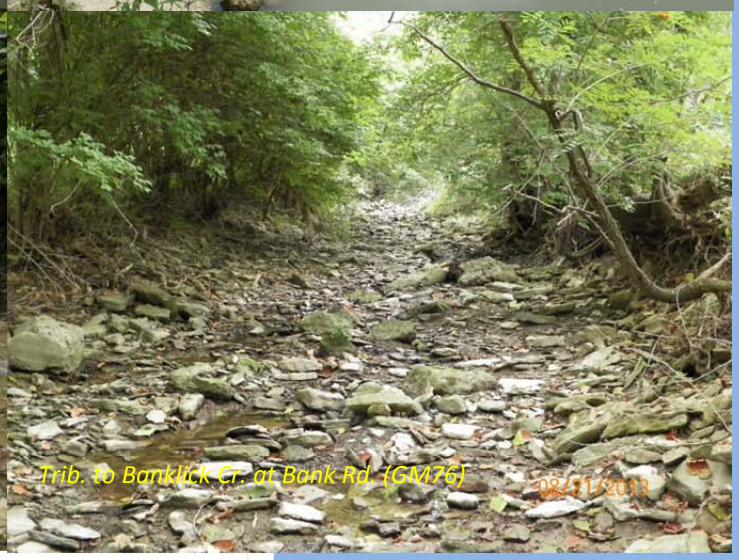
Biological and Water Quality Assessment of the Great Miami River and Tributaries 2013

Great Miami R. at Lost Bridge (GM 21)

Whitewater R. adj. Kilby Rd. (GM 42)


Indian Creek near Millville (BR 23)


Trib. to Banklick Cr. at Bank Rd. (GM76)

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Biological and Water Quality Assessment of the Great Miami River and Tributaries 2013

Hamilton County, Ohio

Technical Report MBI/2014-6-8

MSD Project Number 10180900

June 30, 2014

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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 Great 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 bioassessment follows a similar series of Great Miami River and tributary surveys performed by Ohio EPA in 1980, 1989, 1995, 2007, and 2010. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation, water supply, and human health concerns, can also be assessed.

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

The Great Miami River Biological and Water Quality Assessment gathered relevant information to determine and assess 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 Mill Creek and Duck Creek watersheds contain the most extensive concentration of CSOs in the study area while most other tributaries and the Great Miami R. mainstem are impacted by suburban 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 Great 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. An 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 and NPDES reporting. The 2013 bioassessment of the Great Miami River and tributaries is the third 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 was 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 2013 study area included the Great Miami River mainstem from just downstream of the Hamilton Hydraulic Dam (RM 41.5) to immediately upstream from the mouth of the Ohio River (see Figure 6), a distance of 42 miles. While the upper portion of the Great Miami River mainstem lies outside of the MSDGC service area, it was included because of the potentially significant influence of Hamilton area sources on the Great Miami River in Hamilton Co. and the interpretation of the results. Similarly, tributaries such as Paddys Run were included as well. The Whitewater River was included from the Ohio-Indiana state line (RM 8.9) to the confluence with the Great Miami River at RM 6.45, a distance of nine miles. All other service area tributaries and their watersheds were included with sampling sites located in the upper reaches to drainage areas of <1.0 $mi.^2$. All potential pollution sources were bracketed with sampling sites in order 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 none deal with changing current designated uses for the major mainstem rivers and changes to major tributaries are focused on classifying Primary Headwaters at three headwater sites. 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 2013 Great Miami River biological and water quality assessment.

Current Aquatic Life Use	Recommended Aquatic Life Use/Classification	Number of Segments Affected
Recommended Changes:		
None	WWH	11
None	PHWH 3A	6
None	PHWH 2	7
WWH	PHWH 3A	3
Confirmed Uses:		
EWH	EWH	5
WWH	WWH	46

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

General Conditions in the Great Miami River Mainstem 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 78 sites sampled in 2013 is depicted in Figure 1 and summarized in the conclusions section (Table 4). Of the 78 sites assessed in 2013, 62 were evaluated under the Warmwater Habitat suite of uses and the remaining 16 under the Primary Headwater Habitat assessment methodology. In all, 39 of 62 sites (61.2%) fully attained their applicable aquatic life use. A total of 15 sites were in partial attainment and 7 were in non-attainment; two others were dry (ephemeral). Of the 16 Primary Headwater sites, seven (7) were assigned PHWH Class 2 and nine (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 supporting data are collected at that level. Yet others are at the categorical level (e.g., heavy metals, PAHs) which includes multiple parameters that were 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 were listed with the biological impairments appear in the **Determination of Aquatic Life Use Attainment Status** section. Eight (8) different causal categories and six (6) different source categories were identified for the 2013 study area (Table 2). Of these causes, nutrients, flow

Table 2. Summary of causes and sources associated with biological impairments in the 2013 Great Miami River study area.

Cause	Number	Source	Number
Nutrients	10	Urban Runoff	9
D.O.	6	Agricultural NPS	5
Flow alteration	5	WWTP	4
Organic enrichment	3	Habitat Modification	3
Chlorides	2	Unsewered	3
Habitat alteration	2	Unknown	1
Siltation	2		
Unknown	1		

alteration, and dissolved oxygen (D.O.) were the most frequently listed with urban runoff the most frequently listed source. Classic pollutants such as ammonia and other toxic substances were listed only infrequently and then in localized reaches.

Eutrophication Assessment

The draft Ohio EPA (2011) eutrophication assessment methodology was used to assess the aggregate influence of primary nutrients in the 2013 study area. This is the first use of this tool in the MSDGC service area and it was done in anticipation of it being adopted into the Ohio WQS at some point in the future. This necessitated the collection of benthic chlorophyll a data at each sampling site. This data is used in combination with the fish, macroinvertebrate, total phosphorus and nitrates, and diel D.O. swings that results in an overall Trophic Index Criterion (TIC) score that translates to acceptable, threatened, or impaired eutrophication status.

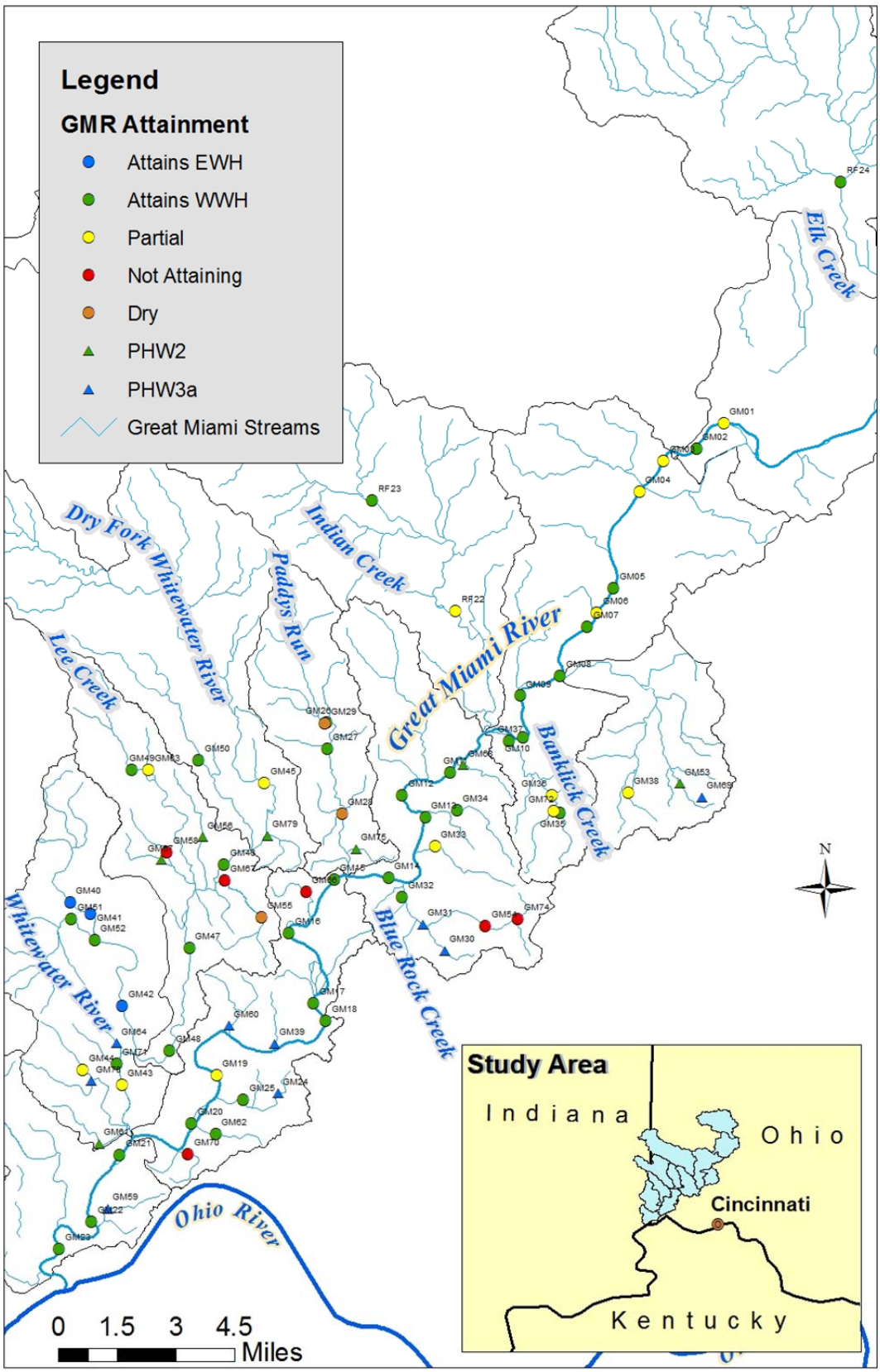

Figure 1. Aquatic life use attainment status for the Warmwater Habitat suite of aquatic life use tiers in the Great Miami River study area during 2013. Site codes correspond to those described in Table 7 of the Study Area description. Sites recommended for evaluation as Primary Headwater Habitat (PHWH) appear as triangles with their resulting classification results. CSO locations appear as light grey circles.

The results for the 23 Great Miami River mainstem sites were 3 acceptable, 13 threatened, and 7 impaired. Acceptable results were found for all 4 Whitewater River mainstem sites. Of the remaining tributaries that had sufficient data to develop a TIC score, 21 were acceptable, 17 threatened, and 8 impaired.

Recreational Use Status

Impairment of recreation uses in the lower Great Miami River study area was not uncommon. Seventy-five (75) sites were sampled in total. The Primary Contact (PC) 30-day geometric mean *E. coli* criterion was exceeded at 48 of 66 sites sampled and most of the attaining sites were in the lower reaches of the Great Miami River mainstem. This included exceedances at all three reference sites. The secondary contact (SC) 30-day geometric mean criterion was exceeded at nine sites. Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the lower Great Miami River it is likely related to upstream wastewater discharges, sanitary sewer overflows (SSOs), urban runoff, and unsewered areas.

Trajectories in Key Indicators

The 2013 assessment of the Great 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 2013 results to prior assessments. A series of five biological and water quality surveys by Ohio EPA dating to 1980, and as recently as 2010, provide the most consistent comparisons in terms of spatial coverage, methods, and indicators and parameters. The focus here is on comparative assessments of the Great Miami River and Whitewater River 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 Great Miami River. Given that the Great Miami River is impacted by multiple watershed level and site-specific impacts 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 Great Miami River mainstem the focus is also on maintaining the improvements made towards full attainment of the Warmwater Habitat (WWH) aquatic life use designation. For the Whitewater River the focus is on attaining and maintaining the Exceptional Warmwater Habitat use designation. 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 can 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 2013 survey. The Area of Degradation (ADV) and Attainment (AAV) methodology (Yoder and Rankin 1995b; Yoder et al. 2005) was used to illustrate the

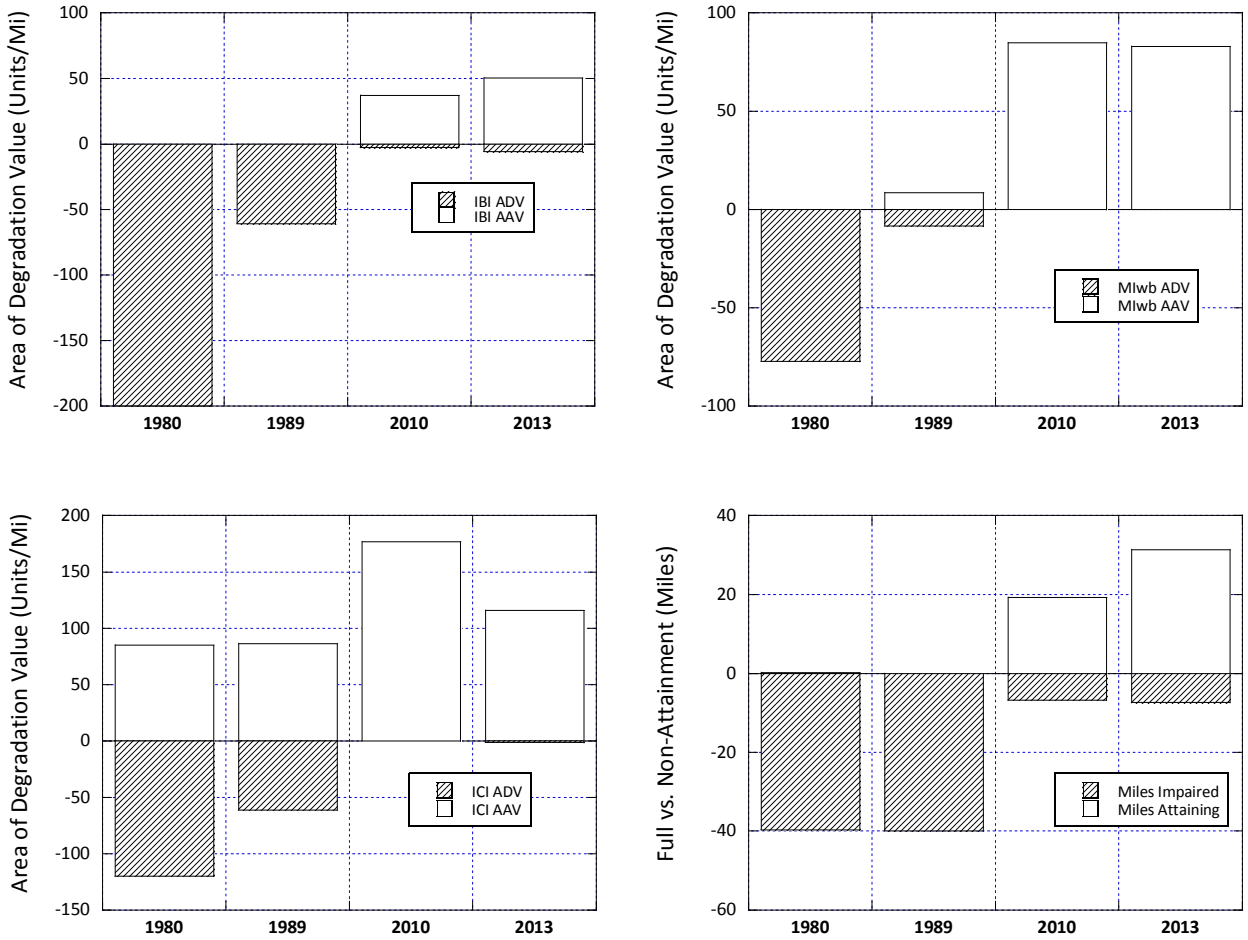

Figure 2. Area of Degradation (ADV) and Area of Attainment (AAV) values for the IBI (upper left), MIwb (upper right), and ICI (lower left) in the lower Great Miami River mainstem between 1980 and 2013. The miles of full and non-attainment of the Warmwater Habitat (WWH) use designation for all sample years for the lower Great 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.

degree of change between the Ohio EPA surveys of 1980, 1989, and 2010 and the 2013 MSDGC survey in the mainstems of the Great Miami and Whitewater 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.

Great 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 1980 and 1989 vs. 2010 and the 2013 MSDGC survey indicates an overall improvement in biological condition since the 1980s (Figure 2).

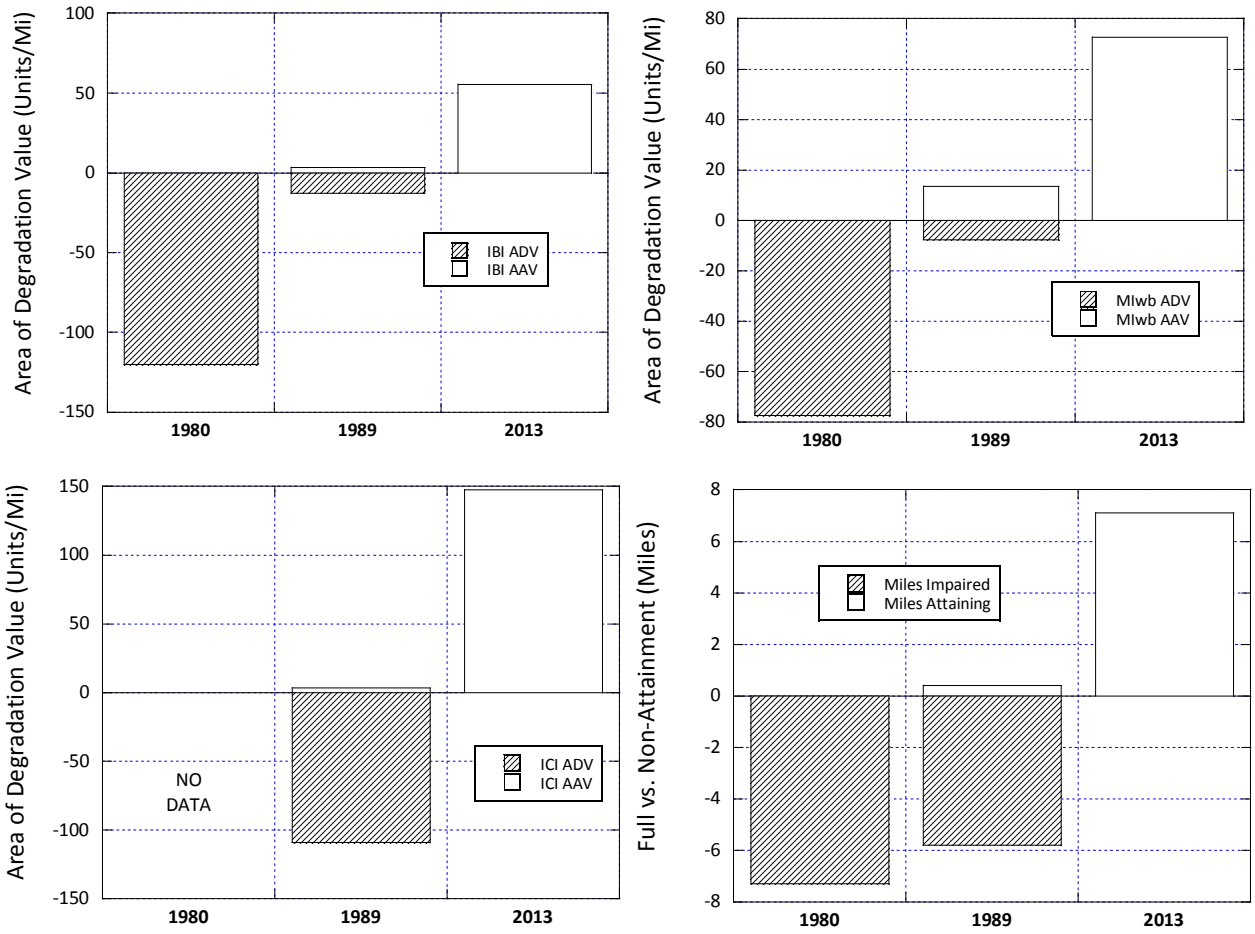

Figure 3. Area of Degradation (ADV) and Area of Attainment (AAV) values for the IBI (upper left), MIwb (upper right), and ICI (lower left) in the Whitewater River mainstem between 1980 and 2013. The miles of full and non-attainment of the Exceptional Warmwater Habitat (EWH) use designation for all sample years for the Whitewater 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.

The IBI in particular exhibited an increase in the AAV and a decrease in the ADV when compared to the 1980s values. A similar trend was observed in the MIwb and ICI (Figure 2). The result of this improvement was a shift to full attainment of WWH and positive AAVs for nearly the entire lower Great Miami River mainstem (Figure 2, lower right). The improvements between the 1980s and 2010 are attributed to improvements in wastewater treatment at WWTPs in the lower mainstem downstream from Dayton (Ohio EPA 2012). The 2013 results confirm that these improvements have both continued and are being maintained.

Whitewater River

The change in ADV/AAV results for the IBI, MIwb, and the ICI between the series of prior Ohio EPA surveys in 1980 and 1989 and the 2013 MSDGC survey indicates a consistent and overall improvement in biological condition since 1980 (Figure 3). All the indices generally showed improving conditions in each successive year with the complete eradication of ADV in 2013

when all sites fully attained EWH aquatic life use (Figure 3, lower right).Again, the improvements in the ADV and AAV are attributed to improved treatment by WWTPs to the lower Whitewater River in Indiana and Ohio.

CONCLUSIONS and RECOMMENDATIONS

Great Miami River Study Area 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 2013 Great Miami River study area in 2010 when they completed their most recent biological and water quality survey (Ohio EPA 2012). 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 2013 Great 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 made in the late 1970s were based 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 had a WWH use by default. The discussion of the recommended assignment of designated uses is organized by the Hydrologic Unit Code (HUC)-12 watershed scale (Watershed Assessment Units = WAUs) or Large River Assessment Units (LRAUs) used by Ohio EPA.

Great Miami River Mainstem and Direct Tributaries

The Great Miami River mainstem has a verified WWH aquatic life use designation based on its confirmation by prior Ohio EPA assessments (Ohio EPA 2013). Since it was first designated by Ohio EPA as WWH in 1980 it is now an existing use (40 CFR Part 131) and as such there is no need to re-validate it with the 2013 results.

Table 3. Assessment of existing aquatic life use (ALU) designations in the 2013 Great Miami River 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 – Great Miami River							
Great Miami River [14-001]	23	5389	Poor-Excellent	Fair-Excellent	Fair-Good	WWH	WWH
WAU 08-08 - Howard Creek - Dry Fork Whitewater River							
Howard Creek [14-304]	1	5.8	Good	Good	Good	WWH	WWH
Unnamed Trib Dry Fork Whitewater R. (8.6) – [14-922]	1	0.9	Poor	NA	NA	None	PHW2
WAU 08-09 - Lee Creek - Dry Fork Whitewater River							
Dry Fork Whitewater River [14-302]	4	81.1	Fair-Excellent	Good-Excellent	Excellent	EWH/ WWH	EWH/ WWH
Lee Creek [14-303]	1	4.9	Fair	Good	Fair	WWH	WWH
Unnamed Trib Dry Fork Whitewater R. (6.73) [14-320]	1	3.2	Good	Fair	Very Poor	None	WWH
Unnamed Trib Dry Fork Whitewater R. (6.30) [14-903]	1	1.20	Poor	NA	NA	None	PHW2
Unnamed Trib to Lee Creek (0.15) – [14-904]	1	1.0	Good	Fair	Very Poor	None	WWH
Unnamed Trib to Unnamed Trib (0.78) to Lee Creek [14-905]	1	1.4	NA	NA	NA	None	PHW2
14-910 - Unnamed Trib to Lee Creek (3.81) [14-910]	1	0.8	Fair	Good	Fair	None	WWH
WAU 08-10 - Jameson Creek - Whitewater River							
Whitewater River – [14-300]	4	1470	Excellent	Excellent	Excellent	EWH	EWH
Sand Run – [14-301]	1	1.1	Good	Excellent	Fair	WWH	WWH
Jameson Creek – [14307]	2	6.7	Good	Excellent	Good	WWH	WWH
14-908 - Unnamed Trib to the Whitewater River(6.45)	1	1	NA	NA	NA	None	PHW2
14-911 - Unnamed Trib to Whitewater River(2.35)	1	0.7	Good	Fair	NA	None	PHW3A
14-917 - Fox Run (to the Whitewater River) (2.05)	1	0.9	Good	Good	Marginally Good	None	WWH
14-921 - Unnamed Trib to Sand Run	1	1.5	Fair	NA	NA	None	PHW3
WAU 09-01 - Pleasant Run - Great Miami River							
14-013 – Pleasant Run	1	0.7	Good	Good	Fair	WWH	WWH
14-901 - Unnamed Trib to Pleasant Run (2.29)	1	0.3	NA	NA	NA	None	PHW2
14-912 - Unnamed Trib to Pleasant Run(5.26)	1	1.2	Good	Good	Poor	None	WWH
WAU 09-02 - Banklick Creek - Great Miami River							
14-012 – Banklick Creek	3	6.3	Good	Fair-Good	Marginally Good – Good	WWH	WWH
14-915 - Unnamed Trib to Banklick Creek(2.55)	1	0.7	NA	NA	NA	None	PHW3A
Unnamed Trib to Banklick Creek (3.13)	1	1.6	Fair	Fair	Marginally Good	None	WWH

Table 3. Assessment of existing aquatic life use (ALU) designations in the 2013 Great Miami River 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
WAU 09-03 - Paddys Run - Great Miami River							
14-005 Paddys Run	4	16.3	Good	Good	Good	WWH	WWH
14-920 - Unnamed Trib to Paddy's Run(0.65)	1	0.7	NA	NA	NA	None	PHW2
WAU 09-04 Dry Run - Great Miami River							
14-006 – Bluerock Creek	3	7.3	Good	Good-NA	Good-NA	EWH	PHW3A - WWH
14-007 – Owl Creek	1	1.6	Good	Marginally Good	Fair	WWH	WWH
14-008 – Dunlap Creek	1	1.8	Good	Good	Marginally Good	WWH	WWH
14-902 - Unnamed Trib to Blue Rock Creek (1.37)	1	2.3	Good	Poor	Poor	None	WWH
14-914 - Unnamed Trib to the Great Miami River(26.52)	1	1.10	NA	NA	NA	None	PHW2
14-919 - Unnamed Trib to Unnamed Trib (2.65) to Blue Rock Cr	1	1.0	Excellent	Very Poor	Very Poor	None	WWH
WAU 09-06 – Jordan Run - Great Miami River							
14-003 – Jordan Creek	2	2.4	NA-Excellent	NA-Good	NA-Good	WWH	PHW3A/ WWH
14-182 – Tributary to Great Miami River	1	0.5	NA	NA	NA	None	PHW3A
14-907 - Unnamed Trib to the Great Miami River(12.0)	1	2.0	NA	NA	NA	None	PHW3A
14-909 - Unnamed Trib to the Great Miami River (8.50)	1	0.6	Good	Good	Marginally Good	None	WWH
14-913 - Unnamed Trib to the G.Miami River 19.2)	1	0.9	Good	Fair	Very Poor	None	WWH
14-916 - Unnamed Trib to the Great Miami River(7.74)	1	1.1	NA	NA	MA	None	PHW3A
Reference Sites							
14-022 – Elk Creek [WAU 07-01]	1	38	Excellent	Marginally Good	-	WWH	WWH
14-010 – Indian Creek [WAU 08-03]	2	102	Excellent	Excellent	-	WWH	WWH

Aquatic Life Use Recommendations for the Lower Great Miami River Study Area

This section focuses on identifying the appropriate aquatic life use classification for streams in each of the Lower Great Miami River 12-digit watersheds and LRAUs.

LRAU 90-02 – Great Miami River

The Great Miami River mainstem has a verified WWH aquatic life use designation based on prior Ohio EPA assessments (Ohio EPA 2010). Since it was first designated by Ohio EPA as WWH in 1980 it is an existing use and as such there is no need to validate it with the 2013 results.

WAU 08-08 - Howard Creek - Dry Fork Whitewater River

MBI sampled two streams in this watershed, Howard Creek (GM50) and a direct tributary (GM79) to the Dry Fork of the Whitewater. Howard Creek is listed an unverified WWH stream and the tributary is unlisted. Howard Creek met the WWH use and the WWH use seems appropriate, at least in the vicinity of our sampling (RM 2.90). MBI recommends that the tributary be classified as a PHW 2 stream because of its small size, lack of flow, and lack of amphibians or sufficient coldwater or EPT taxa.

WAU 08-09 - Lee Creek - Dry Fork Whitewater River

MBI sampled seven streams in the Lee Creek-Dry Fork watershed. The Dry Fork has a verified EWH/WWH aquatic life use, Lee Creek is an unverified WWH stream, and the other tributaries are unlisted. Lee Creek has sufficient habitat to support a WWH aquatic life use and the fish attain this use (GM 49). Of the other 5 streams MBI recommends that two be classified as PHW-2 streams (GM56, GM57) because of low flow and small size and lack of salamanders or sufficient coldwater or EPT macroinvertebrate taxa. MBI concludes that the other three tributaries (GM67, GM58, GM63) have sufficient depth and physical habitat to support a WWH fish and macroinvertebrate assemblage.

GM67 is immediately downstream from Miami Whitewater Lake. The macroinvertebrate community was sampled on September 3, 2013 and appeared to be flow limited. A witness confirmed that the tributary flows only following rainfall events when water spills over the dam. GM 58 had a very poor macroinvertebrate assemblage on August 6, 2013 and appeared to be impacted from upstream sources. A resident observed sewage in the stream apparently emanating from upstream sources. This observation was confirmed by the maximum *E. coli* geometric mean value exceedence of the recreation use criterion at this site.

WAU 08-10 - Jameson Creek - Whitewater River

MBI sampled seven streams in the Jameson Creek - Whitewater River. The Whitewater River has a verified EWH and is meeting this use at all sites. Sand Run and Jameson Creek are unverified WWH streams, and the other tributaries are unlisted. Jameson Creek and Sand Run have sufficient habitat to support a WWH aquatic life use and the fish easily meet this use at all sites (GM 44, GM51, GM52). Of the other 4 streams MBI recommends that Fox Run (GM71) be classified as a WWH stream and the fish and macroinvertebrates fully meet this use. MBI recommends that the unnamed tributary to the Whitewater River (GM 61) be classified as a

PHWH-2 stream because of low flow, small size and lack of salamanders or sufficient coldwater or EPT macroinvertebrate taxa. MBI recommends that the other two tributaries (GM62, GM78) be classified as PHWH 3A streams. These streams are too small to support a WWH use; however, the presence of two-lined salamanders that require permanence of flow and good habitat quality indicate the PHWH 3A as the existing use and the appropriate classification.

WAU 09-01 - Pleasant Run - Great Miami River

MBI sampled three streams in the Pleasant Run watershed. Pleasant Run itself is an unverified warmwater habitat stream and the other two tributaries are undesignated. Pleasant Run (GM 38) has suitable habitat to support a WWH aquatic life use and the fish assemblage attained the criterion associated with that use. One of the tributaries, a tributary to Pleasant Run at RM 5.26 (GM65) also had sufficient habitat to attain a WWH use and the fish assemblage attained the WWH criterion. The third stream, another tributary to Pleasant Run at RM 2.29, was too small to support a WWH use and lacked key salamander species or sufficient coldwater or EPT macroinvertebrate taxa, but had suitable habitat to be classified as a PHW 2 stream.

WAU 09-02 - Banklick Creek - Great Miami River

MBI sampled three streams in the Banklick Run watershed. Banklick Run itself is an unverified warmwater habitat stream and the other two tributaries are undesignated. MBI had three sites in Banklick run (GM 35, GM36, GM37) and the stream had suitable habitat to support a WWH aquatic life use; the stream was attaining the WWH aquatic life use at two of three stations and partially attaining at the third site. One of the tributaries, the tributary to Banklick Run at RM 3.13 (GM72) had sufficient habitat to attain a WWH use and the macroinvertebrate assemblage attained the WWH criterion. The third stream, another tributary to Banklick Run at RM 2.29 (GM69) was too small to support a WWH use, lacked key salamander species or sufficient coldwater or EPT macroinvertebrate taxa, but had suitable habitat to be classified as a PHW 2 stream.

WAU 09-03 - Paddys Run - Great Miami River

MBI sample two streams in the Paddy's Run watershed, Paddys Run itself and an unnamed tributary to it at RM 0.65 (GM75). Paddys run had its WWH use verified during a previous biosurvey. The tributary to Paddys Run was too small to support a WWH use, lacked key salamander species or sufficient coldwater and EPT macroinvertebrate taxa, but had suitable habitat to be classified as a PHW 2 stream.

WAU 09-04 Dry Run - Great Miami River

MBI sampled seven streams in Dry Run – Great Miami River watershed. Bluerock Creek, Owl Creek, and Dunlap Creek all appear in the Ohio WQS as WWH streams, but only Bluerock Creek has had its use verified. Owl Creek and Dunlap Creek both have suitable habitat to support a WWH use and the fish assemblage met the WWH criterion in both streams. Although Bluerock Creek is a verified WWH stream, MBI sampled further into the headwaters than in previous studies and the sites at RMs 1.35 and 2.27 (GM 30, GM31) are small, lack key fish species and the data is more consistent with an existing use of PHW3A because of the presence of key salamander species. Two tributaries to Bluerock Creek (GM54, GM74) are both recommended

as WWH tributaries because of sufficient habitat and deeper pools that should support WWH fish and macroinvertebrate assemblages. A direct tributary to the Great Miami River at RM 26.52 (GM68) is shallow and flow limited and lacks key salamanders and sufficient coldwater and EPT taxa, but has sufficient headwater habitat to support a PHW 2 classification.

WAU 09-06 - Jordan Run - Great Miami River
MBI sampled six streams in Jordan Run – Great Miami River watershed. Jordan Creek is the only stream that appears in the Ohio WQS as a WWH stream, but its use unverified. The lower site on Jordan run (GM25) has sufficient habitat to support a WWH use and fully attain this use for both fish and macroinvertebrates. The upstream site is shallow and although does not support a WWH use has key salamanders to support an existing use of PHW3A. The other small streams in this watershed are all direct tributaries in the lower 12 miles of the Great Miami River. Three of these tributaries have sufficient habitat and depth to support a WWH use and one of these (GM62) fully meets the associated fish and macroinvertebrate criteria. The other three streams (GM 39, GM59 and GM60) are all small and shallow and although they may not be able to achieve the WWH use, they have sufficient habitat and key salamanders to support an existing use of PHW 3A.

Reference Sites
The two reference streams (14-022 – Elk Creek [WAU 07-01]; 14-010 – Indian Creek [WAU 08-03]) each have verified WWH aquatic life uses.

Aquatic Life Use Attainment Status
The status of aquatic life use attainment in the 2013 Great 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 2013 biological and water quality assessment 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. A total of 78 sites were assessed, of which two were dry.

Great Miami River

- Of the 23 Great Miami R. mainstem sites that were evaluated under the Warmwater Habitat suite of uses and biocriteria, 18 were in full attainment of the Warmwater Habitat (EWH) use, 5 in partial attainment of WWH, and none in non-attainment of WWH.
- Of the 20 tributary sites evaluated under the WWH suite of uses, 10 were in full attainment of WWH, 5 in partial attainment, and 5 in non-attainment. Two sites were dry and not evaluated.
- Twelve (12) tributary sites were evaluated under the Primary Headwaters method with 7 classified as PHWH3A and 3 as PHWH2.

Table 4. Aquatic life use attainment status at Great Miami River sites in 2013. 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 Narra-tive	QHEI HHEI	Attain-ment Status	Causes	Sources
Large River Assessment Unit 90-002 – Great Miami River Mainstem									
14-001 – Great Miami River ***(WWH Aquatic Life Use – Existing, Eastern Corn Belt Plains ecoregion)***									
GM01	40.35/40.37	3290	45	9.70	24*	81.8	Partial	Nutrients	WWTPs, Urban runoff
GM02	39.10/39.01	3290	43	9.39	40	83.5	Full		
GM03	38.05/38.27	3620	31*	8.04	-	45.0	Partial	Nutrients	WWTPs, Urban runoff
GM04	37.01/37.05	3630	36*	8.33	36	56.0	Partial		
GM05	34.28/34.30	3640	48	10.06	38	73.8	Full⊙		
GM06	33.50/33.67	3650	38^{ns}	10.13	30*	81.0	Partial ⊙	Nutrients	WWTPs, Urban runoff
GM07	33.07/33.01	3650	38^{ns}	10.02	34^{ns}	76.0	Full⇧		
GM08	31.46/31.20	3650	43	10.18	MG^{ns}	84.0	Full⇧		
GM09	29.98/30.15	3670	42	10.23	34^{ns}	76.0	Full		
GM10	28.24/28.75	3680	45	9.97	40	84.8	Full⇧		
GM11	26.20/27.00	3790	36^{ns}	9.71	MG^{ns}	63.0	Full⊙		
14-001 – Great Miami River ***(WWH Aquatic Life Use – Existing, Interior Plateau ecoregion)***									
GM12	24.65/24.55	3800	45	9.94	44	85.5	Full		
GM13	23.74/23.69	3810	41	10.40	G	78.0	Full⊙		
GM14	21.32/21.65	3820	36^{ns}	9.64	40	85.0	Full		
GM15	19.87/20.05	3840	40	9.35	34	61.8	Full⊙		
GM16	17.89/18.63	3840	45	10.81	G	87.5	Full		
GM17	15.48/15.72	3840	38	9.99	34	81.5	Full⊙		
GM18	14.91/14.70	3870	37^{ns}	10.18	44	86.5	Full⊙		
GM19	10.05/9.97	3880	40	10.30	-	85.0	Full		
GM20	8.55/8.50	3880	47	10.25	42	85.0	Full⊙		
GM21	5.89/5.70	5360	41	9.52	30	84.0	Full		
GM22	3.89/3.83	5370	25*	9.09	38	66.0	Full		
GM23	1.59/1.63	5380	32*	8.54^{ns}	30	69.0	Partial	Nutrients, Backwater	WTTPs, Urban Runoff, Ohio R. Backwater
WAU 08-08 - Howard Creek - Dry Fork Whitewater River									
14-304 – Howard Creek – (***WWH Aquatic Life Use – Existing)***									
GM50	2.85/2.90	5.80	44.0	-	G	66.5	Full		
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6) ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM79	1.40/0.05	0.90	28.0	-	NA	36.5	PHW2		

Table 4. Aquatic life use attainment status at Great Miami River sites in 2013. 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 Narra-tive	QHEI HHEI	Attain-ment Status	Causes	Sources
WAU 08-09 - Lee Creek - Dry Fork Whitewater River									
14-302 – Dry Fork Whitewater River (***EWH Aquatic Life Use – Existing***)									
GM45	10.25/10.21	47.60	42*	9.37^{ns}	E	75.8	Partial ⊙	Nutrients, Dissolved Oxygen	Agricultural runoff
14-302 – Dry Fork Whitewater River (***WWH Aquatic Life Use – Existing***)									
GM46	7.33/7.36	59.70	42	8.53^{ns}	50.0	73.8	Full		
GM47	4.35/4.45	79.10	40	8.66	E	65.8	Full		
GM48	1.25/0.53	81.10	51	9.61	E	48.0	Full		
14-303 – Lee Creek (***WWH Aquatic Life Use – Existing***)									
GM49	4.55/4.68	4.90	44	-	F*	70.8	Partial	Flow limited, dissolved oxygen, nutrients	Agricultural runoff
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM67	0.28/0.31	3.20	34*	-	VP*	54.0	Non	Flow limited, dissolved oxygen, nutrients	Agricultural runoff
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30) ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM56	1.63/1.63	1.20	26	-	NA	38.3/ 49	PHW2		
14-904 - Unnamed Trib to Lee Creek (0.15) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM58	1.15/1.15	1.00	30*	-	VP*	51.5	Non	Organic enrichment, nutrients, chloride	Leaking septic systems, urban runoff
14-905 - Unnamed Trib to Unnamed Trib (0.78) to Lee Creek ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM57	0.36/0.36	1.40	Dry	-	NA	/47	PHW2		
14-910 - Unnamed Trib to Lee Creek (3.81) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM63	0.35/0.39	0.80	42	-	F*	48.8	Partial	Flow limited, D.O.	Agricultural runoff

Table 4. Aquatic life use attainment status at Great Miami River sites in 2013. 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 Narra-tive	QHEI HHEI	Attain-ment Status	Causes	Sources
WAU 08-10 - Jameson Creek - Whitewater River									
14-300 - Whitewater River ***(EWH Aquatic Life Use – Existing)***									
GM40	8.45/8.32	1370	49	10.12	58	79.0	Full⊙		
GM41	7.70/6.98	1370	53	11.08	54	86.5	Full⊙		
GM42	4.80/3.99	1380	50	10.29	58	80.8	Full⊙		
GM43	1.50/1.35	1470	45^{ns}	10.51	58	81.3	Full⊙		
14-301 – Sand Run ***(WWH Aquatic Life Use – Existing)***									
GM44	2.36/2.38	1.10	48	-	F*	66.5	Partial	Flow limited	Natural
14-307 – Jameson Creek ***(WWH Aquatic Life Use – Existing)***									
GM51	0.92/0.94	6.10	48	-	G	69.5	Full		
GM52	0.09/0.14	6.70	50	-	G	62.8	Full		
14-908 - Unnamed Trib to the Whitewater River(6.45) ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM61	0.90/0.90	1.00	Dry	-	NA	/33	PHW2		
14-911 - Unnamed Trib to Whitewater River(2.35) ***(Aquatic Life Use Undesignated/PWH 3A Recommended)***									
GM64	0.28/0.30	0.70	34	-	NA	66.5/ 75	PHW3 A		
14-917 - Fox Run (to the Whitewater River) (2.05) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM71	0.05/0.16	0.90	42	-	MG^{ns}	55.0	Full		
14-921 - Unnamed Trib to Sand Run ***(Aquatic Life Use Undesignated/PWH 3A Recommended)***									
GM78	0.03/0.03	1.50	22	-	NA	49.5/ 77	PHW3 A		
WAU 09-01 - Pleasant Run - Great Miami River									
14-013 – Pleasant Run ***(WWH Aquatic Life Use – Existing)***									
GM38	5.90/5.84	0.70	40	-	F*	66.0	Partial	Flow limited	Urban runoff
14-901 - Unnamed Trib to Pleasant Run (2.29) ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM53	0.02/0.07	0.30	24	-	NA	58.0	PHW2		
14-912 - Unnamed Trib to Pleasant Run(5.26) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM65	5.90/5.84	1.20	42	-	P*	63.8	Non	Flow, chloride	Urban runoff

Table 4. Aquatic life use attainment status at Great Miami River sites in 2013. 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 Narra-tive	QHEI HHEI	Attain-ment Status	Causes	Sources
WAU 09-02 - Banklick Creek - Great Miami River									
14-012 – Banklick Creek ***(WWH Aquatic Life Use – Existing)***									
GM35	3.30/3.41	1.20	40	-	MG^{ns}	0.0	Full		
GM36	2.61/2.63	3.10	34*	-	MG^{ns}	60.0	Partial	Org. Enrichment, dissolved Oxygen	Urban runoff
GM37	0.21/0.35	6.30	38^{ns}	-	G	69.0	Full		
14-915 - Unnamed Trib to Banklick Creek(2.55) ***(Aquatic Life Use Undesignated/PWH 3A Recommended)***									
GM69	0.23/0.23	0.70	Dry	-	NA	/71	PHW3 A		
Unnamed Trib to Banklick Creek (3.13) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM72	0.06/0.25	1.60	32*	-	MG^{ns}	52.0/ 72	Partial	Silt, DO	Urban runoff, habitat loss
WAU 09-03 - Paddys Run - Great Miami River									
14-005 Paddys Run ***(WWH Aquatic Life Use – Existing)***									
GM26	4.50/4.70	6.80	40	-	G	67.5	Full⊙		
GM27	3.80/3.81	9.60	46	-	44.0	69.0	Full		
GM28	1.79/1.79	12.90	Dry	-	Dry	-	-	Flow Issues	Unknown
GM29	0.24/0.24	16.3	Dry	-	Dry	-	-		
14-920 - Unnamed Trib to Paddy's Run(0.65) ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM75	0.30/0.29	0.70	Dry	-	NA	/33	PHW2		
WAU 09-04 Dry Run - Great Miami River									
14-006 – Bluerock Creek ***(Aquatic Life Use WWH)/PWH 3A Recommended)***									
GM30	2.27/2.29	0.70	12	-	NA	66.8/ 78	PHW3 A		
GM31	1.35/1.36	5.70	22	-	NA	70.3/ 78	PHW3 A		
14-006 – Bluerock Creek ***(WWH Aquatic Life Use – Existing)***									
GM32	0.43/0.47	7.30	50	-	G	69.5	Full		
14-007 – Owl Creek ***(WWH Aquatic Life Use – Existing)***									
GM33	0.60/0.61	1.60	38^{ns}	-	F*	61.0	Partial	Flow limited, nutrients (high benthic chlorophyll)	Urban runoff

Table 4. Aquatic life use attainment status at Great Miami River sites in 2013. 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 Narra-tive	QHEI HHEI	Attain-ment Status	Causes	Sources
14-008 – Dunlap Creek ***(WWH Aquatic Life Use – Existing)***									
GM34	0.86/0.90	1.80	40	-	MG^{ns}	60.5	Full		
14-902 - Unnamed Trib to Blue Rock Creek (1.37) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM54	1.75/1.83	2.30	20*	-	P*	62.3	Non	DO. Org. Enrich,	Septic runoff
14-914 - Unnamed Trib to the Great Miami River(26.52) ***(Aquatic Life Use Undesignated/PWH 2 Recommended)***									
GM68	0.23/0.23	1.10	Dry	-	NA	/54	PHW2		
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM74	0.14/0.19	1.00	12*	-	VP*	70.5/ 85	Non	DO. Org. Enrich,	Septic runoff
WAU 09-06 - Jordan Run - Great Miami River									
14-003 – Jordan Creek ***(Aquatic Life Use WWH)/PWH 3A Recommended)***									
GM24	2.25/2.25	0.70	12	-	NA	/88	PHW3 A		
14-003 – Jordan Creek ***(WWH Aquatic Life Use – Existing)***									
GM25	0.82/0.90	2.40	44	-	G	73.3	Full		
14-182 – Tributary to Great Miami River ***(Aquatic Life Use Undesignated/PWH 3A Recommended)***									
GM39	0.21/0.38	0.50	12	-	NA	62.3/ 87	PHW3 A		
14-907 - Unnamed Trib to the Great Miami River(12.0) ***(Aquatic Life Use Undesignated/PWH 3A Recommended)***									
GM60	0.35/0.43	2	26	-	NA	50.5/ 87	PHW3 A		
14-909 - Unnamed Trib to the Great Miami River (8.50) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM62	0.50/0.54	0.60	44	-	MG^{ns}	59.5	Full		
14-913 - Unnamed Trib to the G. Miami River 19.2 .75) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM66	0.59/0.55	0.90	28*	-	VP*	53.0	Non	Org. Enrich	Septic runoff
14-916 - Unnamed Trib to the Great Miami River(7.74) ***(Aquatic Life Use Undesignated/WWH Recommended)***									
GM70	0.32/0.40	1.20	32*	-	P*	41.0	Non	Habitat, silt, nutrients	Hydro-modification

Table 4. Aquatic life use attainment status at Great Miami River sites in 2013. 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 Narra-tive	QHEI HHEI	Attain-ment Status	Causes	Sources
14-906 Unnamed Trib to the Great Miami River (3.7) ***(Aquatic Life Use Undesignated/PWH 3A Recommended)***									
GM59	0.73/0.73	1.10	Dry	-		/72	PHW3 A		
Reference Sites									
14-022 – Elk Creek [WAU 07-01] - ***(WWH Aquatic Life Use – Existing; IP Ecoregion)***									
RF24	3.64/3.84	38	37^{ns}	7.10*		78.0	Partial	Nutrients (elevated benthic chlorophyll)	Agricultural runoff
14-010 – Indian Creek [WAU 08-03] - ***(WWH Aquatic Life Use – Existing; IP Ecoregion)***									
RF23	9.71/9.75	82.30	53.0	9.90		75.5	Full		
RF22	4.28/4.33	102	49.0	9.39		76.0	Full		

^{na} - not applicable; Narratives: E – exceptional; G – good; MG – marginally good; F – Fair; P – poor; VP – very poor.
^{ns} – non-significant departure from applicable biocriterion; * - significant exceedance of applicable biocriterion.
See OAC 3745-1-07, Table 7-14 for the applicable numeric biocriteria.

Whitewater River

- Of the 4 Whitewater R. mainstem sites that were evaluated under the Exceptional Warmwater Habitat use and biocriteria, all were in full attainment of the EWH use.
- Of the 19 tributary sites that were evaluated, 1 was in partial attainment of EWH, 7 in full attainment of WWH, 3 in partial attainment of WWH, and 2 in non-attainment of WWH.
- Six (6) sites were evaluated under the Primary Headwaters method with 2 classified as PHWH3A and 4 as PHWH2.

Recreational Use Status in the Lower Great Miami River Study Area

Impairment of recreation uses in the lower Great Miami River study area was not uncommon. The Primary or Secondary Contact 30-day (geometric mean) criteria (Table 5) were exceeded at 51 of 75 sites (Table 6; Figure 4). The Primary Contact criterion was also exceeded at all three reference sites (Table 6). The 51 exceedences in the study area included 48 exceedances of the Primary Contact criteria and 3 of the Secondary Contact criteria.

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 Great Miami River they are likely related to pump station overflows (PSOs), SSOs, WWTPs, agricultural, nature preserves, urban runoff, and deteriorating conveyance systems in the urban areas.

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

	E. coli Count	
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 Great Miami River study area streams recommended as PHW that were less than one square mile and shallow were assessed as SCR because their small size precluded 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 – Great Miami River

The Great Miami River mainstem is designated as PCB because of the recreational value of this river; the Whitewater River is designated as PCA because of the high aesthetic and aquatic quality (EWH) which results in very high recreational value. Ten of the twenty-three sites on the Great Miami exceeded the PCB criteria for *E. coli* and many exceeded the single value maximum target as well particularly in the upper 20 miles of the study area (Table 6). All four sites in the Whitewater River exceeded the PCA criteria for E. coli. Potential sources of *E. coli* include agricultural sources and WWTP effluents.

Plots of individual sample results of *E. coli* counts in the lower Great Miami mainstem illustrates exceedances of individual values relative to the PCB criterion of 161 MPN (Most Probable Number) in from the 2013 survey (Figure 4) with a smoothing curve; points above the criteria are colored red. The geometric mean values, used to measure attainment of the PCB criterion, exceeded it the upper reaches of the river (RMs 40-26.2), but not areas downstream of this reach.

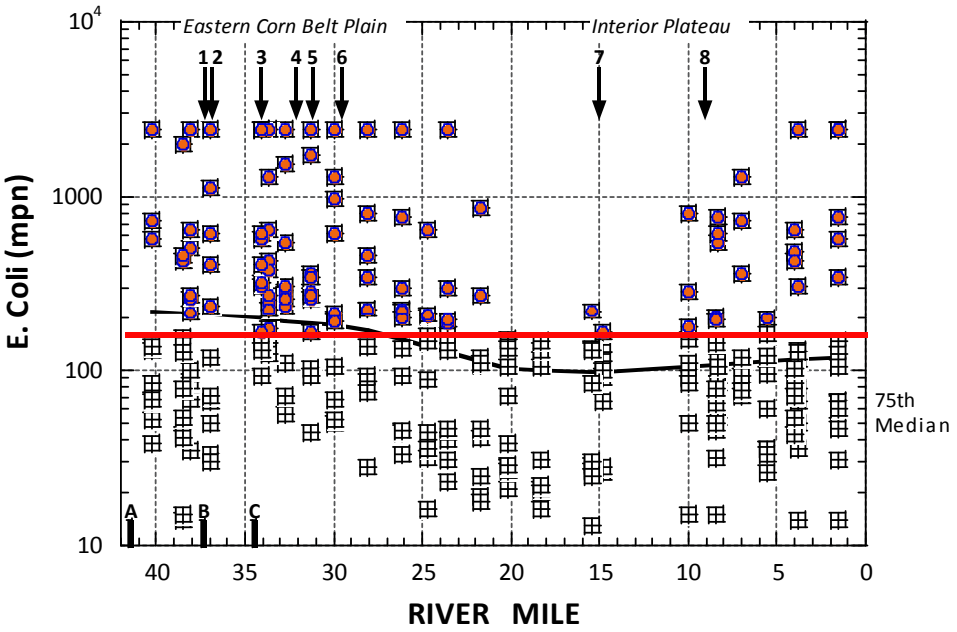

Figure 4. E. coli (MPN) vs. river mile for the lower 45 miles of the Great Miami River during 2013 (top). Red line represents primary contact criteria of 161 MPN; points above this value are shaded red. Black line is a locally weighted smoothing curve through the points. The numbers and letters are discharges and dams listed in Table 9.

Table 6. Bacteriological (E. coli) sampling results in the Great Miami River study area during 2013. 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 criteria are highlighted in yellow (PC – Primary Contact; SC – Secondary Contact).

River Mile	Site ID	Location	Rec. Use	N	E. coli Geom. Mean	E. Coli Max.	Recrea-tion Status
Large River Assessment Unit 90-002 – Great Miami River Mainstem							
14-001 – Great Miami							
GM01	40.30	Ust. Hamilton area - dst. Hydraulic Canal diversion dam	PCB	11	183.1	2420.0	**Non**
GM02	38.55	Ust. Fourmile Creek; dst. old Armco discharges	PCB	11	101.7	1986.0	**Full**
GM03	38.09	Dst. Fourmile Creek	PCB	11	200.5	2420.0	**Non**
GM04	36.98	Dst. Hamilton Municipal EGS	PCB	11	174.4	2420.0	**Non**
GM05	34.12	Dst. Hamilton Recreational Dam; ust. Hamilton WWTP	PCB	11	381.1	2420.0	**Non**
GM06	33.66	Dst. Hamilton WWTP	PCB	11	367.3	2420.0	**Non**
GM07	32.69	Ust. Fairfield WWTP	PCB	11	293.6	2420.0	**Non**
GM08	31.27	Dst. Fairfield WWTP	PCB	11	277.6	2420.0	**Non**
GM09	29.98	American Aggregates bridge; USGS gage	PCB	11	254.5	2420.0	**Non**
GM10	28.15	Adjacent E. River Rd.; ust. Banklick Cr.	PCB	11	210.9	2420.0	**Non**
GM11	26.20	St. Rt. 126; ust. DOE Fernald Closure Project & P&G Lab	PCB	11	174.6	2420.0	**Non**
GM12	24.67	Dst. DOE Fernald Closure Project	PCB	10	92.6	649.0	**Full**
GM13	23.63	Adjacent E. River Rd.	PCB	10	121.8	2420.0	**Full**
GM14	21.70	Blue Rock Rd./New Baltimore; ust. Paddys Run & dst. Bluerock Cr.	PCB	10	74.8	866.0	**Full**
GM15	20.14	Dst. Paddys Run	PCB	9	51.8	152.0	**Full**
GM16	18.30	Gravel mining area	PCB	9	46.8	148.0	**Full**
GM17	15.49	Ust. Taylor Creek WWTP	PCB	9	51.2	219.0	**Full**
GM18	14.88	Dst. Taylor Creek WWTP	PCB	9	77.0	167.0	**Full**
GM19	9.98	Ust. old Hooven Refinery site	PCB	9	116.8	816.0	**Full**
GM20	8.48	U.S. Rt. 50; ust. Whitewater R. & dst. old Hooven Refinery site	PCB	9	68.2	205.0	**Full**
GM21	5.55	Lost Bridge; dst. Whitewater R.	PCB	9	66.3	201.0	**Full**
GM22	3.78	Ust. Shawnee Boat Launch	PCB	10	106.5	2420.0	**Full**
GM23	1.59	Ust. OH-IN state line; Ohio R. influence	PCB	10	70.1	579.0	**Full**
WAU 08-08 - Howard Creek - Dry Fork Whitewater River							
14-304 – Howard Creek							
GM50	2.91	Downstream Howard Rd	PCB	4	498.5	2420.0	**Non**
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6)							
GM79	0.01	Behind residence immed. north of New Haven Rd	PCC	1	260.0	260.0	**Non**
WAU 08-09 - Lee Creek - Dry Fork Whitewater River							
14-302 – Dry Fork Whitewater River							
GM45	10.65	Atherton Ave	PCB	8	512.5	2420.0	**Non**
GM46	7.30	DRY FK. AT Miami-WHITEWATER Park	PCB	8	323.3	816.0	**Non**
GM47	4.34	Harrison Ave	PCB	9	376.8	2420.0	**Non**
GM48	0.53	Kilby Ave	PCB	9	167.5	2420.0	**Non**
14-303 – Lee Creek							
GM49	4.75	Lees Creek Rd and New Biddinger Rd	PCC	4	547.6	2420.0	**Non**
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)							
GM55	1.75	Upstream Strimple Rd	PCC	1	152.0	152.0	**Full**
GM67	0.35	Downstream Harbor Ridge Rd bridge	PCC	4	104.9	1414.0	**Full**
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)							
GM56	1.61	At Baughman Rd bridge	PCC	2	74.7	124.0	**Full**
14-904 - Unnamed Trib to Lee Creek (0.15)							

Table 6. Bacteriological (E. coli) sampling results in the Great Miami River study area during 2013. 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 criteria are highlighted in yellow (PC – Primary Contact; SC – Secondary Contact).

River Mile	Site ID	Location	Rec. Use	N	E. coli Geom. Mean	E. Coli Max.	Recrea-tion Status
GM58	1.14	Access from Starspray Dr west or Sugardale St on east	PCC	1	2420.0	2420.0	**Non**
14-910 - Unnamed Trib to Lee Creek (3.81)							
GM63	0.41	Bridge at Lees Creek Rd	SC	1	65.0	65.0	**Full**
WAU 08-10 - Jameson Creek - Whitewater River							
14-300 - Whitewater River							
GM40	8.32	Jamison Road Bridge; ust. Harrison WWTP	PCA	8	181.3	770.0	**Non**
GM41	6.98	Dst. I-74; dst. Harrison WWTP	PCA	8	187.9	1300.0	**Non**
GM42	3.98	Adjacent Kilby Rd.	PCA	8	144.9	649.0	**Non**
GM43	1.50	Suspension Bridge Road	PCA	8	288.6	2420.0	**Non**
14-301 – Sand Run							
GM44	2.35	Behind residence at 1117 Sand Run Rd	PCC	2	712.9	2420.0	**Non**
14-307 – Jameson Creek							
GM51	0.91	At Lawrence Rd	PCB	4	180.2	921.0	**Non**
GM52	0.20	Behind residence at 9173 Lawrence Rd	PCB	4	385.0	1120.0	**Non**
14-911 - Unnamed Trib to Whitewater River(2.35)							
GM64	0.29	Off residence access road to 5611 Lawrenceberg Rd	SC	1	62.0	62.0	**Full**
14-917 - Fox Run (to the Whitewater River) (2.05)							
GM71	0.06	Behind residence at 5156 Lawrenceburg Rd	PCC	1	308.0	308.0	**Non**
14-921 - Unnamed Trib to Sand Run							
GM78	1.89	Unknown subdivision off 11166 Sand Run Rd	PCC	2	612.5	2420.0	**Non**
WAU 09-01 - Pleasant Run - Great Miami River							
14-013 – Pleasant Run							
GM38	5.78	Brookway Dr & West Kemper Dr north into subdivision	SC	1	727.0	727.0	**Full**
14-901 - Unnamed Trib to Pleasant Run (2.29)							
GM53	0.04	Forester Dr and Pleasant Run Dr into subdivision	SC	2	897.7	2420.0	**Full**
14-912 - Unnamed Trib to Pleasant Run(5.26)							
GM65	5.78	Brookway Dr and West Kemper Dr north into subdivision	PCC	2	2420.0	2420.0	**Non**
WAU 09-02 - Banklick Creek - Great Miami River							
14-012 – Banklick Creek							
GM35	3.30	Crest and Bank Rd	PCC	2	123.2	276.0	**Full**
GM36	2.65	Adj. West Kemper Rd.	PCC	4	884.7	1986.0	**Non**
GM37	0.30	Adj. Burns Rd.	PCB	4	171.6	1733.0	**Non**
14-915 - Unnamed Trib to Banklick Creek(2.55)							
GM69	0.15	Bank Rd/West Kemper	SC	1	866.0	866.0	**Full**
Unnamed Trib to Banklick Creek (3.13)							
GM72	0.15	Bank and Hughes Rd	PCC	2	2047.9	2420.0	**Non**
WAU 09-03 - Paddys Run - Great Miami River							
14-005 Paddys Run							
GM26	4.72	Ust. DOE Fernald 006 (former)	PCB	9	400.1	2420.0	**Non**
GM27	3.82	Dst. DOE Fernald 006 (former)	PCB	8	730.6	2420.0	**Non**
GM28	1.79	Dst. Pilot Plant drainage ditch	PCB	5	660.8	2420.0	**Non**
GM29	0.10	Ust. Mouth	PCB	5	313.9	2420.0	**Non**
WAU 09-04 Dry Run - Great Miami River							
14-006 – Bluerock Creek							
GM30	2.24	Nearest 6102 Blue Rock Rd	SC	1	2420.0	2420.0	**Non**

Table 6. Bacteriological (E. coli) sampling results in the Great Miami River study area during 2013. 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 criteria are highlighted in yellow (PC – Primary Contact; SC – Secondary Contact).

River Mile	Site ID	Location	Rec. Use	N	E. coli Geom. Mean	E. Coli Max.	Recrea-tion Status
GM31	1.53	dst. St. Rt. 128; Reference Site (RF 21)	PCB	2	238.1	727.0	**Non**
GM32	0.45	Adj. Blue Rock Rd.	PCB	4	558.4	2420.0	**Non**
14-007 – Owl Creek							
GM33	0.35	Nearest 6237 Day Rd.	PCC	2	997.3	2420.0	**Non**
14-008 – Dunlap Creek							
GM34	0.87	Dunlap and Gosling Rd.	PCC	2	496.8	866.0	**Non**
14-902 - Unnamed Trib to Blue Rock Creek (1.37)							
GM54	1.72	Off Sheits Road, Newberry Wildlife Sanctuary	PCC	2	77.6	172.0	**Full**
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr							
GM74	0.15	Frontage Rd to I-275, behind Meijer	PCC	1	2420.0	2420.0	**Non**
WAU 09-06 - Jordon Run - Great Miami River							
14-003 – Jordan Creek							
GM24	2.24	Access at 8658 Jordan Rd.	SC	1	1986.0	1986.0	**Non**
GM25	0.91	Adj. Jordan Rd.	PCC	4	528.5	1553.0	**Non**
14-182 – Tributary to Great Miami River							
GM39	0.33	NA	SC	1	1203.0	1203.0	**Non**
14-907 - Unnamed Trib to the Great Miami River(12.0)							
GM60	0.55	Nearest 5217 Hamilton Cleves Pike	PCC	1	579.0	579.0	**Non**
14-909 - Unnamed Trib to the Great Miami River (8.50)							
GM62	0.40	Off Morgan St	SC	1	866.0	866.0	**Full**
14-913 - Unnamed Trib to the G.Miami River 19.2 .75)							
GM66	0.53	Downstream Hamilton Cleves Rd, gravel pit - prob dry	PCC	1	1733.0	1733.0	**Non**
14-916 - Unnamed Trib to the Great Miami River(7.74)							
GM70	0.30	Off Miami View Rd/ Gulf Community Park	PCC	2	517.1	548.0	**Non**
14-906 Unnamed Trib to the Great Miami River (3.7)							
GM59	0.74	Nearest 10656 Lawrenceburg Rd - Hamilton Cty Park	PCC	2	719.6	2420.0	**Non**
Reference Sites							
14-022 – Elk Creek [WAU 07-01]							
RF24	3.65	upst. Dry Run	PCB	10	408.2	2420.0	**Non**
14-010 – Indian Creek [WAU 08-03							
RF23	9.74	adj. Reily-Millville Rd.	PCB	10	348.4	2420.0	**Non**
RF22	4.27	upst. Hamilton-New London Rd.	PCB	10	223.6	2420.0	**Non**

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.

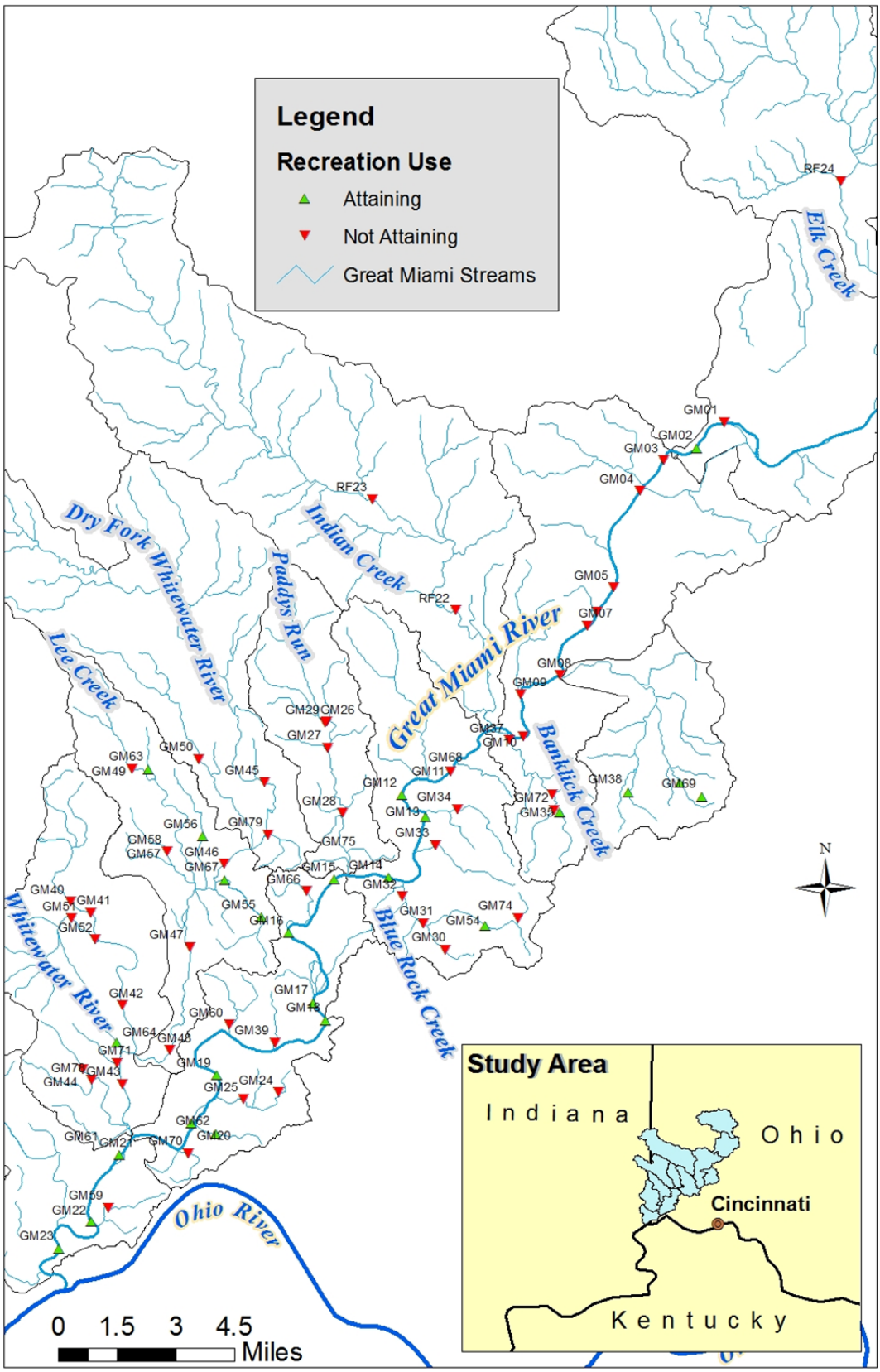

Figure 5. Recreational use attainment status for the Primary Contact suite of use tiers in the Great Miami River study area during 2013 expressed as attainment (blue) or non-attainment (red) based on E. coli values. Site codes correspond to those described in Table 7 of the study area description.

Biological and Water Quality Assessment of the Great Miami River and Tributaries 2013

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 guide and 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.

2013 Great Miami River and Tributaries Assessment Scope and Purpose

The 2013 Great Miami River and tributaries 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 Great Miami River, the Whitewater River downstream from the Indiana-Ohio state line, and tributaries to the Great 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 Great Miami River watersheds included major wastewater treatment plants on the Great Miami and Whitewater River 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 the Mill Creek and parts of the Little Miami River watersheds. However, CSOs are not a major issue in the Great Miami River study area which provides a unique comparison opportunity. MSDGC is working to remediate these issues under a Consent Decree with the U.S. EPA, Ohio EPA and ORSANCO to reduce CSO volume. As part of Phase 1, MSDGC must reduce CSOs in the lower Mill Creek watershed by about 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.

The Great Miami River 2013 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 Mill Creek service area
2010 Little Miami service area
2011 Muddy Creek service area
2012 Mill Creek 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 was changed to June 30 so that the annual watershed monitoring and assessment outlined in MBI (2011) can be used to fulfill this reporting requirement. In addition MSDGC has included the subwatersheds in the Great Miami River study area 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 study area for NPDES reporting.

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 Great Miami River mainstem and the major tributaries. The result was a design that included chemical, physical, and biological sampling at a total of 75 sites in Great Miami River study area as a whole (Table 7). Each site was assigned a unique site code as depicted in Table 7 and Figure 6. An additional three reference sites outside of the Great 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 2013 Great Miami River study area bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites. Regional reference sites outside of Great 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
Large River Assessment Unit 90-002 – Great Miami River Mainstem							
14-001 – Great Miami River							
GM01	C, D, N, H, O, B	FB, HD	40.30 - 40.37	39.437030, -84.51924	3290	Ust. Hamilton area - dst. Hydraulic Canal diversion dam	
GM02	C, D, N, H, O, B	FB, HD	38.55 - 39.10	39.427300, -84.53239	3290	Ust. Fourmile Creek; dst. old Armco discharges	
GM03	C, D, N, H, O, B	FB	38.05 - 38.27	39.422360, -84.54784	3620	Dst. Fourmile Creek	
GM04	C, D, N, H, O, B	FB, HD	36.98 - 37.05	39.409910, -84.55783	3630	Dst. Hamilton Municipal EGS	
GM05	C, D, N, H, O, B	FB, HD	34.12 - 34.30	39.374290, -84.56910	3640	Dst. Hamilton Recreational Dam; ust. Hamilton WWTP	
GM06	C, D, N, H, O, B	FB, HD	33.50 - 33.67	39.364590, -84.57558	3650	Dst. Hamilton WWTP	
GM07	C, D, N, H, O, B	FB, HD	32.69 - 33.07	39.359680, -84.58028	3650	Ust. Fairfield WWTP	
GM08	C, D, N, H, O, B	FB, QL	31.20 - 31.46	39.341560, -84.59277	3650	Dst. Fairfield WWTP	
GM09	C, D, N, H, O, B	FB, HD	29.98 - 30.15	39.332830, -84.61138	3670	American Aggregates bridge; USGS gage	
GM10	C, D, N, H, O, B	FB, HD	28.15 - 28.75	39.316910, -84.60883	3680	Adjacent E. River Rd.; ust. Banklick Cr.	
GM11	C, D, N, H, O, B	FB, QL	26.20 - 27.00	39.310640, -84.63358	3790	St. Rt. 126; ust. DOE Fernald Closure Project & P&G Lab	
GM12	C, D, N, H, O, B	FB, HD	24.55 - 24.67	39.294030, -84.66555	3800	Dst. DOE Fernald Closure Project	
GM13	C, D, N, H, O, B	FB, HD	23.63 - 23.74	39.286860, -84.65416	3810	Adjacent E. River Rd.	
GM14	C, D, N, H, O, B	FB, HD	21.32 - 21.70	39.261960, -84.66277	3820	Blue Rock Rd./New Baltimore; ust. Paddys Run & dst. Bluerock Cr.	
GM15	C, D, N, H, O, B	FB, HD	19.87 - 20.14	39.261770, -84.69548	3840	Dst. Paddys Run	
GM16	C, D, N, H, O, B	FB, HD	17.89 - 18.63	39.243790, -84.71112	3840	Gravel mining area	
GM17	C, D, N, H, O, B	FB, HD	15.48 - 15.72	39.219070, -84.70210	3840	Ust. Taylor Creek WWTP	
GM18	C, D, N, H,	FB, HD	14.70 -	39.209600, -	3870	Dst. Taylor Creek WWTP	

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Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^{-2})	Location Description	USGS QUAD
	O, B		14.91	84.69751			
GM19	C, D, N, H, O, B	FB	9.97 - 10.05	39.188700, -84.74709	3880	Ust. old Hooven Refinery site	
GM20	C, D, N, H, O, B	FB, HD	8.48 - 8.55	39.170200, -84.75873	3880	U.S. Rt. 50; ust. Whitewater R. & dst. old Hooven Refinery site	
GM21	C, D, N, H, O, B	FB, HD	5.55 - 5.89	39.157000, -84.79200	5360	Lost Bridge; dst. Whitewater R.	
GM22	C, D, N, H, O, B	FB, HD	3.78 - 3.89	39.131470, -84.80473	5370	Ust. Shawnee Boat Launch	
GM23	C, D, N, H, O, B	FB, HD	1.59 - 1.80	39.120800, -84.81890	5370	Ust. OH-IN state line; Ohio R. influence	
WAU 08-08 - Howard Creek - Dry Fork Whitewater River							
14-304 – Howard Creek							
GM50	C, D, N, H, O, B	FHW, QL	2.85 - 2.91	39.304990, -84.76288	5.80	Downstream Howard Rd	
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6)							
GM79	C, D, N, H, B	FHW, QL, PHW	0.01 - 1.40	39.277270, -84.72793	0.90	Behind residence immed north of New Haven Rd	
WAU 08-09 - Lee Creek - Dry Fork Whitewater River							
14-302 – Dry Fork Whitewater River							
GM45	C, D, N, H, O, B	FWD, QL	10.21 - 10.65	39.296380, -84.73670	46.90	Atherton Ave	
GM46	C, D, N, H, O, B	FWD, HD	6.95 - 7.36	39.266120, -84.74839	59.70	Mt. Hope	
GM47	C, D, N, H, O, B	FWD, QL	4.34 - 4.45	39.234840, -84.76476	78.50	Harrison Ave	
GM48	C, D, N, H, O, B	FWD, QL	0.53 - 1.25	39.196620, -84.77087	81.10	Kilby Ave	
14-303 – Lee Creek							
GM49	C, D, N, H, O, B	FHW, QL	4.55 - 4.75	39.301070, -84.79633	4.30	Lees Creek Rd and New Biddinger Rd	
GM55	C, D, N, H, B	FHW, QL, PHW	1.75	39.246910, -84.72954	1.80	Upstream Strimple Rd	
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)							
GM67	C, D, N, H, O, B	FHW, QL	0.28 - 0.35	39.259920, -84.74608	3.20	Downstream Harbor Ridge Rd bridge	
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)							
GM56	C, D, N, H, O, B	FHW, QL, PHW	1.61 - 1.63	39.276010, -84.75918	1.20	At Baughman Rd bridge	

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Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^{-2})	Location Description	USGS QUAD
14-904 - Unnamed Trib to Lee Creek (0.15)							
GM58	C, D, N, H, B	FHW, QL, PHW	1.14 - 1.15	39.269440, -84.77599	1.00	Access from Starspray Dr west or Sugardale St on east	
14-905 - Unnamed Trib to Unnamed Trib (0.78) to Lee Creek							
GM57		FHW, QL, PHW	0.36 - 0.38	39.266950, -84.77854	1.40	Off Baughman Rd in Circling Hills Golf Course	
14-910 - Unnamed Trib to Lee Creek (3.81)							
GM63	C, D, N, H, B	FHW, QL, PHW	0.35 - 0.41	39.300740, -84.78670	0.80	Bridge at Lees Creek Rd	
WAU 08-10 - Jameson Creek - Whitewater River							
14-300 - Whitewater River							
GM40	C, D, N, H, O, B	FB, HD	8.32 - 8.45	39.249340, -84.82082	1370	Jamison Road Bridge; ust. Harrison WWTP	
GM41	C, D, N, H, O, B	FB, HD	6.98 - 7.70	39.245710, -84.81066	1370	Dst. I-74; dst. Harrison WWTP	
GM42	C, D, N, H, O, B	FB, HD	3.98 - 4.80	39.222930, -84.79751	1380	Adjacent Kilby Rd.	
GM43	C, D, N, H, O, B	FB, HD	1.35 - 1.50	39.182990, -84.79293	1470	Suspension Bridge Road	
14-301 – Sand Run							
GM44	C, D, N, H, O, B	FHW, QL, PHW	2.35 - 2.38	39.188480, -84.81155	1.10	Behind residence at 1117 Sand Run Rd	
14-307 – Jameson Creek							
GM51	C, D, N, H, O, B	FHW, QL	0.91 - 0.94	39.243270, -84.82007	6.10	At Lawrence Rd	
GM52	C, D, N, H, O, B	FHW, QL	0.09 - 0.20	39.237050, -84.80987	6.60	Behind residence at 9173 Lawrence Rd	
14-908 - Unnamed Trib to the Whitewater River(6.45)							
GM61		FHW, QL, PHW	0.41 - 0.90	39.161090, -84.80244	1.00	Off US 50	
14-911 - Unnamed Trib to Whitewater River(2.35)							
GM64	C, D, N, H, B	FHW, QL, PHW	0.28 - 0.30	39.198560, -84.79566	0.70	Off residence access road to 5611 Lawrenceberg Rd	
14-917 - Fox Run (to the Whitewater River) (2.05)							
GM71	C, D, N, H, B	FHW, QL, PHW	0.05 - 0.16	39.190800, -84.79747	0.90	Behind residence at 5156 Lawrenceburg Rd	
14-921 - Unnamed Trib to Sand Run							
GM78	C, D, N, H, O, B	FHW, QL, PHW	0.03 - 1.89	39.184570, -84.80610	2.80	Unknonn subdivision off 11166 Sand Run Rd	

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Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^{-2})	Location Description	USGS QUAD
WAU 09-01 - Pleasant Run - Great Miami River							
14-013 – Pleasant Run							
GM38	C, D, N, H, B	FHW, QL, PHW	5.78 - 5.90	39.298710, -84.55831	0.70	Brookway Dr & West Kemper Dr north into subdivision	
14-901 - Unnamed Trib to Pleasant Run (2.29)							
GM53	C, D, N, H, O, B	FHW, QL, PHW	0.02 - 0.07	39.302740, -84.53193	0.30	Forester Dr and Pleasant Run Dr into subdivision	
14-912 - Unnamed Trib to Pleasant Run(5.26)							
GM65	C, D, N, H, O, B	FHW, QL, PHW	5.78 - 5.90	39.299120, -8456113	1.20	Brookway Dr and West Kemper Dr north into subdivision	
WAU 09-02 - Banklick Creek - Great Miami River							
14-012 – Banklick Creek							
GM35	C, D, N, H, O, B	FHW, QL, PHW	3.30 - 3.41	39.288720, -84.58912	1.20	Crest and Bank Rd	
GM36	C, D, N, H, O, B	FHW, QL	2.61 - 2.65	39.296020, -84.59363	3.10	Adj. West Kemper Rd.	
GM37	C, D, N, H, O, B	FHW, QL	0.21 - 0.35	39.314190, -84.61475	6.30	Adj. Burns Rd.	
14-915 - Unnamed Trib to Banklick Creek(2.55)							
GM69	C, D, N, H, B	FHW, QL, PHW	0.15 - 0.23	39.298050, -84.52261	0.70	Bank Rd/West Kemper	
Unnamed Trib to Banklick Creek (3.13)							
GM72	C, D, N, H, O, B	FHW, QL, PHW	0.06 - 0.25	39.288810, -84.59540	1.50	Bank and Hughes Rd	
WAU 09-03 - Paddys Run - Great Miami River							
14-005 Paddys Run							
GM26	C, D, N, H, O, B	FHW, QL	4.68 - 4.72	39.319870, -84.70229	6.80	Ust. DOE Fernald 006 (former)	
GM27	C, D, N, H, O, B	FHW, HD	3.80 - 3.82	39.310200, -84.70177	9.60	Dst. DOE Fernald 006 (former)	
GM28	C, D, N, H, O, B	FHW, QL	1.79	39.286640, -84.69341	12.90	Dst. Pilot Plant drainage ditch	
GM29	C, D, N, H, B	FHW, QL	0.10 - 0.24	39.266820, -84.69017	16.30	Ust. Mouth	
14-920 - Unnamed Trib to Paddy's Run(0.65)							
GM75		FHW, QL, PHW	0.29 - 0.30	39.273930, -84.68596	0.70	Downstream New Haven Rd/Hwy 128	
WAU 09-04 Dry Run - Great Miami River							
14-006 – Bluerock Creek							

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Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^{-2})	Location Description	USGS QUAD
GM30	C, D, N, H, B	FHW, QL, PHW	2.24 - 2.29	39.237490, -84.64149	0.70	Nearest 6102 Blue Rock Rd	
GM31	C, D, N, H, O, B	FHW, QL, PHW	1.35 - 1.53	39.245060, -84.65083	5.70	dst. St. Rt. 128; Reference Site (RF 21)	
GM32	C, D, N, H, O, B	FHW, QL	0.43 - 0.47	39.256230, -84.66256	7.30	Adj. Blue Rock Rd.	
14-007 – Owl Creek							
GM33	C, D, N, H, O, B	FHW, QL, PHW	0.35 - 0.61	39.276010, -84.64861	1.60	Nearest 6237 Day Rd.	
14-008 – Dunlap Creek							
GM34	C, D, N, H, O, B	FHW, QL, PHW	0.86 - 0.90	39.289310, -84.63820	1.80	Dunlap and Gosling Rd.	
14-902 - Unnamed Trib to Blue Rock Creek (1.37)							
GM54	C, D, N, H, O, B	FHW, QL, PHW	1.72 - 1.83	39.246510, -84.62206	2.10	Off Sheits Road, Newberry Wildlife Sanctuary	
14-914 - Unnamed Trib to the Great Miami River(26.52)							
GM68		FHW, QL, PHW	0.19 - 0.23	39.306400, -84.63676	1.10	Colerain Ave and East Miami River Road	
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr							
GM74	C, D, N, H, B	FHW, QL, PHW	0.14 - 0.19	39.250860, -84.60713	0.90	Frontage rd to I-275, behind Meijer	
WAU 09-06 - Jordan Run - Great Miami River							
14-003 – Jordan Creek							
GM24	C, D, N, H, B	FHW, QL, PHW	2.24 - 2.25	39.182560, -84.71842	0.70	Access at 8658 Jordan Rd.	
GM25	C, D, N, H, O, B	FHW, QL, PHW	0.82 - 0.91	39.178150, -84.73353	2.30	Adj. Jordan Rd.	
14-182 – Tributary to Great Miami River							
GM39	C, D, N, H, B	FHW, QL, PHW	0.21 - 0.38	39.202940, -84.72025	0.50	NA	
14-907 - Unnamed Trib to the Great Miami River(12.0)							
GM60	C, D, N, H, O, B	FHW, QL, PHW	0.35 - 0.55	39.208050, -84.74057	1.80	Nearest 5217 Hamilton Cleves Pike	
14-909 - Unnamed Trib to the Great Miami River (8.50)							
GM62	C, D, N, H, B	FHW, QL, PHW	0.40 - 0.54	39.166380, -84.74635	0.60	Off Morgan St	
14-913 - Unnamed Trib to the Great Miami River 19.2 .75)							
GM66	C, D, N, H, O, B	FHW, QL, PHW	0.53 - 0.59	39.257050, -84.70875	0.90	Downstream Hamilton Cleves Rd, gravel pit - prob dry	

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Site ID	Chemical Sampling Type	Biological Sample Type	River Mile Range	Site ID Latitude Longitude	Drainage Area (mi^{-2})	Location Description	USGS QUAD
14-916 - Unnamed Trib to the Great Miami River(7.74)							
GM70	C, D, N, H, O, B	FHW, QL, PHW	0.30 - 0.40	39.158620, -84.75828	1.20	Off Miami View Rd/ Gulf Community Park	
14-906 Unnamed Trib to the Great Miami River (3.7)							
GM59	C, D, N, H, O, B	FHW, QL, PHW	0.73 - 0.74	39.137310, -8479539	1.10	Nearest 10656 Lawrenceburg Rd - Hamilton Cty Park	
Reference Sites							
14-022 – Elk Creek [WAU 07-01]							
RF24	C, D, N, H, O, B	FWD, QL	3.64 - 4.64	39.527000, -84.46790	44.90	dst. Dry Run	
14-010 – Indian Creek [WAU 08-03]							
RF23	C, D, N, H, O, B	FWD, QL	9.71 - 9.75	39.402900, -84.68490	82.30	adj. Reily-Millville Rd.	
RF22	C, D, N, H, O, B	FWD, QL	4.27 - 4.33	39.363160, -84.64407	102.00	upst. Hamilton-New London Rd.	

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

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.

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

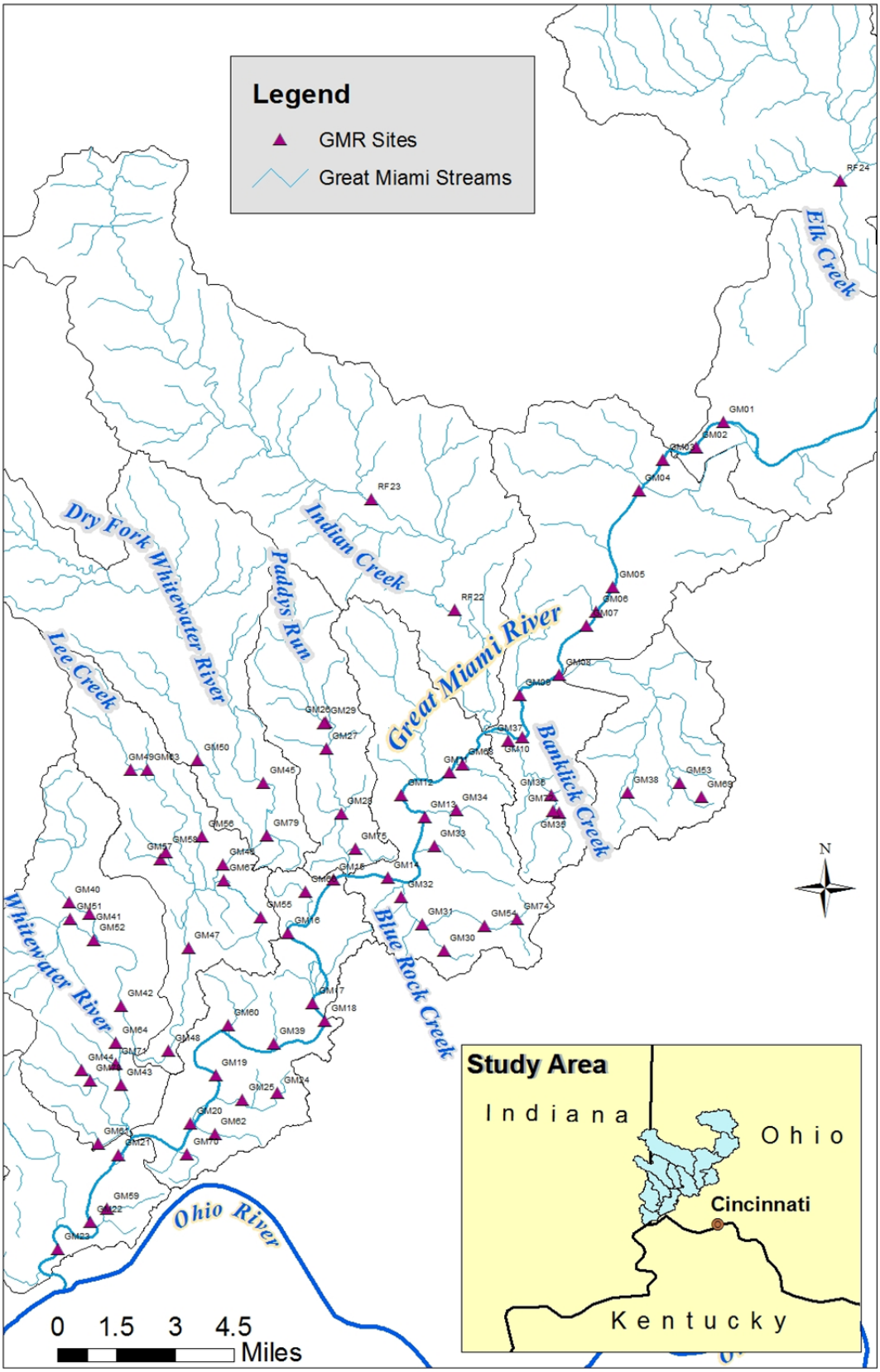

Figure 6. Map of the 2013 Great Miami River study area showing biological, chemical, and physical sampling locations (◢) with the site code and locations of wastewater discharges. The MSDGC service area appears in the study area inset (lower right).

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 6). 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 6 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 Great 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, 2013). 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 July 12 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 Great Miami River and Whitewater River mainstems. 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 Habitat 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 2013). 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 (2013). 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/cm), 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/cm), 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 Great Miami River 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 4) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), 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, 2013). 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 2013).

- 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 2013); 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 2013) 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 2013);
- Six or more taxa from the insect orders Ephemeroptera, Plecoptera and Trichoptera; six or more sensitive macroinvertebrate taxa (Ohio EPA 2013).

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 Great Miami River study area 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 Great Miami River study area.

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 2013 Great Miami River 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 7-9 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 7 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*

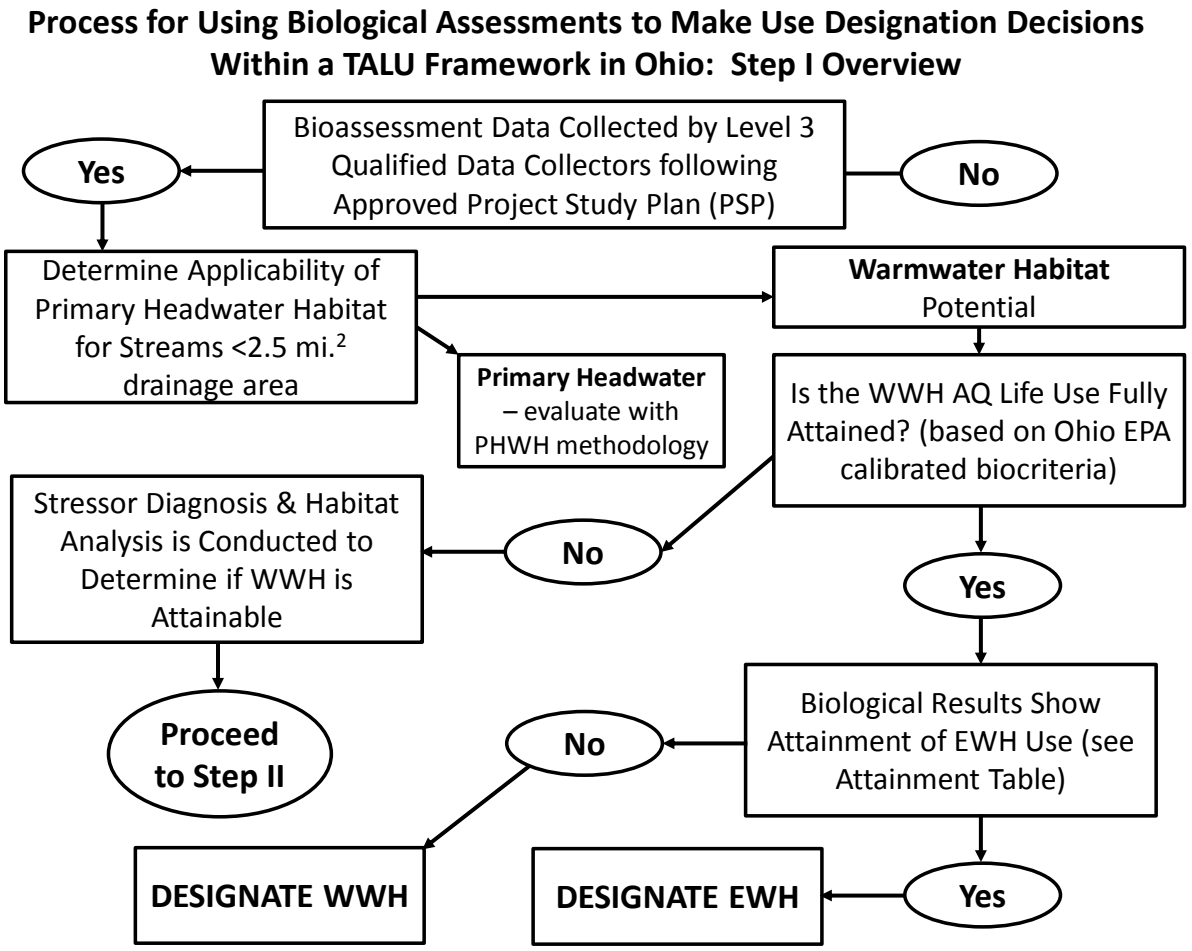

Figure 7. Step I: Overview of the process for using biological assessments to make use designation decisions in Ohio based on the tiered aquatic life uses framework.

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 8).

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 attributes provide for a *sufficiently accurate* prediction of WWH attainability. These attributes

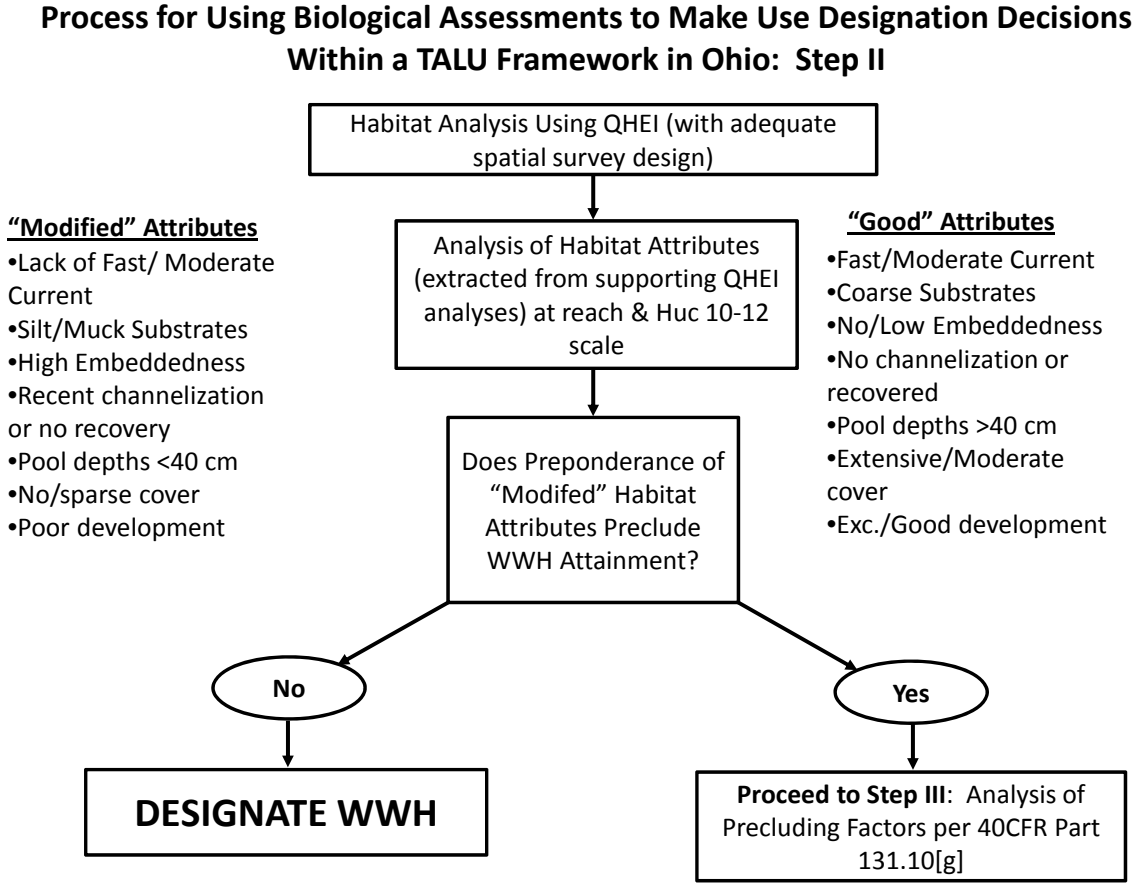

Figure 8. Step II: Using the analysis of habitat attributes to make decisions about WWH use attainability.

are expressed as "good" and "poor" attributes (Figure 8) 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 8. 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 9). 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:

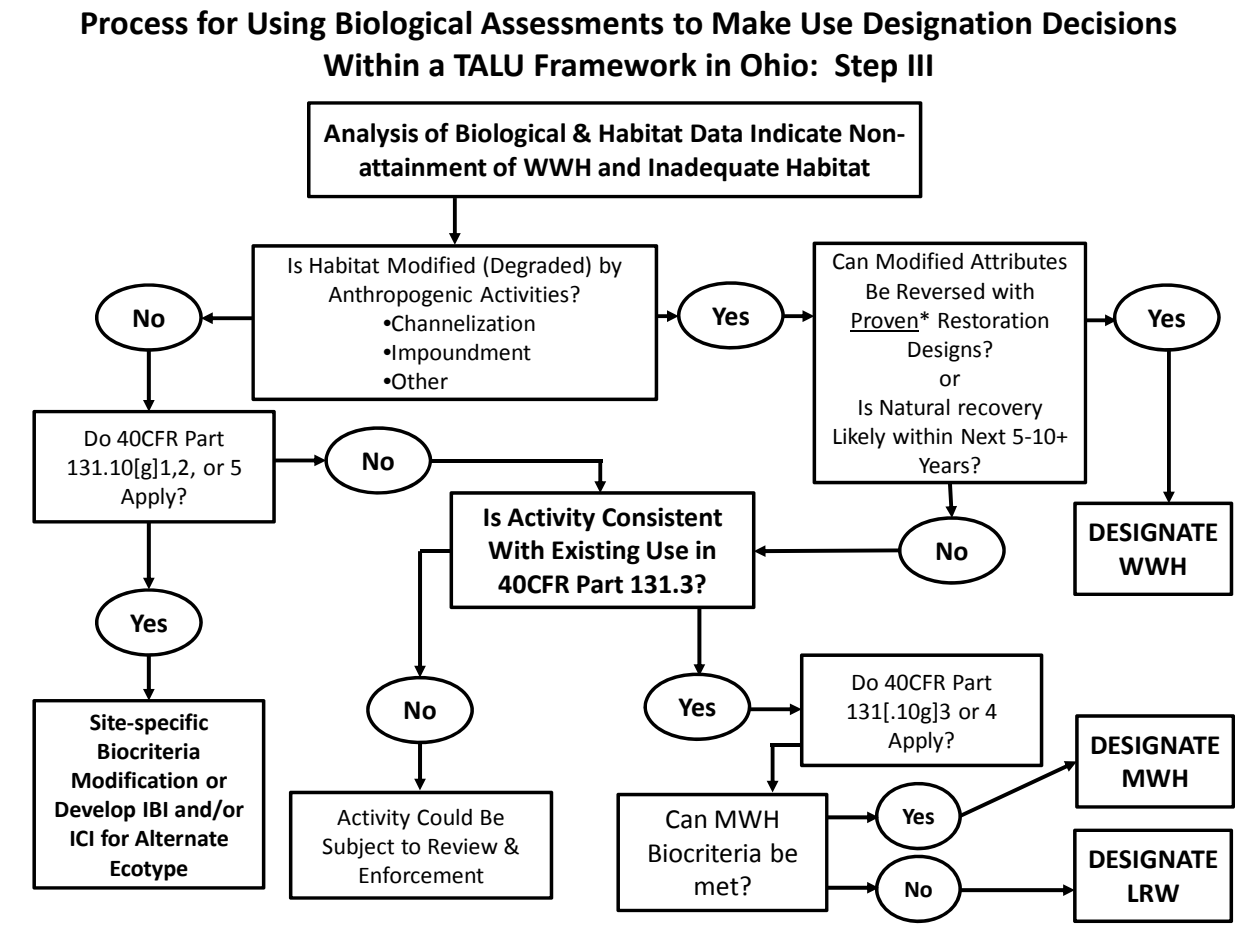

Figure 9. Step III: Overview of the use attainability analysis parts of the use designation process in Ohio.

". . . 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]."

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 10 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.

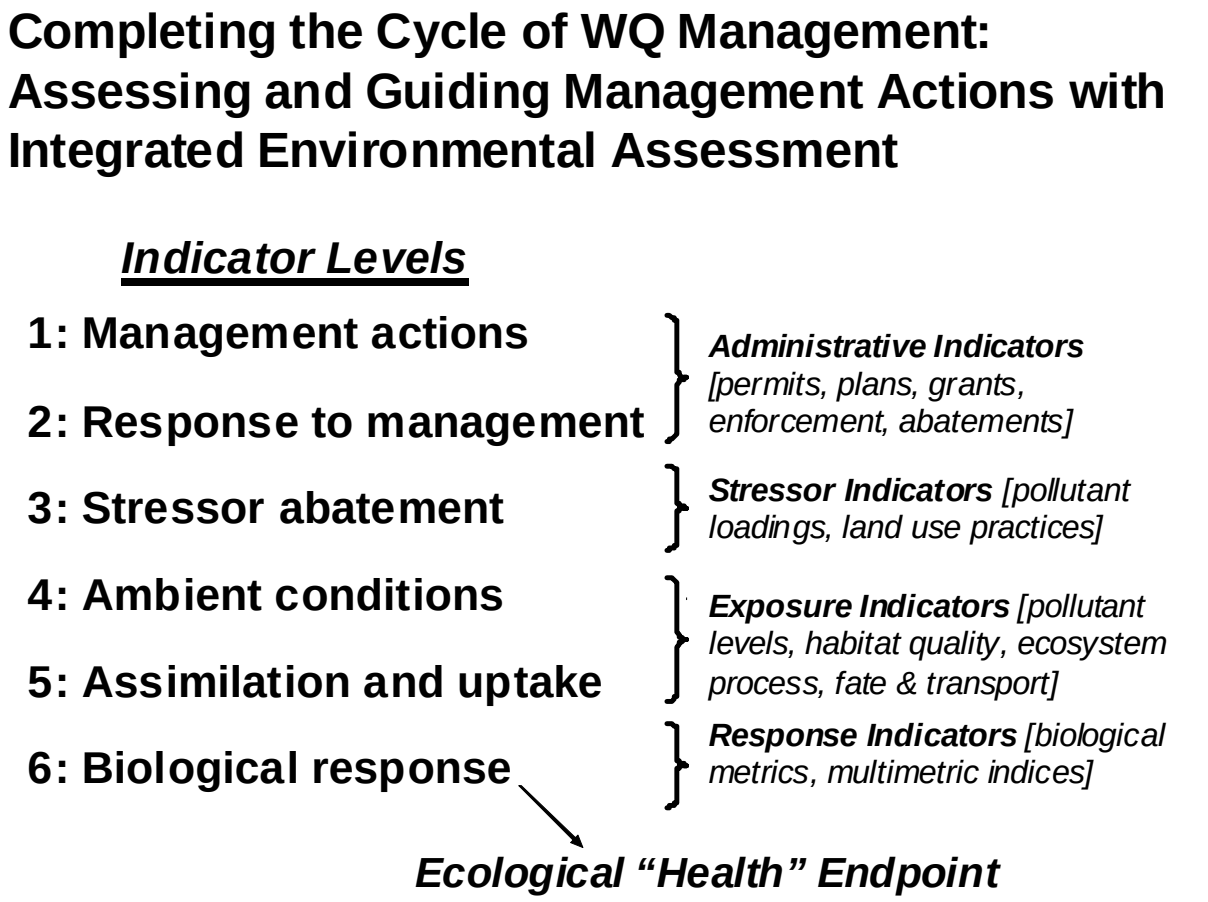

Figure 10. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995) and further enhanced by Karr and Yoder (2004).

STUDY AREA DESCRIPTION

General Setting

The Great 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 Great Miami River mainstem flows southward for ??? miles from the headwaters in Logan County through Miami, Montgomery, Warren, and Hamilton Counties to its confluence with the Ohio River in Hamilton County draining ???? mi^{-2}. The study area is located in the Eastern Corn Belt Plains and Interior Plateau ecoregions (see Figure 6). Along its course the stream has an average gradient of ?.?? feet per mile (ODNR 1960). Major tributaries within the 2013 Great Miami River study area include Jordan Creek, Paddys Run, Indian Creek, Bluerock Creek, Banklick Creek, and the Whitewater River. The eastern tributaries enter the Great Miami River mainstem from the hillsides that characterize the eastern part of the watershed. The western tributaries enter from ground moraine deposits and reflect seasonally intermittent flows as a result. The Great Miami River mainstem is impacted by large volumes of treated municipal and industrial wastewater discharges along its length including the Sidney-Piqua-Troy area, and Dayton, Middletown, and Hamilton. The lower portion of Great Miami River is rural to suburban in nature and some tributary subbasins lie within state and county park and forest lands.

Subecoregion Characteristics

The 2013 Great 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 Great Miami River study area and much of the East Fork of the Great Miami River lie entirely within the Northern Bluegrass subregion (71d) of the Interior Plateau. The remainder of the Great 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 Great 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 in the Great Miami River study area include permitted discharges of municipal and industrial process wastewater, 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 29 point source discharges in the Great Miami River study area that hold NPDES permits. Of these 3 are considered to be major discharges and all are municipal wastewater

Table 8. Level IV subregions of the Great Miami River study area 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 47.5 MGD of capacity is shared by the 4 WWTPs that impact the lower Great Miami River mainstem study area. Another 2.4 MGD of capacity is shared by 2 WWTPs on the Whitewater 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.

Wet Weather Sources

Unlike much of the other parts of the MSDGC service area wet weather sources are not a prominent impact in the lower Great Miami River study area. There are no CSOs and few if any SSOs.

Table 9. Major pollution sources in the 2013 Great Miami River study area. Fig. No. are used in subsequent graphs to depict locations of dams and major discharges.

Facility/Dam/Tributary Confluence	RM	NPDES No.	Flow (MGD)1	Fig. No.
Great Miami River				
Hamilton Hydraulic Dam	41.50			A
Two Mile Dam	37.40			B
Hamilton Municipal Electric Plant	37.17	1IB00008	33.00	1
SMART Paper Holding LLC	36.90	1IA00009	20.00	2
Hamilton Low Dam	34.60			C
Hamilton Water Reclamation Facility	34.00	1PE00002	32.00	3
Fairfield WWTP	32.00	1PD00003	10.00	4
Pleasant Run	31.41			
Southwest Regional Water District	30.14	1IX00053	0.06	5
Banklick Creek	28.27			
Indian Creek	27.70			
Wade Mill Water Reclamation Facility	27.00	1PJ00010	0.50	
Procter & Gamble Co. Miami Valley Lab	25.99	1IN00010	0.10	
U.S. DOE Fernald Closure Project	24.73	1IO00004	6.50	6
Dunlap Run	23.85			
Owl Creek	22.80			
Fort Scott Development WWTP	22.70	1PC00016	0.50	
Blue Rock Creek	21.70			
Paddys Run	20.20			
Unnamed Trib to G. Miami River 19.2	19.20			
Brennan Electric Inc.	15.40	1IN00249	0.001	
Taylor Creek WWTP	15.10	1PK00015	5.50	7
Taylor Creek	14.98			
Kreimer's Bierhaus Restaurant	13.88	1PZ00064	0.005	
Unnamed Trib to G. Miami River 12.70	12.70			
Harrison Bldg and Loan MHNH	11.20	1PZ00089	0.010	
Rivers Edge Commerce Park WWTP	11.10	1PX00064	0.020	
Chevron Products-Cincinnati	9.10	1IG00000	1.58	8
Whitewater River	6.45			
E-Town Sand & Gravel	5.60	1IJ00056	NA	
Lawrenceburg Rd. Ash Landfill	4.50	1IN00125	NA	
Shawnee Lookout Park	3.75	1PG00084	0.004	
Pleasant Run (GMR 31.41)				
Fairfield WTP1	0.30	1IW00000	0.06	
Unnamed Tributary (GMR 19.2)				
Hilltop Metals	0.52	1IH00024	0.0010	
Unnamed Tributary (GMR 12.7)				
Westbrook Village MHP	0.53	1PV00023	0.10	
Miamiview Estates MHP	0.52	1PV00018	0.04	
Whitewater River (GMR 6.45)				
JTM Provisions Co.	7.60	1IH00019		
Harrison WWTP	7.50	1PC00002	2.30	
Whitewater Processing Co. Inc.	7.00	1IN00294	0.04	
Riverview Crossing WWTP	1.65	1PV00096	0.12	
Bruewer Woodworking Mfg. Co.	1.50	1PR00106	0.0030	
Dry Fork (Whitewater R. 2.68)				
Dry Fork MHP	1.10	1PY00001	0.03120	
Fox Run (Whitewater R. 2.07)				
Bond Road Landfill	0.86	1II00075	NA	

RESULTS and DISCUSSION

Chemical/Physical Water Quality

Chemical/physical water quality in the Great 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 Great Miami River mainstem during the period May 1 – September 30 during 2010 and 2013 is depicted in Figure 11 based on a flow gauge 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 2013 were consistently lower than the medians and were at or below the 75 percentile flow. The mainstem Great Miami River flows were at or below the 25th percentile flow in most of August and September in both years. The 2013 flow regime was generally comparable to 2010. All sampling was avoided during high flow events and only conducted at normal base flows returned.

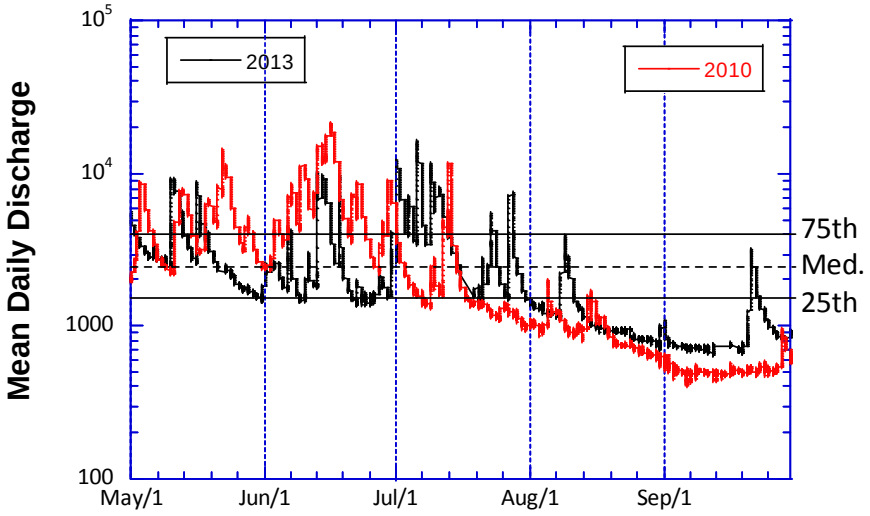

Figure 11. Daily flow measured by the USGS in the Great Miami River at Hamilton (during May 1-September 30, 2010 and 2013.

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 Great 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 Great Miami River study area WAUs. Commonly collected chemical parameters were compared either to criteria in the Ohio WQS (Table 10) or to ecoregion-based benchmarks and biologically derived thresholds in Ohio EPA (1999), for chemical stressors that are commonly associated with urban runoff (Table 11) and for nutrient parameters (Table 12).

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). MBI also calculated the Ohio EPA Trophic Criteria Index (TIC; Ohio EPA 2011) to rate the risk to aquatic life from eutrophication.

LRAU 90-02 – Great Miami River

Only two sites (GM10, GM 19) single excursions of the 4 mg/l minimum criteria for WWH during the 2013 survey (Table 10, Figure 12). Grab samples did reflect substantial elevated daytime D.O. levels and wide diel swings indicate 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 Great Miami River had a number of median TKN values that slightly exceeded regional reference levels for large rivers although some individual values were elevated above back concentrations (Figure 13). BOD values were above reference levels at most sites in the Great Miami River Mainstem (Figure 14). Most of the mainstem was in Full attainment of aquatic life uses, but elevated TKN values could have more of an impact during dryer years. Mean conductivity and chloride levels were slightly elevated compared to reference values, but maximum values were elevated particularly in the upstream reaches of the sampling reach (Figures 18-19).

WAU 08-08 - Howard Creek - Dry Fork Whitewater River

Howard Creek was in Full Attainment of the aquatic use criteria and there were no exceedences of water quality criteria in Howard Creek or the direct tributary (GM79) to the Dry Fork of the Whitewater in this watershed. Although MBI do not assess primary headwater stream for attainment, this reach had low flow conditions, high bank erosion and heavily silted substrates.

WAU 08-09 - Lee Creek - Dry Fork Whitewater River

There dissolved oxygen values before the 4-minimum criteria value at 5 of the 8 sites sampled in this watershed although most sites in this watershed were fully attaining their aquatic life uses. There were also slightly elevated metals concentrations that exceeded WWH criteria for lead, copper, and cadmium the Dry Fork of the Whitewater. Two sites, Lee Creek (GM49) and

Table 10. Conventional pollutant parameters in the Great Miami River study area during 2013 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
Large River Assessment Unit 90-002 – Great Miami River Mainstem			
14-001 – Great Miami River			
GM01	40.30	WWH	
GM02	38.55	WWH	
GM03	38.09	WWH	
GM04	36.98	WWH	
GM05	34.12	WWH	
GM06	33.66	WWH	
GM07	32.69	WWH	
GM08	31.27	WWH	
GM09	29.98	WWH	
GM10	28.15	WWH	D.O. (2.45)
GM11	26.20	WWH	
GM12	24.67	WWH	
GM13	23.63	WWH	Cd (6.80)
GM14	21.70	WWH	Cd (42.30), Cd (42.30)
GM15	20.14	WWH	
GM16	18.30	WWH	
GM17	15.49	WWH	
GM18	14.88	WWH	
GM19	9.98	WWH	D.O. (3.11)
GM20	8.48	WWH	
GM21	5.55	WWH	
GM22	3.78	WWH	
GM23	1.59	WWH	pH (6.24)
WAU 08-08 - Howard Creek - Dry Fork Whitewater River			
14-304 – Howard Creek			
GM50	2.91	WWH	
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6)			
GM79	0.01	PHW2	
WAU 08-09 - Lee Creek - Dry Fork Whitewater River			
14-302 – Dry Fork Whitewater River			
GM45	10.65	EWH	D.O. (3.67); Cd (6.00); Cu (13.00); Pb (16.90)
GM46	7.30	WWH	Cd (5.80); Pb (17.60)
GM47	4.34	WWH	Cd (5.90); Pb (18.30)
GM48	0.53	WWH	D.O. (3.24); Cd (6.90), (6.90); Pb (18.90)
14-303 – Lee Creek			
GM49	4.75	WWH	D.O. (2.69)
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)			
GM67	0.35	WWH	D.O. (3.02), (1.28), (2.53)
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)			
GM56	1.61	PHW2	
14-904 - Unnamed Trib to Lee Creek (0.15)			
GM58	1.14	WWH	D.O. (3.75)

Table 10. Conventional pollutant parameters in the Great Miami River study area during 2013 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
14-910 - Unnamed Trib to Lee Creek (3.81)			
GM63	0.41	WWH	D.O. (0.68)
WAU 08-10 - Jameson Creek - Whitewater River			
14-300 - Whitewater River			
GM40	8.32	WWH	Cd (5.20); Cd (7.60)
GM41	6.98	WWH	pH (4.90); Cd (6.10); Pb (17.60)
GM42	3.98	WWH	pH (5.87); Cd (5.60)
GM43	1.50	WWH	Cd (5.90); Pb (18.40)
14-301 – Sand Run			
GM44	2.35	WWH	
14-307 – Jameson Creek			
GM51	0.91	WWH	
GM52	0.20	WWH	
14-908 - Unnamed Trib to the Whitewater River(6.45)			
GM64	0.29	PHW3A	D.O. (1.04)
14-917 - Fox Run (to the Whitewater River) (2.05)			
GM71	0.06	WWH	
14-921 - Unnamed Trib to Sand Run			
GM78	1.89	PHW3	D.O. (1.83), (3.55)
WAU 09-01 - Pleasant Run - Great Miami River			
14-013 – Pleasant Run			
GM38	5.78	WWH	
14-901 - Unnamed Trib to Pleasant Run (2.29)			
GM53	0.04	PHW2	
14-912 - Unnamed Trib to Pleasant Run(5.26)			
GM65	5.78	WWH	
WAU 09-02 - Banklick Creek - Great Miami River			
14-012 – Banklick Creek			
GM35	3.30	WWH	
GM36	2.65	WWH	D.O. (3.25)
GM37	0.30	WWH	
14-915 - Unnamed Trib to Banklick Creek(2.55)			
GM69	0.15	PHW3A	
Unnamed Trib to Banklick Creek (3.13)			
GM72	0.15	WWH	D.O. (3.50), (3.46)
WAU 09-03 - Paddys Run - Great Miami River			
14-005 Paddys Run			
GM26	4.72	WWH	D.O. (2.57), (2.63), (3.98)
GM27	3.82	WWH	D.O. (3.95), (3.12); Cd (5.90); Pb (19.00)
GM28	1.79	WWH	Cd (5.40)
GM29	0.10	WWH	D.O. (2.56), (3.12), (2.62)

Table 10. Conventional pollutant parameters in the Great Miami River study area during 2013 that exceeded Ohio water quality criteria for aquatic life.

Site ID	River Mile	Aquatic Life Use	Parameters (Values) Exceeding Ohio Aquatic Life Criteria[1]
WAU 09-04 Dry Run - Great Miami River			
14-006 – Bluerock Creek			
GM30	2.24	PHW3A	
GM31	1.53	PHW3A	
GM32	0.45	WWH	
14-007 – Owl Creek			
GM33	0.35	WWH	
14-008 – Dunlap Creek			
GM34	0.87	WWH	
14-902 - Unnamed Trib to Blue Rock Creek (1.37)			
GM54	1.72	WWH	
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr			
GM74	0.15	WWH	
WAU 09-06 - Jordan Run - Great Miami River			
14-003 – Jordan Run			
GM24	2.24	PHW3A	
GM25	0.91	WWH	
14-182 – Tributary to Great Miami River			
GM39	0.33	PHW3A	
14-907 - Unnamed Trib to the Great Miami River(12.0)			
GM60	0.55	PHW3A	Pb (5.80); Zn (133.00), (133.00)
14-909 - Unnamed Trib to the Great Miami River (8.50)			
GM62	0.40	WWH	
14-913 - Unnamed Trib to the G.Miami River 19.2 .75)			
GM66	0.53	WWH	
14-916 - Unnamed Trib to the Great Miami River(7.74)			
GM70	0.30	WWH	
14-906 Unnamed Trib to the Great Miami River (3.7)			
GM59	0.74	PHW3A	
Reference Sites			
14-022 – Elk Creek [WAU 07-01]			
RF24	3.65	WWH	
14-010 – Indian Creek [WAU 08-03]			
RF23	9.74	WWH	
RF22	4.27	WWH	

an unnamed tributary to Lee Creek (GM58) had elevated chloride concentrations which may be associated with leaking sewage observed at site GM58.

WAU 08-10 - Jameson Creek - Whitewater River

The Whitewater River mainstem aquatic biota was excellent as expected with full attainment at all sites; nutrient and urban runoff parameters were not elevated and were similar to reference concentrations. There were slightly elevated metals concentrations that exceeded WWH

criteria for lead, and cadmium and several low pH values (4.90 and 5.87). All of the WWH tributaries (Sand Run, Jameson Creek, Fox Run) had generally good water chemistry concentrations with several scattered exceedences of the DO criteria, and relative low nutrient and urban runoff parameters. The only site with impaired aquatic life was Sand Run (GM44) which was attributed to low flow conditions influencing the macroinvertebrate assemblage.

WAU 09-01 - Pleasant Run - Great Miami River
Pleasant Run and its tributaries generally had elevated chlorides which are related to suburban and urban runoff conditions and likely flashy flows. The low flows associated with flashy flow conditions contributed to in the impairment of Pleasant Run. Chloride concentrations exceeded 200 mg/l in an unnamed tributary (GM58) to Pleasant run, which is an indicator of elevated urban runoff.

WAU 09-02 - Banklick Creek - Great Miami River
Banklick Creek had high conductivity and elevated chloride (318 mg/l at RM 2.65, GM36) related to high urban runoff. Leaking septic systems were associated with lower DO at GM36 and elevated TKN concentrations. Low DO also occurred in a tributary site (GM72) to Banklick Run that had partially impaired aquatic assemblages.

WAU 09-03 - Paddys Run - Great Miami River
Paddys Run attained the WWH aquatic life criteria at the two upstream sites that had flow, but there were some low DO values at three of the four sites. The variation in flow between sites was relatively great with the upper sites having flow while the two larger sites in the lower reaches with relatively large drainage areas (12.9-16.8 mi^{-2}) were dry. A primary headwater tributary that enters Paddy's run at RM 0.65 (GM75) was also affected ephemeral flow conditions.

WAU 09-04 Dry Run - Great Miami River
There no exceedences of conventional chemical parameter criteria at sites in this watershed. Conductivity and chloride were elevated above reference at many of the sites in this watershed likely related to urban runoff. There were also elevated benthic chlorophyll concentrations at a number of the small stream sites in this watershed. In particular, impairment on Owl Creek was exacerbated by low flow, the site at a tributary of Bluerock Creek at RM 1.37 (GM54) had evidence of urban runoff and the tributary to a tributary of Bluerock at RM 2.65 (GM 74) had evidence of leaching sewage and septic conditions.

WAU 09-06 - Jordan Run - Great Miami River
Streams in the Jordan Run watershed had elevated conductivity and chloride compared to reference conditions which is associated with urban runoff. The only parameters that exceeded water quality criteria were for lead and zinc at a direct tributary to the Great Miami River at RM 12.0 (GM60). The unnamed tributary to the Great Miami River (GM66) had elevated sulfates and field crews observed some septic conditions at this site. GM70 was channelized.

Table 11. Urban parameter results in the Great Miami River study area in 2013. Values >reference targets are highlighted in yellow

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Target
Large River Assessment Unit 90-02 – Great Miami River Mainstem												
14-001 – Great Miami River												
GM01	40.30	WWH	806	810	73	57	59	123	443	500	40	46
GM02	38.55	WWH	806	810	72	57	59	123	530	500	36	46
GM03	38.09	WWH	800	810	72	57	63	123	500	500	34	46
GM04	36.98	WWH	805	810	70	57	59	123	480	500	43	46
GM05	34.12	WWH	803	810	71	57	62	123	540	500	34	46
GM06	33.66	WWH	809	810	71	57	58	123	530	500	34	46
GM07	32.69	WWH	797	810	72	57	62	123	510	500	32	46
GM08	31.27	WWH	784	810	74	57	64	123	480	500	41	46
GM09	29.98	WWH	782	810	72	57	53	123	420	500	36	46
GM10	28.15	WWH	766	810	74	57	57	123	460	500	39	46
GM11	26.20	WWH	779	810	74	57	50	123	490	500	35	46
GM12	24.67	WWH	772	810	77	82	52	170	410	520	32	50
GM13	23.63	WWH	792	810	79	82	60	170	420	520	36	50
GM14	21.70	WWH	758	810	79	82	59	170	460	520	35	50
GM15	20.14	WWH	766	810	78	82	57	170	400	520	35	50
GM16	18.30	WWH	782	810	78	82	55	170	420	520	31	50
GM17	15.49	WWH	747	810	78	82	63	170	360	520	38	50
GM18	14.88	WWH	780	810	76	82	58	170	360	520	41	50
GM19	9.98	WWH	771	810	75	82	63	170	405	520	36	50
GM20	8.48	WWH	739	810	74	82	64	170	445	520	34	50
GM21	5.55	WWH	711	810	70	82	55	170	375	520	32	50
GM22	3.78	WWH	755	810	70	82	55	170	495	520	40	50
GM23	1.59	WWH	710	810	65	82	51	170	440	520	61	50
WAU 08-08 - Howard Creek - Dry Fork Whitewater River												
14-304 – Howard Creek												
GM50	2.91	WWH	722	600	41	29	36	104	375	288	8	14
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6)												
GM79	0.01	SC	855	600	47	29	24	104	560	288	117	14
WAU 08-09 - Lee Creek - Dry Fork Whitewater River												
14-302 – Dry Fork Whitewater River												
GM45	10.65	EWH	523	610	25	31	28	120	280	522	17	41
GM46	7.30	WWH	562	610	23	31	24	120	370	522	9	41

Table 11. Urban parameter results in the Great Miami River study area in 2013. Values >reference targets are highlighted in yellow

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Target
GM47	4.34	WWH	529	610	25	31	28	120	280	522	18	41
GM48	0.53	WWH	449	610	23	31	27	120	270	522	12	41
14-303 – Lee Creek												
GM49	4.75	WWH	772	600	78	29	41	104	360	443	22	14
GM55	1.75	WWH	392	600	19	35	25	118	180	468	38	25
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)												
GM67	0.35	WWH	359	600	19	35	17	118	205	468	33	25
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)												
GM56	1.61	PHW2	594	600	39	29	14	104	350	443	21	14
14-904 - Unnamed Trib to Lee Creek (0.15)												
GM58	1.14	WWH	817	600	86	29	61	104	100	443	26	14
14-910 - Unnamed Trib to Lee Creek (3.81)												
GM63	0.41	WWH	502	600	31	29	13	104	280	443	79	14
WAU 08-10 - Jameson Creek - Whitewater River												
14-300 - Whitewater River												
GM40	8.32	WWH	533	810	24	82	30	170	290	727	26	50
GM41	6.98	WWH	541	810	26	82	27	170	300	727	21	50
GM42	3.98	WWH	551	810	27	82	28	170	340	727	26	50
GM43	1.50	WWH	558	810	28	82	29	170	270	727	27	50
14-301 – Sand Run												
GM44	2.35	WWH	730	600	39	35	70	118	415	468	18	25
14-307 – Jameson Creek												
GM51	0.91	WWH	940	600	120	29	87	104	470	443	13	14
GM52	0.20	WWH	691	600	26	29	48	104	345	443	17	14
14-911 - Unnamed Trib to Whitewater River(2.35)												
GM64	0.29	PHW3A	886	600	60	35	66	118	530	468	16	25
14-917 - Fox Run (to the Whitewater River) (2.05)												
GM71	0.06	WWH	613	600	34	35	134	118	390	468	10	25
14-921 - Unnamed Trib to Sand Run												
GM78	1.89	PHW3	856	600	42	35	34	118	495	468	13	25
WAU 09-01 - Pleasant Run - Great Miami River												
14-013 – Pleasant Run												
GM38	5.78	WWH	675	600	68	29	42	104	510	443	12	14

Table 11. Urban parameter results in the Great Miami River study area in 2013. Values >reference targets are highlighted in yellow

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Target
14-901 - Unnamed Trib to Pleasant Run (2.29)												
GM53	0.04	PHW2	1133	600	213	35	58	118	580	468	17	25
14-912 - Unnamed Trib to Pleasant Run(5.26)												
GM65	5.78	WWH	629	600	101	35	66	118	445	468	25	25
WAU 09-02 - Banklick Creek - Great Miami River												
14-012 – Banklick Creek												
GM35	3.30	WWH	1053	600	161	35	94	118	580	468	22	25
GM36	2.65	WWH	1539	600	318	35	207	118	805	468	45	25
GM37	0.30	WWH	1100	600	142	35	146	118	560	468	30	25
14-915 - Unnamed Trib to Banklick Creek(2.55)												
GM69	0.15	PHW3A	603	600	38	35	38	118	400	468	19	25
Unnamed Trib to Banklick Creek (3.13)												
GM72	0.15	WWH	1293	600	234	35	221	118	760	468	15	25
WAU 09-03 - Paddys Run - Great Miami River												
14-005 - Paddys Run												
GM26	4.72	WWH	720	600	50	35	33	118	330	468	11	25
GM27	3.82	WWH	648	600	44	35	29	118	330	468	21	25
GM28	1.79	WWH	723	600	51	35	83	118	460	468	8	25
GM29	0.10	WWH	747	600	31	35	57	118	320	468	64	25
14-006 – Bluerock Creek												
GM30	2.24	PHW3A	673	600	77	35	55	118	320	468	44	25
GM31	1.53	PHW3A	1056	600	157	35	58	118	580	468	15	25
GM32	0.45	WWH	768	600	75	35	74	118	300	468	9	25
14-007 – Owl Creek												
GM33	0.35	WWH	651	600	33	35	22	118	340	468	25	25
14-008 – Dunlap Creek												
GM34	0.87	WWH	782	600	53	35	80	118	475	468	24	25
14-902 - Unnamed Trib to Blue Rock Creek (1.37)												
GM54	1.72	WWH	894	600	136	35	69	118	480	468	12	25
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr												
GM74	0.15	WWH	600	600	73	35	55	118	410	468	4	25
WAU 09-06 - Jordon Run - Great Miami River												
14-003 – Jordan Creek												

Table 11. Urban parameter results in the Great Miami River study area in 2013. Values >reference targets are highlighted in yellow

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Target
GM24	2.24	PHW3A	709	600	61	35	53	118	340	468	29	25
GM25	0.91	WWH	704	600	53	35	60	118	385	468	20	25
14-182 – Tributary to Great Miami River												
GM39	0.33	PHW3A	684	600	50	35	73	118	230	468	19	25
14-907 - Unnamed Trib to the Great Miami River(12.0)												
GM60	0.55	PHW3A	268	600	3	35	55	118	130	468	42	25
14-909 - Unnamed Trib to the Great Miami River (8.50)												
GM62	0.40	WWH	626	600	40	35	58	118	310	468	53	25
14-913 - Unnamed Trib to the G. Miami River 19.2 .75)												
GM66	0.53	WWH	1027	600	80	35	158	118	650	468	30	25
14-916 - Unnamed Trib to the Great Miami River(7.74)												
GM70	0.30	WWH	653	600	53	35	44	118	435	468	28	25
14-906 Unnamed Trib to the Great Miami River (3.7)												
GM59	0.74	PHW3A	666	600	45	35	48	118	445	468	56	25
Reference Sites												
14-022 – Elk Creek [WAU 07-01]												
RF24	3.65	WWH	658	610	28	29	37	107	335	443	5	29
14-010 – Indian Creek [WAU 08-03]												
RF23	9.74	WWH	594	610	29	29	28	107	260	464	24	29
RF22	4.27	WWH	609	610	31	29	30	107	215	464	10	29

Table 12. Nutrient parameter results in the Great Miami River study area in 2013. Values >reference targets are shaded in yellow. BD –indicates below detection.

Site ID	River Mile	Aq. Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m^3) +	Benthic Chlorophyll (mg/m3) ++
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Median?
Large River Assessment Unit 90-002 – Great Miami River Mainstem												
14-001 – Great Miami River												
GM01	40.30	WWH	BD	0.200	2.360	2.000	0.790	0.900	BD	0.300	32.700	150.000
GM02	38.55	WWH	BD	0.200	2.340	2.000	1.000	0.900	BD	0.300	48.100	335.000
GM03	38.09	WWH	BD	0.200	2.270	2.000	1.020	0.900	BD	0.300	34.000	41.200
GM04	36.98	WWH	BD	0.200	2.410	2.000	1.150	0.900	BD	0.300	36.700	139.000
GM05	34.12	WWH	BD	0.200	2.000	2.000	1.120	0.900	BD	0.300	45.400	96.300
GM06	33.66	WWH	BD	0.200	2.120	2.000	1.340	0.900	BD	0.300	70.100	231.000
GM07	32.69	WWH	BD	0.200	2.160	2.000	1.270	0.900	BD	0.300	65.400	148.000
GM08	31.27	WWH	BD	0.200	2.190	2.000	0.660	0.900	BD	0.300	70.500	77.400
GM09	29.98	WWH	BD	0.200	2.210	2.000	0.800	0.900	BD	0.300	22.400	98.600
GM10	28.15	WWH	BD	0.200	2.200	2.000	0.970	0.900	BD	0.300	28.700	100.000
GM11	26.20	WWH	BD	0.200	2.450	2.000	1.150	0.900	BD	0.300	21.900	50.400
GM12	24.67	WWH	BD	0.050	2.290	2.930	0.980	0.900	BD	0.350	60.050	110.000
GM13	23.63	WWH	BD	0.050	1.870	2.930	1.100	0.900	BD	0.350	57.300	119.000
GM14	21.70	WWH	BD	0.050	2.320	2.930	1.210	0.900	BD	0.350	65.750	92.800
GM15	20.14	WWH	BD	0.050	1.640	2.930	0.930	0.900	BD	0.350	82.350	47.500
GM16	18.30	WWH	BD	0.050	1.980	2.930	0.640	0.900	BD	0.350	57.850	72.400
GM17	15.49	WWH	BD	0.050	1.880	2.930	1.030	0.900	BD	0.350	84.100	88.000
GM18	14.88	WWH	BD	0.050	1.810	2.930	0.910	0.900	BD	0.350	93.100	62.500
GM19	9.98	WWH	BD	0.050	1.960	2.930	0.920	0.900	BD	0.350	53.550	72.000
GM20	8.48	WWH	BD	0.050	1.880	2.930	0.830	0.900	BD	0.350	66.300	73.600
GM21	5.55	WWH	BD	0.050	1.740	2.930	0.760	0.900	BD	0.350	64.100	93.100
GM22	3.78	WWH	BD	0.050	1.420	2.930	0.750	0.900	BD	0.350	64.850	93.100
GM23	1.59	WWH	BD	0.050	1.480	2.930	0.850	0.900	BD	0.350	70.500	93.100
WAU 08-08 - Howard Creek - Dry Fork Whitewater River												
14-304 – Howard Creek												
GM50	2.91	WWH	BD	0.100	1.860	2.240	BD	0.500	BD	0.070	1.040	103.000

Table 12. Nutrient parameter results in the Great Miami River study area in 2013. Values >reference targets are shaded in yellow. BD –indicates below detection.

Site ID	River Mile	Aq. Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m^3) +	Benthic Chlorophyll (mg/m3) ++
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Median?
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6)												
GM79	0.01	PHW2	BD	0.100	1.040	2.240	BD	0.500	BD	0.070	1.070	145.000
WAU 08-09 - Lee Creek - Dry Fork Whitewater River												
14-302 – Dry Fork Whitewater River												
GM45	10.65	EWH	BD	0.053	1.530	0.540	BD	0.800	BD	0.150	2.140	55.500
GM46	7.30	WWH	BD	0.053	1.820	0.540	BD	0.800	BD	0.150	4.270	80.200
GM47	4.34	WWH	BD	0.053	1.200	0.540	BD	0.800	BD	0.150	3.200	21.600
GM48	0.53	WWH	BD	0.053	0.610	0.540	BD	0.800	BD	0.150	4.270	67.500
14-303 – Lee Creek												
GM49	4.75	WWH	BD	0.100	0.910	2.240	0.830	0.500	BD	0.070	10.900	10.300
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)												
GM55	1.75	WWH	BD	0.064	0.250	1.180	0.630	0.500	BD	0.130	18.700	236.000
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)												
GM67	0.35	WWH	BD	0.064	0.250	1.180	1.040	0.500	BD	0.130	16.050	182.000
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)												
GM56	1.61	PHW2	BD	0.100	4.400	2.240	BD	0.500	BD	0.070	2.340	54.500
14-904 - Unnamed Trib to Lee Creek (0.15)												
GM58	1.14	WWH	BD	0.100	1.520	2.240	0.640	0.500	0.360	0.070	3.740	11.300
14-910 - Unnamed Trib to Lee Creek (3.81)												
GM63	0.41	WWH	BD	0.100	0.250	2.240	1.020	0.500	BD	0.070	12.300	66.900
WAU 08-10 - Jameson Creek - Whitewater River												
14-300 - Whitewater River												
GM40	8.32	WWH	BD	0.050	1.250	2.930	BD	0.900	BD	0.350	2.970	48.300
GM41	6.98	WWH	BD	0.050	1.240	2.930	BD	0.900	BD	0.350	3.200	168.000
GM42	3.98	WWH	BD	0.050	1.420	2.930	BD	0.900	BD	0.350	5.870	37.400
GM43	1.50	WWH	BD	0.050	1.730	2.930	BD	0.900	BD	0.350	5.340	136.000
14-301 – Sand Run												
GM44	2.35	WWH	BD	0.064	0.760	1.180	0.470	0.500	BD	0.130	1.870	22.200

Table 12. Nutrient parameter results in the Great Miami River study area in 2013. Values >reference targets are shaded in yellow. BD –indicates below detection.

Site ID	River Mile	Aq. Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m^3) +	Benthic Chlorophyll (mg/m3) ++
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Median?
14-307 – Jameson Creek												
GM51	0.91	WWH	BD	0.100	0.250	2.240	0.290	0.500	BD	0.070	8.310	26.200
GM52	0.20	WWH	BD	0.100	0.250	2.240	BD	0.500	BD	0.070	9.910	146.000
14-908 - Unnamed Trib to the Whitewater River(6.45)												
GM64	0.29	PHW3A	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	1.000	22.200
14-917 - Fox Run (to the Whitewater River) (2.05)												
GM71	0.06	WWH	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	2.140	59.700
14-921 - Unnamed Trib to Sand Run												
GM78	1.89	PHW3	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	2.100	71.700
WAU 09-01 - Pleasant Run - Great Miami River												
14-013 – Pleasant Run												
GM38	5.78	WWH	BD	0.100	0.250	2.240	BD	0.500	0.060	0.070	1.000	100.000
14-901 - Unnamed Trib to Pleasant Run (2.29)												
GM53	0.04	PHW2	BD	0.064	0.610	1.180	BD	0.500	BD	0.130	1.040	82.700
14-912 - Unnamed Trib to Pleasant Run(5.26)												
GM65	5.78	WWH	BD	0.064	0.620	1.180	0.450	0.500	BD	0.130	1.000	32.900
WAU 09-02 - Banklick Creek - Great Miami River												
14-012 – Banklick Creek												
GM35	3.30	WWH	BD	0.064	3.470	1.180	0.770	0.500	0.700	0.130	9.350	53.200
GM36	2.65	WWH	BD	0.064	0.420	1.180	0.840	0.500	BD	0.130	5.340	637.000
GM37	0.30	WWH	BD	0.064	0.380	1.180	BD	0.500	BD	0.130	2.910	73.800
14-915 - Unnamed Trib to Banklick Creek(2.55)												
GM69	0.15	PHW3A	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	3.200	210.000
Unnamed Trib to Banklick Creek (3.13)												
GM72	0.15	WWH	BD	0.064	8.300	1.180	1.270	0.500	BD	0.130	1.340	58.600
WAU 09-03 - Paddys Run - Great Miami River												
14-005 Paddys Run												
GM26	4.72	WWH	BD	0.064	0.850	1.180	0.540	0.500	BD	0.130	4.270	92.600
GM27	3.82	WWH	BD	0.064	0.250	1.180	0.440	0.500	BD	0.130	9.780	58.600

Table 12. Nutrient parameter results in the Great Miami River study area in 2013. Values >reference targets are shaded in yellow. BD –indicates below detection.

Site ID	River Mile	Aq. Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m^3) +	Benthic Chlorophyll (mg/m3) ++
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Median?
GM28	1.79	WWH	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	3.200	68.900
GM29	0.10	WWH	BD	0.064	0.920	1.180	BD	0.500	0.510	0.130	16.000	68.900
WAU 09-04 Dry Run - Great Miami River												
14-006 – Bluerock Creek												
GM30	2.24	PHW3A	BD	0.064	0.250	1.180	BD	0.500	0.210	0.130	1.000	42.000
GM31	1.53	PHW3A	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	2.370	29.400
GM32	0.45	WWH	BD	0.064	0.410	1.180	0.390	0.500	BD	0.130	1.340	171.000
14-007 – Owl Creek												
GM33	0.35	WWH	BD	0.064	1.400	1.180	BD	0.500	BD	0.130	3.170	73.400
14-008 – Dunlap Creek												
GM34	0.87	WWH	BD	0.064	0.400	1.180	BD	0.500	BD	0.130	1.570	248.000
14-902 - Unnamed Trib to Blue Rock Creek (1.37)												
GM54	1.72	WWH	BD	0.064	1.160	1.180	BD	0.500	BD	0.130	1.840	153.000
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr												
GM74	0.15	WWH	BD	0.064	0.250	1.180	BD	0.500	BD	0.130	4.810	156.000
WAU 09-06 - Jordan Run - Great Miami River												
14-003 – Jordan Run												
GM24	2.24	PHW3A	BD	0.064	0.250	1.180	BD	0.500	0.280	0.130	1.000	26.600
GM25	0.91	WWH	BD	0.064	0.580	1.180	BD	0.500	BD	0.130	1.040	209.000
14-182 – Tributary to Great Miami River												
GM39	0.33	PHW3A	BD	0.064	0.780	1.180	0.340	0.500	0.190	0.130	1.000	13.700
14-907 - Unnamed Trib to the Great Miami River(12.0)												
GM60	0.55	PHW3A	BD	0.064	1.010	1.180	BD	0.500	BD	0.130	1.000	77.200
14-909 - Unnamed Trib to the Great Miami River (8.50)												
GM62	0.40	WWH	BD	0.064	0.250	1.180	BD	0.500	0.070	0.130	1.000	79.500
14-913 - Unnamed Trib to the G. Miami River 19.2 .75)												
GM66	0.53	WWH	BD	0.064	0.250	1.180	0.610	0.500	BD	0.130	1.000	78.100
14-916 - Unnamed Trib to the Great Miami River(7.74)												
GM70	0.30	WWH	BD	0.064	2.360	1.180	BD	0.500	BD	0.130	1.300	23.700

Table 12. Nutrient parameter results in the Great Miami River study area in 2013. Values >reference targets are shaded in yellow. BD –indicates below detection.

Site ID	River Mile	Aq. Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m^3) +	Benthic Chlorophyll (mg/m3) ++
			Median	Target	Median	Target	Median	Target	Median	Target	Median	Median?
14-906 Unnamed Trib to the Great Miami River (3.7)												
GM59	0.74	PHW3A	BD	0.064	0.620	1.180	0.390	0.500	BD	0.130	1.540	77.200
Reference Sites												
14-022 – Elk Creek [WAU 07-01]												
RF24	3.65	WWH	BD	0.096	1.430	2.800	BD	0.500	BD	0.110	1.070	165.000
14-010 – Indian Creek [WAU 08-03]												
RF23	9.74	WWH	BD	0.096	1.260	2.800	BD	0.500	BD	0.110	5.610	149.000
RF22	4.27	WWH	BD	0.096	1.810	2.800	BD	0.500	BD	0.110	4.740	101.000

+ Shading Ranges for Sestonic Chlorophyll - > 42 mg/m^3 for large rivers

++ Shading Ranges for Benthic Chlorophyll based on Ohio EPA Trophic Criterion Scores– low (empty) - ≤107 mg/m^3; typical 108-183 (light green); 184-320 – elevated above reference (yellow); > 320 – 50% change of biological impairment (red).

Reference Sites

The sites on the reference streams had no exceedences of convention parameters with water quality criteria. Although nutrients were relatively low, there were elevated benthic chlorophyll concentrations.

Great Miami River Study Area Compared to the Mill Creek and Little Miami River Watersheds

CSO impacts were not an issue in the Great Miami River study area as they were in the Mill Creek and many of the Little Miami River watersheds. There were impacts from general urban runoff in the small watersheds adjacent to the Great Miami River and from agricultural sources mainly in the Whitewater watersheds. Where chloride and other “urban parameters” were elevated compared to reference concentrations, the concentrations in the Great Miami River watersheds were lower than in the more urbanized watersheds in Mill Creek and the more urbanized subwatersheds in the Little Miami River such as Duck Creek.

Table 13. Eutrophication assessment using the Ohio EPA Trophic Index Criterion (Ohio EPA 2011) in the Great Miami River study area in 2013. This approach is a composite index approach that acts as translator for the condition of a water body relative to nutrient enrichment.

Site ID	RM	DIN	TP	Benth Chlor.	Sestonic Chlor	DO	DO Swing	Bio. Attain. Status	Nutr. Score	Chlor. Score	Bio Score	DO Score	TIC	Tic Narrative
Large River Assessment Unit 90-002 – Great Miami River Mainstem														
14-001 – Great Miami River ***(WWH Aquatic Life Use – Existing, Eastern Corn Belt Plains ecoregion)***														
GM01	40.30	2.71	0.26	150.00	41.57	10.02	9.53	PARTIAL	1	4	0	0	5.0	Impaired
GM02	38.55	2.45	0.26	335.00	51.04	14.17	18.86	FULL	1	0	12	0	13.0	Impaired
GM03	38.09	2.39	0.26	41.20	37.27	9.15	5.62	PARTIAL	1	8	0	12	21.0	Threatened
GM04	36.98	2.58	0.25	139.00	45.20	10.63	10.88	PARTIAL	1	4	0	0	5.0	Impaired
GM05	34.12	2.24	0.25	96.30	51.61	9.25	8.65	FULL	1	8	12	1	22.0	Acceptable
GM06	33.66	2.37	0.26	231.00	64.40	9.26	8.83	PARTIAL	1	1	0	1	3.0	Impaired
GM07	32.69	2.29	0.26	148.00	64.54	9.74	12.69	FULL-NS	1	4	6	0	11.0	Impaired
GM08	31.27	2.38	0.26	77.40	55.90	11.71	13.23	FULL-NS	1	8	6	0	15.0	Threatened
GM09	29.98	2.34	0.32	98.60	43.35	9.65	15.26	FULL-NS	1	8	6	0	15.0	Threatened
GM10	28.15	2.29	0.29	100.00	45.76	9.79	15.94	FULL	1	8	12	0	21.0	Threatened
GM11	26.20	2.95	0.28	50.40	45.20	9.62	14.71	FULL-NS	1	8	6	0	15.0	Threatened
GM12	24.67	2.95	0.25	110.00	57.29	9.71	13.17	FULL	1	4	12	0	17.0	Threatened
GM13	23.63	2.14	0.29	119.00	60.93	12.69	11.73	FULL	1	4	12	0	17.0	Threatened
GM14	21.70	2.54	0.25	92.80	65.39	12.78	14.20	FULL-NS	1	8	6	0	15.0	Threatened
GM15	20.14	1.99	0.25	47.50	71.76	9.07	6.99	FULL	1	8	12	6	27.0	Acceptable
GM16	18.30	2.52	0.26	72.40	64.21	13.20	11.01	FULL	1	8	12	0	21.0	Threatened
GM17	15.49	2.95	0.26	88.00	83.22	13.82	10.30	FULL	1	8	12	0	21.0	Threatened
GM18	14.88	1.80	0.26	62.50	83.93	13.31	9.23	FULL-NS	1	8	6	0	15.0	Threatened
GM19	9.98	2.46	0.25	72.00	65.35	13.72	10.33	FULL	1	8	12	0	21.0	Threatened
GM20	8.48	1.90	0.26	73.60	73.81	13.73	8.59	FULL	1	8	12	1	22.0	Acceptable
GM21	5.55	1.90	0.26	93.10	61.45	14.02	11.50	FULL	1	8	12	0	21.0	Threatened
GM22	3.78	1.54	0.26	0.00	62.78	16.21	19.86	FULL	1	-99	12	0	-86.0	Impaired
GM23	1.59	1.66	0.25	0.00	63.14	14.91	14.79	PARTIAL	1	-99	0	0	-98.0	Impaired
WAU 08-08 - Howard Creek - Dry Fork Whitewater River														
14-304 – Howard Creek														
GM50	2.91	2.14	0.24	103.00	1.30	5.08	8.04	FULL	1	8	12	1	22.0	Acceptable
14-922 - Unnamed Trib to Dry Fork Whitewater River(8.6)														
GM79	0.01	1.30	0.25	145.00	1.07	5.55	0.00	PHW2	1	4	2	6	13.0	Impaired
WAU 08-09 - Lee Creek - Dry Fork Whitewater River														
14-302 – Dry Fork Whitewater River														
GM45	10.65	1.84	0.24	55.50	3.38	4.83	11.08	PARTIAL	1	8	0	0	9.0	Impaired

Table 13. Eutrophication assessment using the Ohio EPA Trophic Index Criterion (Ohio EPA 2011) in the Great Miami River study area in 2013. This approach is a composite index approach that acts as translator for the condition of a water body relative to nutrient enrichment.

Site ID	RM	DIN	TP	Benth Chlor.	Sestonic Chlor	DO	DO Swing	Bio. Attain. Status	Nutr. Score	Chlor. Score	Bio Score	DO Score	TIC	Tic Narrative
GM46	7.30	2.32	0.24	80.20	120.84	8.09	6.50	FULL-NS	1	8	6	6	21.0	Threatened
GM47	4.34	1.66	0.23	21.60	7.82	7.13	13.41	FULL	1	8	12	0	21.0	Threatened
GM48	0.53	2.25	0.23	67.50	5.62	8.41	8.45	FULL	1	8	12	1	22.0	Acceptable
14-303 – Lee Creek														
GM49	4.75	1.67	0.23	10.30	13.05	4.63	9.49	PARTIAL	1	8	0	0	9.0	Impaired
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)														
GM67	0.35	1.33	0.27	182.00	24.69	4.55	8.39	NON	1	4	0	1	6.0	Impaired
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)														
GM56	1.61	4.67	0.25	54.50	2.34	6.59	0.78	PHW2	1	8	2	12	23.0	Acceptable
14-904 - Unnamed Trib to Lee Creek (0.15)														
GM58	1.14	1.81	0.36	11.30	3.74	3.75	0.00	NON	1	8	0	2	11.0	Impaired
14-910 - Unnamed Trib to Lee Creek (3.81)														
GM63	0.41	0.51	0.25	66.90	12.30	0.68	0.00	PARTIAL	3	8	0	2	13.0	Impaired
WAU 08-10 - Jameson Creek - Whitewater River														
14-300 - Whitewater River														
GM40	8.32	1.77	0.25	48.30	4.86	7.71	4.15	FULL	1	8	12	12	33.0	Acceptable
GM41	6.98	1.52	0.24	168.00	5.90	7.59	3.79	FULL	1	4	12	12	29.0	Acceptable
GM42	3.98	1.65	0.24	37.40	7.36	8.06	4.54	FULL	1	8	12	12	33.0	Acceptable
GM43	1.50	2.15	0.24	136.00	6.47	7.92	4.07	FULL-NS	1	4	6	12	23.0	Acceptable
14-301 – Sand Run														
GM44	2.35	1.02	0.25	22.20	1.87	5.84	2.20	PARTIAL	3	8	0	12	23.0	Acceptable
14-307 – Jameson Creek														
GM51	0.91	0.61	0.26	26.20	9.48	6.32	4.68	FULL	3	8	12	12	35.0	Acceptable
GM52	0.20	0.62	0.24	146.00	13.22	5.52	7.63	FULL	3	4	12	1	20.0	Threatened
14-911 - Unnamed Trib to Whitewater River(2.35)														
GM64	0.29	0.51	0.25	22.20	1.00	1.04	0.00	PHW3	3	8	4	2	17.0	Threatened
14-917 - Fox Run (to the Whitewater River) (2.05)														
GM71	0.06	0.50	0.25	59.70	2.14	7.98	0.00	FULL-NS	3	8	6	6	23.0	Acceptable
14-921 - Unnamed Trib to Sand Run														
GM78	1.89	0.51	0.25	71.70	2.10	2.69	1.72	PHW3	3	8	4	12	27.0	Acceptable
WAU 09-01 - Pleasant Run - Great Miami River														
14-013 – Pleasant Run														

Table 13. Eutrophication assessment using the Ohio EPA Trophic Index Criterion (Ohio EPA 2011) in the Great Miami River study area in 2013. This approach is a composite index approach that acts as translator for the condition of a water body relative to nutrient enrichment.

Site ID	RM	DIN	TP	Benth Chlor.	Sestonic Chlor	DO	DO Swing	Bio. Attain. Status	Nutr. Score	Chlor. Score	Bio Score	DO Score	TIC	Tic Narrative
GM38	5.78	0.51	0.06	100.00	1.00	6.61	0.00	PARTIAL	3	8	0	6	17.0	Threatened
14-901 - Unnamed Trib to Pleasant Run (2.29)														
GM53	0.04	0.86	0.25	82.70	1.04	7.87	0.99	PHW2	3	8	2	12	25.0	Acceptable
14-912 - Unnamed Trib to Pleasant Run(5.26)														
GM65	5.78	0.89	0.25	32.90	1.00	7.36	3.15	NON	3	8	0	12	23.0	Acceptable
WAU 09-02 - Banklick Creek - Great Miami River														
14-012 – Banklick Creek														
GM35	3.30	3.74	0.70	53.20	9.35	7.44	1.74	FULL-NS	1	8	6	12	27.0	Acceptable
GM36	2.65	0.69	0.22	637.00	5.01	6.21	4.88	PARTIAL	3	0	0	12	15.0	Threatened
GM37	0.30	0.65	0.22	73.80	3.04	7.58	3.31	FULL-NS	3	8	6	12	29.0	Acceptable
14-915 - Unnamed Trib to Banklick Creek(2.55)														
GM69	0.15	0.51	0.25	210.00	3.20	5.87	0.00	PHW3	3	1	4	6	14.0	Threatened
Unnamed Trib to Banklick Creek (3.13)														
GM72	0.15	8.57	0.25	58.60	1.34	3.48	0.04	PARTIAL	0	8	0	12	20.0	Threatened
WAU 09-03 - Paddys Run - Great Miami River														
14-005 Paddys Run														
GM26	4.72	7.52	0.25	92.60	7.42	5.17	6.65	FULL	0	8	12	6	26.0	Acceptable
GM27	3.82	0.86	0.25	58.60	8.72	7.01	8.37	FULL	3	8	12	1	24.0	Acceptable
GM28	1.79	0.74	0.25	68.90	3.95	7.99	4.60	Dry	3	8		12		
GM29	0.10	1.24	0.82	0.00	35.89	4.15	5.65	Dry	1			12		
WAU 09-04 Dry Run - Great Miami River														
14-006 – Bluerock Creek														
GM30	2.24	0.51	0.21	42.00	1.00	7.62	0.00	PHW3	3	8	4	6	21.0	Threatened
GM31	1.53	0.51	0.25	29.40	2.37	4.87	0.44	PHW3	3	8	4	12	27.0	Acceptable
GM32	0.45	4.00	0.23	171.00	2.34	60.86	117.09	FULL	1	4	12	0	17.0	Threatened
14-007 – Owl Creek														
GM33	0.35	1.66	0.25	73.40	3.17	6.63	1.62	PARTIAL	1	8	0	12	21.0	Threatened
14-008 – Dunlap Creek														
GM34	0.87	0.66	0.25	248.00	1.57	5.39	0.31	FULL-NS	3	1	6	12	22.0	Acceptable
14-902 - Unnamed Trib to Blue Rock Creek (1.37)														
GM54	1.72	1.42	0.25	153.00	1.84	9.74	1.99	NON	1	4	0	12	17.0	Threatened

Table 13. Eutrophication assessment using the Ohio EPA Trophic Index Criterion (Ohio EPA 2011) in the Great Miami River study area in 2013. This approach is a composite index approach that acts as translator for the condition of a water body relative to nutrient enrichment.

Site ID	RM	DIN	TP	Benth Chlor.	Sestonic Chlor	DO	DO Swing	Bio. Attain. Status	Nutr. Score	Chlor. Score	Bio Score	DO Score	TIC	Tic Narrative
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr														
GM74	0.15	0.51	0.25	156.00	4.81	7.71	0.00	NON	3	4	0	6	13.0	Impaired
WAU 09-06 - Jordan Run - Great Miami River														
14-003 – Jordan Creek														
GM24	2.24	0.51	0.28	26.60	1.00	8.54	0.00	PHW3	3	8	4	6	21.0	Threatened
GM25	0.91	1.62	0.22	209.00	1.27	7.32	3.52	FULL	1	1	12	12	26.0	Acceptable
14-182 – Tributary to Great Miami River														
GM39	0.33	1.03	0.19	13.70	1.00	5.43	0.00	PHW3	3	8	4	6	21.0	Threatened
14-907 - Unnamed Trib to the Great Miami River(12.0)														
GM60	0.55	1.28	0.25	0.00	1.00	6.86	0.00	PHW3	1		4	6	-88.0	
14-909 - Unnamed Trib to the Great Miami River (8.50)														
GM62	0.40	0.51	0.07	79.50	1.00	8.25	0.00	FULL-NS	3	8	6	6	23.0	Acceptable
14-913 - Unnamed Trib to the G. Miami River 19.2 .75)														
GM66	0.53	0.51	0.25	78.10	1.00	5.76	0.00	NON	3	8	0	6	17.0	Threatened
14-916 - Unnamed Trib to the Great Miami River(7.74)														
GM70	0.30	2.62	0.25	23.70	1.30	10.68	3.70	NON	1	8	0	12	21.0	Threatened
14-906 Unnamed Trib to the Great Miami River (3.7)														
GM59	0.74	0.87	0.25	77.20	1.54	7.30	1.14	PHW3	3	8	4	12	27.0	Acceptable
Reference Sites														
14-022 – Elk Creek [WAU 07-01]														
RF24	3.65	2.11	0.23	165.00	1.58	8.21	7.19	PARTIAL	1	4	0	1	6.0	Impaired
14-010 – Indian Creek [WAU 08-03]														
RF23	9.74	2.35	0.24	149.00	8.17	8.13	4.89	FULL	1	4	12	12	29.0	Acceptable
RF22	4.27	3.99	0.24	101.00	8.83	8.25	9.03	FULL	1	8	12	0	21.0	Threatened

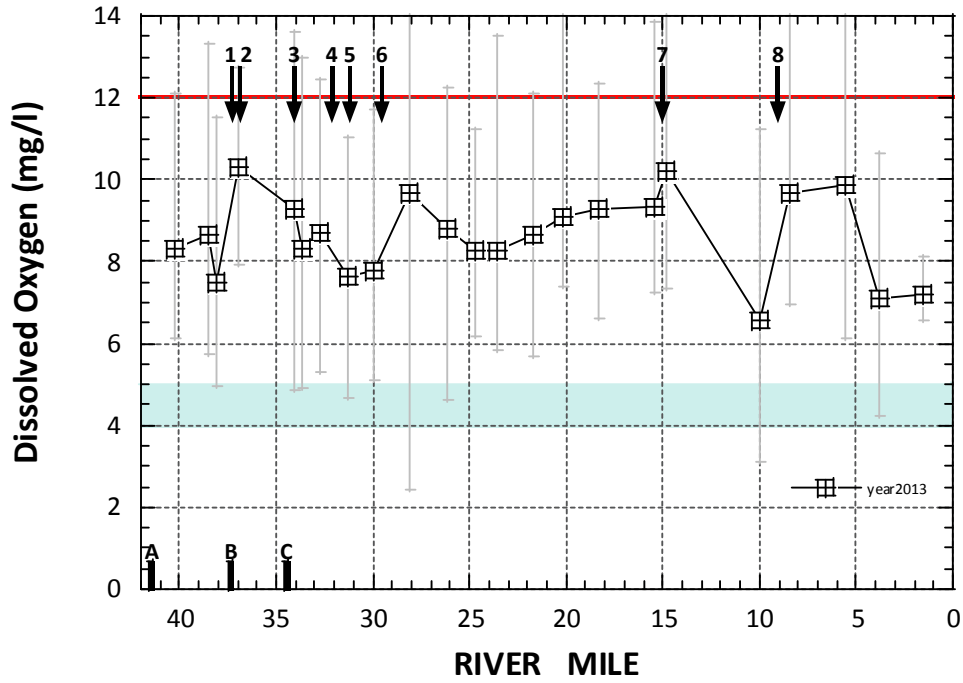

Figure 12. Plot of dissolved oxygen levels for the lower 45 miles of the Great Miami River during 2013. Blue bar presents the 4 mg/l minimum/5 mg/l 24 hr. average WWH D.O. criteria. The red dashed line represents a 12 mg/l level as an upper threshold for excessive diel swings. The numbers and letters are discharges and dams listed in Table 9.

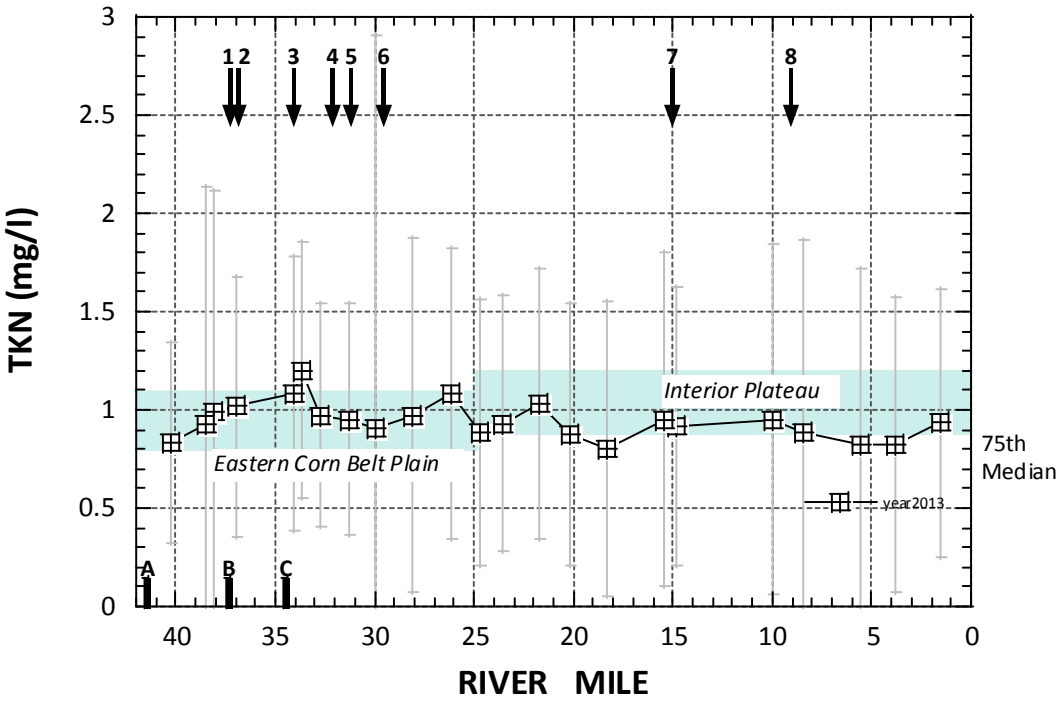

Figure 13. Plot of TKN for the lower 45 miles of the Great Miami River during 2013 (top). Blue bars represent the regional reference value (ecoregion targets) for TKN. The numbers and letters are discharges and dams listed in Table 9.

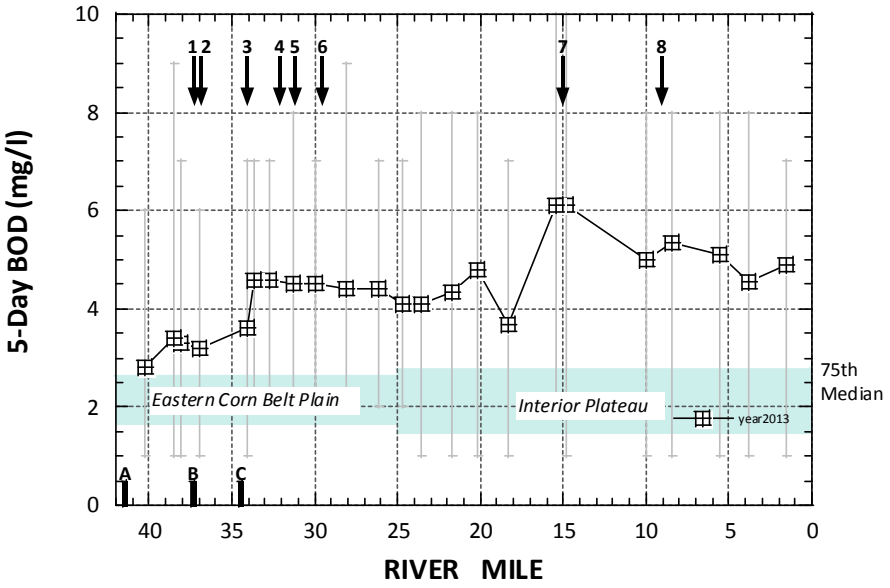

Figure 14. Plot of BOD_5 for the lower 45 miles of the Great Miami River during 2013. Blue areas represent statewide large river reference ranges (ecoregion target) for BOD_5. The numbers and letters are discharges and dams listed in Table 9.

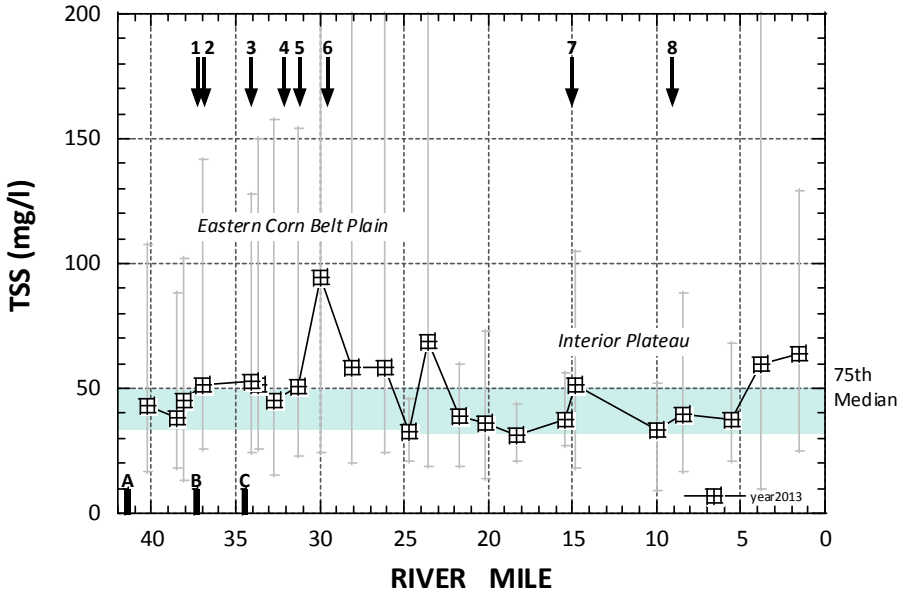

Figure 15. Plot of TSS for the lower 45 miles of the Great Miami River during 2013. Blue areas represent statewide large river reference ranges (ecoregion target) for TSS. The numbers and letters are discharges and dams listed in Table 9.

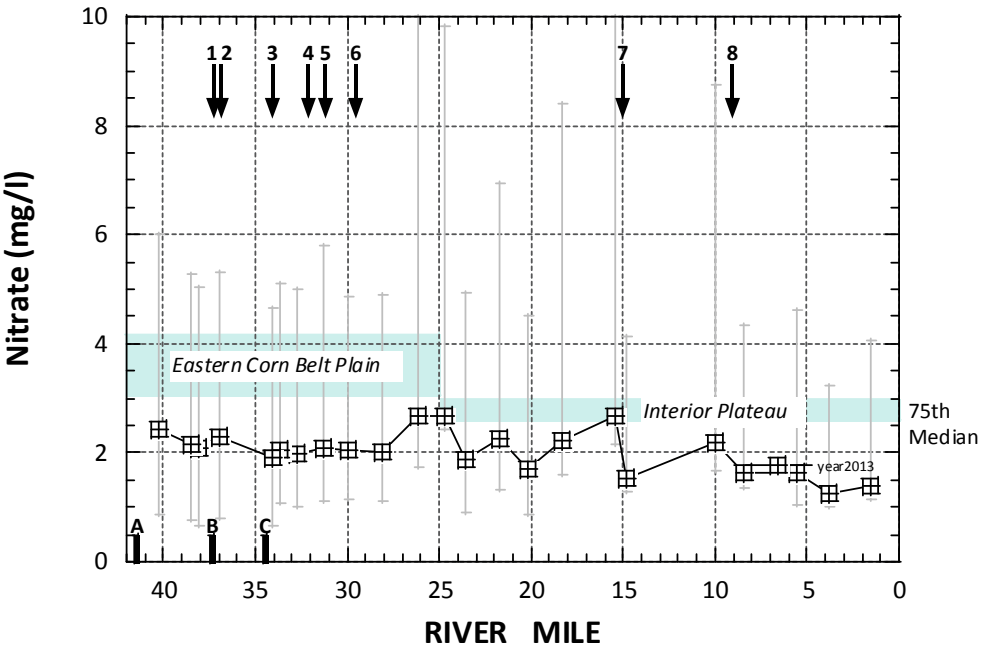

Figure 16. Plot of nitrate for the lower 45 miles of the Great Miami River during 2013. Blue areas represent statewide large river reference ranges (ecoregion target) for nitrate. The numbers and letters are discharges and dams listed in Table 9.

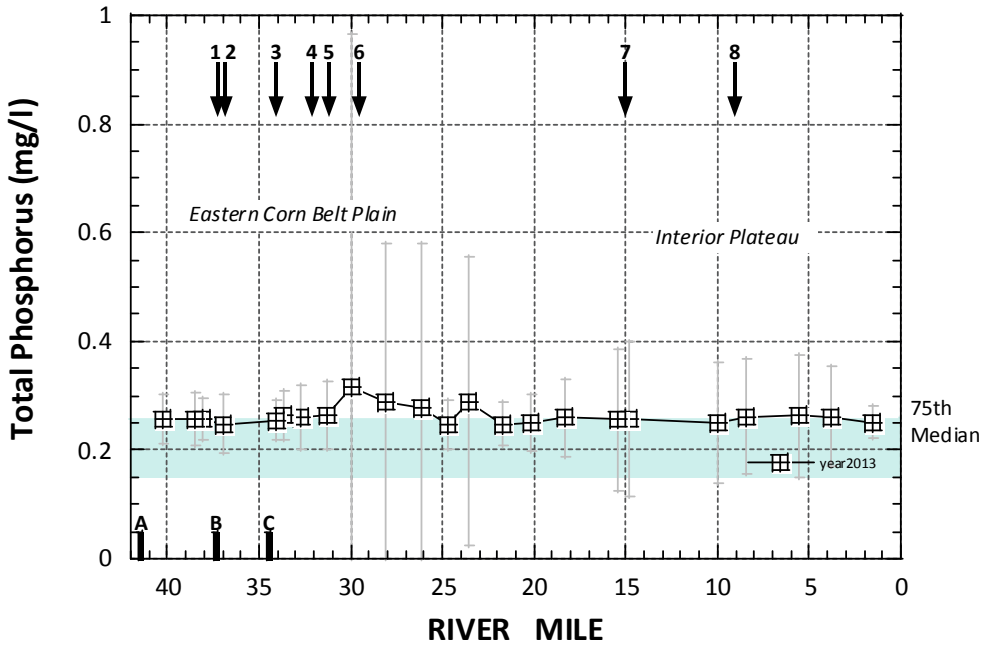

Figure 17. Plot of total phosphorus for the lower 45 miles of the Great Miami River during 2013. Blue areas represent statewide large river reference ranges (ecoregion target) for TP. The numbers and letters are discharges and dams listed in Table 9.

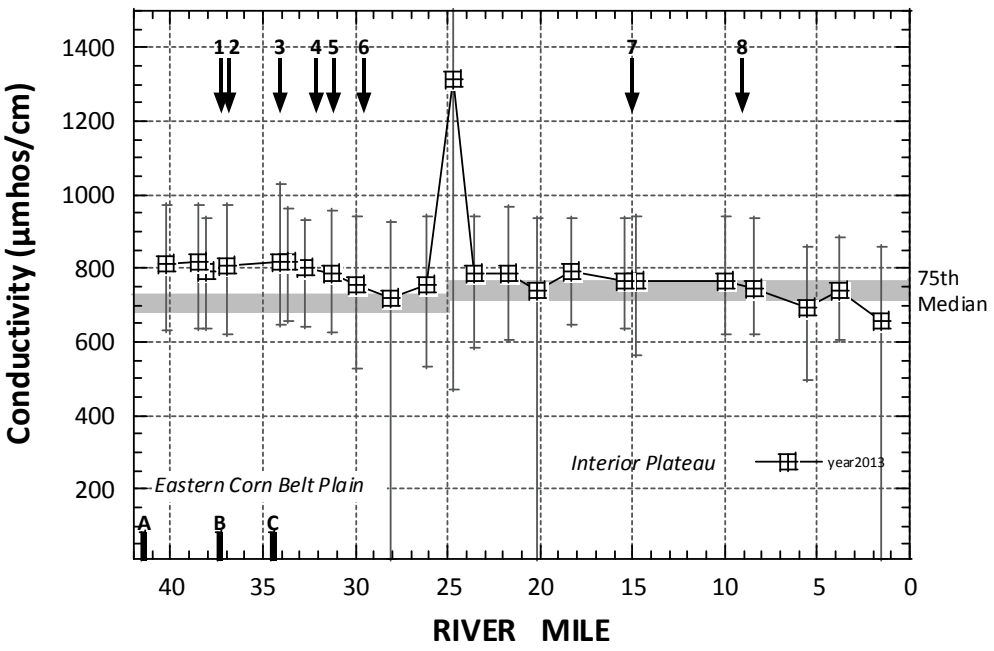

Figure 18. Plot of conductivity for the lower 45 miles of the Great Miami River during 2013. Blue areas represent statewide large river reference ranges (ecoregion target) for conductivity. The numbers and letters are discharges and dams listed in Table 9.

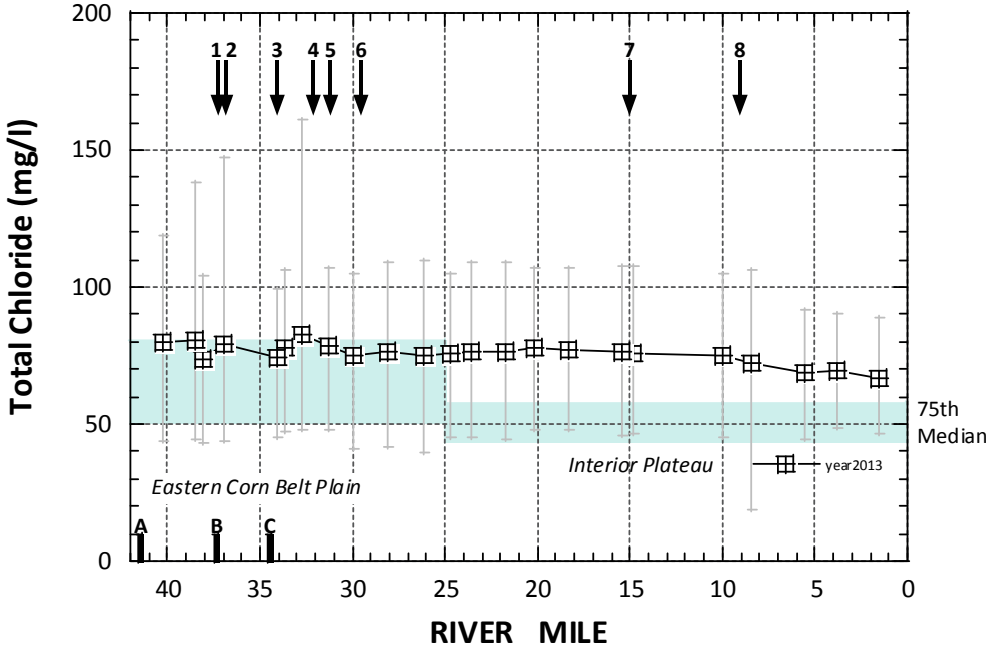

Figure 19. Plot of Total Chloride for the lower 45 miles of the Great Miami River during 2013. Blue areas represent statewide large river reference ranges (ecoregion target) for chloride. The numbers and letters are discharges and dams listed in Table 9.

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 Great Miami River and Whitewater River sites and at selected locations in selected tributaries during July, August, and early September of 2013. 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 - Great Miami River Mainstem

Compared to continuous monitoring data collected by Ohio EPA in 2010 (Ohio EPA 2012), continuous monitoring data during 2013 revealed similar conditions with no D.O. values below the WWH 4.0 mg/l minimum, the 5.0 mg/l 24 hr. average criterion, but a high frequency of "swings" in diel variations >6.0 mg/l above the minimum (10 mg/l. Figure 20, upper) with many values above 15 mg/l in the river. 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 swings in DO contributed to the "Threatened" rating of the Trophic Index Criterion in reaches of the lower Great Miami River despite attainment of the WWH aquatic life use at many sites.

WAU 08-08 - Howard Creek - Dry Fork Whitewater River

Howard Creek was in Full Attainment of the aquatic use criteria and the only issue identified with the continuous monitoring data was the slightly elevated conductivity during both monitoring passes. Elevated conductivity is likely a result of increased runoff compare to reference levels which is a problem if such runoff increases.

WAU 08-09 - Lee Creek - Dry Fork Whitewater River

Sites in the Dry Fork of the Whitewater River did not have any values of dissolved oxygen below the minimum criteria values, but there was a substantial swing in oxygen which is evidence of some enrichment. This corresponds with the impaired eutrophication rating at the upstream EWH site and a threatened TIC score at two other sites the Dry Fork which was driven the observed swing in DO. Lee Creek (GM49) had dissolved oxygen values below the 4 mg/l minimum DO criterion for WWH streams and also had elevated conductivity based on the continuous monitoring results, stressors which are likely contributing to the impaired macroinvertebrate assemblage.

*WAU 08-10 - Jameson Creek - Whitewater Rive*r

The Whitewater River mainstem aquatic biota was excellent as expected with full attainment of the EWH aquatic life use at all sites and the continuous monitoring results were as expected with stable dissolved oxygen levels and conductivity values with the range expected as reference sites. Jameson Creek, in contrast, had DO values below the WWH minimum during the second continuous monitoring pass, although sites in the stream fully attained the WWH aquatic life use. Smaller tributaries chemical stressors were assessed using grab chemistry data.

WAU 09-02 - Banklick Creek - Great Miami River
Banklick Creek had normal dissolved oxygen concentrations, but the high conductivity and elevated chloride (318 mg/l at RM 2.65, GM36) observed in the grab samples were confirmed with the highest conductivity values in the continuous data among the Great Miami River tributaries. These values are very likely related to high urban runoff.

WAU 09-03 - Paddys Run - Great Miami River
The mouth site on Paddys Run had low DO during the September continuous monitoring pass (Figure 22, bottom, right), which was likely exacerbated by the low flows which were to the extent that fish and macroinvertebrates samples were not possible when visited. Conductivity values were slightly elevated or with the range of reference values (Figure 22, bottom).

WAU 09-04 Dry Run - Great Miami River
The downstream site on Bluerock Creek (GM32) and a site on Owl Creek (GM33) had continuous monitoring data. The second pass on Bluerock Creek had the median value below the 5 mg/l average DO criterion and DO values below the 4 mg/l minimum value (Figure 22, top right), although the site attained the WWH biocriteria. Observations on upstream sites (PHW#) and an unnamed tributary were that there were septic impacts in this watershed that may contribute to the periodic DO issue. Both sites also had conductivity values (Figures 22, bottom) that were elevated above reference conditions and is evidence of urban runoff in the watershed. The impairment on Owl Creek was likely exacerbated by low flow.

WAU 09-06 - Jordan Run - Great Miami River
A site on Jordan Run (GM25) was the only site where continuous monitoring data was collected. Dissolved oxygen values were all above the WWH criteria (Figure 22, top) although there was elevated conductivity (Figure 22, bottom) compared to reference conditions which is associated with urban runoff.

Reference Sites
The reference sites has continuous dissolved oxygen concentrations above the WWH criteria (Figure 22, top) and conductivity within the range of reference sites or just slightly above (e.g., Elk Creek, RF24, Figure 22, bottom left). This is consistent with expectation for reference sites.

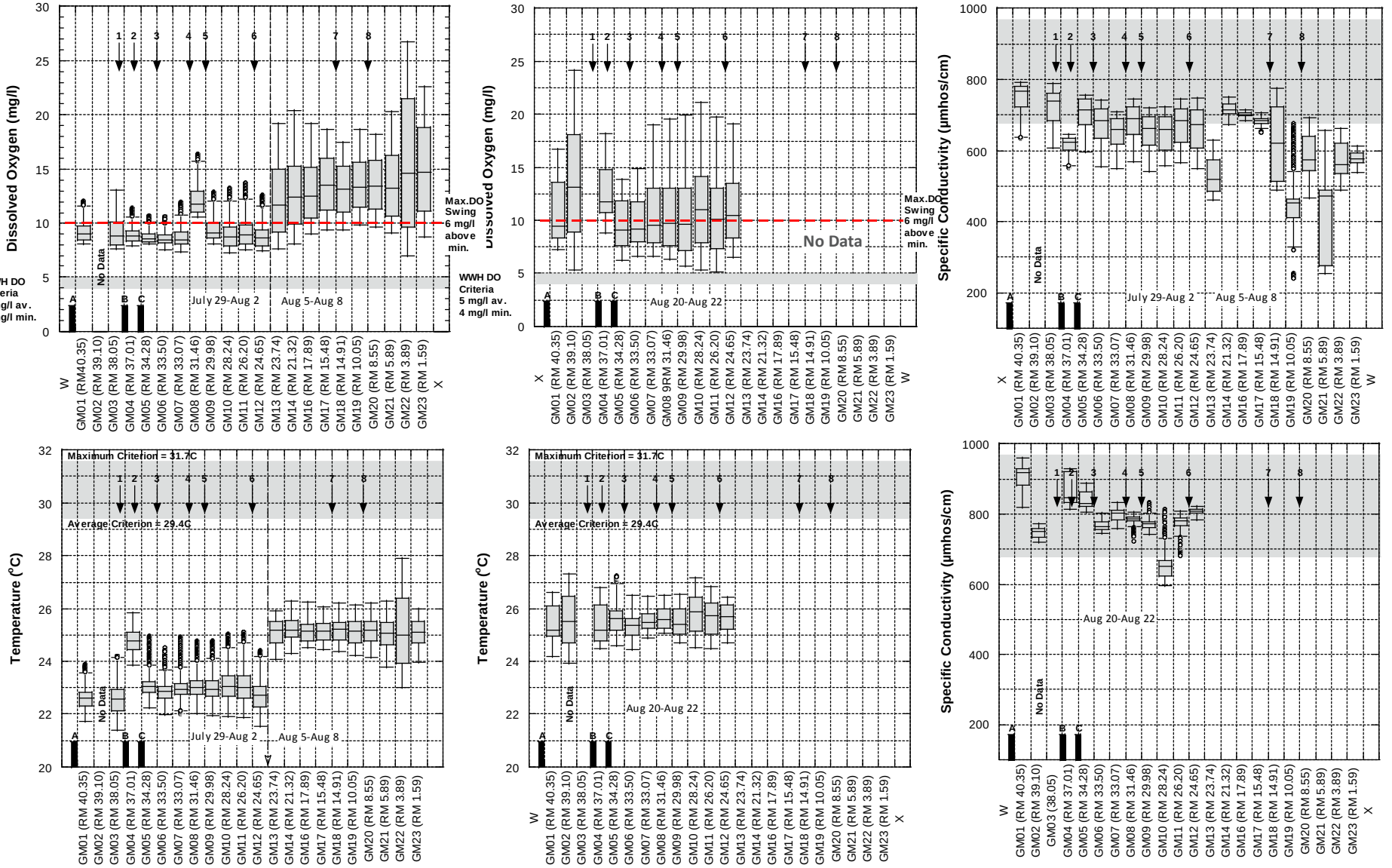

Figure 20. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results in the mainstem of the Great Miami River during late July (left) and mid-August (right) of 2013. The shaded bar is the range between the median and 90th %ile statewide reference values. The numbers and letters are discharges and dams listed in Table 9.

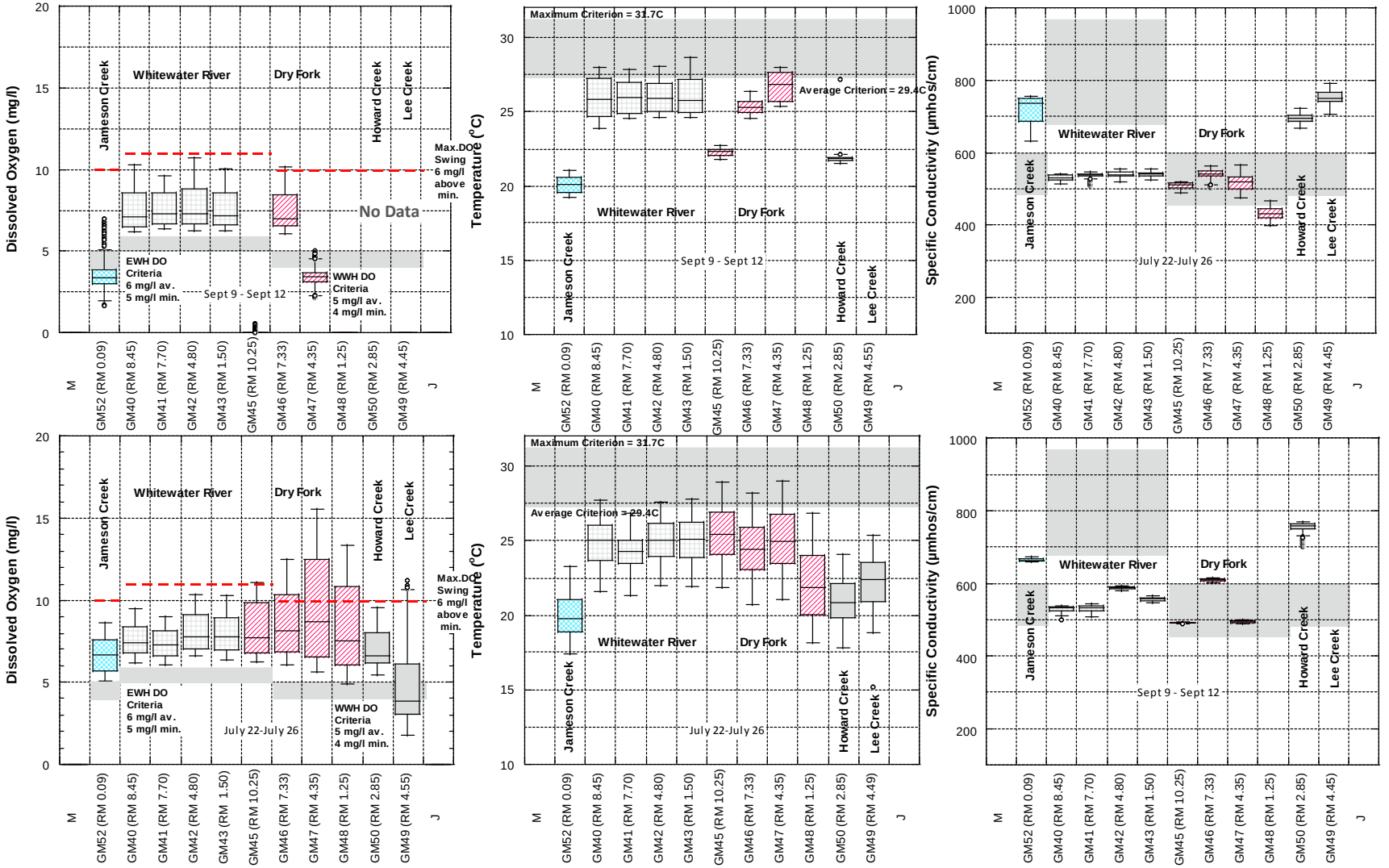

Figure 21. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results in the Whitewater River and Tributaries during late July (left) and early September (right) of 2013. The shaded bar is the range between the median and 90th %ile statewide reference values.

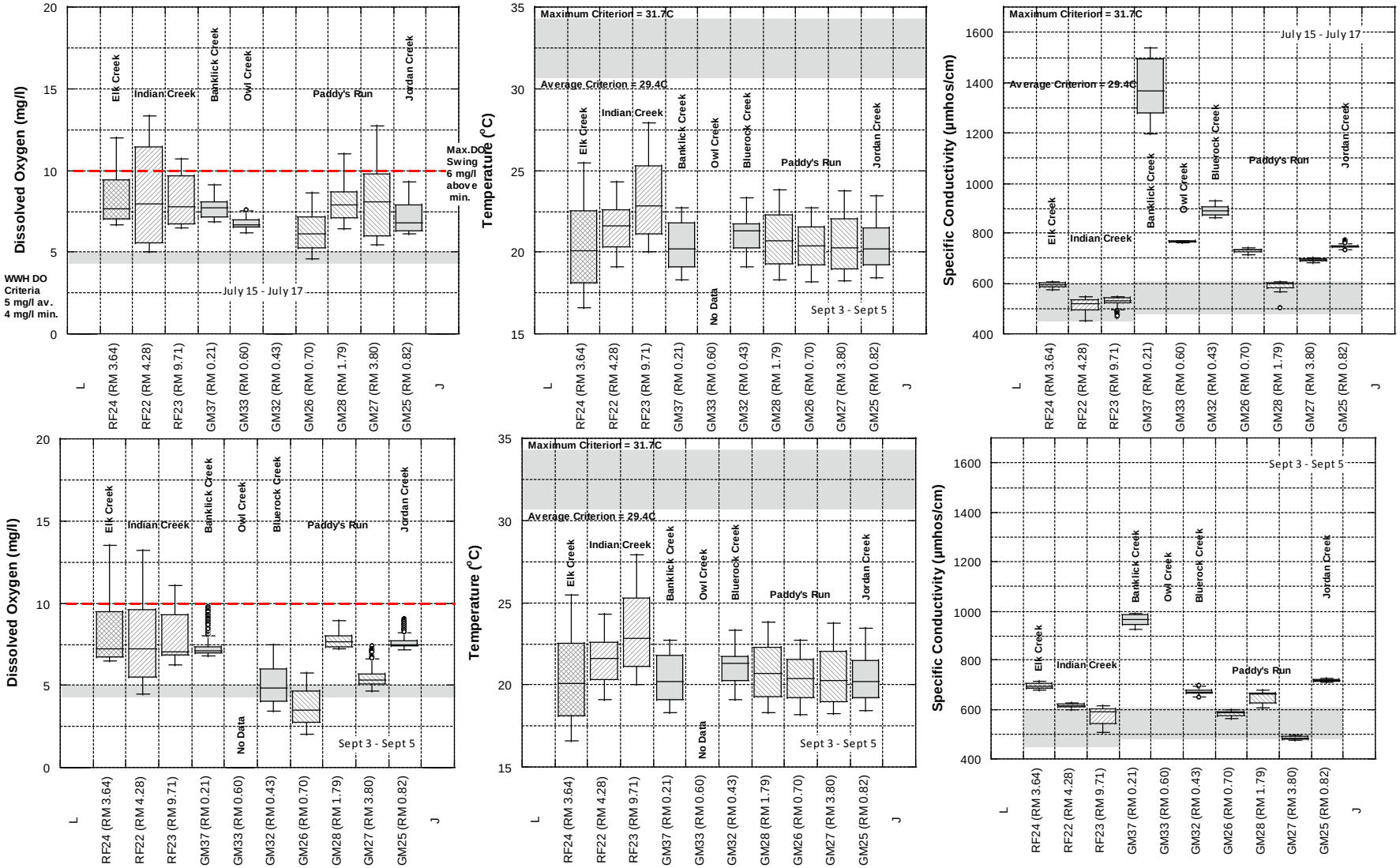

Figure 22. Continuous D.O. (upper), temperature (middle) and conductivity (lower) results in the Great Miami River Tributaries during late July (left) and early September (right) of 2013. The shaded bar is the range between the median and 90th %ile statewide reference values.

Sediment Chemistry

Sediment samples were collected from 46 sites in the Great Miami River and in the 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) for the IP ecoregion 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.

Only 1 or the 46 sites had sediment metal concentrations greater than the PEC (probable effect level), 8 sites with concentrations greater than the threshold effects levels, and 9 sites with concentrations greater than the Ohio SRVs (Table 14). Of these 8 sites that exceeded the TEC levels, 6 were in the Great Miami River mainstem, and one each in the Whitewater River and Jordan Creek.

No sites, for the limited number of parameters where MBI have TEC/PEC benchmarks, exceeded the organic compound benchmarks. 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. There was no pattern or "hot spots" in terms of detections of organic compounds in the Great Miami (similar low rate at all sites), especially in contrast to the Mill Creek and Little Miami River watersheds during previous surveys.

LRAU – Great Miami River

Except for the most downstream site in the Ohio River backwater, there were scattered sites that had slightly elevated metal concentrations (particularly Cd, Cu, Pb, and Zn) in their sediment based on either the Ohio SRV values for the IP ecoregion or the MacDonald TEL benchmarks. The most downstream site is in the Ohio River backwater, and because flow velocities are greatly reduced fine sediments drop out and accumulate compared to swifter flowing upstream reaches.

WAU 08-08 - Howard Creek - Dry Fork Whitewater River

Although metals were detected (5 of 14 tested for), none were considered elevated in Howard Creek (Table 14).

WAU 08-09 - Lee Creek - Dry Fork Whitewater River

Four sediment samples were taken in the Dry Fork of the Whitewater River as well as one sample in Lee Creek and one in an unnamed tributary to the Dry Fork (GM67). Although metals were detected (5 of 14 parameters tested for at each site), none were elevated (Table 14).

WAU 08-10 - Jameson Creek - Whitewater River

Four sediment samples were taken in the Whitewater River and at two sites in Jameson Creek. Although metals were detected (5-6 of 14 parameters tested for at each site), none were considered elevated (Table 14).

Table 14. Sediment metal concentrations in the lower Great Miami River study area that were tested, detected, greater than Ohio sediment reference values (SRV), greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC). Numbers in parentheses are measured values.

Site ID	River Mile	Date	Metals Tested	Metals Detected	> Ohio SRV Guidelines	>TEC and < PEC	>PEC
Large River Assessment Unit 90-002 – Great Miami River Mainstem							
14-001 – Great Miami River							
GM01	40.30	10/21/2013	14	6	Zn (121)		
GM02	38.55	10/21/2013	14	6			
GM03	38.09	10/21/2013	14	6			
GM04	36.98	10/21/2013	14	5			
GM05	34.12	10/21/2013	14	6	Cd (0.33)		
GM06	33.66	10/21/2013	14	6			
GM07	32.69	10/21/2013	14	6			
GM08	31.27	10/22/2013	14	6	Cd (0.41)	Cu (20.4)	
GM09	29.98	10/22/2013	14	6			
GM10	28.15	10/22/2013	14	5	Zn (108)	Cu (18.7)	
GM11	26.20	10/22/2013	14	5	Zn (156)	Pb (32.5), Zn (156)	
GM12	24.67	10/22/2013	14	5			
GM13	23.63	10/22/2013	14	6			
GM14	21.70	10/22/2013	14	5			
GM15	20.14	10/23/2013	14	5			
GM16	18.30	10/23/2013	14	6	Cd (0.88);		
GM17	15.49	10/23/2013	14	6		Cu (18)	
GM18	14.88	10/23/2013	14	5		Cu (23.3)	
GM19	9.98	10/23/2013	14	5			
GM20	8.48	10/23/2013	14	5			
GM21	5.55	10/23/2013	14	5			
GM22	3.78	10/23/2013	14	5			
GM23	1.59	10/23/2013	14	6	As (52.6); Cd (4.5); Cu (203); Pb (186); Zn (838);	Cd (4.50)	As (52.60); Cu (203.00); Pb (186.00); Zn (838.00)
WAU 08-08 - Howard Creek - Dry Fork Whitewater River							
14-304 – Howard Creek							
GM50	2.91	10/24/2013	14	5			
WAU 08-09 - Lee Creek - Dry Fork Whitewater River							
14-302 – Dry Fork Whitewater River							
GM45	10.65	10/24/2013	14	5			
GM46	7.30	10/24/2013	14	5			
GM47	4.34	10/29/2013	14	5			
GM48	0.53	10/29/2013	14	5			
14-303 – Lee Creek							
GM49	4.75	10/29/2013	14	5			

Table 14. Sediment metal concentrations in the lower Great Miami River study area that were tested, detected, greater than Ohio sediment reference values (SRV), greater than the Threshold Effect Concentration (TEC), or greater than the Probable Effect Concentration (PEC). Numbers in parentheses are measured values.

Site ID	River Mile	Date	Metals Tested	Metals Detected	> Ohio SRV Guidelines	>TEC and < PEC	>PEC
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)							
GM67	0.35	10/29/2013	14	5			
WAU 08-10 - Jameson Creek - Whitewater River							
14-300 - Whitewater River							
GM40	8.32	10/24/2013	14	5			
GM41	6.98	10/24/2013	14	6	Cd (0.74)		
GM42	3.98	10/24/2013	14	5		Cu (25)	
GM43	1.50	10/24/2013	14	5			
14-307 – Jameson Creek							
GM51	0.91	10/24/2013	14	5			
GM52	0.20	10/24/2013	14	5			
WAU 09-02 - Banklick Creek - Great Miami River							
14-012 – Banklick Creek							
GM36	2.65	10/29/2013	14	5			
GM37	0.30	10/22/2013	14	5			
WAU 09-03 - Paddys Run - Great Miami River							
14-005 Paddys Run							
GM26	4.72	10/23/2013	14	5			
GM27	3.82	10/23/2013	14	5			
GM28	1.79	10/23/2013	14	5			
WAU 09-04 Dry Run - Great Miami River							
14-006 – Bluerock Creek							
GM32	0.45	10/29/2013	14	5			
WAU 09-06 - Jordan Run - Great Miami River							
14-003 – Jordan Creek							
GM25	0.91	10/23/2013	14	5	Zn (131)	Zn (131)	
Reference Sites							
14-022 – Elk Creek [WAU 07-01]							
RF24	3.65	10/22/2013	14	5			
14-010 – Indian Creek [WAU 08-03]							
RF23	9.74	10/22/2013	14	5			
RF22	4.27	10/22/2013	14	5			

WAU 09-02 - Banklick Creek - Great Miami River

Two sediment samples were taken in Banklick Creek. Although metals were detected (5-6 of 14 parameters tested for at each site), none were considered elevated (Table 14).

WAU 09-03 - Paddys Run - Great Miami River

Three sediment samples were taken in Paddys Run. Although metals were detected (5 of 14 parameters tested for at each site), none were considered elevated (Table 14).

WAU 09-04 Dry Run - Great Miami River
One sediment sample was taken in Bluerock Creek in this watershed. Although metals were detected (5 of 14 parameters tested for at the site), none were considered elevated (Table 14).

WAU 09-06 - Jordan Run - Great Miami River
One sediment sample was taken in Jordan Run. Metals were detected (5-6 of 14 parameters) tested for the tested site and zinc concentrations were elevated compared to the MacDonald TEC benchmark and is considered elevated (Table 14).

Reference Sites
Sediment samples were taken at each of the three reference sites. Although metals were detected (5 of 14 parameters tested for at each site), none were considered elevated (Table 14).

Aquatic Habitat in the Lower Great Miami River Study Area
This section focuses on key habitat stressors in each of the Lower Great 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 Great Miami River study area (Table 15).

LRAU – Great Miami River
Compared to QHEIs collected in 2010 by Ohio EPA, QHEI values collected by MBI in 2013 were very similar with many of the sites in the free-flowing areas scoring in the 80s (Excellent). Both of these sample years were slightly higher than data from 1995, but even greater yet than data from 1989. An examination of individual metrics shows that much of the difference was related to the substrate metric score and the cover metric score. Although sites did not match exactly, improving substrate scores compared to 1980s data is a pattern that has been observed in other agricultural watersheds in Ohio and is correlated with improved tillage practices (e.g., no-till, conservation tillage).

WAU 08-08 - Howard Creek - Dry Fork Whitewater River
Habitat data was good-excellent in Howard Creek with some lower flow conditions and lack of cover influencing the downstream site. Habitat in direct tributary (GM79) to the Dry Fork of the Whitewater in this watershed was in poor condition due to low flow conditions, high bank erosion and heavily silted substrates.

WAU 08-09 - Lee Creek - Dry Fork Whitewater River
Habitat data was poor-excellent in this watershed with habitat conditions ranging from fair-excellent in the Dry Fork of the Whitewater. Habitat scores in the downstream reaches of the Dry Fork (GM48) were lower mostly because of finer substrates and more silt and embedded substrates and some lower flow conditions. Lee Creek had very good habitat conditions. Other small tributaries in this watershed had poor (GM56) to fair (GM 58, GM63, GM67) habitat with lower scores generally related to finer and substrates and low flow conditions.

WAU 08-10 - Jameson Creek - Whitewater River
Habitat data in the EWH Whitewater River mainstem was excellent as expected with scores near or above 80 (excellent scores) at all sites. All of the WWH tributaries (Sand Run, Jameson Creek, Fox Run) had good habitat. The only tributary with a fair QHEI score was the unnamed tributary to Sand Run (GM78, QHEI Score 49.5) which because of its small size was classified as a primary headwater (PHW3A).

WAU 09-01 - Pleasant Run - Great Miami River
Pleasant Run and its tributaries generally had good habitat quality (QHEI scores 58-66) with some issues with embedded and silted conditions in the tributaries (GM53 and GM65) related to suburban and urban runoff conditions and likely flashy flows.

WAU 09-02 - Banklick Creek - Great Miami River
Banklick Creek had good habitat conditions (QHEI scores 58-69) with natural channels, but some issues related to silt and embedded conditions from urban runoff that contributed to the partial attainment at GM36. A sampled tributary (GM72) also had similar silt and embeddedness issues, although channel conditions were also natural. A small tributary (GM69) was classified as a primary headwater (PHW3A).

WAU 09-03 - Paddys Run - Great Miami River
Habitat in the two of the four Paddy's Run sites that had flow was good (QHEI scores 67.5-69) with the only poor attributes related to low flow conditions. The variation in flow between sites was relatively great with the upper sites having flow and the two larger sites in the lower reaches with relatively large drainage areas (12.9-16.8 mi^{-2}) being dry as well as a primary headwater tributary that enters Paddy's Run at RM 0.65 (GM75).

WAU 09-04 Dry Run - Great Miami River
All of the sites in this watershed had good habitat conditions (QHEI scores 60.5 – 70.5) including Bluerock Creek and its tributaries as well as Dunlap Creek and Owl Creek. Physical conditions that influence the aquatic assemblages in these streams include flow issues and some substrate embeddedness likely related to urban influenced runoff.

WAU 09-06 - Jordan Run - Great Miami River
Streams in the Jordan Run watershed ranged from poor to excellent (QHEI scores 40.0 – 73.3) with lack of flow and altered substrates conditions (embedded substrates) from urban runoff being the greatest risk to aquatic life. All streams had natural channels except for GM70 which was channelized (QHEI = 41). A number of the smaller tributaries were classified as primary headwater streams including the upstream-most site on Jordan Creek (GM24).

Reference Sites
Three sites on two reference streams (14-022 – Elk Creek [WAU 07-01]; 14-010 – Indian Creek [WAU 08-03]) all had excellent QHEI scores (76.5-78) and the only poor habitat attributes included some minor silt cover and embeddedness.

Table 15. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Great Miami River study area, 2013 (■ - 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
Large River Assessment Unit 90-002 – Great Miami River Mainstem																																		
14-001 – Great Miami River																																		
GM01	40.35	81.8	■	■		■		■	■	■	■	■	8				●		1			●			●								2	3	0.33
GM02	39.1	83.5	■	■		■	■	■	■	■	■	■	9						0			●											1	5	0.2
GM03	38.05	45		■				■			■		3		●		●		2		●			●	●			●	●		●	6	0.57	1.75
GM04	37.01	56		■				■			■		3	●		●	●		3	●	●	●		●				●	●		●	7	0.5	2
GM05	34.28	73.8		■		■		■	■	■	■	■	7				●		1	●		●			●								3	2	0.5
GM06	33.5	81	■	■		■		■	■	■	■	■	8				●		1			●			●								2	3	0.33
GM07	33.07	76	■	■		■		■	■	■	■		7				●		1		●	●			●				●	●			5	1.33	0.75
GM08	31.46	84	■	■		■	■	■	■	■	■	■	9						0			●											1	5	0.2
GM09	29.98	76	■	■				■		■	■	■	6						0			●		●	●			●					4	1.4	0.71
GM10	28.24	84.8	■	■		■	■	■	■	■	■	■	9						0														0	10	0.1
GM11	26.2	63		■				■	■	■	■	■	6						0	●				●	●			●					4	1.4	0.71
GM12	24.65	85.5	■	■		■	■	■	■	■	■	■	9						0														0	10	0.1
GM13	23.74	78	■	■		■		■	■	■	■	■	8						0			●			●								2	3	0.33
GM14	21.32	85	■	■		■	■	■	■	■	■	■	9						0														0	10	0.1
GM15	19.87	61.8	■	■				■			■		4			●	●		2		●	●		●				●	●		●	6	0.71	1.4
GM16	17.89	87.5	■	■		■	■	■	■	■	■	■	9						0														0	10	0.1
GM17	15.48	81.5	■	■		■	■	■	■	■	■	■	9						0														0	10	0.1
GM18	14.91	86.5	■	■		■	■	■	■	■	■	■	9						0														0	10	0.1

Table 15. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Great Miami River study area, 2013 (■ - 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
GM19	10.05	85	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
GM20	8.55	85	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
GM21	5.89	84	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
GM22	3.89	66	■	■				■			■		4						0		●			●	●			●	●	●		6	0.71	1.4
GM23	1.59	69	■	■			■	■			■		5				●		1		●	●		●				●	●	●		6	0.86	1.17
WAU 08-08 - Howard Creek - Dry Fork Whitewater River																																		
14-304 – Howard Creek																																		
GM50	2.85	66.5	■	■		■	■	■		■	■	■	8				●		1									●			●	2	3	0.33
14-922 - Unnamed Trib to Dry Fork Whitewater River																																		
GM79	1.4	36.5	■				■	■					3		●			●	2		●			●			●	●	●		●	6	0.57	1.75
WAU 08-09 - Lee Creek - Dry Fork Whitewater River																																		
14-302 – Dry Fork Whitewater River																																		
GM45	10.25	75.8	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
GM46	7.33	73.8	■	■		■	■	■		■	■	■	8						0		●							●	●	●		4	1.8	0.56
GM47	4.35	65.8	■	■			■	■			■		5						0					●				●	●	●		4	1.2	0.83
GM48	1.25	48	■								■		2				●		1		●			●	●			●	●	●		6	0.43	2.33
14-303 – Lee Creek																																		
GM49	4.55	70.8	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22

Table 15. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Great Miami River study area, 2013 (■ - 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
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)																																	
GM67	0.28	54	■	■			■	■					4					●	1		●			●				●	●	●		5	0.83	1.2
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)																																	
GM56	1.63	38.3	■				■	■					3		●			●	2		●			●			●	●	●		●	6	0.57	1.75
14-904 - Unnamed Trib to Lee Creek (0.15)																																	
GM58	1.15	51.5	■	■			■	■					4					●	1		●			●				●	●	●		5	0.83	1.2
14-910 - Unnamed Trib to Lee Creek (3.81)																																	
GM63	0.35	48.8	■	■			■	■					4					●	1		●			●			●	●	●		●	6	0.71	1.4
WAU 08-10 - Jameson Creek - Whitewater River																																	
14-300 - Whitewater River																																	
GM40	8.45	79	■	■		■		■	■	■	■	■	8						0			●			●							2	3	0.33
GM41	7.7	86.5	■	■		■	■	■	■	■	■	■	9						0			●										1	5	0.2
GM42	4.8	80.8	■	■		■	■	■	■	■	■	■	9						0			●										1	5	0.2
GM43	1.5	81.3	■	■		■		■	■	■	■	■	8						0			●			●							2	3	0.33
14-301 – Sand Run																																	
GM44	2.36	66.5	■	■	■	■	■	■		■	■	■	9				●		1									●				1	5	0.2
14-307 – Jameson Creek																																	
GM51	0.92	69.5	■	■		■	■	■		■	■	■	8						0						●			●				2	3	0.33
GM52	0.09	62.8	■	■		■	■	■	■		■		7				●		1					●					●	●		3	2	0.5

Table 15. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Great Miami River study area, 2013 (■ - 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
14-911 - Unnamed Trib to Whitewater River(2.35)																																	
GM64	0.28	66.5	■	■			■	■		■	■	■	7						0					●				●				2	2.67	0.38
14-917 - Fox Run (to the Whitewater River) (2.05)																																	
GM71	0.05	55	■	■			■	■			■	■	6						0		●			●				●	●	●		5	1.17	0.86
14-921 - Unnamed Trib to Sand Run																																	
GM78	0.03	49.5	■	■				■		■			4				●	●	2					●	●		●	●			●	5	0.83	1.2
WAU 09-01 - Pleasant Run - Great Miami River																																	
14-013 – Pleasant Run																																	
GM38	5.9	66	■	■		■	■	■		■			6					●	1					●				●			●	3	1.75	0.57
14-901 - Unnamed Trib to Pleasant Run (2.29)																																	
GM53	0.02	58	■	■			■	■					4					●	1		●			●				●	●	●		5	0.83	1.2
14-912 - Unnamed Trib to Pleasant Run(5.26)																																	
GM65	5.9	63.8	■	■		■	■	■		■	■		7						0									●	●	●		3	2	0.5
WAU 09-02 - Banklick Creek - Great Miami River																																	
14-012 – Banklick Creek																																	
GM35	3.3	58	■	■		■	■	■		■	■		7						0		●							●	●	●		4	1.6	0.63
GM36	2.61	60	■	■		■	■	■			■		6						0		●			●				●	●	●		5	1.17	0.86
GM37	0.21	69	■	■		■	■	■		■	■	■	8						0									●			●	2	3	0.33

Table 15. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Great Miami River study area, 2013 (■ - 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
Unnamed Trib to Banklick Creek (3.13)																																	
GM72	0.06	52	■	■		■	■	■					5					●	1		●			●				●	●	●		5	1	1
WAU 09-03 - Paddys Run - Great Miami River																																	
14-005 Paddys Run																																	
GM26	4.68	67.5	■	■			■	■		■	■	■	7						0					●				●				2	2.67	0.38
GM27	3.8	69	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
WAU 09-04 Dry Run - Great Miami River																																	
14-006 – Bluerock Creek																																	
GM30	2.27	66.8	■	■		■	■	■		■		■	7					●	1									●				1	4	0.25
GM31	1.35	70.3	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
GM32	0.43	69.5	■	■		■	■	■		■	■	■	8						0		●			●	●			●	●	●		6	1.29	0.78
14-007 – Owl Creek																																	
GM33	0.6	61	■	■		■	■	■		■			6					●	1									●			●	2	2.33	0.43
14-008 – Dunlap Creek																																	
GM34	0.86	60.5	■	■		■	■	■		■			6					●	1									●			●	2	2.33	0.43
14-902 - Unnamed Trib to Blue Rock Creek (1.37)																																	
GM54	1.75	62.3	■	■		■	■	■			■		6						0		●			●				●	●	●		5	1.17	0.86
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr																																	
GM74	0.14	70.5	■	■	■	■	■	■		■	■	■	9						0				●					●				2	3.33	0.3

Table 15. Qualitative Habitat Evaluation Index (QHEI) scores showing Good and Modified Habitat attributes at sites in the Great Miami River study area, 2013 (■ - 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 09-06 - Jordon Run - Great Miami River																																		
14-003 – Jordan Creek (WWH)																																		
GM25	0.82	73.3	■	■		■	■	■		■	■	■	8						0								●				1	4.5	0.22
14-182 – Tributary to Great Miami River (PHW3A)																																		
GM39	0.21	62.3	■	■		■	■	■		■			6					●	1					●			●			●	3	1.75	0.57
14-907 - Unnamed Trib to the Great Miami River(12.0) (PHW3A																																		
GM60	0.35	50.5	■	■			■	■		■			5				●	●	2					●	●		●			●	4	1.2	0.83
14-909 - Unnamed Trib to the Great Miami River (8.50) (WWH)																																		
GM62	0.5	59.5	■	■		■	■	■				■	6					●	1		●						●	●	●		4	1.4	0.71
14-913 - Unnamed Trib to the G. Miami River 19.2 .75) (WWH)																																		
GM66	0.59	53	■	■			■	■			■		5						0		●			●			●	●	●		5	1	1
14-916 - Unnamed Trib to the Great Miami River(7.74) (WWH)																																		
GM70	0.32	41						■					1			●		●	2	●	●			●	●		●	●	●		7	0.25	4
Reference Sites																																		
14-022 – Elk Creek [WAU 07-01]																																		
RF24	4.64	78	■	■		■	■		■	■	■	■	8				●		1		●										1	4.5	0.22
14-010 – Indian Creek [WAU 08-03]																																		
RF23	9.71	75.5	■	■		■	■	■	■	■	■	■	9				●		1		●								●		2	3.33	0.3
RF22	4.27	76	■	■		■	■	■	■	■	■	■	9				●		1												0	10	0.1

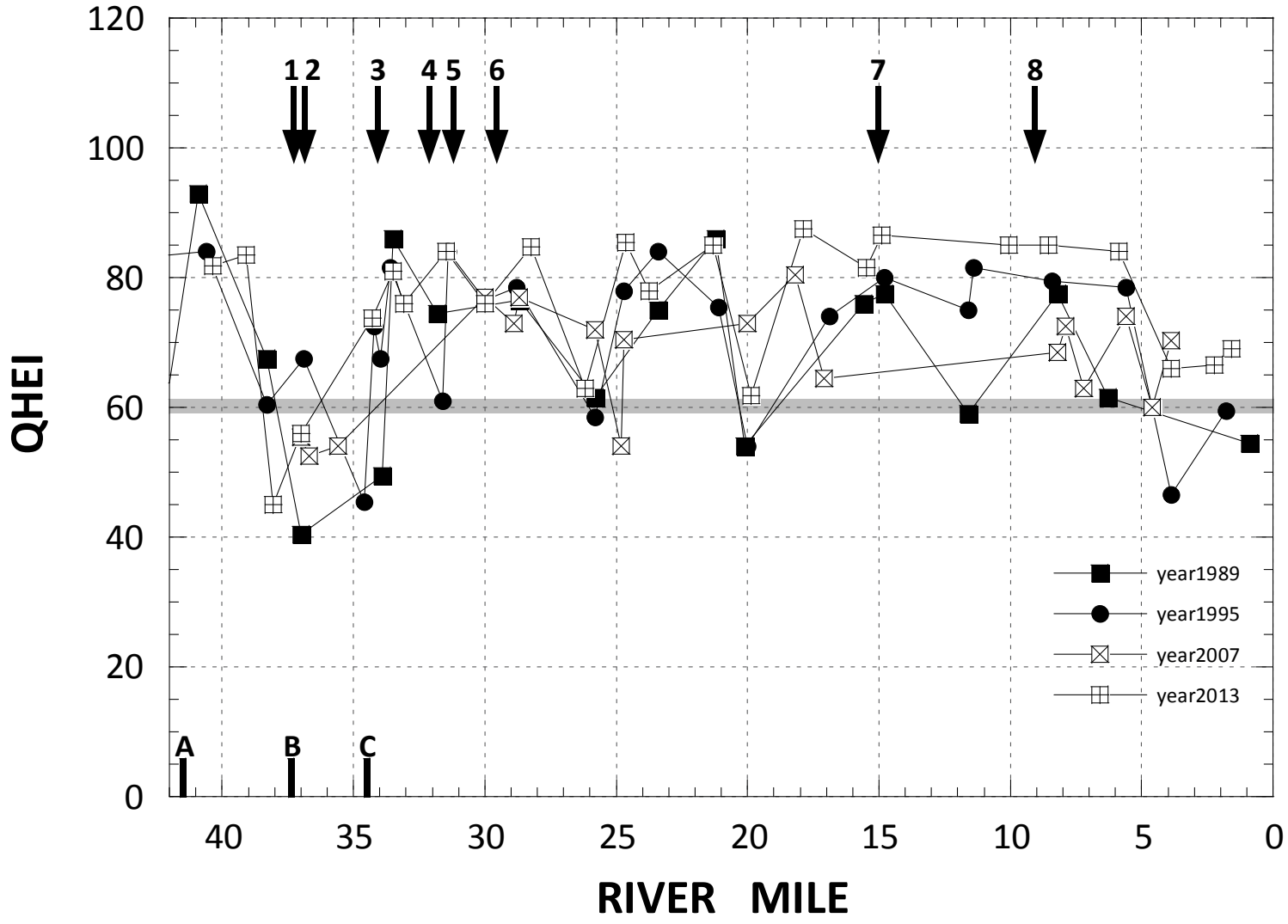

Figure 23. Plot of QHEI (top) vs. river mile in the lower Great Miami River for 1989, 1995, 2007, 2010, and 2013. The thick green band represent thresholds generally indicative of warmwater quality QHEI and habitat attributes. The numbers and letters are discharges and dams listed in Table 9.

Biological Assemblages

Fish and macroinvertebrates were sampled at all wetted sites in 2013. These assemblages were used to assess 49 of the 75 sites in the Great Miami River study area. The remaining 16 were assessed using the Primary Headwater Habitat methodology and two additional sites were dry and assessed with the HHEI.

Fish Assemblage Results 2013

This section focuses on the condition and status of fish assemblages in each of the Great Miami River study area. 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 summarized in Table 16 and individual values listed in Table 17. Overall narrative fish assemblage condition ranged from fishless or very poor to excellent. Of the 60 sites with fish assemblage data that were not assessed as PHWH or were not dry, 47 sites (78.3%) fully attained the IBI biocriteria threshold for WWH or EWH as applicable, and 14 (21.7)% failed to attain the threshold. The non-attaining fraction included 6 (20% of 60 sites) sites that partially attained (either IBI or MIwb attained, but the other index did not). Two sites with an existing WWH use were dry when sampling was attempted. These were not assessed for attainment of the aquatic life use.

Table 16. Fish assemblage sites classified by aquatic life use and attainment or classification status (based on fish data only) during the 2013 lower Great Miami River survey.

Aquatic Life Use	Fish Assemblage Attainment Status			
	N	Full	Partial	Non
EWH	5	4	1	0
WWH	55	43	5	7
WWH (dry)	2	-	-	-
	Primary Headwater Habitat Classification			
PHW 3A	9			
PHW 2	6			

LRAU 90-02 –Great Miami River

In the Great Miami River Mainstem, the partial attainment was due to the failure of the IBI to attain the WWH criterion at three sites (Figure 24, top) and the ICI at two sites (Figure 26, top) while the MIwb met the EWH biocriterion at all sites (Figure 24, bottom). The IBI scores in 2013 were in most cases similar to or higher than the scores collected by Ohio EPA in 2010, and demonstrably better than scores from the 1980, 1989 and 1995 (Figure 24, top).

WAU 08-10 – Jameson Creek - Whitewater River

The fish assemblage condition of the Whitewater River is considered excellent with only the site (GM43) at the mouth slightly impaired (partial) into the good range. This reach had high species

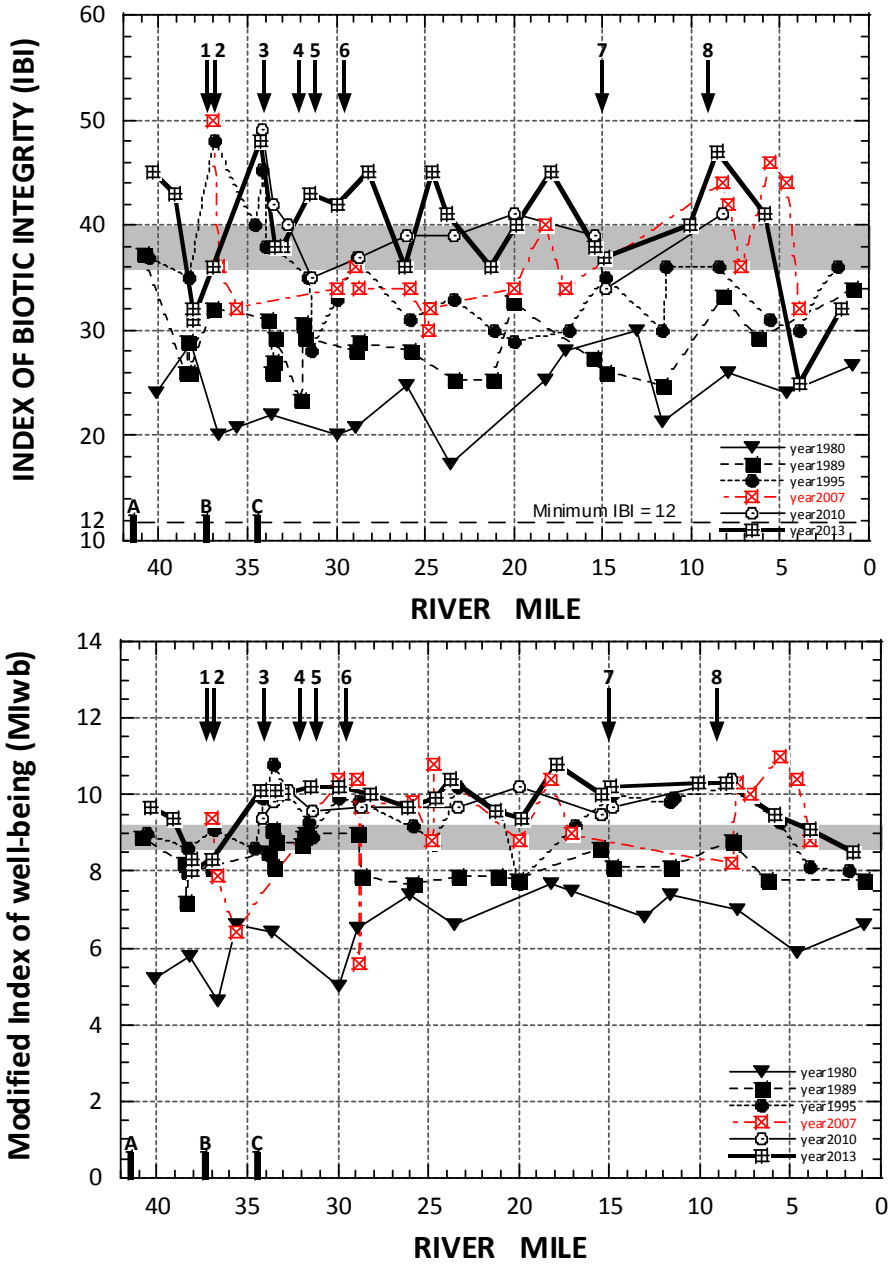

Figure 24. Plots of the Index on Biotic Integrity, IBI (top) or Modified Index of well-being, MIwb (bottom) vs. river mile in the lower Great Miami River during 1980, 1989, 1995, 2007, 2010 and 2013. Shaded bars represent the appropriate biocriteria ranges for the WWH aquatic life use. The numbers and letters are discharges and dams listed in Table 9.

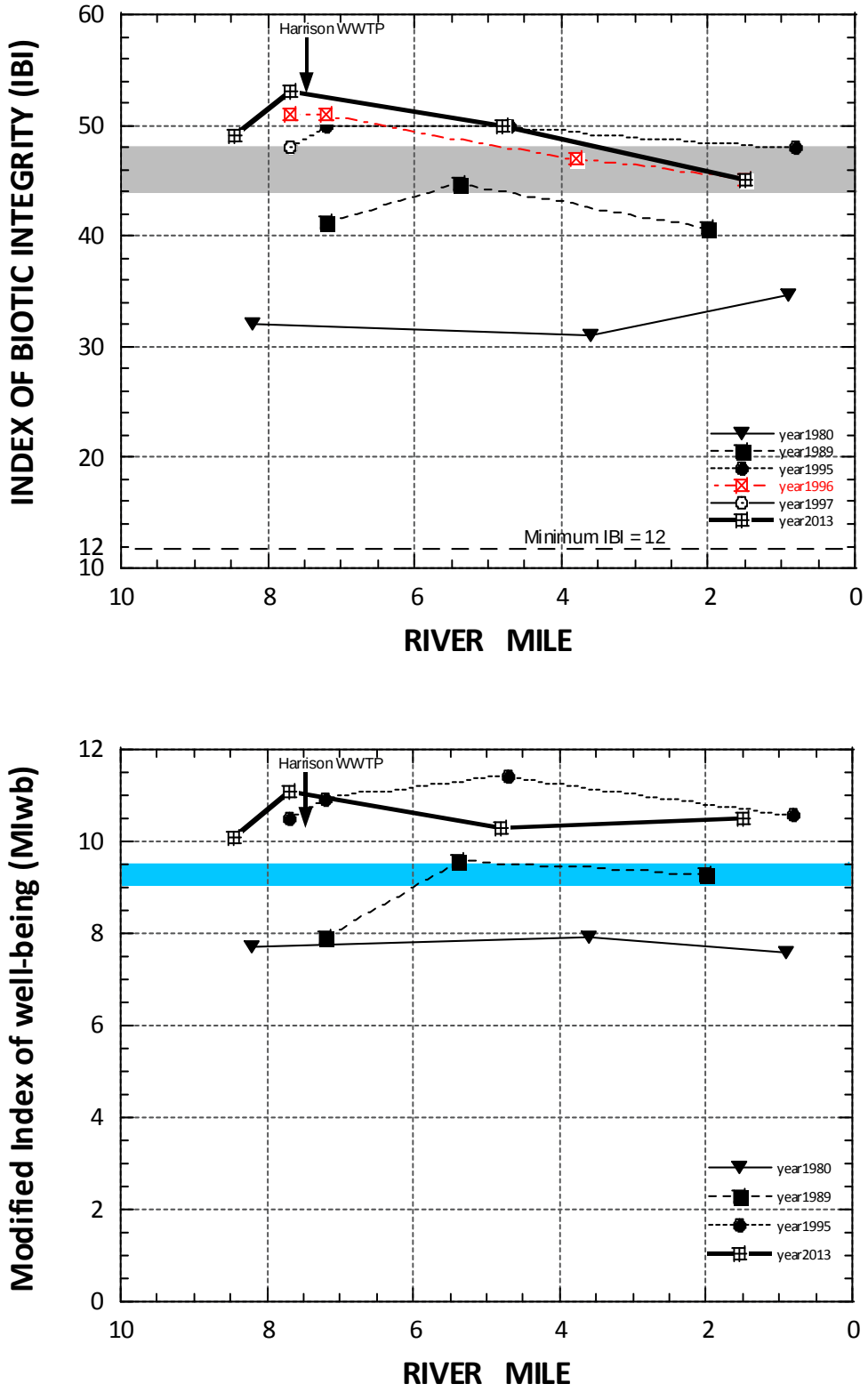

Figure 25. Plots of the Index on Biotic Integrity, IBI (top) and Modified Index of well-being, MIwb (bottom) vs. river mile in Whitewater River during 1980, 1989, 1995, and 2013. Shaded bars represent the appropriate biocriteria ranges for the EWH aquatic life use. The numbers and letters are discharges and dams listed in Table 9.

richness and few tolerant species. This reach has improved substantially compared to 1980 and 1989 surveys when it was impaired by the Harrison WWTP.

WAU 08-08 - Howard Creek - Dry Fork Whitewater River
There were two sites sampled the 08-08 watershed, one on Howard Creek (GM50) and a site on an unnamed tributary site (GM79) to the Dry Fork of the Whitewater River (RM 8.6). Howard Creek attained the WWH biocriterion with an average IBI of 44. The unnamed tributary site (GM79) was too small to attain a WWH aquatic life use and because of limited macroinvertebrate assemblages, lack of salamanders, somewhat limited habitat and low flow conditions was classified as a Primary Headwater Class II stream (PHW2).

WAU 08-09 - Lee Creek - Dry Fork Whitewater River
There were ten sites sampled the 08-09 Lee Creek watershed. There were four sites on Dry Fork of the Whitewater River including three WWH sites and one in an upstream EWH reach. The most upstream site had an impaired IBI although the second sampling pass was in October after some flooding. The three downstream sites attained the criteria for IBI and MIwb. The other six sites were headwater (4) or primary headwater (2).Two of the four sites attained the WWH IBI criterion (GM49, GM63) and two had fair IBI scores (34, 30) that failed to attain the WWH biocriterion (GM58, GM57). Both of Primary Headwater streams were too small to attain a WWH aquatic life use and because of limited macroinvertebrate assemblages, lack of salamanders, somewhat limited habitat and low flow conditions was classified as a Primary Headwater Class II streams (PHW2).

WAU 08-10 - Jameson Creek - Whitewater River
Habitat data in the EWH Whitewater River mainstem was excellent as expected with score near or above 80 (excellent scores). All of the WWH tributaries (Sand Run, Jameson Creek, Fox Run) had good habitat. The only tributary with a lower QHEI score (GM78, 49.5) because of its small size was a small headwater streams that was classified as a primary headwater (PHW3A).

WAU 09-01 - Pleasant Run - Great Miami River
Pleasant Run and its tributaries generally had good habitat quality (QHEI scores 58-66) with some issues with embedded and silted conditions in the tributaries (GM53 and GM 65) related to suburban and urban runoff conditions and likely flashy flows.

WAU 09-02 - Banklick Creek - Great Miami River
Banklick Creek had good habitat conditions (QHEI scores 58-69) with natural channels, but some issues related to silted and embedded conditions from urban runoff that contributed to the partial attainment at GM36. A sampled tributary (GM72) also had similar silt and embeddedness issues, although channel conditions were also natural. A small tributary (GM69) was classified as a primary headwater (PHW3A).

WAU 09-03 - Paddys Run - Great Miami River
Habitat in the two of the four Paddy's Run sites that had flow was good (QHEI scores 67.5-69) with the only poor attributes related to low flow conditions. The variation in flow between sites

was relatively great with the upper sites having flow and the two larger sites in the lower reaches with relatively large drainage areas (12.9-16.8 mi^{-2}) being dry as well as a primary headwater tributary that enters Paddy's Run at RM 0.65 (GM75).

WAU 09-04 Dry Run - Great Miami River
All of the sites in this watershed had good habitat conditions including Bluerock Creek and its tributaries as well as Dunlap Creek and Owl Creek. Physical conditions that influence the aquatic assemblages in these streams include flow issues and some substrate embeddedness likely related to urban runoff.

WAU 09-06 - Jordan Run - Great Miami River
Streams in the Jordan Run watershed ranged from poor to excellent with lack of flow and altered substrates conditions (embedded substrates) from urban runoff being the great risk to aquatic life. All streams had natural channels except for GM70 which was channelized. A number of the smaller tributaries were classified as primary headwater streams including the upstream-most site on Jordan Creek (GM24).

Reference Sites
Three sites on two reference streams (14-022 – Elk Creek [WAU 07-01]; 14-010 – Indian Creek [WAU 08-03]) all had excellent QHEI scores (76.5-78) and the only poor habitat attributes included some minor silt cover and embeddedness.

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Great Miami River study area, 2013.

			Fish Statistics										Macroinvertebrate Statistics				
Site ID	Site RM Range	Drain. Area (mi.^{2})	QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tol-erant	Rel. Number	% DELT	MIwb	IBI	ICI	Narr[1]	Qual EPT	Cold Water taxa	Aq. Life Use
LRAU 90-02 – Great Miami River																	
11-001 – Great Miami River																	
GM01	40.30 - 40.37	3290	81.8	23.5	11.0	0.0	10.83	16.58	785	2.11	9.70	45.0	24.0		16.0	0.0	WWH
GM02	38.55 - 39.10	3290	83.5	18.5	9.0	0.0	11.86	18.11	570	0.69	9.39	43.0	40.0		13.0	0.0	WWH
GM03	38.05 - 38.27	3620	45.0	16.0	6.0	0.0	13.86	28.14	374	0	8.04	31.0	-		-	0.0	WWH
GM04	36.98 - 37.05	3630	56.0	16.0	5.0	0.0	17.52	32.80	628	1.35	8.33	36.0	36.0		14.0	0.0	WWH
GM05	34.12 - 34.30	3640	73.8	22.0	7.5	0.0	2.44	6.02	410	0.65	10.06	48.0	38.0		16.0	0.0	WWH
GM06	33.50 - 33.67	3650	81.0	24.5	7.5	0.0	6.20	7.04	352	1.91	10.13	38.0	30.0		16.0	0.0	WWH
GM07	32.69 - 33.07	3650	76.0	21.5	6.0	0.0	6.35	10.27	361	0.93	10.02	38.0	34.0		16.0	0.0	WWH
GM08	31.20 - 31.46	3650	84.0	25.0	8.0	0.0	4.82	7.22	401	0	10.18	43.0	-	MG	15.0	0.0	WWH
GM09	29.98 - 30.15	3670	76.0	27.0	8.5	0.0	16.04	18.77	564	0	10.23	42.0	34.0		15.0	0.0	WWH
GM10	28.15 - 28.75	3680	84.8	22.5	9.0	0.0	1.83	2.74	330	0.30	9.97	45.0	40.0		18.0	0.0	WWH
GM11	26.20 - 27	3790	63.0	20.0	6.0	0.0	5.03	9.78	297	0.86	9.71	36.0	-	MG	15.0	0.0	WWH
GM12	24.55 - 24.67	3800	85.5	22.0	9.5	0.0	0.22	2.38	405	0.44	9.94	45.0	44.0		14.0	0.0	WWH
GM13	23.63 - 23.74	3810	78.0	23.5	8.0	0.0	4.47	4.77	351	0.61	10.40	41.0	-	G	16.0	0.0	WWH
GM14	21.32 - 21.70	3820	85.0	21.5	7.5	0.0	0	2.80	250	0.45	9.64	36.0	40.0		15.0	0.0	WWH
GM15	19.87 - 20.14	3840	61.8	20.5	3.5	0.0	6.59	8.43	503	0	9.35	40.0	34.0		16.0	0.0	WWH
GM16	17.89 - 18.63	3840	87.5	31.5	12.0	0.0	5.13	7.16	490	0.20	10.81	45.0	-	G	18.0	0.0	WWH
GM17	15.48 - 15.72	3840	81.5	22.5	7.0	0.0	3.75	5.42	323	0.51	9.99	38.0	32.0		13.0	0.0	WWH
GM18	14.70 - 14.91	3870	86.5	19.5	7.0	0.0	0.32	2.74	456	0	10.18	37.0	44.0		16.0	0.0	WWH
GM19	9.97 - 10.05	3880	85.0	28.0	10.0	0.0	0.53	0.53	348	2.49	10.30	40.0	-		-	0.0	WWH
GM20	8.48 - 8.55	3880	85.0	24.0	10.0	0.0	0.21	0.21	376	0.93	10.25	47.0	44.0		20.0	0.0	WWH
GM21	5.55 - 5.89	5360	84.0	21.0	7.0	0.0	0.25	1.07	351	1.22	9.52	41.0	30.0		16.0	0.0	WWH
GM22	3.78 - 3.89	5370	66.0	16.0	3.5	0.0	1.94	4.68	333	2.29	9.09	25.0	38.0		9.0	0.0	WWH
GM23	1.59 - 1.80	5370	69.0	15.0	3.0	0.0	0.77	7.89	410	0.22	8.54	32.0	30.0		1.0	0.0	WWH
WAU 08-08 - Howard Creek - Dry Fork Whitewater River																	
14-304 – Howard Creek																	
GM50	2.85 - 2.91	5.80	66.5	17.0	4.0	2.0	49.74	66.74	2730	0	0	44.0	-	G	10.0	0.0	WWH
14-922 - Unnamed Trib to Dry Fork Whitewater River																	
GM79	0.01 - 1.40	0.90	36.5	4.0	0.0	1.0	50	75	40	0	0	28.0	-	-	2.0	0.0	PHW2
WAU 08-09 - Lee Creek - Dry Fork Whitewater River																	
14-302 – Dry Fork Whitewater River																	
GM45	10.21 - 10.65	46.90	75.8	21.0	10.0	1.0	32.08	28.52	2922	0	9.37	42.0	-	E	19.0	0.0	EWH
GM46	6.95 - 7.36	59.70	73.8	21.5	9.5	2.0	17.23	15.90	1571	0	8.53	42.0	50.0		22.0	1.0	WWH
GM47	4.34 - 4.45	78.50	65.8	19.0	7.5	1.5	18	13.59	903	0.58	8.66	40.0	-	E	18.0	0.0	WWH

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Great Miami River study area, 2013.

			Fish Statistics										Macroinvertebrate Statistics				
Site ID	Site RM Range	Drain. Area ($mi.^2$)	QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tolerant	Rel. Number	% DELT	MIwb	IBI	ICI	Narr[1]	Qual EPT	Cold Water taxa	Aq. Life Use
GM48	0.53 - 1.25	81.10	48.0	26.5	10.0	2.0	29.94	13.74	3467	0	9.61	51.0	-	E	21.0	0.0	WWH
14-303 – Lee Creek																	
GM49	4.55 - 4.75	4.30	70.8	17.0	3.0	2.0	40.34	46.24	2608	0	0	44.0	-	F	5.0	0.0	WWH
14-320 - Unnamed Trib to Dry Fork Whitewater River(6.73)																	
GM67	0.28 - 0.35	3.20	54.0	9.0	1.0	1.0	44.60	52.52	278	0	0	34.0	-	VP	0.0	0.0	WWH
14-903 - Unnamed Trib to Dry Fork Whitewater River(6.30)																	
GM56	1.61 - 1.63	1.20	38.3	4.0	0.0	0.0	92.59	100	162	0	0	26.0	-	-	0.0	0.0	PHW2
14-904 - Unnamed Trib to Lee Creek (0.15)																	
GM58	1.14 - 1.15	1	51.5	8.0	0.0	1.0	80.21	89.58	384	0.52	0	30.0	-	VP	0.0	0.0	WWH
14-910 - Unnamed Trib to Lee Creek (3.81)																	
GM63	0.35 - 0.41	0.80	48.8	8.0	1.0	2.0	71.23	86.30	146	0	0	42.0	-	F	4.0	1.0	WWH
WAU 08-10 - Jameson Creek - Whitewater River																	
14-300 - Whitewater River																	
GM40	8.32 - 8.45	1370	79.0	25.0	10.5	0.0	12.86	11.81	726	0.36	10.12	49.0	58.0		27.0	0.0	WWH
GM41	6.98 - 7.70	1370	86.5	31.5	14.0	0.0	1.71	2.31	754	0.27	11.08	53.0	54.0		25.0	0.0	WWH
GM42	3.98 - 4.80	1380	80.8	23.0	8.0	0.0	14.48	3.93	765	0	10.29	50.0	58.0		24.0	0.0	WWH
GM43	1.35 - 1.50	1470	81.3	26.0	9.0	0.0	3.44	3.34	934	0.27	10.51	45.0	58.0		25.0	0.0	WWH
14-301 – Sand Run																	
GM44	2.35 - 2.38	1.10	66.5	7.0	1.0	3.0	41.67	56.67	120	0	0	48.0	-	F	4.0	0.0	WWH
14-307 – Jameson Creek																	
GM51	0.91 - 0.94	6.10	69.5	19.0	4.0	3.0	40.90	39.58	1506	0	0	48.0	-	G	12.0	1.0	WWH
GM52	0.09 - 0.20	6.60	62.8	23.0	7.0	2.0	45.45	53.93	1628	0	0	50.0	-	G	10.0	2.0	WWH
14-911 - Unnamed Trib to Whitewater River(2.35)																	
GM64	0.28 - 0.30	0.70	66.5	6.0	0.0	2.0	79.37	84.13	126	0	0	34.0	-	-	7.0	1.0	PHW3A
14-917 - Fox Run (to the Whitewater River) (2.05)																	
GM71	0.05 - 0.16	0.90	55.0	10.0	1.0	2.0	54.67	60	225	0	0	42.0	-	MG	6.0	1.0	WWH
14-921 - Unnamed Trib to Sand Run																	
GM78	0.03 - 1.89	2.80	49.5	3.0	0.0	0.0	100	96.30	54	0	0	22.0	-	-	2.0	0.0	PHW3
WAU 09-01 - Pleasant Run - Great Miami River																	
14-013 – Pleasant Run																	
GM38	5.78 - 5.90	0.70	66.0	4.0	0.0	2.0	41.33	53.33	600	0	0	40.0	-	F	4.0	0.0	WWH
14-901 - Unnamed Trib to Pleasant Run (2.29)																	
GM53	0.02 - 0.07	0.30	58.0	3.0	0.0	1.0	58.82	94.12	68	0	0	24.0	-	-	3.0	0.0	PHW2
14-912 - Unnamed Trib to Pleasant Run(5.26)																	

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Great Miami River study area, 2013.

			Fish Statistics										Macroinvertebrate Statistics				
Site ID	Site RM Range	Drain. Area ($mi.^2$)	QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tolerant	Rel. Number	% DELT	MIwb	IBI	ICI	Narr[1]	Qual EPT	Cold Water taxa	Aq. Life Use
GM65	5.78 - 5.90	1.20	63.8	5.0	1.0	2.0	52.01	82.57	746	0	0	42.0	-	P	3.0	1.0	WWH
WAU 09-02 - Banklick Creek - Great Miami River																	
14-915 - Unnamed Trib to Banklick Creek(2.55)																	
GM69	0.15 - 0.23	0.70	0.0	Dry	-	-	-	-	-	-	-	-	-	-	5.0	3.0	PHW3A
14-012 – Banklick Creek																	
GM35	3.30 - 3.41	1.20	29.0	10.0	1.0	3.0	67.11	87.83	608	0	0	40.0	-	MG	6.0	1.0	WWH
GM36	2.61 - 2.65	3.10	60.0	11.0	2.0	2.0	63.46	81.23	810	0.25	0	34.0	-	MG	6.0	3.0	WWH
GM37	0.21 - 0.35	6.30	69.0	10.0	2.0	2.0	19.67	36.48	488	0.41	0	38.0	-	G	11.0	0.0	WWH
Unnamed Trib to Banklick Creek (3.13)																	
GM72	0.06 - 0.25	1.50	52.0	6.0	0.0	3.0	68.75	91.96	224	0	0	32.0	-	MG	7.0	1.0	WWH
WAU 09-03 - Paddys Run - Great Miami River																	
14-005 Paddys Run																	
GM26	4.68 - 4.72	6.80	67.5	14.0	1.0	3.0	40.21	44.87	2318	0	0	40.0	-	G	7.0	0.0	WWH
GM27	3.80 - 3.82	9.60	69.0	19.0	3.0	3.0	39.52	46.97	2146	0	0	46.0	44.0		6.0	1.0	WWH
GM28	1.79	12.90	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-	WWH
GM29	0.10 - 0.24	16.30	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-	WWH
14-920 - Unnamed Trib to Paddy's Run(0.65)																	
GM75	0.29 - 0.30	0.70	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-	PHW2
WAU 09-04 Dry Run - Great Miami River																	
14-006 – Bluerock Creek																	
GM30	2.24 - 2.29	0.70	66.8	1.0	0.0	0.0	100	100	10	0	0	-	-	-	4.0	2.0	PHW3A
GM31	1.35 - 1.53	5.70	70.3	4.0	0.0	0.0	75.40	75.40	252	0	0	22.0	-	-	6.0	0.0	PHW3A
GM32	0.43 - 0.47	7.30	69.5	24.0	9.0	1.0	29.96	30.69	1362	0.15	0	50.0	-	G	8.0	0.0	WWH
14-007 – Owl Creek																	
GM33	0.35 - 0.61	1.60	61.0	9.0	1.0	3.0	58.05	88.51	348	0	0	38.0	-	F	5.0	0.0	WWH
14-008 – Dunlap Creek																	
GM34	0.86 - 0.90	1.80	60.5	9.0	1.0	3.0	64.76	82.86	420	0	0	40.0	-	MG	6.0	1.0	WWH
14-902 - Unnamed Trib to Blue Rock Creek (1.37)																	
GM54	1.72 - 1.83	2.10	62.3	2.0	0.0	0.0	100	100	194	0	0	20.0	-	P	2.0	0.0	WWH
14-914 - Unnamed Trib to the Great Miami River(26.52)																	
GM68	0.19 - 0.23	1.10	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-	PHW2
14-919 - Unnamed Trib to Unnamed Trib(2.65) to Blue Rock Cr																	
GM74	0.14 - 0.19	0.90	70.5	1.0	0.0	0.0	100	100	12	0	0	-	-	VP	0.0	0.0	WWH

Table 17. Key biological and habitat variables for fish and macroinvertebrates in the Great Miami River study area, 2013.

			Fish Statistics										Macroinvertebrate Statistics				
Site ID	Site RM Range	Drain. Area ($mi.^2$)	QHEI	Total Sp.	Sens. Sp.	HW Sp.	% Pioneer	% Tol-erant	Rel. Number	% DELT	MIwb	IBI	ICI	Narr[1]	Qual EPT	Cold Water taxa	Aq. Life Use
WAU 09-06 - Jordon Run - Great Miami River																	
14-003 – Jordan Creek (WWH)																	
GM24	2.24 - 2.25	0.70	66.5	2.0	0.0	0.0	100	100	24	0	0	-	-	-	4.0	1.0	PHW3A
GM25	0.82 - 0.91	2.30	73.3	10.0	2.0	2.0	21	51.50	400	0	0	44.0	-	G	10.0	0.0	WWH
14-182 – Tributary to Great Miami River																	
GM39	0.21 - 0.38	0.50	62.3	0.0	0.0	0.0	0	0	0	0	0	-	--	-	1.0	1.0	PHW3A
14-907 - Unnamed Trib to the Great Miami River(12.0)																	
GM60	0.35 - 0.55	1.80	50.5	5.0	1.0	0.0	66.67	71.43	42	0	0	26.0	-	-	2.0	0.0	PHW3A
14-909 - Unnamed Trib to the Great Miami River (8.50)																	
GM62	0.40 - 0.54	0.60	59.5	9.0	2.0	3.0	73.04	90.43	460	0	0	44.0	-	MG	6.0	3.0	WWH
14-913 - Unnamed Trib to the G. Miami River 19.2 .75)																	
GM66	0.53 - 0.59	0.90	53.0	4.0	0.0	0.0	64.32	64.32	398	0	0	28.0	-	VP	0.0	1.0	WWH
14-916 - Unnamed Trib to the Great Miami River(7.74)																	
GM70	0.30 - 0.40	1.20	41.0	9.0	0.0	1.0	72.50	78.13	320	0	0	32.0	-	P	2.0	1.0	WWH
14-906 Unnamed Trib to the Great Miami River (3.7)																	
GM59	0.73 - 0.74	1.10	0.0	1.0	0.0	0.0	0	0	0	0	0	-	-	-	7.0	2.0	PHW3A
Reference Sites																	
14-022 – Elk Creek [WAU 07-01]																	
RF24	3.64 - 4.64	44.90	78.0	16.0	5.0	3.0	5.09	7.41	1173	0	7.10	37.0	-	-	-	-	WWH
14-010 – Indian Creek [WAU 08-03]																	
RF23	9.71 - 9.75	82.30	75.5	29.0	13.5	1.0	21.34	20.46	1469	0.05	9.90	53.0	-	-	-	-	WWH
RF22	4.27 - 4.33	102	76.0	22.0	11.0	1.5	8.69	8.07	972	0.17	9.39	49.0	-	-	-	-	WWH

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

Macroinvertebrate Assemblage Results 2013

Macroinvertebrate assemblages in the Great Miami study area were representative of fair to good water quality in the mainstem of the Great Miami River and excellent conditions in the Whitewater River. Many of the smaller streams in the basin were evaluated as fair to good water quality, with the exception of a few small tributaries that were rated as poor to very poor because of impairments from leaking septic systems and low flow conditions as will be detailed below. The larger Dry Fork Whitewater River had excellent macroinvertebrate communities.

LRAU 90-02 –Great Miami River

In the Great Miami River Mainstem, the macroinvertebrates met the WWH criteria at all sites where valid data were collected (Table 17, Figure 26). The ICI scores were slight lower than in 2010; however the Qual EPT taxa were similar to data collected during that year. Many of the HD samplers were heavily colonized by *Glypotendipes,* perhaps in response to nutrient and flow conditions during 2013 which depressed the scores of the proportional ICI metrics.

WAU 08-10 – Jameson Creek - Whitewater River

The macroinvertebrate assemblage condition of the Whitewater River is considered excellent with very high ICI scores (one 54, three at 58) and high number of QUAL EPT taxa (24-27). This reach has improved substantially compared to surveys in the 1980s when it was impaired by the Harrison WWTP. Macroinvertebrate assemblages in Jameson Creek (GM51, GM52) were rated as good and in Fox Run (GM71) as marginally good. Sand Run (GM44) was the only WWH tributary not meeting the criterion and was rated as Fair. Two other tributaries were too small to support WWH assemblages, but had southern two-line salamanders and were classified as PHW3A streams.

WAU 08-08 - Howard Creek - Dry Fork Whitewater River

There were two sites sampled the 08-08 watershed, one on Howard Creek (GM50) and a site on an unnamed tributary site (GM79) to the Dry Fork of the Whitewater River (RM 8.6). Howard Creek had a narrative rating of Good and attained the WWH aquatic life use. The unnamed tributary site (GM79) was too small to attain a WWH aquatic life use and because of limited macroinvertebrate assemblages, lack of salamanders, somewhat limited habitat and low flow conditions was classified as a Primary Headwater Class II stream (PHW2).

WAU 08-09 - Lee Creek - Dry Fork Whitewater River

There were ten sites sampled the 08-09 Lee Creek watershed. There four sites on the Dry Fork of the Whitewater River and all were considered Exceptional with one site (GM46) scoring an ICI of 50 and the other three sites (GM45, GM47, GM48) achieving narrative ratings of Excellent. The other six sites were headwater (4) or primary headwater (2). None of the Warmwater sites achieved the macroinvertebrate WWH rating with two in fair condition (Lee Creek, GM49, and an unnamed tributary to Lee Creek, GM63) and two sites in Very Poor Condition (an unnamed tributary to Dry Fork, GM67, and a tributary to Lee Creek, GM58). The Primary Headwater streams were too small to attain a WWH aquatic life use and because of limited macroinvertebrate assemblages, lack of salamanders, somewhat limited habitat and low flow conditions were classified as a Primary Headwater Class II streams (PHW2).

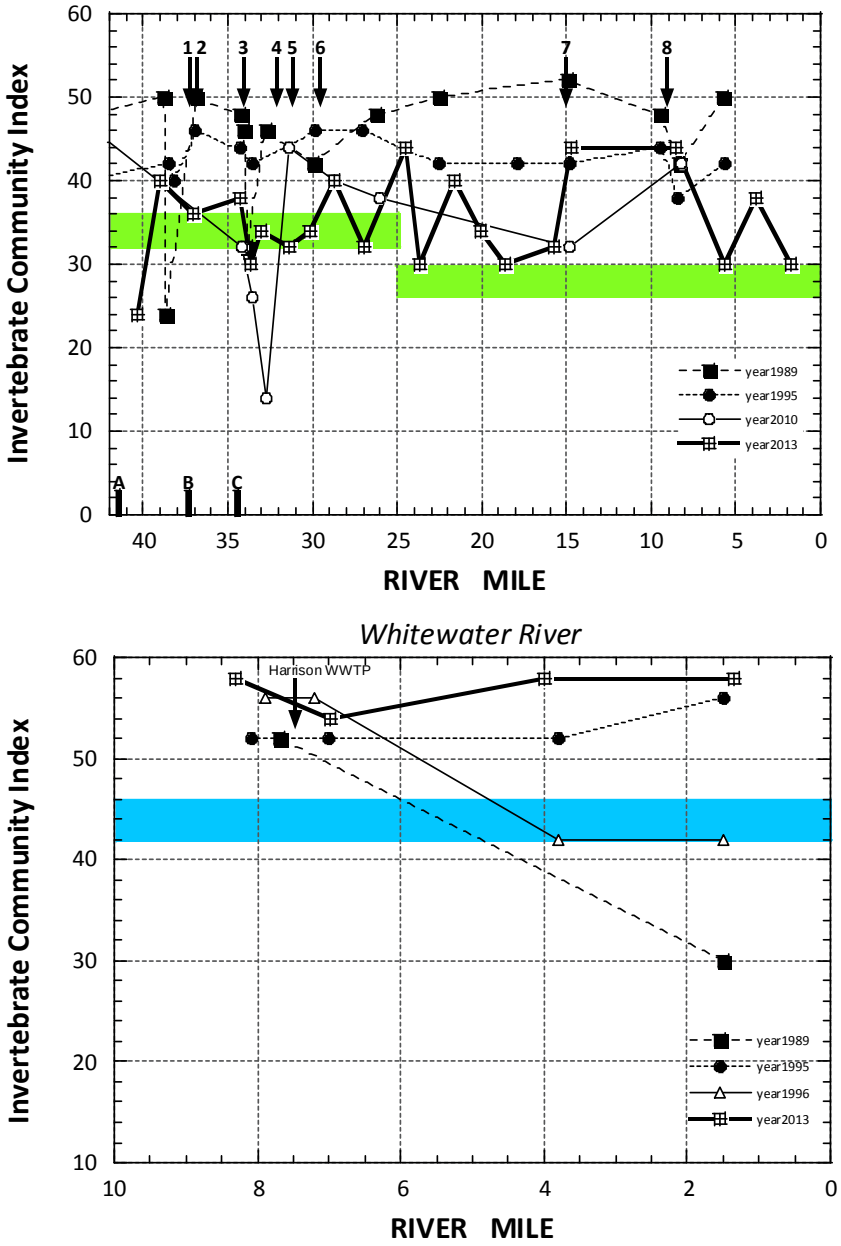

Figure 26. Plot of the ICI vs. river mile in the Great Miami River mainstem (top) and the Whitewater River (bottom) during 2013 and with major prior year Ohio EPA results. The shaded bars represent the applicable ICI biocriteria for the EWH (blue) and WWH (green) aquatic life use tiers. The numbers and letters are discharges and dams listed in Table 9.

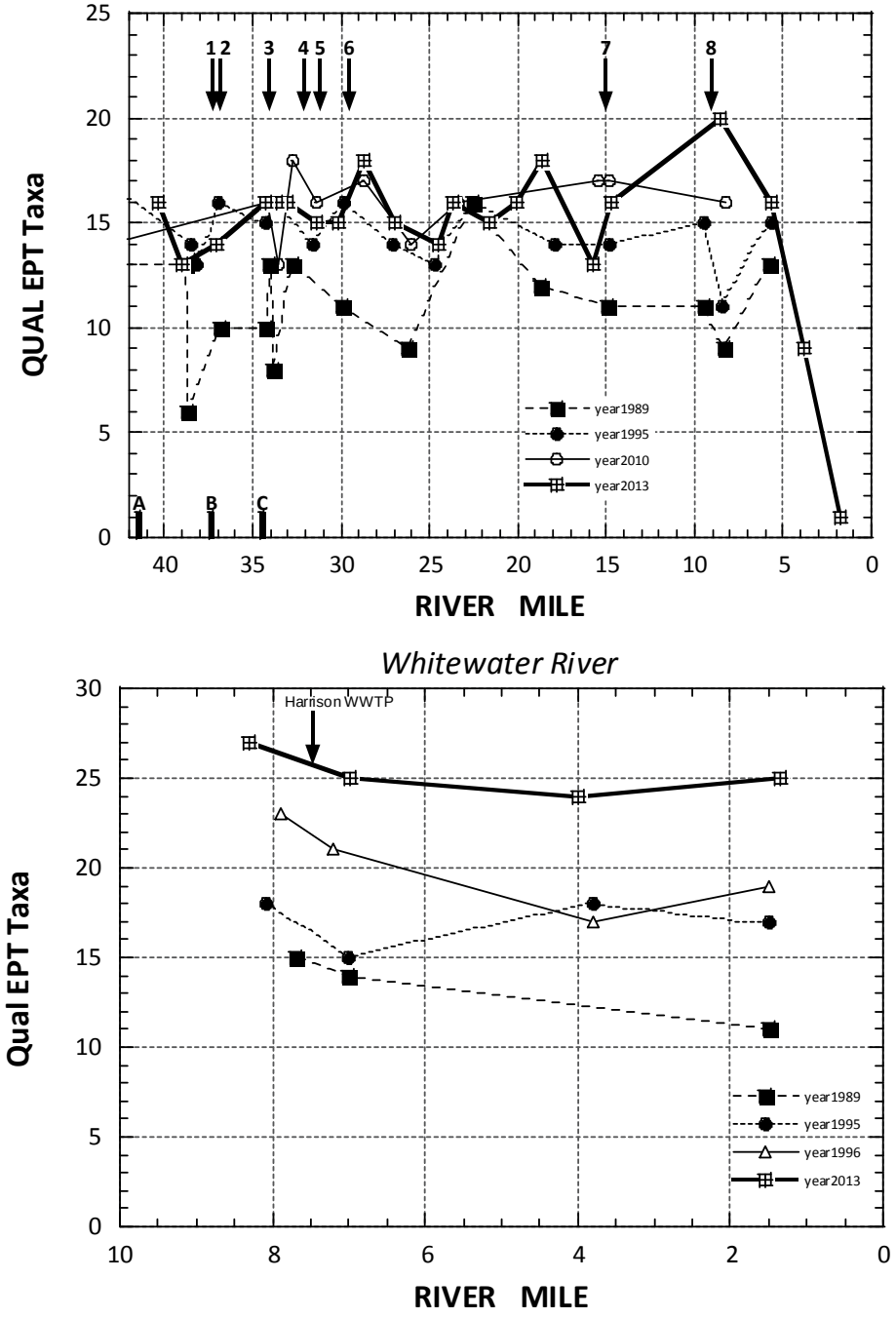

Figure 27. Plot of the qualitative EPT taxa vs. river mile in the Great Miami River mainstem (top) and the Whitewater River (bottom) during 2013 and with major prior year Ohio EPA results.

WAU 08-10 - Jameson Creek - Whitewater River
Macroinvertebrate assemblages in the EWH Whitewater River mainstem were excellent with scores in the highest range of the ICI (1 at 54, 3 at 58) and high richness of QUAL EPT taxa (24-27). Two sites (GM51, GM52) on the WWH Jameson Creek had Good narrative ratings and the site (GM71) on Fox Run was rated as Marginally Good. The site (GM44) on Sand Run was rated as fair and thus failed to achieve the WWH threshold and with an attain IBI score is considered partially impaired. Two tributaries, an unnamed tributary to the Whitewater River (GM64) and an unnamed tributary to Sand Run (RM78), because of their small size and populations of southern two-lined salamanders were classified as PHW3A streams.

WAU 09-01 - Pleasant Run - Great Miami River
We assessed three streams in this watershed. Pleasant Run (GM38) and an unnamed tributary to Pleasant Run (GM65) were assessed as WWH streams and neither achieve the appropriate narrative rating of Good with Pleasant Run rated as Fair and the tributary as Poor and considered limited by urban runoff and sedimentation. The tributary to Pleasant Run at RM 2.29 was small and flow limited although has suitable habitat to be considered as a PHW2 category streams.

WAU 09-02 - Banklick Creek - Great Miami River
There were three streams sampled in the Banklick Creek watershed and two of these were considered to be WWH streams. All sites in these streams (three in Banklick Creek, GM35, GM36, GM37 and one in an unnamed tributary to Banklick Creek GM72) achieved the a rating consistent with the WWH use (three Marginally Good, one Good). The small tributary (GM69) was classified as a primary headwater (PHW3A) based on the populations of southern two-line salamanders, but also had 7 EPT taxa and 1 coldwater taxa.

WAU 09-03 - Paddys Run - Great Miami River
Macroinvertebrate assemblage results in the two of the four Paddy's Run sites (GM26, GM27) met WWH levels, one with a narrative rating of Good and the other with an ICI of 44. The two downstream sites with relatively large drainage areas (12.9-16.8 mi^{-2}) were dry and could not be assessed. A tributary that enters Paddy's Run in this lower dry reach at RM 0.65 (GM75) was also flow limited, but had sufficient natural habitat to be classified as a PHW2 stream.

WAU 09-04 Dry Run - Great Miami River
Macroinvertebrate assemblage were highly variable among eight sites sampled in this watershed and included one rated as Good, one Marginally Good, one Fair, one Poor, one Very Poor, and two sites classified as PHW3A streams and one as a PWH 2. A site (GM32) in Bluerock Creek had the Good rating and the upper two sites (GM30, GM31) were classified as PHW3A because of small size and populations of southern two-line salamanders. The site in Dunlap Creek was rated as Marginally Good. Owl Creek was rated as Fair. Two tributaries two Bluerock Creek (GM54, GM74) were rated as Poor and Very Poor which was attributed to urban runoff and septic impacts exacerbated by low flow conditions. GM 74 was located within a large commercial development off of Colerain Avenue, between Stone Creek Blvd./Havertos Ct. and Interstate 275. Septic drainage was observed entering the stream on 8/20/2013. The sewage

fungus *Sphaerotilis* was also observed present in this tributary. The very poor water quality at GM74 may be impacting the downstream site at GM54. A direct tributary to the Great Miami River in this watershed had too little flow for sampling, but sufficient habitat features to classify as a PHW2 stream.

WAU 09-06 - Jordan Run - Great Miami River

Streams in the Jordan Run watershed had a wide variety of macroinvertebrate assemblage condition which ranged from Very Poor to Good with impaired conditions largely a result of urban runoff and altered substrates magnified by flashy and low flow conditions. All streams had natural channels except for GM70 which was channelized. A number of the smaller tributaries were classified as primary headwater streams including the upstream-most site on Jordan Creek (GM24). The lower site on Jordan Creek was rated as Good and has 10 Qual EPT taxa. The other tributaries in the watershed were all direct tributaries to the Great Miami River with GM66 and GM70 being rated as Very Poor and Poor respectively. One tributary site (GM62) was rated as Marginally Good.

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