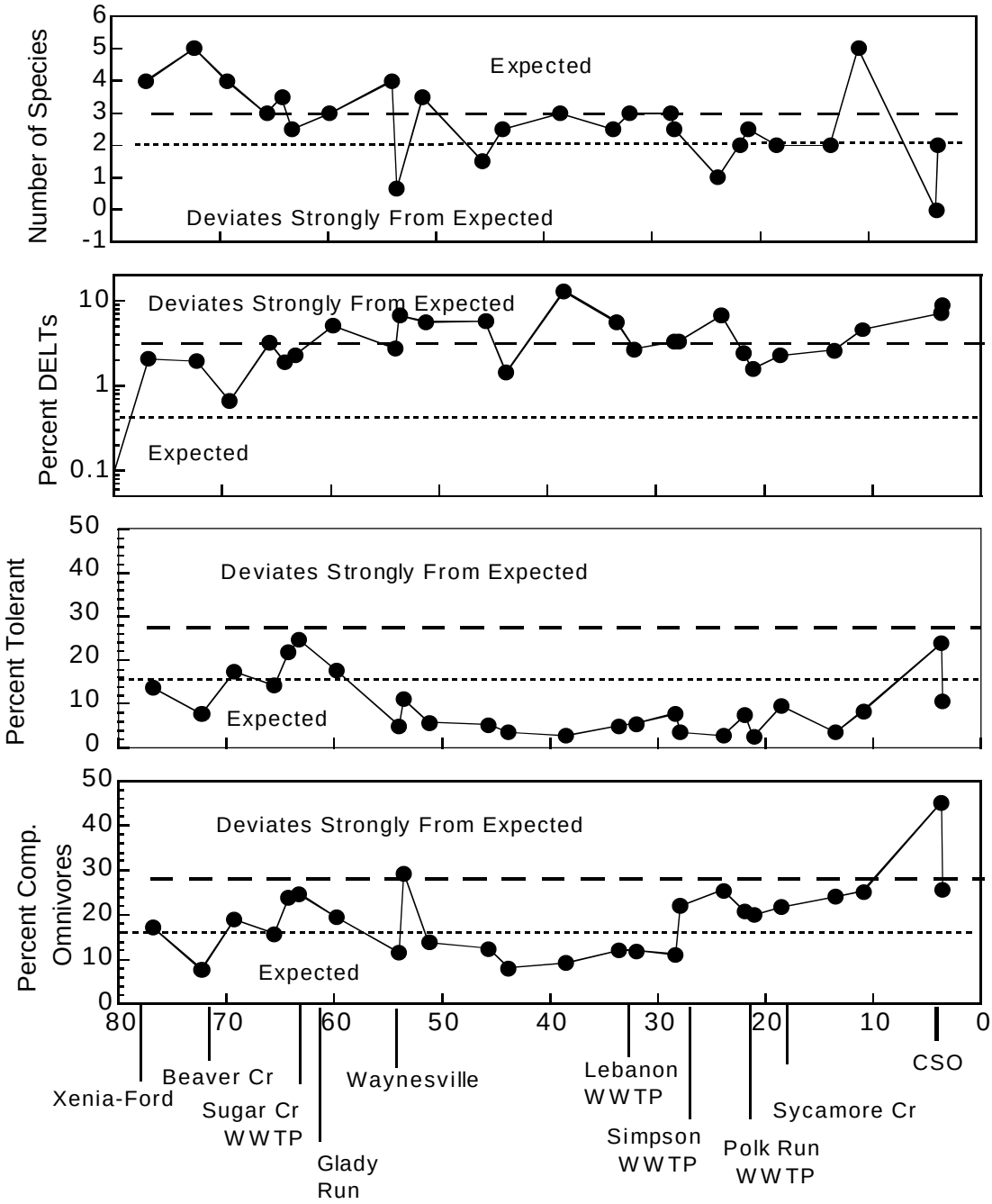



Figure 111. Plots of select component IBI metrics. From the top, number of intolerant species, percent of fish with DELTs, proportion of pollution tolerant fishes, and proportion of omnivores in electrofishing catches from the Little Miami River, 1998 in relation to point source discharges and major tributaries. Dashed horizontal lines show expected ranges derived from least impacted reference sites.

Table 17. Fish community indices from samples collected in the Little Miami study area 1998.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| Little Miami River (11-001) Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| 104.9 | 8.0 | 8 | 1036 | 0.0 | 47.5 | NA | 28* | Fair |
| 101.3 | 12.5 | 14 | 1793 | 0.0 | 44.5 | NA | 41* | Good |
| 98.3 | 14.0 | 17 | 925 | 18.1 | 54.0 | 7.6* | 37* | M.Good |
| 92.2 | 13.0 | 15 | 818 | 15.9 | 67.0 | 7.8* | 40* | M.Good/Good |
| 85.4 | 13.5 | 14 | 617 | 11.4 | 68.0 | 7.8* | 38* | M.Good |
| 83.1[A] | 23.0 | 27 | 569 | 107.9 | 81.5 | 9.8 | 48 | Exceptional |
| 83.1[D] | 23.0 | 27 | 452 | 20.0 | 81.5 | 9.0[ns] | 48[ns] | V.Good |
| 80.6[A] | 18.0 | 25 | 442 | 126.7 | 79.0 | 9.2[ns] | 44[ns] | V.Good |
| 80.6[D] | 21.0 | 25 | 540 | 14.3 | 79.0 | 9.2[ns] | 46[ns] | V.Good |
| *77.0* | *10.0* | *14* | *1005* | *229.6* | | *9.0* | *39* | *Good/M.Good* |
| 76.8 | 20.0 | 26 | 488 | 86.4 | 79.5 | 9.3[ns] | 47[ns] | V.Good |
| 72.3 | 22.0 | 26 | 549 | 99.4 | 82.0 | 9.2[ns] | 48 | V.Good/Except. |
| 69.3 | 20.5 | 24 | 379 | 92.0 | 79.0 | 9.0* | 47[ns] | Good/V.Good |
| 65.6 | 21.0 | 25 | 344 | 76.8 | 77.0 | 8.8* | 43* | Good/ |
| *64.4* | *9.0* | *14* | *440* | *70.3* | | *8.0* | *34* | *Fair/M.Good* |
| 64.2 | 22.0 | 27 | 388 | 129.5 | 74.5 | 9.2[ns] | 42* | V.Good/Good |
| 63.3 | 20.5 | 26 | 350 | 106.6 | 78.0 | 8.8* | 44[ns] | Good/V.Good |
| 59.8 | 23.5 | 30 | 390 | 91.6 | 77.0 | 9.1[ns] | 44[ns] | V.Good |
| 54.0 | 24.0 | 24 | 366 | 126.2 | | 9.5[ns] | 50 | V.Good/Except. |
| *53.8* | *9.0* | *9* | *260* | *16.6* | | *7.0* | *28* | *Fair* |
| 53.6 | 20.0 | 31 | 241 | 113.7 | 65.0 | 8.8* | 39* | Good/M.Good |
| 51.2 | 20.5 | 28 | 445 | 185.9 | 85.5 | 9.5[ns] | 46[ns] | V.Good |
| Interior Plateau (EWH - Existing) | | | | | | | | |
| 45.7 | 19.5 | 24 | 303 | 102.5 | 78.5 | 9.3[ns] | 42* | V.Good/Good |
| 43.8 | 21.0 | 28 | 354 | 114.6 | 82.0 | 9.3[ns] | 46[ns] | V.Good |
| 38.5 | 19.0 | 27 | 421 | 186.7 | 81.0 | 9.0* | 43* | Good |
| 33.6 | 20.0 | 26 | 464 | 178.5 | 81.0 | 9.1[ns] | 45[ns] | V.Good |
| *32.1* | *13.0* | *19* | *960* | *291.0* | | *8.9* | *44* | *Good/V.Good* |
| 32.0 | 26.5 | 35 | 456 | 138.0 | 84.0 | 10.1 | 48 | Exceptional |
| 28.3 | 28.0 | 35 | 517 | 149.0 | 80.5 | 10.2 | 48 | Exceptional |
| 27.9 | 21.5 | 27 | 477 | 177.4 | 81.5 | 9.9 | 44[ns] | Except./V.Good |
| 23.9 | 21.5 | 28 | 271 | 115.7 | 82.5 | 9.1[ns] | 41* | V.Good/Good |
| 21.9 | 25.5 | 33 | 372 | 88.7 | 76.5 | 9.7 | 43* | Except./Good |

Table 17. Continued.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| Little Miami River (11-001) Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| *21.8* | *10.5* | *16* | *325* | *67.6* | | *8.3* | *35* | *M.Good* |
| 21.1 | 22.5 | 29 | 287 | 118.4 | 81.5 | 9.9 | 45$^{ns}$ | Except./V.Good |
| 18.5 | 26.5 | 34 | 251 | 72.7 | 79.0 | 9.6 | 40$^{*}$ | Except./V.Good |
| 13.5 | 21.5 | 27 | 313 | 116.6 | 81.0 | 9.8 | 37$^{*}$ | Except./M.Good |
| 10.9 | 25.5 | 34 | 352 | 136.8 | 84.5 | 9.9 | 39$^{*}$ | Except./M.Good |
| 3.7 | 21.0 | 21 | 226 | 165.9 | 75.5 | 8.9$^{*}$ | 22$^{*}$ | Good/Poor |
| 3.5 | 23.0 | 23 | 422 | 389.7 | | 10.0 | 38$^{*}$ | Except./M.Good |
| Sycamore Creek (11-007) Interior Plateau (WWH - Existing) | | | | | | | | |
| 0.4 | 15.5 | 19 | 520 | 3.5 | 70.5 | 7.6$^{ns}$ | 35$^{*}$ | M.Good/Fair |
| *0.3* | *11.5* | *17* | *588* | *4.2* | | *6.6* | *34* | *Fair* |
| 0.2 | 13.0 | 16 | 409 | 6.0 | 63.5 | 7.1$^{*}$ | 36$^{ns}$ | Fair/M.Good |
| O'Bannon Creek (11-010) Interior Plateau (WWH - Existing) | | | | | | | | |
| 4.3 | 17.0 | 20 | 348 | 5.3 | 72.0 | 7.6$^{ns}$ | 44 | M.Good/Good |
| *2.6* | *14.5* | *16* | *1254* | *10.9* | | *8.0* | *35* | *M.Good/Fair* |
| 2.4 | 16.5 | 18 | 1098 | 6.7 | 69.5 | 8.2 | 37$^{ns}$ | Good/M.Good |
| 0.3 | 21.0 | 26 | 698 | 4.4 | 56.5 | 7.9$^{ns}$ | 40 | M.Good/Good |
| Simpson Creek (11-017) Interior Plateau (WWH - Existing) | | | | | | | | |
| 0.9 | 2.0 | 2 | 62 | 2.3 | 65.5 | NA | 16$^{*}$ | V.Poor |
| 0.1 | 10.0 | 17 | 368 | 2.0 | 57.0 | NA | 42 | Good |
| Muddy Creek (11-020) Interior Plateau (WWH - Existing) | | | | | | | | |
| 3.5 | 10.0 | 12 | 495 | 0.0 | 75.0 | NA | 33$^{*}$ | Fair |
| *3.2* | *7.0* | *8* | *1275* | *1.2* | | *NA* | *36* | *M.Good* |
| 2.5 | 12.0 | 13 | 342 | 6.9 | 69.5 | NA | 30$^{*}$ | Fair |
| 0.7 | 20.5 | 24 | 1538 | 52.8 | 73.5 | NA | 42 | Good |
| Turtle Creek (11-021) Interior Plateau (WWH - Existing) | | | | | | | | |
| 0.3 | 24.0 | 24 | 980 | 9.8 | 70.5 | 9.1 | 50 | V.Good/Except. |
| Newmans Run (11-030) Interior Plateau (WWH - Existing) | | | | | | | | |
| 0.3 | 19.0 | 19 | 1084 | 0.0 | 61.5 | NA | 54 | Except. |

Table 17. Continued.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| Mill Run (11-031) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.9 | 12.0 | 12 | 1230 | 0.0 | 61.5 | NA | 44 | Good |
| Glady Run (11-032) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 5.8 | 7.0 | 7 | 1766 | 3.1 | 51.5 | NA | 36$^{ns}$ | M.Good |
| *4.9* | *5.5* | *6* | *2865* | *16.8* | | *NA* | *31* | *Fair* |
| 4.0 | 7.5 | 9 | 779 | 1.2 | 66.5 | NA | 33$^{*}$ | Fair |
| 2.1 | 11.0 | 14 | 989 | 8.0 | 67.5 | NA | 37$^{ns}$ | M.Good |
| Sugar Creek (11-033) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 2.4 | 21.0 | 21 | 568 | 13.9 | 71.5 | NA | 46 | V.Good |
| 0.4 | 19.0 | 19 | 722 | 4.1 | 71.5 | 8.2$^{ns}$ | 44 | M.Good/Good |
| Little Sugar Creek (11-034) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.5 | 17.0 | 17 | 2098 | 0.0 | 56.5 | NA | 50 | Exceptional |
| Beaver Creek (11-035) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 6.1 | 12.0 | 12 | 614 | 0.0 | 35.0 | NA | 26$^{*}$ | Poor |
| 3.9 | 18.0 | 18 | 526 | 11.6 | 37.5 | NA | 38$^{ns}$ | M.Good |
| 1.6 | 16.0 | 16 | 580 | 14.9 | 57.0 | 6.6$^{*}$ | 28$^{*}$ | Fair |
| 0.5 | 14.5 | 16 | 417 | 23.7 | 76.0 | 7.4$^{*}$ | 32$^{*}$ | Fair |
| *0.4* | *11.5* | *15* | *729* | *22.5* | | *7.3* | *37* | *Fair/M.Good* |
| 0.3 | 18.0 | 23 | 657 | 41.3 | 70.5 | 7.1$^{*}$ | 30$^{*}$ | Fair |
| Little Beaver Creek (11-036) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| | 4.7 | 13.5 | 15 | 1367 | 11.2 | 58.5 | NA | 30$^{*}$ |
| Fair | | | | | | | | |
| *4.6* | *7.5* | *10* | *534* | *3.8* | | *NA* | *24* | *Poor* |
| 3.5 | 14.0 | 16 | 421 | 9.1 | 60.0 | NA | 29$^{*}$ | Fair |
| 0.1 | 17.0 | 20 | 460 | 20.5 | 62.0 | 6.3$^{*}$ | 31$^{*}$ | Fair |
| Ludlow Creek (11-037) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.2 | 8.0 | 8 | 558 | 4.5 | 42.5 | NA | 36$^{ns}$ | M.Good |
| Conner Branch (11-038) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.1 | 11.0 | 11 | 1103 | 0.0 | 76.5 | NA | 50 | Exceptional |

Table 17. Continued.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| Jacoby Branch (11-039) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.3 | 13.0 | 13 | 496 | 0.0 | 67.5 | NA | 48 | V.Good |
| Yellow Springs Creek (11-040) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.1 | 16.0 | 16 | 513 | 0.0 | 70.5 | NA | 52 | Exceptional |
| North Fork Little Miami River (11-041) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 7.1 | 16.0 | 16 | 343 | 0.0 | 54.0 | NA | 40 | Good |
| 2.6 | 15.0 | 15 | 340 | 0.0 | 43.0 | NA | 42 | Good |
| Lisbon Fork (11-043) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.4 | 14.0 | 14 | 2582 | 0.0 | 52.0 | NA | 40 | Good |
| Gilroy Ditch (11-044) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 1.5 | 12.5 | 13 | 1199 | 0.0 | 62.0 | NA | 32* | Fair |
| 1.3 | 13.5 | 16 | 1122 | 0.0 | 59.0 | NA | 40 | Good |
| 0.5 | 12.0 | 12 | 1880 | 0.0 | 49.0 | NA | 42 | Good |
| Shawnee Creek (11-045) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.7 | 16.0 | 16 | 1770 | 12.4 | 85.5 | NA | 48 | V.Good |
| Unnamed Trib @ RM 60.5 (11-053) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.2 | 12.0 | 12 | 848 | 0.0 | 71.0 | NA | 48 | V.Good |
| Unnamed Trib @ RM 62.0 (11-054) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.6 | 8.0 | 8 | 430 | 0.0 | 67.0 | NA | 34* | Fair |
| Todd Fork (11-200) Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| 20.3 | 19.5 | 24 | 293 | 4.5 | 76.0 | 7.8* | 48ns | M.Good/V.Good |
| 19.5 | 23.0 | 23 | 628 | 13.2 | 67.5 | 8.6* | 50 | Good/Except. |
| 15.2 | 27.0 | 27 | 558 | 42.1 | 79.0 | 9.7 | 48ns | Except./V.Good |
| 5.6 | 20.0 | 20 | 620 | 10.1 | 79.0 | 8.8* | 42* | Good |
| 2.6 | 19.0 | 19 | 194 | 4.2 | 78.0 | 7.3* | 38ns | Fair/M.Good |
| 0.3 | 22.0 | 22 | 464 | 17.4 | 67.5 | 9.0ns | 44* | V.Good/Good |

Table 17. Continued.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| Cowan Creek (11-209) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 13.3 | 18.0 | 18 | 146 | 0.0 | | 4.4* | 34* | V.Poor/Fair |
| 12.4 | 18.0 | 18 | 189 | 6.8 | | 7.2* | 34* | Fair |
| 10.9 | 27.0 | 27 | 753 | 8.0 | 73.5 | 8.9 | 44 | V.Good/Good |
| 8.5 | 27.0 | 27 | 771 | 13.4 | | 9.3 | 50 | V.Good/Except. |
| 1.2 | 17.0 | 17 | 398 | 6.0 | 63.0 | 7.8ns | 38ns | M.Good |
| Indian Run (11-211) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.2 | 9.0 | 9 | 664 | 0.0 | | NA | 28* | Fair |
| Cowan Creek (11-209) 1996 Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | 13.3 |
| 20.0 | NA | 445 | 6.9 | | 7.2* | 46 | Fair/V.Good | |
| 12.4 | 24.0 | NA | 1137 | 13.7 | | 5.9* | 40 | Fair/Good |
| 10.9 | 25.0 | NA | 381 | 9.0 | | 8.4 | 46 | Good/V.Good |
| 8.5 | 24.0 | NA | 1025 | 11.7 | | 9.1 | 42 | V.Good/Good |
| 7.0 | 19.0 | NA | 411 | 6.9 | | 8.6 | 36ns | Good/M.Good |
| Indian Creek (11-211) 1996 Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.4 | 10.0 | NA | 1256 | 1.3 | | NA | 30* | Fair |
| Lytle Creek (11-212) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 9.3 | 4.0 | 4 | 212 | 0.0 | | NA | 24* | Poor |
| 7.0 | 8.0 | 8 | 709 | 0.0 | | NA | 28* | Fair |
| *6.7* | *6.0* | *6* | *294* | *0.0* | | *NA* | *24* | *Poor* |
| 6.1 | 5.0 | 15 | 780 | 0.0 | | NA | 32* | Fair |
| 2.6 | 12.0 | 12 | 762 | 0.0 | | NA | 30* | Fair |
| Lytle Creek (11-212) 1996 Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 10.2 | 0.0 | NA | 0.0 | 0.0 | | NA | 12* | Very Poor |
| 9.6 | 4.0 | NA | 238.0 | 0.0 | | NA | 16* | Very Poor |
| 8.8 | 6.0 | NA | 648.0 | 0.0 | | NA | 26* | Poor |
| 8.1 | 9.0 | NA | 878.0 | 0.0 | | NA | 22* | Poor |
| 7.0 | 13.0 | NA | 1798.0 | 0.0 | | NA | 32* | Fair |
| 6.0 | 12.0 | NA | 220.0 | 0.0 | | NA | 28* | Fair |
| 2.9 | 14.0 | NA | 421.6 | 0.0 | | NA | 28* | Fair |
| 1.4 | 23.0 | NA | 1112.0 | 0.0 | | NA | 56 | Exceptional |
| 0.6 | 21.0 | NA | 800.6 | 0.0 | | NA | 46 | V.Good |

Table 17. Continued.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| E. Fork Todd Fork (11-217) Eastern Corn Belt Plain (WWH - Proposed) | | | | | | | | |
| 1.2 | 20.0 | 20 | 417 | 4.4 | 79.5 | 7.9$^{ns}$ | 44 | M.Good/Good |
| Caesar Creek (11-300) Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| 26.5 | 17.0 | 17 | 498 | 0.0 | 65.5 | NA | 42$^{*}$ | Good |
| 23.1 | 14.0 | 14 | 605 | 4.6 | 70.5 | 7.6$^{*}$ | 36$^{*}$ | Fair/M.Good |
| 16.6 | 30.0 | 30 | 1176 | 40.6 | 72.0 | 9.8 | 48$^{ns}$ | Except./V.Good |
| Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.2 | 23.0 | 23 | 373 | 15.2 | 95.0 | 8.5 | 48 | Good/V.Good |
| Flat Fork (11-301) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 1.7 | 8.0 | 8 | 274 | 0.0 | 44.0 | NA | 18$^{*}$ | Poor |
| Jonahs Run (11-302) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 1.3 | 7.0 | 7 | 210 | 0.0 | | NA | 28$^{*}$ | Fair |
| Trace Run (11-303) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 1.8 | 12.0 | 12 | 822 | 0.0 | 67.0 | NA | 44 | Good |
| Buck Run (11-305) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 1.6 | 17.0 | 17 | 636 | 0.0 | 73.5 | NA | 42 | Good |
| Anderson Fork (11-306) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 18.8 | 12.0 | 12 | 1292 | 4.6 | 46.5 | 6.7$^{*}$ | 26$^{*}$ | Fair/Poor |
| 13.9 | 24.0 | 24 | 1722 | 24.9 | 64.0 | 8.6 | 38$^{ns}$ | Good/M.Good |
| Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| 9.4 | 31.0 | 31 | 702 | 24.9 | 74.5 | 9.8 | 50 | Exceptional |
| 5.0 | 28.0 | 28 | 807 | 37.9 | 63.0 | 8.2$^{*}$ | 40$^{*}$ | M.Good/Good |
| Painters Creek (11-307) Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| 0.4 | 19.0 | 19 | 1266 | 0.0 | 64.5 | NA | 46$^{ns}$ | V.Good |

Table 17. Continued.

| Stream/ River Mile | Mean Species | Cumulative Species | Relative Number | Relative Weight | QHEI | Mean MIwb | Mean IBI | Narrative Evaluation |
|---|---|---|---|---|---|---|---|---|
| South Branch Caesar Creek (11-311) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 2.1 | 19.0 | 19 | 1202 | 7.5 | 67.0 | NA | 56 | Exceptional |
| North Branch Caesar Creek (11-312) Eastern Corn Belt Plain (EWH - Existing) | | | | | | | | |
| 6.1 | 20.0 | 20 | 1258 | 44.8 | 61.0 | NA | 36* | M.Good |
| 1.2 | 25.0 | 25 | 1022 | 50.4 | 56.0 | 9.5 | 48ns | Except./V.Good |
| Massie Creek (11-400) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 7.7 | 16.0 | 16 | 1025 | 31.3 | 88.0 | 9.1 | 42 | V.Good/Good |
| 5.6 | 20.0 | 20 | 561 | 58.9 | 82.5 | 8.4 | 42 | Good |
| 4.3 | 13.0 | 13 | 240 | 9.7 | 88.0 | 7.8ns | 38ns | M.Good |
| 1.2 | 20.0 | 20 | 399 | 22.3 | 80.5 | 7.8ns | 42 | M.Good/Good |
| Oldtown Creek (11-401) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.1 | 14.0 | 14 | 1902 | 0.0 | 61.5 | NA | 50 | Exceptional |
| Clark Run (11-402) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 0.5 | 12.0 | 12 | 656 | 0.0 | 74.0 | NA | 50 | Exceptional |
| North Fork Massie Creek (11-403) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 5.9 | 15.0 | 15 | 1774 | 0.0 | 33.5 | NA | 38ns | M.Good |
| 1.2 | 16.0 | 16 | 1928 | 17.0 | 63.5 | 8.6 | 34* | Good/Fair |
| South Fork Massie Creek (11-404) Eastern Corn Belt Plain (WWH - Existing) | | | | | | | | |
| 2.3 | 19.0 | 19 | 2914 | 0.0 | 44.5 | NA | 40 | Good |
| 0.3 | 15.0 | 15 | 701 | 0.0 | 56.0 | NA | 36ns | M.Good |

Table 17. Continued.

| | Ecoregion Biological Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Eastern Cornbelt | | | | Interior Plateau | | | |
| | IBI | | MIwb | | IBI | | MIwb | |
| Site Type | WWH | EWH | WWH | EWH | WWH | EWH | WWH | EWH |
| Headwaters | 40 | 50 | NA | NA | 40 | 50 | NA | NA |
| Wading | 40 | 50 | 8.3 | 9.4 | 40 | 50 | 8.1 | 9.4 |
| Boat | 42 | 48 | 8.5 | 9.6 | 38 | 48 | 8.7 | 9.6 |

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

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

ns - Non significant departure from applicable biological criteria ( 4IBI units or 0.5 MIwb units).

A - Sampler type A, boat methods used.

D - Sampler type D, wading methods used.

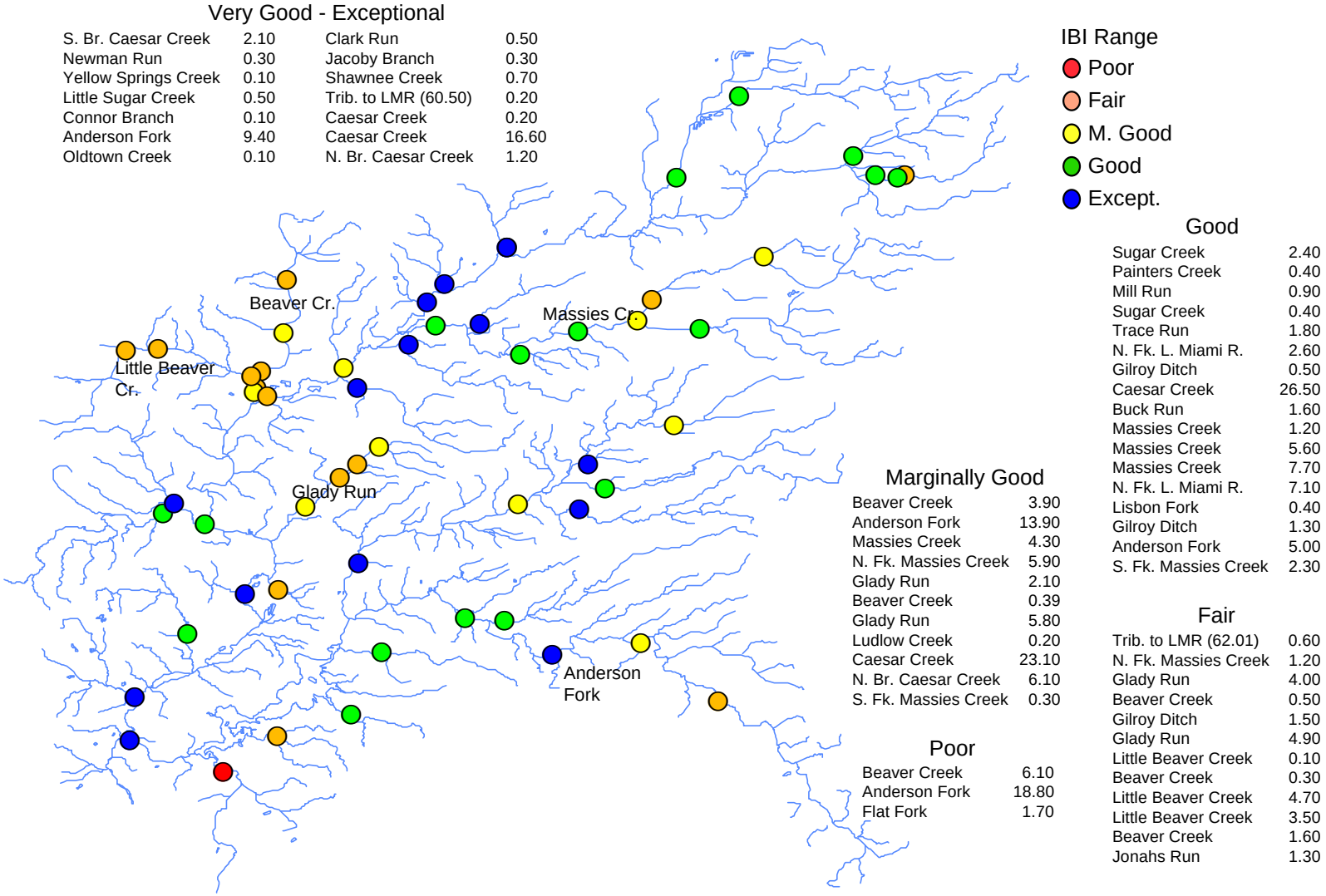



Figure 112. IBI scores by narrative range from electrofishing samples collected in tributaries to the upper Little Miami River, 1998.

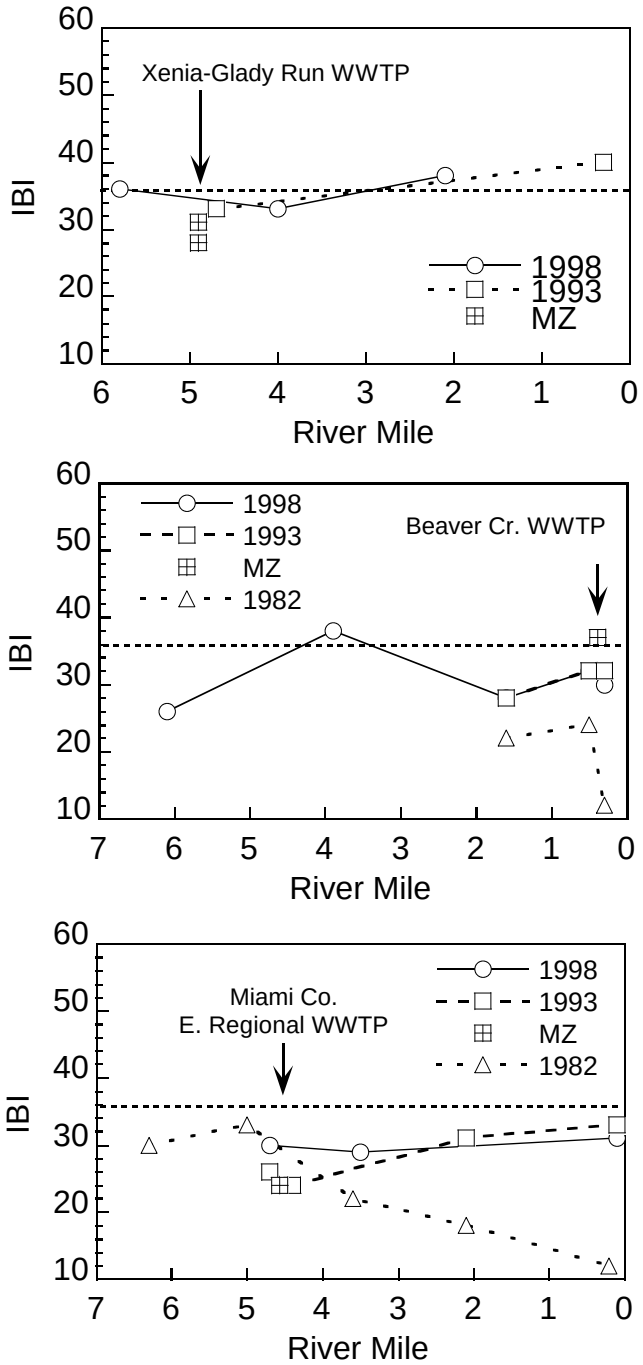



Figure 113. Plots of IBI scores from Glady Run (top panel), Beaver Creek (middle panel), and Little Beaver Creek (bottom panel) in relation to the WWTP dischargers located on each stream.

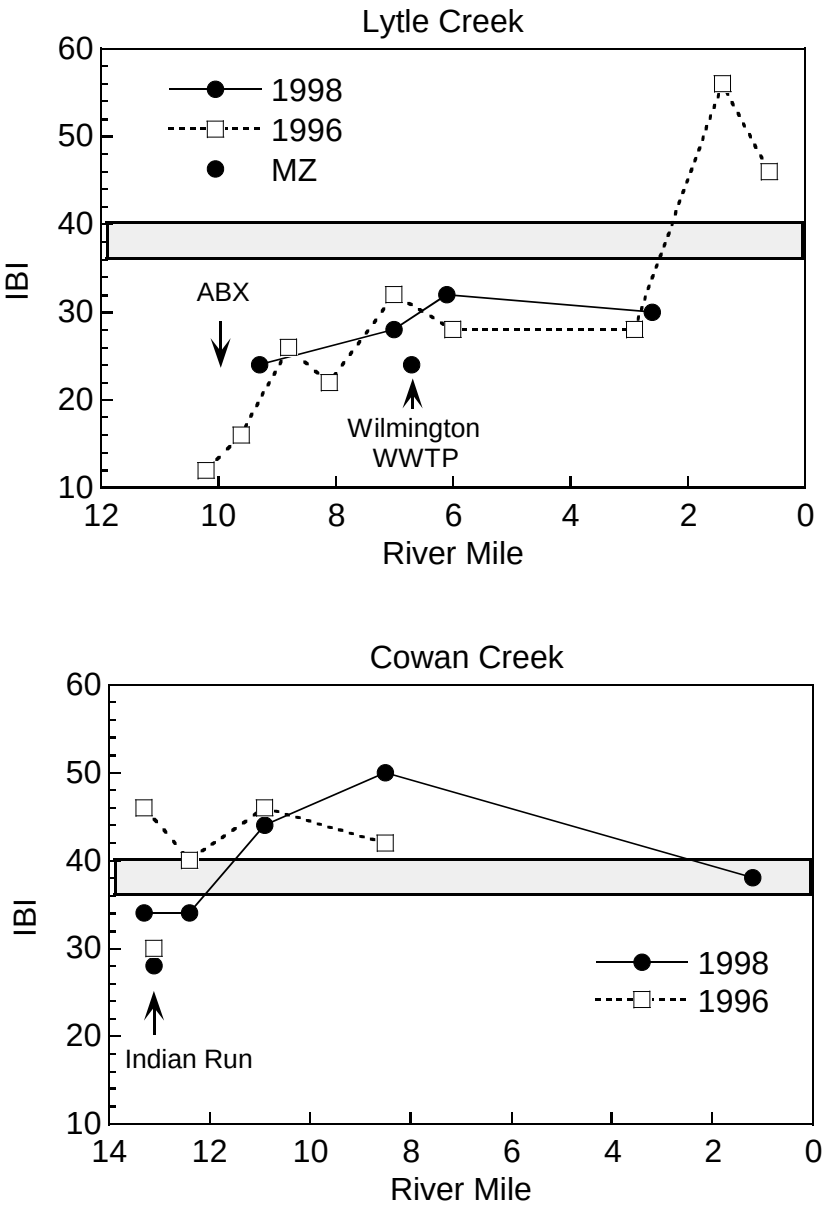



Figure 114. Plots of IBI scores from Lytle Creek (top panel) and Cowan Creek (bottom panel), 1996 and 1998 in relation to the ABX airport and the Wilmington WWTP.

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