Biological and Water Quality Study of Little Miami River and Tributaries 2012

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Biological and Water Quality Study of the Little Miami River and Tributaries 2012

Hamilton County, Ohio

Technical Report MBI/2013-6-8

MSD Project Number 10180900

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Prepared for:

Metropolitan Sewer District of Greater Cincinnati
1081 Woodrow Street
Cincinnati, OH 45204

Submitted by:

Midwest Biodiversity Institute
P.O. Box 21561
Columbus, Ohio 43221-0561
Chris O. Yoder, Research Director
cyoder@mwbinst.com

Table of Contents

APPENDICES (see enclosed DVD)

List of Tables

List of Figures

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Glossary of Terms

Ambient Monitoring	Sampling and evaluation of receiving waters not necessarily associated with episodic perturbations.
Antidegradation Policy	The part of state water quality standards that protects existing uses, prevents degradation of high quality waterbodies unless certain determinations are made, and which protects the quality of outstanding national resource waters.
Aquatic Assemblage	An association of interacting populations of organisms in a given waterbody, for example, the fish assemblage or the benthic macroinvertebrate assemblage.
Aquatic Community	An association of interacting assemblages in a given waterbody, the biotic component of an ecosystem.
Aquatic Life Use (ALU)	A beneficial use designation in which the waterbody provides suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms; classifications specified in State water quality standards relating to the level of protection afforded to the resident biological community by the custodial State agency.
Assemblage	Refers to all of the various species of a particular taxonomic grouping (e.g., fish, macroinvertebrates, algae, submergent aquatic plants, etc.) that exist in a particular habitat. Operationally this term is useful for defining biological assessment methods and their attendant assessment mechanisms, i.e., indices of biotic integrity (IBI), O/E models, or fuzzy set models.
Attainment Status	The state of condition of a waterbody as measured by chemical, physical, and biological indicators. Full attainment is the point at which measured indicators signify that a water quality standard has been met and it signifies that the designated use is both attained and protected. Non-attainment is when the designated use is not attained based on one or more of these indicators being below the required condition or state for that measure or parameter.

Attribute	A measurable part or process of a biological system.
Beneficial Uses	Desirable uses that acceptable water quality should support. Examples are drinking water supply, primary contact recreation (such as swimming), and aquatic life support.
Benthic Macroinvertebrates	Animals without backbones, living in or on the substrates, of a size large enough to be seen by the unaided eye, and which can be retained by a U.S. Standard No. 30 sieve (0.595 mm openings). Also referred to as benthos, infauna, or macrobenthos.
Best Management Practice	An engineered structure or management activity, or combination of these that eliminates or reduces an adverse environmental effect of a pollutant, pollution, or stressor effect.
Biological Assessment	An evaluation of the biological condition of a waterbody using surveys of the structure and function of a community of resident biota; also known as bioassessment. It also includes the interdisciplinary process of determining condition and relating that condition to chemical, physical, and biological factors that are measured along with the biological sampling.
Biological Criteria (Biocriteria)	Scientific meaning: quantified values representing the biological condition of a waterbody as measured by structure and function of the aquatic communities typically at reference condition; also known as biocriteria. Regulatory meaning: narrative descriptions or numerical values of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use, implemented in, or through state water quality standards.
Biological Condition Gradient	A scientific model that describes the biological responses within an aquatic ecosystem to the increasing effects of stressors.
Biological Diversity	Refers to the variety and variability among living organisms and the ecological complexes in which they

	occur. Diversity can be defined as the number of different taxa and their relative frequencies. For biological diversity, these taxa are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes; also known as biodiversity.
Biological Indicator	An organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions; also known as a bioindicator.
Biological Integrity	The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region (after Karr and Dudley 1981).
Biological Monitoring	The use of a biological entity (taxon, species, assemblage) as a detector and its response as a measure of response to determine environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods; also known as biomonitoring.
Biological Survey	The collection, processing, and analysis of a representative portion of the resident aquatic community to determine its structural and/or functional characteristics and hence its condition using standardized methods.
Bioregion	Any geographical region characterized by a distinctive flora and/or fauna.
Clean Water Act (CWA)	An act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 et seq.; referred to herein as the CWA.
CWA Section 303(d)	This section of the Act requires States, territories, and authorized Tribes to develop lists of impaired waters

	for which applicable water quality standards are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. States, territories, and authorized Tribes are to submit their list of waters on April 1 in every even-numbered year.
CWA Section 305(b)	Biennial reporting required by the Act to describe the quality of the Nation's surface waters, to serve as an evaluation of progress made in maintaining and restoring water quality, and describe the extent of remaining problems.
Criteria	Limits on a particular pollutant or condition of a waterbody presumed to support or protect the designated use or uses of a waterbody. Criteria may be narrative or numeric and are commonly expressed as a chemical concentration, a physical parameter, or a biological assemblage endpoint.
DELT Anomalies	The percentage of Deformities, Erosions (e.g., fins, barbels), Lesions and Tumors on fish assemblages (DELT). An important fish assemblage attribute that is a commonly employed metric in fish IBIs.
Designated Uses	Those uses specified in state water quality standards for each waterbody or segment whether or not they are being attained.
Disturbance	Any activity of natural or human causes that alters the natural state of the environment and its attributes and which can occur at or across many spatial and temporal scales.
Ecological integrity	The summation of chemical, physical, and biological integrity capable of supporting and maintaining a balanced, integrated adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in the region.

Ecoregion	A relatively homogeneous geographical area defined by a similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables; ecoregions are portioned at increasing levels of spatial detail from level I to level IV.
Existing Use	A use that was actually attained in a waterbody on or after November 28, 1975, whether or not they are included in the state water quality standards (November 28, 1975 is the date on which U.S. EPA promulgated its first water quality standards regulation in 40CFR Part 131). Existing uses must be maintained and cannot be removed.
Functional Organization	The summation of processes required for normal performance of a biological system (may be applied to any level of biological organization).
Headwater Habitat Evaluation Index	A modification of the QHEI that is applied at Primary Headwater Habitat stream sites.
Index of Biotic Integrity (IBI)	An integrative expression of site condition across multiple metrics comprised of attributes of a biological assemblage. It refers to the index developed by Karr (1981) and explained by Karr et al. (1986). It has been used to express the condition of fish, macroinvertebrate, algal, and terrestrial assemblages throughout the U.S. and in each of five major continents.
Metric	A calculated term or enumeration representing an attribute of a biological assemblage, usually a structural aspect, that changes in a predictable manner with an increased effect of human disturbance.
Monitoring and Assessment	The entire process of collecting data from the aquatic environment using standardized methods and protocols, managing that data, analyzing that data to make assessments in support of multiple program objectives, and disseminating the assessments to stakeholders and the public.
Multimetric Index	An index that combines assemblage attributes, or metrics, into a single index value. Each metric is tested

	and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition.
Narrative Biocriteria	Written statements describing the narrative attributes of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use.
Natural Condition	This includes the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence.
Numeric Biocriteria	Specific quantitative and numeric measures of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use.
Primary Headwater Habitat	A range in size of headwater streams generally less than 1.0 square mile in drainage area, but may be as large as 3.0 square miles. These are streams that are naturally and due to stream size alone incapable of supporting a fish assemblage consistent with the Warmwater Habitat (WWH) biological criteria. In such cases a different set of biological assemblages (lungless salamanders and invertebrates) and habitat assessment technique (Headwater Habitat Evaluation Index) are applied.
Qualitative Habitat Evaluation Index	A qualitative habitat evaluation assessment tool that is applied to streams and rivers in Ohio and which is used to identify habitat variables that are important to attainment of the Ohio biological criteria.
Reference Condition	The condition that approximates natural, unimpacted to best attainable conditions (biological, chemical, physical, etc.) for a waterbody. Reference condition is best determined by collecting measurements at a number of sites in a similar waterbody class or region under minimally or least disturbed conditions (by human activity), if they exist. Since undisturbed or minimally disturbed conditions may be difficult or

	impossible to find in some states, least disturbed conditions, combined with historical information, models or other methods may be used to approximate reference condition as long as the departure from natural or ideal is comprehended. Reference condition is used as a benchmark to establish numeric biocriteria.
Reference Site	A site selected to represent an approximation of reference condition and by comparison to other sites being assessed. For the purpose of assessing the ecological condition of other sites, a reference site is a specific locality on a waterbody that is minimally or least disturbed and is representative of the expected ecological condition of other localities on the same waterbody or nearby waterbodies.
Regional Reference Condition	A description of the chemical, physical, or biological condition based on an aggregation of data from reference sites that are representative of a waterbody type in an ecoregion, subregion, bioregion, or major drainage unit.
Stressors	Physical, chemical, and biological factors that can adversely affect aquatic organisms. The effect of stressors is apparent in the biological responses.
Use Attainability Analysis (UAA)	A structured scientific assessment of the physical, chemical, biological or economic factors affecting attainment of the uses of waterbodies.
Use Classes	A broad capture of a designated use for general purposes such as recreation, water supply, and aquatic life.
Use Subclasses	A subcategorization of use classes into discrete and meaningful descriptions. For aquatic life this would include a hierarchy of warmwater and cold water uses and additional stratification provided by different levels of warmwater uses and further stratification by waterbody types.
TALU Based Approach	This approach includes tiered aquatic life uses (TALU) based on numeric biological criteria and

	implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification.
Tiered Aquatic Life Uses (TALUs)	As defined: The structure of designated aquatic life uses that incorporates a hierarchy of use subclasses and stratification by natural divisions that pertain to geographical and waterbody class strata. TALUs are based on representative ecological attributes and these should be reflected in the narrative description of each TALU tier and be embodied in the measurements that extend to expressions of that narrative through numeric biocriteria and by extension to chemical and physical indictors and criteria. As used: TALUs are assigned to water bodies based on the protection and restoration of ecological potential. This means that the assignment of a TALU tier to a specific waterbody is done with regard to reasonable restoration or protection expectations and attainability. Hence knowledge of the current condition of a waterbody and an accompanying and adequate assessment of stressors affecting that waterbody are needed to make these assignments.
Total Maximum Daily Load (TMDL)	The maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. Alternatively, a TMDL is an allocation of a water pollutant deemed acceptable to attain the designated use assigned to the receiving water.
Water Quality Standards (WQS)	A law or regulation that consists of the designated use or uses of a waterbody, the narrative or numerical water quality criteria (including biocriteria) that are necessary to protect the use or uses of that particular waterbody, and an antidegradation policy.
Water Quality Management	A collection of management programs relevant to a water resource protection that includes problem identification, the need for and placement of best management practices, pollution abatement actions, and measuring the effectiveness of management actions.

List of Acronyms

AAV	Area of Attainment Value
ADV	Area of Degradation Value
ALU	Aquatic Life Use
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DC	Direct Current
DELT	Deformities, Erosions, Lesions, Tumors
DNR	Department of Natural Resources
D.O.	Dissolved Oxygen
DQO	Data Quality Objective
ECBP	Eastern Corn Belt Plains
EPT	Ephemeroptera, Plecoptera, Trichoptera
EWH	Exceptional Warmwater Habitat
GIS	Geographic Information System
GPS	Global Positioning System
HHEI	Headwater Habitat Evaluation Index
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity

ICI	Invertebrate Community Index
IP	Interior Plateau
IPS	Integrated Prioritization System
LRAU	Large River Assessment Unit
LRW	Limited Resource Waters
MBI	Midwest Biodiversity Institute
MGD	Million Gallons per Day
MIwb	Modified Index of Well-Being
MPN	Most Probable Number
MSDGC	Metropolitan Sewer District of Greater Cincinnati
NPDES	National Pollution Discharge Elimination System
OAC	Ohio Administrative Code
OSUMB	Ohio State University Museum of Biodiversity
PAH	Polycyclic Aromatic Hydrocarbons
PCR-A	Primary Contact Recreation – Class A
PCR-B	Primary Contact Recreation – Class B
PCR-C	Primary Contact Recreation – Class C
PCR	Primary Contact Recreation
PEC	Probable Effects Concentration
PHWH	Primary Headwater Habitat
PSP	Project Study Plan
QHEI	Qualitative Habitat Evaluation Index

RM	River Mile
SCR	Secondary Contact Recreation
SRV	Sediment Reference Value
SSO	Sanitary Sewer Overflow
TALU	Tiered Aquatic Life Use
TDS	Total Dissolved Solids
TEC	Threshold Effects Concentration
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
UTM	Universal Transverse Mercator Coordinate
VOC	Volatile Organic Compound
WAU	Waterbody Assessment Unit
WQS	Water Quality Standards
WWH	Warmwater Habitat
WWTP	Wastewater Treatment Plant

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 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. The latter is the case with this study in that Little Miami River represents a collection of tributary watersheds and two mainstem river assessment units that have a complex mix of overlapping stressors and sources in a setting that ranges from developed urban to suburban to rural. This assessment is a follow-up to a similar series of Little Miami River and tributary surveys performed by Ohio EPA in 1983, 1989, 1998, and 2007. 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, can also be assessed.

Scope of the Little Miami River and Tributaries Biological and Water Quality Assessment

The Little Miami River and Tributaries Biological and Water Quality Assessment gathered relevant information to determine and wherever possible explain current conditions. Understanding and improving water quality is an important component of Project Groundwork, the largest capital improvement program to reduce CSOs within the MSDGC service area. The Duck Creek watershed contains the most extensive concentration of CSOs in the study area while most other tributaries and the mainstem are impacted by urban development and sanitary wastewater flows.

This assessment was designed to address three major objectives:

1. Determine the extent to which biological assemblages, habitat, and water quality are impaired (using Ohio EPA methods and criteria);
2. Determine the categorical stressors and sources that are associated with those impairments wherever possible; and,
3. Contribute to the existing databases for the Little Miami River and Tributaries to track and better understand changes through time that occur as the result of abatement actions or other factors.

The data presented herein were processed, evaluated, and synthesized as a biological and water quality assessment of aquatic life and recreational use status. This assessment is directly comparable to those accomplished previously by Ohio EPA, such that long term trends in status can be examined, and causes and sources of impairment can be confirmed, appended, or removed. This report includes a summary of major findings and recommendations for future monitoring, follow-up investigations, and any immediate actions that may be needed to resolve readily diagnosed impairments. The baseline data established by this study contributes to a process termed the Integrated Priority System (IPS) that is being developed to help determine and prioritize remedial projects for the MSDGC service area.

EXECUTIVE SUMMARY

Scope and Purpose

In 2010 MSDGC and MBI began developing a plan that would lead to ways to identify and potentially align Project Groundwork to assist in improving water quality in the MSDGC service area. The initial step was a four- year rotational watershed assessment plan that would produce applicable biological and water quality monitoring data that would assist MSDGC in its capital planning. The 2012 bioassessment of the Little Miami River and tributaries is the second of four years of sampling and analysis that is being conducted following the design of a comprehensive plan for the MSDGC service area (MBI 2011). The emphasis of each annual bioassessment is to determine the status of aquatic life and recreational uses as they are defined in the Ohio Water Quality Standards (WQS) and as assessed by Ohio EPA. The sampling and analysis is performed by Level 3 Qualified Data Collectors and under a Project Study Plan approved by Ohio EPA under the specifications of the Ohio Credible Data Law.

An intensive pollution survey design that employs a high density of sampling sites and biological, chemical, and physical parameters was followed. The principal objectives of the assessment were to verify existing aquatic life and recreational use designations, assign such uses to unlisted streams and stream segments, make recommendations for any changes to existing use designations, report attainment status following Ohio EPA practices, and determine associated causes and sources of impairment wherever possible. The determination of causes and sources of impairments to aquatic life and recreational uses also followed practices similar to those employed by Ohio EPA. As such, these determinations are typically categorical as opposed to the identification of specific pollutants. However, the results of this study will be incorporated in a regional assessment of stressors and their root causes and sources throughout the MSDGC service area and adjoining ecoregions and subregions. This will include more detailed analyses of regional patterns in limiting stressors and it will include the data generated by the annual bioassessments, historically available biological, chemical, and physical data, and ancillary data available in GIS coverages. Termed the Integrated Prioritization System (IPS) it will assist MSDGC and others in better evaluating and designing restoration projects.

The 2012 study area included the Little Miami River mainstem from U.S. Rt. 22 (RM 27.9) to downstream from Kellogg Ave. immediately upstream from the mouth of the Ohio River. The East Fork of the Little Miami River was included from immediately downstream from the Harsha Reservoir outlet (RM 19.5) to the confluence with the Little Miami River (RM 11.5). While the East Fork is technically outside of the MSDGC service area, it was included in the survey because of its potentially significant influence on the Little Miami River mainstem and on the interpretation of the 2012 results. Similarly, tributaries such as O'Bannon Creek were included as well. All service area tributaries and their watersheds were included in the 2012 survey with sampling sites located in the upper reaches at drainage areas of <1.0 mi^2. All potential pollution sources were bracketed with sampling sites and also to reveal the extent and severity of impairments in proximity to individual and aggregated sources of impact on water quality, habitat, and biological condition.

Summary of Findings

Aquatic Life Use Attainability Analysis

A major objective of the MSDGC bioassessments is to determine if existing aquatic life uses presently assigned to streams and rivers in the MSDGC service area are appropriate and attainable. In terms of the recommended use changes highlighted in Table 1 only 3 deal with changing current designated uses for the major mainstem rivers and tributaries. Most of the recommendations include previously undesignated streams as Warmwater Habitat (WWH) or previously undesignated streams as Primary Headwater Habitat (PHWH). A detailed listing of use changes appears in the recommendations section (Table 3).

Table 1. Summary of recommended aquatic life use changes based on use attainability analyses conducted for the 2012 Little Miami River biological and water quality assessment.

Current Aquatic Life Use	Recommended Aquatic Life Use/Classification	Number of Segments Affected
None	WWH	11
None	LRW	1
None	PHWH 3A	8
None	PHWH 2	7
WWH	PHWH 3A	1
LRW	WWH	1
LRW	PHWH 1	1

WWH – Warmwater Habitat; LRW – Limited Resource Waters; PHWH – Primary Headwater Habitat

The dry weather conditions experienced in 2012 were taken into account in reviewing and recommending revised use designations, especially for the smaller streams.

General Conditions in the Little Miami River and Tributaries

The primary indicator of overall condition in terms of aquatic life is the status of recommended and existing aquatic life use designations based on attainment of the Ohio biological criteria (OAC 3745-1-07, Table 14). The status of these uses is portrayed as full, partial, or non-attainment as explained in the methods section. A map of the attainment and classification status of the 108 sites sampled in 2012 is depicted in Figure 1 and summarized in the conclusions section (Table 4). Of the 111 sites assessed in 2012, 93 were evaluated under the Warmwater suite of uses (2 additional sites were dry) and the remaining 16 under the Primary Headwater assessment methodology. In all, only 19 of 93 sites fully attained their applicable aquatic life use. A total of 43 sites were in partial attainment and 31 were in non-attainment. Of the 16 Primary Headwater sites, 7 were PHWH Class 2 and 9 were PHWH Class 3A.

Causes and Sources of Non-attainment

The determination of causes and sources of aquatic life use impairment was accomplished by associating exceedances of various chemical and physical thresholds that are known to adversely affect aquatic organisms. These assignments are in most cases categorical (e.g., habitat alterations, nutrient enrichment) and may include multiple types of effects and mechanisms. Some can be parameter specific (e.g., dissolved oxygen) since the data are collected at that level. Yet others are at the category of parameter level (e.g., heavy metals, PAHs) which may include multiple parameters that are analyzed. In addition, some parameters can be proxies for a wider range of more specific causes. Sources are also necessarily categorical and can vary in their inclusion of or connection to specific activities. The causes and sources that we listed along with the biological impairments appear in the Determination of Aquatic Life Use Attainment Status section. Eleven (11) different causal categories and 10 different source categories were identified for the 2012 study area (Table 2). Of these causes, flow alteration, chlorides, and organic enrichment were the most frequently listed with urban runoff the most frequently listed source. Classic pollutants such as ammonia, oxygen demanding substances, and toxic substances were listed only infrequently and then in localized reaches.

Table 2. Summary of causes and sources associated with biological impairments in the 2012 Little Miami River study area.

Cause	Number	Source	Number
Flow modification	40	Urban Runoff	59
Chlorides	33	Combined Sewers	14
Organic enrichment	31	Unknown	13
D.O.	17	WWTP	10
Nutrients	12	Natural	9
Metals	12	Habitat Modification	4
Habitat	8	Dam Release	3
Siltation	4	Agricultural NPS	2
Ammonia	2	Impoundment	1
Loss of Connectance	2	Unsewered	1
Unknown	2		

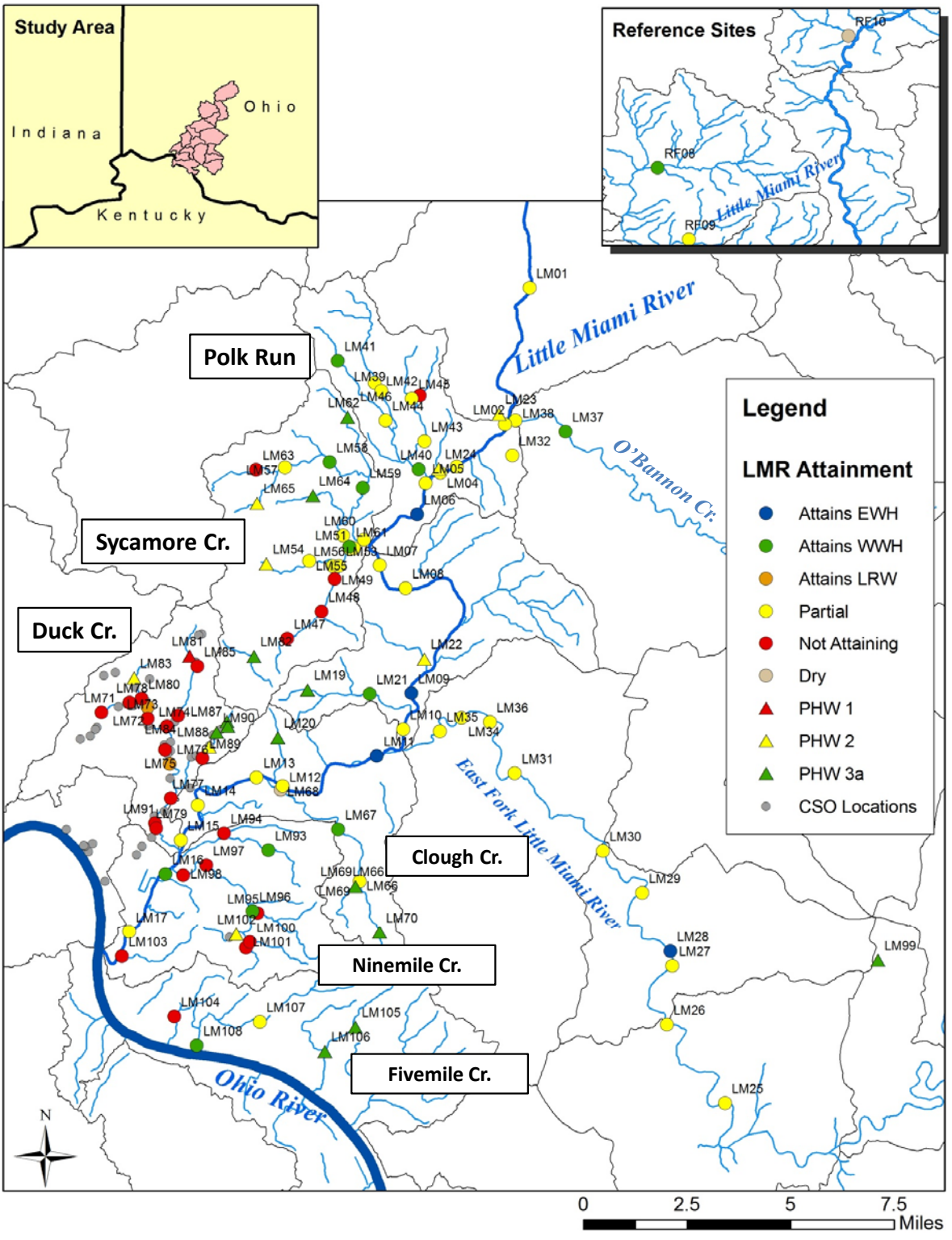

Figure 1. Aquatic life use attainment status for the Warmwater Habitat suite of aquatic life use tiers in the Little Miami River study area during 2012. Site codes correspond to those described in Table 5 of the study area description. Sites recommended for evaluation as Primary Headwater Habitat (PHWH) appear as triangles with their classification results. CSO locations appear as light grey circles.

Trajectories in Key Indicators

The 2012 assessment of the Little Miami River and tributaries provides an opportunity to gauge the effectiveness of past and ongoing attempts to improve and maintain water quality and biological conditions by comparing the 2012 results to similarly conducted prior assessments. A series of four biological and water quality surveys by Ohio EPA dating to 1983 and as recently as 2007 provide the most consistent comparison in terms of spatial coverage, methods, and indicators and parameters. The focus herein is on comparative assessments of the Little Miami River and East Fork mainstems.

Developing an understanding of the temporal trajectory of the key indicators and parameters that comprise an adequate monitoring approach to the assessment of a watershed or water body is crucial in providing feedback to the variety of stakeholders that are involved with the Little Miami River. Given that the Little Miami River is impacted by a variety of watershed level and site-specific impacts the complexity of being able to understand and then develop management responses to observed problems is a complex challenge. While the arbiter of success has almost exclusively focused on the full restoration of listed impairments, in the case of the Little Miami River mainstem the focus is also on maintaining an already existing high quality consistent with the prevailing use designation of Exceptional Warmwater Habitat (EWH). The ability to show incremental change is critical for providing important feedback about the effectiveness of water quality management efforts which must be adaptive in order to succeed. As such, the type of monitoring and assessment that was employed in this survey was designed to provide results that could be used to demonstrate the degree and direction of incremental change.

The results of the bioassessment using the primary indices that comprise the Ohio biocriteria were used to quantify the degree to which overall aquatic life conditions have changed through time up to and including the 2012 survey. The Area of Degradation (ADV) and Attainment (AAV) methodology (Yoder and Rankin 1995b; Yoder et al. 2005) was used to illustrate the degree of change between the Ohio EPA surveys of 1983, 1993, 1998, and 2007 and the 2012 MSDGC survey in the mainstems of the Little Miami and East Fork Little Miami Rivers. The ADV/AAV term is a quantitative expression of the degree to which the biological index values are either above or below the applicable biocriterion and the lineal distance of river over which it occurs. As such it is a numerical expression of the "quantity" of biological attainment or impairment. When normalized to a standard distance (e.g., per mile) it can be an effective indicator of the degree of incremental change that is taking place over time.

Little Miami River Mainstem

The change in ADV/AAV results for the Index of Biotic Integrity (IBI), the Modified Index of Well-Being (MIwb), and the Invertebrate Community Index (ICI) between the series of Ohio EPA surveys in 1983, 1993, 1998, and 2007 and the 2012 MSDGC survey indicates an overall decline in biological condition compared to 2007 (Figure 2). The IBI in particular exhibited a decline in the AAV and an increase in the ADV when compared to the 2007 values. A general decline in the MIwb and ICI was evident in lower AAV values as opposed to any substantial increases in ADV values compared to 2007. In fact, the 2012 results for the IBI, MIwb, and ICI were similar

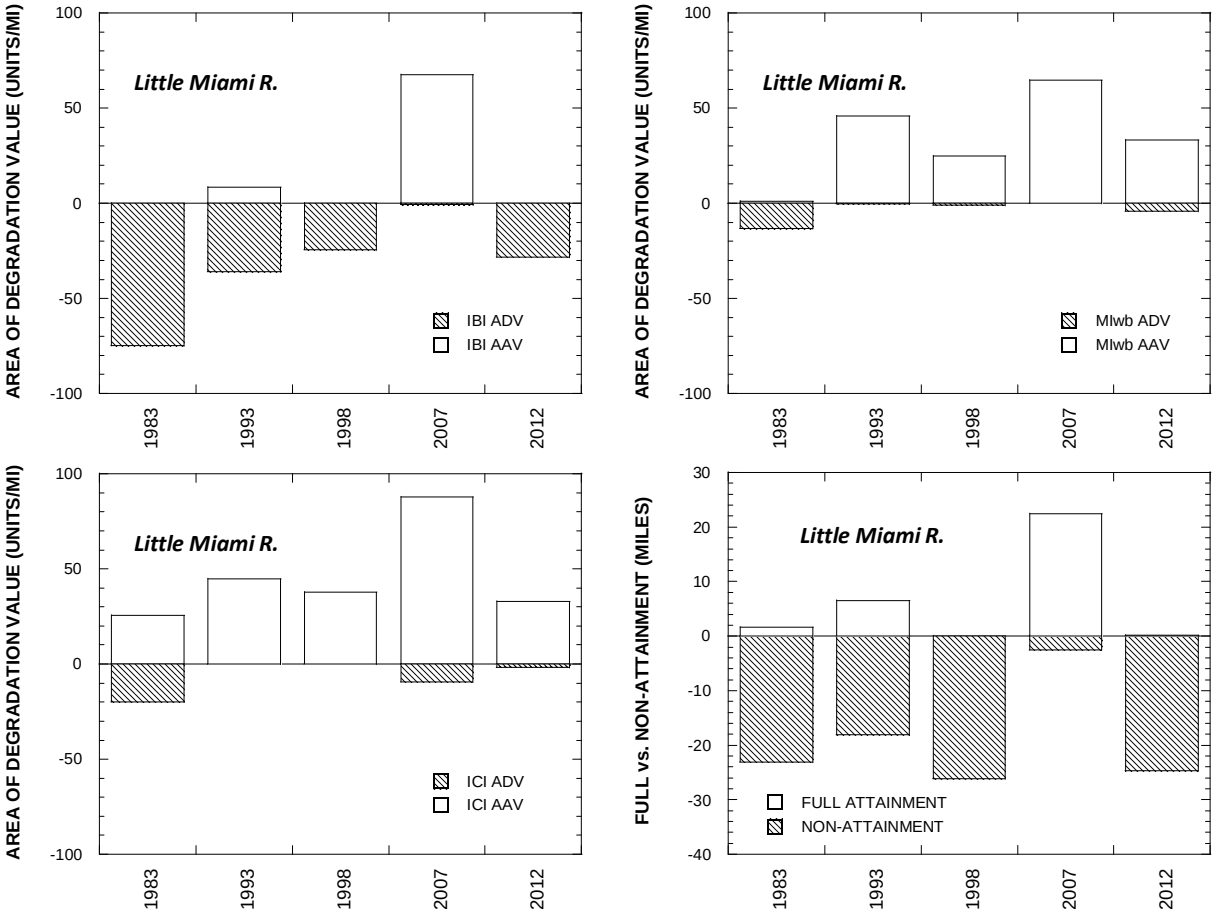

Figure 2. Area of Degradation (ADV) and Area of Attainment (AAV) values for the IBI (upper left), MIwb (upper right), and ICI (lower right) in the lower Little Miami River mainstem between 1983 and 2012. The miles of full and non-attainment of the Exceptional Warmwater Habitat (EWH) use designation for all sample years for the lower Little Miami River mainstem are depicted in the lower right panel. ADV is expressed as a negative value, AAV as a positive value with increases in ADV signaling degradation, increases in AAV signaling improvement.

to the 1998 results. Attainment status also showed a marked decline in 2012 due primarily to IBI scores failing to meet the EWH biocriteria resulting in partial attainment for much of the mainstem in 2012.

East Fork Little Miami River

The East Fork Little Miami River was sampled between the Harsha Reservoir outlet and the mouth in 2012. The change in ADV/AAV results for the IBI, MIwb, and the ICI between the series of prior Ohio EPA surveys in 1982, 1993, and 1998 and the 2012 MSDGC survey indicates a consistent and overall decline in biological condition since 1982 (Figure 3). The IBI in particular showed a consistent decline in each successive year with the near complete loss of AAV in 1998 and 2007 and an increase in the ADV through 2012 more than doubling the largest prior value in 1993. The MIwb and ICI changes were more in the reduction of AAV units with

the ADV being perceptible only for the MIwb in 2012. In terms of miles of full and non-attainment, zero miles were in full attainment in 2012 continuing a decline that was first noted by Ohio EPA between 1993 and 1998.

Recreational Use Status

Impairment of recreation uses in the lower Little Miami River study area was not uncommon. The Primary Contact (PC) 30-day geometric mean criterion was exceeded at 38 of 92 sites sampled. It was also exceeded at 1 of the reference sites (RF09, Dry Run). The single sample maximum criterion was exceeded at 32 of 92 sites and two of the three reference sites. High minimum values were highlighted as an indicator of chronic bacterial impairment and at some sites minimum values greater than the geometric mean PC criterion underscored the higher frequency of exceedances observed throughout the study area. Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the lower Little Miami River it is likely related to combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), urban runoff, and unsewered areas.

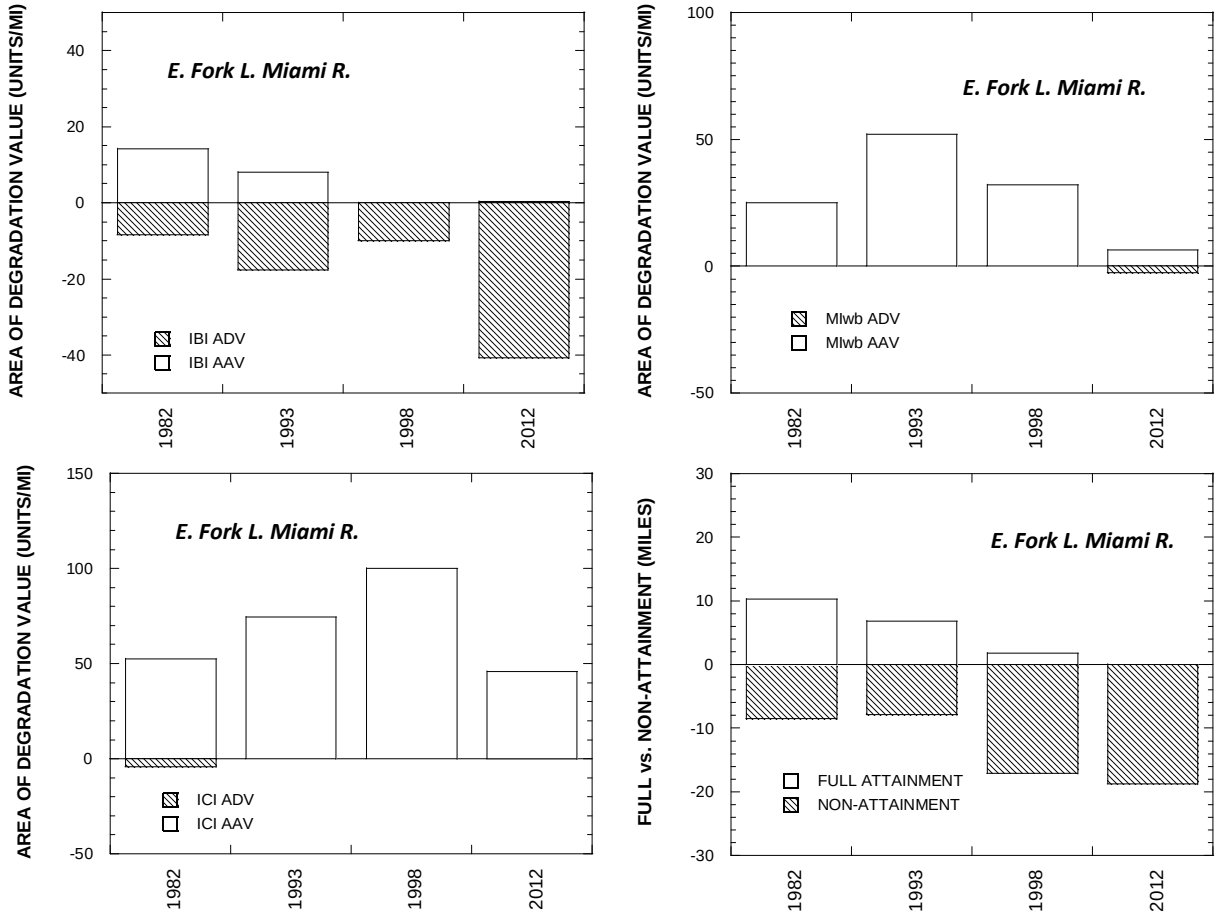

Figure 3. Area of Degradation (ADV) and Area of Attainment (AAV) values for the IBI (upper left), MIwb (upper right), and ICI (lower right) in the East Fork Little Miami River mainstem between 1982 and 2012. The miles of full and non-attainment of the Exceptional Warmwater Habitat (EWH) use designation for all sample years for the East Fork Little Miami River mainstem are depicted in the lower right panel. ADV is expressed as a negative value, AAV as a positive value with increases in ADV signaling degradation, increases in AAV signaling improvement.

CONCLUSIONS and RECOMMENDATIONS

Little Miami River Study Area Designated Use Attainment Status

A principal objective of the MSDGC service area watershed bioassessment plan is to evaluate existing aquatic life and recreational use designations and to recommend new uses for undesignated or unverified streams and recommend changes to current uses when appropriate. Ohio EPA last reviewed the aquatic life and recreational designations in parts of the 2012 Little Miami River study area in 2007 when they completed their most recent biological and water quality survey (Ohio EPA 2009). Although not formally codified in the Ohio WQS, the Primary Headwater Habitat (PHWH) classification scheme and the subclasses for such headwater streams based on flow, habitat, and biological assemblages (macroinvertebrates and salamanders) that are unique to these streams was used as an assessment endpoint. The PHWH potential was considered alongside the recommendations for unnamed streams and revisions to current aquatic life uses within the codified suite of Warmwater Habitat uses. Aquatic life use attainment status was then determined by comparing the biological index values derived from the fish and macroinvertebrate assemblages to the biological criteria in the Ohio WQS (OAC 3745-1) for the recommended uses. The results of this process for each site in the 2012 Little Miami River study area are presented herein. In addition, the causes and sources that were associated with biological impairments were also identified.

The status of current recreational uses was likewise assessed by determining the attainability of the applicable recreational use tier and then basing the status assessment on the verified or recommended recreational use. Ohio EPA recognizes two major categories of recreational uses, Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR). The PCR use has three subcategories (A, B, and C) based on the plausibility of different levels of human body contact recreation in and on the water.

Aquatic Life Use Recommendations

Existing aquatic life uses in the Ohio WQS consist of either verified uses based on the results of a biosurvey or unverified or “default” uses based on designations first made in the 1978 and 1985 Ohio WQS. Unverified designations were based largely on best professional judgment as the present-day biological assessment methods and numerical biocriteria simply did not exist at that time. Many of the smaller streams did not have a use listed in the Ohio WQS, but in lieu of that they are generally considered to have a default WWH use. Discussion of the assignment of designated uses is organized by the Hydrologic Unit Code (HUC)-12 watershed scale (Watershed Assessment Units = WAUs) or Large River Assessment Unit (LRAU) used by Ohio EPA.

Little Miami River Mainstem and Direct Tributaries

The Little Miami River mainstem has a verified EWH aquatic life use designation based on prior Ohio EPA assessments (Ohio EPA 2009). Since it was first designated by Ohio EPA as EWH in 1983 it is an existing use and as such there is no need to validate it with the 2012 results.

Table 3. Assessment of existing aquatic life use (ALU) designations in the 2012 Little Miami River watersheds study area. The respective biological assemblage and habitat assessment results are summarized along with the existing ALU. The recommended ALU is also listed and represents a change if different from the existing ALU.

Stream	No. of Sites	Size (mi^2)	Habitat Evaluation	Fish Evaluation	Macro. Evaluation	Existing ALU	Recom-mended ALU
LRAU 90-02 – Little Miami River							
Little Miami River [11-001]	17	1760.00	Fair-Excellent	Fair-Very Good	Good-Excellent	EWH[a]	EWH[a]
Unnamed Trib to Little Miami River at RM 0.83 [11-047]	1	1.70	Good	Excellent	Poor	None	WWH
Unnamed Trib to Little Miami River at RM 13.1 [11-066]	1	3.00	Good	Good	Good	None	WWH
Unnamed Trib to Little Miami River at RM 7.75 [11-067]	1	0.50	Good	NA	NA	None	PHW3A
Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami R. [11-068]	1	0.60	Excellent	NA	NA	None	PHW3A
Unnamed Trib to Little Miami River at 24.06 [11-082]	1	1.60	Fair	NA	NA	None	PHW2
Unnamed Trib to Little Miami River at RM 21.82 [11-083]	1	0.80	Fair	NA	NA	None	PHW2
Unnamed Trib to Little Miami River at 13.8 [11-085]	1	1.20	Good	NA	NA	None	PHW2
WAU 09-02 – O'Bannon Creek							
O'Bannon Creek [11-010]	2	59.00	Good	Fair-Excellent	Good	WWH	WWH
WAU 14-02 – Polk Run							
Polk Run [11-009]	3	10.00	Good-Excellent	Fair-Excellent	Marg. Good-Good	WWH	WWH
Unnamed Trib to Polk Run at RM 1.79 [11-069]	2	2.40	Good-Excellent	Fair-Good	Marg. Good-Good	None	WWH
Unnamed Trib to Polk Run at RM 0.70 [11-070]	2	2.50	Excellent	Fair	Fair-Marg. Good	None	WWH
Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run [11-071]	1	1.10	Good	Fair	Good	None	WWH
WAU 14-01 – Sycamore Creek							
Sycamore Creek [11-007]	6	23.30	Fair-Good	Poor-Excellent	Fair-Good	WWH	WWH
North Branch Sycamore Creek [11-008]	5	9.90	Good-Excellent	Fair-Excellent	Good	WWH	WWH
Trib To Sycamore Cr. (RM 1.12) [11-049]	3	5.70	Good	Poor-Fair	Good	None	WWH
Unnamed Trib to N Branch Sycamore Creek at RM 5.3 [11-072]	1	0.30	Fair	Na	Na	None	PHW2
Unnamed Trib to N Branch Sycamore Creek at RM 5.4 [11-073]	1	1.10	Good	Fair	Poor	None	WWH
Unnamed Trib to N Br Sycamore Cr at RM 0.75 [11-074]	1	0.50	Good	Na	Na	None	PHW3A
Trib to North Branch Sycamore Creek at RM 2.33	1	0.60	Good	Na	Na	None	PHW3A

Table 3. Assessment of existing aquatic life use (ALU) designations in the 2012 Little Miami River watersheds study area. The respective biological assemblage and habitat assessment results are summarized along with the existing ALU. The recommended ALU is also listed and represents a change if different from the existing ALU.

Stream	No. of Sites	Size (mi^2)	Habitat Evaluation	Fish Evaluation	Macro. Evaluation	Existing ALU	Recom-mended ALU
[11-084]							
Unnamed Trib (1.82) to Trib to Sycamore Creek (1.1 [11-086]	1	1.60	Fair	Na	Na	None	PHW2
WAU 13-05 – East Fork Little Miami River							
East Fork Little Miami River [11-100]	11	499.00	Fair-Excellent	Fair-Very Good	Excellent	EWH	EWH
WAU 14-05 – Dry Run							
Dry Run [11-005]	4	5.40	Fair-Excellent	Fair-Good	Good	WWH	PHW3aWWH
Trib to Dry Run (4.20) [11-064]	1	0.90	Good	Na	Na	None	PHW3A
WAU 14-04 – Duck Creek							
Duck Creek [11-004]	9	14.60	Very Poor-Poor	Very Poor-Fair	Very Poor-Fair	LRW	LRW
East Fork Duck Creek [11-051]	4	3.40	Poor-Fair	Poor	Very Poor	LRW	PHW-I/WWH
Unnamed Trib to Duck Creek at RM 4.8 [11-075]	2	1.40	Poor-Fair	Na-Very Poor	Na-Very Poor	None	PHWII/LRW
Little Duck Creek [11-076]	6	1.70	Poor-Good	Fair	Poor-Good	None	WWH
Unnamed Trib to Little Duck Creek at RM 4.42 [11-077]	1	1.40	Good	Na	Na	None	PHW3A
WAU 14-06 Clough Creek							
Clough Creek [11-002]	5	8.00	Good	Poor-Good	Fair-Good	WWH	WWH
McCullough Run [11-003]	1	1.70	Poor	Fair	Very Poor	WWH	WWH
Unnamed Trib to McCullough Run at RM 1.08 [11-078]	1	0.90	Good	Very Good	Fair	None	WWH
Trib to Unnamed Trib to Clough Creek at RM3.06 [11-079]	1	0.70	Good	Poor	Fair	None	WWH
UT at RM 0.66 to UT to Clough Creek at RM 3.06 [11-080]	1	1.10	Good	Na	Poor	None	PHW2
UT at RM 0.95 to UT to Clough Creek at RM 3.06 [11-081]	1	0.90	Good	Poor	Poor	None	WWH
WAU 12-08 Five Mile Creek – Ohio River							
Five Mile Creek [10-001]	2	4.80	Good	Fair-Excellent	Marg. Good	WWH	WWH
Eight Mile Creek [10-002]	1	0.80	Excellent	Na	Na	None	PHW3A
Trib to Eight Mile Creek at RM 1.01 [10-130]	1	1.10	Good	Na	Na	None	PHW3A
Four Mile Creek [10-537]	1	1.10	Good	Poor	Fair	WWH	WWH
WAU 08-03 Turtle Creek							
Turtle Creek [11-021]	1	22.50	Good	Good	Marg. Good	WWH	WWH
Dry Run [11-022]	1	4.90	Good	Good	Fair	WWH	WWH
Newman Run [11-030]	1	9.50	Na	Na	Na	EWH	EWH

[a]lower 3 miles are in the Ohio River influenced/impounded reach and designated WWH.

The tributary to the Little Miami River at RM 0.83 (LM103, 11-047) has sufficient habitat (QHEI=65), depth and flow to support the WWH use. Sampling revealed 17 fish species (IBI=52) that may be the result of the close proximity to the Little Miami River mainstem. The macroinvertebrate assemblage was evaluated as poor. The tributary to the Little Miami at RM 13.1 (LM21, 11-066) also had sufficient habitat (QHEI=63), depth, and flow to merit a WWH recommendation and both assemblages attained WWH. The tributary to the Little Miami River at RM 7.75 (LM20, 11-067) was too small (0.5 $mi.^2$) and shallow to support a WWH assemblage, but larval two-lined salamanders were collected thus it is recommended as a PWH3A stream. Similarly, the tributary (RM 2.7) to the tributary to the Little Miami River at RM 7.75 (LM19, 11-068) was too small (0.6 $mi.^2$) and shallow to support WWH, but two-line salamanders were collected thus it is recommended as PHW3A. The remaining three tributaries (LM23, 11-082; LM24, 11-083; and LM22, 11-085) were ephemeral, but due to natural conditions (HHEI = 50, 50, and 58) and they are recommended as PHW2 (intermittent).

Designated Aquatic Life Uses in WAU 13-05 - East Fork Little Miami River
Only the mainstem East Fork Little Miami River was sampled in this WAU and it already has an existing, verified EWH aquatic life use designation that has been verified during multiple survey events.

Designated Aquatic Life Uses in WAU 14-01 - Sycamore Creek
Eight streams were sampled in this watershed and only two had verified, existing aquatic life uses, Sycamore Creek (11-007) and the North Branch of Sycamore Creek (11-008), and both are existing and verified WWH. Of the undesignated streams two, the tributary to Sycamore Creek at RM 1.12 (LM53,LM55, LM56; 11-049) and the tributary to the North Fork of Sycamore Creek at RM 5.4 (LM 63, 11-073), are recommended as WWH. The first (11-049) at 5 $mi.^2$ is clearly deep enough to support WWH assemblages it has good quality macroinvertebrate assemblages. The tributary to the North Branch of Sycamore Creek is smaller (1.1 $mi.^2$), but has sufficient depth and habitat and a fish IBI score near WWH attainment (IBI=32). The remaining streams in the Sycamore Creek subwatershed are recommended as PHWH. The two tributaries to the North Branch of Sycamore Creek (LM64, 11-074; LM62, 11-084) are recommended as PHW3A because of the presence of larvae of two-lined salamanders and good HHEI scores. The other two streams were ephemeral (LM 65, 11-072, tributary to N. Branch at RM 5.3 and LM54, 11-086, tributary to a tributary (RM 1.82) to Sycamore Creek at RM 1.12) due to natural conditions and are recommended as PHW2 (intermittent).

Designated Aquatic Life Uses in WAU 14-02 – Polk Run – Little Miami River
Polk Run has an existing and verified WWH use. Three tributaries to Polk Run (LM41, LM44, 11-069; LM42, LM43, 11-070; LM45, 11-071) were assessed and recommended as WWH. All have QHEI scores >70 and sufficient depth to support WWH assemblages. Four of the five sites meet WWH for macroinvertebrates and one of the five fish samples attained as well.

Designated Aquatic Life Uses in WAU 14-04 – Duck Creek
In this watershed Duck Creek and the East Fork of Duck Creek (*aka* Deerfield Run) have a verified LRW aquatic life use. Any aquatic life use lower than WWH is reviewable every three-

years. Duck Creek was assigned the Limited Resource Waters (LRW) use because for much of its length has been converted to a concrete channel, largely devoid of any aquatic habitat. The 2012 data has not changed that assessment and the stream remains limited by the concrete channels that comprise much of the length of Duck Creek. However, the 2012 results show that the East Fork of Duck Creek (11-051, sites: LM81, LM85, LM84, LM74) is not consistent with the LRW use. The original designation was likely been made based on either limited assessment data or an extrapolation of the results from Duck Creek. Although highly urbanized, most of the stream channels except at LM84 are natural. The most upstream site that is not underground (LM81) is habitat limited and ephemeral and is recommended as PHW1 (ephemeral). Two of the three downstream sites have natural channels and habitat consistent with WWH, thus it is recommended for the East Fork. The upper portion of the tributary to Duck Creek at RM 4.8 (LM83, 11-075) was ephemeral and is recommended as PHW2 (intermittent). The lower site (LM80) was extensively altered and considered isolated by its confluence with the concrete channel of Duck Creek, thus it is recommended for LRW.

Three other tributaries that were not previously monitored were sampled. The largest of these was Little Duck Creek (11-076). Unlike Duck Creek, channels in this stream were mostly natural, although stretches showed the effects of the urban nature of the watershed. The upper portions (>RM 2.30; sites LM86, LM87, LM90) are recommended as WWH. These sites were rated as good or marginally good for macroinvertebrates and were just below the WWH headwater biocriterion of 36 for fish (all sites >34). One issue that arose when examining these sites was the difficulty in determining the upper boundary of the watershed from the upper reaches of the Sycamore Creek watershed. The USGS Stream Stats tool, which we used for watershed delineations, identified the upper reaches of the Little Duck Watershed as part of the Sycamore Creek watershed. If this is not the case, then the drainage area of the Little Duck would increase and IBI scores when calculated at the larger drainage areas could decline somewhat.

From RM 1.80 downstream Little Duck Creek lost flow, largely because of the urban nature of the watershed and because of natural losses to groundwater as it approached the Little Miami River. At this point we recommend that the lower reaches also be designated as WWH until the nature of the flow issues in the lower reaches can be resolved. The tributary to Little Duck Creek (LM82) was small and there was too little flow for fish sampling; however, primary headwater monitoring resulted in a high HHEI score (76) and the presence of larvae of two-lined salamander, thus it is recommended as a PHW3A.

Designated Aquatic Life Uses in WAU 14-05 – Dry Run

In this watershed Dry Run (11-005) had a verified, existing WWH aquatic life use. The monitoring that occurred historically in Dry Run was conducted in larger downstream reaches. A site in the headwaters of Dry Run (LM70, RM 5.60-5.70, 0.80 $mi.^2$) was assessed and it is recommended as PHW3A due to its small size, good HHEI (62), and presence of larval two-lined salamanders. The remainder of Dry Run should maintain the verified and existing WWH use. The undesignated tributary at RM 4.2 (LM69) was too small and shallow for the WWH use and

it is recommended as a PHW3A because of a good HHEI score (70) and the presence of larval two-lined salamanders.

Designated Aquatic Life Uses in WAU 14-06 – Clough Creek
In this watershed two streams with existing, verified aquatic life uses, Clough Creek (11-002) and McCullough Run (11-003), were assessed. Three small undesignated tributaries were also assessed. The unnamed tributary to McCullough Run at RM 1.08 should be designated as WWH. It has sufficient depth and habitat to meet WWH and the site (LM93) currently attains the WWH biocriteria for fish and macroinvertebrates. The unnamed tributary (0.95) to an unnamed tributary of Clough Creek (RM3.06, LM100) has sufficient habitat (QHEI = 60.7), depth, and flow to support WWH.

Designated Aquatic Life Uses in WAU 12-08 - Nine Mile Creek
Three of the four streams sampled in this watershed have existing and verified aquatic life uses. The unnamed tributary to Eight Mile Creek at RM 1.01 (LM106) is undesignated. Although it has good aquatic habitat (QHEI = 71.5) its small size (1.1 $mi.^2$) and shallow depths suggest that a PHWH classification is more appropriate. Because of the presence of larvae of two-lined salamanders we recommend a PHW3A.

Designated Aquatic Life Uses in WAU 08-03 - Turtle Creek and WAU 09-02 - O'Bannon Creek
The streams in the Turtle Creek watershed were sampled as reference sites for the Little Miami River study and their aquatic life use attainability was assessed by Ohio EPA during the 1998 bioassessment (Ohio EPA 2000). Similarly, the WWH use for O'Bannon Creek has also been verified during earlier Ohio EPA surveys. As such, the existing uses have been established.

One last note of importance is the influence of low flow conditions during 2012 when interpreting aquatic life use potential in small streams in the interior plateau (IP) ecoregion. Newman Run fully attained EWH during the 1998 Ohio EPA bioassessment, yet it was dry during both the fish and macroinvertebrate sampling visits in 2012 despite a 9 $mi.^2$ drainage area. Fish IBI scores were mostly in the 50s during sampling across four years between 1983 and 2002, although macroinvertebrates were in the fair range during previous visits which was attributed to low flows (Ohio EPA 2000). The influence of the extremely low flow conditions during 2012 will be an important consideration in assigning aquatic life uses based on only on data from 2012.

Aquatic Life Use Attainment Status
The status of aquatic life use attainment in the 2012 Little Miami River study area was determined based on the verified and recommended use designations discussed previously and in accordance with Ohio EPA methods and practice. In addition to listing the status of each site, the proximate causes and sources are also indicated for any impaired sites (Table 4). The following is a summary of the findings of the 2012 biological and water quality study highlighting the attainment status based on recommended aquatic life uses, key aspects of biological condition and water quality, and a summary of the causes and sources that were assigned to impaired sites.

Little Miami River

- Of the 17 Little Miami R. mainstem sites that were evaluated under the Warmwater Habitat suite of uses and biocriteria, 3 were in full attainment of the Exceptional Warmwater Habitat (EWH) use, 12 in partial attainment of EWH, and none in non-attainment of EWH; of the two WWH sites at the mouth, one site was in full attainment and the other in partial attainment.
- The 2012 results represent a decline in attainment status compared to the most recent 2007 Ohio EPA results when all except the most downstream site were in full attainment of EWH and reflected a significant improvement over 1998. The pattern in 2012 indicates that the decline in quality emanates from upstream of the 2012 study area with no local sources being strongly associated with the declines. Flow conditions were generally similar between 2012 and 2007 and reflected below median flows during each year.
- The decline in 2012 was the result of the failure of the fish Index of Biotic Integrity (IBI) to meet the EWH biocriterion. Only three of 15 values technically met the EWH biocriterion, but these were at the boundary of the insignificant departure for this index, further underscoring the below expected performance of the fish assemblage.
- The reduction in the quality of the fish assemblage was substantial and widespread. A total of eight fish species that were present in 2007 were missing in 2012 and 16 additional species exhibited marked declines in distribution and abundance. Fifteen of these 24 species are classified as highly intolerant to pollution.
- Seven species increased in distribution and abundance and four of these are classified as moderately to highly tolerant of pollution.
- DELT (deformities, erosions, lesions, and tumors) anomalies on fish were generally <0.5-1.0% in 2012, which is consistent with the 2007 results and in marked contrast with the elevated anomalies observed in 1998. As such the biological response in 2012 is different than in 1998 when excessive nutrients were an associated stressor.
- Excursions of the EWH dissolved oxygen (D.O.) criteria were more frequent in 2012 compared to 2007. These occurred between RM 18.6 and RM 6.0, coinciding with the discharge from the Polk Run WWTP. In addition to the EWH D.O. exceedances, diel swings of >6 mg/l and maximum values of 10-15 mg/l were more frequent in 2012 compared to 2007.
- The primary nutrient total phosphorus was not elevated in 2012 compared to 2007 and values were in fact lower, possibly the result of phosphorus removal treatment at some WWTPs in the upper and middle Little Miami mainstem in the late 1990s and early 2000s.
- Total nitrate (NO_3-N), total Kjeldahl nitrogen (TKN), and total suspended solids (TSS) were somewhat elevated in 2012 compared to 2007 with more frequent exceedances of regional reference concentrations.
- Habitat quality as measured by the QHEI revealed substantially lower scores at some of the comparable sites between 2012 and 2007, although most scores were >70-75 indicating very good to exceptional quality habitat.

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
Large River Assessment Unit 05090202 9002 – Little Miami River, O'Bannon Creek to Ohio River									
11-001 – Little Miami River ***(EWH Aquatic Life Use – Existing)***									
LM01	27.80/ 27.80	1070.00	42*	10.57	44 ^{ns}	73.0	Partial⇩	D.O., organic enrichment	unknown
LM02	23.70/ 24.10	1150.00	43*	10.02	48	76.5	Partial⇩	D.O., organic enrichment	unknown
LM03	22.10/ 22.80	1150.00	36*	9.14^{ns}	50	69.5	Partial⇩	D.O., organic enrichment	unknown
LM04	21.70/ 21.80	1150.00	41*	10.09	32na (Mixing Zone)	75.0	Partial	D.O., organic enrichment	unknown
LM05	21.25/ 21.40	1160.00	42*	9.67	42^{ns}	74.0	Partial⇩	D.O., organic enrichment	unknown
LM06	20.60/ 20.60	1160.00	44^{ns}	9.99	42^{ns}	82.0	FULL⊙		
LM07	18.40/ 18.60	1190.00	39*	9.92	44^{ns}	72.0	Partial	D.O., organic enrichment	unknown
LM08	17.60/ 17.60	1190.00	42*	10.20	42^{ns}	84.0	Partial⇩	D.O., organic enrichment	unknown
LM09	12.90/ 13.10	1200.00	44^{ns}	9.53	50	81.5	FULL⊙		
LM10	11.80/ 12.40	1210.00	42*	9.93	44^{ns}	75.5	Partial	D.O., organic enrichment	unknown
LM11	11.20/ 10.90	1710.00	44^{ns}	9.89	46	88.5	FULL		
LM12	8.30/ 8.00	1710.00	41*	9.62	-	73.5	Partial⇩	D.O., organic enrichment	unknown
LM13	7.10/ 7.30	1720.00	40*	9.95	48	75.0	Partial	D.O., organic enrichment	unknown
LM14	6.00/ 5.30	1720.00	36*	7.86*	42^{ns}	54.5	Partial	D.O., organic enrichment	unknown
LM15	4.30/ 4.10	1730.00	35*	8.48*	44^{ns}	59.5	Partial	D.O., organic enrichment	unknown
11-001 – Little Miami River ***(WWH Aquatic Life Use – Existing)***									
LM16	3.00/ 3.40	1750.00	39^{ns}	9.76	42	72.3	FULL⊙		
LM17	1.40/ 1.40	1760.00	36*	8.18	18na	64.0	Partial	Impoundment	Ohio River backwater

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-047 - Unnamed Trib to Little Miami River at RM 0.83 ***(Aquatic Life Use Undesignated / WWH Recommended)***									
LM103	0.20/ 0.10	1.70	52	NA	Poor*	65.0	NON	Habitat, TP	Urban runoff, natural
11-066 - Unnamed Trib to Little Miami River at RM 13.1 ***(Aquatic Life Use Undesignated / WWH Recommended)***									
LM21	1.50/ 1.50	3.00	36^{ns}	NA	Good	63.0/	FULL		
11-067 - Unnamed Trib to Little Miami River at RM 7.75 ***(Aquatic Life Use Undesignated / PHW3A Recommended)***									
LM20	1.20/ 1.20	0.50	24na	NA	NA	/72.0	PHW3A		
11-068 - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River at RM ***(Aquatic Life Use Undesignated / PHW3A Recommended)***									
LM19	0.50/ 0.50	0.6	12na	NA	NA	/83.0	PHW3A		
11-082 - Unnamed Trib to Little Miami River at 24.06 ***(Aquatic Life Use Undesignated / PHW2 (Intermittent) Recommended)***									
LM23	0.20/ 0.20	1.60	Dry	NA	NA	Na/50	PHW2		
11-083 - Unnamed Trib to Little Miami River at RM 21.82 ***(Aquatic Life Use Undesignated / PHW2 (Intermittent) Recommended)***									
LM24	0.10/ 0.10	0.80	Dry	NA	NA	Na/50	PHW2		
11-085 - Unnamed Trib to Little Miami River at 13.8 ***(Aquatic Life Use Undesignated / PHW2 (Intermittent) Recommended)***									
LM22	0.30/ 0.30	1.20	Dry	NA	NA	Na/58	PHW2		
WAU 09-02 - O'Bannon Creek									
11-010 - O'Bannon Creek ***(WWH Aquatic Life Use – Existing)***									
LM37	1.80/ 1.90	54.30	52	9.22	34	71.3	FULL⊙		
LM38	0.10/ 0.10	59.00	44	7.34*	Good	71.0	Partial⇩	Nutrients	WWTP, urban runoff
WAU 13-05 - East Fork Little Miami River									
11-100 - East Fork Little Miami River ***(EWH Aquatic Life Use – Existing)***									
LM25	19.50/ 19.50	344.00	42*	9.10ns	44^{ns}	85.5	Partial⇧	Flow	Ustr. Impoundment

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-100 - East Fork Little Miami River ***(EWH Aquatic Life Use – Existing)***									
LM26	15.00/ 14.90	352.00	47 ^{ns}	8.86*	48	89.3	Partial⊙	Flow	Ustr. Impoundment
LM27	13.70/ 13.90	364.00	43*	8.64*	48	80.5	Partial⇩	Flow	Ustr. Impoundment
LM28	13.20/ 12.90	372.00	45 ^{ns}	9.81	52	80.5	FULL		
LM29	11.00/ 11.00	376.00	41*	8.57*	44 ^{ns}	81.0	Partial⊙	D.O., Org. enrich., nutrients	WWTP, Urban runoff
LM30	9.10/ 9.00	380.00	43*	9.16^{ns}	46	93.0	Partial⇧	D.O., Org. enrich., nutrients	WWTP, Urban runoff
LM31	5.60/ 5.60	485.00	39*	8.75*	46	71.5	Partial⊙	Habitat, siltation, D.O., Org. enrich., nutrients	WWTP, Urban runoff
LM32	4.30/ 4.30	491.00	41*	8.60*	50	74.0	Partial⇩	Habitat, siltation, nutrients, Org. enrich.,	WWTP, Urban runoff
LM34	2.00/ 2.10	494.00	35*	9.53^{ns}	42^{ns}	69.8	Partial⊙	Habitat, siltation, Org. enrich., nutrients	WWTP, Urban runoff
LM35	1.00/ 1.60	498.00	38*	9.41^{ns}	48	81.5	Partial	Nutrients, Org. enrich.,	WWTP, Urban runoff
LM36	0.70/ 0.70	499.00	35*	9.06*	50	63.0	Partial⊙	Habitat, siltation, D.O., Org. enrich.,	WWTP, Urban runoff
WAU 14-01 - Sycamore Creek									
11-007 - Sycamore Creek ***(WWH Aquatic Life Use – Existing)***									
LM47	3.50/ 3.60	3.50	26*	NA	Fair*	60.8	NON	Chlorides, nutrients, metals	Urban runoff
LM48	2.40/ 2.40	4.80	26*	NA	MG^{ns}	73.0	NON	Chlorides,metals	Urban runoff
LM49	1.60/ 1.50	6.60	24*	NA	Good	72.5	NON	Chlorides,metals	Urban runoff

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-007 - Sycamore Creek ***(WWH Aquatic Life Use – Existing)***									
LM50	0.70/ 1.10	12.70	28*	NA	MG^{ns}	65.3	Partial⊙	Chlorides,metals	Urban runoff
LM51	0.50/ 0.30	22.70	42	7.30*	Good	59.3	Partial⇩	Habitat	Sewer line, Urban runoff
LM52	0.20/ 0.20	23.30	51	7.85*	MG^{ns}	68.0	Partial⇩	Ammonia, Chlorides,	WWTP, Urban runoff
11-008 - North Branch Sycamore Creek at RM 0.64 ***(WWH Aquatic Life Use – Existing)***									
LM57	5.00/ 5.20	2.90	34*	NA	Good	77.3	Partial	Chlorides	Urban runoff
LM58	4.30/ 3.70	4.40	36^{ns}	NA	Good	83.0	FULL		
LM59	2.10/ 2.00	7.30	36^{ns}	NA	Good	88.0	FULL		
LM60	0.50/ 0.40	9.80	34*	NA	34	72.8	Partial	Loss of connectance, chloride	Culvert, urban runoff
LM61	0.10/ 0.05	9.90	54	NA	36	86.0	FULL		
11-049 - Trib To Sycamore Cr. (RM 1.12) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM55	1.00/ 1.00	5.30	24*	NA	Good	73.5	Partial	Chlorides, flow, unknown	Urban runoff, natural
LM56	0.30/ 0.20	5.60	32*	NA	Good	74.0	Partial	Chlorides, flow	Urban runoff, natural
LM53	0.10/ 0.10	5.70	24*	NA	Good	66.0	Partial	Chlorides, flow	Urban runoff, natural
11-072 - Unnamed Trib to N Branch Sycamore Creek at RM 5.3 ***(Aquatic Life Use Undesignated / PHW2 (Intermittent) Recommended)***									
LM65	1.10/ 1.10	0.20	Dry	NA	NA	Na/44	PHW2		
11-073 - Unnamed Trib to N Branch Sycamore Creek at RM 5.4 ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM63	0.60/ 0.60	1.10	32*	NA	Poor	71.0/ 74.0	NON	Chlorides	Urban runoff
11-074 - Unnamed Trib to N Br Sycamore Cr at RM 0.75 ***(Aquatic Life Use Undesignated/PHW3A Recommended)***									
LM64	1.40/ 1.40	0.50	16na	NA	NA	76.0/ 63.0	PHW3A		

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-084 - Trib to North Branch Sycamore Creek at RM 2.33 ***(Aquatic Life Use Undesignated/PHW3A Recommended)***									
LM62	1.80/ 1.65	0.60	20na	NA	NA	76.0/ 67.0	PHW3A		
11-086 - Unnamed Trib (1.82) to Trib to Sycamore Creek (1.12) ***(Aquatic Life Use Undesignated/PHW2 (Intermittent) Recommended)***									
LM54	0.40/ 0.40	1.60	Dry	NA	NA	NA/ 58.0	PHW2		
WAU 14-02 - Polk Run-Little Miami									
11-009 - Polk Run ***(WWH Aquatic Life Use – Existing)***									
LM46	3.20/ 3.20	2.60	28*	NA	MG^{ns}	82.0	Partial	Chlorides, flow	Urban runoff
LM39	3.00/ 2.90	2.70	32*	NA	Good	69.5	Partial	Chlorides, flow	Urban runoff
LM40	0.30/ 0.30	10.00	52	NA	Good	68.0	FULL		
11-069 - Unnamed Trib to Polk Run at RM 1.79 ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM41	2.50/ 2.60	1.30	36^{ns}	NA	MG^{ns}	71.5	FULL		
LM44	0.40/ 0.40	2.40	30*	NA	Good	78.0	Partial	Chlorides, flow	Urban runoff
11-070 - Unnamed Trib to Polk Run at RM 0.70 ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM42	2.00/ 1.90	0.00	30*	NA	Fair	76.5	NON	Chlorides, flow	Urban runoff
LM43	0.70/ 0.80	2.50	28*	NA	MG^{ns}	75.0	Partial	Chlorides, flow	Urban runoff
11-071 - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM45	0.20/ 0.20	1.10	30*	NA	Good	73.0	Partial	Chlorides, flow	Urban runoff
WAU 14-04 - Duck Creek									
11-004 - Duck Creek ***(LRW Aquatic Life Use – Existing) [Confluence to RM 2.4]***									
LM71	6.00/ 6.00	2.20	12*	NA	VP*	20.0	NON	Organic enrichment, metals	CSOs, urban runoff
LM78	5.20/ 5.20	3.50	12*	NA	VP*	18.5	NON	Organic enrich., metals	CSOs, urban runoff

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-004 - Duck Creek ***(LRW Aquatic Life Use – Existing) [Confluence to RM 2.4]***									
LM72	4.60/ 4.60	5.10	26*	NA	Poor	40.0	FULL		
LM73	4.40/ 4.40	5.80	12*	NA	Poor	18.5	NON	Organic enrichment, metals	CSOs, urban runoff
LM75	3.30/ 3.30	11.40	12*	NA	Fair	22.5	NON⊙	Organic enrichment, metals	CSOs, urban runoff
LM76	2.90/ 2.90	11.80	32	NA	Fair	33.5	FULL		
11-004 - Duck Creek ***(WWH Aquatic Life Use – Existing) [RM 2.4 to Mouth]***									
LM77	1.80/ 1.80	14.30	30*	NA	Fair	48.0	NON	Organic enrichment, metals, Flow	CSOs, urban runoff, habitat degradation
LM91	1.00/--	14.50	Dry	NA	Dry	NA	NON⊙	Flow, organic enrichment, metals,	CSOs, urban runoff, habitat degradation
LM79	0.90/ 0.90	14.60	Dry	NA	VP*	NA	NON	Flow, organic enrichment, metals,	CSOs, urban runoff, habitat degradation
LM81	0.10/ 0.10	15.3	Dry	NA	Dry	NA	NON	Flow, organic enrichment, metals,	CSOs, urban runoff, habitat degradation
11-051 - East Fork Duck Creek (Deerfield Creek) ***(LRW Aquatic Life Use – Existing)/PHWI Recommended***									
LM81	2.30/2.30	0.5	Dry	NA	Dry	Na/ 17	NON	Chlorides, flow	Urban runoff
11-051 - East Fork Duck Creek (Deerfield Creek) ***(LRW Aquatic Life Use – Existing)/WWH Recommended***									
LM85	1.90/ 1.50	1.30	18*	NA	VP*	59.0	NON	Chlorides, flow	Urban runoff
LM84	0.50/ 0.60	2.40	24*	NA	VP*	39.0	NON	Chlorides, flow	Urban runoff
LM74	0.15/ 0.15	3.40	28*	NA	VP*	51.0	NON	Chlorides, flow	Urban runoff

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-075 - Unnamed Trib to Duck Creek at RM 4.8 ***(Aquatic Life Use Undesignated/PHW2 (Intermittent)***									
LM83	0.80/ 0.80	1.20	Dry	NA	Dry	Na/41	PHW2		
11-075 - Unnamed Trib to Duck Creek at RM 4.8 ***(Aquatic Life Use Undesignated/LRW Recommended)***									
LM80	0.20/ 0.20	1.40	12*	NA	VP*	36.5	NON	Org. enrichment chlorides, flow	CSOs, urban runoff
11-076 - Little Duck Creek ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM86	2.70/ 2.70	0.40	34*	NA	Good	46.5	Partial	Chlorides, Flow	Urban runoff
LM87	2.60/ 2.60	0.50	34*	NA	Good	48.8	Partial	Chlorides, Flow	Urban runoff
LM90	2.40/ 2.30	0.50	34*	NA	MG^{ns}	59.0	Partial	Chlorides, Flow	Urban runoff
LM88	1.80/ 1.80	0.80	Dry	NA	Dry	NA	NON	Chlorides, Flow	Urban runoff
LM89	1.40/ 1.40	1.10	30*	NA	Poor*	37.0	NON	Flow	Urban runoff
LM91	1.00/ 0.00	0.70	Dry	NA	Dry	NA	NON	Organic enrichment, flow	CSOs, Urban runoff
LM92	0.20/ 0.00	1.70	Dry	NA	Dry	NA	NON	D.O., Organic enrichment, Flow	CSOs, Urban runoff
11-077 - Unnamed Trib to Little Duck Creek at RM 4.42 ***(Aquatic Life Use Undesignated/PHW3A Recommended)***									
LM82	0.10/ 0.10	1.40	Dry	NA	NA	NA/ 76.0	PWH3A		
WAU 14-05 - Dry Run-Little Miami									
11-005 - Dry Run ***(WWH Aquatic Life Use – Existing)/PHW3A Recommended)***									
LM70	5.60/ 5.70	0.80	20*	NA	NA	NA/ 62.5	PHW3A		
11-005 - Dry Run ***(WWH Aquatic Life Use – Existing)***									
LM66	4.10/ 4.10	3.20	30*	NA	Good	56.5	Partial	Unknown, flow	Natural, Urban runoff

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-005 - Dry Run ***(WWH Aquatic Life Use – Existing)***									
LM67	2.50/ 2.50	4.70	44	NA	Good	76.5	FULL		
LM68	0.60/ 0.00	5.40	Dry	NA	Dry	NA	NA	Flow	Natural, Urban Runoff
11-064 - Trib to Dry Run (4.20) ***(Aquatic Life Use Undesignated/PHW3A Recommended)***									
LM69	0.10/ 0.10	0.90	Dry	NA	Good^{na}	NA/ 70.0	PHW3A		
WAU 14-06 - Clough Creek-Little Miami									
11-002 - Clough Creek ***(WWH Aquatic Life Use – Existing)***									
LM99	4.60/ 4.60	0.90	20*	NA	Fair*	56.3	NON	Chlorides, flow	Urban runoff
LM95	3.20/ 3.20	2.00	30*	NA	Fair*	56.5	NON	Chlorides, flow, nutrients	Urban runoff
LM96	3.00/ 3.10	2.00	36na	NA	Good	57.8	FULL		
LM97	1.20/ 1.20	7.50	26*	NA	34	65.0	NON	Chlorides, flow	Urban runoff
LM98	0.60/ 0.40	8.00	26*	NA	Good	57.5	NON⇩	D.O., chlorides, flow	CSOs, Urban runoff
11-003 - McCullough Run ***(WWH Aquatic Life Use – Existing)***									
LM94	1.30/ 1.30	1.70	34*	NA	VP*	37.0	NON	Chlorides, habitat, flow	CSOs, Urban runoff
11-078 - Unnamed Trib to McCullough Run at RM 1.08 ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM93	1.50/ 1.40	0.90	46	NA	MG^{ns}	56.8	FULL		
11-079 – Trib to Unnamed Trib to Clough Creek at RM 3.06 ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM101	1.05/ 1.05	0.70	24*	NA	Fair	58.8	NON	Chlorides, TP, flow	Urban runoff
11-080 - UT at RM 0.66 to UT to Clough Creek at RM 3.06 ***(Aquatic Life Use Undesignated/PHW2 Recommended)***									
LM102	0.20/ 0.20	1.10	Dry	NA	Poor*	NA/72	PHW2		

Table 4. Aquatic life use attainment status at Little Miami River sites in 2012. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on performance of the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality and potential to support an aquatic life use. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded; PHWH are green shaded. Sampling locations are grouped by the mainstem (LRAU) and HUC 12 subwatershed level WAU (watershed assessment unit). Changes in attainment status from previous reported assessments are denoted as improving (⇧), no change (⊙), or declining (⇩) compared to the most recent prior assessment.

Site ID	River Mile	Drainage Area (mi.^{2})	IBI	MIwb	ICI or Narrative	QHEI/ HHEI	Attainment Status	Causes	Sources
11-081 - UT at RM 0.95 to UT to Clough Creek at RM 3.06 ***(Aquatic Life Use Undesignated/WWH Recommended)***									
LM100	0.20/0.10	0.90	24*	NA	Poor*	60.8	NON	Chlorides, TP, flow	CSOs, Urban runoff
WAU 12-08 - Ninemile Creek-Ohio River									
10-001 - Five Mile Creek ***(WWH Aquatic Life Use – Existing)***									
LM107	2.40/ 2.50	2.60	28*	NA	MG^{ns}	67.5	Partial	Loss of connectance, chlorides, flow	Culvert, Urban runoff, natural
LM108	0.10/ 0.20	4.80	52	NA	MG^{ns}	70.8	FULL		
10-002 - Eight Mile Creek ***(WWH Aquatic Life Use – Existing)/PHW3A Recommended in HW***									
LM105	2.10/ 2.00	0.80	12na	NA	NA	71.0/ 90.0	PHW3A		
10-130 - Trib to Eight Mile Creek at RM 1.01 ***(Aquatic Life Use Undesignated/PHW3A Recommended)***									
LM106	0.10/ 0.10	1.10	18na	NA	NA	71.5/ 68.0	PHW3A		
10-537 - Four Mile Creek ***(WWH Aquatic Life Use – Existing)***									
LM104	0.80/ 0.90	1.10	18*	NA	Fair*	66.0/ 77.0	NON	Ammonia, flow	Unsewered, urban runoff, natural
WAU 08-03 - Turtle Creek									
11-021 – Turtle Creek ***(WWH Aquatic Life Use – Existing)***									
RF08	6.10/ 6.10	22.50	40	NA	MG^{ns}	69.0	FULL		
11-022 – Dry Run ***(WWH Aquatic Life Use – Existing)***									
RF09	1.80/ 1.80	4.90	38^{ns}	NA	Fair*	63.0	Partial	Nutrients, flow	Ag. runoff, natural
11-030 – Newman Run ***(EWH Aquatic Life Use – Existing)***									
RF10	0.30/ 0.00	9.50	Dry	NA	Dry	NA	NA	Flow, D.O.	Natural, ag and urban runoff

^{na} - not applicable; Narratives: E – exceptional; G – good; MG – marginally good; F – Fair; P – poor; VP – very poor.
^{ns} – nonsignificant departure from applicable biocriterion; * - significant exceedance of applicable biocriterion.
See OAC 3745-1-07, Table 7-13 for the applicable numeric biocriteria.

- An initial attempt to diagnose the 2012 impairment of the EWH use included examining the number of D.O. sensitive fish species. These species declined in 2012 compared to 2007 and were only slightly higher than the numbers observed in 1998 when the EWH use was substantially impaired.
- The decline in the Little Miami River biological assemblages were revealed in the ADV/AAV analyses with ADV values for the IBI being the same as in 1998. AAVs for the MIwb and ICI were also similar to 1998, both reflecting an overall reduction compared to 2007 even though both indices mostly attained the EWH biocriteria in 2012.
- Causes of impairment were assigned to marginal D.O. and organic enrichment, but specific sources were not assigned.
- A more detailed diagnosis of the decline observed in 2012 is not possible at this time, but will be pursued as part of the ongoing regional analysis of stressors in support of the Integrated Prioritization System (IPS). However, as a result of the potential uncertainties and implications resulting from the finding of non-attainment in 2012, follow-up biological sampling was conducted in 2013 and within an extended study area (upstream) in an effort to verify the 2012 findings and to gain indications of any obvious problems that were overlooked by the more truncated 2012 study design.

East Fork Little Miami River

- Of the 11 East Fork Little Miami R. mainstem sites that were evaluated under the Warmwater Habitat suite of uses and biocriteria, 1 was in full attainment of the EWH use and the remaining 10 in partial attainment.
- There was a marked difference in the fish IBI scores between the two sampling passes. The August 13-15 sampling pass reflected attainment of the EWH IBI biocriterion at 5 sites mostly in the upper one-half of the sampled segment. The October 1-4 sampling pass had consistently lower IBI scores, none attaining the EWH biocriterion and several below to WWH biocriterion.
- The segment sampled in 2012 extends from the Harsha reservoir outlet to the mouth at the Little Miami River. Dewatering of the Harsha Reservoir stilling basin was conducted August 20-22 between the two fish sampling passes.
- Water temperatures measured in the Little Miami River during July 17-19 showed a significant spike in temperatures downstream from the East Fork confluence such that Ohio average and maximum temperature criteria were exceeded. Maximum temperatures approached and exceeded the avoidance temperatures of intolerant fish species. While no corresponding temperature data was collected in the East Fork during this time, the results indicate the East Fork as a source of elevated temperatures, at least periodically. Successive temperature recordings during August 28-30 showed an increase downstream from the East Fork, but no exceedances of temperature criteria.
- Water sample data did not reveal any particular problems or exceedances of water quality criteria or regional reference thresholds.
- ADV values for the IBI were the highest in 2012 of all prior survey years dating back to 1982, reflecting a steady decline in the quality of the fish assemblage. The MIwb and ICI

showed reductions in AAV values both reflecting a reduction compared to 1998 even though both indices largely attained their EWH biocriteria in 2012.

- Causes of impairment included flow fluctuations, D.O., organic enrichment, habitat modifications, and siltation. Sources included the Harsha Reservoir, urban runoff, and WWTPs.

Sycamore Creek and Tributaries

- Of the 19 sites located in the Sycamore Creek subbasin 15 were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 3 were in full attainment of WWH, 8 in partial attainment of WWH, and 4 in non-attainment of WWH. Four sites were evaluated under the PHWH classification scheme.
- The partial and non-attainment of WWH was due mostly to the poor quality fish assemblages especially in the smaller drainage areas where past habitat modifications due to sewer line construction were prevalent and chlorides, metals, and nutrients were elevated from urban runoff. However, a few sites exhibited good to exceptional quality biological assemblages. Two of the PHWH sites were classified as IIIA which is the highest quality among the PHWH subclasses.
- Water quality in Sycamore Creek was typical of watersheds with a high degree of urbanization with excursions of exceedances of heavy metals (copper and lead), elevated conductivity, elevated chlorides, and elevated total dissolved solids (TDS). Flows were also limiting in some of the smaller tributaries and were likely exacerbated by the dry weather conditions throughout the 2012 index period.
- Causes of impairment included chlorides, metals, habitat, and low flows. Sources included habitat modifications, urban runoff, and natural conditions.

Polk Run and Tributaries

- Of the 8 sites located in the Polk Run subbasin all were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 2 were in full attainment of WWH, 5 in partial attainment of WWH, and 1 in non-attainment of WWH. No sites were evaluated under the PHWH classification scheme.
- The partial and non-attainment of WWH was due mostly to fair quality fish and marginal macroinvertebrate assemblages especially in the smaller drainage areas where low flows and chlorides were elevated from urban runoff. The site at the mouth of Polk Run exhibited good to exceptional quality biological assemblages.
- Water quality in Polk Run was typical of watersheds with a high degree of urbanization with elevated conductivity, elevated chlorides, and elevated total dissolved solids (TDS). Flows were also limiting in some of the smaller tributaries and were likely exacerbated by the dry weather conditions throughout the 2012 index period.
- Causes of impairment included chlorides and low flow and the source was urban runoff.

Duck Creek

- Of the 24 sites located in the Duck Creek subbasin 21 were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 2 were in full attainment of

the LRW use, 3 in partial attainment of the recommended WWH use, and the remaining 19 in non-attainment of the existing LRW and recommended WWH uses.

- Biological assemblages typically reflected very poor to poor quality in the segments of Duck Creek and tributaries that are highly modified and impacted by CSOs. However, some sites did reflect fair to good quality and indication of lesser impacts primarily in an absence of CSOs.
- Water quality in Duck Creek was typical of watersheds with a high degree of urbanization and CSOs with excursions of D.O., exceedances of heavy metals (copper and lead), elevated temperatures, elevated TKN, elevated conductivity, elevated chlorides, and elevated TDS.
- While Duck Creek is the most impacted and modified tributary subbasin in the study area with concreted channels being widespread, the increased spatial resolution of the 2012 survey found that some tributaries had good water quality and suitable habitat.
- Causes of impairment included organic enrichment, metals, flow modifications, chlorides, and unknown. Sources included habitat modifications, CSOs, and urban runoff.

Dry Run and Tributary

- Of the 5 sites located in the Dry Run subbasin 3 were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 1 was in full attainment of WWH, 1 in partial attainment of WWH, and 1 in non-attainment of WWH. One (1) site was evaluated under the PHWH classification scheme.
- The partial attainment of WWH was due the fair quality fish assemblage at site LM66 which was attributed to low flows due to natural conditions. The site at the mouth of Dry Run was not sampled due to ephemeral conditions. The tributary to Dry Run was assessed as a PHWH and was classified as a PHW IIIA.
- Water quality in Dry Run was good where water samples were collected with no exceedances of any criteria or thresholds.
- Causes of impairment included low flows due to mostly natural conditions.

Clough Creek and Tributaries

- Of the 10 sites located in the Clough Creek subbasin 9 were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 2 were in full attainment of WWH and 7 in non-attainment of WWH. A single site was evaluated under the Primary Headwater Habitat (PHWH) classification scheme.
- The non-attainment of WWH was due mostly to poor to fair quality fish and very poor to fair quality macroinvertebrate assemblages and due to a wide variety of impacts.
- Water quality in Clough Creek was impacted by urbanization and by CSOs at 3 sites. Elevated conductivity, chlorides, and TDS were characteristic of the sites not influenced by CSOs. Flows were also limiting in some of the smaller tributaries and were likely exacerbated by the dry weather conditions throughout the 2012 index period.
- Causes of impairment included chlorides, low flows, nutrients and the sources included urban runoff and CSOs.

Ohio River Tributaries (Fourmile, Fivemile, and Eightmile Creeks)

- Of the 5 Ohio R. direct tributary site 3 were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 1 was in full attainment of WWH, 1 in partial attainment of WWH, and 1 in non-attainment of WWH. Two sites were evaluated under the PHWH classification scheme.
- The partial and non-attainment of WWH was due to poor to fair quality fish and fair to marginal macroinvertebrate assemblages. The site at the mouth of Fivemile Creek had an exceptional quality fish assemblage. The two PHWH sites were classified as PWH IIIA.
- Water quality in Fivemile Creek was typical of watersheds with a high degree of urbanization with elevated conductivity, chlorides, and TDS. Flows were also limiting at the upstream most site and were likely exacerbated by the dry weather conditions throughout the 2012 index period. Fourmile Creek was impacted by raw sewage apparently from an unsewered area.
- Causes of impairment included chlorides, ammonia, and low flows and the source was urban runoff and an unsewered area.

Direct Little Miami River Tributaries

- Seven direct and unnamed tributaries to the Little Miami River were included in the 2012 study area.
- Of the 7 unnamed tributary sites two (2) were evaluated under the Warmwater Habitat suite of uses and biocriteria. Of these 1 was in full attainment of WWH and 1 in non-attainment of WWH. Five (5) sites were evaluated under the Primary Headwater Habitat (PHWH) classification scheme.
- The non-attainment of WWH at the RM 0.83 tributary (LM103) was due to the poor quality macroinvertebrate assemblage which contrasted markedly with an exceptional fish assemblage. Water quality at this site was characterized by excessive nutrients from urban runoff.
- Of the five PHWH sites, 2 were classified PHW IIIA and 3 PWH II.

Regional Reference Sites

- Three reference sites were located outside the 2012 Little Miami River study area and included Turtle Creek, Dry Run, and Newman Run. Full attainment of WWH was the result in Turtle Creek. The results in Dry Run reflected partial attainment due to a fair macroinvertebrate assemblage. Newman Run was not sampled due to ephemeral conditions precipitated by the dry weather conditions during the 2012 index period.

Recreational Use Status in the Lower Little Miami River Study Area

Impairment of recreation uses in the lower Little Miami River watershed was not uncommon throughout all of the subwatersheds that were sampled. The Primary Contact 30-day (geometric mean) criterion (Table 5) was exceeded at 38 of 92 sites (Table 6; Figure 4A). It was also exceeded at one of the three reference sites (RF09, Dry Run). The single sample maximum criterion was exceeded at 32 of 92 sites and at two of the three reference sites.

The geometric mean is the key criterion used to determine recreational use attainment and the single sample maximum is typically only used to determine use attainment at public bathing beaches, but not for streams and rivers. High minimum values were highlighted as an indicator of the chronic nature of the recreational use impairment as minimum values greater than the geometric mean criterion underscored the high frequency of exceedances. Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the lower Little Miami River they are likely related to CSOs, sanitary sewer overflows (SSOs), WWTPs, urban runoff, and deteriorating sewage collection systems in the older urban areas.

Table 5. E. coli criteria for Ohio streams and rivers (OAC 3745-1).

	E. coli Counts	
Recreation Use	Seasonal Geometric Mean	Single Sample Maximum
PCR-A	126	298
PCR-B	161	523
PCR-C	206	940
SCR	1,030	1,030

Recreational Use Recommendations

The Ohio WQS have multiple recreational use categories as described above. The "default" recreational use for Ohio streams is PCR-B unless there is direct evidence that another subcategory is more appropriate (e.g., PCR-A, PCR-B, or SCR). PCR-C is assigned to streams where primary contact recreation activities are limited to wading or are infrequent due to shallow depths. PCR-A is assigned to water bodies where full body immersion is plausible hence depths and volume need to be sufficient to support activities like swimming. SCR is restricted to those streams that are:

- rarely used for water based recreation such as, but not limited to, wading;
- are situated in remote, sparsely populated areas;
- have restricted access points; and,
- have insufficient depth to provide full body immersion, thereby greatly limiting the potential for water based recreation activities.

In the assessment of recreational uses in the Lower Little Miami River watershed MBI designated streams considered as a PHW aquatic life use as SCR because their small size precludes any full body immersion (generally less than 1 mi^2 with pool depths <40 cm). Most streams <5 mi^2 with a WWH aquatic life use were assigned to PCR-C use since wading was plausible, but because of their shallow depths full body immersion would be unlikely. Once the uses were addressed, attainment status was based on the geometric mean of *E. coli* results compared to the criteria for each aquatic life use. The recreational use criteria for *E. coli* vary with the specific use tier related to recreation intensity and importance (Table 5).

LRAU – 90-02 – Little Miami River

The Little Miami River mainstem is designated as PCA because of the high recreational value of this river. Fifteen of the sixteen sites on the Little Miami exceeded the PCA criteria for *E. coli* and all exceeded the single value maximum target as well (Table 6). Potential sources of *E. coli* include agricultural sources as well as urban runoff, CSOs, SSOs, and WWTP effluents. Exceedances of the PCB or PCC *E. coli* criteria were not evident in two tributaries.

Table 6. Bacteriological (E. coli) sampling results in the Little Miami River study area during 2011. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow (PC – Primary Contact; SC – Secondary Contact).

River Mile	Site ID	Location	Recr. Use	N	E. coli Geom. Mean	E. Coli Max.	Recrea-tion Status
		LRAU 90-02 – Little Miami River mainstem					
		11-001: Little Miami River					
27.80	LM01	Dst. Old 3C highway	PCA	17	143.1	687.0	NON
23.70	LM02	Dst. E. Loveland Ave.	PCA	17	113.4	866.0	FULL
22.10	LM03	Ust. Polk WWTP	PCA	17	184.2	1203.0	NON
21.70	LM04	Mixing Zone	PCA	17	95.6	1046.0	NA
21.25	LM05	Dst. Bridge St.	PCA	17	139.2	816.0	NON
19.30	LM06	At Lake Isabella Canoe Launch	PCA	17	148.3	1986.0	NON
18.10	LM07	Adj. Glendale Milford Rd.	PCA	12	163.3	2420.0	NON
17.10	LM08	Adj. Kelly Nature Preserve	PCA	16	210.8	1986.0	NON
12.90	LM09	Milford Canoe Launch; US 50 bridge	PCA	11	97.4	816.0	FULL
11.50	LM10	Ust. Confluence with E. Fork LMR	PCA	15	153.8	866.0	NON
10.90	LM11	Dst. Confluence with E. Fork LMR	PCA	15	172.3	2420.0	NON
8.00	LM12	Bass Island Canoe Launch	PCA	17	207.4	2420.0	NON
6.80	LM13	Ust. Train Tracks below boulder field	PCA	13	194.8	2420.0	NON
5.30	LM14	Ust. Duck Cr./ Adj. Mariemont Gardens Park	PCA	17	232.7	2420.0	NON
4.00	LM15	At. Otto Armlender Park Canoe Launch	PCA	17	234.9	2420.0	NON
3.00	LM16	Dst. Beechmont Ave. / Clough Creek	PCA	17	225.4	2420.0	NON
1.40	LM17	Start Ust. Kellogg Ave.	PCA	17	256.5	2420.0	NON
		11-047 - Unnamed Trib to Little Miami River at RM 0.83					
0.10	LM103	Kellogg Rd.	PCB	1	99.0	99.0	FULL
		11-066 - Unnamed Trib to Little Miami River at RM 13.1					
1.50	LM21	At Red Bird Hollow	PCC	4	187.0	613.0	FULL
		WAU 09-02 – O'Bannon Creek					
		11-010 - O'Bannon Creek					
1.80	LM37	at O'Bannon Creek Rd.	PCB	8	185.4	1733.0	NON
0.10	LM38	at Loveland Park	PCB	9	492.4	2420.0	NON
		WAU – 14-02 – Polk Run					
		11-009 - Polk Run					
3.20	LM46	Ust. 7 Gables Rd.	PCC	2	276.6	461.0	NON
2.90	LM39	Montgomery Rd.	PCC	3	277.3	649.0	NON
0.30	LM40	at East Kemper Rd.	PCB	4	254.6	2420.0	NON
		WAU – 14-01 – Sycamore Creek					
		11-007 - Sycamore Creek					
3.50	LM47	Dst. Camargo Rd.	PCC	4	920.4	1986.0	NON
2.40	LM48	Ust. Kugler Mills Rd off Loveland Maderia Rd.	PCC	4	666.2	1203.0	NON
1.50	LM49	Loveland Maderia Rd @ pull-off by trib	PCB	8	131.6	2420.0	FULL
0.70	LM50	Ust. Spooky Hollow Rd.	PCB	8	180.2	2420.0	FULL
0.30	LM51	Ust. Sycamore Creek WWTP outfall	PCB	8	83.8	326.0	FULL
0.10	LM52	Dst. Sycamore Creek WWTP outfall	PCB	8	93.7	727.0	FULL
		11-008 - North Branch Sycamore Creek					
5.00	LM57	Behind 10478 Adventure Lane	PCC	2	144.5	147.0	FULL
3.70	LM58	behind Bethesda North Hospital	PCC	2	275.6	291.0	NON
2.00	LM59	Hopewell Rd.	PCB	2	119.2	148.0	FULL
0.40	LM60	SR 126	PCB	2	122.5	147.0	FULL
0.05	LM61	Loveland Maderia Rd. (confluence)	PCB	2	335.3	365.0	NON
		11-084 - Trib to North Branch Sycamore Creek at RM 2.33					
1.65	LM62	Cincinnati Christian Academy	SC	1	1986.0	1986.0	NON

Table 6. Bacteriological (E. coli) sampling results in the Little Miami River study area during 2011. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow (PC – Primary Contact; SC – Secondary Contact).

River Mile	Site ID	Location	Recr. Use	N	E. coli Geom. Mean	E. Coli Max.	Recrea-tion Status
		11-072 - Unnamed Trib to N Branch Sycamore Creek at RM 5.3					
0.75	LM65	RM 0.75	SC	1	194.0	194.0	FULL
		11-086 - UT (1.82) UT to Sycamore Cr. (1.12)					
0.40	LM54	RM 0.4	SC	1	30.0	30.0	FULL
		11-073 - Unnamed Trib to N Branch Sycamore Creek at RM 5.4					
0.60	LM63	Adj. Old Pfeiffer Rd. @ Ursuline H.S.	PCC	1	1120.0	1120.0	NON
		11-074 - Unnamed Trib to N Br Sycamore Cr at RM 0.75					
1.40	LM64	Ust. Bike path	SC	1	435.0	435.0	FULL
		11-049 - Trib To Sycamore Cr. (RM 1.12)					
0.90	LM55	Blome Rd.	PCB	1	125.0	125.0	FULL
0.20	LM56	Ust. Loveland Maderia Rd. Ust. OEPA site	PCB	2	133.7	365.0	FULL
0.10	LM53	at confluence of Sycamore Creek	PCB	1	93.0	93.0	FULL
		WAU 13-05 – East Fork Little Miami River					
		11-100 - East Fork Little Miami River					
19.50	LM25	Dst. E. Fork Lake @ end of Elklick Rd.	PCA	17	22.6	1553.0	FULL
14.90	LM26	Ust. Hwy 222	PCA	9	141.2	411.0	NON
13.70	LM27	RM 13.7	PCA	16	151.2	700.0	NON
12.90	LM28	Clermont Co. Parks Building Adj. Hwy 222	PCA	9	389.9	1300.0	NON
11.00	LM29	Ust. Pull off @ Patchell Rd & Highway 222	PCA	9	233.4	1300.0	NON
9.00	LM30	Stonelick Rd.	PCA	17	150.9	2420.0	NON
5.60	LM31	Ust. SR 50; Ust. Clermont Co. WWTP	PCA	16	230.0	4000.0	NON
4.30	LM32	Dst. Clermont Co. WWTP	PCA	8	212.8	2420.0	NON
2.00	LM34	at SR 131 extension	PCA	8	180.3	980.0	NON
1.00	LM35	Dst. Milford WWTP	PCA	8	202.6	866.0	NON
0.70	LM36	Dst. S. Milford Rd.	PCA	16	321.7	5500.0	NON
		WAU 14-05 – Dry Run					
		11-005 - Dry Run					
5.50	LM70	Clough Pike	SC	1	2420.0	2420.0	NON
4.10	LM66	Ust. 8 Mile Rd.	PCC	2	315.6	579.0	NON
2.50	LM67	Dst. Batavia Pike	PCC	2	428.1	980.0	NON
		11-064 - Trib to Dry Run (4.20)					
0.10	LM69	RM 0.1	SC	1	326.0	326.0	FULL
		WAU 14-04 Duck Creek					
		11-004 - Duck Creek					
6.00	LM71	at Duck Creek Rd. (upstream)	SC	2	2192.3	2420.0	NON
5.20	LM78	adj. 562 and I-71	SC	8	1700.0	2420.0	NON
4.60	LM72	Dst. Duck Creek Rd.	SC	2	572.0	1203.0	FULL
4.40	LM73	Ust. Madison Rd.	SC	8	667.3	2420.0	FULL
3.30	LM75	at Erie Ave.	SC	8	336.7	2420.0	FULL
2.30	LM76	RM 2.3	PCB	8	585.8	2420.0	NON
1.80	LM77	at Power St.	PCB	8	535.4	2420.0	NON
0.90	LM79	RM 0.9	PCB	7	756.5	2420.0	NON
		11-051 - East Fork Duck Creek					
0.15	LM74	Dst. CSO 71 and 66	PCC	7	1058.0	2420.0	NON
1.50	LM85	Stewart Ave. across from BMW dealer	PCC	1	186.0	186.0	FULL
0.50	LM84	adj. Red Bank Rd. behind School	PCC	1	411.0	411.0	NON
		11-075 - Unnamed Trib to Duck Creek at RM 4.8					
0.10	LM80	Kennedy Ave.	SC	2	1849.8	2420.0	NON

Table 6. Bacteriological (E. coli) sampling results in the Little Miami River study area during 2011. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow (PC – Primary Contact; SC – Secondary Contact).

River Mile	Site ID	Location	Recr. Use	N	E. coli Geom. Mean	E. Coli Max.	Recrea-tion Status
		11-076 - Little Duck Creek					
2.70	LM86	at Madison Rd.	SC	1	276.0	276.0	FULL
2.60	LM87	at Plainville Rd.	SC	1	228.0	228.0	FULL
2.30	LM90	Settle Rd.	SC	2	393.7	866.0	FULL
1.70	LM88	RM 1.7	SC	2	417.1	1553.0	FULL
1.30	LM89	Watterson Rd.	PCC	2	449.9	816.0	NON
0.20	LM92	RM 0.2	PCC	2	624.2	2420.0	NON
11-077 - Unnamed Trib to Little Duck Creek at RM 4.42							
0.10	LM82	RM 0.1	SC	2	685.2	2420.0	FULL
		WAU 14-06 – Clough Run					
		11-002 - Clough Creek					
4.60	LM99	at Wolfangle Rd.	SC	1	161.0	161.0	FULL
3.20	LM95	upstream bridge at Clough Pike	PCC	2	106.2	179.0	FULL
1.20	LM97	behind maple farm off Clough Pike	PCB	3	435.9	1300.0	NON
0.40	LM98	Elstun Rd and Beechmont Ave.	PCB	3	337.9	2420.0	NON
		11-003 - McCullough Run					
1.30	LM94	at US32 across from sod farm and soccer field	PCC	1	60.0	60.0	FULL
1.40	LM93	Ragland Rd.	PCC	1	2420.0	2420.0	NON
		11-079 - Trib to Unnamed Trib to Clough Creek at RM3.06					
1.00	LM101	Paddison Rd.	PCC	1	214.0	214.0	FULL
		11-080 - UT at RM 0.66 to UT to Clough Creek at RM 3.06					
0.20	LM102	RM 0.2	SC	1	185.0	185.0	FULL
		11-081 - UT at RM 0.95 to UT to Clough Creek at RM 3.06					
0.10	LM100	Robinway Dr.	PCC	1	179.0	179.0	FULL
		WAU – 12-08 Five Mile Creek					
		10-001 - Five Mile Creek					
2.40	LM107	adj. 5 Mile Rd.	PCC	1	45.0	45.0	FULL
0.10	LM108	Dst. SR 52 on Ramp	PCC	4	527.4	2420.0	NON
		10-002 - Eight Mile Creek					
2.00	LM105	Greenleaf Dr.	SC	4	256.0	435.0	FULL
0.70	LM104	Ust. 4 mile Rd.	PCC	4	453.1	1733.0	NON
		WAU 08-03 – Reference Sites (Turtle Creek)					
		11-021 - Turtle Creek					
6.10	RF08	at Glosser Rd.	PCB	7	129.4	291.0	FULL
		11-022 - Dry Run					
1.80	RF09	at Township Rd. 82	PCB	7	304.2	1046.0	NON
		11-030 - Newman Run					
0.30	RF10	RM 0.3	PCB	6	119.5	2420.0	FULL

Ohio Recreation Use *E. coli* criteria: PCA - 126 cfu/100 ml; PCB - 161 cfu/100 ml; PCC - 206 cfu/100 ml; SC - 1030 cfu/100 ml.

Plots of individual sample results of *E. coli* counts in the lower Little Miami mainstem illustrates the high frequency of exceedances of the PCA criterion of 126 MPN (Most Probable Number) in 2011 (MSDGC monthly stations) and from the 2012 survey (Figures 4A and 4B). This appeared to be more than what was observed by Ohio EPA in 2007, although the frequency of sampling was lower in 2007. Nevertheless, the observed increases in counts of *E. coli* provides another line of evidence that organic enrichment may have been elevated in recent years compared to 2007.

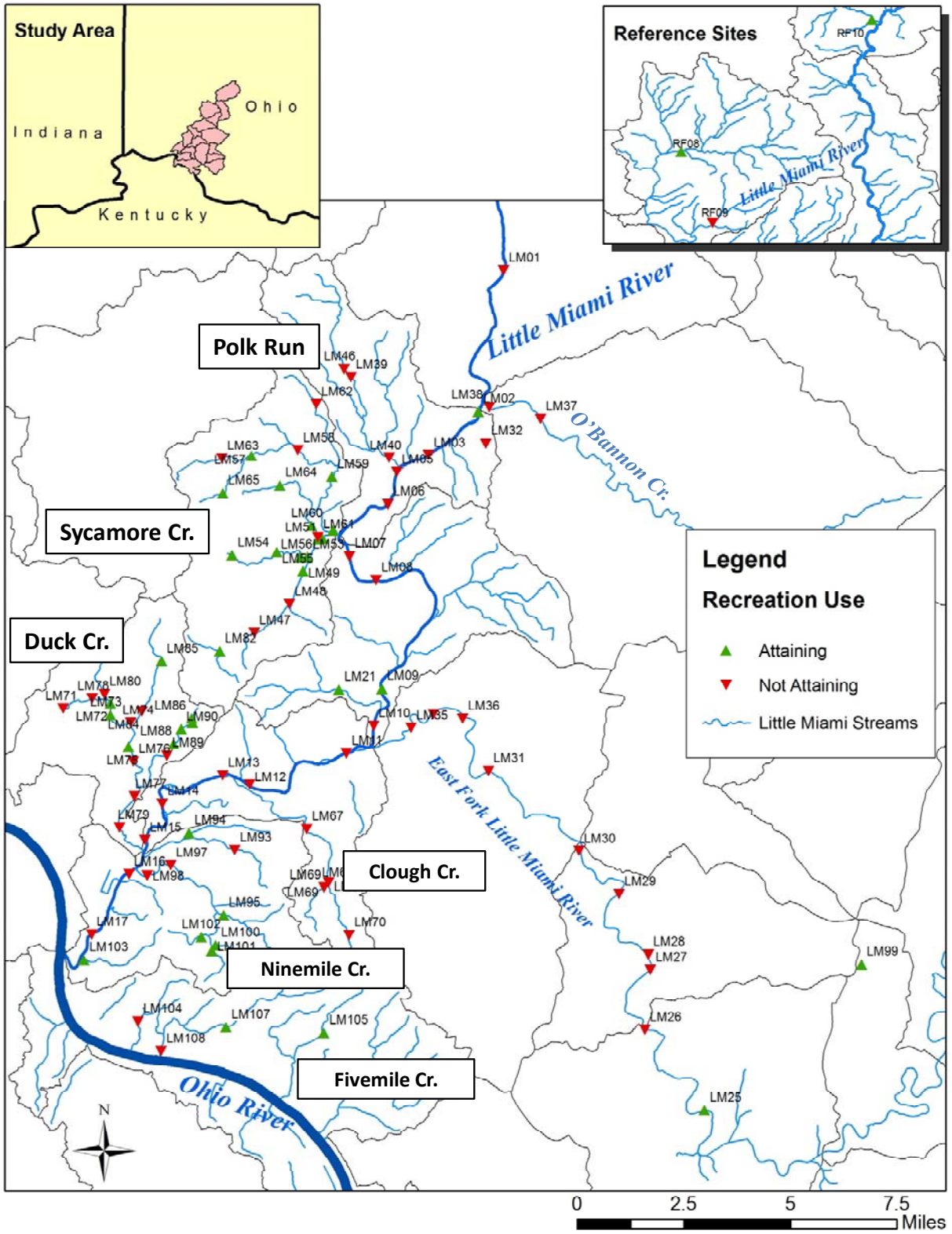

Figure 4A. Recreational use attainment status for the Primary Contact suite of use tiers in the Little Miami River study area during 2012 expressed as attainment (blue) or non-attainment (red) based on E. coli values. Site codes correspond to those described in Table 5 of the study area description.

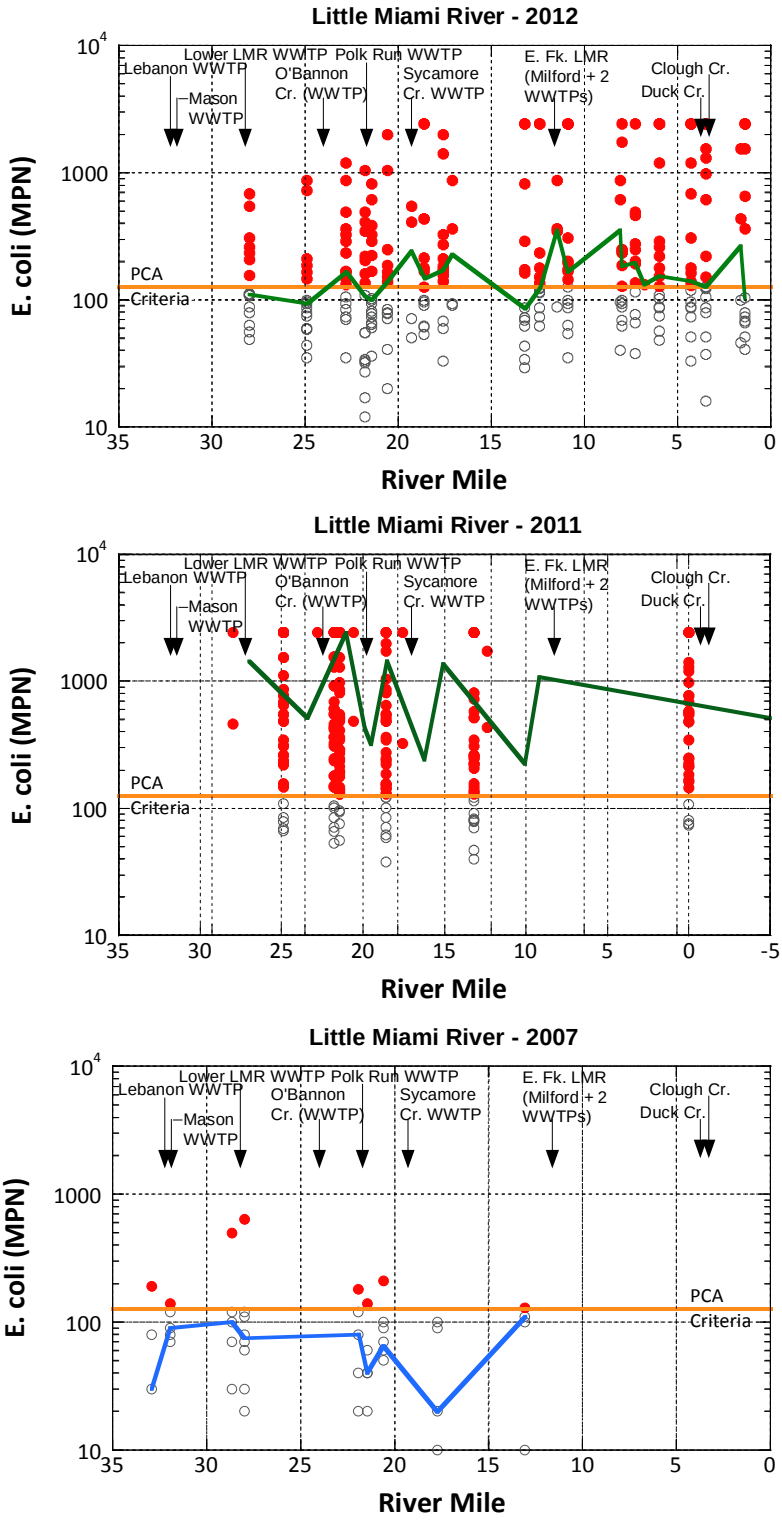

Figure 4B. E. coli (MPN) vs. river mile for the lower 35 miles of the Little Miami river during 2012 (top), 2011 (middle) and 2007 (bottom). Lines on each graph represent median values at each site.

WAU 09-02 – O'Bannon Creek

The E. coli criteria (PCB) was exceeded at both of the sites on O'Bannon Creek, but counts were higher downstream of the O'Bannon WWTP. The upstream site is about 29% forested with the other land use including agricultural and scattered residential uses. The *E. coli* geometric mean criteria were not exceeded at similar sites sampled by Ohio EPA during 2007 and 2008 although the maximum value was elevated at the downstream site during 2008.

WAU 14-01 – Polk Run

All three sites sampled in Polk Run exceeded the PCC or PCB criteria for *E. coli.* Most of the Polk Run watershed is heavily residential and subject substantial urban runoff. Ohio EPA did not sample Polk Run for E. coli during the 2007 survey.

WAU 14-01 – Sycamore Creek

Sycamore Creek exceeded the PCB or PCC criteria for *E. coli* at two of the six stations in the headwater area and at two of the five stations on the North Fork of Sycamore Creek. Of the six smaller tributaries with limited sampling (Table 4), only two of the sites (LM62, SC and LM63, PCC) exceeded their PCC or SC criteria. The lower two sites did not exceed the PCB criteria during 2012 or during the Ohio EPA survey during 2007. Bacteria were highest in the headwater reaches with chemical signatures of urban runoff (e.g., conductivity, chlorides).

WAU 13-05 – East Fork Little Miami River

The East Fork Little Miami is classified as PCA because of the high ecological quality and recreation use of the river. It had exceedances of the *E. coli* criteria at all but the site immediately downstream of the reservoir as well as exceedances of the single maximum target at all sites. Only the downstream-most site was sampled during 2007 and 2008 and it attaining the PCA use, but exceeded the criteria in 2008.

WAU 14-05 – Dry Run

All of the sites on Dry Run had elevated *E. coli* levels, but sites only had 1-2 samples. A small tributary that confluences at RM 4.2 did not exceed its SC criterion. Dry Run was not sampled by Ohio EPA in 2007/8.

WAU 14-04 – Duck Creek

The Duck Creek watershed is most heavily urban impacted watershed in the lower Little Miami River and has a substantial number of SSO and CSO discharge points. In addition, large portions of Duck Creek are concrete-lined channels. Upstream of RM 2.9 Duck Creek has been classified as a Limited Resource Water use and is also a Secondary Contact recreation use. The upper most sites on Duck Creek (LM71 and LM 78) have an impaired SC recreation use and all of the lower PCB sites are impaired as well. All sites in the stream had counts higher than the single maximum target of 1030 MPN. The tributaries to Duck Creek showed some scattered exceedances, but sites had only 1-2 samples (Table 6). Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the Duck Creek watershed are likely related to CSOs, SSOs, urban runoff, and aged and deteriorating sewage collection systems in the older urban areas.

WAU 14-06 – Clough Creek
On the basis of 1-3 samples per station, the streams in the Clough Creek watershed had exceedances of the *E. coli* criteria at 3 of 9 samples and exceed the single maximum target at 3 of 9 sites. The highest values are associated with the presence of CSOs.

WAU 12-08 – Nine Mile Creek
Two of the four sites in the Nine Mile Creek watershed (LM108, Five Mile Creek at RM 0.2 and LM104, Four Mile Creek at RM 0.9 had exceedances of the *E. coli* criteria (PCC). The upstream site on Five Mile Creek (LM107) and the site on Eight Mile Creek (LM105, SC) did not exceed the criteria.

WAU 08-03 – Turtle Creek/Reference Sites.
The *E. coli* criterion (PCB) was exceeded at one of the three reference sites (Dry Run, RF09). Although these are reference sites (i.e., least impacted) and Dry Run has about 37% forest, it also has agricultural land uses that likely contribute to the elevated *E. coli* levels.

Biological and Water Quality Study of the Little Miami River and Tributaries 2012

INTRODUCTION

The Midwest Biodiversity Institute (MBI) is under contract to the Metropolitan Sewer District of Greater Cincinnati (MSDGC) to develop and execute a watershed-based monitoring and biological assessment plan for the MSDGC service area within Hamilton County, Ohio. The plan was developed in 2010-11 and it is based on a four-year rotating watershed sequence (MBI 2011). The spatial and temporal sampling design and the biological, chemical, and physical indicators and parameters that are to be collected at each sampling site are described in the plan. Biological sampling methods for fish and macroinvertebrate assemblages and habitat assessment are supported by chemical and physical measures and ancillary information about pollution sources and other stressors for the overall biological assessment. The plan is intended to guide the development of detailed study plans for annual field work and subsequent data analysis and reporting during 2011-14 and to assist MSDGC in its capital planning. The spatial sampling design employs a combination of a geometric (stratified-random) and targeted-intensive pollution surveys. This design helps to fulfill multiple management purposes and goals in addition to the determination of the status of the biological assemblages and their relationship to chemical, physical, and biological stressors. As such, the principles of adequate monitoring (ITFM 1995; Yoder 1998) were employed in anticipation that the resulting biological assessments will be used to support the development of cost-effective watershed management responses to existing and emerging issues.

Principles of Watershed Bioassessment

Monitoring should address the relevant scale(s) at which management is applied. This can range from site-specific investigations of individual streams up to watershed scale assessments of condition. Such monitoring programs are constructed so that the baseline data and information supports assessments at the *same scale at which management is applied.* The specific designs, indicators, and assessment tools used must be tailored to the regional peculiarities in climate, soils, land use, geology, ecological resources (flora and fauna), socioeconomic influences, and geography. Thus the indicators that are used need to be sufficiently developed and calibrated to reflect these influences and at the scale at which management is being planned and conducted. In general monitoring objectives usually include:

- defining status and trends;
- identification of existing and emerging problems;
- support of water quality management policy and program development;
- evaluating management program effectiveness;
- responding to emergencies, and
- continued development and improvement of the understanding of the basic chemical, physical, and biological processes that affect environmental quality.

Effective monitoring and, by extension, water quality management programs, require a supporting infrastructure in terms of personnel and logistical support to carry out monitoring from a "cost-of-doing-business" standpoint. This means that monitoring resources must be tailored to meet the management needs of the statewide, regional, or local scale through space and time. It is under these principles that the watershed bioassessment program initiated by MSDGC is being conducted.

MSDGC intends to use the results and analysis of the monitoring and bioassessment program to accomplish the following:

1. Determine the status of service area rivers and streams in quantitative terms, i.e., not only if the waterbody is impaired but the spatial extent and severity of the impairment;
2. Evaluate the appropriateness of existing aquatic life and recreational use designations and make recommendations for any changes to those designations;
3. Determine the proximate stressors that contribute to the observed impairments for the purpose of targeting management actions to those stressors; and,
4. Develop an IPS following the example of that developed for the DuPage River Salt Creek Working Group (DRSCWG; Miltner et al. 2010). This will produce a quantitative model that yields restoration actions focused on parameters and stressors that will most likely result in improved aquatic resource condition and water quality. It is intended to assist MSDGC in making decisions about how to prioritize pollution abatement projects.

To meet objectives 1 and 2 above the assessments will need to be based on data generated by methods and implementation must be in conformance with the provisions of the Ohio Credible Data Law (ORC 6111.51). Under the regulations that govern the Credible Data program at Ohio EPA, all data and analyses must be collected and performed under the direction of Level 3 Qualified Data Collectors (OAC 3745-4). MSDGC intends to use the data to evaluate the attainability of aquatic life and recreational uses and determine the status of service area rivers and streams. As such, the sampling and analysis of the biological and physical condition conducted herein conforms to these provisions by the development and submittal of annual Level 3 Project Study Plans (PSP).

MSDGC Watershed Bioassessment Scope and Purposes

The MSDGC project study area consists of eleven subwatersheds and the Ohio River mainstem within Hamilton County and parts of adjoining counties. These watersheds are impacted by a variety of stressors including municipal and industrial point source discharges of wastewater, habitat modifications in the form of modified stream channels, run-of-river low head dams, riparian encroachment, and channelization, and nonpoint source runoff from widely differing degrees of landscape modifications from rural to suburban to intensive urban development. The urban impact gradient is the strongest in Lower and Middle Mill Creek watersheds lessening somewhat across the Little Miami and Great Miami River subwatersheds. CSOs are the most numerous in the Mill Creek watershed and adjacent Little Miami River tributaries (i.e., Duck Creek) and some have subsumed historical streams.

2012 Little Miami River Watershed Assessment Scope and Purpose

The 2012 Little Miami River watersheds assessment included 4 of the 11 subwatersheds that are part of the overall MSDGC service area watershed monitoring plan (MBI 2011). This included the lower 25 miles of the mainstem of the Little Miami River, the East Fork of the Little Miami River below the Harsha Reservoir, and tributaries to the Little Miami River in Hamilton Co. and the fringes of adjoining counties. In addition to the baseline purposes of the MSDGC service area monitoring plan, specific assessment issues in Little Miami River watersheds included a high density of CSO outfalls in the Duck Creek watershed, major wastewater treatment plants on the Little Miami and East Fork mainstems, and developing suburban areas throughout the watershed study area. The issue of PHWH streams was also included in the survey design.

Cincinnati has the fifth highest volume of CSO in the U.S. (MSDGC 2011a) As a result, water quality has been significantly impacted in parts of the Little Miami River watersheds. MSDGC is working to remediate these issues under a consent decree with the U.S. Dept. of Justice and U.S. EPA to reduce CSO volume by 2 billion gallons by 2018. To resolve the public health and water quality issues, MSDGC has implemented Project Groundwork, a multi-year and multi-billion dollar initiative that includes hundreds of sewer improvements and stormwater control projects (MSDGC 2011a). The role of the watershed monitoring program is to support these initiatives by providing current information about baseline conditions, provide feedback about the effectiveness of new and past remediation efforts, and to assure that restoration resources are targeted to the actions and places that have the greatest return on investment. As such the 2012 Little Miami River watersheds assessment is the first step in that process.

The Little Miami River 2012 watershed monitoring is also being used to fulfill MSDGC National Pollution Discharge Elimination System (NPDES) permit reporting requirements. Part II, G. "Instream Monitoring" of the MSDGC CSO NPDES permit states the following:

"G. Instream Monitoring

> *As required by NPDES permit 1PX00022*AD, the permittee conducted instream studies to evaluate the chemical specific and biological impacts associated with combined sewer overflows in its Little Miami River watersheds, Little Miami and Muddy Creek service areas. The permittee developed a plan of study for this monitoring in consultation with Ohio EPA. A series of letters between the permittee and Ohio EPA from February through June 1994 document the Agency's acceptance of the plan of study. The permittee conducted instream sampling in the Little Miami River watersheds service area during 1994, the Little Miami service area in 1995, and the Muddy Creek service area in 1996. As required by the NPDES permit, the permittee submitted reports in March of the following year for each service area. The permittee has continued the instream monitoring program for each service area on a three-year rotating schedule. It submitted the most recent report on the Little Miami service area in March 2008.*

During the term of this permit, the permittee shall continue this monitoring program by conducting instream chemical specific and biological monitoring as follows:

2008 Muddy Creek service area
2009 Little Miami River watersheds service area
2010 Little Miami service area
2011 Muddy Creek service area
2012 Little Miami River watersheds service area
2013 Little Miami service area

The permittee shall conduct the monitoring in accordance with the plan of study as it has been updated and maintained during the ongoing instream studies. Not later than March 1 of each year, the permittee shall submit a report to Ohio EPA Southwest District Office on the previous year's stream study."

The March 1 date has been changed to June 30 so that the annual watershed monitoring and assessment outlined in MBI (2011) can be used to support this reporting requirement. In addition MSDGC plans to include the subwatersheds in the Great Miami River basin in the rotational schedule for the chemical and biological sampling/reporting. Ohio EPA accepted both the June 30 reporting date and the inclusion of the GMR basin segments to the sequence of MSDGC watershed assessments.

METHODS

Watershed Assessment Design

The delineation of sampling locations for the MSDGC service area bioassessment followed a stepwise process (MBI 2011). This consisted of accounting for historical sampling locations of Ohio EPA and MSDGC and then filling gaps in that coverage to meet the goals of this project. Since the MSDGC service area is rich in current and historical Ohio EPA biological and chemical and MSDGC chemical sampling locations MBI delineated those sites first in the GIS coverage for the 11 subwatersheds. This was followed by a geometric draw that was then merged with the existing Ohio EPA and MSDGC sites. A total of eight drainage area "panels" were derived from the geometric draw starting at 164 mi^2 (the drainage area occupied by the Mill Creek subbasin) and subsequently halving each reduction to a drainage area of approximately 1.0 mi^2. Overlapping historical and geometric sites were then merged resulting in the first allocation of potential sampling sites. The geometric draw yielded the most unique "new" sites mostly at drainage areas less than 5-10 mi^2. The merged sites were then apportioned by each of the 11 subwatersheds in spreadsheets that include the site coordinates, the Ohio EPA basin and stream code, the Ohio EPA river mile, and our assignments of biological, chemical, and physical indicators and frequencies (MBI 2011). Additional targeted sites were added during a detailed study planning phase in order to position sites upstream and downstream from major discharges, sources of potential releases and contamination, and major physical modifications such as dams and to provide a "pollution profile" along the Little Miami River mainstem and the major tributaries. The result was a design that included chemical, physical, and biological sampling at a total of 108 sites in Little Miami River study area as a whole (Table 7). Each site was assigned a unique site code as depicted in Table 7 and Figure 5. An additional three reference sites outside of the Little Miami River study area were sampled as part of a network of 22 reference sites for the MSDGC service area.

Biological and Water Quality Surveys

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a water body specific or watershed scale. Biological, chemical, and physical monitoring and assessment techniques are employed in biosurveys to meet three major objectives:

1. Determine the extent to which use designations assigned in the state WQS or equivalent policies or procedures are either attained or not attained;
2. Determine if use designations and/or goals set for or 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.

Table 7. List of sampling locations and sample types for the 2012 Little Miami River watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites. Regional reference sites outside of Little Miami River study area that are sampled as part of the overall MSDGC four year monitoring plan are also included. Absolute location points with latitude-longitude values for macroinvertebrates, fish, chemical, and sediment sampling locations are listed in Appendix A-1 (Ust. – upstream; Dst. – downstream).

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
LRAU 90-02 – Little Miami River							
[11-001] - Little Miami River							
LM01	C, D, N, H, O, B, S,	HD, QL, FB	27.80 - 28.00	39.316360, -84.25214	1070	Dst. Old 3C highway	Mason
LM02	C, D, N, H, O, B, S,	HD, QL, FB	23.70 - 24.90	39.268770, -84.26057	1150	Dst. E. Loveland Ave.	Mason
LM03	C, D, N, H, O, B, S,	HD, QL, FB	22.10 - 22.80	39.257500, -84.27302	1150	Ust. Polk WWTP	Mason
LM04	C, D, N, H, O, B, S,	HD, QL, FB	21.70 - 21.80	39.250290, -84.28937	1150	Mixing Zone	Mason
LM05	C, D, N, H, O, B, S,	HD, QL, FB	21.25 - 21.45	39.246390, -84.29568	1160	Dst. Bridge St.	East Cincinnati
LM06	C, D, N, H, O, B, S,	HD, QL, FB	19.30 - 20.60	39.235340, -84.29900	1160	At Lake Isabella Canoe Launch	East Cincinnati
LM07	C, D, N, H, O, B, S,	HD, QL, FB	18.10 - 18.60	39.217090, -84.31494	1190	Adj. Glendale Milford Rd.	East Cincinnati
LM08	C, D, N, H, O, B, S,	HD, QL, FB	17.10 - 17.60	39.209420, -84.30300	1190	Adj. Kelly Nature Preserve	East Cincinnati
LM09	C, D, N, H, O, B, S,	HD, QL, FB	12.90 - 13.20	39.172780, -84.29861	1200	US 50 bridge	East Cincinnati
LM10	C, D, N, H, O, B, S,	HD, QL, FB	11.50 - 12.40	39.165260, -84.29910	1210	Ust. Confluence with E. Fork LMR	East Cincinnati
LM11	C, D, N, H, O, B, S,	HD, QL, FB	10.90 - 11.20	39.152510, -84.30492	1710	Dst. Confluence with E. Fork LMR	East Cincinnati
LM12	C, D, N, H, O, B, S,	QL, FB	8.00 - 8.30	39.136360, -84.34762	1710	At Bass Island Canoe Launch	East Cincinnati
LM13	C, D, N, H, O, B, S,	HD, QL, FB	6.80 - 7.30	39.141360, -84.36654	1720	Ust. RR bridge	East Cincinnati
LM14	C, D, N, H, O, B, S,	HD, QL, FB	5.30 - 6.00	39.133880, -84.38654	1720	Ust. Duck Cr./ Adj. Mariemont Gardens Park	East Cincinnati
LM15	C, D, N, H, O, B, S,	HD, QL, FB	4.00 - 4.30	39.121450, -84.39675	1730	At. Otto Armlender Park Canoe Launch	East Cincinnati

Table 7. Continued.

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
LM16	C, D, N, H, O, B, S,	HD, QL, FB	3.00 - 3.50	39.109430, -84.40178	1750	Beechmont Ave./ Clough Creek	East Cincinnati
LM17	C, D, N, H, O, B, DS	HD, QL, FB	1.40 - 1.60	39.085010, -84.42072	1760	at Kellogg Ave.	East Cincinnati
[11-082] - Unnamed Trib to Little Miami River at 24.06							
LM23	C, D, N, B	PHW	0.20	39.271500, -84.26401	1.6	adj. Kwanis Park	Mason
[11-083] - Unnamed Trib to Little Miami River at RM 21.82							
LM24		PHW	0.10	39.251550, -84.29015	0.8	Kemper Rd. at MSD	Mason
[11-085] - Unnamed Trib to Little Miami River at 13.8							
LM22	C, D, N, B	PHW	0.30	39.184500, -84.29354	1.2	Across road from Indian Hill Public Works; horse trail to Creek	East Cincinnati
[11-066] - Unnamed Trib to Little Miami River at RM 13.1							
LM21	C, D, N, H, O, B	QL, FHW	1.50	39.171670, -84.31737	3	At Red Bird Hollow	East Cincinnati
[11-068] - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River (RM13.1)							
LM19	C, D, N, B	QL, FHW	0.50	39.172180, -84.34544	0.6	Dst. Drake Rd.	East Cincinnati
[11-067] - Unnamed Trib to Little Miami River at RM 7.75							
LM20	C, D, N, O, B, S	QL, FHW, PHW	1.20	39.155060, -84.35799	0.5	At Walton Creek Rd.	East Cincinnati
[11-047] - Unnamed Trib to Little Miami River at RM 0.83							
LM103	C, D, N, O, B	QL, FHW, PHW	0.10 - 0.20	39.076260, -84.42218	1.7	dst. Kellogg Ave.	East Cincinnati
WAU 09-02 – O'Bannon Creek							
[11-010] - O'Bannon Creek (LMR RM 24.06)							
LM37	C, D, N, H, O, B, S,	FWD	1.80 - 1.90	39.264740, -84.23219	54.3	at O'Bannon Creek Rd.	Morrow
LM38	C, D, N, H, O, B, S,	QL, FWD	0.10	39.269550, -84.25632	59	at Loveland Park	Mason
WAU 14-02 – Polk Run							
[11-009] - Polk Run (LMR RM 21.54)							
LM46	C, D, N, H, O, B, S	QL, FHW, PHW	3.20 - 3.90	39.280510, -84.31976	2.6	Ust. 7 Gables Rd.	Mason
LM39	C, D, N, H, O, B, S,	QL, FHW	2.90 - 3.10	39.277940, -84.31708	2.8	Dst. Montgomery Rd.	Mason
LM40	C, D, N, H, O, B, DS	HD, QL, FHW	0.30	39.251140, -84.29913	10	at East Kemper Rd.	Mason
[11-069] - Unnamed Trib to Polk Run at RM 1.79							
LM41	C, D, N, B	QL, FHW, PHW	2.50 - 2.60	39.289160, -84.33758	1.3	8073 School Rd.	Mason
LM44	C, D, N, B	QL, FHW, PHW	0.40	39.267800, -84.31475	2.4	adj. Old Creek Trail; Dst. Terwilliger Trail Rd.	Mason

Table 7. Continued

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
[11-070] - Unnamed Trib to Polk Run at RM 0.70							
LM42	C, D, N, B	QL, FHW, PHW	1.90 - 2.00	39.277160, -84.29975	0.8	Behind Conveyer System Manufacture (W. Loveland & Glen Lake Rd.)	Mason
LM43	C, D, N, B	QL, FHW, PHW	0.70 - 0.80	39.262120, -84.29613	2.5	Heartwood Ct. at abandon Rd.	Mason
[11-071] - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run							
LM45	C, D, N, B	QL, FHW, PHW	0.20	39.275880, -84.30340	1.1	behind CUSA plant off of Commercial Dr.	Mason
WAU 14-01 – Sycamore Creek							
[11-007] - Sycamore Creek (LMR RM 19.2)							
LM47	C, D, N, H, O, B, S,	QL, FHW	3.50 - 3.60	39.189410, -84.35679	3.4	Dst. Carmargo Rd.	East Cincinnati
LM48	C, D, N, H, O, B, S,	QL, FHW	2.40	39.200040, -84.34042	4.8	Ust. Kugler Mills Rd off Loveland Maderia Rd.	East Cincinnati
LM49	C, D, N, H, O, B, S,	HD, QL, FHW	1.50 - 1.60	39.211560, -84.33441	6.6	adj. Loveland Maderia Rd @ pull-off by trib	East Cincinnati
LM50	C, D, N, H, O, B, S,	FHW	0.70 - 1.10	39.216900, -84.33190	12.5	Ust. Spooky Hollow Rd.	East Cincinnati
LM51	C, D, N, H, O, B, S,	HD, QL, FWD	0.30 - 0.50	39.224890, -84.32351	22.8	Ust. Sycamore Creek WWTP outfall	East Cincinnati
LM52	C, D, N, H, O, B, S,	QL, FWD	0.10 - 0.20	39.225800, -84.32250	23.3	Dst. Sycamore Creek WWTP outfall	East Cincinnati
[11-008] - North Branch Sycamore Creek							
LM57	C, D, N, H, O, B, S	QL, FHW	5.00 - 5.20	39.249200, -84.36217	2.9	at Pfeiffer Rd.	Mason
LM58	C, D, N, H, O, B, S	QL, FHW	3.70 - 4.30	39.252640, -84.33923	4.4	behind Bethesda Hospital	Mason
LM59	C, D, N, H, O, B, S	QL, FHW	2.00 - 2.10	39.244340, -84.32349	7.3	Dst. Hopewell Rd.	East Cincinnati
LM60	C, D, N, H, O, B, S	HD, QL, FHW	0.40 - 0.50	39.228730, -84.33315	9.8	At SR 126	East Cincinnati
LM61	C, D, N, H, O, B, DS	HD, QL, FHW	0.05 - 0.10	39.222960, -84.32886	10	Ust. Loveland Maderia Rd.	East Cincinnati

Table 7. Continued

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
[11-049] - Trib To Sycamore Cr. (RM 1.12)							
LM55	C, D, N, O, B, S	QL, FHW	0.90 - 1.00	39.217700, -84.34671	5.3	Ust. Blome Rd.	East Cincinnati
LM56	C, D, N, H, O, B, S	QL, FHW	0.20 - 0.30	39.216300, -84.33630	5.6	Ust. Loveland Maderia Rd. Ust. OEPA site	East Cincinnati
LM53	C, D, N, B	HD, QL, FHW	0.10	39.216410, -84.33323	5.7	at confluence of Sycamore Creek	East Cincinnati
[11-072] - Unnamed Trib to N Branch Sycamore Creek at RM 5.3							
LM65	C, D, N, B	PHW	0.75 - 1.10	39.237130, -84.37125	0.2	Dst. Maple Dale Elementary School	East Cincinnati
[11-073] - Unnamed Trib to N Branch Sycamore Creek at RM 5.4							
LM63	C, D, N, B	QL, FHW, PHW	0.60	39.248880, -84.37217	1.1	Adj. Old Pfeiffer Rd. @ Ursuline H.S.	East Cincinnati
[11-077] - Unnamed Trib to Sycamore Creek at RM 4.42							
LM82	C, D, N, H, O, B	QL, PHW	0.10	39.183260, -84.37000	1.4	Behind baseball field.	East Cincinnati
[11-074] - Unnamed Trib to N Br Sycamore Cr at RM 0.75							
LM64	C, D, N, B	QL, FHW, PHW	1.40	39.240450, -84.34632	0.5	Ust. Bike path	East Cincinnati
[11-084] - Trib to North Branch Sycamore Creek at RM 2.33							
LM62	C, D, N, B	QL, FHW, PHW	1.65 - 1.80	39.269740, -84.33316	0.6	Cincinnati Christian Academy	Mason
[11-086] - Unnamed Trib (1.82) to Trib to Sycamore Creek (1.12)							
LM54	C, D, N, B	PHW	0.40	39.216060, -84.36608	1.6	behind house on Pepperell Rd.	East Cincinnati
WAU 13-05 – East Fork Little Miami River							
[11-100] - East Fork Little Miami River (LMR RM 11.5)							
LM25	C, D, N, H, O, B, DS	HD, QL, FWD	19.50	39.032860, -84.15144	344	Dst. E. Fork Lake @ end of Elklick Rd.	Batavia
LM26	C, D, N, H, O, B, DS	HD, QL, FWD	14.90 - 15.60	39.060050, -84.17868	352	Clermont Sportsman's Club	Batavia
LM27	C, D, N, H, O, B, DS	HD, QL, FWD	13.70 - 13.90	39.078100, -84.17963	364	Dst. Main St., Batavia	Batavia
LM28	C, D, N, H, O, B, DS	HD, QL, FWD	12.90 - 13.20	39.089300, -84.18619	372	Behind Clermont Co. Parks Building Adj. Hwy 222	Batavia

Table 7. Continued

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
LM29	C, D, N, H, O, B, DS	HD, QL, FWD	11.00 - 11.30	39.102080, -84.19579	376	Patchell Rd. and Hwy. 22	Batavia
LM30	C, D, N, H, O, B, DS	HD, QL, FWD	9.00 - 9.10	39.120390, -84.20888	380	Dst. Stonelick Rd.	Batavia
LM31	C, D, N, H, O, B, DS	HD, QL, FWD	5.60	39.145760, -84.25092	485	Ust. SR 50; Ust. Clermont Co. WWTP	East Cincinnati
LM32	C, D, N, H, O, B, S,	HD, QL, FWD	4.30	39.257260, -84.25720	491	Dst. Clermont Co. WWTP	Mason
LM34	C, D, N, H, O, B, S,	HD, QL, FB	2.00 - 2.10	39.163070, -84.27795	494	at. SR131 extension	East Cincinnati
LM35	C, D, N, H, O, B, S,	HD, QL, FB	1.00 - 1.60	39.163290, -84.28280	498	Dst. Milford WWTP	East Cincinnati
LM36	C, D, N, H, O, B, S,	HD, QL, FB	0.70	39.163290, -84.26286	499	Dst. S. Milford Rd.	East Cincinnati
WAU 14-05 – Dry Run							
[11-005] - Dry Run (LMR RM 7.54)							
LM70	C, D, N, O, B, S	QL, FHW, PHW	5.50 - 5.70	39.086330, -84.30877	0.7	Ust. Clough Pike	East Cincinnati
LM66	C, D, N, H, O, B, S	QL, FHW	4.10 - 4.20	39.105300, -84.31891	3.1	Ust. 8 Mile Rd.	East Cincinnati
LM67	C, D, N, H, O, B, S	QL, FHW	2.50	39.123760, -84.32921	4.7	Dst. Batavia Pike	East Cincinnati
LM68			0.60	39.136880, -84.35579	5.4	at Bass Island Park	East Cincinnati
[11-064] - Trib to Dry Run (4.20)							
LM69	C, D, N, B	QL, PHW	0.10 - 0.20	39.103280, -84.32314	0.9	Ust. 8-Mile Creek	East Cincinnati
[11-004] - Duck Creek (LMR RM 3.87)							
LM71	C, D, N, H, O, B, S	QL, FHW, PHW	6.00	39.161710, -84.43745	2.2	at Duck Creek Rd. (upstream)	East Cincinnati
LM78	C, D, N, H, O, B	QL, FHW, PHW	5.20 - 5.30	39.165000, -84.42643	3.2	Adj. SR I-71 N.	East Cincinnati
LM72	C, D, N, H, O, B, S,	QL, FHW	4.60 - 4.70	39.164790, -84.41734	5.1	Dst. Duck Creek Rd.	East Cincinnati
LM73	C, D, N, H, O, B, S	QL, FHW	4.40	39.160180, -84.41657	5.8	Ust. Madison Rd.	East Cincinnati
LM75	C, D, N, H, O, B, S	QL, FHW	3.30	39.149450, -84.40827	11.4	at Erie Ave.	East Cincinnati
LM76	C, D, N, H, O, B, S,	HD, QL, FHW	2.30 - 2.90	39.144570, -84.40589	11.8	adj. Red Bank Rd.	East Cincinnati
LM77	C, D, N, H, O, B, S,	QL, FHW	1.80	39.132570, -84.40484	14.3	at Power St.	East Cincinnati
LM91	O, S		1.00	39.123530, -84.41154	14.5	Linwood Park	East Cincinnati
LM79	C, D, N, H, O, B, DS	QL	0.90	39.121900, -84.41085	14.6	at Wooster Pike	East Cincinnati
[11-051] - East Fork Duck Creek							
LM81		FHW, PHW	2.30 - 6.10	39.187090, -84.40059	0.3	4016 Plainfield Rd.	East Cincinnati

Table 7. continued

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
LM85	C, D, N, H, B	QL, FHW, PHW	1.50 - 1.90	39.178640, -84.39526	1.5	Stewart Ave. across from BMW dealer	East Cincinnati
LM84	C, D, N, H, B, DS	QL, FHW, PHW	0.50 - 0.60	39.162630, -84.40243	2.3	adj. Red Bank Rd.	East Cincinnati
LM74	C, D, N, H, O, B, S,	QL, FHW, PHW	0.15 - 0.20	39.158850, -84.40648	3.4	Dst. CSO 71 and 66	East Cincinnati
[11-075] - Unnamed Trib to Duck Creek at RM 4.8							
LM83		PHW	0.80	39.174040, -84.42355	1.2	Ust. Home Depot	East Cincinnati
LM80	C, D, N, H, O, B	QL, FHW, PHW	0.10 - 0.20	39.167100, -84.41972	1.4	Dst. Kennedy Ave.	East Cincinnati
[11-076] - Little Duck Creek							
LM86	C, D, N, H, B	QL, FHW, PHW	2.70	39.160030, -84.38106	0.4	at Madison Rd.	East Cincinnati
LM87	C, D, N, H, B	QL, FHW, PHW	2.60	39.158430, -84.38071	0.5	at Plainville Rd.	East Cincinnati
LM90	C, D, N, H, O, B	QL, FHW, PHW	2.30 - 2.40	39.156390, -84.38515	0.5	at Settle Rd.	East Cincinnati
LM88	C, D, N, H, O, B	PHW	1.70 - 1.80	39.151000, -84.38855	0.8	at Bramble Rd.	East Cincinnati
LM89	C, D, N, H, O, B	QL, FHW, PHW	1.30 - 1.40	39.147010, -84.39137	1.1	at Watterson Rd.	East Cincinnati
LM92	C, D, N, H, B		0.20	39.135860, -84.40015	1.7	at Wooster Pike	East Cincinnati
WAU 14-06 Clough Creek							
[11-003] - McCullough Run (LMR RM 3.7)							
LM94	C, D, N, B	QL, FHW, PHW	1.30	39.120980, -84.38039	1.7	at US32 across from sod farm and soccer field	East Cincinnati
LM93	C, D, N, B	QL, FHW, PHW	1.40 - 1.60	39.115660, -84.35649	0.8	at Ragland Rd.	East Cincinnati
[11-002] - Clough Creek (LMR RM 3.36)							
LM99	C, D, N, H, O, B, DS	QL, FHW, PHW	4.60	39.084350, -84.08518	0.9	at Wolfangle Rd.	Batavia
LM95	C, D, N, H, O, B, DS	QL, FHW, PHW	3.20	39.093450, -84.36401	2	upstream bridge at Clough Pike	East Cincinnati
LM96	C, D, N, H, O, B, DS	QL, FHW, PHW	3.00 - 3.10	39.095340, -84.36769	5.4	Ust. Berkshire Rd. bridge	East Cincinnati
LM97	C, D, N, H, O, B, DS	HD, QL, FHW	1.20	39.109550, -84.38788	7.5	behind maple farm off Clough Pike	East Cincinnati
LM98	C, D, N, H, O, B, DS	QL, FHW	0.40 - 0.60	39.105810, -84.39481	7.8	at Elstun Rd and Beechmont Ave.	East Cincinnati
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06							
LM101	C, D, N, O, B, S	QL, FHW, PHW	1.00 - 1.05	39.081010, -84.36864	0.7	at Paddison Rd.	East Cincinnati

Table 7. Continued

Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^2)	Location Description	USGS QUAD
[11-080] - UT at RM 0.66 to UT to Clough Creek at RM 3.06							
LM102	C, D, N, O, B	QL, PHW	0.20 - 0.60	39.085840, -84.37257	1.1	Ust. Berkshire Rd.	East Cincinnati
[11-081] - UT at RM 0.95 to UT to Clough Creek at RM 3.06							
LM100	C, D, N, O, B	QL, FHW, PHW	0.10 - 0.20	39.082790, -84.36616	0.9	Ust. Robinway Dr.	East Cincinnati
WAU 12-08 Five Mile Creek – Ohio River							
[10-001] - Five Mile Creek							
LM107	C, D, N, H, O, B, DS	QL, FHW, PHW	2.40 - 2.90	39.095980, -84.36810	2.3	at 5-Mile Rd.	East Cincinnati
LM108	C, D, N, H, O, B, DS	QL, FHW	0.10 - 0.20	39.049300, -84.38827	4.7	Dst. SR 52 on Ramp	East Cincinnati
LM105	C, D, N, H, O, B, DS	QL, FHW, PHW	2.00 - 2.10	39.055180, -84.31911	0.8	behind 8456 Greenleaf Dr.	East Cincinnati
[10-130] - Trib to Eight Mile Creek at RM 1.01							
LM106	C, D, N, B	QL, FHW, PHW	0.10	39.045770, -84.33173	1.1	Ust. 8 Mile Rd.	East Cincinnati
[10-537] - Four Mile Creek							
LM104	C, D, N, H, O, B, DS	QL, FHW, PHW	0.70 - 0.90	39.057910, -84.39752	1.1	Ust. 4-Mile Rd.	East Cincinnati
WAU 08-03 Turtle Creek							
[11-021] - Turtle Creek							
RF08	C, D, N, H, O, B, DS	FHW	6.10 - 6.80	39.431380, -84.22480	22.5	at Glosser Rd.	Morrow
[11-022] - Dry Run							
RF09	C, D, N, H, O, B, DS	FHW	1.80	39.383790, -84.20396	4.9	at Township Rd. 82	Morrow
[11-030] - Newman Run							
RF10	C, D, N, H, O, B, DS	0.30	39.518420, -84.09859	9.5	at S. Cincinnati Columbus Rd.	Waynesville	RF10

HD= macroinvertebrate artificial substrate; QL – macroinvertebrate qualitative; FH = fish headwater; FW = fish wading; FB – fish boat; C= conventional water chemistry; D= demand; N= nutrients; H= heavy metals; O= organics water chemistry; B= bacterial; S= sediment chemistry; DS= Datasonde; PHW= primary headwater

[1]= fish and macroinvertebrates sampled by EnviroScience Inc.

The data gathered in a biosurvey is processed, evaluated, and synthesized in one of several assessment reports or outputs. This can range from a comprehensive, integrated watershed report to summaries compiled for state 305(b) reporting and extended products (e.g., 303[d] lists). Each assessment also addresses recommendations for revisions to WQS, future monitoring needs, problem discovery, or other actions which may be needed to resolve impairments of or threats to 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 may also be addressed.

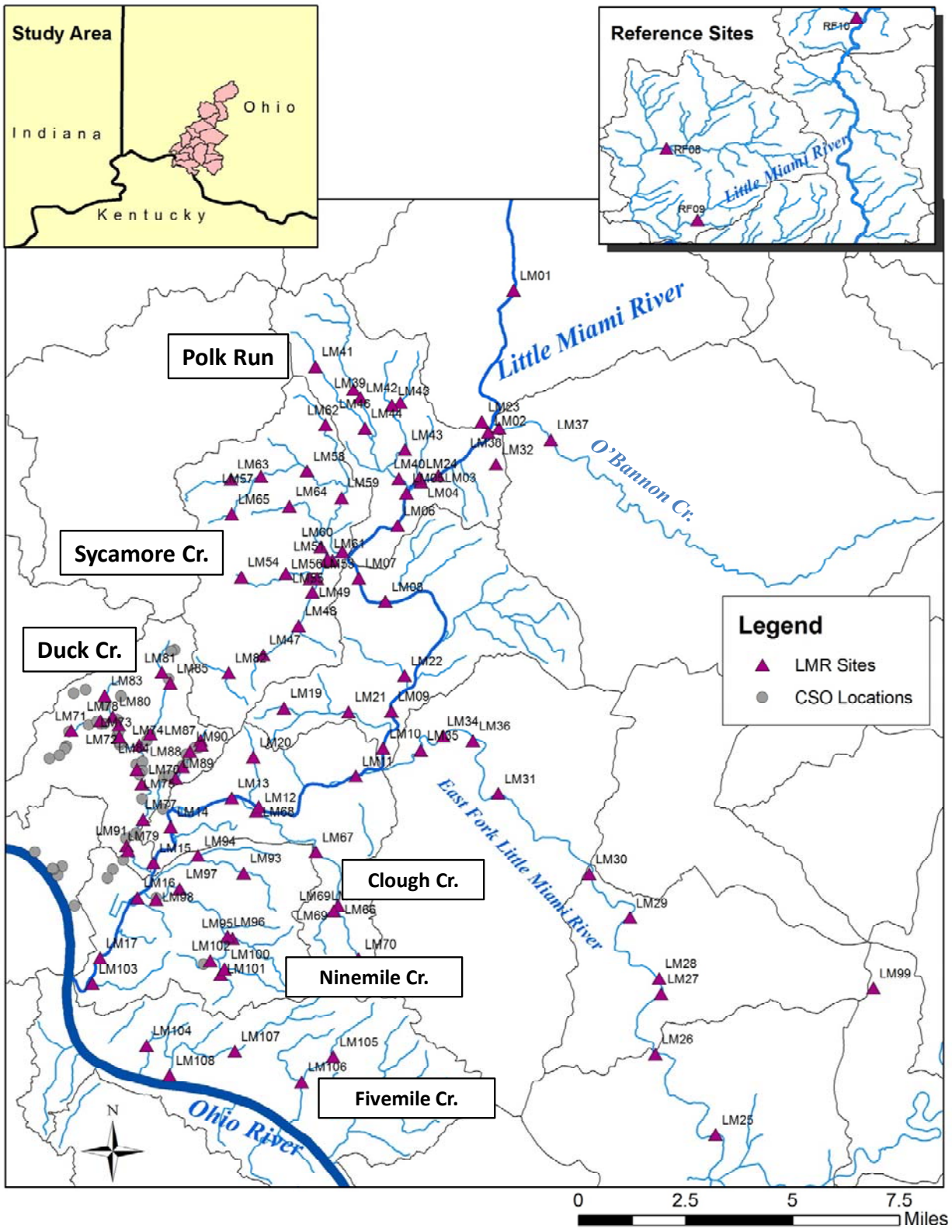

Figure 5. Map of the 2012 Little Miami River study area showing biological, chemical, and physical sampling locations (◢) with the site code, locations of wastewater discharges, and locations of CSOs. The MSDGC service area appears in the study area inset (lower right).

Functional support provided by individual basin assessments for specific water quality management activities includes the 305(b) reporting process, TMDLs/303(d) listing, revising water quality standards (i.e., use designations, criteria refinements and modifications), and NPDES permit support. Support is also provided for other management issues including site-specific 404/401 reviews, 319 projects, and enforcement actions. A positive consequence of this type of sustained, routine, and standardized effort is a database and informational resource, which supports ongoing water quality management efforts in the aggregate. This includes the development of new and improved assessment tools, improved and refined criteria, indicators development and use, concepts, policies, and rules. The critical concept is that by doing the level of monitoring and assessment that is required by the rotating basin approach, the basic informational infrastructure needed to support the entirety of water quality management is in place when the need for such support is realized. This demonstrates how this type of sustained approach is inherently anticipatory. This type of monitoring and assessment is essential to maintaining and improving the overall water quality management process.

Monitoring Networks and Design

Adequate monitoring employs a stepwise approach to the selection and use of the variety of chemical, physical, and biological indicators and measures that are currently available. The decision(s) about which indicators and parameters to use are based on:

1. The type of aquatic resource being assessed (*i.e.,* headwater stream, wadeable stream, non-wadeable large river, lake or reservoir, wetland, etc.);
2. The environmental complexity of the setting (includes consideration of all potential stressors); and,
3. The water quality management objectives and purposes that are at issue.

For example, in a small, headwater stream with only one or two potential stressors, the two biological organism groups may be assessed using a relatively rapid bioassessment protocol accompanied by a *qualitative* habitat assessment, and comparatively limited chemical water quality sampling analyzing for field, demand, and nutrient series parameters. A relative few (e.g., 2-3) sampling sites would suffice and the field sampling would be completed in the matter of a few hours with one visit for biology and habitat and 1-3 samples for chemical/physical parameters. The resulting assessment could be turned around in a matter of a few days if necessary. In more complex watershed settings with multiple management issues, multiple and complex stressors, and the potential for the discovery of unknown and undocumented sources, the cumulative sampling requirements are more intensive, but may include many of the preceding example within a watershed. In addition, the bioassessment protocols are tailored to the resource that now includes mainstem rivers and streams. The accompanying habitat assessment remains much the same, but chemical water quality sampling includes more intensive and frequent sampling for heavy metals, other selected toxics, and organic scans of both the water column and bottom sediments. Continuous monitoring of temperature and D.O. would also be included in complex settings. The density and distribution of sampling sites would be in proportion to the size of the watershed and would also consider the location and

entry of potential stressors into the aquatic ecosystem. A systematic sampling effort spans a summer-fall index period (mid-June through mid-October), requiring many sampling days and multiple field crews to complete. Data analysis and reporting culminate in the production of a comprehensive assessment months after the sampling is completed. This ensures that the careful analysis of multiple indicators and assignments of causes and sources is performed in accordance with sound indicator practice and procedures.

A key issue within watershed assessment is the selection of spatial and temporal monitoring designs. It is now widely recognized that fixed station designs that were once the mainstay of State monitoring programs are simply insufficient to meet the previously stated program objectives. However, this is not to conclude that fixed stations do not have an appropriate role in a monitoring program. Simply stated, they are *alone* insufficient to support management decision-making at the local watershed scale. Selecting information-effective spatial monitoring designs is a critical step in the process of developing an adequate watershed monitoring program.

A relatively new design that has recently been implemented in Ohio is termed the Geometric Site Selection process - it is used as part of the statewide five-year rotating basin approach (Ohio EPA 1999). This design is employed within watersheds that correspond to the 10-12 digit HUC scale in order to fulfill multiple water quality management objectives in addition to the conventional focus on status assessment. It is employed at a spatial scale that is representative of the scale at which watershed management is generally being conducted. In the Midwestern U.S., most HUC 10 watersheds drain approximately 150-300 mi^2. Sites within a watershed of this size are allocated based on a geometric progression of drainage areas starting with the area at the mouth of the mainstem river or stream and working “upwards” through the various tributaries to the primary headwaters (Figure 3). This approach allocates sampling sites in a semi-random fashion and according to the stratification of available stream and river sizes based on drainage area. It is then supplemented by a targeted selection of additional sampling sites that are used to focus on localized management issues such as point source discharges, habitat modifications, and other potential impacts within a watershed.

This design also fosters data analysis that takes into consideration overlying natural and human caused influences within the streams of a watershed. The example in Figure 3 also demonstrates the multiple management issues that are supported including the proportionate assessment of the member streams and rivers, applying tiered designated uses for aquatic life, the development of TMDLs that include the inter-relationships of both pollutant and non-pollutant stressors, and the development of a comprehensive spatially representative database through time. Other benefits of this design include the application of cost-effective sampling methods on a watershed scale, development of a stratified database, and the enhanced ability to capture previously unassessed streams. The design has been particularly useful for watersheds that are targeted for total maximum daily load (TMDL) development in that unassessed waters and incomplete or outdated assessments can be addressed prior to TMDL development.

The delineation of recommended sampling locations of the MSDGC watershed bioassessment was developed following a stepwise process. Since the MSDGC service area is fairly rich in current and historical Ohio EPA biological and chemical and MSDGC chemical sampling locations MBI delineated those sites first in the GIS coverage for the 11 subwatersheds. This was followed by a geometric draw that was then merged with the existing Ohio EPA and MSDGC sites. A total of eight drainage "panels" were derived from the geometric draw starting at 164 mi^2 and subsequently halving each reduction down to 1.0 mi^2. Overlapping sites were merged and generally included sites greater than 10 mi^2 resulting in the first allocation of potential sampling sites. The geometric draw yielded the most unique "new" sites at drainage areas less than 5-10 mi^2. The merged sites were then apportioned by each of the 3 subwatersheds in spreadsheets that included the site coordinates, Ohio EPA stream and basin code, Ohio EPA river mile, and our assignments of biological, chemical, and physical sampling gear and methods. Additional targeted sites were added during the pre-field study planning downstream from major discharges, potential pollution sources, and dams and to provide a "pollution profile" of Little Miami River mainstem and major tributaries.

Measuring Incremental Changes

Incremental change is defined here to represent a measurable and technically defensible, change in the condition of a water body within which it has been measured. Most commonly this is termed "incremental improvement" in which the condition of a water body that does not yet fully meet all applicable WQS can be tracked as to the direction of any changes. The general principles of incremental change are defined as follows (after Yoder and Rankin 2008):

- ***measurement of incremental change*** can be accomplished in different ways, provided the measurement method is scientifically sound, appropriately used, and sufficiently sensitive enough to generate data from which signal can be discerned from noise;
- ***measurable parameters and indicators*** of incremental change include biological, chemical, and physical properties or attributes of an aquatic ecosystem that can be used to reliably indicate a change in condition; and,
- ***a positive change in condition*** means a measurable improvement that is related to a reduction in a specific pollutant load, a reduction in the number of impairment causes, a reduction in an accepted non-pollutant measure of degradation, or an increase in an accepted measure of waterbody condition relevant to designated use support.

This was accomplished for this study by comparing the results of prior, comparable assessments. In this case the 1992 bioassessment by Ohio EPA (1994) serves as the baseline against which the 2011 results can be compared to assess incremental changes in key parameters and indicators.

Biological Methods

Selection of the appropriate biological assessment method is primarily driven by defining appropriate data quality objectives (DQOs), which are determined by the cumulative array of management goals and objectives, and standards set by state or federal agencies. For the

MSDGC watersheds these are defined by the applicable protocols published by the Ohio EPA (1987a,b; 1989a,b; 1999, 2002, 2006, 2009, 2012). Additionally, the management issues which occur in the study area are varied and complex. MSDGC is under a consent decree to develop implementation plans to reduce wet weather discharges from CSOs to service area rivers and streams by *2 billion gallons* by 2018. As such the goals for the MSDGC program are to:

- Develop a comprehensive, systemic tool for tracking and sharing water quality data, including trends, conditions and opportunities; and,
- Use an IPS tool for capital planning and environmental program opportunities for maximum benefit to align with water quality needs.

As such MSDGC will require data that meets the specification of the Ohio WQS as it will be used to assess current aquatic life and recreational use designations, to determine the extent and severity of impairments, and document incremental changes that result from management intervention and abatement actions.

Fish Assemblage Methods

Methods for the collection of fish at wadeable sites was performed using a tow-barge or long-line pulsed direct current (D.C.) electrofishing equipment based on a T&J 1736 DCV electrofishing unit described by Ohio EPA (1989). An ETS AbP-3 battery powered backpack electrofishing unit was used as an alternative to the long line in the smallest streams and in accordance with the restrictions described by Ohio EPA (1989).

A three person crew carried out the sampling protocol for each type of wading equipment. Sampling effort was indexed to lineal distance and ranged from 150- 200 meters in length. Non-wadeable sites were sampled with a raft-mounted pulsed D.C. electrofishing device. A Smith-Root 2.5 GPP unit was mounted on a 14' Sea eagle raft with an electrode array in keeping with Ohio EPA (1989a) electrofishing design specifications. Sampling effort for this method was 500 meters. A summary of the key aspects of each method appears the Bioassessment Plan (MBI 2011). Sampling distance was measured with a Global Positioning System (GPS) unit or laser range finder. Sampling locations were delineated using the GPS mechanism and indexed to latitude/longitude and Universal Transverse Mercator (UTM) coordinates at the beginning, end, and mid-point of each site. The location of each sampling site was indexed by river mile (using river mile zero as the mouth of the river).

Sampling was conducted during a June 16-October 15 seasonal index period twice at all sites. Samples from each site were processed by enumerating and recording weights by species and in some cases by life stage (y-o-y, juvenile, adult). All captured fish were immediately placed in a live well, bucket, or live net for processing. Water was replaced and/or aerated regularly to maintain adequate dissolved oxygen levels in the water and to minimize mortality. Fish not retained for voucher or other purposes were released back into the water after they had been identified to species, examined for external anomalies, and weighed. Weights were recorded at level 1-5 sites only. Fish measuring less than 15-20 mm in length were generally not included in the data as a matter of practice.

The incidence of external anomalies was recorded following procedures outlined by Ohio EPA (1989) and refinements made by Sanders et al. (1999). While the majority of captured fish were identified to species in the field, any uncertainty about the field identification of individual fish required their preservation for later laboratory identification. Fish were preserved for future identification in borax buffered 10% formalin and labeled by date, river or stream, and geographic identifier (e.g., river mile). Identification was made to the species level at a minimum and to the sub-specific level if necessary. A number of regional ichthyology keys were used and included the Fishes of Ohio (Trautman 1981). Vouchers were deposited at and verified by The Ohio State University Museum of Biodiversity (OSUMB).

Macroinvertebrate Assemblage Methods

Macroinvertebrates were sampled using modified Hester-Dendy artificial substrate samplers (quantitative sample) and a qualitative dip net/hand pick method in accordance with Ohio EPA macroinvertebrate assessment procedures (Ohio EPA 1989a). The artificial substrates were exposed for a colonization period of six weeks between July12 and September 14 and placed to ensure adequate stream flow over the plates, but in general samplers should be set where flow is 0.3 feet/second over the plates. A qualitative sample using a triangular frame dip net and hand picking was collected at the time of substrate retrieval. All samples were initially preserved in a 10% solution of formaldehyde. Substrates were transferred to the laboratory, disassembled, sieved (standard no. 30 and 40), and transferred to 70% ethyl alcohol.

Qualitative samples were collected at each site either at the time of artificial substrate retrieval or as a standalone assessment of sites generally <10 $mi.^2$. These samples were collected using a triangular frame 30-mesh dip net. All available habitats were sampled at a given site for a total time of at least 30 minutes and thereafter until no new taxa were observed based on visual examination. These samples were preserved in 70% ethanol and included representatives of each taxon and an estimate of relative abundance using narrative descriptors (Ohio EPA 1989a). Qualitative sample data are used to supplement the quantitative samples in the case of artificial substrate sets, but also function as standalone assessment for sites where the artificial substrates were either not retrieved or otherwise made unusable.

Laboratory sample processing of both the quantitative and qualitative samples included an initial scan and pre-pick for large and rare taxa followed by subsampling procedures in accordance with Ohio EPA (1989a). Identifications were performed to the lowest taxonomic resolution possible for the commonly encountered orders and families, which is genus/species for most organisms. From these results, the density of macroinvertebrates per square foot is determined as well as a taxonomic richness and an Invertebrate Community Index (ICI; Ohio EPA 1987; DeShon 1995) score for the quantitative samples and a narrative assessment for the standalone qualitative samples.

Area of Degradation (ADV) and Area of Attainment Values (AAV)

The ADV (Yoder and Rankin 1995b; Yoder et al. 2005) was originally developed to quantify the extent and severity of departures from biocriterion within a defined river reach. For reaches

that exceed a biocriterion it is expressed as an AAV that quantifies the extent to which minimum attainment criteria are surpassed is. The ADV/AAV correspond to the area of the polygon formed by the longitudinal profile of IBI scores and the straight line boundary formed by a criterion, the ADV below and the AAV above. The computational formula (after Yoder et al. 2005) is:

ADV/AAV = ∑ [(aIBIa + aIBIb) – (pIBIa +pIBIb)] *(RMa – RMb), for a = 1 to *n,* where;

aIBIa = actual IBI at river mile a,
aIBIb = actual IBI at river mile b,
pIBIa = IBI biocriterion at river mile a,
pIBIb = IBI biocriterion at river mile b,
RMa = upstream most river mile,
RMb = downstream most river mile, and
n = number of samples.

The average of two contiguous sampling sites is assumed to integrate biological assemblage status for the distance between the points. The intensive pollution survey design typically positions sites in close enough proximity to sources of stress and along probable zones of impact and recovery so that meaningful changes are adequately captured. Biological assemblages as portrayed by their respective indices have been observed to change predictably in proximity to major sources and types of pollution in numerous instances (Ohio EPA1987a; Yoder and Rankin 1995b; Yoder and Smith 1999; Yoder et al. 2005). Thus, the longitudinal connection of contiguous sampling points produces a reasonably accurate portrayal of the extent and severity of impairment in a specified river reach as reflected by the indices (Yoder and Rankin 1995a).

The total ADV/AAV for a specified river segment is normalized to ADV/AAV units/mile for making comparisons between years and rivers. The ADV is calculated as a negative (below the biocriterion) expression; the AAV is calculated as a positive (above the biocriterion) expression. Each depicts the extent and degree of impairment (ADV) and attainment (AAV) of a biological criterion, which provides a more quantitative depiction of quality than do pass/fail descriptions. It also allows the visualization of incremental changes in condition that may not alter the pass/fail status, but are nonetheless meaningful in terms of incremental change over space and time. In these analyses, the WWH biocriterion for the fish and macroinvertebrate indices, which vary by use designation and ecoregion, were used as the threshold for calculating the ADV and AAV for the Little Miami River watersheds mainstem. The WWH use designation represents the minimum goal required by the CWA for the protection and propagation of aquatic life, thus it was used as a standard benchmark for the ADV/AAV analyses.

Primary Headwater Methods

PHWH methods were also applied to all sites <2.5 mi.^{2} in anticipation that the resulting site assessment would need to be based on the PHWH system of classification. An exception was at stream sites that were completely dry during any of the sampling visits in which case a HHEI

was applied at a minimum. Methods for the collection of macroinvertebrates and salamanders at PHWH sites followed the qualitative macroinvertebrate collection techniques used by the Ohio EPA for all stream types (Ohio EPA 1989) and in accordance with the PHWH manual (Ohio EPA 2012). Salamander collections are made in two 30 feet subsections of the 200 feet stream reach assessed for a PHWH evaluation. Each subsection was chosen where an optimal number and size of cobble type microhabitat substrates are present. A minimum of 30 minutes was spent searching for salamanders. At least five larvae and two juvenile-adults of each species type observed were preserved. Adult and juvenile salamanders were placed into plastic bags with moist leaf litter. The larva are transported in stream water and placed in a cooler and brought back to the lab for preparation of voucher specimens.

Habitat Assessment

Physical habitat was evaluated using the QHEI developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 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 baseline Clean Water Act goal expectations (e.g., the WWH in the Ohio WQS).

Physical habitat was also evaluated at the PHWH sites using the Headwater Habitat Evaluation Index (HHEI) developed by Ohio EPA (2012). The HHEI scores various attributes of the physical habitat that have been found to be statistically important determinants of biological community structure in PHWH streams with drainage areas less than 1 $mi.^2$. Statistical analysis of a large number of physical habitat measurements showed that three QHEI habitat variables (channel substrate composition, bank full width, and maximum pool depth) are sufficient in distinguishing the physical habitat of Class 1, 2, and 3 PHWH streams using the HHEI. The characterization of the channel substrate includes a visual assessment of a 200 feet stream reach using a reasonably detailed evaluation of both the dominant types of substrate and the total number of substrate types. Bank full width is a morphological characteristic of streams that is determined by the energy dynamics related to flow and has been found to be a strong discriminator of the three classes of PWHW streams in Ohio. The bank full width is the average of 3-4 separate bank full measurements along the stream reach. The maximum pool depth within the stream reach is important since it is a key indicator of whether the stream can support a WWH fish assemblage. Streams with pools less than 20-40 cm in depth during the

low flow periods of the year are less likely to have WWH fish assemblages and thus more likely to have viable populations of lungless salamanders, which replace fish as the key vertebrate indicator in PHWH streams.

Chemical/Physical Methods

Chemical/physical assessment for the MSDGC service area includes the collection and analysis of water samples for chemical/physical and bacterial analysis and sediment samples for determining sediment chemical quality. Methods for the collection of water column chemical/physical and bacterial samples followed the procedures of Ohio EPA (2009) and MSDGC (2011c). Sediment chemical sampling followed that described by Ohio EPA (2009). All laboratory analysis was performed and/or overseen by MSDGC.

Water Column Chemical Quality

Water column chemical quality was determined by the collection and analysis of grab water samples, instantaneous measurements recorded with a water quality meter, and continuous measurements recorded at 3-4 day intervals in the mainstem and larger tributary sites and at the reference sites.

Grab Sampling

Grab samples of water were collected with a stainless steel bucket from a location as close to the center point of the stream channel as possible by MBI and MSDGC sampling crews. Samples were collected from the upper 12-24" of the surface and then transferred to sample containers in accordance with MSDGC procedures (MSDGC 2011c). Sampling was conducted between mid-June and mid-October and under "normal" summer-fall low flows – elevated flows following precipitation events were avoided and sampling was delayed until flows subsided. The frequency of sampling ranged from approximately weekly at mainstem sites and sites with multiple impacts to bi-weekly, 4 times per season, 2 times per season, and once at Primary Headwater sites. Water samples were collected provided there was sufficient water depth to collect a sample without disturbing the substrates. Instantaneous values for temperature (°C), conductivity (µS/cm2), pH (S.U.), and dissolved oxygen (D.O.; mg/l) were recorded with a YSI Model 664 meter at the time of grab sample collection.

Continuous Recordings

Continuous readings of temperature (°C), conductivity (µS/cm2), pH (S.U.), and dissolved oxygen (D.O.; mg/l) were recorded with a YSI 6920 V2 Sonde ("Datasonde") instrument at mainstem, major tributary, and reference site locations. The Datasondes were set as close as possible to the Thalweg (i.e., deepest part of the stream channel) in a PVC enclosure that ensured no contact with the stream bottom or other solid objects. The Datasondes were positioned vertically where depth allowed by driving steel fence posts into the bottom and positioning the PVC enclosure in an upright position. Where the depth was too shallow the PVC enclosure was secured in a horizontal position in an area of the stream channel with continuous flow. All Datasondes were secured against theft or vandalism as much as possible. Datasondes were deployed for a 3-4 day continuous interval between mid-July and early September during

periods of maximum summer temperatures and normal low flows. Readings were taken at 15 minute intervals. At the time of retrieval data was downloaded to a YSI Model 650 Instrument with high memory capacity and then transferred to a PC for storage and later analysis.

Sediment Chemical Quality

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each sampling location using decontaminated stainless steel spoons and excavated using nitrile gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001).

Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with teflon® lined lids, placed on ice (to maintain 4^{o}C) in a cooler, and delivered to Metropolitan Sewer District of Greater Cincinnati, Division of Industrial Waste Lab. Sediment data is reported on a dry weight basis. Sediment samples were analyzed for inorganics (metals), nutrients, volatile organic compounds, semivolatile organic compounds, PCBs, total petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs) and cyanide.

Determining Use Attainment Status

Use attainment status is a term which describes the degree to which environmental parameters or indicators are either above or below criteria specified by the Ohio WQS (Ohio Administrative Code 3745-1). For the Little Miami River watersheds assessment two use designations are being evaluated, aquatic life and recreation in and on the water by humans. Hence the process herein is referred to as the determination of aquatic life and recreational status for each sampling site. The process is applied to data collected by ambient assessments and applies to rivers and streams outside of discharge mixing zones.

Aquatic Life

Aquatic life use attainment status is determined by the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-13). Numerical biological criteria are based on multimetric biological indices which include the IBI and MIwb, which indicate the response of the fish assemblage, and the ICI, which indicates the response of the macroinvertebrate assemblage. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984) and subsequently modified by Ohio EPA (1987) for application to Ohio rivers and streams. The ICI was developed by Ohio EPA (1987) and is 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 (Gammon 1976; Gammon *et al.* 1981). Numerical biocriteria 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 indices meet the applicable biocriteria. Partial attainment means that one or more of the indices fails to meet the applicable biocriteria. Non-attainment means that none of the indices meet the applicable biocriteria or one of the organism groups reflects poor or

very poor quality. An aquatic life use attainment table (see Table 2) 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 use attainment table is further organized by Ohio EPA Waterbody Assessment Unit so that the results can be used by Ohio EPA for assessment purposes.

Primary Headwater Habitat (PHWH)
Sites that were determined to be PHWH streams were assessed by that Ohio EPA methodology (Ohio EPA 2002, 2012). Determining the applicability of the PHWH classification entailed first ruling out the applicability and attainability of the WWH suite of uses. Once this determination was made the sites were assigned to one of the 3 PHWH classes and their subclasses if applicable. The possible class assignments are described as follows:

Class 1 – These are ephemeral streams. They have little or no aquatic life potential, except seasonally when flowing water is present for short time periods following precipitation or snow melt. Streams assigned to Class 1 PHWH may be typified by one or more of the following characteristics:

- no significant habitat for aquatic fauna;
- no significant aquatic wildlife use; and
- limited or no potential to achieve higher PHWH class functions.

Class 2 – These streams are normally intermittent, but may have perennial flow. They may exhibit moderately diverse communities of warm water adapted native fauna present either seasonally or year-round. The native fauna is characterized by species of vertebrates (temperature facultative species of amphibians and pioneering species of fish) and benthic macroinvertebrates. Pool depth and water volume are normally insufficient to support the biological criteria associated with other sub-categories of aquatic life described in OAC Rule 3745-1-07. Prevailing temperature conditions in Class 2 PHWH streams prevent establishment of Class 3 biology and function.

Class 3 – These are perennial streams in which the prevailing flow and temperature conditions in Class 2 PHWH streams are influenced by groundwater. They exhibit moderately diverse to highly diverse communities of cold water adapted native fauna present year-round. Pool depth and water volume are normally insufficient to support the biological criteria associated with other sub-categories of aquatic life described in OAC Rule 3745-1-07:

- Class 3A PHWH – These are perennial streams that exhibit diverse communities of native fauna. The native fauna is characterized by:

  - reproducing populations of one or more of these salamander species (sub-species): the Northern Two-Lined Salamander *(Eurycea bislineata bislineata)*, the Southern

Two-Lined Salamander *(Eurycea bislineata cirrigera)*, the Northern Longtail Salamander *(Eurycea longicauda)*, or;

- benthic macroinvertebrates, including four or more cold water macroinvertebrate taxa from Attachment 3 of the Ohio EPA *Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams Version 3.0* (Ohio EPA 2012).

- Class 3B PHWH – These are perennial streams that exhibit superior species composition or diversity of native fauna. The native fauna is characterized by:

  - a reproducing population of one or more vertebrate species as listed in Table 7 of the Ohio EPA *Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams Version 3.0* (Ohio EPA 2012); or
  - a macroinvertebrate community consisting of at least four cold water taxa from Attachment 3 of the Ohio EPA *Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams Version 3.0* (Ohio EPA 2012) and also having two or more of the following attributes:

- Six or more cold water macroinvertebrate taxa listed in Attachment 3 of the Ohio EPA *Field Evaluation Manual for Ohio's Primary Headwater Streams Version 3.0* (Ohio EPA 2012);
- Six or more taxa from the insect orders Ephemeroptera, Plecoptera and Trichoptera; six or more sensitive macroinvertebrate taxa (Ohio EPA 2012).

Recreation

Water quality criteria for determining attainment of recreational uses are established in the Ohio WQS (OAC 3745-1-07; Table 7-13) based upon the quantities of bacterial indicators *(Escherichia coli)* present in the water column. *Escherichia coli (E. coli)* bacteria are microscopic organisms that are normally present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour 1977). There is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are being developed including current research supported by MSDGC. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where wastes have been deposited. Pathogenic (disease-causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor every type of pathogen. Fecal indicator bacteria by themselves, including *E. coli,* are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means the water has received fecal matter from one or multiple sources. Swimming or other recreation-based contact with water having a high *E. coli* counts may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes,

and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

Streams in the Little Miami River watersheds are designated as PCR and/or SCR use in the Ohio WQS (OAC 3745-1- 24). Water bodies with a designated recreation use of PCR ". . . are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving" (OAC 3745-1- 07 [B][4][b]). There are three subclasses of the PCR use that reflect differences in the potential frequency and intensity of human uses. Streams designated PCR class A support, or potentially support, frequent primary contact recreation activities. Streams designated PCR class B support, or potentially support, occasional primary contact recreation activities. Streams designated as PCR class C support, or potentially support, infrequent primary contact recreation activities. Streams designated as SCR use are rarely used for water based recreation. The Ohio WQS also include a bathing waters (BW) recreational use designation that applies to public beaches, but none occur in Little Miami River watersheds.

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

Determining Use Attainability

Use designation reviews and recommendations for revisions, if necessary, are a direct product of the 2011 Little Miami River watersheds watershed assessment. The spatial sampling scheme was designed to enhance this function of the watershed assessment and is applied to individual streams and stream segments. Ohio's aquatic life uses are designated based on the *demonstrated potential* to attain a particular use tier based on the following sequence (in order of importance):

1. Attainment of the numeric biological criteria (if attaining WWH or higher – attainment of the EWH biocriteria for both assemblages is required to be designated as EWH); and,

2. If the WWH use designation is not met, the habitat potential is determined by an analysis of a QHEI habitat attributes matrix which is used to determine the potential to attain the WWH use at a minimum.

As such this represents a "UAA type" of process even though a use attainability analysis (UAA) is technically not required to designate uses at or above the "CWA minimum" (i.e., WWH in Ohio). This process is inherently data driven so that the same sequence of decision-making is executed regardless of the relationship of the current use designation to the minimum CWA goal. To designate uses less than WWH (i.e., MWH or LRW), a UAA ***is required*** and includes the

consideration of the factors that essentially preclude WWH use attainment including the feasibility of restoring the waterbody. Under such an approach the following information and knowledge is required:

1. The present attainment status of the waterbody based on a biological assessment performed in accordance with the requirements of the Ohio WQS;

2. A habitat assessment to evaluate the potential to attain at least the WWH use; and,

3. A reasonable relationship between the impaired state and the precluding anthropogenic activities or other factors based on an assessment of multiple indicators used in their appropriate indicator roles and a demonstration consistent with 40CFR Part 131.10 [g][1-6].

Hence the biological assessment and the attendant habitat assessment tool are essential in making this determination. If the WWH use biocriteria are attained then that is the "best" demonstration that the use is attainable at a minimum. If the EWH biocriteria are attained *by both assemblages,* then that is justification for assigning EWH. Both scenarios are consistent with the definition of existing use in 40CFR Part 131.1 as:

> *". . . those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards."*

If the WWH biocriteria are not attained, then the accompanying habitat assessment is used to determine if the habitat quality is capable of supporting WWH. If habitat is sufficient, then WWH will be the assigned use. If habitat is not sufficient, then a UAA process is employed to determine if there are precluding factors under the U.S. EPA WQS regulations (40CFR Part 131.10[g]) that are essentially "permanent" preclusions to WWH attainment. In this case the options are to either effect proven restoration techniques or assign the MWH or LRW use designations. Figures 6-8 provide an overview of the sequence of steps of the UAA process that starts with utilizing the results of the supporting biological assessment.

The initial decisions in Figure 6 focus first on biological status, specifically if the WWH biocriteria are attained or not. The reason for this is that the WWH biocriteria are the minimum condition that meets the baseline goal of the CWA, i.e., "the protection and propagation of fish, shellfish, and wildlife". This benchmark is also important because it determines the point at which a UAA is required even though the entire process that is outlined herein is "UAA like" and requires consideration of the same types of data and analyses. If the WWH biocriteria are fully attained, then this use will apply because meeting this benchmark of attainability has been directly demonstrated. If biological attainment of the Exceptional Use biocriteria is demonstrated *by both assemblages,* then this use is designated because the attainability of this TALU tier has likewise been demonstrated. Again, each is consistent with the definition of existing use in 40CFR Part 131.3. The Exceptional Use is unique among the TALU tiers in that it requires a showing a biological attainment to be designated as such. Hence it functions as a *preservation*

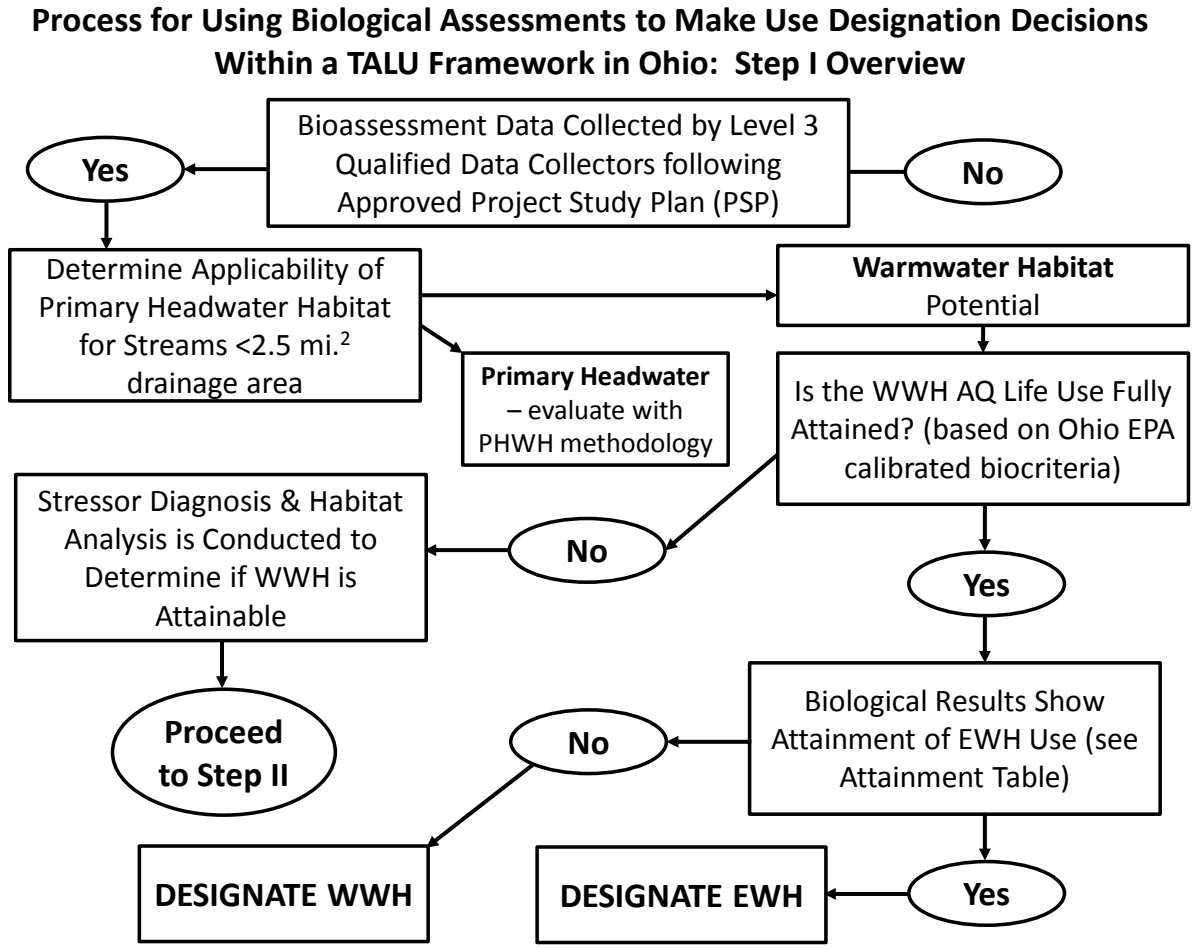

Figure 6. Step I: Overview of the process for using biological assessments to make use designation decisions in Ohio based on the tiered aquatic life uses framework.

use within a TALU framework, whereas WWH is by comparison a restoration use. Hence, attainment of either the General or Exceptional Use biocriteria triggers a straightforward decision to designate those uses. Non-attainment of the WWH biocriteria triggers a stressor diagnosis approach that is inherent to a tiered uses approach in order to determine if WWH is attainable, which leads to step II (Figure 6).

The habitat assessment that is conducted as part of the biological assessment is now relied upon to provide the information and analysis that is needed to determine if WWH is indeed attainable. This part of the process determines if the attributes of the extant habitat are sufficient to support biological assemblages consistent with the WWH biocriteria. This requires the use of the supporting analyses of the relationship between QHEI habitat attributes and the biological assemblages that yield sufficiently predictive relationships such that biological attainability can be determined. This descriptive work was accomplished at the stream and river class level by Ohio EPA (Rankin 1989, 1995). The Ohio EPA analyses yielded thresholds of QHEI scores that generally correspond to WWH attainment and also identified which QHEI

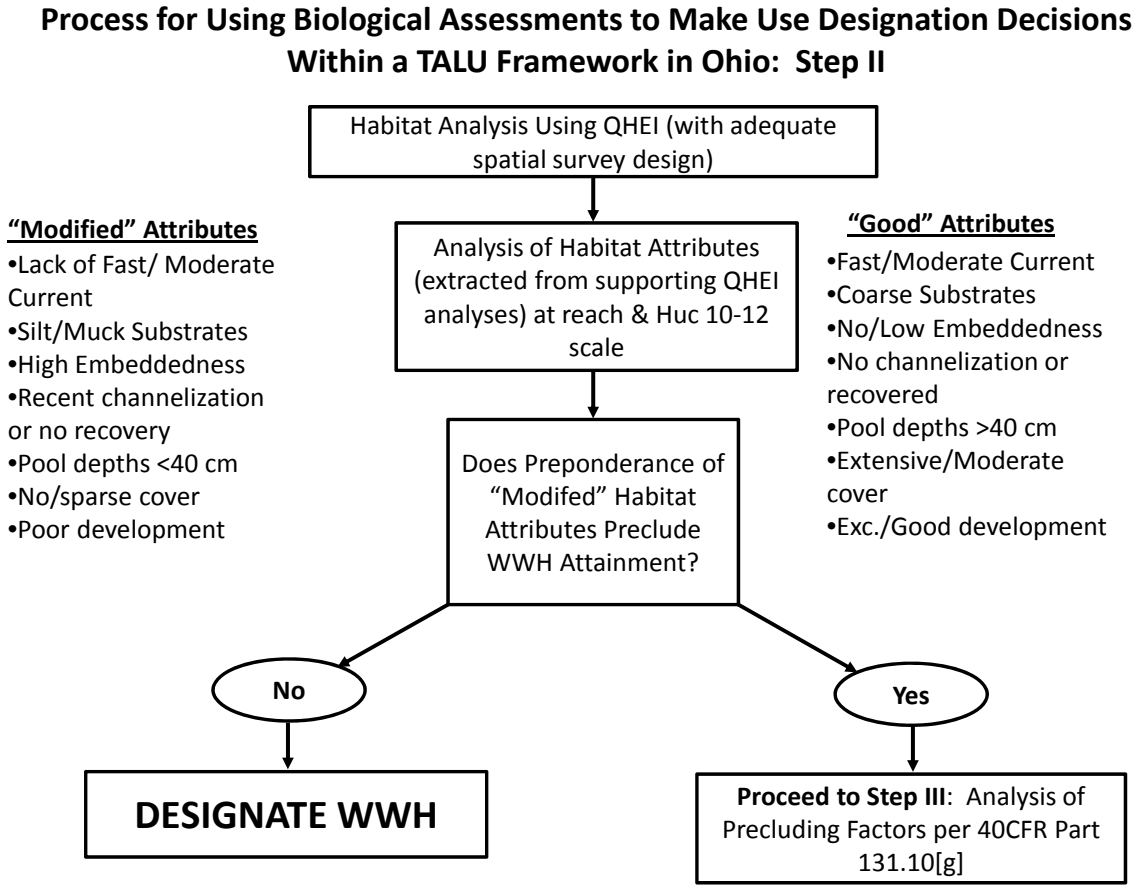

Figure 7. Step II: Using the analysis of habitat attributes to make decisions about WWH use attainability.

attributes provide for a *sufficiently accurate* prediction of WWH attainability. These attributes are expressed as "good" and "poor" attributes (Figure 6) the former being comprised of attributes that accumulate to promote biological attainment and the latter having the opposite effect, i.e., those attributes that deter biological assemblages consistent with WWH attainment. The QHEI thresholds and attributes derived for Ohio (Rankin 1989, 1995) are highlighted in Figure 5. For example, a QHEI score $\geq$60 is an indication that WWH is attainable, but a score <45 indicates that biological attainment of WWH is less likely. Added to these index thresholds are the occurrence and preponderance of good and poor habitat attributes which help sharpen the decision about WWH attainability. Once this information is analyzed on a reach level basis, a decision about WWH attainability in the absence of direct WWH biological attainment can then be made. If the analysis indicates that habitat is not limiting, then WWH is the resulting decision. However, if the analysis indicates that the habitat attributes are insufficient and therefore limiting, then an analysis of the precluding factors consistent with 40CFR Part 131.10[g] is performed (proceed to Step III, Figure 8). This process is formally known as a Use Attainability Analysis (UAA).

A use that is "lower" than what is recognized as consistent with the CWA, i.e., WWH or higher in Ohio, can be assigned provided an acceptable UAA is conducted. A UAA is defined as:

". . . a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in §131.10[g]."

Process for Using Biological Assessments to Make Use Designation Decisions Within a TALU Framework in Ohio: Step III

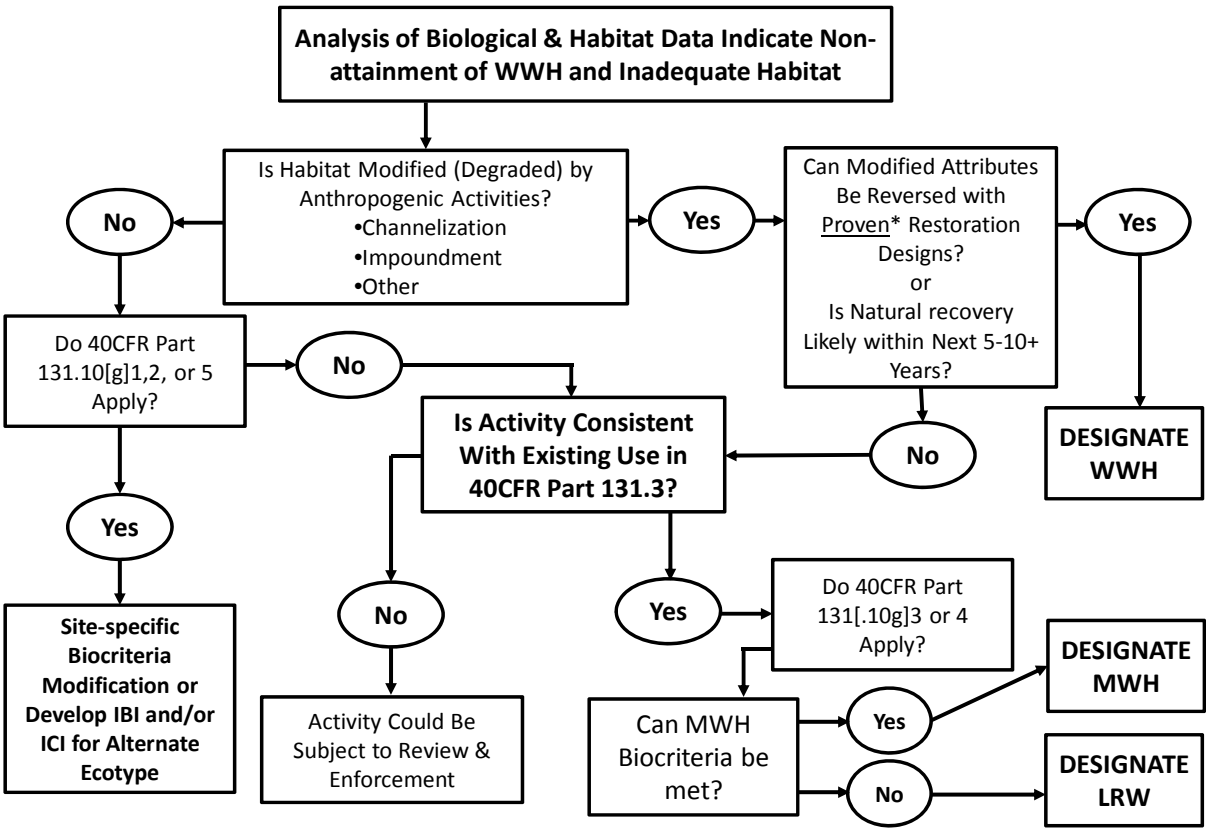

Figure 8. Step III: Overview of the use attainability analysis parts of the use designation process in Ohio.

Those criteria are as follows:

"40CFR Part 131.10[g]: States may remove a designated use which is not an existing use, as defined in Section 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because:

1. *Naturally occurring pollutant concentrations prevent the attainment of the use; or*
2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or*

3. *Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or*
4. *Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or*
5. *Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or*
6. *Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact."*

The process arrives at this point because the biological assessment revealed non-attainment of the WWH biological criteria and the analysis of habitat attributes showed habitat to be deficient for supporting biological assemblages consistent with WWH. Since it has already been determined that attributes of habitat are insufficient to support WWH, the next task is to determine the "origin" of the deficient habitat, i.e., is it of natural or of anthropogenic (i.e., human activity caused) origin? If it is determined not to be the result of anthropogenic activities, then a determination of whether 40CFR Part 131.10[g][1], [2], or [5] should apply as needed. These are considered to be "natural factors" that could *naturally* preclude attainment of the WWH biological criteria. It would also suggest that either a site-specific modification of the biocriteria is needed or consideration of an alternate ecotype with a distinct biological assessment tool and/or index is needed. If this phenomenon is encountered on a regional or ecotype basis then the latter option is preferred. In all likelihood the stream and river class-specific development of the biological indices by Ohio EPA should have "captured" most of these natural factors, but the process is available should something have been overlooked.

Almost any habitat caused non-attainment of WWH in Ohio will be related to anthropogenic habitat impacts that are either of recent or legacy origins. If this is the case then it next needs to be determined if the habitat alterations can be reversed with *proven* restoration designs or if they are of recent enough origin that they are eligible for an enforcement action. "Proven" refers to restoration designs that have been shown to restore biological assemblage quality consistent with the WWH biological criteria endpoints and supported by an analysis of restored QHEI attributes. Simply assuming that WWH will be attained because a restoration activity has been undertaken is alone insufficient to satisfy this part of Step III. If there are indeed *proven* designs and these are effectively implemented then WWH could be deemed as attainable. If no restoration actions have been taken or are as yet unproven then the remaining parts of 40CFR Part 131.10[g] will need to be considered.

In the MSDGC service area it is expected that the majority of habitat alterations that lead to UAA considerations will most commonly include channelization in support of flood control and other modifications designed to deal with surface runoff in urban settings and possibly also by impoundment of riverine habitats by "run-of-river" low head dams. Each of these has been shown to not only alter habitat such that CWA goals cannot be attained, but also can result in

essentially permanent modifications. This is exemplified in 40CFR Part 131.10[g][3] and [4] in that these modifications are due to human actions that are perpetual in their tenure (e.g., [g][3]) and which represent hydrological modifications that cannot be operated in a manner consistent with the WWH use (e.g., [g][4]). If the actions are consistent with these parts of 40CFR Part 131.10[g] then either MWH or LRW will be designated. The distinction between MWH and LRW is largely based on the attainability of the MWH biological criteria which are less stringent than the WWH use biocriteria.

Determining Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine biological status (i.e., unimpaired or impaired, narrative ratings of quality) and assigning associated causes and sources of impairment utilizing the accompanying chemical/physical data and source information (e.g., point source loadings, land use). The identification of impairment in rivers and streams is straightforward - the numerical biological indices are the principal arbiter of aquatic life use attainment and impairment following the guidelines of Ohio EPA (1987). The rationale for using the biological results in the role as the principal arbiter within a weight of evidence framework has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Yoder 1991; Yoder 1995).

Describing the causes and sources associated with observed biological impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures (Yoder and Rankin 1995; Yoder and DeShon 2003). Thus the assignment of associated causes and sources of biological impairment in this report represents the association of impairments (based on response indicators) with stressor and exposure indicators using linkages to the bioassessment data based on previous experiences with analogous situations and impact types. For example, exceedances of established chemical thresholds such as chronic and acute water quality criteria or sediment effect thresholds can be grounds for listing such categories of parameters and even individual pollutants provided that they co-occur with a biological impairment. The reliability of the identification of associated causes and sources is increased where many such prior associations have been observed. The process is similar to making a medical diagnosis in which a physician relies on multiple lines of evidence concerning patient health. Such diagnoses are based on previous research which experimentally or statistically links symptoms and test results to specific diseases or pathologies. Thus a physician relies on clinical experiences in interpreting symptoms (*i.e.,* test results, multiple lines of evidence) to establish a diagnosis, potential causes and/or sources of the malady, a prognosis, and a strategy for alleviating the symptoms of the disease or condition. As in medical science, where the ultimate arbiter of success is the eventual recovery and well-being of the patient, the ultimate measure of success in water quality management is the restoration of lost or damaged ecosystem attributes including biological assemblage structure and function.

Hierarchy of Water 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. A tiered approach that links the results of administrative actions with true environmental measures was employed by our analyses. This integrated approach is outlined in Figure 8A 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, assimilative capacity); 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). An example is the aggregate effect of billions of dollars spent on water pollution control since the early 1970s that have been determined with quantifiable measures of environmental condition (Yoder et al. 2005).

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 the Ohio EPA biological endpoints. Other response indicators can include target assemblages, *i.e.,* rare, threatened, endangered, special status, and declining species or bacterial levels that 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 (Yoder and Rankin 1998).

Causal Associations

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 Integrated Report (303[d] report) and other technical products.

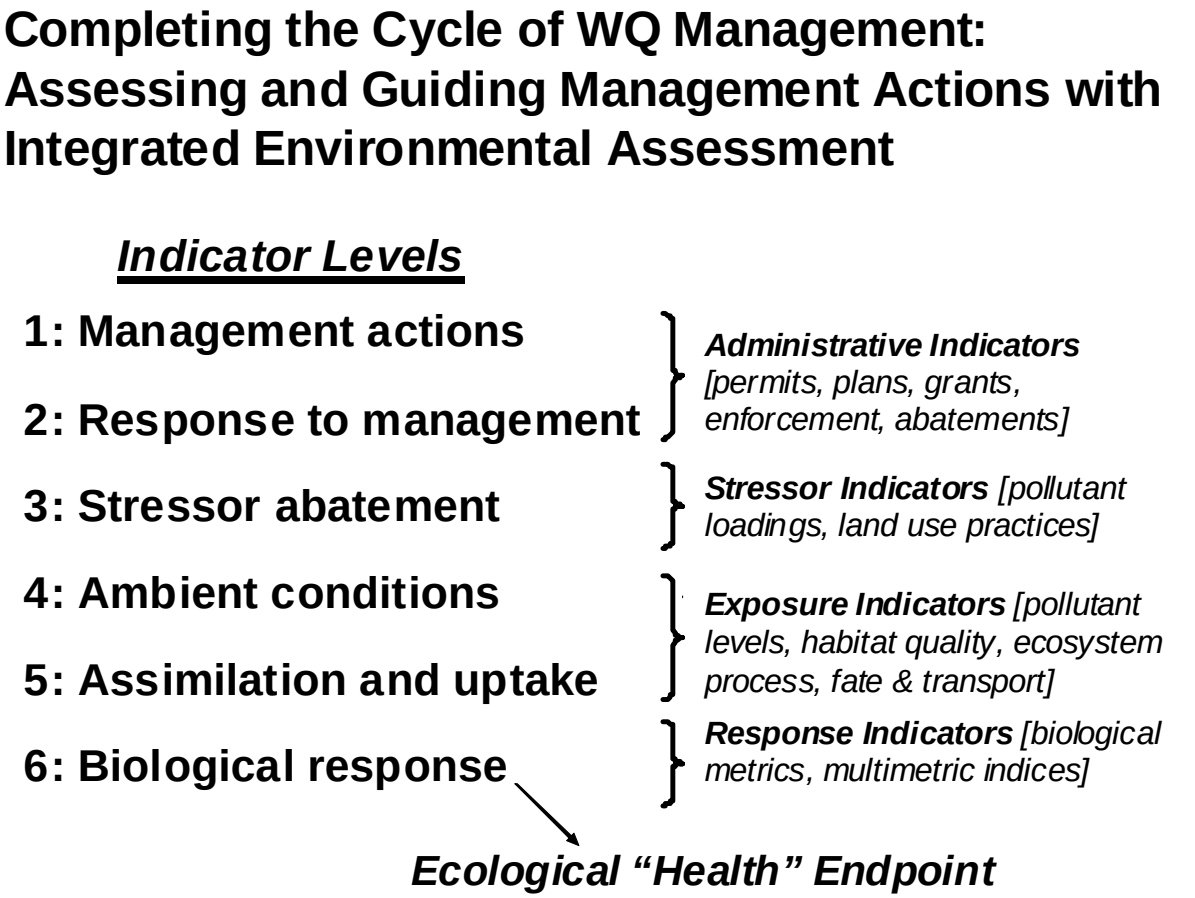

Figure 8A. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995) and further enhanced by Karr and Yoder (2004).

STUDY AREA DESCRIPTION

General Setting

The Little Miami River study area lies in southwest Ohio and is generally bounded by the Mill Creek and Great Miami River basins to the northwest, the Whiteoak Creek subbasin to the east, and the Ohio River to the south. The Little Miami River mainstem flows southward for 111 miles from the headwaters in Clark County through Greene, Warren, and Clermont Counties to its confluence with the Ohio River in Hamilton County draining 1757 mi^2. The study area is located in the Eastern Corn Belt Plains and Interior Plateau ecoregions (see Figure 5). Along its course the stream has an average gradient of 6.35 feet per mile (ODNR 1960). Major tributaries within the 2012 Little Miami River study area include O'Bannon Creek, Polk Run, Sycamore Creek, Dry Creek, Duck Creek, Clough Creek, and the East Fork of the Little Miami River. These tributaries enter the Little Miami River mainstem from the hillsides that characterize the watershed. The upper portion of Little Miami River mainstem located in Warren County is mostly rural, but suburban development has occurred over the past 3 decades. The lower portion of Little Miami River is urban in nature and some tributary subbasins are almost completely developed.

Subecoregion Characteristics

The 2012 Little Miami River study area lies within two different level III ecoregions, the Interior Plateau (IP) and the Eastern Corn Belt Plains (ECBP; Omernik 1987). More recent delineations of Level IV subregions provide more detail for the four components of ecoregions - surficial geology, soils, potential natural vegetation, and land use (Woods et al. 1995). The lower Little Miami River study area and much of the East Fork of the Little Miami River lie entirely within the Northern Bluegrass subregion (71d) of the Interior Plateau. The remainder of the Little Miami River study area lies within the Pre-Wisconsinan Drift Plains subregion (55d) of the Eastern Corn Belt Plains ecoregion. The southernmost portion of the study area overlies the Wisconsinan Drift Plains subregion (55d) and the northern portion and the East Fork of the Little Miami River lies within the Loamy High-lime Till Plains subregion (55b) of the ECBP ecoregion. The characteristics of each subregion appear in Table 8.

Description of Pollution Sources and Other Stressors

Pollution sources and general stressors are numerous in the Little Miami River watersheds subwatersheds. These sources include permitted discharges of municipal and industrial process wastewater, discharges from combined and sanitary sewer overflows (CSO and SSO), runoff and releases from industrial facilities, urban runoff and its associated chemical pollution and hydrological alterations, and direct and indirect habitat alterations. These are described in the following discussions and many are included in Table 9.

Point Sources

There are 23 point source discharges in the Little Miami River study area that hold NPDES permits. Of these 10 are considered to be major discharges and all are municipal wastewater

Table 8. Level IV subregions of the Little Miami River watersheds watershed and their key attributes (from Woods et al. 1995).

Level IV Subregion	Physiography	Geology	Soils	Potential Natural Vegetation	Land Use/Land Cover
Loamy, High Lime Till Plains (55b)	Glaciated; level to rolling glacial till plain with low gradient streams; also end moraines and glacial outwash landforms.	Loamy, high lime, late-Wisconsinan glacial till and also glacial outwash and scattered loess overlie Paleozoic carbonates and shale.	Alfisols (Hapludalfs, Epiaqualfs, Endoaqualfs), Mollisols (Argiaquolls, Endoaquolls, Argiudolls), Entisols (Fluvaquents)	Mostly beech forest; also, oak-sugar maple forest, elm-ash swamp forest on poorly-drained valley bottoms and ground moraines.	Extensive corn, soybean, and livestock farming; also scattered beech-maple, pin oak-swamp, white oak woodlands. Urban-industrial activity in municipal areas.
Pre-Wisconsinan Drift Plains (55d)	Glaciated. Dissected glacial till plain with low to medium gradient streams.	Deeply leached, acidic pre-Wisconsinan clay-loam glacial till and thin loess overlie Paleozoic carbonates.	Alfisols (Fragiudalfs, Hapludalfs, Fragiaqualfs, Glossaqualfs), Entisols (Fluvaquents)	Mostly beech forest, elm-ash swamp forest; also oak-sugar maple forest.	Soybean, livestock, corn, general, and tobacco farming; where poorly-drained or rugged, pin oak-swamp, white oak flatwoods, and beech-maple woodlands.
Northern Bluegrass (71d)	Unglaciated and glaciated; dissected plains and hills with medium gradient, gravel bottom streams. Steep slopes, high relief near Ohio River.	Discontinuous loess and leached pre-Wisconsinan glacial till deposits. Ordovician limestone and shale.	Alfisols (Hapludalfs, Fragiudalfs), Mollisols (Hapludolls)	Mixed meso-phytic forest, mixed oak forest, oak-sugar maple forest; along Ohio River, bottomland hardwoods.	Mosaic of forest, agriculture, and urban-industrial activity near Cincinnati and elsewhere along Ohio River. Wooded where steep

treatment plants. A total of 54.4 MGD of capacity is shared by the 7 WWTPs that impact the lower Little Miami River mainstem study area. Another 17.4 MGD of capacity is shared by 3 WWTPs on the lower East Fork of the Little Miami River. All of these WWTPs operate at what may be termed "advanced treatment" levels for oxygen demanding substances and ammonia removal, which is typical for WWTPs with permits based on meeting the Ohio WQS. Following the 1998 bioassessment of the Little Miami River in which Ohio EPA found significant impairment of the fish assemblages in particular, upgrades to WWTPs followed and some of these included phosphorus removal, mostly in the upper one-half of the mainstem. The results of the 2007 survey (Ohio EPA 2009) reflected one of the most significant improvements in the status of any major mainstem river in the 30 year history of these surveys by Ohio EPA. To quote the 2009 Ohio EPA report:

> *". . . the overall turnaround of the Little Miami River's biotic integrity can be attributed to improved treatment and operations at several Wastewater Treatment Plants (WWTPs) in the watershed. Many facilities that were previously operating at or over capacity since the last survey in 1998 were upgraded, while others began actively removing phosphorus from treated effluent. These improvements, in turn, allowed for the rebound of the fish community, which has historically borne the brunt of impacts from nutrient over-enrichment in the river."*

The current status of phosphorus removal for the relevant WWTPs assessed by the 2012 survey appears in Table 10.

Wet Weather Sources

Wet weather sources merit description since they are prominent in the Duck Creek subbasin. The two major sources of wet weather related pollution in the 2012 study area emanate from CSOs and SSOs. These occur because the volume of sanitary wastewater and stormwater entering the MSDGC sewer system during precipitation events (i.e., during "wet weather") exceeds the capacity of the collection system. There are two types of pipes that carry wastewater in Hamilton County, "combined sewers" and "sanitary sewers." Combined sewers collect and transport both sewage and stormwater, while sanitary sewers collect and transport only sewage. Wastewater discharges that are released to the environment from sanitary sewer systems before they reach a treatment plant are known as "sanitary sewer overflows," or SSOs. The term SSO can also refer to a sanitary sewer overflow structure or outfall. Discharges that escape the system before reaching a treatment plant are known as "combined sewer overflows," or CSOs. Approximately one-third of MSDGC's sewers are CSOs and the rest are sanitary sewers (MSDGC 2006).

In the MSDGC collection system, the primary cause of SSOs is a lack of system capacity. This happens when the sewer system receives increased flows as a result of "infiltration and inflow," or I/I, which is the entry into the sewer system of "clean" rain water through leaks in the system caused by deteriorating pipes and tree roots growing into the sewers ("infiltration"), as well as through roof drains, manhole covers and yard drains ("inflow"), thus exacerbating the lack of capacity. As a result, during periods of rainfall or snowmelt, wastewater is frequently discharged from overflow structures into area rivers and streams. The MSDGC system has approximately 80 such overflow points, which discharge wastewater when the pipes become too full. These SSO structures were constructed many years ago, consistent with the then-acceptable approach for addressing overloaded sanitary sewer systems. In contrast, a combined sewer system is designed to transport both sewage and storm water. These systems are largely an "artifact" of an earlier way of building sewers and have not been newly constructed in the United States for decades. Combined sewers are generally not designed to be big enough to carry wastewater plus all of the rainfall from the area's larger storms. Thus, combined sewers are designed to discharge from combined sewer overflow points, or "CSOs." MSDGC has approximately 200 CSO discharge points in its collection system (MSDGC 2006).

Table 9. Major pollution sources in the 2012 Little Miami River study area.

Receiving Stream	Length (Miles)	Gradient (ft/mi)	Drainage Area (mi^2)	River Mile	Site Code/RM	Facility Name/Description	NPDES Permit No.
O'Bannon Creek	12	24	59.1	2.57	LM37/ 1.8	O'Bannon Creek Regional WWTP	1PK00017
Polk Run	5.5	62	10.2	0.1		Polk Run WWTP	1PK00019
Sycamore Creek	2.6	17.7	6.86	0.26	LM53/ 0.1	Sycamore Creek WWTP	1PK00005
East Fork Little Miami	81.7	7.6	499	20.5	LM25/ 19.5	US DOA William H Harsha Lake	1PN00000
East Fork Little Miami				13.5	LM28/ 13.2	City of Batavia WWTP	1PB00001
East Fork Little Miami				12.6	LM29/ 11.0	Clermont Co. Middle East Fork Regional WWTP	1PK00010
East Fork Little Miami				4.9	LM32/ 4.3	Clermont Co. Lower East Fork Regional WWTP	1PK00009
East Fork Little Miami				4.9	LM32/ 4.3	USEPA Experimental Stream Facility	1IN00116
East Fork Little Miami				1.6	LM35/ 1.0	Milford WWTP	1PC00005
Duck Creek	8.2	27.6	15.5	5.14	LM72/ 4.6	CSOs: 054, 135, 170, 187, 214, 500, 501, 549, 550, 551, 552, 553	
Duck Creek				4.5	LM73/ 4.4	CSOs: 043, 061	
Duck Creek				3.98		CSOs: 064, 066, 068, 188, 205, 554, 555, 556	
Duck Creek				3.38	LM75/ 3.3	CSOs: 080, 136	
Duck Creek				2.4	LM77/ 1.8	CSOs: 083, 084, 199, 503, Little Duck Creek	
Little Duck Creek				1.9		CSO 071	
Little Duck Creek				1.7		CSOs: 069, 072, 074, 075, 076	
Little Duck Creek				1.15		CSOs: 078, 079	
Clough Creek	5.7	67.9	8.31	2.5	LM97/ 1.2	CSO 182	
Little Miami	105.5	6.5	1757	32.1		Lebanon WWTP	1PC00003
Little Miami				31.95		Mason WWTP	1PC00004
Little Miami				30.7		Deerfield-Hamilton WTP	1IY00162
Little Miami				28.14		Lower Little Miami WWTP	1PK00018
Little Miami				21	LM05/ 21.25	Arrowhead Park WWTP	1PH00014
Little Miami				18.8	LM07/ 18.4	Lake Remington MHP	1PV00101
Little Miami				16.8		MGS Water Sub District	1IX00030
Little Miami				16.1		Wards Corner Regional WWTP	1PK00021
Little Miami				14.2		Villiage of Indian Hill WWTP	1IX00050
Little Miami				13.3	LM09/ 12.9	Milford Waterworks	1IW00110
Little Miami				10	LM12/ 8.3	Evans Landscaping Inc	1IN00298
Little Miami				5.9	LM14/ 6.0	Cincinnati Steel Treating Co; Keebler and Co	1IN00237; 1IH00022
Little Miami				4.45	LM15/ 4.3	CSO 656	
Little Miami				3.5	LM16/ 3.0	CSOs: 085, 086, 470, 471, 476, Duck Creek	
Little Miami				0.8		Richard Miller WWTP	1IV00040

Table 10. Phosphorus removal treatment and facility status at significant WWTP discharges to the Little Miami River mainstem.

WWTP Facilities	LMR River Mile	Phos. Removal Status	Phos. Removal Date	Avg. Design Flow (mgd)	Recent Expansion (last 10 yrs.)	Recent Expansion Date
Upper LMR						
Xenia - Ford Rd	77.03	Biological	1999	3.6	**No**	1999
Beaver Creek (Green Co.)	72.74	Yes*	2013	8.5	Yes	2006
Eastern Regional (Montgomery Co.)	72.74	Chemical	2005	13.0	**No**	1993
Sugar Creek (Green Co.)	64.43	Biological	2009	9.9	Yes	2009
Xenia - Glady Run	63.72	Biological	1999	4.0	**No**	1999
Waynesville (minor)	53.77	Chemical	2008	0.71	**No**	2002
Lower LMR						
Lebanon	32.10	**No**	--	6.0	Yes	2003
Mason #2 (new in 2006)	31.95	Biological	2006	13.0	Yes	2006
Lower Little Miami (Warren Co.)	28.14	Yes*	2013	12.0	Yes	2012
O'Bannon Creek (Clermont Co.)	24.00	**No**	Poss. 2015	4.4	**No**	2001
Polk Run (Hamilton Co.)	21.80	**No**	Poss. 2015	8.0	**No**	2001
Sycamore Creek (Hamilton Co.)	19.22	Biological	2010	9.0	Yes	2010
Wards Corner (minor) Clermont Co.	16.10	Chemical**	2009	2.0	New	2009
East Fork LMR						
Middle East Fork (Clermont Co.)	11.5 (12.6)	**No**	Poss. 2015	7.2	**No**	?
Lower East Fork (Clermont Co.)	11.5 (4.9)	**No**	Poss. 2015	9.0	Yes	2006
Milford	11.5 (1.61)	**No**	--	1.2	Yes	2007

* Specific P removal processes were not determined. **The Wards Corner Regional WWTP was designed to meet final effluent limits for total P of 1.0 mg/l (30 day average) and 1.5 mg/l (7 day average) via biological treatment at 2.0 MGD. This plant is currently <5 % of design capacity and is not able to meet effluent limits for total P thru biological removal processes. Clermont Co. is currently using chemical addition and supplemental sludge handling to meet effluent limits for total P (Source: NPDES Permit Fact Sheet).

To remedy SSOs and CSOs, the County and City signed Consent Decrees in 2002 and 2003 with U.S. EPA, Ohio EPA, and ORSANCO that establish a judicially enforceable framework for ensuring that MSDGC develops and implements sophisticated, long-term plans for remedying the overflows resulting from the aging sewer system. The decrees also require MSDGC to implement millions of dollars of interim measures to ameliorate these problems while developing and implementing the long-term remedial measures.

RESULTS and DISCUSSION

Chemical/Physical Water Quality

Chemical/physical water quality in the Little Miami River study area was characterized by data collected via grab samples from the water column at all wetted sites, continuous measurements over 3-4 consecutive day periods at selected mainstem, tributary, and reference sites, and by sediment chemistry from samples collected at all mainstem, selected tributaries, and all reference sites once in October. The results were evaluated by assessing exceedances of criteria in the Ohio WQS, by exceedances of regional reference thresholds for nutrient and "urban" parameters, and by exceedances of probable effect levels for sediment chemistry (MacDonald et al. 2000). As such, the chemical/physical data herein serves as an indicator of exposure and stress and in support of the biological data for assessing the attainment of designated aquatic life uses and to assist in assigning associated causes and sources. In addition, the discussion of the results is organized by Ohio EPA Waterbody Assessment Units (WAU; Ohio EPA 2010). Bacteria data were collected by grab samples at all sites and were used primarily to determine the status of recreational uses in accordance with the Ohio WQS. Ohio EPA protocols for determining attainment of the applicable designated recreational use tier were followed.

Flow Regime

The flow regime in the Little Miami and East Fork Little Miami River mainstems during the period June 1 – September 30 is depicted in Figure 9 based on flow gauges operated by the U.S. Geological Survey. What are referred to herein as normal summer-fall flows are approximated by the statistical median flows that vary somewhat throughout this time period. Actual flows in 2012 were consistently lower than the medians and were at or below the 80% duration flow. The mainstem Little Miami River flows were at or below the Q7,10 flow in September. The 2012 flow regime was generally comparable to 2007 and much lower than flows in 1998. All sampling was avoided during these high flow events and was not resumed until normal base flows returned.

Water Column Chemistry – Grab Sampling

Water quality was assessed by grab samples collected at predetermined locations in the water column and at graduated frequencies at all sites in the Little Miami River study area. Parameter groupings included field, demand, ionic strength, nutrients, heavy metals, and organic compounds. Continuous measurements over 3-4 consecutive day periods were made at selected mainstem, tributary, and reference sites for D.O. (mg/l), pH (S.U.), conductivity (µS/cm), and temperature (°C) using YSI Datasonde continuous recorders.

This section focuses on key chemical stressors and their concentrations in each of the Little Miami River study area WAUs. Commonly collected chemical parameters were compared either to criteria in the Ohio WQS (Table 11A) or to ecoregion-based benchmarks and biologically derived thresholds in Ohio EPA (1999) for nutrients (Table 11B) and chemical

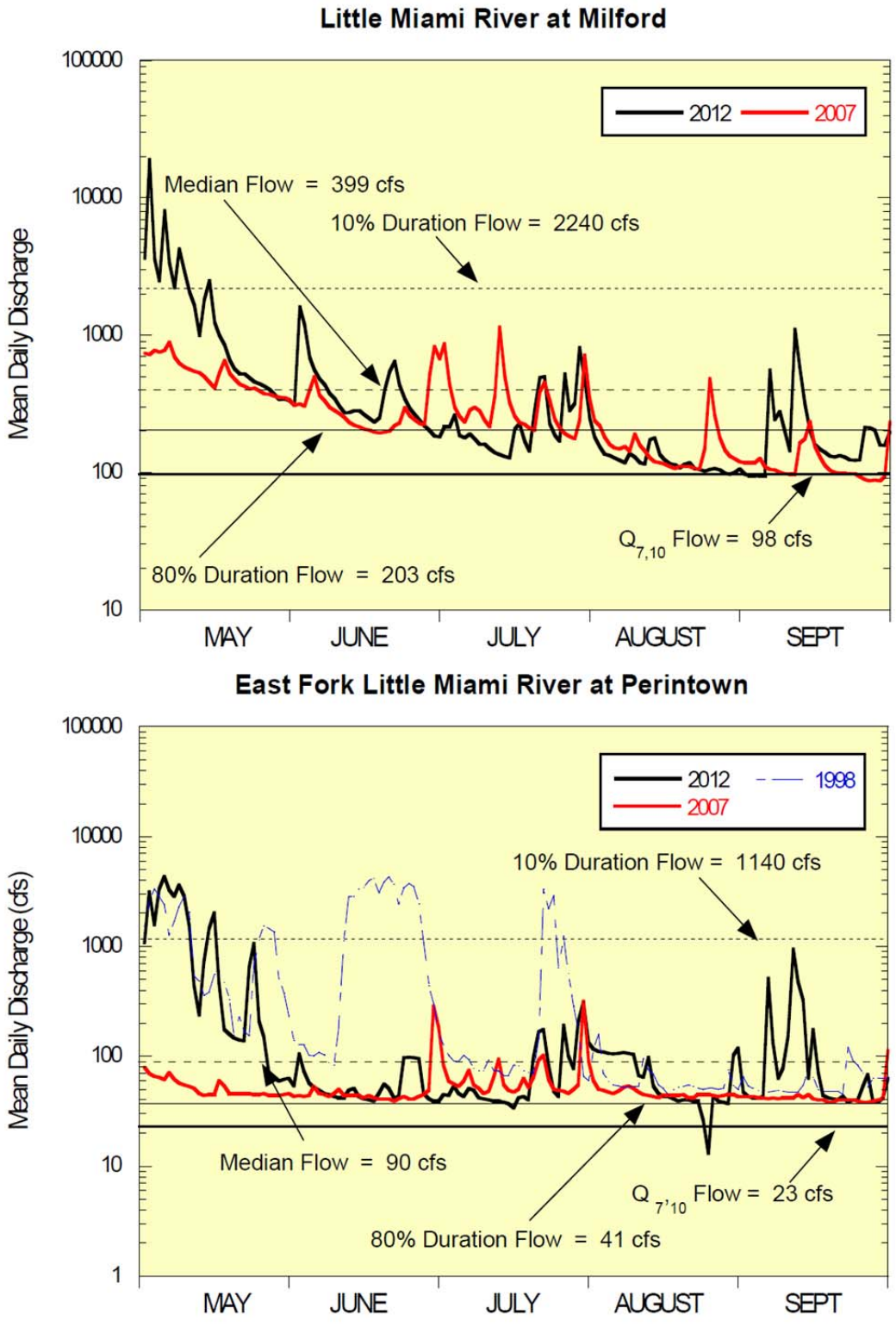

Figure 9. Daily flow measured by the USGS in the Little Miami River at Milford (RM 13.0) and the East Fork Little Miami River at Perintown (RM 6.4) during May 1-September 30, 1998, 2007, and 2012.

Table 11A. Conventional pollutant parameters in the Little Miami River study area during 2012 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
LRAU 90-02 – Little Miami River			
11-001 – Little Miami River			
LM01	28.00	EWH	Pb (27.70)
LM02	24.90	EWH	Pb (15.60)
LM03	22.80	EWH	None
LM04[a]	21.80	EWH	D.O. (5.62);
LM05	21.45	EWH	None
LM06	20.60	EWH	None
LM07	18.60	EWH	D.O. (4.65), (5.74), (5.18), (4.71); T.Amm (1.232)
LM08	17.60	EWH	None
LM09	13.20	EWH	D.O. (5.92); T.Amm (9.903)
LM10	12.40	EWH	D.O. (5.53), (5.30), (4.70); Pb (12.40);
LM11	10.90	EWH	D.O. (5.58); Pb (15.60)
LM12	8.00	EWH	D.O. (5.25), (5.86), (5.94)
LM13	7.30	EWH	Pb (14.00)
LM14	6.00	EWH	D.O. (5.84), (5.40)
LM15	4.30	EWH	Pb (16.30)
LM16	3.50	WWH	Temp C (29.6); Pb (18.70)
LM17	1.40	WWH	None
[11-047] - Unnamed Trib to Little Miami River at RM 0.83			
LM103	0.20	WWH	None
[11-066] - Unnamed Trib to Little Miami River at RM 13.1			
LM21	1.50	WWH	Pb (14.70)
[11-067] - Unnamed Trib to Little Miami River at RM 7.75			
LM20	1.20	PHW3A	None
[11-068] - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River (RM13.1)			
LM19	0.50	PHW3A	None
[11-081] - Unnamed Trib to Little Miami River at 13.8			
LM22	0.00	PHW2	None
[11-082] - Unnamed Trib to Little Miami River at 24.06			
LM23	0.20	PHW2	None
WAU 09-02 – O'Bannon Creek			
[11-010] - O'Bannon Creek (LMR RM 24.06)			
LM37	1.90	WWH	Pb (20.90)
LM38	0.10	WWH	Pb (21.00)
WAU 14-02 – Polk Run			
[11-009] - Polk Run (LMR RM 21.54)			
LM46	3.90	WWH	None
LM39	3.10	WWH	None
LM40	0.30	WWH	None
[11-069] - Unnamed Trib to Polk Run at RM 1.79			
LM41	2.60	WWH	pH (6.44)
LM44	0.40	WWH	None

Table 11A. Conventional pollutant parameters in the Little Miami River study area during 2012 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
[11-070] - Unnamed Trib to Polk Run at RM 0.70			
LM42	2.00	WWH	None
LM43	0.80	WWH	None
[11-071] - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run			
LM45	0.20	WWH	pH (6.39)
WAU 14-01 – Sycamore Creek			
[11-007] - Sycamore Creek (LMR RM 19.2)			
LM47	3.60	WWH	None
LM48	2.40	WWH	None
LM49	1.60	WWH	Pb (23.00)
LM50	1.10	WWH	Cu (17.50)
LM51	0.50	WWH	None
LM52	0.20	WWH	T.Amm (2.685)
[11-008] - North Branch Sycamore Creek			
LM57	5.20	WWH	None
LM62	4.20	PHW3A	None
LM58	3.70	WWH	None
LM59	2.10	WWH	None
LM60	0.50	WWH	None
LM61	0.10	WWH	None
[11-072] - Unnamed Trib to N Branch Sycamore Creek at RM 5.3			
LM65	1.10	PHW2	None
LM54	0.40	PHW2	None
[11-073] - Unnamed Trib to N Branch Sycamore Creek at RM 5.4			
LM63	0.60	WWH	None
[11-074] - Unnamed Trib to N Br Sycamore Cr at RM 0.75			
LM64	1.40	PHW3A	None
[11-049] - Trib To Sycamore Cr. (RM 1.12)			
LM55	1.00	WWH	None
LM56	0.30	WWH	None
LM53	0.10	WWH	None
WAU 13-05 – East Fork Little Miami River			
[11-100] - East Fork Little Miami River (LMR RM 11.5)			
LM25	19.50	EWH	Pb (11.30)
LM26	14.90	EWH	Pb (12.30)
LM27	13.90	EWH	Pb (19.80)
LM28	13.20	EWH	D.O. (5.77), (5.76)
LM29	11.30	EWH	D.O. (5.69), (5.11), (5.23), (5.90), (5.97)
LM30	9.00	EWH	D.O. (5.95); Pb (11.40)
LM31	5.60	EWH	D.O. (5.94); Pb (21.70)
LM32	4.30	EWH	Pb (18.00)
LM34	2.10	EWH	Pb (13.70)
LM35	1.60	EWH	Cu (15.50); Pb (14.30); Pb (15.60)

Table 11A. Conventional pollutant parameters in the Little Miami River study area during 2012 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
LM36	0.70	EWH	D.O. (5.48), (5.53); Pb (13.60); Pb (18.10)
WAU 14-05 – Dry Run			
[11-005] - Dry Run (LMR RM 7.54)			
LM70	5.70	PHW3A	None
LM66	4.20	WWH	None
LM67	2.50	WWH	None
[11-064] - Trib to Dry Run (4.20)			
LM69	0.20	PHW3A	None
WAU 14-03 – Duck Creek			
[11-004] - Duck Creek (LMR RM 3.87)			
LM71	6.00	LRW	None
LM78	5.30	LRW	Cu (37.80), (37.80); Cu (76.10); Cu (180.00) ; Cu (59.70), ; Cu (46.10); Cu (35.00),
LM72	4.70	LRW	None
LM73	4.40	LRW	Temp C (31.8); Cu (19.00)
LM75	3.30	LRW	Pb (33.30)
LM76	2.90	WWH	D.O. (0.48); Cu (20.90); Pb (30.20)
LM77	1.80	WWH	None
LM91	1.00	WWH	None
LM79	0.90	WWH	D.O. (3.81), (3.20)
LM74	0.20	WWH	None
[11-051] - East Fork Duck Creek			
LM85	1.90	WWH	None
LM84	0.60	WWH	None
[11-075] - Unnamed Trib to Duck Creek at RM 4.8			
LM80	0.20	LRW	None
[11-076] - Little Duck Creek			
LM86	2.70	PHW3A	None
LM87	2.60	PHW3A	Pb (41.70)
LM90	2.40	PHW3A	Pb (25.00)
LM88	1.80	PHW2A	None
LM89	1.40	MWH	None
LM92	0.20	WWH	D.O. (2.39), (3.80)
[11-077]- Unnamed Trib to Little Duck Creek at RM 4.42			
LM82	0.10	WWH	None
WAU 14-06 Clough Creek			
[11-002] - Clough Creek (LMR RM 3.36)			
LM99	4.60	PHW3A	None
LM95	3.20	WWH	None
LM96	3.10	WWH	None
LM97	1.20	WWH	None
LM98	0.60	WWH	D.O. (3.75); Pb (16.90)

Table 11A. Conventional pollutant parameters in the Little Miami River study area during 2012 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
[11-003] - McCullough Run (LMR RM 3.7)			
LM94	1.30	WWH	None
11-078 - Unnamed Trib to McCullough Run at RM 1.08			
LM93	1.60	WWH	None
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06			
LM101	1.10	WWH	None
[11-080] - UT at RM 0.66 to UT to Clough Creek at RM 3.06			
LM102	0.60	PHW2	None
[11-081] - UT at RM 0.95 to UT to Clough Creek at RM 3.06			
LM100	0.20	WWH	None
WAU 12-08 Five Mile Creek – Ohio River			
[10-001] - Five Mile Creek			
LM107	2.90	WWH	None
LM108	0.20	WWH	None
10-002 - Eight Mile Creek			
LM105	2.10	PHW3A	None
[10-130] - Trib to Eight Mile Creek at RM 1.01			
LM106	0.10	PHW3A	None
[10-537] - Four Mile Creek			
LM104	0.90	WWH	T.Amm (3.799)
WAU 08-03 Turtle Creek			
[11-021] - Turtle Creek			
RF08	6.80	WWH	D.O. (2.80), (3.17), (3.55); Pb (30.00)
11-022] - Dry Run			
RF09	1.80	CWH	None
[11-030] - Newman Run			
RF10	0.30	EWH	D.O. (3.52), (5.56), (3.38), (3.39), (5.10), (3.60)

[a]- mixing zone sample.

Table 11B. Nutrient parameter results in the Little Miami River study area in 2012. Values >reference targets are shaded in yellow.

Site ID	River Mile	Aquatic Life Use	Ammonia-N (mg/l)		Nitrate-Nitrite-N (mg/l)		Kjeldahl N (mg/l)		Total Phosphorus (mg/l)	
			Median	Target	Median	Target	Median	Target	Median	Target
LRAU 90-02 – Little Miami River										
11-001 – Little Miami River										
LM01	28.00	EWH	0.030	0.050	2.450	2.930	0.630	0.900	0.025	0.350
LM02	24.90	EWH	0.030	0.050	1.610	2.930	0.670	0.900	0.025	0.350
LM03	22.80	EWH	0.030	0.050	1.520	2.930	0.660	0.900	0.025	0.350
LM04[a]	21.80	EWH	0.030	0.050	9.060	2.930	1.160	0.900	1.100	0.350
LM05	21.45	EWH	0.030	0.050	1.780	2.930	0.660	0.900	0.025	0.350
LM06	20.60	EWH	0.030	0.050	1.910	2.930	0.740	0.900	0.025	0.350
LM07	18.60	EWH	0.030	0.050	2.100	2.930	0.770	0.900	0.025	0.350
LM08	17.60	EWH	0.030	0.050	1.850	2.930	0.730	0.900	0.025	0.350
LM09	13.20	EWH	0.030	0.050	1.930	2.930	0.680	0.900	0.025	0.350
LM10	12.40	EWH	0.030	0.050	1.990	2.930	0.800	0.900	0.025	0.350
LM11	10.90	EWH	0.030	0.050	1.460	2.930	0.710	0.900	0.025	0.350
LM12	8.00	EWH	0.030	0.050	1.740	2.930	0.830	0.900	0.025	0.350
LM13	7.30	EWH	0.030	0.050	1.600	2.930	0.860	0.900	0.025	0.350
LM14	6.00	EWH	0.030	0.050	1.520	2.930	0.770	0.900	0.025	0.350
LM15	4.30	EWH	0.030	0.050	1.530	2.930	0.750	0.900	0.025	0.350
LM16	3.50	WWH	0.030	0.050	1.500	2.930	0.790	0.900	0.025	0.350
LM17	1.40	WWH	0.030	0.050	1.540	2.930	0.870	0.900	0.025	0.350
[11-047] - Unnamed Trib to Little Miami River at RM 0.83										
LM103	0.20	WWH	0.030	0.064	0.250	1.180	0.110	0.500	0.320	0.130
[11-066] - Unnamed Trib to Little Miami River at RM 13.1										
LM21	1.50	WWH	0.030	0.064	1.620	1.180	0.970	0.500	0.025	0.130
[11-067] - Unnamed Trib to Little Miami River at RM 7.75										
LM20	1.20	PHW3A	0.030	0.064	0.770	1.180	0.250	0.500	0.025	0.130
[11-068] - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River (RM13.1)										
LM19	0.50	PHW3A	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
[11-085] - Unnamed Trib to Little Miami River at 13.8										
LM22	0.00	PHW2	0.030	0.064	0.250	1.180	1.110	0.500	0.025	0.130
[11-082] - Unnamed Trib to Little Miami River at 24.06										
LM23	0.20	PHW2	0.030	0.064	0.250	1.180	1.660	0.500	0.025	0.130
WAU 09-02 – O'Bannon Creek										
[11-010] - O'Bannon Creek (LMR RM 24.06)										
LM37	1.90	WWH	0.030	0.053	5.490	0.540	0.250	0.800	0.810	0.150
LM38	0.10	WWH	0.030	0.053	13.600	0.540	0.250	0.800	1.600	0.150
WAU 14-02 – Polk Run										
[11-009] - Polk Run (LMR RM 21.54)										
LM46	3.90	WWH	0.030	0.064	0.250	1.180	0.460	0.500	0.025	0.130
LM39	3.10	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM40	0.30	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
[11-069] - Unnamed Trib to Polk Run at RM 1.79										
LM41	2.60	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM44	0.40	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
[11-070] - Unnamed Trib to Polk Run at RM 0.70										
LM42	2.00	WWH	0.030	0.064	0.600	1.180	0.250	0.500	0.025	0.130
LM43	0.80	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
[11-071] - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run										
LM45	0.20	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130

Table 11B. Nutrient parameter results in the Little Miami River study area in 2012. Values >reference targets are shaded in yellow.

Site ID	River Mile	Aquatic Life Use	Ammonia-N (mg/l)		Nitrate-Nitrite-N (mg/l)		Kjeldahl N (mg/l)		Total Phosphorus (mg/l)	
			Median	Target	Median	Target	Median	Target	Median	Target
WAU 14-01 – Sycamore Creek										
[11-007] - Sycamore Creek (LMR RM 19.2)										
LM47	3.60	WWH	0.030	0.064	2.170	1.180	0.340	0.500	0.500	0.130
LM48	2.40	WWH	0.030	0.064	0.250	1.180	0.410	0.500	0.260	0.130
LM49	1.60	WWH	0.030	0.064	0.250	1.180	0.370	0.500	0.025	0.130
LM50	1.10	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM51	0.50	WWH	0.030	0.053	0.250	0.540	0.250	0.800	0.025	0.150
LM52	0.20	WWH	0.030	0.053	0.250	0.540	0.580	0.800	0.025	0.150
[11-008] - North Branch Sycamore Creek										
LM57	5.20	WWH	0.030	0.064	0.390	1.180	0.250	0.500	0.025	0.130
LM62	4.20	PHW3A	0.030	0.064	0.250	1.180	0.570	0.500	0.025	0.130
LM58	3.70	WWH	0.030	0.064	0.250	1.180	0.240	0.500	0.025	0.130
LM59	2.10	WWH	0.030	0.064	3.220	1.180	0.250	0.500	0.025	0.130
LM60	0.50	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM61	0.10	WWH	0.030	0.064	3.020	1.180	0.430	0.500	0.025	0.130
[11-072] - Unnamed Trib to N Branch Sycamore Creek at RM 5.3										
LM65	1.10	PHW2	0.030	0.064	0.250	1.180	0.750	0.500	0.025	0.130
LM54	0.40	PHW2	0.030	0.064	0.250	1.180	0.330	0.500	0.025	0.130
[11-073] - Unnamed Trib to N Branch Sycamore Creek at RM 5.4										
LM63	0.60	WWH	0.030	0.064	0.250	1.180	0.610	0.500	0.025	0.130
[11-074] - Unnamed Trib to N Br Sycamore Cr at RM 0.75										
LM64	1.40	PHW3A	0.030	0.064	0.250	1.180	1.100	0.500	0.025	0.130
[11-049] - Trib To Sycamore Cr. (RM 1.12)										
LM55	1.00	WWH	0.030	0.064	0.500	1.180	0.260	0.500	0.025	0.130
LM56	0.30	WWH	0.030	0.064	0.160	1.180	0.380	0.500	0.220	0.130
LM53	0.10	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
WAU 13-05 – East Fork Little Miami River										
[11-100] - East Fork Little Miami River (LMR RM 11.5)										
LM25	19.50	EWH	0.030	0.126	0.460	0.960	0.610	0.700	0.150	0.330
LM26	14.90	EWH	0.030	0.126	0.250	0.960	0.590	0.700	0.025	0.330
LM27	13.90	EWH	0.030	0.126	0.570	0.960	0.500	0.700	0.025	0.330
LM28	13.20	EWH	0.030	0.126	0.500	0.960	0.580	0.700	0.025	0.330
LM29	11.30	EWH	0.030	0.126	3.080	0.960	0.740	0.700	0.470	0.330
LM30	9.00	EWH	0.030	0.126	2.440	0.960	0.620	0.700	0.025	0.330
LM31	5.60	EWH	0.030	0.126	1.790	0.960	0.640	0.700	0.025	0.330
LM32	4.30	EWH	0.030	0.126	3.370	0.960	0.620	0.700	0.620	0.330
LM34	2.10	EWH	0.030	0.126	3.340	0.960	0.540	0.700	0.620	0.330
LM35	1.60	EWH	0.030	0.126	4.150	0.960	0.450	0.700	0.630	0.330
LM36	0.70	EWH	0.030	0.126	3.360	0.960	0.590	0.700	0.560	0.330
WAU 14-05 – Dry Run										
[11-005] - Dry Run (LMR RM 7.54)										
LM70	5.70	PHW3A	0.030	0.064	1.030	1.180	0.670	0.500	0.025	0.130
LM66	4.20	WWH	0.030	0.064	1.080	1.180	0.280	0.500	0.280	0.130
LM67	2.50	WWH	0.030	0.064	0.380	1.180	0.180	0.500	0.280	0.130
[11-064] - Trib to Dry Run (4.20)										
LM69	0.20	PHW3A	0.030	0.064	0.560	1.180	0.250	0.500	0.025	0.130

Table 11B. Nutrient parameter results in the Little Miami River study area in 2012. Values >reference targets are shaded in yellow.

Site ID	River Mile	Aquatic Life Use	Ammonia-N (mg/l)		Nitrate-Nitrite-N (mg/l)		Kjeldahl N (mg/l)		Total Phosphorus (mg/l)	
			Median	Target	Median	Target	Median	Target	Median	Target
WAU 14-06 – Duck Creek										
[11-004] - Duck Creek (LMR RM 3.87)										
LM71	6.00	LRW	0.030	0.064	1.390	1.180	0.600	0.500	0.025	0.130
LM78	5.30	LRW	0.030	0.064	0.590	1.180	2.980	0.500	0.910	0.130
LM72	4.70	LRW	0.030	0.064	0.250	1.180	0.840	0.500	0.025	0.130
LM73	4.40	LRW	0.030	0.064	0.250	1.180	0.810	0.500	0.025	0.130
LM75	3.30	LRW	0.030	0.064	1.320	1.180	0.610	0.500	0.025	0.130
LM76	2.90	WWH	0.030	0.064	1.250	1.180	0.590	0.500	0.025	0.130
LM77	1.80	WWH	0.030	0.064	0.250	1.180	0.700	0.500	0.025	0.130
LM91	1.00	WWH	0.030	0.064	0.250	1.180	0.410	0.500	0.025	0.130
LM79	0.90	WWH	0.030	0.064	0.250	1.180	0.600	0.500	0.025	0.130
LM74	0.20	WWH	0.030	0.064	0.250	1.180	0.500	0.500	0.025	0.130
[11-051] - East Fork Duck Creek										
LM85	1.90	WWH	0.030	0.064	0.740	1.180	0.250	0.500	0.025	0.130
LM84	0.60	WWH	0.030	0.064	0.250	3.150	0.250	0.500	0.025	0.340
[11-075] - Unnamed Trib to Duck Creek at RM 4.8										
LM80	0.20	LRW	0.030	0.064	0.390	1.180	0.750	0.500	0.025	0.130
[11-076] - Little Duck Creek										
LM86	2.70	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM87	2.60	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM90	2.40	WWH	0.030	0.064	0.250	1.180	0.410	0.500	0.025	0.130
LM88	1.80	WWH	0.030	0.064	0.250	1.180	0.370	0.500	0.025	0.130
LM89	1.40	WWH	0.030	0.064	2.860	1.180	0.830	0.500	0.025	0.340
LM92	0.20	WWH	0.030	0.064	0.250	1.180	1.060	0.500	0.025	0.130
077										
LM82	0.10	PHW3A	0.030	0.064	1.240	1.180	1.060	0.500	0.025	0.130
WAU 14-06 Clough Creek										
[11-002] - Clough Creek (LMR RM 3.36)										
LM99	4.60	PHW3A	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM95	3.20	WWH	0.030	0.064	0.250	1.180	0.380	0.500	0.430	0.130
LM96	3.10	WWH	0.030	0.064	5.590	1.180	0.250	0.500	0.025	0.130
LM97	1.20	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM98	0.60	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
[11-003] - McCullough Run (LMR RM 3.7)										
LM94	1.30	WWH	0.030	0.064	0.630	1.180	0.580	0.500	0.025	0.130
11-078 - Unnamed Trib to McCullough Run at RM 1.08										
LM93	1.60	WWH	0.030	0.064	0.640	1.180	0.470	0.500	0.025	0.130
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06										
LM101	1.10	WWH	0.030	0.064	0.250	1.180	0.350	0.500	0.660	0.130
[11-080] - UT at RM 0.66 to UT to Clough Creek at RM 3.06										
LM102	0.60	PHW2	0.030	0.064	0.250	1.180	0.270	0.500	0.350	0.130
[11-081] - UT at RM 0.95 to UT to Clough Creek at RM 3.06										
LM100	0.20	WWH	0.030	0.064	0.250	1.180	0.180	0.500	0.310	0.130
WAU 12-08 Five Mile Creek – Ohio River										
[10-001] - Five Mile Creek										
LM107	2.90	WWH	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
LM108	0.20	WWH	0.030	0.064	0.510	1.180	0.250	0.500	0.025	0.130

Table 11B. Nutrient parameter results in the Little Miami River study area in 2012. Values >reference targets are shaded in yellow.

Site ID	River Mile	Aquatic Life Use	Ammonia-N (mg/l)		Nitrate-Nitrite-N (mg/l)		Kjeldahl N (mg/l)		Total Phosphorus (mg/l)	
			Median	Target	Median	Target	Median	Target	Median	Target
10-002 - Eight Mile Creek										
LM105	2.10	PHW3A	0.030	0.064	0.560	1.180	0.400	0.500	0.025	0.130
[10-130] - Trib to Eight Mile Creek at RM 1.01										
LM106	0.10	PHW3A	0.030	0.064	0.250	1.180	0.250	0.500	0.025	0.130
[10-537] - Four Mile Creek										
LM104	0.90	WWH	0.030	0.064	0.250	1.180	0.340	0.500	0.025	0.130
WAU 08-03 Turtle Creek										
[11-021] - Turtle Creek										
RF08	6.80	WWH	0.030	0.053	0.250	0.540	0.250	0.800	0.025	0.150
11-022] - Dry Run										
RF09	1.80	CWH	0.030	0.064	0.250	0.490	0.250	0.500	0.025	0.050
[11-030] - Newman Run										
RF10	0.30	EWH	0.030	0.064	0.250	0.490	0.250	0.500	0.025	0.050

[a]-mixing zone

stressors that are commonly associated with urban runoff (Table 11C). The biologically derived thresholds relate concentrations to levels associated with attainment of fish IBIs and macroinvertebrate ICIs for appropriate aquatic life uses in Interior Plateau (IP) or Eastern Corn Belt Plains (ECBP) ecoregions (Ohio EPA 1999).

LRAU – 90-02 –Lower Little Miami River Mainstem

Seven sites had one or more excursions of the 6 mg/l dissolved oxygen 24-hour average or the 5 mg/l minimum criteria for EWH between RM 18.6 and RM 6.0 (Table 11A). During the 2007 Ohio EPA survey (Ohio EPA 2009) there was a single excursion of the EWH D.O. criterion along a much longer length of the Little Miami River mainstem. Evident in the grab samples (Table 11A, Figure 10) were more excursions below 6.0 and 5.0 mg/L during 2012 compared to Ohio EPA results in 2007.

In addition, the sites at RM 17.6 and upstream had more values with elevated D.O. levels above 12-15 mg/l (Figure 10) compared to 2007 (not pictured, Ohio EPA 2009). Elevated daytime D.O. levels and wide diel swings indicates an indirect effect of nutrient enrichment. TKN is a measure of organic nitrogen and is also an indicator of organic enrichment. The mainstem of the Little Miami River had a number of TKN values that exceeded regional reference levels for large rivers and the frequency of the highest values ($\geq$2 mg/l) was higher than they were in 2007 (Figure 11). In addition, 5-day BOD concentrations were elevated above regional reference values (Figure 12) which occurred on the same days with wide diel D.O. swings and elevated TKN concentrations.

Chloride levels were elevated slightly above reference levels for large rivers, but declined below the confluence with the East Fork which carries much lower concentrations of TDS and chlorides than does the Little Miami River thus acting to dilute those values (Table 11C). This

Table 11C. Urban parameter results in the Little Miami River study area in 2012. Values >reference targets are highlighted in yellow.

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS		T-Cu		T-Pb		T-Zn	
			Med-ian	Tar-get	Med-ian	Tar-get	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Targ et	Med-ian	Target
LRAU 90-02 – Little Miami River																		
11-001 – Little Miami River																		
LM01	28.00	EWH	895	810	125.0	82.0	56.0	170.3	470.0	727.0	16.0	50.0	7.610	5.0	5.82	4.0	12.45	30.0
LM02	24.90	EWH	802.0	810.0	98.5	82.0	47.5	170.3	440.0	727.0	18.0	50.0	6.4	5.0	3.0	4.0	8.460	30.0
LM03	22.80	EWH	781.0	810.0	96.6	82.0	51.0	170.3	430.0	727.0	18.0	50.0	8.0	5.0	3.0	4.0	9.960	30.0
LM04	21.80	EWH	1092	810.0	184.0	82.0	75.5	170.3	590.0	727.0	14.0	50.0	11.9	5.0	4.52	4.0	23.0	30.0
LM05	21.45	EWH	791.0	810.0	95.7	82.0	52.8	170.3	440.0	727.0	16.0	50.0	6.770	5.0	3.0	4.0	9.440	30.0
LM06	20.60	EWH	749.0	810.0	93.6	82.0	50.0	170.3	430.0	727.0	18.0	50.0	6.280	5.0	3.0	4.0	9.0	30.0
LM07	18.60	EWH	825.5	810.0	103.3	82.0	49.5	170.3	425.0	727.0	19.0	50.0	7.540	5.0	3.0	4.0	11.45	30.0
LM08	17.60	EWH	796.0	810.0	99.6	82.0	56.0	170.3	410.0	727.0	22.0	50.0	7.580	5.0	3.0	4.0	11.5	30.0
LM09	13.20	EWH	772.0	810.0	107.0	82.0	50.2	170.3	400.0	727.0	20.0	50.0	8.510	5.0	4.26	4.0	18.4	30.0
LM10	12.40	EWH	746.0	810.0	77.9	82.0	43.2	170.3	360.0	727.0	24.0	50.0	6.740	5.0	3.0	4.0	14.3	30.0
LM11	10.90	EWH	630.0	810.0	76.3	82.0	46.0	170.3	340.0	727.0	22.0	50.0	6.580	5.0	3.0	4.0	8.030	30.0
LM12	8.00	EWH	697.0	810.0	82.7	82.0	46.5	170.3	350.0	727.0	21.0	50.0	6.810	5.0	3.0	4.0	11.950	30.0
LM13	7.30	EWH	702.5	810.0	80.6	82.0	46.8	170.3	380.0	727.0	20.0	50.0	9.1	5.0	3.0	4.0	9.670	30.0
LM14	6.00	EWH	714.0	810.0	80.7	82.0	49.2	170.3	380.0	727.0	22.0	50.0	7.0	5.0	3.83	4.0	13.45	30.0
LM15	4.30	EWH	711.0	810.0	80.3	82.0	46.2	170.3	380.0	727.0	20.0	50.0	7.670	5.0	5.56	4.0	9.810	30.0
LM16	3.50	WWH	714.0	810.0	83.5	82.0	46.2	170.3	370.0	727.0	20.0	50.0	7.260	5.0	4.0	4.0	12.5	30.0
LM17	1.40	WWH	696.0	810.0	83.2	82.0	47.5	170.3	380.0	727.0	26.0	50.0	7.880	5.0	3.0	4.0	9.390	30.0
[11-047] - Unnamed Trib to Little Miami River at RM 0.83																		
LM103	0.20	WWH	541.0	600.0	51.0	35.0	94.5	118.75	440.0	468.0	6.0	25.0	6.740	5.0	3.0	3.0	14.3	15.0
[11-066] - Unnamed Trib to Little Miami River at RM 13.1																		
LM21	1.50	WWH	474.0	600.0	106.0	35.0	57.5	118.75	430.0	468.0	20.0	25.0	7.110	5.0	5.13	3.0	9.560	15.0
[11-067] - Unnamed Trib to Little Miami River at RM 7.75																		
LM20	1.20	PHW3A	459.0	600.0	141.0	35.0	78.5	118.75	560.0	468.0	8.0	25.0	0.0	5.0	7.960	3.0	0.0	15.0
[11-068] - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River (RM13.1)																		
LM19	0.50	PHW3A	520.0	600.0	160.0	35.0	61.5	118.75	510.0	468.0	22.0	25.0	0.0	5.0	7.960	3.0	0.0	15.0
[11-085] - Unnamed Trib to Little Miami River at 13.8																		
LM22	0.00	PHW2	376.0	600.0	59.6	35.0	51.0	118.75	390.0	468.0	10.0	25.0	7.110	5.0	5.31	3.0	9.560	15.0
[11-082] - Unnamed Trib to Little Miami River at 24.06																		
LM23	0.20	PHW2	340.0	600.0	58.8	35.0	62.5	118.75	330.0	468.0	14.0	25.0	7.110	5.0	5.31	3.0	9.560	15.0
WAU 09-02 – O'Bannon Creek																		
[11-010] - O'Bannon Creek (LMR RM 24.06)																		
LM37	1.90	WWH	790.0	610.0	90.1	31.0	69.9	120.0	330.0	522.58	14.0	41.3	11.960	5.0	3.0	3.0	27.850	15.0
LM38	0.10	WWH	847.0	610.0	82.2	31.0	82.0	120.0	410.0	522.58	12.0	41.3	7.920	5.0	3.0	3.0	27.1	15.0

Table 11C. Urban parameter results in the Little Miami River study area in 2012. Values >reference targets are highlighted in yellow.

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS		T-Cu		T-Pb		T-Zn	
			Med-ian	Tar-get	Med-ian	Tar-get	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Targ et	Med-ian	Target
WAU 14-02 – Polk Run																		
[11-009] - Polk Run (LMR RM 21.54)																		
LM46	3.90	WWH	971.5	600.0	206.5	35.0	80.0	118.75	750.0	468.0	9.0	25.0	7.2	5.0	3.0	3.0	7.2	15.0
LM39	3.10	WWH	939.0	600.0	150.0	35.0	75.5	118.75	510.0	468.0	4.0	25.0	10.4	5.0	7.09	3.0	13.8	15.0
LM40	0.30	WWH	727.0	600.0	106.4	35.0	63.0	118.75	455.0	468.0	7.0	25.0	8.960	5.0	7.40	3.0	43.75	15.0
[11-069] - Unnamed Trib to Polk Run at RM 1.79																		
LM41	2.60	WWH	644.0	600.0	71.6	35.0	64.0	118.75	420.0	468.0	8.0	25.0	8.960	5.0	7.4	3.0	43.75	15.0
LM44	0.40	WWH	587.0	600.0	74.2	35.0	76.0	118.75	350.0	468.0	6.0	25.0	8.960	5.0	7.4	3.0	43.75	15.0
[11-070] - Unnamed Trib to Polk Run at RM 0.70																		
LM42	2.00	WWH	818.0	600.0	129.0	35.0	78.5	118.75	530.0	468.0	42.0	25.0	8.960	5.0	12.050	3.0	43.75	15.0
LM43	0.80	WWH	457.0	600.0	67.3	35.0	46.8	118.75	290.0	468.0	4.0	25.0	8.960	5.0	12.050	3.0	43.75	15.0
[11-071] - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run																		
LM45	0.20	WWH	531.0	600.0	89.7	35.0	55.0	118.75	310.0	468.0	14.0	25.0	8.960	5.0	12.050	3.0	43.75	15.0
WAU 14-01 – Sycamore Creek																		
[11-007] - Sycamore Creek (LMR RM 19.2)																		
LM47	3.60	WWH	928.5	600.0	136.5	35.0	52.75	118.75	425.0	468.0	5.0	25.0	6.920	5.0	7.6	3.0	34.45	15.0
LM48	2.40	WWH	835.5	600.0	103.2	35.0	37.35	118.75	395.0	468.0	3.0	25.0	9.2	5.0	6.050	3.0	13.5	15.0
LM49	1.60	WWH	798.0	600.0	103.0	35.0	49.5	118.75	410.0	468.0	8.0	25.0	6.680	5.0	3.0	3.0	11.330	15.0
LM50	1.10	WWH	705.0	600.0	96.5	35.0	52.5	118.75	400.0	468.0	12.0	25.0	8.090	5.0	3.0	3.0	8.940	15.0
LM51	0.50	WWH	712.0	610.0	87.8	31.0	44.8	120.0	340.0	522.58	10.0	41.3	6.390	5.0	3.0	3.0	9.560	15.0
LM52	0.20	WWH	768.0	610.0	125.0	31.0	67.5	120.0	430.0	522.58	6.0	41.3	7.0	5.0	3.0	3.0	36.150	15.0
[11-008] - North Branch Sycamore Creek																		
LM57	5.20	WWH	946.5	600.0	247.5	35.0	90.75	118.75	640.0	468.0	9.0	25.0	7.630	5.0	4.88	3.0	6.890	15.0
LM62	4.20	WWH	736.0	600.0	128.0	35.0	42.2	118.75	350.0	468.0	12.0	25.0	7.630	5.0	5.48	3.0	53.1	15.0
LM58	3.70	WWH	993.0	600.0	218.0	35.0	75.5	118.75	650.0	468.0	13.0	25.0	7.860	5.0	5.85	3.0	8.420	15.0
LM59	2.10	WWH	728.0	600.0	188.0	35.0	53.75	118.75	480.0	468.0	5.5	25.0	8.150	5.0	5.62	3.0	14.150	15.0
LM60	0.50	WWH	646.5	600.0	83.550	35.0	42.150	118.75	415.0	468.0	9.5	25.0	8.4	5.0	3.0	3.0	10.9	15.0
LM61	0.10	WWH	729.0	600.0	160.2	35.0	70.75	118.75	425.0	468.0	23.0	25.0	7.630	5.0	5.48	3.0	53.1	15.0
[11-072] - Unnamed Trib to N Branch Sycamore Creek at RM 5.3																		
LM65	1.10	PHW2	583.0	600.0	278.0	35.0	144.0	118.75	670.0	468.0	10.0	25.0	7.630	5.0	5.48	3.0	53.1	15.0
LM54	0.40	PHW2	684.0	600.0	66.8	35.0	118.0	118.75	390.0	468.0	14.0	25.0	7.0	5.0	3.0	3.0	36.150	15.0
[11-073] - Unnamed Trib to N Branch Sycamore Creek at RM 5.4																		
LM63	0.60	WWH	883.0	600.0	148.0	35.0	128.0	118.75	500.0	468.0	20.0	25.0	7.630	5.0	5.48	3.0	53.1	15.0
[11-074] - Unnamed Trib to N Br Sycamore Cr at RM 0.75																		
LM64	1.40	PHW3A	1200	600.0	38.9	35.0	59.8	118.75	330.0	468.0	66.0	25.0	7.630	5.0	5.48	3.0	53.1	15.0

Table 11C. Urban parameter results in the Little Miami River study area in 2012. Values >reference targets are highlighted in yellow.

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS		T-Cu		T-Pb		T-Zn	
			Med-ian	Tar-get	Med-ian	Tar-get	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Targ et	Med-ian	Target
[11-049] - Trib To Sycamore Cr. (RM 1.12)																		
LM55	1.00	WWH	869.0	600.0	107.0	35.0	47.2	118.75	410.0	468.0	16.0	25.0	7.0	5.0	3.0	3.0	36.150	15.0
LM56	0.30	WWH	519.0	600.0	67.150	35.0	42.1	118.75	235.0	468.0	7.5	25.0	8.460	5.0	8.75	3.0	11.460	15.0
LM53	0.10	WWH	559.0	600.0	73.0	35.0	48.5	118.75	440.0	468.0	12.0	25.0	7.0	5.0	3.0	3.0	36.150	15.0
WAU 13-05 – East Fork Little Miami River																		
[11-100] - East Fork Little Miami River (LMR RM 11.5)																		
LM25	19.50	EWH	254.0	726.3	14.2	55.0	17.5	115.0	166.0	529.5	2.5	31.0	7.1	5.0	3.0	3.0	7.620	20.0
LM26	14.90	EWH	267.0	726.3	14.7	55.0	21.2	115.0	180.0	529.5	8.0	31.0	5.090	5.0	3.0	3.0	8.390	20.0
LM27	13.90	EWH	275.0	726.3	15.6	55.0	21.7	115.0	176.0	529.5	6.0	31.0	6.180	5.0	3.0	3.0	11.650	20.0
LM28	13.20	EWH	283.0	726.3	16.1	55.0	21.8	115.0	160.0	529.5	10.0	31.0	2.75	5.0	3.0	3.0	6.35	20.0
LM29	11.30	EWH	362.0	726.3	26.1	55.0	28.8	115.0	210.0	529.5	10.0	31.0	6.6	5.0	3.0	3.0	10.5	20.0
LM30	9.00	EWH	359.0	726.3	23.1	55.0	26.8	115.0	210.0	529.5	9.0	31.0	5.830	5.0	3.0	3.0	14.950	20.0
LM31	5.60	EWH	359.0	726.3	24.9	55.0	28.9	115.0	212.0	529.5	12.0	31.0	4.770	5.0	3.0	3.0	10.2	20.0
LM32	4.30	EWH	471.0	726.3	37.4	55.0	37.8	115.0	250.0	529.5	27.0	31.0	6.670	5.0	3.16	3.0	12.3	20.0
LM34	2.10	EWH	477.0	726.3	43.1	55.0	41.5	115.0	230.0	529.5	22.0	31.0	6.99	5.0	3.0	3.0	14.3	20.0
LM35	1.60	EWH	461.0	726.3	43.8	55.0	45.2	115.0	270.0	529.5	20.0	31.0	10.15	5.0	3.0	3.0	15.0	20.0
LM36	0.70	EWH	500.0	726.3	41.1	55.0	36.0	115.0	250.0	529.5	30.0	31.0	7.730	5.0	3.0	3.0	16.1	20.0
WAU 14-05 – Dry Run																		
[11-005] - Dry Run (LMR RM 7.54)																		
LM70	5.70	PHW3A	428.0	600.0	28.3	35.0	44.5	118.75	250.0	468.0	12.0	25.0	6.290	5.0	6.0	3.0	6.0	15.0
LM66	4.20	WWH	533.0	600.0	35.9	35.0	63.5	118.75	300.0	468.0	8.0	25.0	0.0	5.0	5.0	3.0	9.0	15.0
LM67	2.50	WWH	569.5	600.0	47.3	35.0	50.75	118.75	365.0	468.0	8.0	25.0	6.290	5.0	6.0	3.0	6.0	15.0
[11-064] - Trib to Dry Run (4.20)																		
LM69	0.20	PHW3A	763.0	600.0	82.6	35.0	73.5	118.75	340.0	468.0	3.0	25.0	6.290	5.0	6.0	3.0	6.0	15.0
WAU 14-03 – Duck Creek																		
[11-004] - Duck Creek (LMR RM 3.87)																		
LM71	6.00	LRW	1174	600.0	237.5	35.0	128.5	118.75	565.0	468.0	5.5	25.0	6.9	5.0	13.05	3.0	18.650	15.0
LM78	5.30	LRW	1100	600.0	175.0	35.0	114.0	118.75	625.0	468.0	176.0	25.0	41.95	5.0	27.850	3.0	152.0	15.0
LM72	4.70	LRW	1116	600.0	205.5	35.0	144.0	118.75	620.0	468.0	10.5	25.0	8.380	5.0	9.65	3.0	14.0	15.0
LM73	4.40	LRW	1005	600.0	205.0	35.0	116.0	118.75	575.0	468.0	14.0	25.0	8.360	5.0	3.0	3.0	13.030	15.0
LM75	3.30	LRW	1060	600.0	152.5	35.0	123.0	118.75	620.0	468.0	13.0	25.0	9.370	5.0	4.73	3.0	21.3	15.0
LM76	2.90	WWH	1041.	600.0	143.5	35.0	126.5	118.75	625.0	468.0	12.0	25.0	8.870	5.0	4.84	3.0	15.8	15.0
LM77	1.80	WWH	913.5	600.0	139.0	35.0	109.5	118.75	585.0	468.0	10.0	25.0	6.0	5.0	4.93	3.0	10.850	15.0
LM79	0.90	WWH	816.0	600.0	116.0	35.0	85.5	118.75	500.0	468.0	13.0	25.0	9.890	5.0	3.0	3.0	14.8	15.0
LM74	0.20	WWH	1158	600.0	226.0	35.0	116.0	118.75	660.0	468.0	10.0	25.0	9.35	5.0	3.0	3.0	13.9	15.0

Table 11C. Urban parameter results in the Little Miami River study area in 2012. Values >reference targets are highlighted in yellow.

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS		T-Cu		T-Pb		T-Zn	
			Med-ian	Tar-get	Med-ian	Tar-get	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Targ et	Med-ian	Target
[11-051] - East Fork Duck Creek																		
LM85	1.90	WWH	981.0	600.0	153.0	35.0	137.0	118.75	650.0	468.0	4.0	25.0	4.890	5.0	15.7	3.0	17.2	15.0
LM84	0.60	MWH	1304	600.0	290.0	0.340	114.0	118.75	730.0	468.0	11.0	25.0	3.570	5.0	28.9	3.0	19.8	15.0
[11-075] - Unnamed Trib to Duck Creek at RM 4.8																		
LM80	0.20	LRW	1341	600.0	282.2	35.0	85.7	118.75	770.0	468.0	11.5	25.0	10.1	5.0	14.5	3.0	22.150	15.0
[11-076] - Little Duck Creek																		
LM86	2.70	WWH	750.0	600.0	76.2	35.0	80.0	118.75	510.0	468.0	4.0	25.0	6.730	5.0	17.7	3.0	20.7	15.0
LM87	2.60	WWH	744.0	600.0	78.5	35.0	83.0	118.75	500.0	468.0	4.0	25.0	6.480	5.0	41.7	3.0	15.3	15.0
LM90	2.40	WWH	786.5	600.0	76.8	35.0	82.3	118.75	440.0	468.0	18.0	25.0	7.910	5.0	14.0	3.0	11.550	15.0
LM88	1.80	WWH	686.5	600.0	75.150	35.0	48.65	118.75	435.0	468.0	7.0	25.0	7.730	5.0	13.35	3.0	11.850	15.0
LM89	1.40	WWH	556.5	600.0	57.45	35.0	50.5	118.75	320.0	468.0	10.0	25.0	6.75	5.0	11.4	3.0	19.5	15.0
LM92	0.20	WWH	399.5	600.0	31.4	35.0	27.3	118.75	170.0	468.0	32.0	25.0	0.0	5.0	8.45	3.0	8.930	15.0
WAU 14-06 Clough Creek																		
[11-002] - Clough Creek (LMR RM 3.36)																		
LM99	4.60	PHW3A	872.0	600.0	96.4	35.0	56.0	118.75	460.0	468.0	10.0	25.0	8.99	5.0	3.0	3.0	0.0	15.0
LM95	3.20	WWH	811.0	600.0	100.45	35.0	66.15	118.75	470.0	468.0	9.0	25.0	4.930	5.0	12.3	3.0	16.1	15.0
LM96	3.10	WWH	695.0	600.0	86.3	35.0	62.8	118.75	390.0	468.0	6.0	25.0	0.0	5.0	3.0	3.0	0.0	15.0
LM97	1.20	WWH	704.0	600.0	87.5	35.0	67.5	118.75	350.0	468.0	8.0	25.0	7.75	5.0	11.3	3.0	10.2	15.0
LM98	0.60	WWH	639.0	600.0	77.5	35.0	70.0	118.75	310.0	468.0	2.0	25.0	7.560	5.0	13.1	3.0	11.470	15.0
[11-003] - McCullough Run (LMR RM 3.7)																		
LM94	1.30	WWH	755.0	600.0	107.0	35.0	39.2	118.75	460.0	468.0	8.0	25.0	0.0	5.0	8.45	3.0	8.930	15.0
11-078 - Unnamed Trib to McCullough Run at RM 1.08																		
LM93	1.60	WWH	415.0	600.0	27.3	35.0	38.0	118.75	280.0	468.0	94.0	25.0	0.0	5.0	8.45	3.0	8.930	15.0
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06																		
LM101	1.10	WWH	760.0	600.0	83.6	35.0	58.5	118.75	490.0	468.0	14.0	25.0	6.740	5.0	3.0	3.0	14.3	15.0
[11-080] - UT at RM 0.66 to UT to Clough Creek at RM 3.06																		
LM102	0.60	PHW2	962.0	600.0	111.0	35.0	74.8	118.75	590.0	468.0	14.0	25.0	6.740	5.0	3.0	3.0	14.3	15.0
[11-081] - UT at RM 0.95 to UT to Clough Creek at RM 3.06																		
LM100	0.20	WWH	641.0	600.0	78.3	35.0	52.2	118.75	440.0	468.0	10.0	25.0	6.740	5.0	3.0	3.0	14.3	15.0
WAU 12-08 Five Mile Creek – Ohio River																		
[10-001] - Five Mile Creek																		
LM107	2.90	WWH	1015	600.0	160.0	35.0	78.0	118.75	570.0	468.0	2.0	25.0	0.0	5.0	3.0	3.0	0.0	15.0
LM108	0.20	WWH	531.0	600.0	52.95	35.0	52.45	118.75	340.0	468.0	10.0	25.0	7.920	5.0	6.68	3.0	8.890	15.0
10-002 - Eight Mile Creek																		
LM105	2.10	PHW3A	828.0	600.0	113.5	35.0	67.0	118.75	440.0	468.0	6.0	25.0	7.660	5.0	3.0	3.0	10.150	15.0

Table 11C. Urban parameter results in the Little Miami River study area in 2012. Values >reference targets are highlighted in yellow.

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS		T-Cu		T-Pb		T-Zn	
			Med-ian	Tar-get	Med-ian	Tar-get	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Target	Med-ian	Targ et	Med-ian	Target
[10-130] - Trib to Eight Mile Creek at RM 1.01																		
LM106	0.10	PHW3A	347.0	600.0	66.1	35.0	73.2	118.75	390.0	468.0	6.0	25.0	7.660	5.0	13.2	3.0	10.150	15.0
[10-537] - Four Mile Creek																		
LM104	0.90	WWH	682.0	600.0	64.95	35.0	65.0	118.75	305.0	468.0	31.0	25.0	7.480	5.0	6.8	3.0	8.8	15.0
WAU 08-03 Turtle Creek																		
[11-021] - Turtle Creek																		
RF08	6.80	WWH	607.0	610.0	60.55	31.0	45.0	120.0	310.0	522.58	7.5	41.3	7.99	5.0	3.0	3.0	8.220	15.0
11-022] - Dry Run																		
RF09	1.80	CWH	759.0	600.0	44.3	31	38.5	118.75	380.0	468.0	6.0	25.0	6.9	5.0	6.16	3.0	11.8	15.0
[11-030] - Newman Run																		
RF10	0.30	EWH	625.0	600.0	23.0	31	31.2	118.75	350.0	468.0	4.0	25.0	6.490	5.0	5.0	3.0	11.7	15.0

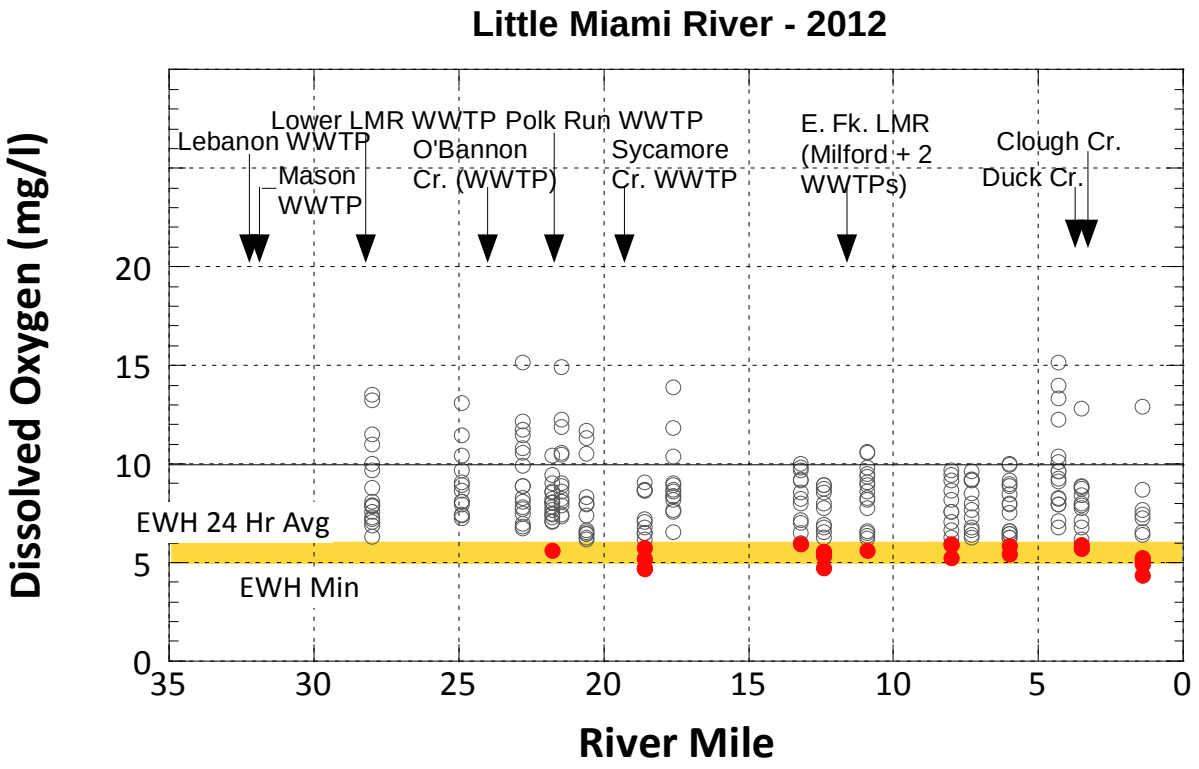

Figure 10. Plot of dissolved oxygen levels for the lower 35 miles of the Little Miami River during 2012. Orange bar presents the 5 mg/l minimum/6 mg/l 24 hr. average EWH D.O. criteria. The red dashed line represents a 12 mg/l level as an upper threshold for excessive diel swings.

pattern is evident in conductivity values (which typically co-vary with chloride) in both the grab samples and the Datasonde data from sites along the Little Miami River.

Despite the wider diel D.O. swings in the Little Miami River, concentrations of both TP and nitrate were lower at most locations than in 1998 or 2007 (Figure 13). There were spikes in both parameters locally downstream from the Lower Little Miami River WWTP and a spike in TP (Figure 13, top) downstream from the confluence with Duck Creek.

WAU 09-02 - (O'Bannon Creek)

Both sites on O'Bannon Creek (11-010; LM37, LM38) were located downstream of the O'Bannon WWTP. The upstream site attained the WWH aquatic life use, but the downstream site was partially impaired because of a low MIwb score. Both sites on O'Bannon Creek had elevated conductivity and chloride concentrations compared to reference concentrations and the suburban nature of the watershed was influencing the events. Both sites also had elevated nitrate and total phosphorus levels that may be partly attributed to the O'Bannon WWTP, especially given the magnitude of the values.

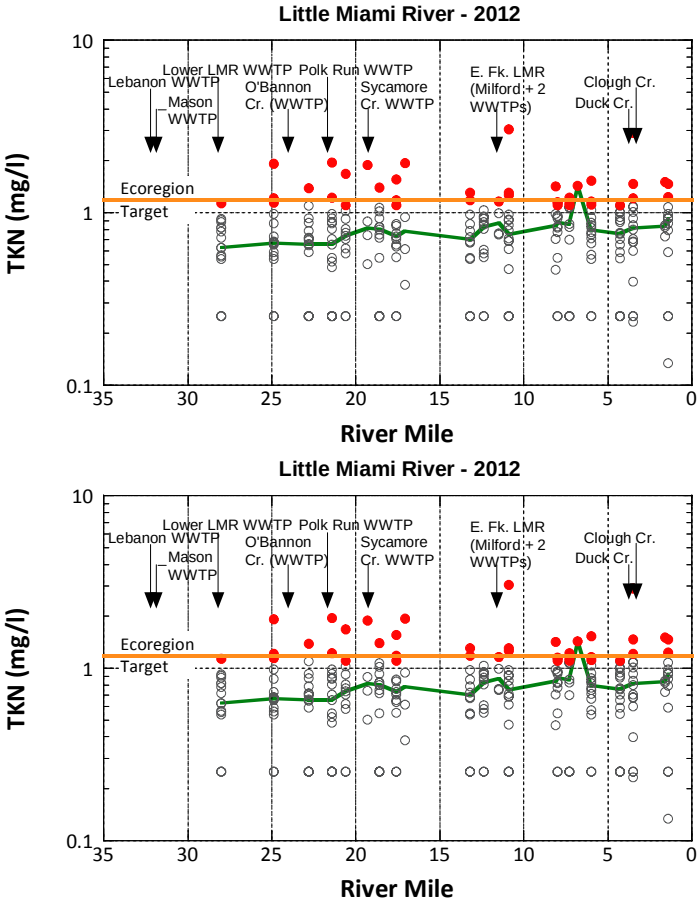

Figure 11. Plot of TKN for the lower 35 miles of the Little Miami River during 2012 (top) and 2007 (bottom). Orange bar represents the regional reference value (ecoregion target) for TKN. The green (upper) and blue (lower) lines are the result of connecting the median values at each site.

WAU 13-05 - East Fork Little Miami River Mainstem

Five sites in the East Fork Little Miami River had very slight exceedances of the 6 mg/l 24-hour average D.O. criterion although none were below the minimum criterion of 5 mg/l (Figure 14).

Compared to the Little Miami River mainstem and other streams in that watershed the East Fork had low conductivities and chloride levels that diluted the higher levels in the Little Miami River downstream from the confluence.

WAU 14-01 - Sycamore Creek

Sycamore Creek (11-007) was impaired or partially throughout its length. The only water quality exceedance was for total ammonia at the mouth site (RM 0.2, LM52). Conductivity and total chloride from urban runoff was elevated throughout the stream which could contribute to aquatic life impairment along with very low flow conditions during 2012 (Table 11C). Nutrients were low, perhaps due to low flows except at the most upstream site that had elevated nitrate concentrations (Table 11B).

The North Branch Sycamore Creek (confluence to Sycamore at RM 0.64) met the WWH ALUSE at three of five sites and partially attained WWH at the other two sites due to slight depressions in the IBI scores. Habitat conditions in the North Branch (mean QHEI = 81.4) were excellent and were high than those in Sycamore Creek which were still considered good (mean QHEI = 66.5) and may explain these sites performing better despite even elevated conductivity, TDS, and chlorides compared to Sycamore Creek (Table 11C).

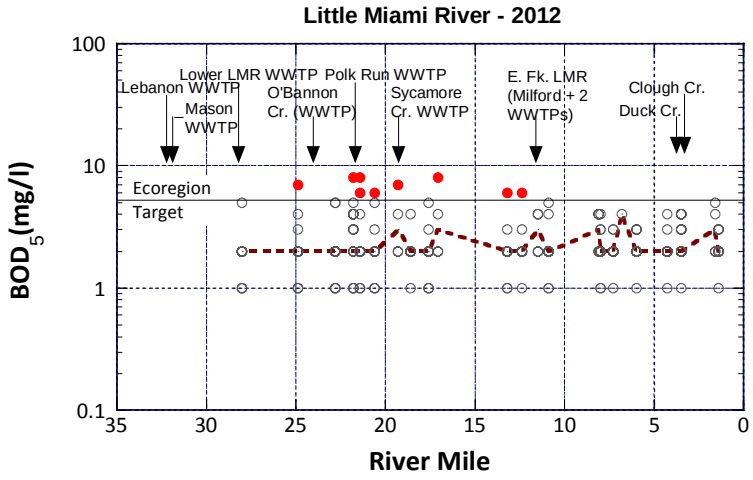

Figure 12. Plot of BOD_5 for the lower 28 miles of the Little Miami River during 2012. Solid line represents statewide large river reference value (ecoregion target) for BOD_5. The dashed line is the result of connecting the median values at each site.

(Table 11C). This same pattern was evident in a tributary to Sycamore Creek at RM 1.12 (LM53, LM55, LM56). All of these streams had small drainage sizes (0.2-5.7 $mi.^2$) and were also affected by the low flow conditions during 2012. For example, both LM54 and LM65 were dry.

WAU 14-02 - Polk Run

Polk Run and all of its sampled tributaries are WWH or recommended to be WWH and have QHEI scores considered good-excellent. Polk Run and its tributaries did not show exceedances of conventional water quality criteria with the exception of slight depressions in pH at two tributaries (LM41, pH 6.55 and LM45, pH 6.39). All of the sites had elevated chlorides (range 67-206) and the sites in Polk Run had elevated TDS and conductivity (Table 11C). Nutrients were not elevated in the Polk Run watershed (Table 11B).

WAU 14-04 - Duck Creek

The Duck Creek watershed is generally the most severely impaired in the study area with many reaches converted to concrete channels (LRW reaches) and most of the watershed subject to urban runoff and CSOs. There were exceedances of dissolved oxygen at two sites in Duck Creek (RM 2.9, LM76; RM 0.9, LM79) and one site in Little Duck Creek (RM 0.2, LM 92) (Table 11A). There were also exceedances of metals such as copper and lead at four sites in Duck Creek as well an exceedance of the temperature criteria at LM73 (Table 11A). The temperature exceedance was also observed in the continuous (Datasonde) data at LM77. Elevated temperatures in shallow concrete bottom channels are a pattern we observed in Mill Creek during 2011 (MBI 2012). Most sites (8 of 10) in Duck Creek has elevated TKN (organic nitrogen) which is associated with organic enrichment that can come from SSOs and CSOs as well as urban runoff (Table 11). Little Duck Creek has elevated TKN in the lower two sites (LM89, LM92) which are in the more urban reaches and downstream of the CSOs on the streams (Table 11B). Almost all sites have elevated conductivities, TDS, and chlorides that are associated with CSOs, SSOs and heavy urban runoff (Table 11C). The high conductivity levels are supported by results from continuous (Datasonde) samplers that demonstrated that nearly all values were greater than 1000 µS/cm.

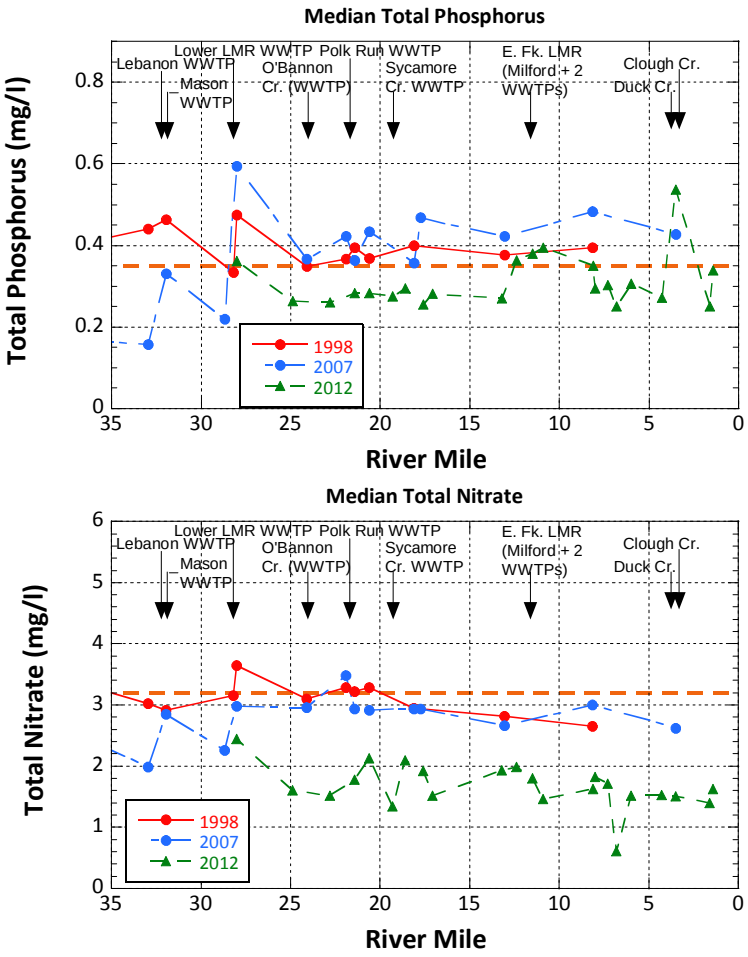

Figure 13. Plots of total phosphorus (top) and total nitrate (bottom) for the lower 28 miles of the Little Miami River during 1998, 2007, and 2012. Dashed orange line represents statewide reference for large rivers.

The East Fork of Duck Creek did not have exceedances of conventional water quality parameters (Table 11A). Two tributaries, (11-075, Trib to Duck Creek at RM 4.8, LM80; and 11-077, Trib to Little Duck Creek at RM 4.42, LM82) also had elevated TKN levels, likely associated with CSOs and urban runoff (Table 11B).

WAU 14-05 - Dry Run

There were no exceedances of conventional water quality criteria at sites in the Dry Run watershed (Table 10). There was an elevation of TKN at the headwater site in Dry Run (Table 11B) and perhaps a slight elevation of chlorides at the mouth of Dry Run (Table 11C) although the major influence on the biota was habitat degradation in the upper sites and low flows throughout, but particularly at the downstream site where lack of flow precluded fish or macroinvertebrate sampling.

WAU 14-06 - Clough Creek

Of the sites in the Clough Creek watershed, only the site at the mouth of Clough Creek (RM 0.6, LM98 had exceedances of a water quality criteria (D.O., Pb) (Table 11A). All of the sites in Clough Creek and McCullough Run had elevated conductivity and chlorides due to urban runoff (Table 11C); McCullough Run also had slightly elevated TKN concentrations (Table 11B). These are likely due to urban runoff. Habitat characteristics also suggest that urban runoff (i.e., flashiness of flows) may be an influence as well as low flows during 2012.

WAU 12-08 - Ninemile Creek

All five sites sampled in this watershed were small headwater sites (0.8-4.6 mi.^{2}). Two of three WWH sites in this watershed were partially impaired (Fivemile Creek, LM107) or impaired (Fourmile Creek, LM104) and two others were classified as PHW3A (LM105 and LM106). The sites on Fivemile Creek (LM107) and Fourmile Creek (LM104) that were impaired both had elevated conductivity and chloride levels that may contribute to the aquatic life impairment

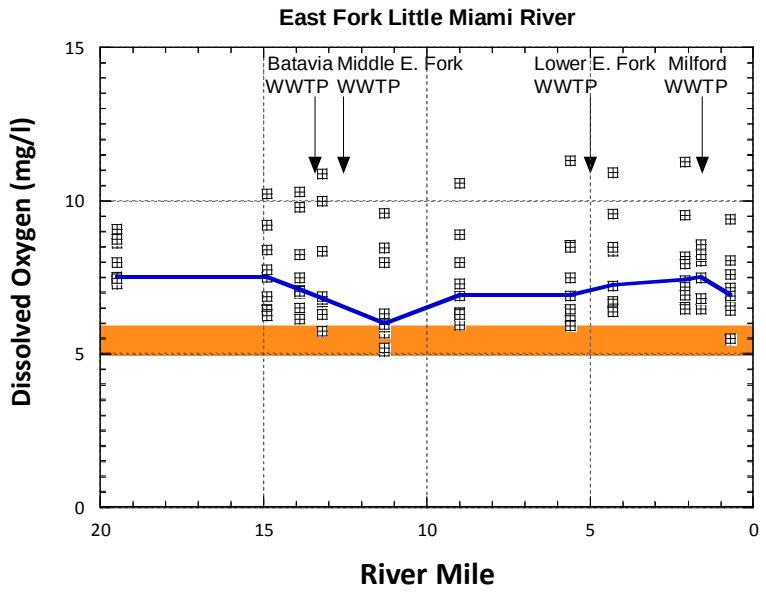

Figure 14. Plot of dissolved oxygen levels for the East Fork of the Little Miami River during 2012. The shaded orange bar presents the 5 mg/l minimum/6 mg/l 24 hr. average EWH D.O. criteria.

(Table 11C) that was likely exacerbated by the low flow conditions.

WAU 08-03 - (Turtle Creek)
This watershed contained three Ohio EPA biocriteria reference sites for wadeable streams of the IP ecoregion. Turtle Creek (11-021, RF08) met the WWH biocriteria despite some exceedances of the dissolved oxygen water quality criteria (Table 11A). Dry Creek (11-022, RF09) had no exceedances of basic water quality parameters. Newman Run (11-030, RF10) was too dry to collect fish and invertebrates when visited, but on occasions where water was flowing and chemical samples collected there were exceedances of the dissolved oxygen criteria (Table 11A). Extremely low flow conditions likely contributed to dissolved oxygen problems in these waters. There are agricultural and urban land uses in these watersheds; however, elevated conductivity and chloride compared to reference conditions (Table 11C) indicate that runoff events also can contribute to the D.O. excursions.

Continuous Monitoring

D.O. (mg/l), temperature (◦C), conductivity (µS/cm), and pH (S.U.) were monitored continuously over two or three 3-4 consecutive day periods at all mainstem Little Miami River and East Fork of Little Miami River sites and at selected locations in selected tributaries during July, August, and early September. An initial inspection of the results showed patterns and exceedances of various criteria and thresholds for D.O., temperature, and conductivity hence those results are further discussed. The results for pH were by contrast less revealing except that the diel ranges corresponded to those commonly associated with diel D.O. fluctuations.

LRAU – 90-02 - Little Miami River Mainstem

Compared to continuous monitoring data collected by Ohio EPA in 2007 (Ohio EPA 2009), continuous monitoring data during 2012 revealed more frequent D.O. values below the EWH 5.0 mg/l minimum, the 6.0 mg/l 24hr average criterion, and a higher frequency of “swings” in diel variations >6.0 mg/l (Figure 15, upper). Swings in D.O. are indicative of excessive nutrient enrichment and its effects on algal production and its effects on the D.O. regime (Miltner et al. 2011). The 2012 D.O. profiles were similar to those observed by Ohio EPA in their 1999 follow-up monitoring to the 1998 bioassessment (Ohio EPA 2000) values.

Temperature data in the lower reach of the Little Miami River mainstem downstream from the confluence with the East Fork of the Little Miami River showed numerous exceedances of the average and maximum temperature criteria during the July 17-19, 2012 time period (Figure 15, middle). The August monitoring event in this reach revealed lower temperatures, but showed the same elevation of temperatures downstream from the East Fork. These results show that the East Fork is a source of thermal enrichment to the Little Miami River mainstem.

Conductivity in the mainstem Little Miami River during continuous sampling periods was within the regional reference range for large rivers in Ohio (Figure 15, lower). The East Fork of the Little Miami River had lower conductivity and "diluted" the higher conductivity values in the Little Miami River downstream from the confluence.

WAU 13-05 - East Fork Little Miami River

Continuous D.O. in the East Fork Little Miami River revealed some values below the EWH 6.0 mg/l 24-hour average criterion, but no wide swings in the diel D.O. range were observed like what was observed in the mainstem Little Miami River (Figure 16, upper). Some excursions above the average temperature criteria occurred, but none exceeded the maximum criterion (Figure 16, middle). Continuous temperature data was not collected during the Harsha Lake draw-down of August 20-22. The exceedances of the maximum temperature criteria in the mainstem Little Miami River downstream from the East Fork confluence during July 17-19, despite "dilution" by cooler temperatures in the Little Miami River, indicates that the maximum criterion was likely exceeded in the East Fork Little Miami, perhaps by a wide margin.

Conductivity was well-below the statewide regional reference values in the East Fork (Figure 16, lower) and it acts to "dilute" the higher conductivity in the Little Miami River mainstem downstream from the confluence (Figure 15, lower).

WAU 09-02 – O'Bannon Creek

The downstream O'Bannon Creek site (LM38) near the mouth had some continuous D.O. values below the WWH 5.0 mg/l 24-hr average criterion (Figure 17, upper) although diel D.O. swings during the single period of sampling were not >6 mg/l. The downstream site (LM38) also had warmer temperatures with the median near the 24-hr average temperature criterion (Figure 17, middle). As with many streams that are impacted by WWTPs and urban development, continuous conductivity results were well above the regional reference threshold for streams in the Interior Plateau (Figure 17, lower).

WAU 14-01 – Sycamore Creek/North Branch Sycamore Creek

Three of the six Sycamore Creek sites (LM48, LM50, LM52) revealed some continuous D.O. values in mid-August below the WWH 5mg/l 24-hr average criterion (Figure 17, upper left) and diel D.O. swings >6.0 mg/l. There were some individual temperature readings above the average criterion, but no values exceeded the maximum criterion (Figure 17, middle). Conductivity results were well above the regional reference threshold for streams (Figure 17, lower). The North Branch of Sycamore Creek had ranges of D.O. (Figure 17, top) and

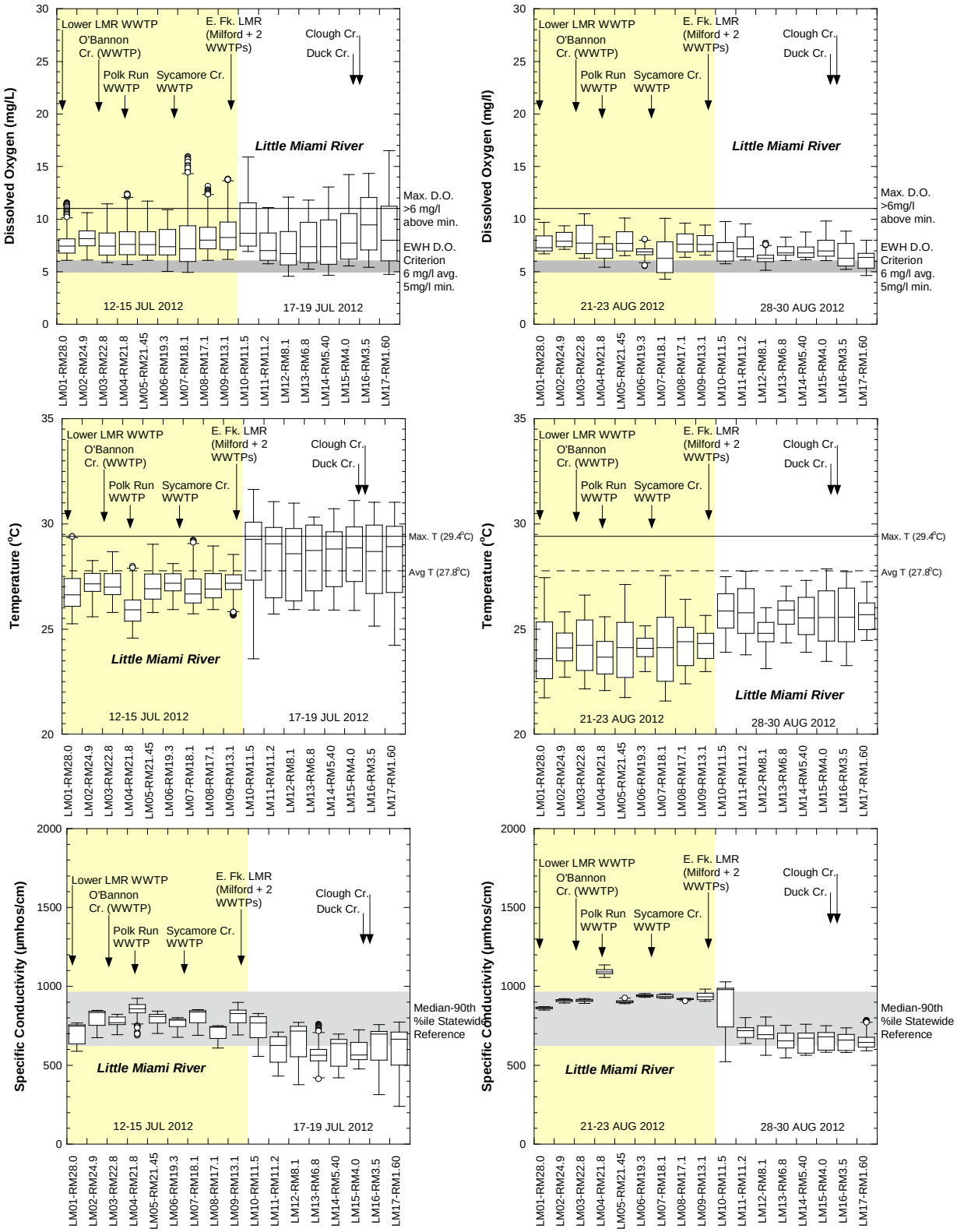

Figure 15. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results in the mainstem of the Little Miami river during mid-July (left shaded yellow) and late August (right half) of 2012.

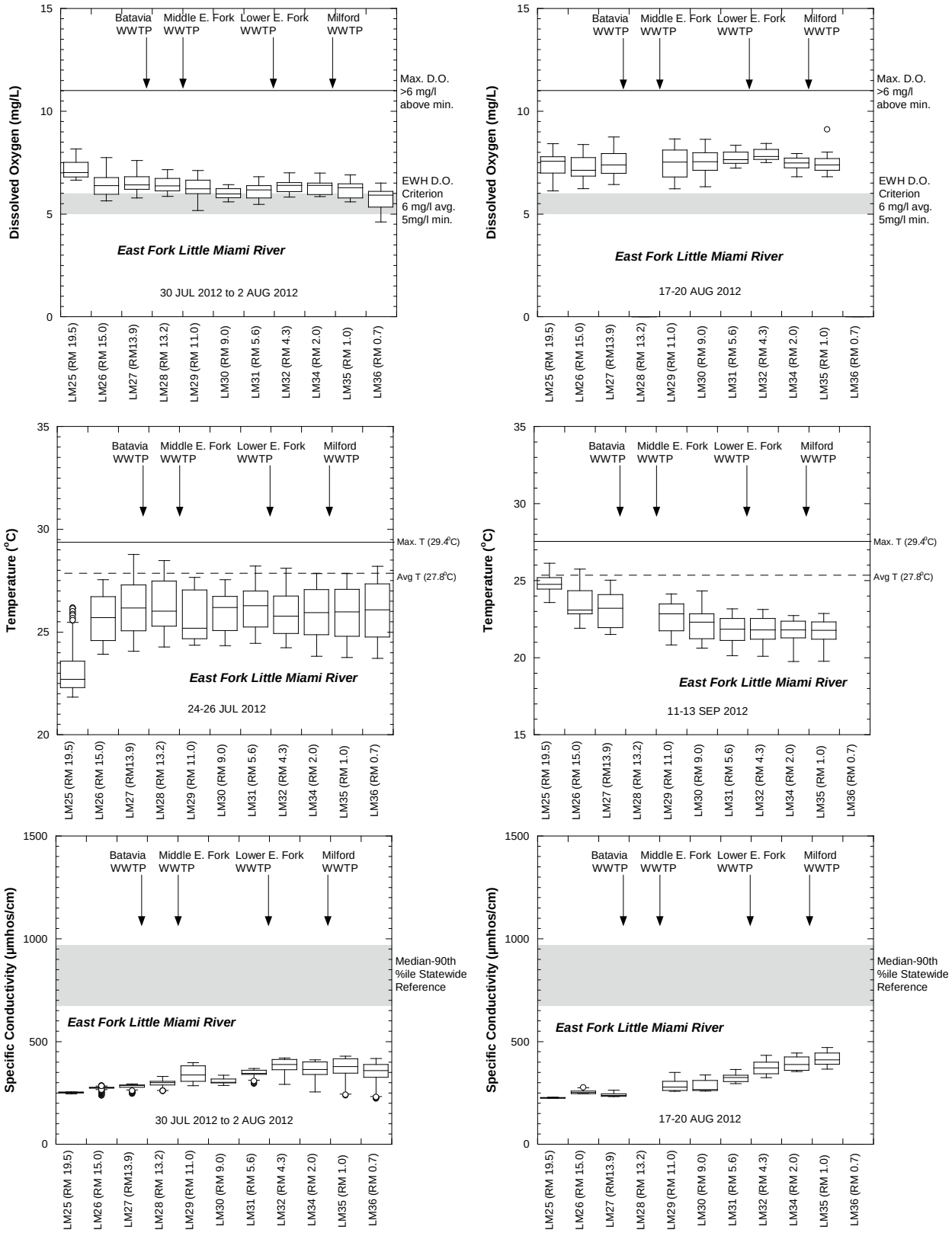

Figure 16. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results in the mainstem of the East Fork Little Miami river during late July (left) and mid-August (right) of 2012. The shaded bar is the range between the median and 90th %ile statewide reference values.

temperature (Figure 17, middle) that were more consistent with regional reference thresholds and only slightly elevated conductivity compared to regional reference conditions (Figure 17, bottom).

WAU 14-04 – Duck Creek

D.O. in Duck Creek during the early-August period was variable, but several sites had wide diel D.O. swings (Figure 18, top). Site LM79 had a diel swing of nearly 12 mg/l. Data from September was less variable with higher D.O. and lower diel variation. Temperatures were elevated in Duck Creek at the first site downstream from the concrete channel (LM77) having a median that exceeded the WWH average criterion with more than 25% of the values in excess of the WWH maximum temperature criterion (Figure 18, middle). In the LRW reaches of Duck Creek there were no exceedances of the much more lenient LRW criteria during the early August sample. Conductivity levels in Duck Creek were the highest in the study area and well above regional reference thresholds (Figure 18, lower).

WAU 14-06 – Clough Creek

The upstream-most Clough Creek site (LM99) exceeded the WWH D.O. 24-hr average and minimum criteria during both the early August and late September periods (Figure 18, upper). The next two downstream sites had either low D.O. values (LM96) or a moderate diel D.O. swing (LM95) during the early August sample. Temperatures were elevated at three of the sites during the early August period with values greater than the WWH average and a few values greater than the maximum criterion at the downstream most site (Figure 18, middle). Conductivity at the upstream-most site (LM99; Figure 18, lower) was highly elevated compared to regional reference thresholds.

WAU 14-02 – Polk Run

Neither of the Polk Run sites had low D.O. concentrations (Figure 19, upper). Temperatures were relatively normal during both the mid-August and late-September sampling periods (Figure 19, middle). Conductivity, however, was high compared to regional reference thresholds and were reflective of the urban development in this watershed (Figure 19, lower).

WAU 12-08 - Ninemile Creek

The median D.O. in Fivemile Creek was below the WWH 5.0 mg/l 24-hr average criterion with some values less than the 4 mg/l minimum criterion (Figure 19, upper). Eight Mile Creek had a few values below the WWH 5 mg/l average criterion, whereas the upstream site in Five Mile Creek (LM107) had more than 25% of the values below the WWH 4 mg/l minimum criterion and diel D.O. swings >6.0 mg/l (Figure 19, upper). The downstream site on Five Mile Creek (LM108) had good D.O. levels during this period (median ≈8.0 mg/l) with only minor variation in diel D.O. (Figure 19, upper).

Temperature patterns in these streams mirrored the D.O. results with elevated temperatures in Four Mile Creek (LM104; <25% > WWH average) and the upstream site on Five Mile Creek where the median was higher than the WWH average and values exceeding the WWH maximum criterion (Figure 19, middle). The other two sites (LM 105, LM 108) had cooler

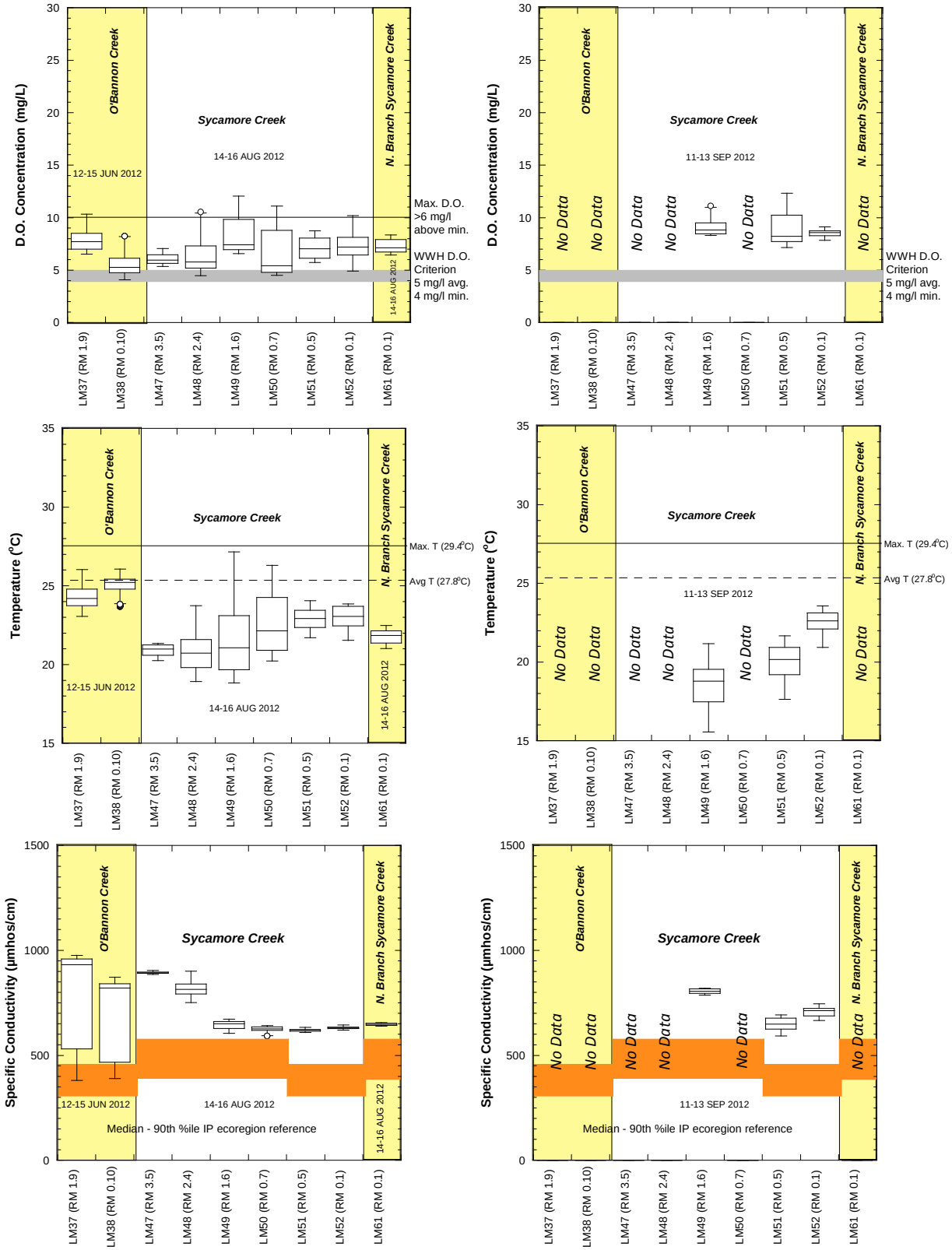

Figure 17. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results from O'Bannon Creek (left yellow shaded), Sycamore Creek, and North Fork Sycamore Cr. (right yellow shaded) during mid-August (left) and mid-September (right) of 2012. The shaded orange bar is the range between the median and 90th %ile statewide specific conductivity reference values.

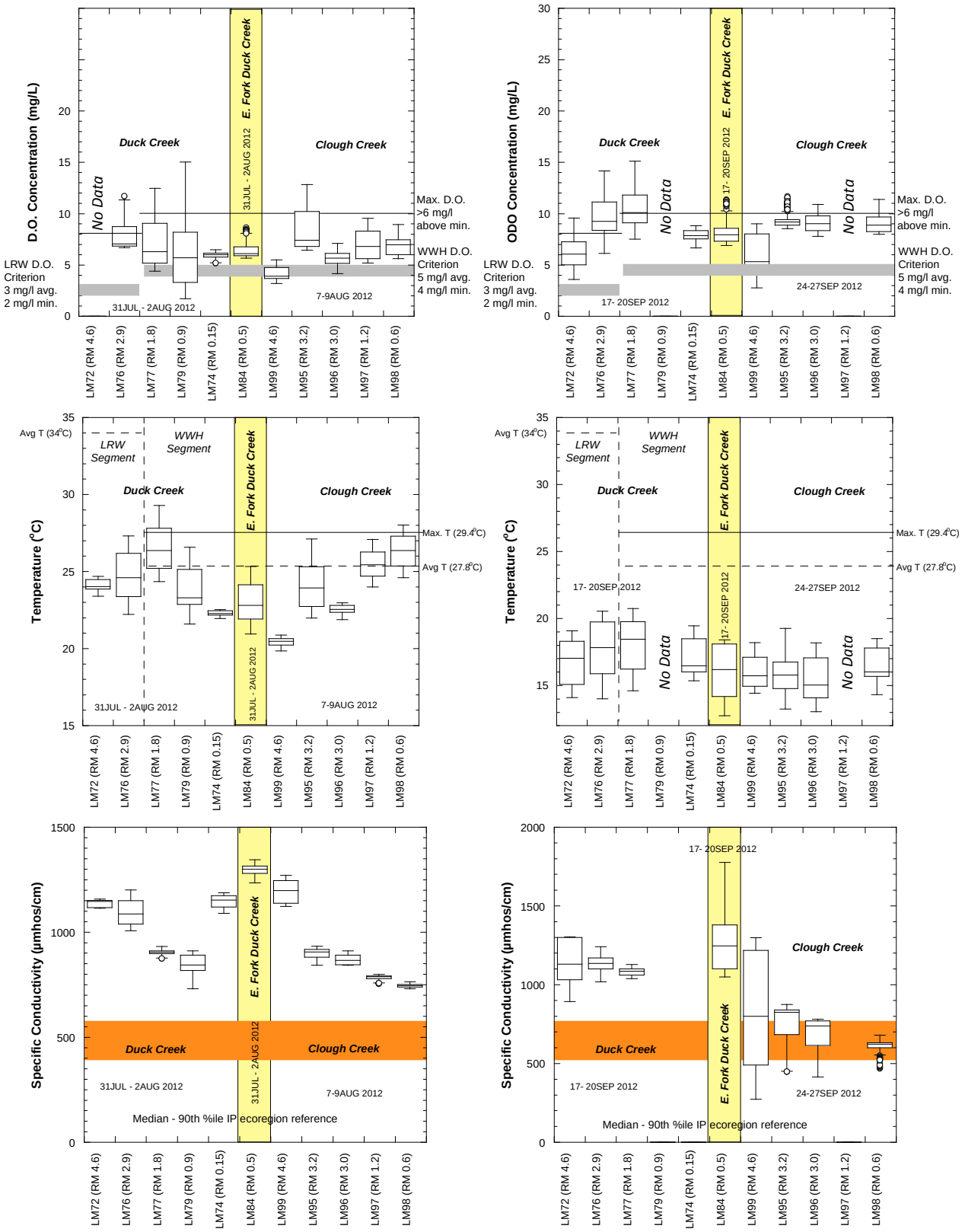

Figure 18. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results from Duck Creek, East Fork Duck Creek (yellow shaded) and Clough Creek during early August (left) and mid-September (right) of 2012. The shaded bar is the range between the median and 90th %ile statewide specific conductivity reference values.

temperatures during this period with all values less than the WWH average criterion (Figure 19, middle). All sites had conductivity values well above the regional reference thresholds for headwater streams in the Interior Plateau ecoregion (Figure 19, lower).

WAU 08-03 – Turtle Creek (Reference Sites)
Continuous monitoring was conducted in the three reference sites in the study area - Turtle Creek, Dry Run, and Newman Run (Figure 20, upper) during mid-August and late September. All three sites had D.O. values below the WWH 5.0 mg/l 24-hr average criterion and Dry Run and Newman Run had values below the WWH 4 mg/l minimum criterion (Figure 20, upper). Dry Run had diel D.O. swings >6.0 mg/l during both periods and Newman Run was dry in September. The low D.O. values were likely accentuated by the critically low flows during 2012. Temperatures exceeded the WWH maximum criterion in Turtle Creek, but were much lower at the other sites in August and all sites in September (Figure 20, middle). Conductivity values were within regional reference thresholds for Turtle Creek and only slightly above for Dry Run and Newman Run (Figure 20, lower).

Sediment Chemistry
Sediment samples were collected from 49 sites in the Little Miami River and selected sites in the major tributaries. Analyses were conducted for heavy metals and organic compounds. The MacDonald et al. (2000) consensus-based levels and the Ohio EPA (2008) sediment reference values (SRV) were used to screen for potential adverse effects to aquatic life. MacDonald et al. (2000) described two values for sediment metals and organic compounds - a threshold effects concentration (TEC) and a probable effects concentration (PEC), the latter being more certain of harmful effects.

Ten (10) of 49 sites had no sediment metal concentrations greater than the PEC (probable effect level), 12 sites with concentrations greater than the threshold effects levels, and 16 sites with concentrations greater than the Ohio SRVs (Table 12). Of these 12 sites that exceeded the TEC levels, 6 were in Duck Creek, two in the Little Miami River (LM8 and LM9), and four in the headwaters of Sycamore Creek. The sites that also exceeded the Ohio SRVs included two additional sites in Duck Creek, a site in Dry Run, and a site on the North Branch of Sycamore Creek.

No sites, for the limited number of parameters where we have TEC/PEC benchmarks, exceeded the organic compound benchmarks (Table 13). Even so, the pattern of detections vs. tested counts can be useful to identify sites where values are greater than the detection limit, but which do not exceed the benchmarks. Greater detection of these compounds can help identify areas and sources that may prove to be a threat. The Little Miami River mainstem had few detected compounds, whereas the greatest number and frequency of detections was highest in the Duck Creek subbasin.

LRAU 90-02 – Little Miami River
The lower Little Miami River had few exceedances of the Ohio SRV or TEC benchmarks except at adjacent stations LM8 and LM9 (RMs 17.6 and 13.2). These stations are located downstream of

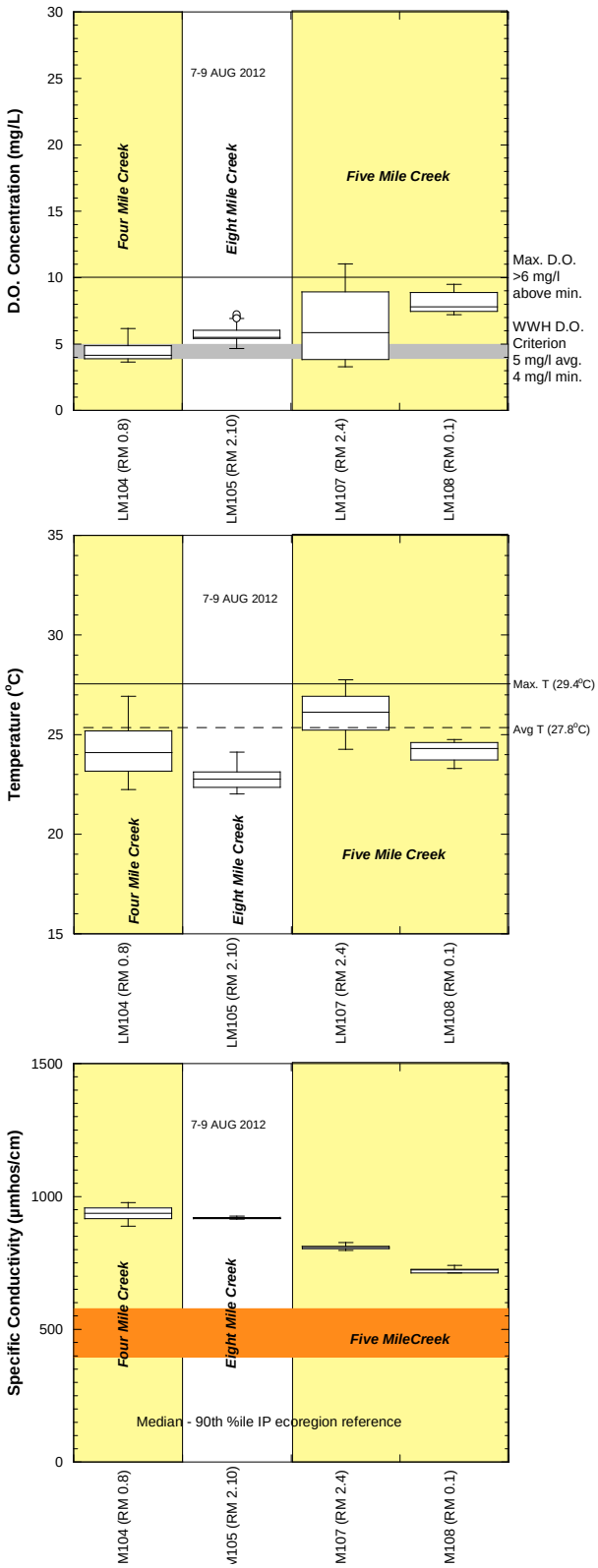

Figure 19. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results from Fourmile Creek (yellow shaded left), Eightmile Creek, and Fivemile Creek (yellow shaded right) during mid-August (left) and late September (right) of 2012. The shaded bar is the range between the median and 90th %ile statewide specific conductivity reference values.

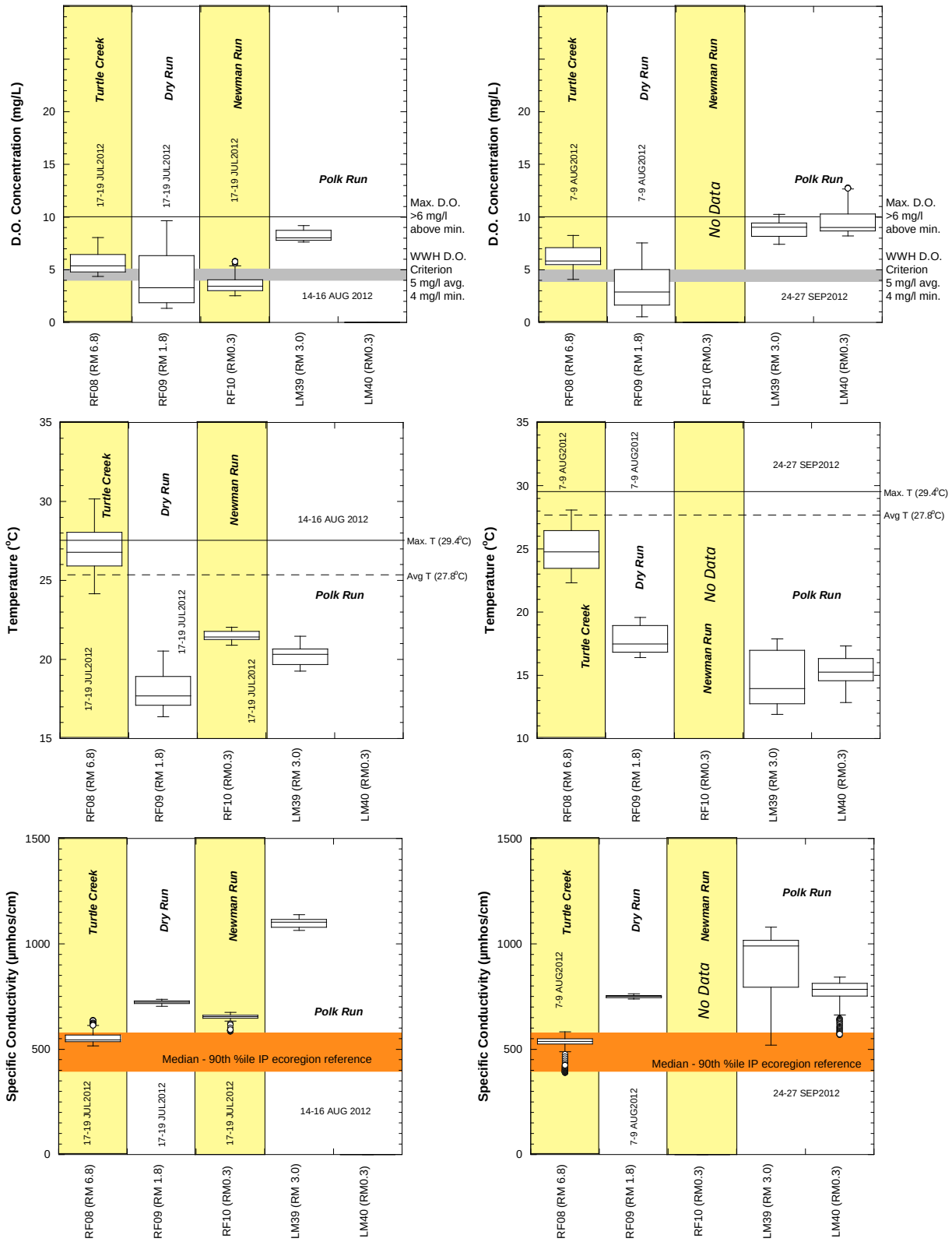

Figure 20. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results from Turtle Run (left yellow shaded), Dry Run, Newman Run (middle yellow shaded) and Polk run during mid-August (left) and late September (right) of 2012. The shaded bar is the range between the median and 90th %ile statewide specific conductivity reference values.

Sycamore Creek. Data collected at 13.07 by Ohio EPA in 2007 did not identify values above sediment metal benchmarks.

WAUs 90-02 O'Bannon Creek and 14-02 Polk Run
There were no exceedances of sediment metal benchmarks in the O'Bannon Creek or Polk Run watersheds. This matched data collected by Ohio in 2007 where no exceedances of benchmarks were noted.

WAU 14-01 – Sycamore Creek
The four headwater sites in Sycamore Creek, upstream of the Sycamore WWTP and the North Fork confluence had sediments metal above Ohio SRV and the TEC benchmarks for arsenic, lead, copper and zinc. The headwater reaches of Sycamore Creek also had more organic compounds detected than all other subwatersheds except for Duck Creek; none of the organic compounds exceeded TEC organic benchmarks. The sediment metals may have originated from urban runoff from roads and other urban impervious surfaces. There was a sediment sample from the mouth from the 1999 Ohio EPA survey that largely had low sediment metals and they did not sample in the headwaters.

WAU 13-05 – East Fork Little Miami River
There were no exceedances of the Ohio SRV or TEC benchmarks at four of the lower sites in the East Fork of the Little Miami River. A single site at RM 0.77 sampled by Ohio EPA in 2007 also showed no exceedances of sediment metals benchmarks.

WAU 14-03 - Duck Creek
Duck Creek had the most exceedances of metals benchmarks of any small subwatershed in the lower Little Miami watershed. Every site sampled (8 sites) had metal elevated above the Ohio SRV benchmarks and 6 of these sites also had metal concentrations above the TEC benchmarks (Table 12). Arsenic, copper, lead and zinc are the predominant metals that exceed these benchmarks. Although there we no exceedances of organic compound benchmarks in Duck Creek if had up to 15 organic compounds detected in the sediments, more than others in the watershed except for the upper reaches of Sycamore Creek. Metal and organic compounds in the sediments can come from urban runoff from roadways and urban impervious surfaces, but also from CSOs and SSOs that occur in the Duck Creek watershed.

Table 12. Sediment metal concentrations in the lower Little Miami River study area that were tested, detected, >Ohio sediment reference values (SRV), greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC).

Site ID	River Mile	Date	Metals Tested	Metals Detected	< Ohio SRV Guidelines	>TEC and < PEC	>PEC
LRAU 90-02 – Little Miami River							
11-001 – Little Miami River							
LM01	28.00	20121022	8	8			
LM02	24.90	20121022	8	8			
LM03	22.80	20121022	8	8			
LM04	21.80	20121022	8	8			
LM05	21.45	20121022	8	8			
LM06	20.60	20121022	8	8			
LM07	18.60	20121023	8	8			
LM08	17.60	20121023	8	8	Cd (0.47); Cu (44.20); Zn (182.00); Fe (39400.00); Ca (97800.00)	As (9.98); Cu (44.20); Pb (38.10); Zn (182.00)	
LM09	13.20	20121023	8	8	Cd (0.52); Zn (129.00)	Zn (129.00)	
LM10	12.40	20121023	8	8			
LM11	10.90	20121023	8	8			
LM12	8.00	20121023	8	8			
LM13	7.30	20121023	8	8			
LM14	6.00	20121024	8	8			
LM15	4.30	20121023	8	8			
LM16	3.50	20121022	8	8			
[11-067] - Unnamed Trib to Little Miami River at RM 7.75							
LM20	1.20	20121025	8	8			
WAU 09-02 – O'Bannon Creek							
[11-010] - O'Bannon Creek (LMR RM 24.06)							
LM37	1.90	20121023	8	8			
LM38	0.10	20121022	8	8			
WAU 14-02 – Polk Run							
[11-009] - Polk Run (LMR RM 21.54)							
LM46	3.90	20121024	8	8			
LM39	3.10	20121024	8	8			
WAU 14-01 – Sycamore Creek							
[11-007] - Sycamore Creek (LMR RM 19.2)							
LM47	3.60	20121024	8	8	As (16.20); Fe (31500.00)	As (16.20); Pb (44.20)	

Table 12. Sediment metal concentrations in the lower Little Miami River study area that were tested, detected, >Ohio sediment reference values (SRV), greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC).

Site ID	River Mile	Date	Metals Tested	Metals Detected	< Ohio SRV Guidelines	>TEC and < PEC	>PEC
LM48	2.40	20121024	8	8	As (15.10)	As (15.10)	
LM49	1.60	20121024	8	8	Zn (152.00)	Zn (152.00)	
LM50	1.10	20121024	8	8	Cu (32.00); Pb (51.10); Zn (101.00)	Cu (32.00); Pb (51.10)	
LM51	0.50	20121022	8	8			
LM52	0.20	20121022	8	8			
[11-008] - North Branch Sycamore Creek							
LM57	5.20	20121025	8	8	Cd (0.33)		
LM58	3.70	20121025	8	8			
LM59	2.10	20121025	8	8			
LM60	0.50	20121022	8	8			
[11-049] - Trib To Sycamore Cr. (RM 1.12)							
LM55	1.00	20121025	8	8			
LM56	0.30	20121025	8	8			
WAU 13-05 – East Fork Little Miami River							
[11-100] - East Fork Little Miami River (LMR RM 11.5)							
LM32	4.30	20121023	8	8			
LM34	2.10	20121023	8	8			
LM35	1.60	20121023	8	8			
LM36	0.70	20121023	8	8			
WAU 14-05 – Dry Run							
[11-005] - Dry Run (LMR RM 7.54)							
LM70	5.70	20121024	8	8			
LM66	4.20	20121025	8	8	Cd (0.31)		
LM67	2.50	20121025	8	8			
WAU 14-03 – Duck Creek							
[11-004] - Duck Creek (LMR RM 3.87)							
LM71	6.00	20121024	8	8	Ca (175000.0); Mg (43000.00)		
LM72	4.70	20121023	8	8	As (13.40); Cd (0.33); Cu (32.40)	As (13.40); Cu (32.40)	
LM73	4.40	20121024	8	8	As (28.70); Cd (0.56); Cu (52.30); Zn (129.00)	As (28.70); Cu (52.30); Pb (42.20); Zn (129.00)	

Table 12. Sediment metal concentrations in the lower Little Miami River study area that were tested, detected, >Ohio sediment reference values (SRV), greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC).

Site ID	River Mile	Date	Metals Tested	Metals Detected	< Ohio SRV Guidelines	>TEC and < PEC	>PEC
LM75	3.30	20121023	8	8	As (11.70); Cd (0.42); Cu (103.00); Pb (106.00); Zn (141.00)	As (11.70); Cu (103.00); Pb (106.00); Zn (141.00)	
LM76	2.90	20121023	8	8	Cd (0.43); Cu (28.40)		
LM77	1.80	20121024	8	8	As (11.30); Pb (48.80)	As (11.30); Pb (48.80)	
LM91	1.00	20121024	8	8	Cd (0.46); Cu (45.30); Zn (120.00)	As (10.20); Cu (45.30); Pb (42.00)	
LM74	0.20	20121023	8	8	Cu (34.30); Pb (53.50); Zn (106.00)	Cu (34.30); Pb (53.50)	
WAU 14-06 Clough Creek							
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06							
LM101	1.10	20121024	8	8			

Table 13. Sediment organic compound concentrations in the lower Little Miami River watershed that were tested, detected, greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC).

Site ID	River Mile	Date	Aq. Life Use	Organic Compounds Tested	Organic Compounds Detected	>TEC and < PEC	>PEC
LRAU 90-02 – Little Miami River							
11-001 – Little Miami River							
LM01	28.00	20121022	EWH	135	4		
LM02	24.90	20121022	EWH	134	4		
LM03	22.80	20121022	EWH	134	3		
LM04	21.80	20121022	EWH	125	3		
LM05	21.45	20121022	EWH	134	3		
LM06	20.60	20121022	EWH	134	4		
LM07	18.60	20121023	EWH	134	4		
LM08	17.60	20121023	EWH	133	3		
LM09	13.20	20121023	EWH	106	0		
LM10	12.40	20121023	EWH	106	0		
LM11	10.90	20121023	EWH	134	5		
LM12	8.00	20121023	EWH	135	4		
LM13	7.30	20121023	EWH	135	4		
LM14	6.00	20121024	EWH	106	0		
LM15	4.30	20121023	EWH	135	4		
LM16	3.50	20121022	WWH	135	4		
[11-067] - Unnamed Trib to Little Miami River at RM 7.75							
LM20	1.20	20121025	PHW3A	106	1		
WAU 09-02 – O'Bannon Creek							
[11-010] - O'Bannon Creek (LMR RM 24.06)							
LM37	1.90	20121023	WWH	134	3		
LM38	0.10	20121022	WWH	135	4		
WAU 14-02 – Polk Run							
[11-009] - Polk Run (LMR RM 21.54)							
LM46	3.90	20121024	WWH	135	14		
LM39	3.10	20121024	WWH	133	10		
WAU 14-01 – Sycamore Creek							
[11-007] - Sycamore Creek (LMR RM 19.2)							
LM47	3.60	20121024	WWH	132	19		
LM48	2.40	20121024	WWH	135	14		
LM49	1.60	20121024	WWH	134	10		
LM50	1.10	20121024	WWH	133	3		
LM51	0.50	20121022	WWH	128	4		
LM52	0.20	20121022	WWH	134	4		
[11-008] - North Branch Sycamore Creek							
LM57	5.20	20121025	WWH	135	19		
LM58	3.70	20121025	WWH	106	1		
LM59	2.10	20121025	WWH	106	0		
LM60	0.50	20121022	WWH	134	4		
[11-049] - Trib To Sycamore Cr. (RM 1.12)							
LM55	1.00	20121025	WWH	135	16		
LM56	0.30	20121025	WWH	134	10		

Table 13. Sediment organic compound concentrations in the lower Little Miami River watershed that were tested, detected, greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC).

Site ID	River Mile	Date	Aq. Life Use	Organic Compounds Tested	Organic Compounds Detected	>TEC and < PEC	>PEC
WAU 13-05 – East Fork Little Miami River							
[11-100] - East Fork Little Miami River (LMR RM 11.5)							
LM32	4.30	20121023	EWH	135	4		
LM34	2.10	20121023	EWH	134	3		
LM35	1.60	20121023	EWH	135	4		
LM36	0.70	20121023	EWH	135	4		
WAU 14-05 – Dry Run							
[11-005] - Dry Run (LMR RM 7.54)							
LM70	5.70	20121024	PHW3A	106	0		
LM66	4.20	20121025	WWH	106	0		
LM67	2.50	20121025	WWH	106	0		
WAU 14-03 – Duck Creek							
[11-004] - Duck Creek (LMR RM 3.87)							
LM71	6.00	20121024	LRW	135	13		
LM72	4.70	20121023	LRW	135	9		
LM73	4.40	20121024	LRW	135	12		
LM75	3.30	20121023	LRW	135	15		
LM76	2.90	20121023	WWH	135	9		
LM77	1.80	20121024	WWH	106	4		
LM91	1.00	20121024	WWH	106	1		
LM74	0.20	20121023	WWH	134	15		
WAU 14-06 Clough Creek							
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06							
LM101	1.10	20121024	WWH	106	0		

Stream Habitat in the Lower Little Miami River Watershed

This section focuses on key habitat stressors in each of the Lower Little Miami River 12-digit watersheds. This assessment is based on the QHEI and its metrics, submetrics, and individual attributes. A QHEI matrix showing both good and poor habitat attributes (after Rankin 1995) was developed for each site in the Little Miami River study area (Table 14).

LRAU – Little Miami River

Compared to QHEIs collected in 1998 and 2007 by Ohio EPA, QHEI values in 2012 were consistently lower, although in most cases it was less than 10 points (Figure 21, top). An examination of individual metrics shows that much of the difference was related to the cover metric score (Figure 21, bottom; Table 14). It is uncertain whether cover changed substantially since 2007, but perhaps a more likely scenario is that the low flows during 2012 may have isolated some cover features from the sampling transect (e.g., woody debris, rootwads, undercut banks). Nevertheless, the intolerant and sensitive fish species that have declined in the Little Miami are mostly habitat and fluvial specialist species that are dependent on having

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

Site ID	River Mile	QHEI	Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes													Ratios	
			No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
LRAU 90-02 – Little Miami River																																	
11-001 – Little Miami River																																	
LM01	27.8	**73**	■	■		■		■		■	■	■	7				●		1					●	●			●				3	2	0.5
LM02	23.7	**76.5**	■	■			■	■	■	■	■	■	8				●		1			●		●	●							3	2.25	0.44
LM03	22.1	**69.5**	■	■							■	■	4				●		1		●	●		●	●			●	●			6	0.71	1.4
LM04	21.7	**75**	■	■		■		■	■	■	■		7				●		1						●				●	●		3	2	0.5
LM05	21.25	**74**	■	■			■	■	■	■	■		7				●		1					●	●				●	●		4	1.6	0.63
LM06	20.6	**82**	■	■		■		■	■	■	■	■	8				●		1						●							1	4.5	0.22
LM07	18.4	**72**	■	■		■					■	■	5				●		1		●	●		●	●			●	●			6	0.86	1.17
LM08	17.6	**84**	■	■		■	■	■	■	■	■	■	9				●		1		●				●				●			3	2.5	0.4
LM09	12.9	**81.5**	■	■		■	■	■	■	■	■	■	9				●		1		●											1	5	0.2
LM10	11.8	**75.5**	■	■				■		■	■	■	6				●		1		●			●	●			●		●		5	1.17	0.86
LM11	11.2	**88.5**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM12	8.3	**73.5**	■	■		■	■		■	■	■	■	8				●		1			●		●	●							3	2.25	0.44
LM13	7.1	**75**	■	■				■		■	■	■	6						0			●		●	●			●		●		5	1.17	0.86
LM14	6	**54.5**	■	■			■			■	■	■	6				●		1			●		●		●		●		●		5	1.17	0.86
LM15	4.3	**59.5**	■	■			■			■	■	■	6				●		1			●		●	●	●		●				5	1.17	0.86

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

Site ID	River Mile	QHEI	Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes												Ratios	
			No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
11-001 – Little Miami River																																	
LM16	3	**72.3**	■	■		■		■		■	■	■	7						0			●			●			●	●	●		5	1.33	0.75
LM17	1.4	**64**	■	■				■			■		4						0		●	●		●	●			●	●		●	7	0.63	1.6
[11-047] - Unnamed Trib to Little Miami River at RM 0.83																																	
LM103	0.2	**65**	■	■		■	■	■	■				6					●	1		●								●	●		3	1.75	0.57
[11-066] - Unnamed Trib to Little Miami River at RM 13.1																																	
LM21	1.5	**63**	■	■				■		■	■	■	6				●		1					●	●			●				3	1.75	0.57
[11-067] - Unnamed Trib to Little Miami River at RM 7.75																																	
LM20	1.2	**70**	■	■		■	■	■		■	■	■	8						0					●	●			●				3	2.25	0.44
[11-068] - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River (RM13.1)																																	
LM19	0.5	**70**	■	■				■		■		■	5					●	1			●		●	●			●				4	1.2	0.83
WAU 09-02 – O'Bannon Creek																																	
[11-010] - O'Bannon Creek (LMR RM 24.06)																																	
LM37	1.8	**71.3**	■	■		■	■	■		■	■	■	8				●		1		●				●			●				3	2.25	0.44
LM38	0.1	**71**	■	■		■		■			■	■	6						0		●			●	●			●	●			5	1.17	0.86
WAU 14-02 – Polk Run																																	
[11-009] - Polk Run (LMR RM 21.54)																																	
LM46	3.2	**82**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

			Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes												Ratios	
Site ID	River Mile	QHEI	No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
[11-009] - Polk Run (LMR RM 21.54)																																	
LM39	3	**69.5**		■		■	■	■			■		5						0	●								●	●	●		4	1.2	0.83
LM40	0.3	**68**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
[11-069] - Unnamed Trib to Polk Run at RM 1.79																																	
LM41	2.5	**71.5**	■	■		■	■	■		■		■	7					●	1									●				1	4	0.25
LM44	0.4	**78**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
[11-070] - Unnamed Trib to Polk Run at RM 0.70																																	
LM42	2	**76.5**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
LM43	0.7	**75**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
[11-071] - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run																																	
LM45	0.2	**73**	■	■		■	■	■		■		■	7					●	1									●				1	4	0.25
WAU 14-01 – Sycamore Creek																																	
[11-007] - Sycamore Creek (LMR RM 19.2)																																	
LM47	3.5	**60.8**		■		■	■	■			■		5						0	●								●	●	●		4	1.2	0.83
LM48	2.4	**73**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
LM49	1.6	**72.5**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
LM50	0.7	**65.3**	■	■		■	■	■		■	■	■	8				●		1		●		●	●				●	●			5	1.5	0.67
LM51	0.5	**59.3**						■		■	■	■	4				●		1	●			●	●	●			●				5	0.83	1.2

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

Site ID	River Mile	QHEI	Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes													Ratios	
			No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
[11-007] - Sycamore Creek (LMR RM 19.2)																																		
LM52	0.2	**68**		■		■	■	■	■		■	■	7				●		1	●	●			●	●			●	●	●		7	1	1
[11-008] - North Branch Sycamore Creek																																		
LM57	5	**77.3**	■	■		■	■	■	■	■	■	■	9						0		●											1	5	0.2
LM58	4.3	**83**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM59	2.1	**88**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM60	0.5	**72.8**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
LM61	0.1	**86**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
[11-049] - Trib To Sycamore Cr. (RM 1.12)																																		
LM55	1	**73.5**	■	■		■	■	■			■	■	7						0									●	●			2	2.67	0.38
LM56	0.3	**74**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
LM53	0.1	**66**	■	■	■	■	■		■	■	■	■	9				●		1				●									1	5	0.2
[11-073] - Unnamed Trib to N Branch Sycamore Creek at RM 5.4																																		
LM63	0.6	**71**	■	■			■	■		■	■	■	7						0					●				●				2	2.67	0.38
[11-074] - Unnamed Trib to N Br Sycamore Cr at RM 0.75																																		
LM64	1.4	**76**	■	■		■	■	■		■		■	7					●	1									●				1	4	0.25
[11-084] - Trib to North Branch Sycamore Creek at RM 2.33																																		
LM62	1.8	**76**	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

Site ID	River Mile	QHEI	Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes													Ratios	
			No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
WAU 13-05 – East Fork Little Miami River																																		
[11-100] - East Fork Little Miami River (LMR RM 11.5)																																		
LM25	19.5	**85.5**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM26	15	**89.3**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM27	13.7	**80.5**	■	■		■		■	■	■	■	■	8						0						●							1	4.5	0.22
LM28	13.2	**80.5**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM29	11	**81**	■	■		■		■	■	■	■	■	8						0						●							1	4.5	0.22
LM30	9.1	**93**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
LM31	5.6	**71.5**	■	■			■	■			■		5						0		●	●		●				●	●	●		6	0.86	1.17
LM32	4.3	**74**	■	■				■			■	■	5						0		●	●		●	●			●	●			6	0.86	1.17
LM34	2	**69.8**	■	■				■	■		■		5						0		●	●		●	●				●	●		6	0.86	1.17
LM35	1	**81.5**	■	■		■	■	■	■	■	■	■	9						0		●	●										2	3.33	0.3
LM36	0.7	**63**	■	■				■			■		4						0		●	●		●	●			●	●		●	7	0.63	1.6
WAU 14-05 – Dry Run																																		
[11-005] - Dry Run (LMR RM 7.54)																																		
LM70	5.6	**62.5**	■	■			■	■		■	■	■	7						0					●				●				2	2.67	0.38
LM66	4.1	**56.5**		■			■			■	■	■	5				●		1	●				●				●				3	1.5	0.67

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

			Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes													Ratios	
Site ID	River Mile	QHEI	No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
LM67	2.5	**76.5**	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
WAU 14-03 – Duck Creek																																		
[11-004] - Duck Creek (LMR RM 3.87)																																		
LM71	6	**20**			■								1	●		●	●	●	4					●	●	●		●	●	●		6	0.29	3.5
LM78	5.2	**18.5**			■								1	●		●	●	●	4					●		●		●	●	●		5	0.33	3
LM72	4.6	**40**		■							■		2	●			●		2		●			●	●			●	●	●		6	0.43	2.33
LM73	4.4	**18.5**											0	●			●	●	3					●	●	●		●	●	●		6	0.14	7
LM75	3.3	**22.5**											0	●			●	●	3					●	●	●		●	●	●		6	0.14	7
LM76	2.9	**33.5**											0			●	●	●	3	●				●	●			●	●	●		6	0.14	7
LM77	1.8	**48**		■									1			●	●	●	3	●				●	●			●	●	●		6	0.29	3.5
[11-051] - East Fork Duck Creek																																		
LM85	1.9	**59**	■	■				■		■	■		5						0		●			●	●			●	●	●		6	0.86	1.17
LM84	0.5	**39**		■									1			●	●	●	3	●	●			●				●	●		●	6	0.29	3.5
LM74	0.15	**51**	■	■				■			■		4						0		●			●	●			●	●	●		6	0.71	1.4
[11-075] - Unnamed Trib to Duck Creek at RM 4.8																																		
LM80	0.2	**36.5**		■									1			●	●	●	3	●				●	●			●	●	●		6	0.29	3.5
[11-076] - Little Duck Creek																																		
LM86	2.7	**46.5**		■							■		2				●		1	●	●			●	●			●	●	●		7	0.38	2.67

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

Site ID	River Mile	QHEI	Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes												Ratios	
			No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
[11-076] - Little Duck Creek																																	
LM87	2.6	**48.8**	■	■			■				■		4				●		1		●			●				●	●	●		5	0.83	1.2
LM90	2.4	**59**	■	■			■	■		■			5					●	1					●	●			●	●	●		5	1	1
LM89	1.4	**37**		■							■		2			●	●		2	●	●			●				●	●		●	6	0.43	2.33
WAU 14-06 Clough Creek																																	
[11-002] - Clough Creek (LMR RM 3.36)																																	
LM99	4.6	**56.3**	■	■			■	■		■		■	6				●	●	2					●				●				2	2.33	0.43
LM95	3.2	**56.5**	■	■		■				■		■	5				●	●	2					●	●			●				3	1.5	0.67
LM96	3	**57.8**	■	■			■	■		■	■	■	7				●		1					●				●				2	2.67	0.38
LM97	1.2	**65**	■	■		■		■		■	■	■	7				●		1				●		●			●				3	2	0.5
LM98	0.6	**57.5**	■	■	■					■	■	■	6				●		1				●	●	●			●				4	1.4	0.71
[11-003] - McCullough Run (LMR RM 3.7)																																	
LM94	1.3	**37**						■					1	●		●	●	●	4					●				●	●	●		4	0.4	2.5
11-078 - Unnamed Trib to McCullough Run at RM 1.08																																	
LM93	1.5	**56.8**		■				■		■		■	4				●	●	2	●				●	●			●	●	●		6	0.71	1.4
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06																																	
LM101	1.05	**58.8**	■	■						■	■	■	5				●		1					●	●			●				3	1.5	0.67

Table 14. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Little Miami River study area, 2012 (■ - good habitat attribute; ● - high influence modified attribute; ● - moderate influence modified attribute).

Site ID	River Mile	QHEI	Good Habitat Attributes											High Influence Modified Attributes						Moderate Influence Modified Attributes												Ratios	
			No Channelization	Boulder, Cobble, Gravel	Silt Free	Good-Excellent Development	Moderate-High Sinuosity	Moderate-Extensive Cover	Fast Flow w Eddies	Little to No Embeddedness	Max Depth > 40 cm	No Riffle Embeddedness	"Good" Habitat Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse No Cover	Max Depths <40 cm	High Influence Poor Attributes	Recovering from Channelization	Mod-High Silt Cover	Sand Substrates (Boatable sites)	Hardpan Origin	Fair- Poor Development	Low Sinuosity	≤ 2 Cover Types	Intermittent Flow or Pools <20 cm	No Fast Current Types	Mod-Extensive Embeddedness	Mod-Extensive Riffle Embeddedness	No Riffle	Poor Habitat Attributes	Ration of Poor (High) to Good	Ration of Poor (All) to Good
[11-081] - UT at RM 0.95 to UT to Clough Creek at RM 3.06																																	
LM100	0.2	**60.8**	■	■			■			■	■	■	6				●		1					●	●			●				3	1.75	0.57
WAU 12-08 Five Mile Creek – Ohio River																																	
[10-001] - Five Mile Creek																																	
LM107	2.4	**67.5**		■		■	■	■	■	■		■	7					●	1	●												1	4	0.25
LM108	0.1	**70.8**	■	■		■		■	■		■	■	7						0						●				●			2	2.67	0.38
10-002 - Eight Mile Creek																																	
LM105	2.1	**71**	■	■	■	■	■	■		■		■	8					●	1									●				1	4.5	0.22
[10-130] - Trib to Eight Mile Creek at RM 1.01																																	
LM106	0.1	**71.5**	■	■	■	■	■	■		■		■	8					●	1									●				1	4.5	0.22
[10-537] - Four Mile Creek																																	
LM104	0.8	**66**		■		■	■	■	■	■	■	■	8						0	●	●												2	3	0.33
WAU 08-03 Turtle Creek																																	
[11-021] - Turtle Creek																																	
RF08	6.1	**69**	■	■		■		■		■	■	■	7				●		1		●				●				●	●			4	1.6	0.63
[11-022] - Dry Run																																	
RF09	1.8	**63**	■	■			■	■			■	■	6						0		●			●				●	●			4	1.4	0.71

diverse and high quality habitat attributes to complete and sustain critical parts of their life cycle (e.g., spawning).

WAU 09-02 – O'Bannon Creek
The habitat conditions in O'Bannon Creek (11-010) at sites LM37 and LM38 were in very good condition on the basis of QHEI scores (71.3 and 71, respectively). These habitat conditions are clearly supportive of the expected biological assemblages of a WWH aquatic life use. Habitat attributes that are negative include moderate silt cover at both sites and moderate embeddedness at the downstream site (Table 14).

WAU 14-02 - Polk Run
All sites sampled in the Polk Run watershed had good-excellent habitat based on QHEI scores (range 68-82). Potential problems are not related to a lack of physical habitat. The only consistent negative habitat attribute in this subwatershed was the lack of fast current velocity that was probably accentuated because of the dry conditions during the summer of 2012 (Table 14).

WAU 14-01 - Sycamore Creek
Only one site in Sycamore Creek watershed had fair habitat with all of the other 16 having either good (10 sites) or excellent habitat (6 sites). Flow, rather than habitat is a more limiting natural factor in these streams. Lower Sycamore Creek has a few sites that have been channel modified and retain some poor habitat attributes including sparse cover, moderate siltation and embeddedness (Table 14).

WAU 13-05 - East Fork Little Miami River
Physical habitat conditions were generally considered "excellent" through the 20 mile reach that was assessed although sites in the lower six miles had elevated silt cover and substrate embeddedness (Table 14) which can be problematic for EWH systems. A correlation of QHEI vs. IBI in this reach (r^2 = 0.67; Figure 22) suggests that much of the variation in IBI in the East Fork is correlated with habitat conditions, although the range of habitat quality is typically associated with IBI scores in the exceptional range (IBI $\geq$48-50). There was a distinct difference between the first and second sampling passes likely due to the Harsha Lake draw-down during August 20-22. The habitat-IBI correlation generally reflects the general pattern of better habitat supporting higher quality fish assemblages.

WAU 14-04 – Duck Creek
Duck Creek is the most physical habitat limited watershed in the lower Little Miami River study area. Stream habitat was not listed as a cause of impairment in the LRW reaches of Duck Creek because it is already factored in through the application of the non-fishable LRW ALUSE designation. Impairment is related to acute impacts of CSO and urban runoff that are perhaps accentuated by the concrete streams channels. Nearly all of the sites in the Duck Creek watershed lacked any fast current (Table 14) and this likely is an important stress on the biological assemblages and accentuated by the especially low flows in 2012. The East Fork Duck Creek had natural channels at two of three sites (Table 14), so we concluded the LRW

designation was likely in error and based either on limited data or an over-extrapolation of the results from the lower mainstem. Even with the natural channels, the urban nature of the watershed resulted in moderate to heavy silt cover, moderate embeddedness, and fair-poor riffle development. These conditions were similar to those found in Little Duck Creek where there was widespread embeddedness of the urban influenced stream channels.

WAU 14-06 - Clough Creek

The streams sampled in Clough Creek were all small headwater streams (0.9-8 $mi.^2$). With the exception of McCullough Run (LM94, 11-003, QHEI = 37) all streams had natural channels and had habitat considered "good" for small headwater streams (Table A; QHEI scores > 55). Other than McCullough Run, none of the streams had issues with sedimentation and abnormal amounts of silt. Most issues were related to flow and the urban nature of the watershed.

WAU 12-08 - Nine mile Creek

Physical habitat conditions for the four streams (five stations) sampled in this watershed were also considered to be good (QHEI range 66-71.5) and capable of supporting WWH aquatic assemblages or PHWH classes in the primary headwaters (Table 14). Negative habitat attributes were few (Table 14) and scattered and do not appear to be limiting to aquatic life in any stream sampled.

WAU 08-03 – Turtle Creek (Reference Sites)

During 2012 habitat condition based on the QHEI reference sites (RF08 and RF09) was good (Table 14; QHEI=68 and 63, respectively). A third headwater reference site (RF10 on Newman Run) was dry when visited and a QHEI score was not possible. Previous assessments by Ohio EPA found an exceptional fish assemblage which was a testament to the dry conditions during summer of 2012. Turtle Creek and Dry Run did have moderate siltation and substrate embeddedness which indicates these streams are likely affected by agricultural and/or urban runoff (Table 14).

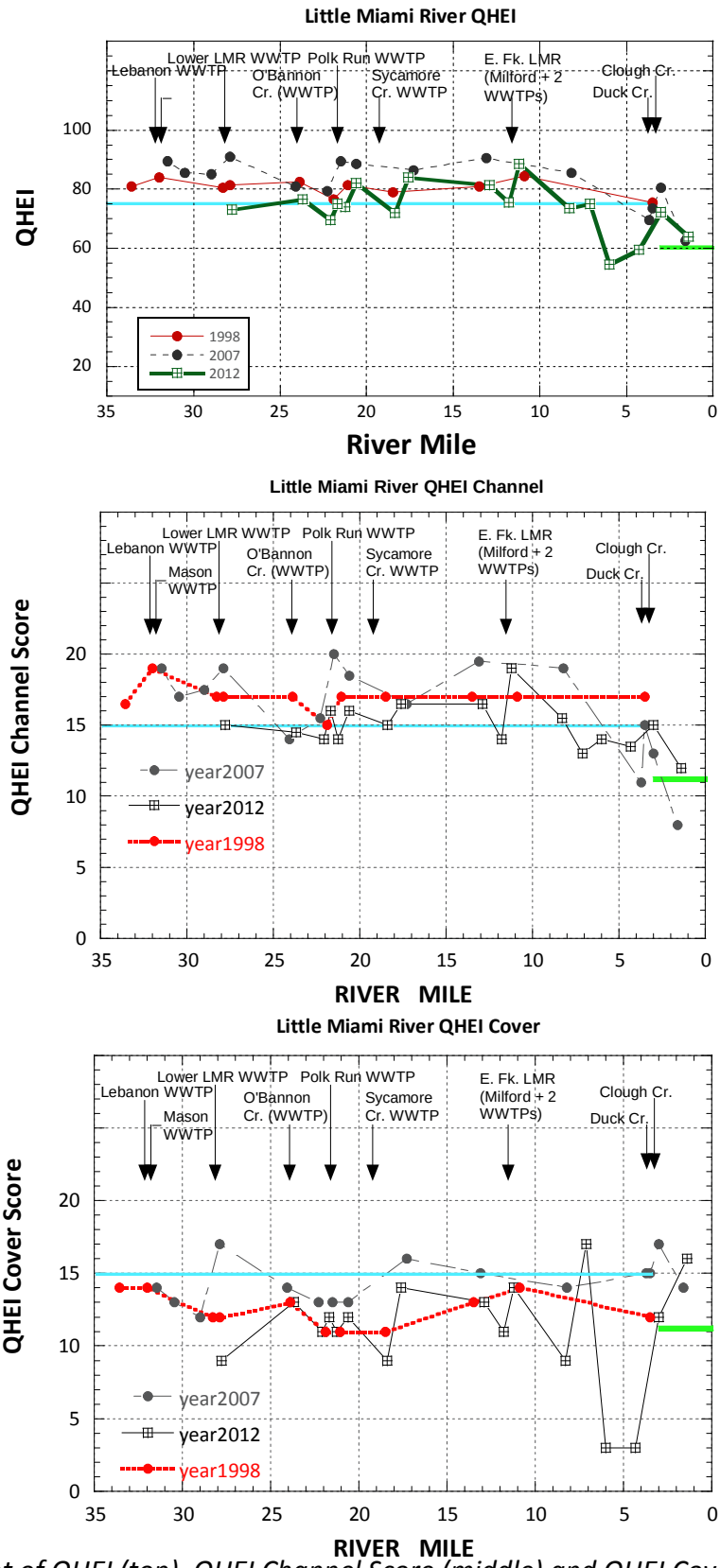

Figure 21. Plot of QHEI (top), QHEI Channel Score (middle) and QHEI Cover Score (bottom) vs. river mile in the lower Little Miami River for 1998, 2007 and 2012. The blue lines represent thresholds generally indicative of exceptional quality QHEI and habitat attributes.

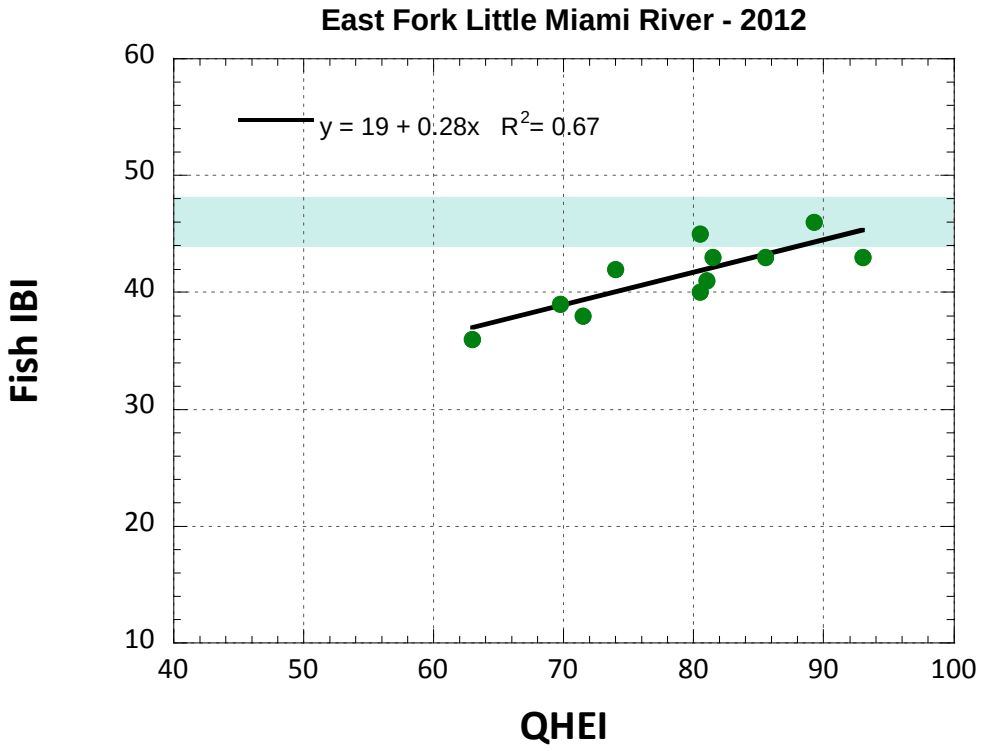

Figure 22. Correlation of QHEI with IBI in the lower East Fork Little Miami River downstream from the Harsha Reservoir during 2012. The blue shaded bar is the range from the IBI EWH biocriterion and the range of nonsignificant departure.

Biological Assemblages

Fish and macroinvertebrates were sampled at all wetted sites in 2012. These assemblages were used to assess 93 of the 108 sites in the Little Miami River watersheds watershed. The remaining 15 were assessed using the Primary Headwater Habitat methodology. Two additional sites were dry and these were assessed with the HHEI.

Fish Assemblage Results 2012

This section focuses on the condition and status of fish assemblages in each of the Little Miami River watersheds. This assessment is based on the presence and relative abundance of key fish species and traits or metrics that are expected in healthy or reference streams. Key fish assemblage results are listed in Table 15 and summarized in Table 17. Overall narrative fish assemblage condition ranged from fishless or very poor to excellent. Of the 86 sites with fish assemblage data that were not assessed as PHWH or were not dry, 79.1% failed to attain the IBI biocriteria threshold for WWH or LRW as applicable, which included 24.4% of sites that partially attained (either IBI or MIwb attained, but the other index did not). Eight sites with an existing WWH (7) or EWH (1) use were dry when sampling was attempted. Of these we did not assess two (ephemeral flow conditions), but considered 6 sites as non-attaining because lack of flow was considered partly related to urban impacts.

Table 15. Fish assemblage sites classified by aquatic life use and attainment or classification status during the 2012 lower Little Miami River survey.

Aquatic Life Use	Fish Assemblage Attainment Status			
	N	Full	Partial	Non
EWH	26	4	17	5
WWH	53	14	4	35
WWH (dry)	8	NA	NA	6
LWR	7	2	NA	5
	Primary Headwater Habitat Classification			
PHW3A	9			
PHW2	7			

LRAU 90-02 – Lower Little Miami River

In the Little Miami River Mainstem, the partial attainment was due to the failure of the IBI to attain the EWH criterion (Figure 23, top) while the MIwb met the EWH biocriterion at all but the lower two sites (Figure 23, bottom). The difference in the IBI scores between 2007 and 2012 is biologically significant and strongly related to the loss or decline of intolerant fish species (Figure 24, top). The EWH character of the Little Miami is strongly dependent on the presence and abundance of sensitive and intolerant species. Compared to 2007, when most sites across the same reach fully attained all of the EWH biocriteria, there has been a substantial change in the distribution and abundance of intolerant and sensitive fish species; these changes are summarized in Table 16. Figure 24 illustrates the difference in the number of intolerant species

in the lower Little Miami River between 2007 and 2012. Between 2007 and 2012, sites in the Little Miami River in this study reach declined from 5 of 1 or 3 of 1, at most sites. It should be noted that the three sites that still fully attained the EWH biocriteria in 2012 were sites with the highest quality habitat as measured by the QHEI (82, 81.5, and 88.5).

Of the seven small direct tributaries to the Little Miami River that were sampled, five were very small and classified as PHWII or IIIa. Two where recommended as WWH (11-047, LM103; 11-066, LM21) and both of these had fish IBI score that attained the WWH biocriterion for headwater streams. Site LM103 had an IBI of 52 and was considered to be somewhat influenced by its close proximity to the mainstem.

Table 16. Changes in fish species occurrence or abundance in the lower Little Miami River mainstem between 2007 and 2012.

Not Collected (Absent)	**Declined in Abundance**	**Increased in Abundance**
Variegate darter	Black redhorse	Longear sunfish
Blue sucker	Silver redhorse	Bluegill sunfish
Highfin carpsucker	Golden redhorse	Spotted bass
Suckermouth minnow	Northern hog sucker	Smallmouth bass
Rosyface shiner	Smallmouth redhorse	Bluntnose minnow
Striped shiner	Silver shiner	Emerald shiner
River shiner	Spotfin shiner	Gizzard shad
Northern madtom	Bullhead minnow	Longear sunfish
	Stoneroller	
	Stonecat	
	Mountain madtom	
	Slenderhead darter	
	Logperch	
	Greenside darter	
	Banded darter	
	Rainbow darter	

WAU 13-05 - East Fork Little Miami River

The fish assemblage condition of the East Fork of the Little Miami varied substantially between the first (Aug) and second (Oct) passes with the October IBIs being lower at every site (Figure 25). Table D summarizes key changes in IBI fish metrics between these two time periods. In general, total species, sensitive species, sucker species, sunfish species and relative weight and abundance were higher in August than in October. Reservoir draw-down and discharge of warm water and altered flows very likely explains the difference in fish assemblage condition between these samples (see discussion of temperature impacts).

WAU 09-02 - O'Bannon Creek

The fish assemblage at two sites in O'Bannon Creek attained the WWH except for the lower site MIwb that may have been depressed by runoff affects from this urbanizing area. The downstream site is also below the O'Bannon Creek wastewater treatment plant.

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Little Miami River study area, 2012.

Site ID	Site RM Range	Drain. Area (mi.^{2})	Fish Statistics										Macroinvertebrate Statistics				Aq. Life Use
			QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tol-erant	Rel. Number	% DELT	IBI	MIwb	ICI	Narr[1]	Qual EPT	Cold Water taxa	
LRAU 90-02 – Little Miami River																	
11-001 – Little Miami River																	
LM01	27.80 - 28.00	1070.00	73.0	22.0	8.0	0.0	2.63	2.63	796.6	1.57	42.0	10.57	44.0		19.0	0.0	EWH
LM02	23.70 - 24.90	1150.00	76.5	23.5	9.5	0.0	8.60	8.60	658.0	0.31	43.0	10.02	48.0		12.0	0.0	EWH
LM03	22.10 - 22.80	1150.00	69.5	19.0	7.0	0.0	5.87	5.99	613.0	0.48	36.0	9.14	50.0		17.0	0.0	EWH
LM04	21.70 - 21.80	1150.00	75.0	22.5	10.0	0.0	2.60	2.76	501.0	0.32	41.0	10.09	32.0[b]		8.0	0.0	EWH
LM05	21.25 - 21.45	1160.00	74.0	22.5	8.5	0.0	9.96	10.13	708.0	0.86	42.0	9.67	42.0		14.0	0.0	EWH
LM06	19.30 - 20.60	1160.00	82.0	25.5	9.5	0.0	13.42	13.72	988.0	0.30	44.0	9.99	42.0		12.0	0.0	EWH
LM07	18.10 - 18.60	1190.00	72.0	23.5	9.0	0.0	22.37	22.61	902.0	0.96	39.0	9.92	44.0		15.0	0.0	EWH
LM08	17.10 - 17.60	1190.00	84.0	22.0	8.5	0.0	5.54	5.85	699.0	0.19	42.0	10.20	42.0		13.0	0.0	EWH
LM09	12.90 - 13.20	1200.00	81.5	22.0	8.0	0.0	0.50	0.70	939.0	0.35	44.0	9.53	50.0		15.0	0.0	EWH
LM10	11.50 - 12.40	1210.00	75.5	23.0	9.0	0.0	10.81	10.97	1075.0	0.11	42.0	9.93	44.0		14.0	0.0	EWH
LM11	10.90 - 11.20	1710.00	88.5	22.5	6.0	0.0	2.31	2.85	595.1	0.41	44.0	9.89	46.0		18.0	0.0	EWH
LM12	8.00 - 8.30	1710.00	73.5	22.5	6.5	0.0	6.82	8.22	434.0	0.56	41.0	9.62	0.0		16.0	0.0	EWH
LM13	6.80 - 7.30	1720.00	75.0	21.5	5.5	0.0	7.63	9.71	783.0	0.36	40.0	9.95	48.0		15.0	0.0	EWH
LM14	5.30 - 6.00	1720.00	54.5	16.0	6.0	0.0	1.81	1.95	483.0	0.00	36.0	7.86	42.0		13.0	0.0	EWH
LM15	4.00 - 4.30	1730.00	59.5	19.5	6.5	0.0	6.73	6.88	797.0	0.15	35.0	8.48	44.0		22.0	0.0	EWH
LM16	3.00 - 3.50	1750.00	72.3	21.0	4.5	0.0	1.85	2.80	887.0	0.06	39.0	9.67	42.0		14.0	0.0	EWH
LM17	1.40 - 1.60	1760.00	64.0	15.0	4.0	0.0	3.28	3.28	422.0	0.14	36.0	8.17	18.0		0.0	0.0	WWH
[11-047] - Unnamed Trib to Little Miami River at RM 0.83																	
LM103	0.10 - 0.20	1.70	65.0	16.0	6.0	1.0	53.89	55.09	668.0	0.30	52.0	0.00	0.0	P	2.0	0.0	WWH
[11-066] - Unnamed Trib to Little Miami River at RM 13.1																	
LM21	1.50	3.00	63.0	6.0	1.0	2.0	15.08	61.81	398.0	0.00	36.0	0.00	0.0	G	7.0	1.0	WWH
[11-067] - Unnamed Trib to Little Miami River at RM 7.75																	
LM20	1.20	0.50	70.0	2.0	0.0	1.0	75.45	100.00	220.0	0.00	24.0	0.00	0.0		5.0	0.0	PHW 3A
[11-068] - Unnamed Trib (RM 2.7) to Unnamed Trib to Little Miami River (RM13.1)																	
LM19	0.50	0.60	12.0	1.0	0.0	0.0	0.00	0.00	0.0	0.00	12.0	0.00	0.0		0.0	0.0	PHW 3A
[11-082] - Unnamed Trib to Little Miami River at 24.06																	
LM23	0.20	1.60	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		0.0	0.0	PHW 2
[11-083] - Unnamed Trib to Little Miami River at 21.8																	
LM24	0.10	0.80	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		0.0	0.0	PHW 2
[11-085] - Unnamed Trib to Little Miami River at 13.8																	
LM22	0.30	1.20	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		0.0	0.0	PHW 2

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Little Miami River study area, 2012.

Site ID	Site RM Range	Drain. Area (mi.^{2})	Fish Statistics										Macroinvertebrate Statistics				Aq. Life Use
			QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tolerant	Rel. Number	% DELT	IBI	MIwb	ICI	Narr[1]	Qual EPT	Cold Water taxa	
WAU 09-02 – O'Bannon Creek																	
[11-010] - O'Bannon Creek (LMR RM 24.06)																	
LM37	1.80 - 1.90	54.30	71.3	25.0	12.0	1.0	18.37	17.63	783.8	0.07	52.0	9.26	34.0		9.0	1.0	WWH
LM38	0.10	59.00	71.0	20.0	8.5	0.5	20.61	22.55	423.8	0.00	44.0	7.34	0.0	G	32.0	0.0	WWH
WAU 14-02 – Polk Run																	
[11-009] - Polk Run (LMR RM 21.54)																	
LM46	3.20 - 3.90	2.60	82.0	8.0	0.0	1.0	75.00	86.89	488.0	0.00	28.0	0.00	0.0	MG	5.0	0.0	WWH
LM39	2.90 - 3.10	2.80	69.5	9.0	0.0	2.0	64.49	80.61	856.0	0.70	32.0	0.00	0.0	G	6.0	1.0	WWH
LM40	0.30	10.00	68.0	20.0	8.0	1.0	20.86	21.37	2742.0	0.00	52.0	0.00	28.0	G	7.0	0.0	WWH
[11-069] - Unnamed Trib to Polk Run at RM 1.79																	
LM41	2.50 - 2.60	1.30	71.5	7.0	0.0	1.0	48.48	60.10	792.0	0.25	36.0	0.00	0.0	MG	5.0	1.0	WWH
LM44	0.40	2.40	78.0	8.0	0.0	1.0	71.74	88.30	906.0	0.00	30.0	0.00	0.0	G	7.0	0.0	WWH
[11-070] - Unnamed Trib to Polk Run at RM 0.70																	
LM42	1.90 - 2.00	0.80	76.5	4.0	0.0	0.0	82.25	82.25	552.0	0.00	30.0	0.00	0.0	F	4.0	0.0	WWH
LM43	0.70 - 0.80	2.50	75.0	5.0	0.0	1.0	53.44	69.64	494.0	0.40	28.0	0.00	0.0	MG	5.0	0.0	WWH
[11-071] - Unnamed Trib (RM 1.77) to Unnamed Trib to Polk Run																	
LM45	0.20	1.10	73.0	5.0	0.0	1.0	68.03	71.00	538.0	0.00	30.0	0.00	0.0	G	6.0	1.0	WWH
WAU 14-01 – Sycamore Creek																	
[11-007] - Sycamore Creek (LMR RM 19.2)																	
LM47	3.50 - 3.60	3.40	60.8	4.0	0.0	1.0	54.18	86.14	1890.0	0.00	26.0	0.00	0.0	F	3.0	0.0	WWH
LM48	2.40	4.80	73.0	3.0	0.0	1.0	52.66	76.77	1128.0	0.00	26.0	0.00	0.0	MG	5.0	0.0	WWH
LM49	1.50 - 1.60	6.60	72.5	5.0	0.0	1.0	35.84	71.39	692.0	1.16	24.0	0.00	24.0	G	9.0	0.0	WWH
LM50	0.70 - 1.10	12.50	65.3	11.0	2.0	2.0	50.30	59.76	656.0	0.00	28.0	0.00	24.0	MG	7.0	0.0	WWH
LM51	0.30 - 0.50	22.80	59.3	18.5	8.5	1.0	28.64	32.41	314.3	0.48	42.0	7.30	24.0	G	11.0	0.0	WWH
LM52	0.10 - 0.20	23.30	68.0	19.0	8.5	1.0	4.57	5.01	343.5	0.23	51.0	7.85	0.0	MG	8.0	0.0	WWH
[11-008] - North Branch Sycamore Creek																	
LM57	5.00 - 5.20	2.90	77.3	7.0	0.0	1.0	36.54	42.05	1308.0	0.00	34.0	0.00	0.0	G	6.0	0.0	WWH
LM58	3.70 - 4.30	4.40	83.0	8.0	0.0	2.0	22.18	33.96	2886.0	1.11	36.0	0.00	0.0	G	7.0	0.0	WWH
LM59	2.00 - 2.10	7.30	88.0	11.0	1.0	2.0	36.12	37.45	2104.0	0.10	36.0	0.00	0.0	G	9.0	0.0	WWH
LM60	0.40 - 0.50	9.80	72.8	11.0	2.0	2.0	40.76	51.59	5226.0	0.00	34.0	0.00	34.0		9.0	0.0	WWH
LM61	0.05 - 0.10	10.00	86.0	24.0	8.0	2.0	29.54	33.74	1808.0	0.00	54.0	0.00	36.0		8.0	0.0	WWH
[11-049] - Trib To Sycamore Cr. (RM 1.12)																	
LM55	0.90 - 1.00	5.30	73.5	3.0	0.0	0.0	45.01	45.01	742.0	5.12	24.0	0.00	0.0	G	7.0	0.0	WWH
LM56	0.20 - 0.30	5.60	74.0	6.0	0.0	2.0	47.90	52.74	1240.0	0.00	32.0	0.00	0.0	G	8.0	0.0	WWH
LM53	0.10	5.70	66.0	5.0	0.0	2.0	61.39	68.65	1378.0	0.00	24.0	0.00	22.0	G	8.0	0.0	WWH
[11-072] - Unnamed Trib to N Branch Sycamore Creek at RM 5.3																	
LM65	0.75 - 1.10	0.20	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		8.0	0.0	PHW 2

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Little Miami River study area, 2012.

Site ID	Site RM Range	Drain. Area (mi.^{2})	Fish Statistics										Macroinvertebrate Statistics				Aq. Life Use
			QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tol-erant	Rel. Number	% DELT	IBI	MIwb	ICI	Narr[1]	Qual EPT	Cold Water taxa	
[11-073] - Unnamed Trib to N Branch Sycamore Creek at RM 5.4																	
LM63	0.60	1.10	32.0	5.0	0.0	1.0	54.02	63.22	348.0	0.00	32.0	0.00	0.0	P	1.0	0.0	NONE
[11-074] - Unnamed Trib to N Br Sycamore Cr at RM 0.75																	
LM64	1.40	0.50	71.0	1.0	0.0	0.0	100.00	100.00	100.0	0.00	16.0	0.00	0.0		0.0	0.0	PHW 3A
[11-084] - Trib to North Branch Sycamore Creek at RM 2.33																	
LM62	1.65 - 1.80	0.60	76.0	1.0	0.0	0.0	100.00	100.00	440.0	0.00	20.0	0.00	0.0		1.0	1.0	PHW 3A
[11-086] - Unnamed Trib (1.82) to Trib to Sycamore Creek (1.12)																	
LM54	0.40	1.60	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		1.0	1.0	PHW 2
WAU 13-05 – East Fork Little Miami River																	
[11-100] - East Fork Little Miami River (LMR RM 11.5)																	
LM25	19.50	344.00	88.5	21.5	9.5	0.5	15.13	15.79	797.3	0.67	42.0	9.10	44.0		16.0	0.0	EWH
LM26	14.90 - 15.60	352.00	89.3	22.5	10.0	1.0	10.12	9.94	694.5	0.27	47.0	8.86	48.0		25.0	0.0	EWH
LM27	13.70 - 13.90	364.00	80.5	24.0	12.5	0.0	20.16	20.88	694.5	0.28	43.0	8.64	48.0		22.0	0.0	EWH
LM28	12.90 - 13.20	372.00	80.5	27.0	11.5	0.0	10.51	11.17	425.3	0.38	45.0	9.81	52.0		24.0	0.0	EWH
LM29	11.00 - 11.30	376.00	81.0	24.5	10.5	1.0	11.55	12.58	827.3	0.19	41.0	8.57	44.0		16.0	0.0	EWH
LM30	9.00 - 9.10	380.00	93.0	23.5	11.0	0.5	5.81	5.81	630.8	0.17	43.0	9.16	46.0		17.0	0.0	EWH
LM31	5.60	485.00	71.5	21.0	8.0	0.0	9.19	10.12	310.5	0.71	39.0	8.75	46.0		20.0	0.0	EWH
LM32	4.30	491.00	74.0	20.5	7.5	0.0	7.80	8.31	697.5	0.00	41.0	8.60	50.0		16.0	1.0	EWH
LM34	2.00 - 2.10	494.00	69.8	19.5	6.5	0.0	0.35	2.27	575.0	0.19	35.0	9.53	42.0		18.0	0.0	EWH
LM35	1.00 - 1.60	498.00	81.5	27.0	9.5	0.0	2.21	2.73	806.0	0.25	38.0	9.41	50.0		17.0	0.0	EWH
LM36	0.70	499.00	63.0	19.5	4.5	0.0	5.87	7.58	476.0	0.42	35.0	9.07	50.0		17.0	0.0	EWH
WAU 14-05 – Dry Run																	
[11-005] - Dry Run (LMR RM 7.54)																	
LM70	5.50 - 5.70	0.70	62.5	1.0	0.0	0.0	100.00	100.00	290.0	0.00	20.0	0.00	0.0		4.0	0.0	PHW 3A
LM66	4.10 - 4.20	3.10	56.5	4.0	0.0	1.0	28.28	56.55	290.0	0.00	30.0	0.00	0.0	G	6.0	0.0	WWH
LM67	2.50	4.70	76.5	10.0	2.0	1.0	22.83	45.81	2576.0	0.00	44.0	0.00	0.0	G	8.0	0.0	WWH
LM68	0.60	5.40	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		8.0	0.0	WWH
[11-064] - Trib to Dry Run (4.20)																	
LM69	0.10 - 0.20	0.90	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0	G	7.0	1.0	PHW 3A
WAU 14-03 – Duck Creek																	
[11-004] - Duck Creek (LMR RM 3.87)																	
LM71	6.00	2.20	20.0	0.0	0.0	0.0	0.00	0.00	0.0	0.00	12.0	0.00	0.0	VP	0.0	0.0	LRW
LM78	5.20 - 5.30	3.20	18.5	0.0	0.0	0.0	0.00	0.00	2.0	0.00	12.0	0.00	0.0	VP	1.0	0.0	LRW
LM72	4.60 - 4.70	5.10	40.0	4.0	0.0	0.0	97.33	97.33	300.0	0.67	26.0	0.00	0.0	P	2.0	0.0	LRW

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Little Miami River study area, 2012.

Site ID	Site RM Range	Drain. Area (mi.^{2})	Fish Statistics										Macroinvertebrate Statistics				Aq. Life Use
			QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tolerant	Rel. Number	% DELT	IBI	MIwb	ICI	Narr[1]	Qual EPT	Cold Water taxa	
[11-004] - Duck Creek (LMR RM 3.87)																	
LM73	4.40	5.80	18.5	1.0	0.0	0.0	100.00	100.00	2.0	0.00	12.0	0.00	0.0	P	2.0	0.0	LRW
LM75	3.30	11.40	22.5	0.0	0.0	0.0	0.00	0.00	0.0	0.00	12.0	0.00	0.0	F	4.0	0.0	LRW
LM76	2.30 - 2.90	11.80	33.5	4.0	0.0	1.0	5.47	29.69	256.0	0.00	32.0	0.00	18.0	F	5.0	0.0	LRW
LM77	1.80	14.30	48.0	9.0	0.0	1.0	37.61	56.48	1388.0	0.00	32.0	0.00	0.0	F	4.0	0.0	WWH
LM91	1.00	14.50	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		4.0	0.0	WWH
LM79	0.90	14.60	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0	VP	0.0	0.0	WWH
[11-051] - East Fork Duck Creek																	
LM81	2.30	0.30	NA	0.0	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		0.0	0.0	WWH
LM85	1.50 - 1.90	1.50	59.0	3.0	0.0	1.0	71.43	78.57	28.0	0.00	18.0	0.00	0.0	VP	0.0	0.0	WWH
LM84	0.50 - 0.60	2.30	39.0	4.0	0.0	1.0	67.89	73.39	218.0	0.92	24.0	0.00	0.0	VP	1.0	0.0	WWH
LM74	0.15 - 0.20	3.40	51.0	8.0	0.0	1.0	58.08	68.71	978.0	0.20	28.0	0.00	0.0	VP	3.0	1.0	WWH
[11-075] - Unnamed Trib to Duck Creek at RM 4.8																	
LM83	0.80	1.20	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		3.0	1.0	PHW 2
LM80	0.10 - 0.20	1.40	36.5	1.0	0.0	0.0	100.00	100.00	18.0	0.00	12.0	0.00	0.0	VP	0.0	0.0	LRW
[11-076] - Little Duck Creek																	
LM86	2.70	0.40	46.5	4.0	0.0	1.0	39.05	82.30	1808.0	0.11	34.0	0.00	0.0	G	7.0	0.0	WWH
LM87	2.60	0.50	48.8	4.0	0.0	1.0	40.85	73.83	940.0	0.00	34.0	0.00	0.0	G	6.0	1.0	WWH
LM90	2.30 - 2.40	0.50	59.0	4.0	0.0	1.0	47.24	73.49	1486.0	0.00	34.0	0.00	0.0	MG	5.0	1.0	WWH
LM88	1.70 - 1.80	0.80	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		5.0	1.0	WWH
LM89	1.30 - 1.40	1.10	37.0	5.0	0.0	1.0	69.35	73.33	1860.0	0.00	30.0	0.00	0.0	P	2.0	1.0	WWH
LM92	0.20	1.70	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		2.0	1.0	WWH
LM82	0.10	1.40	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		0.0	0.0	WWH
WAU 14-06 Clough Creek																	
[11-002] - Clough Creek (LMR RM 3.36)																	
LM99	4.60	0.90	56.3	2.0	0.0	1.0	63.83	100.00	188.0	0.00	20.0	0.00	0.0	F	3.0	1.0	PHW 3A
LM95	3.20	2.00	56.5	5.0	1.0	1.0	39.83	79.24	472.0	0.00	30.0	0.00	0.0	F	3.0	0.0	WWH
LM96	3.00 - 3.10	5.40	57.8	9.0	1.0	1.0	47.74	73.14	1504.0	0.00	36.0	0.00	0.0	G	6.0	0.0	WWH
LM97	1.20	7.50	65.0	10.0	1.0	1.0	64.94	73.60	1894.0	0.00	26.0	0.00	34.0		7.0	0.0	WWH
LM98	0.40 - 0.60	7.80	57.5	7.0	1.0	1.0	32.37	72.11	760.0	0.00	26.0	0.00	0.0	G	8.0	0.0	WWH
[11-003] - McCullough Run (LMR RM 3.7)																	
LM94	1.30	1.70	37.0	12.0	1.0	1.0	78.71	83.17	404.0	0.00	34.0	0.00	0.0	VP	0.0	0.0	WWH
11-078 - Unnamed Trib to McCullough Run at RM 1.08																	
LM93	1.40 - 1.60	0.80	56.8	7.0	1.0	2.0	40.15	74.82	548.0	0.00	46.0	0.00	0.0	MG	5.0	0.0	WWH
[11-079] - Trib to Unnamed Trib to Clough Creek at RM3.06																	
LM101	1.00 - 1.05	0.70	58.8	2.0	0.0	1.0	80.99	100.00	242.0	0.00	24.0	0.00	0.0	F	4.0	0.0	WWH

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Little Miami River study area, 2012.

Site ID	Site RM Range	Drain. Area (mi.^{2})	Fish Statistics										Macroinvertebrate Statistics				Aq. Life Use
			QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tol-erant	Rel. Number	% DELT	IBI	MIwb	ICI	Narr[1]	Qual EPT	Cold Water taxa	
[11-080] - UT at RM 0.66 to UT to Clough Creek at RM 3.06																	
LM102	0.20 - 0.60	1.10	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0	P	2.0	2.0	PHW 2
[11-081] - UT at RM 0.95 to UT to Clough Creek at RM 3.06																	
LM100	0.10 - 0.20	0.90	60.8	5.0	0.0	0.0	93.26	93.82	356.0	3.37	24.0	0.00	0.0	P	2.0	0.0	WWH
WAU 12-08 Five Mile Creek – Ohio River																	
[10-001] - Five Mile Creek																	
LM107	2.40 - 2.90	2.30	67.5	4.0	0.0	1.0	27.70	72.30	592.0	0.00	28.0	0.00	0.0	MG	5.0	0.0	WWH
LM108	0.10 - 0.20	4.70	70.8	21.0	7.0	2.0	27.09	34.49	1270.0	0.00	52.0	0.00	0.0	MG	5.0	0.0	WWH
10-002 - Eight Mile Creek																	
LM105	2.00 - 2.10	0.80	71.0	1.0	0.0	0.0	100.00	100.00	2.0	0.00	12.0	0.00	0.0		2.0	0.0	PHW 3A
[10-130] - Trib to Eight Mile Creek at RM 1.01																	
LM106	0.10	1.10	71.5	3.0	0.0	1.0	78.16	100.00	174.0	0.00	18.0	0.00	0.0		4.0	0.0	PHW 3A
[10-537] - Four Mile Creek																	
LM104	0.70 - 0.90	1.10	66.0	2.0	0.0	1.0	82.35	100.00	34.0	23.53	18.0	0.00	0.0	F	4.0	0.0	WWH
WAU 08-03 Turtle Creek																	
[11-021] - Turtle Creek																	
RF08	6.10 - 6.80	22.50	69.0	24.0	9.0	2.0	71.47	68.66	6842.0	0.00	40.0	0.00	0.0		4.0	0.0	WWH
[11-022] - Dry Run																	
RF09	1.80	4.90	63.0	11.0	1.0	2.0	26.17	63.46	810.0	0.00	38.0	0.00	0.0		4.0	0.0	WWH
[11-030] - Newman Run																	
RF10	0.30	9.50	NA	DRY	0.0	0.0	0.00	0.00	0.0	0.00	DRY	0.00	0.0		4.0	0.0	EWH

1 – Narrative evaluation: E – Exceptional; VG – Very Good; G – Good; MG – Marginally Good; F – Fair; P – Poor; VP – Very Poor.
b – mixing zone

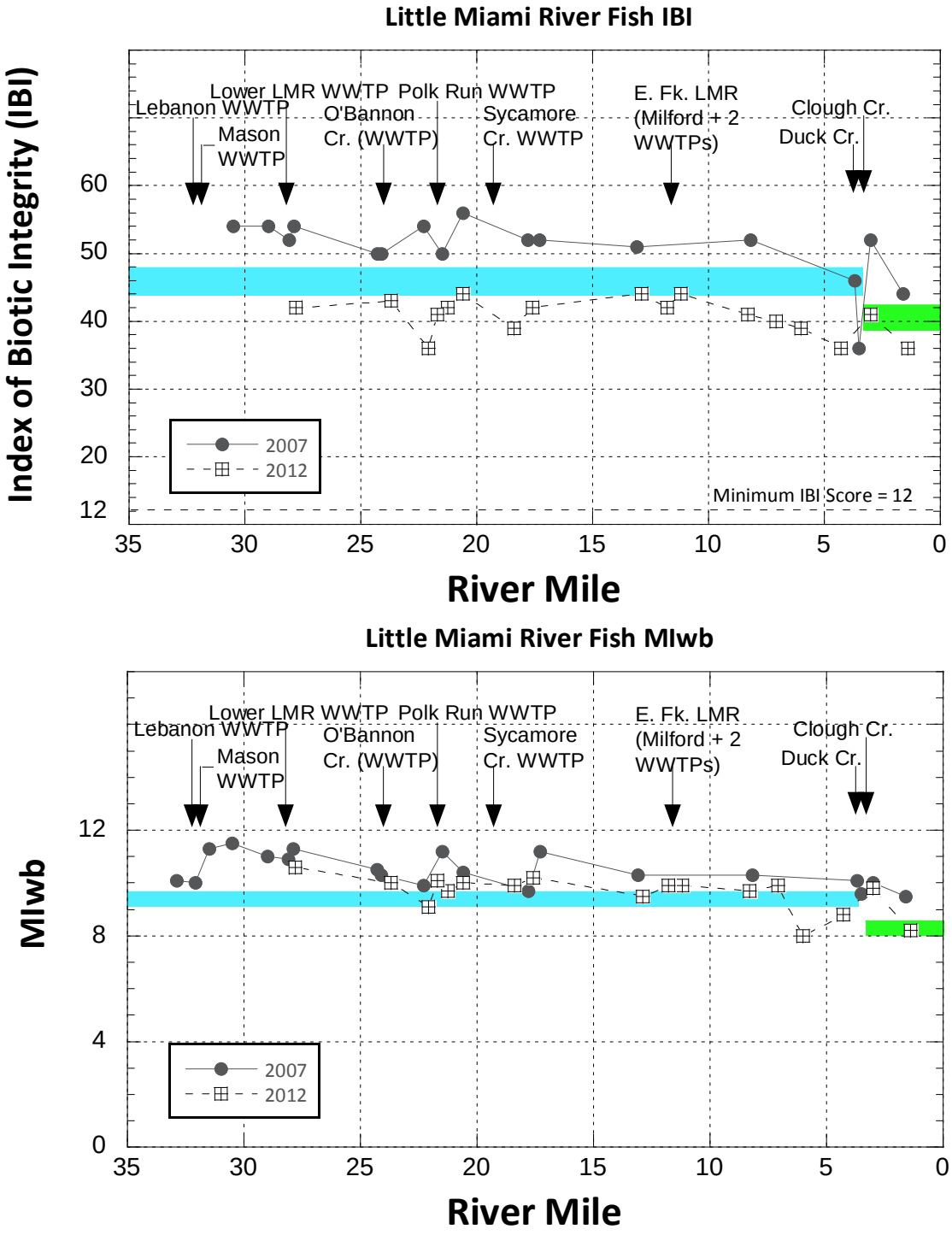

Figure 23. Plots of the Index on Biotic Integrity, IBI (top) or Modified Index of well-being, MIwb (bottom) vs. river mile in the lower Little Miami River during 2007 and 2012. The shaded bars represent the applicable biocriteria ranges by aquatic life use tier; blue = EWH; green = WWH.

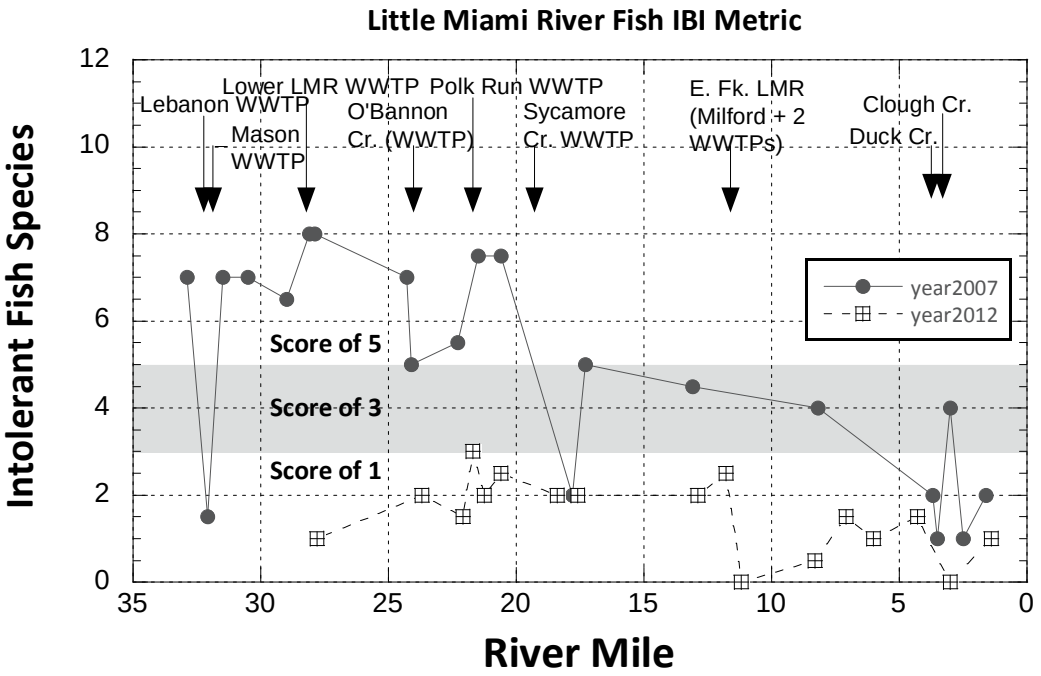

Figure 24. Plot of the intolerant fish species vs. river mile in the lower Little Miami River during 2007 and 2012. Shaded bar represents the appropriate IBI scores for the intolerant fish metric for boatable rivers.

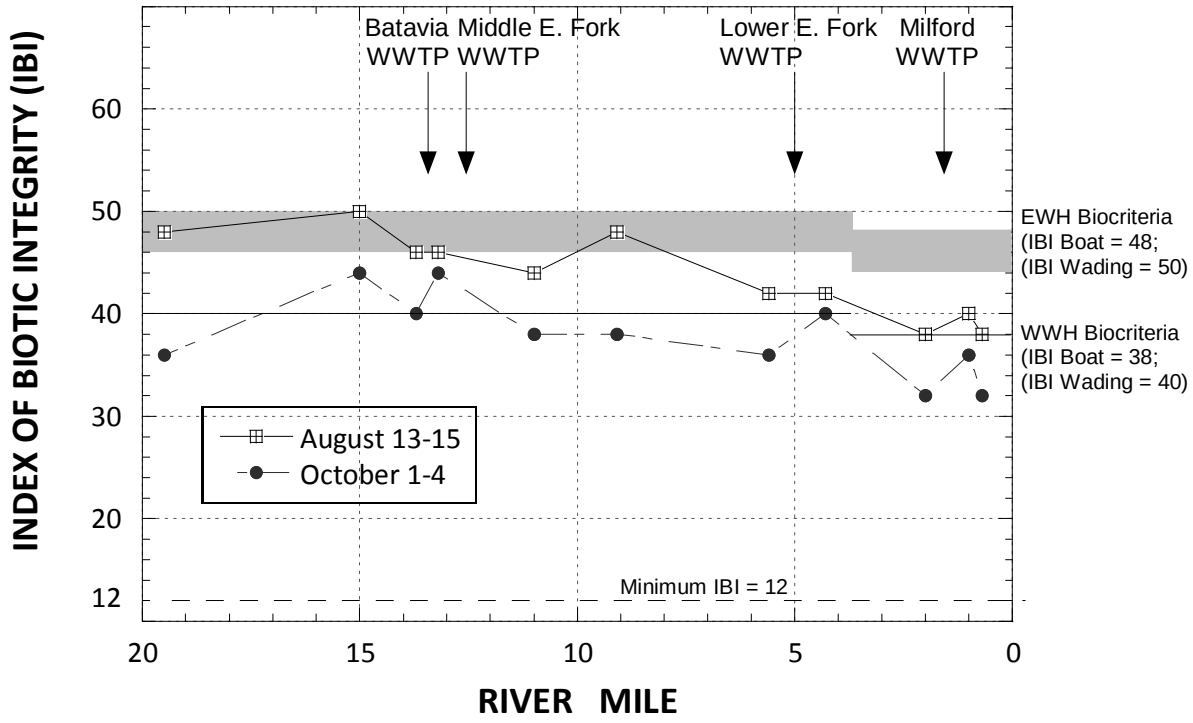

Figure 25. Plot of the IBI vs. river mile in the lower East Fork Little Miami River during each pass collected during 2012. The shaded bars represent the applicable IBI biocriteria metric (upper) and index (lower) scores for wading (RM 4-20) and boatable sites (RM 0-4).

WAU 14-01 - Sycamore Creek

The fish assemblages in Sycamore Creek are poor in the headwaters, the most urban part of the watershed and improve as the streams increases in size. The downstream most two sites (LM51, LM52) meet the WWH IBI biocriterion, but are impaired due to suppressed MIwb scores. These sites have some intolerant species (banded darter, rosyface shiner, stonecat madtom), but have relatively low relative number and biomass which lower the MIwb. The upstream sites (RM 3.5-0.7, LM47-50) are influenced by urban runoff and are predominately a tolerant assemblage of headwater species that includes creek chub, western blacknose dace, and white sucker).

The Sycamore Creek watershed generally has good-excellent habitat (QHEI scores up to 88) and the substrates and nutrients conditions support large number of the herbivorous central stoneroller. The downstream sites have flow from WWTPs and the North Branch of Sycamore Creek. Historical data was not collected above RM 1.5, but data from 2007 and 1991 upstream of the mouth, upstream of the North Branch and upstream of the Sycamore WWTP sites had higher IBI scores in those reaches compared to 2012 (Figure 26).

The North Branch of Sycamore Creek has IBI scores that met the IBI criterion at 3 of 5 sites (Table 17; Figure 26) and was slightly lower (IBI=34) than the biocriteria target at the other two sites. It had more sensitive species in its downstream reaches than in the most upstream reaches where urban runoff was most pronounced. Upstream the North Branch was predominantly composed of tolerant headwater species. Three sites in a tributary to Sycamore Creek at RM 1.12 (LM53, LM55 and LM56) were also impaired (IBIs 24-32) and predominantly composed of tolerant headwater species (creek chub, western blacknose dace). A tributary to the North Fork at RM 5.4 (11-073; LM63), also subject to urban runoff, was similarly impaired (IBI=32) with an assemblage of tolerant headwater species. The remainder of the sites in the Sycamore were either too small to support anything more than pioneering species (e.g., creek chub, LM62, LM64) or were dry when visited (LM54, LM65) and were classified as PHW reaches.

WAU 14-02 - Polk Run

The Polk Run watershed has two of seven sites that were sampled meeting the WWH headwater IBI biocriterion (Polk Run, 11-009, LM40 at RM 0.30 and LM41 on the unnamed Trib to Polk Run at RM 1.79, 11-069). The downstream Polk Run site (LM40) had sensitive fish species including northern hog sucker, smallmouth bass, and greenside and banded darters and its IBI (52) was likely inflated somewhat by its proximity to its confluence with the Little Miami River. The other sites and tributaries were influence by urban runoff and had impaired fish IBI scores (range 28-32) and were characterized by populations of largely tolerant headwater species (creek chub, western blacknose dace, bluntnose minnow and white sucker)

WAU 14-04 - Duck Creek

Duck Creek is the most severely disturbed watershed in the lower Little Miami River. This is reflected by the LRW aquatic life use designation on Duck Creek itself. Upstream sites were sampled and had no fish (RM 6.0 and 5.2; LM71, LM78, IBI scores = 12). A tributary to Duck Creek in this reach (11-075, LM80) was also a concrete channel with a single tolerant fish

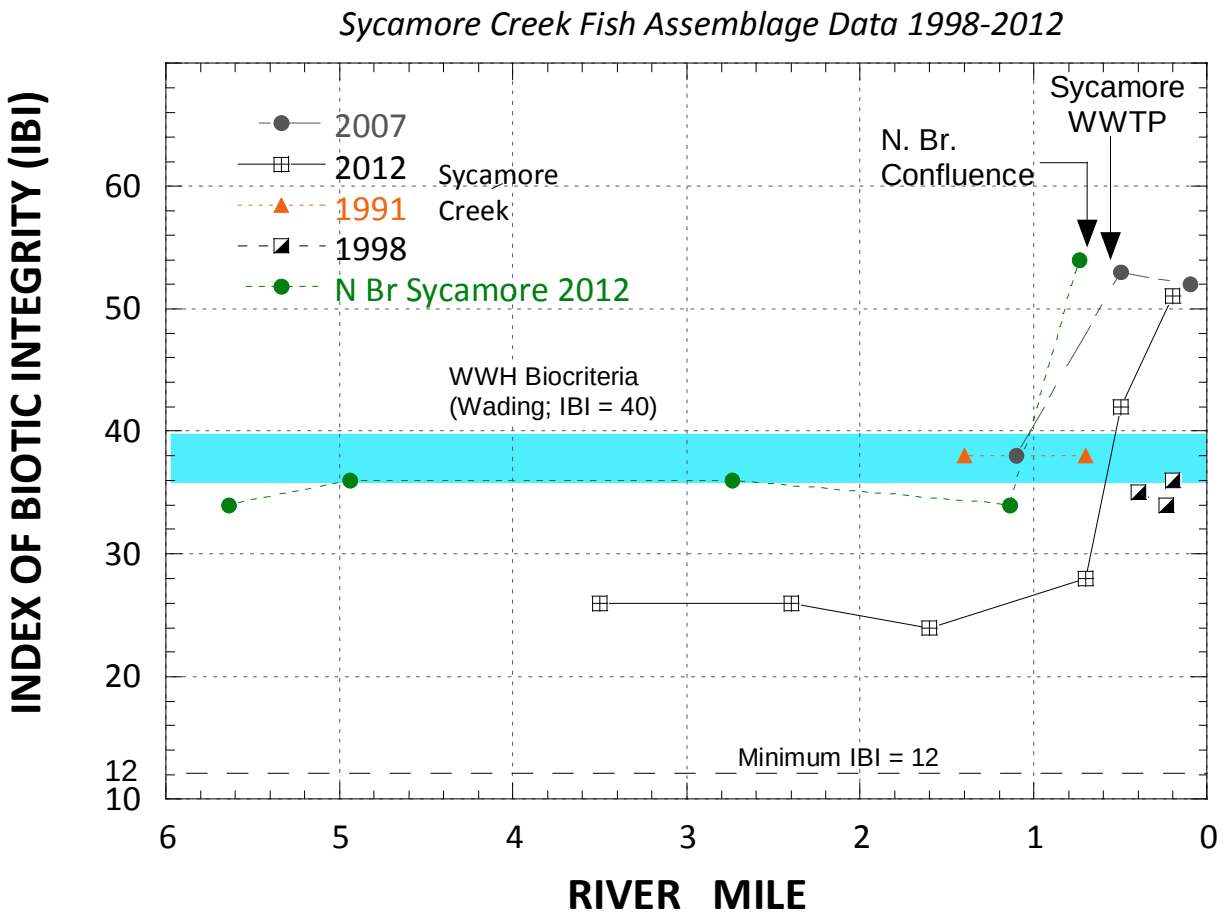

Figure 26. Plot of the IBI vs. river mile in Sycamore Creek from 1998-2012 and in the North Branch during 2012. The shaded bar represents the applicable WWH IBI biocriterion for wadeable and headwater streams in the IP ecoregion.

species (green sunfish), the site had an IBI of 12 and was recommended to be designated as LRW. Two sites fully attained the low expectations for IBIs for LRW with IBI scores of 26 and 32. These sites were however, predominated by tolerant species and other LRW sites had either no or only a single species collected. The lower 1.8 miles of Duck Creek has more natural channel features and retains a WWH aquatic life use. Three of four sites in this reach (LM79, LM81, LM91); however, were dry and could not be sampled. We did consider these as impaired and not meeting the WWH because the flow limitations are at least partly related to the urban, modified nature of the watershed in this reach.

The East Fork of Duck Creek was designated as LRW by Ohio EPA, based on limited data; however our inclusion of more sites resulted in the East Fork being recommended as a WWH aquatic life use because of natural channels and habitat, albeit, in a very urban watershed (see use designation setting). The fish assemblage is degraded at the three WWH sites (IBI scores 18-28) with the assemblage primary comprised of tolerant fish species primary related to urban runoff and CSO impacts.

Little Duck Creek was not sampled previously by Ohio EPA and our data suggests it should be a WWH stream. Sites consisted of multiple fish species that are tolerant (e.g., creek chub, western blacknose dace, white sucker) and impaired IBI scores 30-34 or dry sites, particularly near the mouth as the stream reaches the Little Miami River floodplain. As with Duck Creek we consider these streams to be impaired even though they could not be sampled because of urban contributions to low flow conditions. Two small streams, too small to support permanent fish assemblages were assigned the PHWH classifications.

WAU 14-05 – Dry Run – Little Miami River

In this watershed the only site that met the IBI biocriterion was the middle site on Dry Run (11-005, LM67) at RM 2.5. This site had an IBI of 44 had two darter species including the intolerant banded darter. The next upstream site (LM66, RM 4.1) was considered a WWH site, but was impaired with an IBI of 30 and primarily tolerant headwater species. The most upstream site only had creek chubs, but had sufficient flow and habitat to support two-line salamanders and was classified as a PHWIIIa reach. The site at the mouth was dry at RM 0.6 (LM68) as the stream flowed in the Little Miami River floodplain during 2012 and an upstream tributary was also too dry to sample (11-064, LM69) although it was able to sampled for the PHWH classification and had enough water to support two-lined salamanders and be classified as a PHW3A reach.

WAU 14-06 – Clough Creek

This fish assemblages in this watershed are characterized by mostly tolerant headwater species, or species of intermediate tolerance (e.g., silverjaw minnow) although sites with a little less severe impacts have populations of rainbow and fantail darters.

WAU 12-08 - Nine Mile Creek – Ohio River

Most of the small streams in this watershed had assemblages characterized by tolerant headwater species including western blacknose dace and creek chub. The exception was the site at the mouth of Fivemile Creek (10-001; LM108) which had 22 species including sensitive small stream species such as banded and rainbow darter as well as others that likely migrated in from Ohio River including gizzard shad, emerald shiner, goldfish, and flathead catfish. Although clearly a WWH stream the proximity to the Ohio River likely inflated the IBI score.

Macroinvertebrate Assemblage Results 2012

Macroinvertebrate assemblages in the Little Miami watershed were representative of very good to exceptional water quality in the mainstem of the Little Miami River and the East Fork Little Miami River. Many smaller headwater streams in the basin that were located in highly urban areas were evaluated as very poor to fair water quality, as also was most of the mainstem of Duck Creek and East Fork Duck Creek. Tributaries over 5 square miles that were marginally good to good water quality included Sycamore Creek, Polk Run and Clough Creek.

LRAU 05090202 9002 - Little Miami River

During 2012 macroinvertebrates collected on the artificial substrate samplers on the mainstem of the Little Miami River from RM 27.8 to RM 3.0 had ICI scores from 42 to 50 in the very good to exceptional range (Figure 27). The number of mayfly, caddisfly and stonefly (EPT) taxa

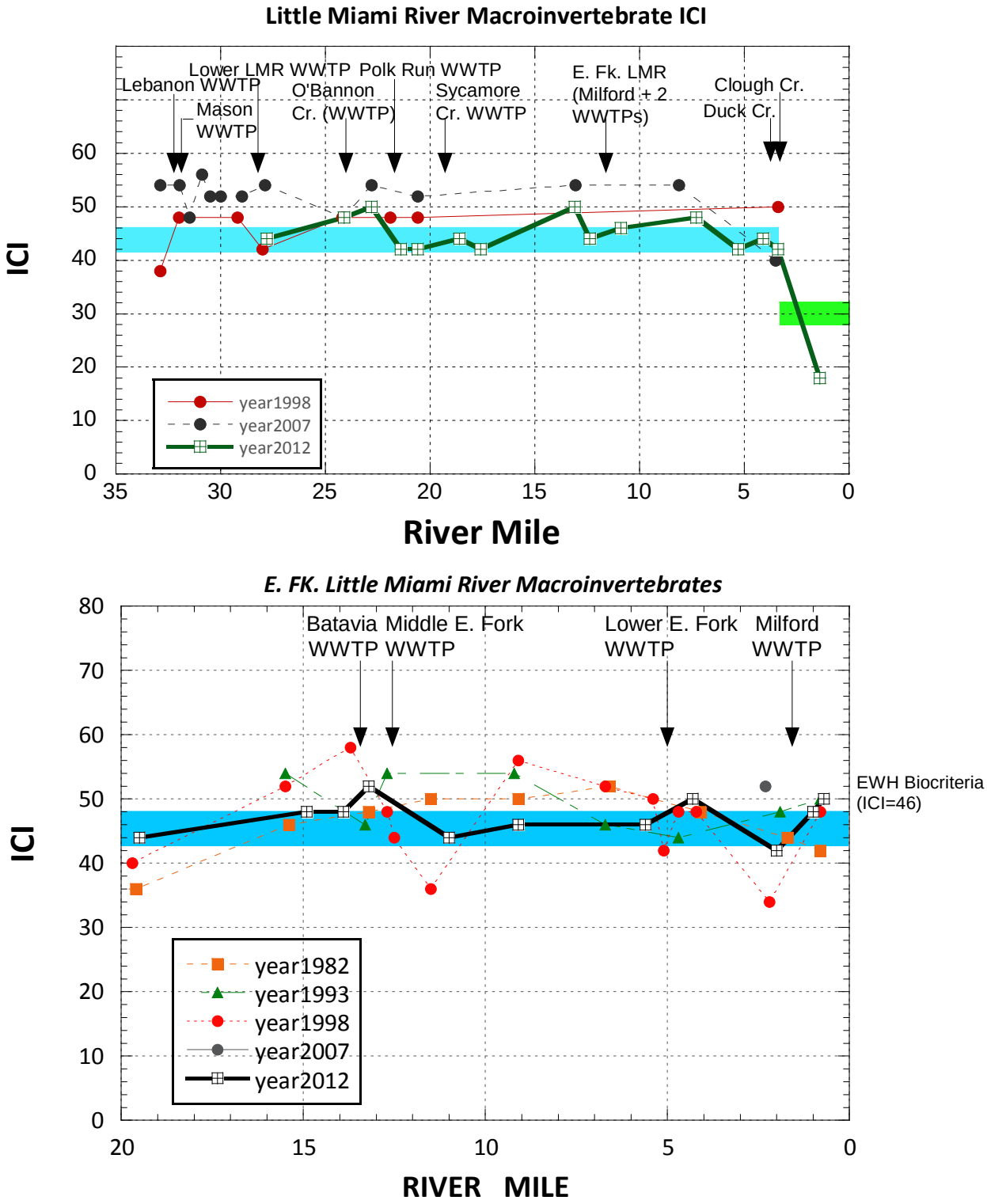

Figure 27. Plot of the ICI vs. river mile in the Little Miami River mainstem (top) and the East Fork Little Miami River (bottom) during 2012 and with all prior year Ohio EPA results. The shaded bars represent the applicable ICI biocriteria for the EWH (blue) and WWH (green) aquatic life use tiers.

collected from the natural substrates at these sites ranged from 12 to 22. The total number of sensitive species collected from both the natural and the artificial substrates combined ranged from 16 to 29. The artificial substrate samplers were lost at Little Miami River RM 8.0, but the qualitative assessment was exceptional based on the 16 EPT and 17 sensitive taxa collected along with the predominance of mayflies, caddisflies and Tanytarsini midges. The other exceptional sites in the Little Miami River mainstem had from 12 to 18 qualitative EPT taxa and 14 to 18 sensitive taxa. The Little Miami River sites RM 21.8 and 1.4 had lower ICI scores but were located in a mix zone (ICI = 32) of a WWTP and the backwater (ICI= 18) of the Ohio River where biocriteria do not apply.

WAU 08-03 – Turtle Creek

Macroinvertebrates assemblages collected at reference sites in 2012 on Newman Run, Dry Run RM 1.8 and Turtle Creek RM 6.1 were affected by low flow conditions. Artificial substrate samplers were set at Newman Run, but the stream was dry at retrieval. The other two reference sites had sufficient flow over the artificial substrates at the set, but upon retrieval there was no flow over the HDs. The qualitative samples collected on the natural substrates on Dry Run and Turtle Creek had 3 and 8 EPT taxa and were evaluated as fair and good, respectively. The fair condition of the macroinvertebrate community at the Dry Run reference may in part be due to the low flow during 2012. The site was mostly intermittent and a pool area upstream from the bridge had large amounts of algae.

WAU 09-02 – O'Bannon Creek

Two sites were sampled on O'Bannon Creek at RMs 1.9 and 0.1. The upstream site RM 1.9 had an ICI score of 34 and the qualitative sample had 9 EPT taxa collected on the natural substrates. Samplers were lost at the downstream site. The site at RM 0.1 was evaluated as good with 16 EPT taxa and 8 sensitive taxa collected, with mayflies, caddisflies and Tanytarsini midges predominant.

WAU 12-08 – Ninemile Creek

Macroinvertebrate assemblages collected in the Ohio River tributaries ranged from fair in Four Mile Creek RM 0.8 to marginally good at Five Mile Creek RMs 2.4 and 0.2. Eight Mile Creek RM 2.1 and the tributary to Eight Mile Creek were evaluated as PHWH Class 3A based on salamander populations present.

WAU 13-05 – East Fork Little Miami River

During 2012 macroinvertebrates collected on the artificial substrate samplers on the mainstem of the East Fork Little Miami River from RM 27.8 to RM 3.0 had ICI scores from 42 to 52 in the very good to exceptional range (Figure 26). The number of mayfly, caddisfly and stonefly (EPT) taxa collected from the natural substrates at these sites ranged from 16 to 25. The total number of sensitive species collected from both the natural and the artificial substrates combined ranged from 17 to 29. Samplers were set and retrieved before the release of water from the Harsha Lake dam in the summer of 2012.

WAU 14-01 – Sycamore Creek

WWH Water Quality evaluations based on the macroinvertebrate communities present on the natural substrates ranged from poor to good in the Sycamore Creek basin. Community assessments were based on the natural substrates at the lower Sycamore Creek sites since retrieval flow conditions over the artificial substrates was not optimal (less than 0.3 feet/sec.) and/or samplers were silted in. Artificial substrate samplers were retrieved from the North Branch Sycamore Creek at the lower two sites RM 0.5 and 0.05, which had ICI scores in the good range of 34 and 36, respectively. The most upstream site of Sycamore Creek at RM 3.6 and a tributary to the North Branch Sycamore Creek RM 1.1 (off of Pfeiffer Rd) were located in concentrated urban areas and the macroinvertebrate assemblages were evaluated as fair and poor, respectively,. As the drainage area increased and the locales became less concentrated urban areas, macroinvertebrate community performance was marginally good to good in Sycamore Creek, North Branch Sycamore Creek and in the larger tributaries.

Two of four sites were evaluated as PHWH Class 2 sites based on HHEI scores and the ephemeral (dry) conditions present. These two dry sites were located in urban settings prone to flashy drainage during storm events. The other two PHWH sites were evaluated as Class 3 based on salamander populations present.

WAU 14-02 – Polk Run

Qualitative macroinvertebrate samples were collected at eight sites in the Polk Run basin. Eight of the sites were evaluated as marginally good to good. The upstream site on the tributary to Polk Run (1.79) was evaluated as fair with only 4 EPT taxa and tolerant snails predominate.

WAU 14-04 – Duck Creek

Very poor to fair macroinvertebrate communities were collected at all sites in Duck Creek and the East Fork Duck Creek. The general area of these creeks is close to I-71 between Stewart Ave. and Edmond Rd. interchanges, and Red Bank Road. Septic odors, plastic trash and/or algal growths were observed at most of these sites. The modified channel of Duck Creek was evident at RMs 5.2, 4.4 and 3.3 where the channel bottom and margin wall is completely encased in concrete.

Little Duck Creek originated along Carmargo Rd. which less urbanized than the rest of the basin. The upper three sites were sampled just downstream from the headwaters from East Fork Rd (RM 2.7) to Settle St. (RM 2.3). These sites were similar in habitat and macroinvertebrate assemblages collected and evaluated as good. Little Duck Creek became more urbanized downstream from RM 2.3 and had dry sections with no flow during the summer of 2012. The only site that had flow in this downstream segment was a short section at RM 1.5 which had only 2 EPT taxa collected and evaluated as poor.

Three sampling site locations ranging in drainage size from 0.1 to 1.4 square miles (sq. mi.) were evaluated as Primary Headwater Habitats (PHWH). Two locations were dry (ephemeral) during summer and were evaluated as PHWH Class 1 or 2, and the other as Class 3A based on salamander populations present.

WAU 14-05 – Dry Run

During 2012, macroinvertebrates collected at RMs 4.1 and 2.5 in Dry Run were evaluated as good with 6 to 8 EPT taxa. The site at Dry Run RM 5.6 and a tributary to Dry Run were evaluated as PHWH Class 3A based on salamander populations present. The mouth site of Dry Run at RM 0.1 was dry during the summer and was not sampled for macroinvertebrates.

WAU 14-06 – Clough Creek

One tributary to Clough Creek was evaluated as PHWH Class 2 based on HHEI scores and the ephemeral (dry) conditions present during fish sampling. Smaller drainage size streams (0.7 to 2.0 sq. mi.) in the Clough Creek basin in 2012 had very poor to fair macroinvertebrate communities, except the tributary to McCullough Creek which had a marginally good assessment. The McCullough Creek lower sites at RMs 3.0 to 0.4 had higher number of total and EPT taxa than most of the other sites and were evaluated as good. One HD was retrieved in McCullough Creek at RM 1.2 with an ICI score of 34.

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