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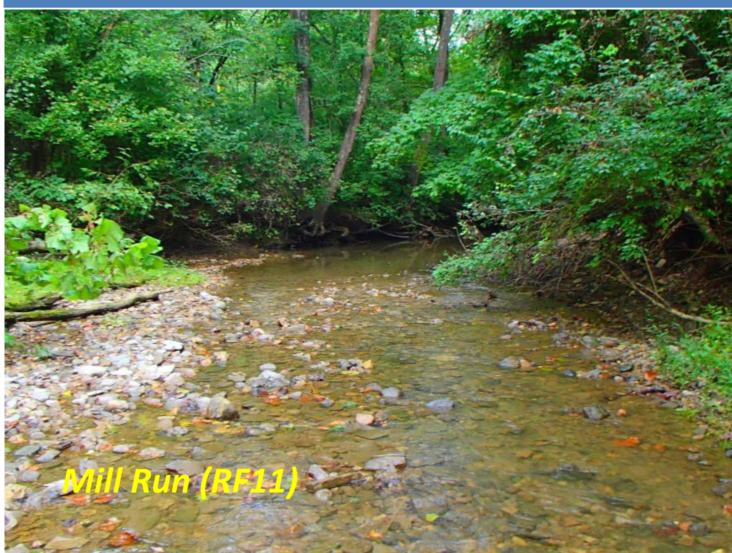
Biological and Water Quality Assessment of the Ohio River, Direct Ohio River Tributaries, and Taylor Creek 2014



Mill Run (RF11)

Rapid Run (RR02)

Taylor Creek (GM82)

Ohio River (OR28)

MSD Agreement 15x11039
Project Number 10180900

Report citation:

Midwest Biodiversity Institute (MBI). 2015. Biological and Water Quality Assessment of the Ohio River, Direct Ohio River Tributaries, and Taylor Creek 2014. Hamilton County, Ohio. Technical Report MBI/2015-6-7. MSD Project Number 10180900. Columbus, OH 43221-0561. 149 pp. + appendices. www.midwestbiodiversityinst.org/publications/.

Biological and Water Quality Assessment of the Ohio River, Direct Ohio River Tributaries, and Taylor Creek 2014

Hamilton County, Ohio

Technical Report MBI/2014-6-7

MSD Project Number 10180900

September 30, 2015

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Acknowledgements

Chris O. Yoder, MBI, served as the report editor and project manager. Contributions to the report and the analyses included Edward T. Rankin, Vickie L. Gordon, Mick L. Micacchion, Martin J. Knapp, Jack Freda, and Rachel Day, all of MBI. Database management and data analysis was provided by Edward T. Rankin and Vickie L. Gordon. Field crew leaders were Vickie L. Gordon (fish assemblage), Martin J. Knapp (macroinvertebrate assemblage), and Sarah Atkins (Datasondes and chemical assessment) Field sampling assistance was provided by Alex Roller-Knapp, Blair Prusha, Sarah Atkins, Cory Hoffman, and Julie Backus. Logistical and administrative support was provided by Allison Boehler and Julia Meeker. Chemical analysis was provided by the MSDGC Division of Industrial Waste laboratory. Laboratory support and coordination was provided by Wanda Harney, James Davis, and Lindsay Movosky of MSDGC. Overall MSDGC project management was directed by Ting Lu, Laith Alfaqih, and Bruce Whitteberry. We also thank ORSANCO for the assistance provided by Jeff Thomas, Ryan Argo, and Robert Tewes with the Ohio River mainstem biological data analyses and their advice about the assessment of that data.

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)	<u>Scientific meaning</u>: 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. <u>Regulatory meaning</u>: 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
ORFIn	Ohio River Fish Index
ORMIn	Ohio River Macroinvertebrate Index
ORSANCO	Ohio River Valley Water Sanitation Commission
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
SNAP	Stream Nutrient Assessment Procedure
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 the 2014 study in that the subject streams and rivers represent a collection of tributary subwatershed and one mainstem river 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 surveys performed by Ohio EPA in the 1990s and by ORSANCO since 2005. 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 2014 Biological and Water Quality Assessment

The 2014 Biological and Water Quality Assessment gathered relevant information to determine and assess current conditions in the Ohio River mainstem throughout the Markland navigation pool, Direct Tributaries to the Ohio River between Mill Creek and the Great Miami River, and the Taylor Creek watershed. Understanding and improving water quality is an important component of Project Groundwork, the largest capital improvement program to reduce CSOs and SSOs within the MSDGC service area. The Mill Creek, Duck Creek, and Direct Ohio River Tributary watersheds contain the most extensive concentration of CSOs in the MSDGC Service Area. While the L. Miami River and Great Miami R. mainstems and tributaries lack CSOs they are impacted by suburban development, unsewered areas, and treated sanitary wastewater. The 2014 biological and water quality assessment had three major objectives:

1. Determine the extent to which biological assemblages, habitat, and water quality are impaired (using Ohio EPA and ORSANCO 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 Ohio River mainstem, Direct Tributaries, and Taylor Creek 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 and ORSANCO, 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 recommend-ations 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 developed a plan that would lead to ways to identify and 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 2014 bioassessment is the fourth 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 (and ORSANCO for the Ohio River mainstem). 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 with a high density of sampling sites and biological, chemical, and physical parameters was followed. The principal objectives 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 (and ORSANCO for the Ohio River mainstem). As such, these determinations are typically categorical with the identification of specific pollutants when possible. 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 subregions. This will include a more detailed analyses of regional patterns in limiting stressors and it will include the data generated by the MSDGC 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 and planning for expansion into less developed areas of Hamilton County.

The 2014 study area included the Ohio River mainstem along the length of the Markland navigation pool, Direct Tributaries to the Ohio River between Mill Creek and the Great Miami River, and the Taylor Creek watershed. A combined geometric/intensive pollution survey design was used to select sampling sites in the Direct Tributaries and the Taylor Creek watershed with sampling sites located in the upper reaches to drainage areas of <1.0 $mi.^2$. An intensive pollution survey design was used to select sites along the Ohio River mainstem making use of prior ORSANCO sampling locations as much as possible. In addition, 15 sites comprising the ORSANCO probabilistic design in the Markland pool were also included. 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 Ohio aquatic life uses presently assigned to streams and rivers in the MSDGC service area are appropriate and attainable. This analysis is limited to the Direct Ohio River Tributaries and Taylor Creek which are covered by the Ohio WQS. The Ohio River mainstem is excluded as it is covered under ORSANCO standards and designations.

Aquatic Life Use Recommendations for the Direct Tributaries and Taylor Creek Watersheds

In terms of the recommended use changes highlighted in Table 1 none deal with changing existing designated uses for the major mainstem rivers. Two streams (Rapid Run and Wulff Run) were designated as Limited Resource Waters (LRW) in 1992 because of the wholesale loss of habitat due to the recent installation of sewer lines in the bedrock stream channels. This activity de-watered the channel as water disappeared into the subsurface of the resulting boulder-fragment debris torrent and/or into the interceptor sewer buried beneath. At that time this was viewed as an irreversible impact, hence the LRW designation. Although the bedrock-debris torrent is still present, the subsurface spaces have since filled with enough fines (clays, sands) and thus elevating the water level such that sufficient pools are now available to support fair quality fish and macroinvertebrate assemblages, still short of the baseline Warmwater Habitat (WWH) goal for Ohio streams. Most of the recommendations herein 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 2014 Direct Tributaries and Taylor Creek biological and water quality assessment. The Ohio R. mainstem is excluded from these analyses.*

Current Aquatic Life Use	Recommended Aquatic Life Use/Existing Use Classification	Number of Segments Affected
	Recommended Changes	
None	WWH	12
None	PHW3A	7
None	PHW2	3
WWH	PHW3A	1
LRW	TBD	3
	Confirmed Uses	
WWH	WWH	25
WWH – Warmwater Habitat; LRW – Limited Resource Waters; PHWH – Primary Headwater Habitat		

General Conditions in the Ohio River Mainstem

On the basis of the Ohio River Fish Index (ORFIn) the condition of the Ohio River in the Markland pool exceeded the baseline expectations derived by ORSANCO for the five reach habitat types at all 49 sites (100%, Figure 1). From a narrative perspective conditions within the Markland pool ranged from fair (the minimum expectation) to good and excellent.

General Conditions in the Direct Tributaries and Taylor Creek

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 51 sites sampled in 2014 is depicted in Figure 2 and summarized in the conclusions section (Table 4). Of the 51 sites assessed in 2014, 40 were evaluated under the WWH suite of uses and the remaining 11 under the PHWH assessment methodology. In all, 11 of 40 sites (27.5%) fully attained their applicable aquatic life use. A total of 8 sites were in partial attainment and 21 were in non-attainment. Of the 11 PHWH sites, three (3) were assigned PHWH Class 2 and eight (8) 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, chlorides) 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 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.

Taylor Creek

Five different causal categories and five different source categories were identified for the 2014 Direct Tributaries study area (Table 2). Of these causes, flow alterations, chlorides, and organic enrichment were the most frequently listed with urban runoff the most frequently listed source. Classic pollutants such as ammonia and other toxic substances were not major problems with some minor elevations of sediment metals at the mouth of Taylor Creek that were not associated with any biological impairments.

Direct Tributaries

Six different causal categories and seven different source categories were identified for the 2014 Direct Tributaries study area (Table 2). Of these causes organic enrichment, flow alterations, siltation, and ammonia were the most frequently listed with CSOs the most frequently listed source.

Table 2. *Summary of causes and sources associated with biological impairments in the 2014 Taylor Creek study area. More than one cause can be listed for the same site.*

Cause	Number	Source	Number
Flow	14	Urban Runoff	13
Chlorides	13	Flow Alteration	3
Organic enrichment	10	Unsewered Area	2
Habitat	5	Hydromodification	2
Siltation	1	Loss of Connectivity	1
Total Sites Assessed	28		

Elevated ammonia concentrations were associated with CSOs, but other toxic substances were not major problems with some minor sediment metals elevated at two sites downstream of CSOs.

Table 3. *Summary of causes and sources associated with biological impairments in the 2014 Direct Tributaries study area. More than one cause can be listed for the same site.*

Cause	Number	Source	Number
Organic enrichment	8	CSOs	7
Flow	7	Unsewered Area	4
Siltation	5	Hydromodification	3
Ammonia	3	Urban runoff	3
Habitat	2	Sewer Line constr.	1
D.O.	2	Natural	1
PAHs	2	Golf Course	1
Total Sites Assessed	23		

Ohio River Mainstem

On the basis of the fish assemblage data, all sites in the Markland Pool were meeting ORSANCO expectations and as a result there are no causes and sources to list. Certain parameters are of interest in relation to trends as well as potential influences on aquatic life (e.g., nutrients) and these data will be discussed in the appropriate sections of this report.

Eutrophication Assessment

Ohio River Mainstem

ORSANCO has been collecting focused data related to the potential impacts of nutrients in the Ohio River since 2000. ORSANCO has had algal samples are analyzed at the Diatom Research Herbarium and Laboratory of Northern Kentucky University and nutrient parameters are analyzed by Cardinal Laboratories in Covington, Kentucky (http://www.orsanco.org/algae-a-nutrient-monitoring). The characteristics of this program (from the above website) include:

- "bi-weekly monitoring for algal counts and genus-level identification;

- biweekly monitoring of total phosphorus, ammonia-nitrogen, TKN, and nitrite + nitrate-nitrogen; and,
- biweekly monitoring of chlorophyll α.

This effort provides a consistent enumeration and identification of algae and establishes river-wide trends in algae composition and abundance, provides early warning capabilities to downstream water utilities for adverse conditions caused by algae, and provides data for the future development of nutrient criteria.

Direct Tributaries to Ohio River and Taylor Creek
The most recent draft Ohio EPA (February 25, 2015) Stream Nutrient Assessment Procedure (SNAP) methodology was used to assess the aggregate influence of primary nutrients in the Direct Tributary and Taylor Creek watersheds (Table 4). This is the second year of use for this type of tool (the draft Trophic Index Criterion [TIC] was used in 2013) in the MSDGC service area and it is being done in anticipation of the SNAP being adopted into the Ohio WQS at some point in the near future. Using this approach necessitates the collection of the following data:

- benthic chlorophyll α;
- total phosphorus and nitrate-N;
- continuous dissolved oxygen (D.O.) to quantify diel D.O. swings; and,
- fish and macroinvertebrate assemblage results.

In addition, to make certain calls of impairment or threat, two or more years of this type of data are required. This data is assessed to make a determination of whether impairment by nutrients is likely or whether nutrients pose an imminent threat.

Direct Tributaries
The results for the three sites with sufficient data suggest that because of the D.O. swings at two sites and the underperformance of the biological indices, site MU03 in Muddy Creek would be listed as impaired due to nutrients (Table 4). The benthic chlorophyll α results were considered low at all sites. Site MU02 in Muddy Creek, which is currently attaining the WWH aquatic life use, would be considered as “threatened.” However, the SNAP procedure requires two or more years of this type of data for a threatened designation.

Taylor Creek
None of the three sites evaluated were impaired for nutrients. The results at two sites suggest that because of the observed diel D.O. swings there is a possibility of a threat to the existing attainment of the WWH aquatic life use (Table 4). However, the SNAP procedure requires two or more years of this type of data for a threatened designation.

Reference Sites
None of the reference sites had D.O. swings or benthic chlorophyll α values that would trigger a SNAP listing of threatened due to nutrients (Table 4).

Table 4. *Key variables used in the draft Ohio EPA Stream Nutrient Assessment Procedure (SNAP); the analysis was limited to where continuous dissolved oxygen (D.O.) data was available to identify the maximum diel D.O. swing. Yellow shaded results exceed SNAP criteria.*

Site ID	River Miles	Attain-ment Status	Max. D.O. Swing	Benthic Chloro-phyll α	TP[1]	DIN[2]	TKN	QHEI	IBI(pIBI)
Taylor Creek									
GM83	3.53/3.53	Full	9.30	136.0	0.25	2.62	0.67	53.0	52 (36.5-38.3)
GM81	1.62/1.62	Full	6.55	72.7	0.25	0.88	0.62	68.0	52 (38.5-40.6)
GM80	0.80/0.80	Full	3.28	73.3	0.25	0.57	0.65	66.5	45 (38.3-40.4)
Muddy Creek									
MU03	2.72/2.72	NON	6.91	153	0.25	0.37	ND	46.0	26 (35.6-37.2)
MU02	2.25/2.25	FULL	11.94	120	0.25	0.06	ND	63.5	40 (37.9-39.9)
MU01	0.17/---	NON	3.04	26.3	0.25	1.76	1.0	38.0	28 (34.5-35.9)
Reference Sites									
RF11	0.90/0.90	FULL	3.18	30	0.25	0.45	ND	70.5	52 (38.8-41.0)
RF14	3.10/3.10	FULL	5.29	136	0.25	0.27	ND	74.5	51 (39.4-41.7)
RF13	1.00/1.00	FULL	3.89	19.2	0.25	0.18	ND	72.0	49 (39.0-41.3)
RF15	0.50/0.50	FULL	4.32	26.2	0.25	0.43	0.78	67.5	36 (38.4-40.6)
RF16	0.10/0.20	FULL	5.26	66	0.25	2.23	0.77	71.0	46 (38.9-41.1)
RF17	0.05/0.20	FULL	3.12	100	0.25	0.38	0.66	73.8	42 (39.3-41.6)

Equations for determining whether biology is underperforming based on habitat:
25^{th}%tile: pIBI = 29.96 + 0.157·QHEI
15^{th}%tile: pIBI = 29.47 + 0.133·QHEI
[1] – Elevated risk level for aquatic life impairment $\geq$ 0.40
[2] – Elevated risk level for aquatic life impairment $\geq$ 3.60

Recreational Use Status

The status of recreational uses was accomplished using the *E. coli* criteria specified by ORSANCO for the Ohio River mainstem (ORSANCO 2012) and by the Ohio WQS for the Direct Tributaries, Taylor Creek, and the Year 4 reference sites.

Ohio River Mainstem

Sampling frequency for measuring compliance with the 30-day geometric mean and 90-day 25% exceedance thresholds were insufficient with the data collected in 2014. However, the results are useful to identify locations of potential impairments and because of the spatial density of sampling locations to refine current knowledge about specific sources and/or areas of fecal bacteria. Using the average of all samples collected exceedances of the ORSANCO primary contact criteria (geometric mean of 130 CFU/100mL) occurred at two of the 49 sites in the study area, one site each downstream of Muddy Creek and Rapid Run. A total of 15 of the 49 sites had maximum values >240 CFU/100 ml which is the threshold for "not to be exceeded in greater than 25% of the samples during 90 day period". While the number of samples collected were insufficient to measure against this criterion, using the results as a not-to-exceed value could help identify where such exceedances are more likely to occur. Most of these occurred adjacent to or downstream from clusters of CSOs or tributaries with CSOs in

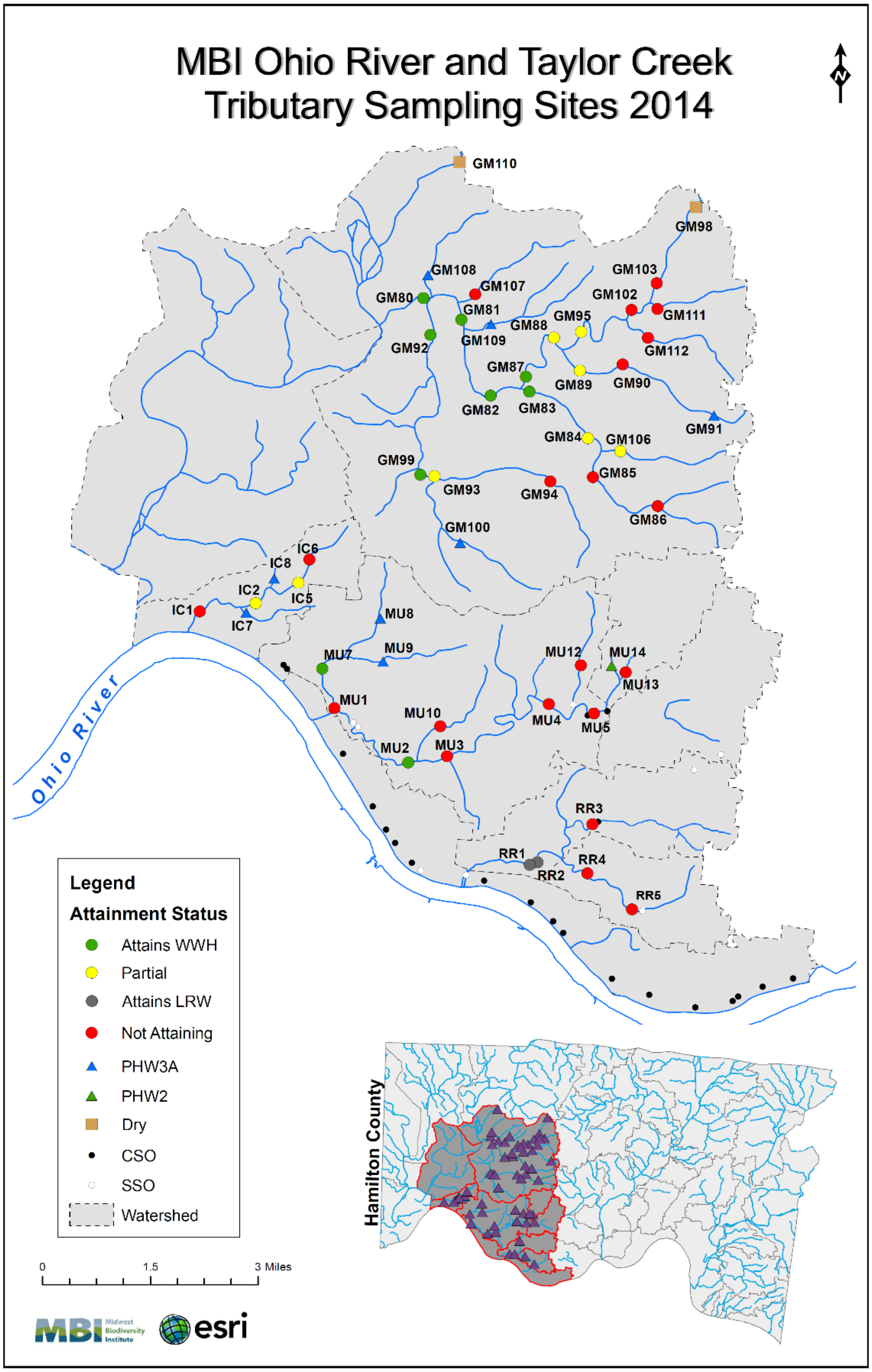

***Figure 1**. Aquatic life use attainment status for the Warmwater Habitat suite of aquatic life use tiers in the Direct Tributaries and Taylor Creek watersheds during 2014. Site codes correspond to those described in Table 9 of the Study Area description. Sites recommended for evaluation as Primary Headwater Habitat (PHWH) appear as triangles with their resulting PHWH classification results. MSDGC CSO locations appear as black circles.*

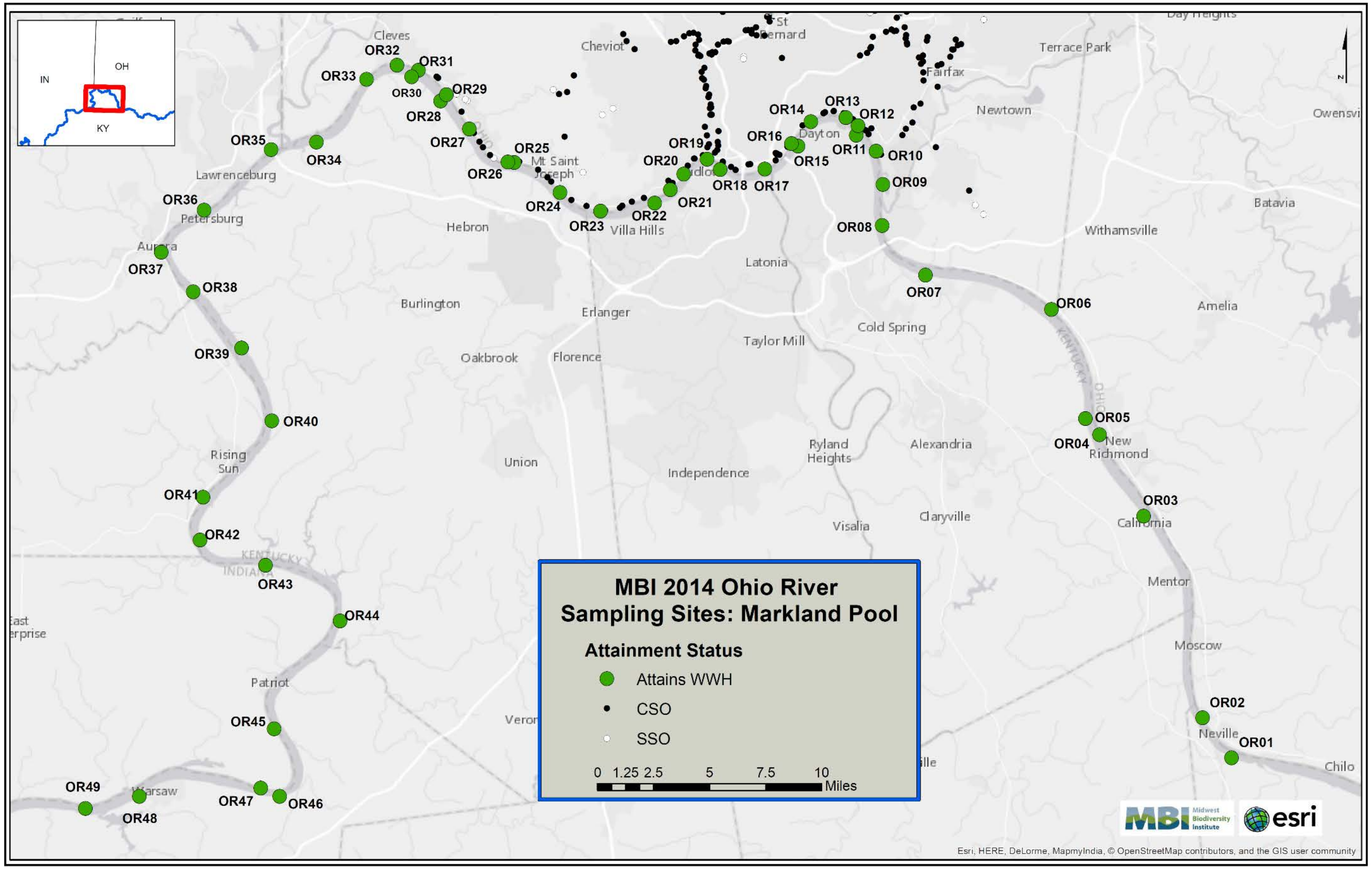

***Figure 2**. Aquatic life use attainment status for the Ohio River mainstem at sites in the Markland navigation pool during 2014. Site codes correspond to those described in Table 9 of the Study Area description. MSDGC CSO locations appear as black circles. CSOs along the KY shoreline are not shown.*

Cincinnati. Identifying the sources of fecal bacteria in urban areas can be a complex process, but it is likely related to combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), urban runoff, and unsewered areas in the vicinity. These results also illustrate the periodicity of high *E. coli* values in the mainstem that follow periods of elevated runoff and CSO discharges.

Direct Tributaries to Ohio River and Taylor Creek

Although exceedances of the Ohio EPA primary and secondary contact criteria were widespread, the magnitude of values varied by subwatershed with the reference sites with the lowest geometric means (Figure 3). Watersheds with CSO contributions (Muddy Creek, Rapid Run) had higher geometric means than watersheds without CSOs (Taylor Creek and Reference Sites) except for Indian Creek (urban runoff, but no CSO contribution).

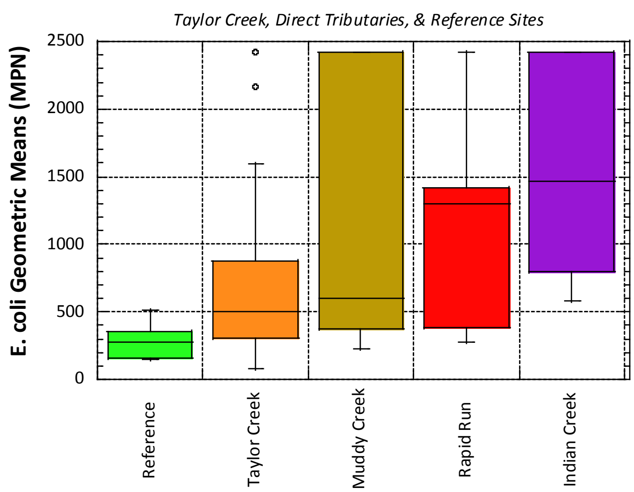

Figure 3*. E. coli geometric mean values by subwatershed for Taylor Creek, the Direct Ohio River tributaries, and reference sites.*

Direct Tributaries

Impairment of recreational uses in the Direct Tributaries to the Ohio River was common. The Primary Contact (PC) 30-day geometric mean *E. coli* criterion was exceeded at 14 of 14 sites sampled. The secondary contact (SC) 30-day geometric mean criterion was exceeded at three of five sites with sufficient data to calculate a geometric mean. Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the Direct Tributaries (Muddy Creek, Rapid Run) it is likely related to CSOs, SSOs, and urban runoff (Indian Creek).

Taylor Creek

Impairment of recreation uses in Taylor Creek was common. The Primary Contact (PC) 30-day geometric mean *E. coli* criterion was exceeded at 20 of 22 sites sampled. The secondary contact (SC) 30-day geometric mean criterion was exceeded at one of four sites with sufficient data to calculate a geometric mean. Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the Taylor Creek it is likely related to failing septic systems, leaking sanitary lines/connections, and urban runoff. Geometric mean concentrations were higher than at the reference sites, but generally much lower than other sites within the Direct Ohio River tributaries (Figure 3).

Reference Sites
Impairment of recreation uses was observed at the reference sites. The Primary Contact (PC) 30-day geometric mean *E. coli* criterion was exceeded at 4 of the 6 sites sampled. Even though there were exceedances of this criterion values in reference sites were on average, much lower than in the Direct Ohio River tributaries or Taylor Creek (Figure 3).

Trajectories in Key Indicators
The 2014 bioassessment provides an opportunity to gauge the effectiveness of past and ongoing attempts to improve and maintain water quality and biological conditions by comparing to prior assessments. A series of biological and water quality surveys by Ohio EPA dating back to 1992, and as recently as 2010, provide the most consistent comparisons in terms of spatial coverage, methods, and indicators and parameters. Prior assessments by ORSANCO provide the data to examine temporal changes since 2005 and 2009 in the Ohio River mainstem (OSANCO 2015).

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 have interests in the MSDGC service area streams and rivers. Given that the 2014 study area 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 several of the tributaries (e.g., Rapid Run) the focus is also on maintaining the improvements observed since the original documentation of severely degraded conditions. For the majority of area streams the focus is on attaining and maintaining the 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 and the ORSANCO thresholds for the ORFIn and ORMIn were used to quantify the degree to which overall aquatic life conditions have changed through time up to and including the 2014 surveys.

Ohio River Mainstem
ORSANCO (2015) has been using a similar design to sample fish assemblages since 2005 (also 2009) in the Markland Pool. A comparison of the ORSANCO collected fish data (excluding the more dense MBI sampling design) by ORSANCO has identified that although the pool still meets the ORFIn warmwater benchmark that was attained in 2005 and 2009, average conditions have

declined from very good conditions in the 2005 (mean ORFIn = 43.4) and 2009 (mean ORFIn = 43.4) surveys to good conditions (mean ORFIN = 37.7) in 2014. This was associated with declines in catches of certain sensitive fish species (mooneye, silver chub, sauger, logperch, and skipjack herring) between 2005 and 2014. The cause of this change is unknown, but ORSANCO did not rule out natural population fluctuations of key fish species.

Direct Tributaries

The primary streams of the Direct Tributaries to the Ohio River that we sampled have a history of biological impairments from CSOs, SSOs, sewer line construction, and urban runoff. Data from the early 1990s in Muddy Creek indicates that conditions, as measured by the IBI, were similarly impaired at RM 5.3 and slightly more degraded at RM 2.7 in 2014. Several of these tributaries (e.g., Rapid Run, Wulff Run) were designated as LRW because of the magnitude of the habitat alterations from the placement of sewer lines directly in the stream channel. In Rapid Run the excavation of the bedrock layers resulted in a massive debris torrent of mixed hard and soft materials. The routing of the interceptor sewer lines in the bottom coupled with the harsh runoff conditions allowed water to infiltrate the sewer system. Both of these conditions essentially dewatered the stream under normal low flows. Since the original documentation of severely degraded conditions in 1991, the interstitial spaces among the debris torrent have been filled with fine materials and the wetted channel has moved back to the surface in more areas. The result is the availability of permanent pools and incrementally improved biological quality from very poor to fair.

Taylor Creek

The MBI survey in 2014 was more intensive (i.e., more sites) than the historical database from 1991 or from the more recent Ohio EPA survey in 2010. Of the eight sites in the watershed that were replicated, conditions were similar in six and slightly improved at two. Most of the new sites in 2014 are smaller headwater or primary headwater sites. Taylor Creek was spared the habitat alterations experienced by Rapid Run in that interceptor sewer lines installed after 1992 were routed outside of the stream channels, thus the quality documented prior to their construction has been maintained.

CONCLUSIONS and RECOMMENDATIONS

2014 Study Area Aquatic Life 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 appropriate 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 2014 study area in 2012 for the Taylor Creek watershed (Ohio EPA 2012) and prior to that in 1991 for selected Direct Tributaries impacted by sewer line construction (Ohio EPA 1992). Although not formally codified in the Ohio WQS, the Primary Headwater Habitat (PHWH) classification scheme and the subclasses based on flow, habitat, and biological assemblages (macroinvertebrates and salamanders) that are unique to these streams was also used as an assessment endpoint. The PHWH potential was considered alongside the recommendations for unnamed streams and revisions within the codified suite of Warmwater Habitat uses, the choice being made based on the data that was collected. Aquatic life use attainment status was determined for the Warmwater Habitat suite of uses 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 current or recommended uses. Aquatic life use attainment was determined for the Ohio River mainstem using the ORSANCO biological indices and thresholds for the fish index only (ORFIn) as the macroinvertebrate index (ORMIn) is under development. The results of this process for each site in the 2014 study area are presented herein. In addition, the causes and sources that were associated with observed biological impairments were also identified.

The status of recreational uses in the Direct Tributary and Taylor Creek watersheds 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. Recreational use status for the Ohio River mainstem followed the approach used by ORSANCO (ORSANCO 2012, 2013).

Aquatic Life Use Recommendations

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. 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 “default” WWH use. The discussion of the recommended assignment of designated uses in this study (Table 5) is organized by the Hydrologic Unit Code (HUC)-12 watershed scale (Watershed Assessment Units = WAUs) used by Ohio EPA.

***Table 5**. Assessment of existing aquatic life use (ALU) designations in the Direct Tributaries and Taylor Creek watersheds in 2014. 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	Macroinv. Evaluation	Existing ALU	Recom-mended ALU
WAU 09-05 – Taylor Creek Watershed							
Taylor Creek (14-004)	7	26.5	Fair-Excellent	Poor-Excellent	Fair-Good	WWH	WWH
Unnamed Trib. to Taylor Creek @ RM 4.9 (14-277)	1	0.9	Excellent	Good	Fair	None	WWH
Forfeit Run (Trib to Taylor Cr.@ RM1.42) (14-278)	1	1.4	Good	Fair	Fair	None	WWH
Eagle Creek (Trib to Taylor Cr. At RM 0.91) (14-279)	1	0.7	Good	-	-	None	PHW3A
Unnamed Trib to Taylor Creek @ RM1.74 (14-280)	1	0.1	Dry	-	-	None	PHW2
Unnamed Trib to the GMR @ RM16.3 (14-281)	1	0.3	Good	-	-	None	PHW3A
Briarly Creek (14-148)	5	7.1	Fair-Good	Fair-Good	Fair-Good	WWH	PHW3a(1) /WWH(4)
Unnamed Trib to Briarly Creek @ RM1.44 (14-282)	1	1.2	Good	Fair	Fair	None	WWH
Wesselman Creek (14-149)	4	7.6	Poor-Good	Poor-Excellent	Fair-Good	WWH	WWH
Unnamed Trib to Wesselman Creek @ RM2.59 (14-275)	1	1.4	Poor	-	-	None	PHW3A
Steel Creek (14-150)	3	4.4	Fair-Good	Poor-Fair	Fair-Good	WWH	WWH
Unnamed Trib to Steel Creek (14-164)	1	0.1	Dry	-	-	None	PHW2
Unnamed Trib to Steel Creek (14-276)	1	1.2	Good	Poor	Poor	None	WWH
WAU 02-03 – Muddy Creek Watershed							
Muddy Creek (23-007)	5	16.6	Fair-Good	Very Poor-Good	Very Poor-Excellent	WWH	WWH
Unnamed Trib to Muddy Creek @ RM2.37 (23-071)	1	0.7	Good	Very Poor	Very Poor	None	WWH
Unnamed Trib to Muddy Creek @ RM5.97 (23-072)	1	1.0	Good	Fair	Very Poor	None	WWH
Unnamed Trib to Muddy Creek @ RM 6.53 (23-073)	1	1..9	Dry	-	Very Poor	None	WWH
UT RM 0.45 to UT to Muddy Cr @ RM 5.97 (14-074)	1	0.1	Fair	-	-	None	PHW2
Unnamed Trib to Muddy Creek @ RM0.3 (23-075)	2	2.8	Fair-Good	NA – Good	NA – Good	None	PHW3A/ WWH
UT @ 0.95 to UT to Muddy Creek @ RM0.3 (23-076)	1	1.0	Good	-	-	None	PHW3A
WAU 02-04 –Rapid Run Watershed							
Rapid Run (23-008)	3	9.0	Poor-Fair	Very Poor-Poor	Very Poor – Fair	LRW	-[1]
Wulff Creek (23-012)	1	2.2	Good	Poor	Poor	LRW	WWH

***Table 5**. Assessment of existing aquatic life use (ALU) designations in the Direct Tributaries and Taylor Creek watersheds in 2014. 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	Macroinv. Evaluation	Existing ALU	Recom-mended ALU
Unnamed Trib to Wulff Run @ RM0.77 (23-077)	1	1.3	Good	Poor	Very Poor	None	WWH
Indian Creek Watershed							
Indian Creek (23-019	4	2.3	Fair-Excellent	Poor-Fair	Fair-M.Good	None	WWH
Unnamed Trib to Indian Creek	1	0.4	Good	-	-	None	PHW3A
Unnamed Trib to Indian Creek @ RM1.55 (23-070)	1	0.1	Fair	-	-	None	PHW3A
Reference Sites							
Mill Run (11-031)	1	7.8	Excellent	Excellent	Good	WWH	WWH
Stonelick Creek (11-107)	2	75.7	Excellent	Excellent	Very Good-Excellent	WWH	WWH
Fivemile Creek (11-138)	1	10.4	Good	Good	Good	WWH	WWH
W. Fk. E.Fk. Little Miami River (11-150)	1	29.1	Excellent	Excellent	M.Good	WWH	WWH
Dodson Creek (11-151)	1	29.1	Excellent	Good	Good	WWH	WWH

[1]We recommend that Ohio EPA re-evaluate the LRW use in Rapid Run and other streams influenced by instream sewer line construction.

The streams that have verified WWH aquatic life use designations based on confirmation by a prior Ohio EPA assessment (Ohio EPA 1992, 2012) and which are confirmed herein are considered to be an existing use (40 CFR Part 131). Streams that were not included in prior Ohio EPA assessments are evaluated herein to either verify the default use or recommend the appropriate use, which now becomes the existing use.

Aquatic Life Use Recommendations

This section focuses on identifying the appropriate aquatic life use classification for streams in each of the 2014 study area 12-digit watersheds (Table 5).

WAU 09-05 – Taylor Creek Watershed

The aquatic life uses for the major streams in the Taylor Creek watershed were mostly verified or designated based on the 1992 Ohio EPA assessment of instream sewer line construction impacts (Ohio EPA 1992). For the streams that were previously assessed by Ohio EPA the only difference is the upstream most site (GM91) on Briarly Creek that is recommended to be changed from WWH, which is based on an extrapolation from data collected downstream, to an existing use classification of PHWH3A based on the lack of a WWH fish assemblage and the presence of populations of two-lined salamander.

Of the tributaries sampled in 2014 that are currently undesignated, we recommend that four of these streams (GM106, GM107, GM112, and GM103) be designated as WWH because of the presence fish and macroinvertebrate assemblages that attain WWH and/or the presence of sufficient habitat attributes to support the WWH designation. Three other tributaries (GM108, GM109, and GM100) did not reveal the presence of WWH assemblages of fish and macroinvertebrates, but had sufficient flow and habitat and sufficient macroinvertebrates and viable populations of two-lined salamander to support the existing use classification of PHWH3A. Two other small streams (GM110 and GM98) had flow, habitat, and macroinvertebrate taxa consistent with the existing use classification PHWH2.

WAU 02-03 – Muddy Creek Watershed

The WWH aquatic life use for Muddy Creek was verified based on the 1992 Ohio EPA assessment of instream sewer line construction impacts (Ohio EPA 1992). The 2014 results support the original WWH designation for Muddy Creek.

Of the tributaries sampled in 2014 that are currently undesignated, four (MU10, MU12, MU13, and MU07) are recommended as WWH because of fish and macroinvertebrate attainment of WWH and/or sufficient habitat attributes to support WWH. Two tributaries (MU08 and MU09) did not support WWH assemblages of fish and macroinvertebrates, but had sufficient flow and habitat and key macroinvertebrate indicators and viable populations of two-lined salamander to demonstrate an existing use classification as PHWH3A. One stream (MU14) had flow, habitat and macroinvertebrate taxa consistent with the PHWH2 classification.

WAU 02-04 –Rapid Run Watershed

The aquatic life use for Rapid Run was designated based on the 1992 Ohio EPA assessment of instream sewer line construction impacts (Ohio EPA 1992). This report documented that the then accepted practice of instream sewer line construction in Hamilton and eastern Clermont Counties had severe and presumably irreversible effects on instream habitat so as to preclude attainment of the WWH use designation. The initial construction included trenched excavations of the limestone and shale layers of bedrock that are common to area streams. This and the backfilling of the unconsolidated materials created debris torrents which resulted in the severe alteration of channel morphology and substrates and stream dewatering during low flows. In some areas the sewer lines were exposed which resulted in infiltration of stream water into the sewers. The extent of the debris torrents and dewatering in some streams was sufficiently severe that a LRW designation was assigned. Based on observations made in Rapid Run in 2014 surface flows have recovered enough to provide pools for biological assemblages in fair condition which is an incremental improvement from the poor and very poor assemblages observed in 1991. This raises questions about the current applicability of the LRW designation, thus further study of this designation by Ohio EPA is recommended. The fish and macroinvertebrate assemblages now meet the biocriteria applicable to the Modified Warmwater Habitat-Channel Modified (MWH-C), but the applicability of this designation to a permitted action is questionable. At this time it is more conservative to retain the LRW designation as all of these streams fail to meet or demonstrate the capacity to meet WWH.

Of the tributaries sampled in 2014 that are currently undesignated, four (MU10, MU12, MU13, and MU07) are recommended as WWH because the fish and macroinvertebrate assemblages attain WWH and/or there were sufficient habitat attributes to support WWH. Two tributaries

(MU08 and MU09) did not support WWH assemblages of fish and macroinvertebrates, but had sufficient flow and habitat and key macroinvertebrate indicators and viable populations of two-lined salamander to support the existing use classification of PHWH3A. One stream (MU14) flow, habitat, and macroinvertebrate taxa consistent with the PHWH2 classification.

Indian Creek Watershed
Indian Creek (23-019) is a direct tributary that had not been previously assessed and was currently undesignated. Habitat quality ranged from fair to excellent and is capable of supporting the WWH designation. Three of four sites had marginally good macroinvertebrate assemblages, evidence that supports the WWH potential. Siltation and flow alterations from urban runoff and a golf course were responsible for an impaired fish assemblage. Two unnamed tributaries (IC07 and IC08) had sufficient flow and habitat and evidence of key macroinvertebrate indicators and viable populations of two-lined salamander to assign an existing use classification of PHWH3A.

Reference Sites
The five reference streams sampled (Mill Creek [RF11], Stonelick Creek [RF13 and RF14], Fivemile Creek [RF15], W. Fk E. Fk. Little Miami River [RF16], and Dodson Creek [RF17]) all had verified WWH uses which was confirmed by the 2014 assessment (all sites fully attained WWH).

Aquatic Life Use Attainment Status
The status of aquatic life use attainment in the 2014 study area was determined based on the verified and recommended use designations of this study and in accordance with Ohio EPA methods and practices for the Direct Tributaries and Taylor Creek (Table 6). For the Ohio River mainstem we determined aquatic life use attainment status (Table 7) based on the ORFIn (fish assemblage) which follows current ORSANCO practice. The ORMIn (macroinvertebrates assemblage) results were included in the results since it will be incorporated into the biological assessments conducted by ORSANCO starting in 2015 (ORSANCO 2014).

The proximate causes and sources associated with an impairment were also indicated (Tables 6 and 7). The following highlights attainment status based on verified and recommended aquatic life uses, key aspects of biological condition and water quality, and a summary of the proximate causes and sources that were assigned to impaired sites. A total of 51 sites were assessed in the Direct Tributaries and Taylor Creek and 49 sites were assessed in the Ohio River mainstem.

Direct Ohio River Tributaries

- Two of 15 Direct Ohio River Tributary sites were in full attainment of WWH and two in full attainment of LRW, two in partial attainment of WWH, and 11 in non-attainment of WWH and one in non-attainment of LRW (Table 6).
- Four Direct Tributary sites were classified as PHWH3A and one as PHWH2.

Taylor Creek and Tributaries

- Seven of 22 Taylor Creek and tributary sites were in full attainment of WWH, six in partial attainment of WWH, and nine in non-attainment of WWH (Table 6).
- Four (4) tributary sites were classified as PHWH3A and two as PHWH2.

***Table 6**. Aquatic life use attainment status at sites in Taylor Creek, Direct Ohio River Tributaries, and reference sites in 2014. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources 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 arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Historoical changes in attainment status are denoted as improving (⇧), unchanged (⊙), or declining (⇩) compared to the most recent prior assessment. Causes and sources are listed in order of importance.*

Site ID	River Miles	Drain-age Area mi^2	IBI	MIwb	ICI	Narra-tive	QHEI/ HHEI[1]	Aq. Life Status	Causes	Sources
WAU 09-05 – Taylor Creek Watershed										
Taylor Creek – WWH - Existing										
GM86	6.30/6.30	1.2	32*	na		F*	62.5/96	**NON**	Org enrich, Flow, Silt, Chlorides	Urban runoff
GM85	4.98/4.98	2.2	23*	na		F*	76.5/96	**NON**	Org enrich, Chlorides, Flow	Urban runoff
GM84	4.60/4.60	3.9	42	na		F*	75	**Partial**	Org enrich, Chlorides, Flow	Urban runoff
GM83	3.53/3.53	5.0	52	na		G	53	**FULL** ⇧		
GM82	2.93/2.93	12.6	42	na	52		63	**FULL** ⊙		
GM81	1.62/1.62	14.3	52	na	54		68	**FULL** ⊙		
GM80	0.80/0.80	26.5	45	9.0	48		66.5	**FULL** ⊙		
Unnamed Trib to Taylor Creek @RM 4.9 (Aquatic Life Use Undesignated/WWH Recommended)										
GM106	0.28/0.28	0.9	38^{ns}	na		F*	73.5/89	**Partial**	Org enrich, Chlorides, Flow	Urban runoff
Forfeit Run (Trib to Taylor Cr. @RM 1.42) (Aquatic Life Use Undesignated/WWH Recommended)										
GM107	0.30/0.30	1.4	26*	na		F*	61.8/61	**NON**	Habitat[2], Silt, Flow	Hydromodification; Connectivity
Eagle Creek (Trib to Taylor Cr. @RM 0.91) (Aquatic Life Use Undesignated/PHW3A Recommended)										
GM108	0.28/0.28	0.7	12	na			68.5/65	**PHW3A**		
Unnamed Trib to Taylor Creek @RM 1.74 (Aquatic Life Use Undesignated/PHW3A Recommended)										
GM109	0.45/0.45	0.9	12	na			59.5/94	**PHW3A**		
Unnamed Trib to the GMR @RM 16.3 (Aquatic Life Use Undesignated/PHW2 Recommended)										
GM110	1.75/0.00	0.1	Dry	na			-/34	**PHW2**		
Briarly Creek (WWH Existing/PHW3A Recommended)										
GM91	3.90/3.90	0.3	26	na			63/81	**PHW3A**		

[1] HHEI – Headwater Habitat Evaluation Index.
[2] Concrete poured on stream bottom next to highway.

***Table 6**. Aquatic life use attainment status at sites in Taylor Creek, Direct Ohio River Tributaries, and reference sites in 2014. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources 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 arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Historoical changes in attainment status are denoted as improving (⇧), unchanged (⊙), or declining (⇩) compared to the most recent prior assessment. Causes and sources are listed in order of importance.*

Site ID	River Miles	Drain-age Area mi^2	IBI	MIwb	ICI	Narra-tive	QHEI/ HHEI[1]	Aq. Life Status	Causes	Sources
					Briarly Creek (WWH Existing/Recommended)					
GM90	2.45/2.45	1.3	34*	na		F*	53.3/-	**NON**	Org enrich, Chlorides, Flow	Urban runoff, Septic systems
GM89	1.82/1.70	2.1	32*	na		MG^{ns}	52.8/90	**Partial**	Org enrich, Chlorides, Flow	Urban runoff, Septic systems
GM88	1.22/1.22	6.6	30*	na		MG^{ns}	65.3	**Partial** ⊙	Org enrich, Chlorides, Flow	Urban runoff
GM87	0.20/0.10	7.1	46	na		G	64	**FULL** ⇧		
					Unnamed Trib to Briarly Creek @RM 1.44 (Aquatic Life Use Undesignated/WWH Recommended)					
GM112	0.46/0.46	1.2	32*	na		F*	67.8/72	**NON**	Org enrich, Chlorides, Flow	Urban Runoff
					Wesselman Creek (WWH Existing/Recommended)					
GM94	4.72/4.72	1.1	24*	na		F*	56/96	**NON**	Org enrich; Chlorides, Flow	Urban runoff
GM93	3.00/3.00	2.6	34*	na		G	39.5	**Partial**	Habitat[3]	Hydromod.
GM99	2.90/2.90	5.7	40	na		G	64.5	**FULL** ⊙		
GM92	0.50/0.50	7.6	52	na		G	68	**FULL** ⊙		
					Unnamed Trib to Wesselman Creek @RM 2.59 (Aquatic Life Use Undesignated/PHW3A Recommended)					
GM100	1.21/1.21	1.4	20	na			37/86	**PHW3A**		
					Steel Creek (WWH Existing)					
GM111	2.16/2.16	0.8	32*	na		F*	55.5/82	**NON**	Habitat; Chlorides, Flow	Urban runoff, Flow alteration
GM102	1.79/1.79	2.6	24*	na		F*	54/92	**NON**	Habitat; Chlorides, Flow	Urban runoff, Flow alteration

[3] Step dams within site.

***Table 6**. Aquatic life use attainment status at sites in Taylor Creek, Direct Ohio River Tributaries, and reference sites in 2014. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources 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 arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Historoical changes in attainment status are denoted as improving (⇧), unchanged (⦿), or declining (⇩) compared to the most recent prior assessment. Causes and sources are listed in order of importance.*

Site ID	River Miles	Drain-age Area mi^2	IBI	MIwb	ICI	Narra-tive	QHEI/ HHEI[1]	Aq. Life Status	Causes	Sources
GM95	0.30/0.30	4.4	26*	na		MG^{ns}	58.8	**Partial**	Habitat; Chlorides, Flow	Urban runoff, Flow alteration
Unnamed Trib to Steel Creek (Aquatic Life Use Undesignated/PHW2 Recommended)										
GM98	2.30/0.00	0.1	Dry	na			-/48	**PHW2**		
Unnamed Trib to Steel Creek (Aquatic Life Use Undesignated/WWH Recommended)										
GM103	0.31/0.31	1.2	22*	na		F*	59.5/92	**NON**	Org enrich, Chlorides, Flow	Urban runoff
WAU 02-03 – Muddy Creek Watershed										
Muddy Creek (WWH Existing/Recommended)										
MU05	6.35/6.35	5.4	12*	na		VP*	62	**NON**	Org. Enrich., Ammonia, PAHs	CSO, urban runoff
MU04	5.40/5.40	5.4	12*	na		VP*	63.3	**NON** ⦿	Org. Enrich.	CSO, SSO, urban
MU03	2.72/2.72	12.3	26*	na		F*	46	**NON** ⇩	Org. Enrich., Flow, Construction[4] Habitat, PAHs	Hydromodification, CSO
MU02	2.25/2.25	12.1	40	na	48		63.5	**FULL**		
MU01	0.17/---	16.6	28*	na		NC	38	**NON**	Silt, Habitat, Flow	Hydromod., Ohio R. Backwater
Unnamed Trib to Muddy Creek @RM 2.37 (Aquatic Life Use Undesignated/WWH Recommended)										
MU10	0.60/0.60	0.7	12*	na		VP*	57.3/85	**NON**	Org. Enrich., Flow	Urban, unknown[5]
Unnamed Trib to Muddy Creek @RM 5.97 (Aquatic Life Use Undesignated/WWH Recommended)										
MU12	0.65/0.65	1	26*	na		VP*	61.5/72	**NON**	Flow[6]	Hydromodification

[4] Bridge construction
[5] Raw sewage was observed instream with no known CSO or SSO in proximity therefore source is unknown.
[6] Dst. lake outlet; stream flow may cease under dry weather conditions.

***Table 6**. Aquatic life use attainment status at sites in Taylor Creek, Direct Ohio River Tributaries, and reference sites in 2014. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources 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 arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Historoical changes in attainment status are denoted as improving (⇧), unchanged (⊙), or declining (⇩) compared to the most recent prior assessment. Causes and sources are listed in order of importance.*

Site ID	River Miles	Drain-age Area mi^2	IBI	MIwb	ICI	Narra-tive	QHEI/ HHEI[1]	Aq. Life Status	Causes	Sources
Unnamed Trib to Muddy Creek @RM 6.53 (Aquatic Life Use Undesignated/WWH Recommended)										
MU13	0.60/0.60	1.9	Dry	na		VP*	-/84	**NON**	Org Enrich.[7], Ammonia	CSO
UT RM 0.45 to UT to Muddy Cr @RM 5.97 (Aquatic Life Use Undesignated/PHW2 Recommended)										
MU14	0.20/0.20	0.1	12	na			44/70	**PHW2**		
Unnamed Trib to Muddy Creek @RM 0.3 (Aquatic Life Use Undesignated/PHW3A Recommended)										
MU08	1.80/1.80	0.7	24	na			68.3/82	**PHW3A**		
Unnamed Trib to Muddy Creek @RM 0.3 (Aquatic Life Use Undesignated/WWH Recommended)										
MU07	0.60/0.60	2.8	36^{ns}	na		G	53.3	**FULL**		
UT @ 0.95 to UT to Muddy Creek @RM 0.3 (Aquatic Life Use Undesignated/PHW3A Recommended)										
MU09	0.60/0.60	1	26	na			57/70	**PHW3A**		
WAU 02-04 Rapid Run Watershed										
Rapid Run (LRW Existing/Further Study Recommended)										
RR03	2.70/2.70	2.2	12*	na		VP*	39.8/87	NON	Org. enrichment, Ammonia	CSOs
RR02	1.20/1.20	5.8	24	na		F	56.5	FULL		
RR01	-- /0.35	9	Dry	na		MG	-	**FULL**		
Wulff Creek (LRW Existing)/WWH Recommended)										
RR04	0.55/0.55	2.2	20*	na		P*	67/77	**NON**	Org Enrichment[8]	CSO
Unnamed Trib to Wulff Run @RM 0.77 (Aquatic Life Use Undesignated/WWH Recommended)										
RR05	0.68/0.68	1.3	24*	na		VP*	59/92	**NON**	Org. Enrichment	Urban runoff, sewer line
Indian Creek Watershed										
Indian Creek Aquatic Life Use Undesignated/WWH Recommended)										
IC06	2.43/2.43	0.5	24*	na		MG^{ns}	72/74	**NON**	Silt, Flow	Urban runoff

[7] Dst. major CSO; diapers, toilet paper, and sewage debris observed instream and on riparian vegetation.
[8] Dst. CSO and instream sewer line and exposed sewer line.

***Table 6**. Aquatic life use attainment status at sites in Taylor Creek, Direct Ohio River Tributaries, and reference sites in 2014. Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the biological assemblages. The Qualitative Habitat Evaluation Index (QHEI) measures physical habitat quality. Causes and sources 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 arranged by HUC 12 subwatershed Watershed Assessment Units (WAUs). Historoical changes in attainment status are denoted as improving (⇧), unchanged (⦿), or declining (⇩) compared to the most recent prior assessment. Causes and sources are listed in order of importance.*

Site ID	River Miles	Drain-age Area mi^2	IBI	MIwb	ICI	Narra-tive	QHEI/ HHEI[1]	Aq. Life Status	Causes	Sources
IC05	2.08/2.08	1.1	34*	na		MG^{ns}	52.5/86	**Partial**	Silt, Flow	Urban runoff
IC02	1.22/1.22	1.5	26*	na		MG^{ns}	62/79	**Partial**	Silt, Flow	Golf course
IC01	0.30/0.30	2.3	24*	na		F*	58.5/71	**NON**	Silt	Natural[9]
Unnamed Trib to Indian Creek (Aquatic Life Use Undesignated/PHW3A Recommended)										
IC07	0.13/0.13	0.4	12	na			62/77	**PHW3A**		
Unnamed Trib to Indian Creek @RM 1.55 (Aquatic Life Use Undesignated/PHW3A Recommended)										
IC08	1.50/0.00	0.1	12	na			52/72	**PHW3A**		
Reference Sites										
Mill Run (WWH Existing/Recommended)										
RF11	0.90/0.90	7.8	52	na	40	MG^{ns}	70.5	**FULL**		
Stonelick Creek (WWH Existing/Recommended)										
RF14	3.10/3.10	73.5	51	9.12	50	-	74.5	**FULL**		
RF13	1.00/1.00	75.7	49	9.23	-	VG	72	**FULL**		
Fivemile Creek (WWH Existing/ Recommended)										
RF15	0.50/0.50	10.4	36^{ns}	na	-	G	67.5	**FULL**		
W. Fk. E. Fk. Little Miami River (WWH Existing/ Recommended)										
RF16	0.10/0.20	29.1	46	8.72		MG^{ns}	71	**FULL**		
Dodson Creek (WWH Existing/Recommended)										
RF17	0.05/0.20	32.4	42*	7.2*	42^{ns}		73.8	**FULL**		

Ohio River Mainstem

- Of the 49 Ohio R. mainstem sites that were evaluated *all* were in full attainment of the ORSANCO thresholds for ORFIn which is currently used to assess aquatic life use attainment for the Ohio River (Table 7). Of the attaining sites 9 (19%) were considered excellent, 27 (56%) were very good, 9 (19%) were good, and 2 (4%) were fair. Table 7 also reports the ORMIn results which will be incorporated into Ohio River mainstem biological assessments in 2015.

[9] Dst. beaver dam.

***Table 7**. Aquatic life use attainment status at Ohio River mainstem sites in 2014. Ohio River Fish Index (ORFIn) and Ohio River Macroinvertebrate Index (ORMIn) scores are based on the observed performance of each biological assemblage. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded. Ohio EPA large river IBI, MIwb, and ICI scores are presented for comparison. Sampling locations are arranged from upstream to downstream through the Markland navigation pool. Bank: OH – river right (OH/IN); L DB– river left (KY; looking dst.). ORMin scores in red were collected and processed by ORSANCO.*

Site ID	River Mile (Fish/Macro.)	Bank	Drainage Area (mi.^{2})	HBT Class	Adjust-ed ORFin	Observ-ed ORFin	ORMIn	Attain-ment Status[1]	IBI	MIwb	ICI	QHEI	Causes	Sources
	Ohio River (90-001)													
OR01	438.20/438.20	KY	69501	B	46.71	72.08	23.08	Full	44	9.10	26	48.0		
OR02	440.00/440.00	OH	69501	C	44.55	50.64	-[2]	Full	44	9.65	-	50.3		
OR03	447.50/447.50	KY	71000	C	44.55	65.35	11.35	Full	44	8.49	26	49.3		
OR04	450.80/450.80	OH	71000	D	41.8	61.77	-	Full	44	9.12	-	48.5		
OR05	451.80/ -	KY	71000	D	41.8	60.93	-	Full	40	8.99	-	44.0		
OR06	455.40/455.40	OH	71000	C	44.55	69.54	14.32	Full	48	10.03	24	46.8		
OR07	460.00/ -	KY	71000	C	44.55	52.6	17.36	Full	38	8.87	-	41.5		
OR08	462.60/462.60	OH	71000	D	41.8	48.2	-	Full	40	8.56	-	42.0		
OR09	464.30/464.30	OH	73000	C	44.55	65.42	24.85	Full	50	9.86	32	50.8		
OR10	465.30/ -	OH	73000	C	44.55	62.37	-	Full	48	9.68	-	50.5		
OR11	465.80/ -	KY	73000	D	41.8	64.22	-	Full	38	9.38	-	48.5		
OR12	466.20/466.20	OH	73000	B	46.71	80.08	27.05	Full	48	9.71	-	46.3		
OR13	466.50/ -	OH	73000	B	46.71	66.54	25.48	Full	38	9.40	-	45.0		
OR14	468.40/468.40	OH	73000	A	50.03	75.17	17.79	Full	54	9.77	30	51.5		
OR15	469.20/469.20	KY	73000	C	44.55	62.88	31.54	Full	42	8.04	34	51.0		
OR16	469.30/469.30	OH	73000	A	50.03	59.62	16.05	Full	42	9.21	28	49.0		
OR17	470.50/470.50	KY	73000	A	50.03	81.24	18.89	Full	48	9.59	32	46.5		
OR18	472.50/472.50	KY	73000	B	46.71	73.79	-	Full	52	9.78	-	47.5		
OR19	472.51/472.51	OH	73000	B	46.71	63.54	21.61	Full	42	9.32	36	41.5		
OR20	473.80/473.80	OH	73000	A	50.03	66.48	-	Full	50	9.74	-	49.0		
OR21	474.30/474.30	OH	73000	A	50.03	78.27	11.01	Full	54	10.14	20	47.2		
OR22	474.60/ -	KY	73000	B	46.71	82.3	20.06	Full	48	9.18	-	48.8		
OR23	477.00/477.00	OH	73000	C	44.55	71.82	30.37	Full	40	8.58	32	44.3		
OR24	478.70/478.70	OH	73000	D	41.8	70.59	16.20	Full	44	8.51	24	44.5		
OR25	480.60/480.60	OH	75000	C	44.55	78.53	-	Full	48	9.46	-	44.0		

***Table 7**. Aquatic life use attainment status at Ohio River mainstem sites in 2014. Ohio River Fish Index (ORFIn) and Ohio River Macroinvertebrate Index (ORMIn) scores are based on the observed performance of each biological assemblage. Causes and sources of impairment are listed at sites that did not fully attain their use – sites in full attainment are blue shaded. Ohio EPA large river IBI, MIwb, and ICI scores are presented for comparison. Sampling locations are arranged from upstream to downstream through the Markland navigation pool. Bank: OH – river right (OH/IN); L DB– river left (KY; looking dst.). ORMin scores in red were collected and processed by ORSANCO.*

Site ID	River Mile (Fish/Macro.)	Bank	Drainage Area (mi.²)	HBT Class	Adjust-ed ORFin	Observ-ed ORFin	ORMIn	Attain-ment Status[1]	IBI	MIwb	ICI	QHEI	Causes	Sources
OR26	481.10/481.10	OH	75000	D	41.8	56.4	21.48	Full	46	9.39	30	34.5		
OR27	483.00/483.00	OH	75000	D	41.8	67.22	-	Full	46	9.34	-	44.0		
OR28	484.10/484.10	KY	75000	D	41.8	57.76	-	Full	42	9.41	-	40.0		
OR29	484.20/484.20	OH	75100	C	44.55	66.49	17.45	Full	50	9.36	30	46.3		
OR30	485.70/485.70	OH	75100	C	44.55	73.29	-	Full	50	9.82	-	45.3		
OR31	485.90/ -	KY	75350	D	41.8	54.05	30.04	Full	34	9.20	-	37.5		
OR32	486.20/486.20	OH	75350	D	41.8	66.67	11.90	Full	40	8.90	28	31.8		
OR33	487.50/ -	KY	75350	B	46.71	72.14	-	Full	50	8.65	-	45.3		
OR34	490.10/490.10	KY	75500	B	46.71	72.19	60.00	Full	46	10.14	30	44.3		
OR35	491.80/491.80	IN	75500	D	41.8	52.36	11.19	Full	30	8.47	30	41.3		
OR36	495.00/495.00	IN	81000	D	41.8	64	9.10	Full	36	9.14	28	36.5		
OR37	497.20/497.20	IN	81000	B	46.71	75.37	60.00	Full	48	10.10	28	46.3		
OR38	498.60/ -	KY	81000	C	44.55	71.91	31.22	Full	-	-	-	43.5		
OR39	501.30/501.30	KY	81000	C	44.55	71.91	9.58	Full	46	9.96	26	47.8		
OR40	504.10/504.10	IN	81000	B	46.71	68.79	17.03	Full	48	9.90	32	42.5		
OR41	507.50/507.50	KY	81000	D	41.8	50.69	19.73	Full	38	8.49	30	43.5		
OR42	509.50/ -	IN	81000	E	39.59	60.7	-	Full	40	9.69	-	41.3		
OR43	511.90/511.90	KY	81000	D	41.8	70.68	15.85	Full	50	10.36	30	43.3		
OR44	515.80/515.80	IN	81000	B	46.71	70.92	20.52	Full	48	10.54	28	48.0		
OR45	520.80/ -	KY	81000	B	46.71	68.91	40.58	Full	48	9.79	-	47.5		
OR46	523.60/523.60	IN	81000	B	46.71	74.4	60.00	Full	48	10.21	32	48.8		
OR47	524.30/ -	KY	81000	D	41.8	58.13	38.95	Full	36	9.50	-	40.0		
OR48	529.00/529.00	KY	81000	D	41.8	52.39	16.55	Full	42	9.74	20	33.3		
OR49	530.50/0.00	IN	81000		-	-	8.67	-	-	-	-	42.0		

[1] Attainment status based on adjusted ORFIn results.
[2] No ORMIn score calculated due to lost H-D sampler.

2014 Study Area Recreational Use Attainment Status

The assessment of recreational use designations and status was done separately for the Direct Tributaries/Taylor Creek and the Ohio River mainstem. The former were assessed using the approach of Ohio EPA and consistent with the Ohio WQS. The Ohio River mainstem was assessed using the approach of ORSANCO and WQS applicable to the Ohio River mainstem.

Direct Tributaries and Taylor Creek

The geometric mean is the principal criterion used to determine recreational use attainment and the single sample maximum is typically *used only to determine use attainment at public bathing beaches*, but **not** for streams and rivers. This is especially the case where sample size is small which weakens the capacity to identify true impairment. However, TNTC ("too numerous to count", 2420) maximum *E. coli* values in streams were highlighted as an indication of episodic exceedances the same as the geometric mean criterion underscores the chronic nature of observed exceedances. Identifying the sources of fecal bacteria in urban areas can be a complex process, but in the Direct Tributaries they are most likely related to CSOs, pump station overflows (PSOs), SSOs, urban runoff, and deteriorating sewage conveyances in these watersheds. Taylor Creek is not affected by CSOs and exceedances there are most likely related to pump station overflows (PSOs), septic systems, and urban runoff.

Recreational Use Recommendations

The Ohio WQS have multiple recreational use tiers and as such the *E. coli* criteria vary with the specific tier related to recreational use intensity and importance (Table 8). The "default" recreational use for Ohio streams is PCR-B unless there is sufficient evidence that another subcategory is more appropriate (e.g., PCR-A, PCR-C, or SCR). PCR-C is assigned to streams where primary contact recreation activities are either limited to wading or are infrequent due to shallow pool 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 and canoeing. SCR is restricted to those streams that are:

***Table 8**. 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

- 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 2014 study area streams recommended as PHWH were assessed as SCR because their small size precludes full body immersion (pool depths generally <40 cm). Most streams <5.0 $mi.^2$ with a WWH aquatic life use were assigned to PCR-C use since wading is more likely, but their shallow depths (<1 meter) preclude full body immersion. Once the attainability of the recreational use tiers was evaluated, attainment status was assessed using the geometric mean of *E. coli* results compared to the criteria for the applicable recreational use tier. These results are presented in Table 9 and mapped in Figure 5.

Direct Tributaries

Nearly all of the direct tributaries (20 of 23 sites; 87%) to the Ohio River had exceedances of the *E. coli* criteria for PCR-B, PCR-C, or SCR recreation use tiers and 13 of 23 had samples with a maximum reported value greater than the TNTC value of 2420 during at least one sampling event (Table 9). Some of these values were associated with the presence of CSOs, but others (Indian Creek) were associated with other sources such as SSOs and urban runoff.

Taylor Creek

Taylor Creek and its tributaries (21 of 26 sites; 80.8%) had exceedances of the *E. coli* criteria for PCR-B, PCR-C, or SCR recreation use tiers and 18 of 26 had samples greater than the TNTC value of 2420 during at least one sampling event (Table 9). Most of these exceedances were associated with general urban runoff.

Reference Sites

Four (RF11, 13, 15, and 17) of the six reference sites were in non-attainment of the PCR-B recreational geometric mean criterion (Table 9). Two sites (RF 11 and 15) had high values greater than the TNTC values of 2420. Two sites (RF14 and 16) were in full attainment of the PCR-B use tier.

Ohio River Mainstem

There were only two exceedances of the geometric mean ORSANCO *E. coli* criteria of 130 MPN in the Markland Pool and these occurred downstream of the Muddy Creek (OR31, RM 485.7) and Rapid Run (OR32, RM 486.2) confluences (Table 10; Figure 4). An increase in maximum *E. coli* values extended from downstream of the Muddy Creek WWTP (OR26, RM 481.1) at nine of ten sites (OR26 to OR35 and OR37) with the magnitude of the *E. coli* values increasing substantially downstream of Muddy Creek (OR31, RM 485.7) and again at the site (OR35) downstream of the Great Miami River. Mapped results appear in Figure 6.

***Table 9**. Bacteriological (E. coli) sampling results during summer-fall normal flows in the Taylor Creek and direct Ohio River tributaries study area during 2014. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow and sites with only a single sample are italicized (PC – Primary Contact; SC – Secondary Contact); sites with any values at the TNTC (too numerous to count) value of 2420 are highlighted in orange.*

Site ID	RM	Location	Recre-ation Use	N	*E.coli* Min.	*E. coli* Geo. Mean	*E. coli* Max.	Cri-teria GM	Attain-ment Status
		WAU 09-05 – Taylor Creek Watershed							
		Taylor Creek							
GM86	6.3	near 4540 Reemelin Road	PCC	3	326	756.1	2420	206	**NON**
GM85	4.98	Intersection of Johnson & Reemelin Rds.	PCC	3	91	494.2	2420	206	**NON**
GM84	4.6	end of Service Road near I-74	PCC	3	2420	2420	2420	206	**NON**
GM83	3.53	UST. Harrison Rd. bridge (600 meters)	PCB	6	24	123.4	2420	161	**FULL**
GM82	2.93	Harrison Rd. bridge	PCB	3	86	163.4	488	161	**NON**
GM81	1.62	between I-74 & Harrison Ave. near TC Valero	PCB	6	199	365.8	980	161	**NON**
GM80	0.8	near Harrison & Wesselman intersection	PCB	6	91	222.1	921	161	**NON**
		Unnamed Trib to Taylor Creek @RM 4.9							
GM106	0.28	residence 5310 Haft Rd. near I-74	SC	2	549	1152.6	2420	1030	**NON**
		Forfeit Run (Trib to Taylor Cr. @RM 1.42)							
GM107	0.3	Forfeit Run Rd.	PCC	2	261	794.7	2420	206	**NON**
		Eagle Creek (Trib to Taylor Cr. @RM 0.91)							
GM108	0.28	Pull-off near 7430 Eagle Creek Rd.	SC	2	35	291	2420	1030	**FULL**
		Unnamed Trib to Taylor Creek @RM 1.74							
GM109	0.45	across from 6830 Mullen Ave.	SC	2	96	482	2420	1030	**FULL**
		Briarly Creek (14-148)							
GM91	3.9	near bridge at 3852 Ridgedale Dr.	SC	3	140	724	2420	1030	**FULL**
GM90	2.45	at bridge crossing near 5994 Gaines Rd.	PCC	3	88	301.1	1733	206	**NON**
GM89	1.82	adj. to Briarly Creek Rd.	PCC	3	179	513.8	1553	206	**NON**
GM88	1.22	at Sheed Rd. bridge	PCC	3	109	471.4	2420	206	**NON**
GM87	0.2	Dst. West Fork Rd. Bridge	PCC	3	30	76.1	186	206	**FULL**
		Unnamed Trib to Briarly Creek @RM 1.44							
GM112	0.46	near mailboxes at end of Hubble Road	PCC	2	649	1135.3	1986	206	**NON**
		Wesselman Creek							
GM94	4.72	road crossing near 6250 Wesselman Rd.	PCC	3	1733	2165.1	2420	206	**NON**

***Table 9**. Bacteriological (E. coli) sampling results during summer-fall normal flows in the Taylor Creek and direct Ohio River tributaries study area during 2014. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow and sites with only a single sample are italicized (PC – Primary Contact; SC – Secondary Contact); sites with any values at the TNTC (too numerous to count) value of 2420 are highlighted in orange.*

Site ID	RM	Location	Recre-ation Use	N	*E.coli* Min.	*E. coli* Geo. Mean	*E. coli* Max.	Cri-teria GM	Attain-ment Status
		***Wesselman Creek** (continued)*							
GM93	2.9	adj. to Wesselman Rd.	PCC	3	57	693.7	2420	206	**NON**
GM99	2.9	Dst. Taylor Rd. bridge crossing	PCB	3	58	338.4	2420	161	**NON**
GM92	0.5	7695 Wesselman Rd.	PCB	3	135	274.9	921	161	**NON**
		Unnamed Trib to Wesselman Creek @RM 2.59							
GM100	1.21	between Taylor & Old Taylor Rd.	PCC	2	1046	1591	2420	206	**NON**
		Steel Creek							
GM111	2.16	Beerman Road bridge Crossing	PCC	3	93	816.7	2420	206	**NON**
GM102	1.79	Downstream from Sheed Road	PCC	3	488	881	2420	206	**NON**
GM95	0.3	Sheed Rd. bridge	PCC	3	115	403.5	2420	206	**NON**
		Unnamed Trib to Steel Creek							
GM103	0.31	Sheed Rd bridge; near 7764 Sheed Rd.	PCC	2	2420	2420	2420	206	**NON**
		WAU 02-03 – Muddy Creek Watershed							
		Muddy Creek							
MU05	6.35	Sidney & Muddy Creek Pull-Off	PCB	2	2420	2420	2420	161	**NON**
MU04	5.4	Beneath Ebenezer Road bridge	PCB	2	488	1086.7	2420	161	**NON**
MU03	2.72	Beneath Cleves-Warsaw Pike bridge	PCB	6	54	343.3	2420	161	**NON**
MU02	2.25	Beneath Hillside Ave. bridge	PCB	6	197	435.3	2420	161	**NON**
MU01	0.17	at the confluence with Ohio River	PCB	6	28	393.5	2420	161	**NON**
		Unnamed Trib to Muddy Creek @RM 2.37							
MU10	0.6	Van Blaricum Rd. bridge crossing	SC	1	649	*649*	*649*	1030	**FULL**
		Unnamed Trib to Muddy Creek @RM 5.97							
MU12	0.65	Gloria Dell Lutheran Church	PCC	1	2420	*2420*	*2420*	206	**NON**
		Unnamed Trib to Muddy Creek @RM 6.53							
MU13	0.6	Intersection of Werk Rd & Westborne Dr.	PCC	1	2420	*2420*	*2420*	206	**NON**
		Unnamed Trib to Muddy Creek @RM 0.3							
MU08	1.8	Fairway Glen Dr. bridge crossing	SC	1	2420	*2420*	*2420*	1030	**NON**

***Table 9**. Bacteriological (E. coli) sampling results during summer-fall normal flows in the Taylor Creek and direct Ohio River tributaries study area during 2014. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow and sites with only a single sample are italicized (PC – Primary Contact; SC – Secondary Contact); sites with any values at the TNTC (too numerous to count) value of 2420 are highlighted in orange.*

Site ID	RM	Location	Recre-ation Use	N	*E.coli* Min.	*E. coli* Geo. Mean	*E. coli* Max.	Cri-teria GM	Attain-ment Status
		Unnamed Trib to Muddy Creek @RM 0.3							
MU07	0.6	Addyston VFW Parking lot	PCC	1	365	*365*	*365*	206	**NON**
		UT @ 0.95 to UT to Muddy Creek @RM 0.3							
MU09	0.6	pull-off near Addyston Town Sign	PCC	1	548	*548*	*548*	206	**NON**
		UT RM 0.45 to UT to Muddy Cr @RM 5.97							
MU14	0.2	Andres Lane Crossing	SC	1	228	*228*	*228*	1030	**FULL**
		WAU 02-04 –Rapid Run Watershed							
		Rapid Run							
RR03	2.7	Near Rapid Run Rd. DST. CSO 523	PCC	1	2420	*2420*	*2420*	206	**NON**
RR02	1.2	Bender Road Crossing	PCB	2	66	271.9	1120	161	**NON**
RR01	0.1	Bender Road Crossing	PCB	1	1300	*1300*	*1300*	161	**NON**
		Wulff Creek							
RR04	0.55	Wulff Run Road	PCC	1	387	*387*	*387*	206	**NON**
		Unnamed Trib to Wulff Run @RM 0.77							
RR05	0.68	near intersection of Oakwood & Delhi Rd.	PCC	1	1414	*1414*	*1414*	206	**NON**
		WAU 02-05 – Indian Creek Watershed							
		Indian Creek (23-019)							
IC06	2.43	Hampshire Road Crossing	SC	2	1414	1849.8	2420	1030	**NON**
IC05	2.08	Near Hole #5 tee off	PCC	2	488	1086.7	2420	206	**NON**
IC02	1.22	Near Aston Oaks Golf Club	PCC	2	411	798.9	1553	206	**NON**
IC01	0.30	Near Tisch Scientific Parking Lot	PCC	2	2420	2420	2420	206	**NON**
		Unnamed Trib to Indian Creek							
IC07	0.13	at Dead End of Stonehaven Dr.	SC	1	579	*579*	579	1030	**Full**
		Unnamed Trib to Indian Creek @RM 1.55							
IC08	1.5	Cross roads Church lower parking lot	SC	1	2420	*2420*	2420	1030	**NON**

***Table 9**. Bacteriological (E. coli) sampling results during summer-fall normal flows in the Taylor Creek and direct Ohio River tributaries study area during 2014. All values are expressed as the most probable number (MPN) per 100 ml of water. Geometric mean values were used to determine attainment of the applicable recreation uses; values above the geometric mean water quality criterion are highlighted in yellow and sites with only a single sample are italicized (PC – Primary Contact; SC – Secondary Contact); sites with any values at the TNTC (too numerous to count) value of 2420 are highlighted in orange.*

Site ID	RM	Location	Recre-ation Use	N	*E.coli* Min.	*E. coli* Geo. Mean	*E. coli* Max.	Cri-teria GM	Attain-ment Status
		Reference Sites							
		Mill Run							
RF11	0.9	off Route 42	PCB	6	46	248.1	2420	161	**NON**
		Stonelick Creek							
RF14	3.1	5353 Stonelick Corners Rd.	PCB	7	8	148.5	1733	161	**FULL**
RF13	1.0	US RTE. 50 upstream	PCB	7	150	350.5	866	161	**NON**
		Fivemile Creek							
RF15	0.5	Bluesky Park Road Bridge	PCB	7	72	513.2	2420	161	**NON**
		W. Fk. E. Fk. Little Miami River							
RF16	0.1	State Route 123	PCB	7	11	154.4	488	161	**FULL**
		Dodson Creek							
RF17	0.05	Ford near mouth	PCB	6	19	306.3	687	161	**NON**

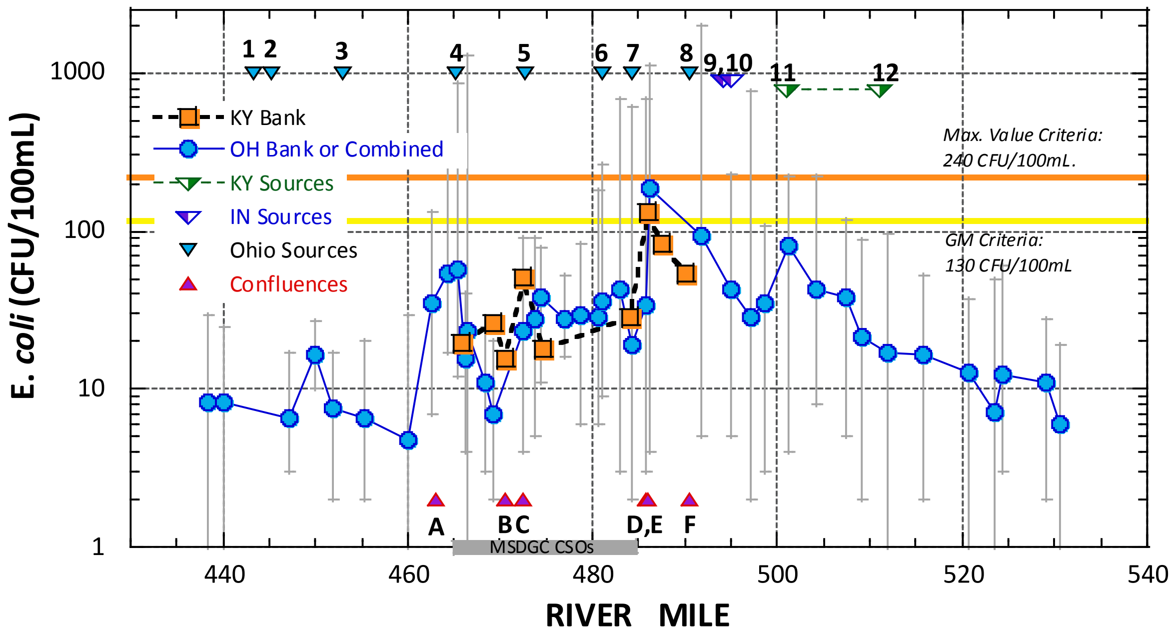

***Figure 4**. E. coli (CFU/100mL) vs. river mile for sites sampled in the Ohio River Markland navigation pool during 2014 (top). Yellow line represents primary contact geometric mean criteria of 130 CFU/100mL and orange line maximum criteria of 240 CFU/100mL.*

***Table 10**. Bacteriological (E. coli) sampling results in the Ohio River study area (Markland Pool) during summer-fall normal flows in 2014. All values are expressed as Colony Forming Units (CFU) per 100 ml of water. ORSANCO E. coli criteria[1] were used to determine attainment of the applicable recreation use; values above the geometric mean are highlighted in yellow and maximum value water quality criteria are highlighted in orange.*

Site ID	River Mile	Bank	Location	N	Min. *E.coli* (CFU)	Geometric Mean *E. coli*	Max. *E. coli* (CFU)	Status
Ohio River (90-001)								
OR01	438.3	KY	Dst. Meldahl L&D	6	1	8.3	29	Full
OR02	440.0	OH	Dst. Neville, OH	6	1	8.2	25	Full
OR03	447.2	KY	Ust. New Richmond, OH; Mentor, KY	5	3	6.5	17	Full
OR04	450.0	OH	Ust. Nine Mile Creek	6	10	16.3	27	Full
OR05	451.8	KY	@Oneonta, KY; ust. from Beckjord Station	6	2	7.6	17	Full
OR06	455.4	OH	Dst. NineMile Creek WWTP	5	2	6.5	20	Full
OR07	460.0	KY	Dst. outfall #1 Materials Co.	6	1	4.8	29	Full
OR08	462.6	OH	Ust. LMR Dst. old ramp	6	7	34.6	133	Full
OR09	464.3	OH	Dst. LMR; Ust. L. Miami WWTP	6	17	53.2	326	Full
OR10	465.3	OH	Dst. L. Miami WWTP	6	12	57.2	866	**NON**
OR11	465.8	KY	bank opposite CSOs 466-469	6	4	19.4	51	Full
OR12	466.2	OH	Dst. CSO's 466-469	5	4	15.6	40	Full
OR13	466.5	OH	Dst. CSO 657	6	1	23.4	1300	**NON**
OR14	468.4	OH	Dst. 11 CSOs (448-453; 458-460; 465; 667)	6	3	11.1	25	Full
OR15	469.2	KY	Bellevue, KY	6	4	26.4	866	**NON**
OR16	469.3	OH	Dst. CSOs 446-447	6	2	7	20	Full
OR17	470.5	KY	Dst. CSOs 443-444; 461-465	6	3	15.5	81	Full
OR18	472.5	KY	Dst. Covington, KY, opposite Cincinnati	6	8	50.7	579	**NON**
OR19	472.5	OH	Dst. Mill Creek (barges in the zone)	6	4	23.2	91	Full
OR20	473.8	OH	Dst. CSOs 422-425	6	5	27.7	91	Full
OR21	474.3	OH	Dst. Boldface Creek	6	11	38.3	78	Full
OR22	474.6	KY	Opposite CSOs & Mill Creek	6	2	18.1	51	Full

***Table 10**. Bacteriological (E. coli) sampling results in the Ohio River study area (Markland Pool) during summer-fall normal flows in 2014. All values are expressed as Colony Forming Units (CFU) per 100 ml of water. ORSANCO E. coli criteria[1] were used to determine attainment of the applicable recreation use; values above the geometric mean are highlighted in yellow and maximum value water quality criteria are highlighted in orange.*

Site ID	River Mile	Bank	Location	N	Min. *E.coli* (CFU)	Geometric Mean *E. coli*	Max. *E. coli* (CFU)	Status
OR23	477	OH	Fleeting area (barges in site) dst. CSOs 412-416	6	16	27.8	52	Full
OR24	478.7	OH	Dst. CSOs 410-411	6	6	29.6	84	Full
OR25	480.6	OH	Ust. Muddy Creek	6	6	28.6	179	Full
OR26	481.1	OH	Dst. Muddy Creek WWTP	6	9	35.9	261	**NON**
OR27	483	OH	Dst. CSOs 403-406	6	3	42.3	687	**NON**
OR28	484.1	KY	opposite Indian Creek	6	4	28.2	461	**NON**
OR29	484.2	OH	Dst. Indian Creek; INEOS ABS	6	2	18.9	613	**NON**
OR30	485.7	OH	dst. CSOs 675-676	6	3	34.1	687	**NON**
OR31	485.9	KY	Dst. Muddy Creek KY	6	7	133.5	2420	**NON**
OR32	486.2	OH	Dst. Rapid Run	6	4	183.7	1120	**NON**
OR33	487.5	KY	Dst. North Bend, IN	6	3	82.2	866	**NON**
OR34	490.1	KY	Ust. GMR Confluence/ across from Markland PP	6	6	54.4	461	**NON**
OR35	491.8	IN	Dst. GMR confluence; Ust. Tanners Creek Power Station	6	5	92.3	1986	**NON**
OR36	495	IN	Dst. Tanners Creek	6	5	42.5	228	Full
OR37	497.2	IN	Aurora, IN	6	2	28.3	770	**NON**
OR38	498.6	KY	Ust Laughery Creek opposite bank	6	3	34.9	107	Full
OR39	501.3	KY	Dst. Western Regional WWTP (KY)	6	4	81.4	222	Full
OR40	504.1	IN	end at Daymark	6	8	42.6	222	Full
OR41	507.5	KY	Dst. Rising Sun, IN	6	5	38.5	118	Full
OR42	509.2	IN	Dst. Arnold Creek opposite bank	6	2	21.1	89	Full
OR43	511.9	KY	across from Lick Creek	6	1	16.8	96	Full
OR44	515.8	IN	Ust. Big South Fork Creek	6	2	16.5	52	Full
OR45	520.8	KY	Ust. Paint Lick Creek (KY)	6	1	12.8	37	Full

Table 10*. Bacteriological (E. coli) sampling results in the Ohio River study area (Markland Pool) during summer-fall normal flows in 2014. All values are expressed as Colony Forming Units (CFU) per 100 ml of water. ORSANCO E. coli criteria[1] were used to determine attainment of the applicable recreation use; values above the geometric mean are highlighted in yellow and maximum value water quality criteria are highlighted in orange.*

Site ID	River Mile	Bank	Location	N	Min. *E.coli* (CFU)	Geometric Mean *E. coli*	Max. *E. coli* (CFU)	Status
OR46	523.6	IN	Dst. Big Sugar Creek (KY)	6	1	7.2	49	Full
OR47	524.3	KY	at field w/rip rap very shallow	6	3	12.2	60	Full
OR48	529	KY	across from confluence Turtle Creek (IN)	6	2	10.9	28	Full
OR49	530.5	IN	Ust. Markland Dam	6	1	6	19	Full

[1]The ORSANCO WQS for *E. coli* state that no single sample should be greater than 240/100mL and should not exceed 130/100mL as a monthly geometric mean (at least 5 samples required).

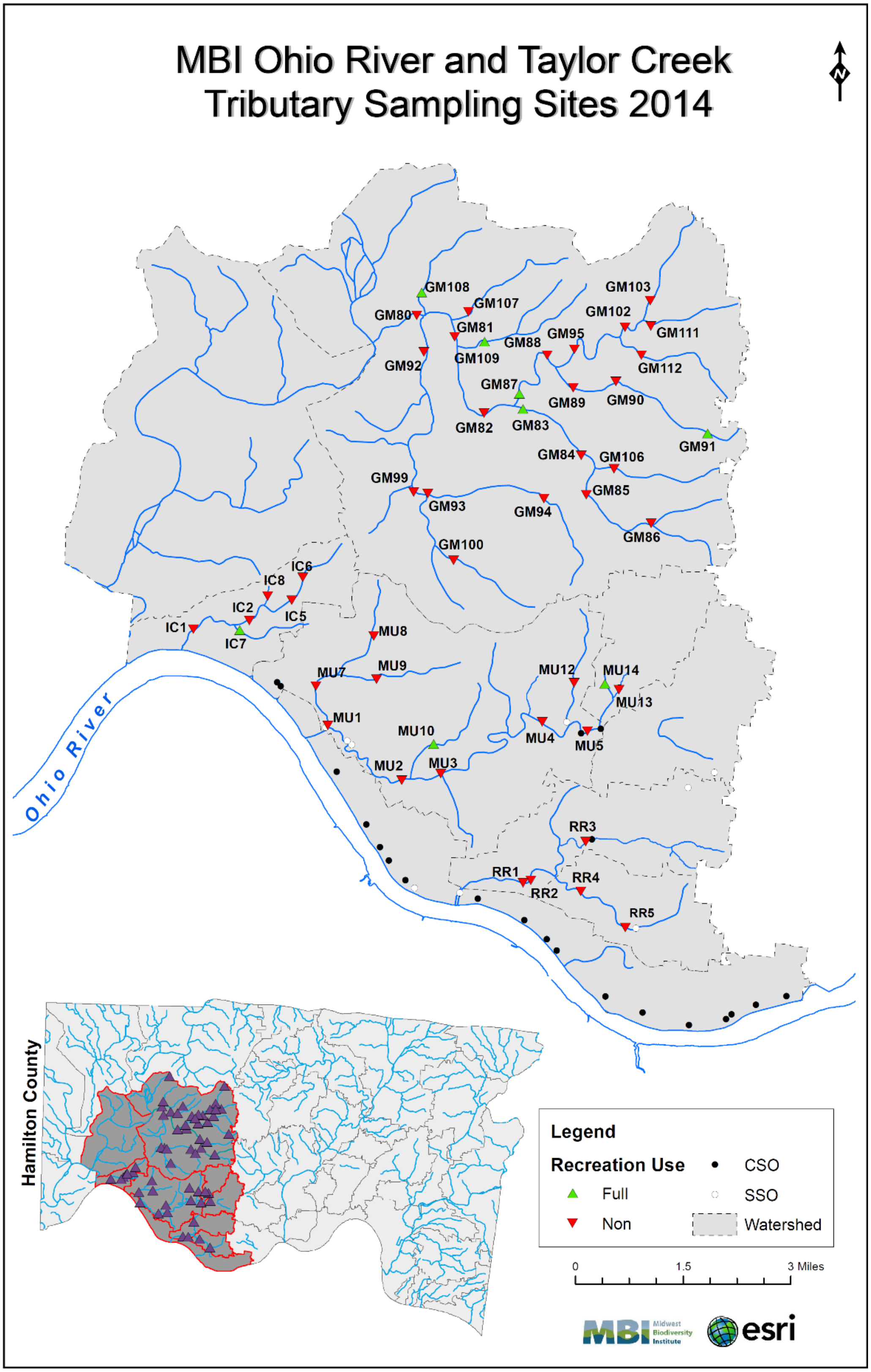

***Figure 5**. Map of recreational use attainment status for the Primary Contact suite of use tiers in the Direct Tributaries and Taylor Creek watersheds during 2014 expressed as attainment (blue) or non-attainment (red) based on E. coli values. MSDGC CSO locations appear as black circles.*

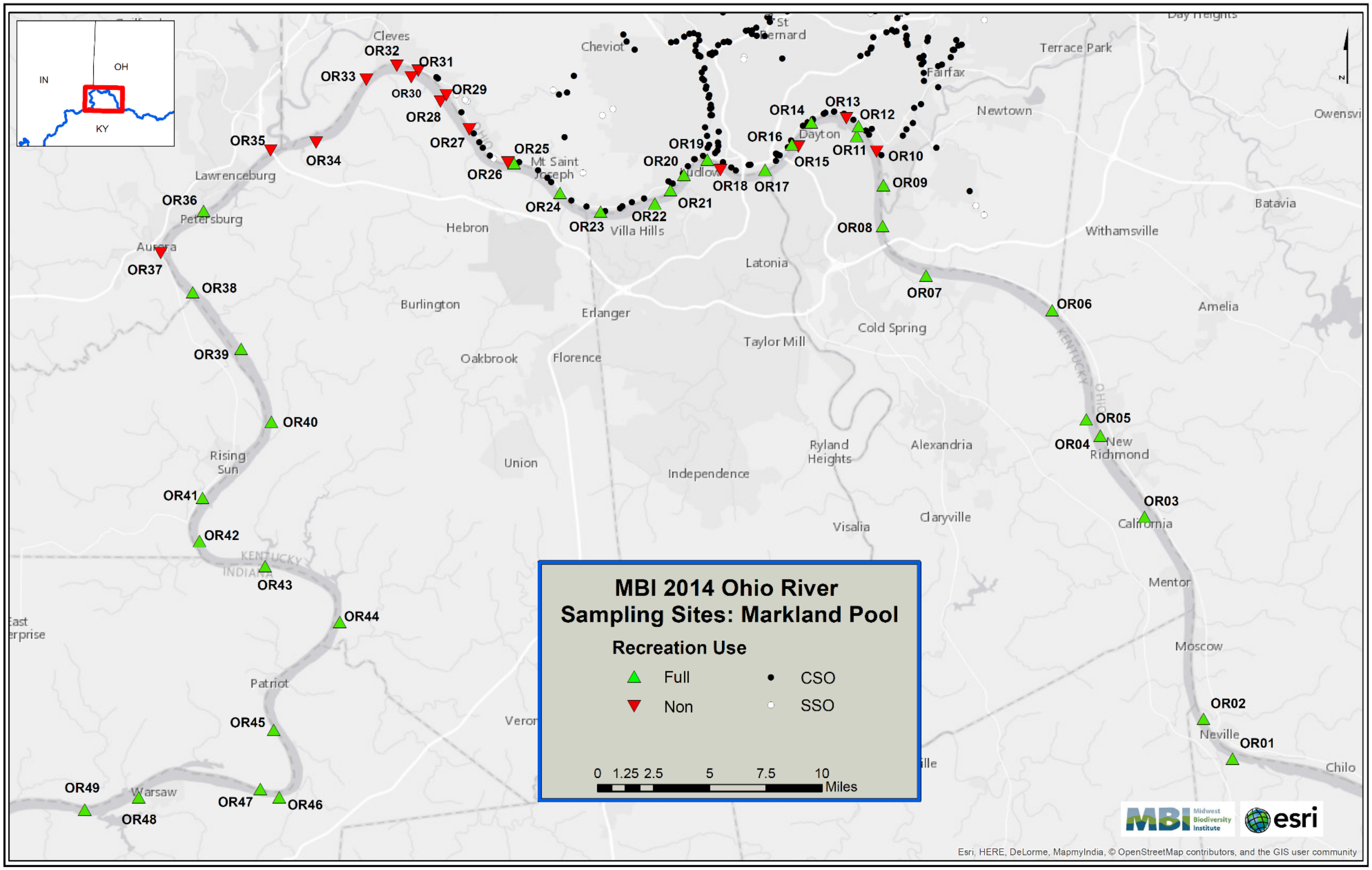

Figure 6. *Map of recreational use attainment status for the Primary Contact suite of use tiers in the Ohio River Markland pool during 2014 expressed as attainment (blue) or non-attainment (red) based on E. coli values. MSDGC CSO locations appear as black circles. CSOs along the KY shoreline are not shown.*

Biological and Water Quality Assessment of the Ohio River, Direct Tributaries, and Taylor Creek 2014

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. Complete an Integrated Prioritization System (IPS) Excel tool (by end of 2015) 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.

2014 Direct Tributaries, Taylor Creek, and Ohio River Assessment Scope and Purpose

The 2014 Direct Tributaries, Taylor Creek, and Ohio River assessment included 3 of the 11 subwatersheds and the Ohio River mainstem all of which are part of the overall MSDGC service area watershed monitoring plan (MBI 2011). This included the Direct Ohio River Tributaries between Mill Creek and the Great Miami River, the Taylor Creek watershed, and the Ohio River mainstem within the Markland navigation pool. In addition to the baseline purposes of the MSDGC service area monitoring plan, specific assessment issues in 2014 study area included major wastewater treatment plants on the Ohio River mainstem, CSOs in the Direct Tributaries, and developing suburban areas throughout the Taylor Creek watershed. The issue of PHWH streams was also included in the survey design.

Cincinnati has the fifth highest volume of CSOs in the U.S. (MSDGC 2011a). As a result, water quality has been significantly impacted in the Ohio River mainstem, Mill Creek, the Direct Ohio River Tributaries, and parts of the Little Miami River (i.e., Duck Creek). However, CSOs are not a major issue in the Taylor Creek watershed 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 2014 monitoring is also being used to fulfill National Pollution Discharge Elimination System (NPDES) permit reporting requirements by MSDGC. Part II, G.

"Instream Monitoring" of the MSDGC CSO NPDES permit issued June 30, 2014 states the following:

"G. Instream Monitoring

> *As required by this NPDES permit, since 1994, the permittee has been conducting instream studies to evaluate the chemical specific and biological impacts associated with combined sewer overflows in its Mill Creek, 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 documented the Agency's acceptance of the plan of study.*
>
> *Under that plan of study, the permittee has conducted monitoring in each service area on a three-year rotating schedule. During this permit cycle, the permittee will be adding the Great Miami River, and the monitoring will be on a four-year rotating schedule.*
>
> *The Watershed Monitoring and Bioassessment Plan for the MSD Greater Cincinnati Service Area, Hamilton County, Ohio; Technical Report MBI/5-11-3 (2011, Midwest Biodiversity Institute) provides the overall framework for the instream monitoring conducted during the term of this NPDES permit. It will allow the permittee to conduct studies to support its ongoing Capital Improvement Program and Wet-Weather Improvement Program.*
>
> *During the term of this permit, the permittee shall conduct instream chemical specific and biological monitoring as follows:*
>
> *2014 Ohio River Tributaries/Muddy Creek*
> *2015 Completion of Integrated Priority System (IPS)*
> *2016 Mill Creek*
> *2017 Little Miami River*
> *2018 Great Miami River/Ohio River Tributaries*
> *2019 Ohio River Tributaries/Muddy Creek*
>
> *The permittee shall submit a report on the 2014, 2016, 2017, 2018 and 2019 stream studies to the Ohio EPA Southwest District Office no later than June 30 of the following year."*

METHODS

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.

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 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 7 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 the Ohio River mainstem and in 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 and 2010 bioassessments by Ohio EPA (1994, 2014) serve as the baseline against which the 2014 results can be compared to assess incremental changes in key parameters and indicators. In the Ohio River data collected and analyzed by ORSANCO in 2005 and 2009 in Markland Pool form the basis for measuring incremental changes. The more dense sampling design of sites collected by MBI in the Markland Pool forms the basis for future trend analyses of the Ohio River in the Cincinnati area.

Direct Ohio River Tributaries and Taylor Creek

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 the mouth of each subwatershed and subsequently halving each reduction to a drainage area of approximately 0.5-1.0 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 (e.g., Ohio River mainstem, Table 11 and Figure 8) in order to position sites upstream and downstream from major discharges, sources of potential releases and contamination, and major physical modifications to provide a "pollution profile" along each major tributary and in the Ohio River mainstem. The result was a design that included chemical, physical, and biological sampling at a total of 49 sites in the Ohio River mainstem (Table 11) and 51 sites in the Direct Tributaries and Taylor Creek watersheds (Table 12). Each site was assigned a unique site code as depicted in Tables 11 and 12 and Figures 7 and 8. An additional six (6) reference sites outside of the 2014 study area were sampled as part of a network of 22 Ohio EPA regional reference sites that are relevant to the MSDGC service area.

Table 11. *List of sampling locations and sample types for the 2014 Ohio River mainstem bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Bank	Drainage Area mi^2	Lat/Long	Chemical Sample Types[1]	Biological Sample Types[2]	Location
				Ohio River (90-001)			
OR01	438.20	KY	69501	38.799840, -84.20663	C, D, N, H, O, B	F,M	Dst. Meldahl Lock & Dam
OR02	440.00	OH	69501	38.819930, -84.22541	C, D, N, H, O, B	F,M	Dst. Neville, OH
OR03	447.50	KY	71000	38.921350, -84.26343	C, D, N, H, O, B	F,M	Ust. New Richmond, OH; Mentor, KY
OR04	450.80	OH	71000	38.962070, -84.29193	C, D, N, H, O, B	F,M	Ust. Nine Mile Creek
OR05	451.80	KY	71000	38.970120, -84.30106	C, D, N, H, O, B	F,M	@ Oneonta, KY; ust from Beckjord Station
OR06	455.40	OH	71000	39.024890, -84.32283	C, D, N, H, O, B	F,M	Dst. NineMile Creek WWTP
OR07	460.00	KY	71000	39.042120, -84.40434	C, D, N, H, O, B	F,M	Dst. outfall #1 Materials Co.
OR08	462.60	OH	71000	39.066980, -84.43224	C, D, N, H, O, B	F,M	Ust. L. Miami R.; dst. old ramp
OR09	464.30	OH	73000	39.087610, -84.43191	C, D, N, H, O, B	F,M	Dst. L. Miami R.; Ust. L. Miami WWTP
OR10	465.30	OH	73000	39.104300, -84.43606	C, D, N, H, O, B	F,M	Dst. L. Miami WWTP
OR11	465.80	KY	73000	39.112140, -84.44894	C, D, N, H, O, B	F,M	Bank opposite CSOs 466-469
OR12	466.20	OH	73000	39.116990, -84.44794	C, D, N, H, O, B	F,M	Dst. CSOs 466-469
OR13	466.50	OH	73000	39.116990, -84.44794	C, D, N, H, O, B	F,M	Dst. CSO 657
OR14	468.40	OH	73000	39.118950, -84.47844	C, D, N, H, O, B	F,M	Dst. 11 CSOs 448-453; 458-460; 465; 667
OR15	469.20	KY	73000	39.106750, -84.48659	C, D, N, H, O, B	F,M	Bellevue, KY
OR16	469.30	OH	73000	39.106750, -84.48659	C, D, N, H, O, B	F,M	Dst. CSOs 446-447
OR17	470.50	KY	73000	39.095200, -84.50801	C, D, N, H, O, B	F,M	Dst. CSOs 443-444, 461-465
OR18	472.50	KY	73000	39.095120, -84.53683	C, D, N, H, O, B	F,M	Dst. Covington, KY, opposite Cincinnati
OR19	472.51	OH	73000	39.100190, -84.54529	C, D, N, H, O, B	F,M	Dst. Mill Creek (barges in the zone)
OR20	473.80	OH	73000	39.100190, -84.54529	C, D, N, H, O, B	F,M	Dst. CSOs 422-425

***Table 11**. List of sampling locations and sample types for the 2014 Ohio River mainstem bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Bank	Drainage Area mi²	Lat/Long	Chemical Sample Types[1]	Biological Sample Types[2]	Location
OR21	474.30	OH	73000	39.084920, -84.56899	C, D, N, H, O, B	F,M	Dst. Boldface Creek
OR22	474.60	KY	73000	39.078340, -84.57909	C, D, N, H, O, B	F,M	Opposite CSOs & Mill Creek
OR23	477.00	OH	73000	39.074190, -84.61421	C, D, N, H, O, B	F,M	Fleeting area (barges in site) dst. CSOs 412-416
OR24	478.70	OH	73000	39.074190, -84.61421	C, D, N, H, O, B	F,M	Dst. CSOs 410-411
OR25	480.60	OH	75000	39.098500, -84.66988	C, D, N, H, O, B	F,M	Ust. Muddy Creek
OR26	481.10	OH	75000	39.098790, -84.67392	C, D, N, H, O, B	F,M	Dst. Muddy Creek WWTP
OR27	483.00	OH	75000	39.115290, -84.69874	C, D, N, H, O, B	F,M	Dst. CSOs 403-406
OR28	484.10	KY	75000	39.129420, -84.71737	C, D, N, H, O, B	F,M	opposite Indian Creek
OR29	484.20	OH	75100	39.132590, -84.71352	C, D, N, H, O, B	F,M	Dst. Indian Creek; INEOS ABS
OR30	485.70	OH	75100	39.144830, -84.73161	C, D, N, H, O, B	F,M	dst. CSOs 675-676
OR31	485.90	KY	75350	39.141460, -84.73612	C, D, N, H, O, B	F,M	Dst. Muddy Creek KY
OR32	486.20	OH	75350	39.147280, -84.74551	C, D, N, H, O, B	F,M	Dst. Rapid Run
OR33	487.50	KY	75350	39.140220, -84.76521	C, D, N, H, O, B	F,M	Dst. North Bend, IN
OR34	490.10	KY	75500	39.108810, -84.79754	C, D, N, H, O, B	F,M	Ust. GMR Confluence/ across from Markland PP
OR35	491.80	IN	75500	39.108810, -84.79754	C, D, N, H, O, B	F,M	Dst. GMR confluence; Ust. Tanners Creek Power Station
OR36	495.00	IN	81000	39.074700, -84.87015	C, D, N, H, O, B	F,M	Dst. Tanners Creek
OR37	497.20	IN	81000	39.053510, -84.89761	C, D, N, H, O, B	F,M	Aurora, IN
OR38	498.60	KY	81000	39.033770, -84.87719	C, D, N, H, O, B		Ust Laughery Creek opposite bank
OR39	501.30	KY	81000	39.005620, -84.84573	C, D, N, H, O, B	F,M	Dst. Western Regional WWTP (KY)
OR40	504.10	IN	81000	38.969090, -84.82629	C, D, N, H, O, B	F,M	end at Daymark

***Table 11**. List of sampling locations and sample types for the 2014 Ohio River mainstem bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Bank	Drainage Area mi^2	Lat/Long	Chemical Sample Types[1]	Biological Sample Types[2]	Location
OR41	507.50	KY	81000	38.930820, -84.87059	C, D, N, H, O, B	F,M	Dst. Rising Sun, IN
OR42	509.50	IN	81000	38.909190, -84.87263	C, D, N, H, O, B	F,M	Dst. Arnold Creek opposite bank
OR43	511.90	KY	81000	38.896580, -84.83035	C, D, N, H, O, B	F,M	across from Lick Creek
OR44	515.80	IN	81000	38.868530, -84.78226	C, D, N, H, O, B	F,M	Ust. Big South Fork Creek
OR45	520.80	KY	81000	38.814300, -84.82495	C, D, N, H, O, B	F,M	Ust. Paint Lick Creek (KY)
OR46	523.60	IN	81000	38.780462, -84.82139	C, D, N, H, O, B	F,M	Dst. Big Sugar Creek (KY)
OR47	524.30	KY	81000	38.784580, -84.83350	C, D, N, H, O, B	F,M	at field w/ rip rap very shallow
OR48	529.00	KY	81000	38.780500, -84.91191	C, D, N, H, O, B	F,M	across from confluence Turtle Creek (IN)
OR49	530.50	IN	81000	38.774300, -84.94670	C, D, N, H, O, B		Ust. Markland Dam (IN)

[1] C – conventional; D – demand; N – nutrients; H – heavy metals; O – organics; B – sediment chemistry.
[2] F – fish; M – macroinvertebrates.

***Table 12**. List of sampling locations and sample types for the 2014 Direct Tributaries and Taylor Creek watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites (QHEI). Regional reference sites that are sampled as part of the overall MSDGC four year monitoring plan are also included. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Drainage Area mi^2	Latitude - Longitude	Chemistry Data Type[1]	Biological Data Type[2]	Location
WAU 09-05 – Taylor Creek Watershed						
Taylor Creek						
GM86	6.30	1.2	39.175520, -84.62398	C, D, N, H, O, B	QL, FHW, PHW	near 4540 Reemelin Road
GM85	4.98	2.2	39.181000, -84.64100	C, D, N, H, O, B	QL, FHW, PHW	Intersection of Johnson & Reemelin Rds.
GM84	4.60	3.9	39.188900, -84.64250	C, D, N, H, O, B	QL, FHW	end of Service Road near I-74
GM83	3.53	5	39.198000, -84.65800	C, D, N, H, O, B, DS	QL, FHW	UST. Harrison Rd. bridge (600 meters)
GM82	2.93	12.6	39.197000, -84.66800	C, D, N, H, O, B	HD, QL, FHW	Harrison Rd. bridge
GM81	1.62	14.3	39.212200, -84.67610	C, D, N, H, O, B, DS	HD, QL, FHW	between I-74 & Harrison Ave. near TC Valero
GM80	0.80	26.5	39.216400, -84.68610	C, D, N, H, O, B, DS	HD, QL, FWD	near Harrison & Wesselman intersection
Unnamed Trib to Taylor Creek @RM 4.9						
GM106	0.28	0.9	39.186380, -84.63401	C, D, N, H, B	QL, FHW, PHW	residence 5310 Haft Rd. near I-74
Forfeit Run (Trib to Taylor Cr. @RM 1.42)						
GM107	0.30	1.4	39.217333, -84.67269	C, D, N, H, B	QL, FHW, PHW	Forfeit Run Rd.
Eagle Creek (Trib to Taylor Cr. @RM 0.91)						
GM108	0.28	0.7	39.221000, -84.68500	C, D, N, H, B	QL, FHW, PHW	Pull-off near 7430 Eagle Creek Rd.
Unnamed Trib to Taylor Creek @RM 1.74						
GM109	0.45	0.9	39.211400, -84.66841	C, D, N, H, B	QL, FHW, PHW	across from 6830 Mullen Ave.

***Table 12**. List of sampling locations and sample types for the 2014 Direct Tributaries and Taylor Creek watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites (QHEI). Regional reference sites that are sampled as part of the overall MSDGC four year monitoring plan are also included. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Drainage Area mi^2	Latitude - Longitude	Chemistry Data Type[1]	Biological Data Type[2]	Location
Unnamed Trib to the GMR @RM 16.3						
GM110	1.75	0.1	39.244020, -84.67751		FHW, PHW	Near 7164 Thompson Rd.
Briarly Creek						
GM91	3.90	0.3	39.194000, -84.61000	C, D, N, H, O, B	QL, FHW, PHW	near bridge at 3852 Ridgedale Dr.
GM90	2.45	1.3	39.204000, -84.63400	C, D, N, H, O, B	QL, FHW	at bridge crossing near 5994 Gaines Rd.
GM89	1.82	2.1	39.202500, -84.64500	C, D, N, H, O, B	QL, FHW, PHW	adj. to Briarly Creek Rd.
GM88	1.22	6.6	39.209000, -84.65200	C, D, N, H, O, B	QL, FHW	at Sheed Rd. bridge
GM87	0.20	7.1	39.201000, -84.65900	C, D, N, H, O, B	QL, FHW	Dst. West Fork Rd. Bridge
Unnamed Trib to Briarly Creek @RM 1.44						
GM112	0.46	1.2	39.209430, -84.62759	C, D, N, H, B	QL, FHW, PHW	near mailboxes at end of Hubble Road
Wesselman Creek						
GM94	4.72	1.1	39.180000, -84.65200	C, D, N, H, O, B	QL, FHW, PHW	road crossing near 6250 Wesselman Rd.
GM93	3.00	2.6	39.180500, -84.68210	C, D, N, H, O, B	QL, FHW	adj. to Wesselman Rd.
GM99	2.90	5.7	39.180700, -84.68575	C, D, N, H, O, B	QL, FHW	Dst. Taylor Rd. bridge crossing
GM92	0.50	7.6	39.209000, -84.68400	C, D, N, H, O, B	QL, FHW	7695 Wesselman Rd.

***Table 12**. List of sampling locations and sample types for the 2014 Direct Tributaries and Taylor Creek watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites (QHEI). Regional reference sites that are sampled as part of the overall MSDGC four year monitoring plan are also included. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Drainage Area mi^2	Latitude - Longitude	Chemistry Data Type[1]	Biological Data Type[2]	Location
Unnamed Trib to Wesselman Creek @RM 2.59						
GM100	1.21	1.4	39.167130, -84.67499	C, D, N, H, B	QL, FHW, PHW	between Taylor & Old Taylor Rd.
Steel Creek						
GM111	2.16	0.8	39.215350, -84.62528	C, D, N, H, O, B	QL, FHW, PHW	Beerman Road bridge Crossing
GM102	1.79	2.6	39.215000, -84.63200	C, D, N, H, O, B	QL, FHW, PHW	Downstream from Sheed Road
GM95	0.30	4.4	39.210300, -84.64500	C, D, N, H, O, B	QL, FHW	Sheed Rd. bridge
Unnamed Trib to Steel Creek						
GM98	2.30	0.1	39.236000, -84.61600		FHW, PHW	Trib south of pond, Gravel road access
Unnamed Trib to Steel Creek						
GM103	0.31	1.2	39.220460, -84.62561	C, D, N, H, B	QL, FHW, PHW	Sheed Rd bridge; near 7764 Sheed Rd.
WAU 02-03 – Muddy Creek Watershed						
Muddy Creek						
MU05	6.35	5.4	39.133360, -84.63928	C, D, N, H, O, B	FHW	Sidney & Muddy Creek Pull-Off
MU04	5.40	5.4	39.135000, -84.65100	C, D, N, H, O, B	FHW	Beneath Ebenezer Road bridge
MU03	2.72	12.3	39.124000, -84.67700	C, D, N, H, O, B, DS	FHW	Beneath Cleves-Warsaw Pike bridge
MU02	2.25	12.1	39.122540, -84.68707	C, D, N, H, O, B, DS	FHW	Beneath Hillside Ave. bridge

***Table 12**. List of sampling locations and sample types for the 2014 Direct Tributaries and Taylor Creek watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites (QHEI). Regional reference sites that are sampled as part of the overall MSDGC four year monitoring plan are also included. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Drainage Area mi²	Latitude - Longitude	Chemistry Data Type[1]	Biological Data Type[2]	Location
***Muddy Creek** (continued)*						
MU01	0.17	16.6	39.133180, -84.70658	C, D, N, H, O, B, DS	FHW	Confluence with Ohio River
Unnamed Trib to Muddy Creek @RM 2.37						
MU10	0.60 - 0.60	0.7	39.130000, -84.67900	C, D, N, H, B	QL, FHW, PHW	Van Blaricum Rd. bridge crossing
Unnamed Trib to Muddy Creek @RM 5.97						
MU12	0.65 - 0.65	1	39.143000, -84.64300	C, D, N, H, B	QL, FHW, PHW	Gloria Dell Lutheran Church
Unnamed Trib to Muddy Creek @RM 6.53						
MU13	0.60 - 0.60	1.9	39.141810, -84.63134	C, D, N, H, B	QL, FHW, PHW	Intersection of Werk Rd & Westborne Dr.
Unnamed Trib @RM 0.45 to UT to Muddy Cr @RM 5.97						
MU14	0.20 - 0.20	0.1	39.143000, -84.63500	C, D, N, H, B	QL, FHW, PHW	Andres Lane Crossing
Unnamed Trib to Muddy Creek @RM 0.3						
MU08	1.80	0.7	39.151490, -84.69523	C, D, N, H, O, B	FHW, PHW	Fairway Glen Dr. bridge crossing
Unnamed Trib to Muddy Creek @RM 0.3						
MU07	0.60	2.8	39.141060, -84.70992	C, D, N, H, B	FHW	Addyston VFW Parking lot
Unnamed Trib @RM 0.95 to UT to Muddy Creek @RM 0.3						
MU09	0.60	1	39.142770, -84.69425	C, D, N, H, B	FHW, PHW	pull-off near Addyston Town Sign
WAU 02-04 –Rapid Run Watershed						
Rapid Run						
RR03	2.70	2.2	39.111000, -84.63900	C, D, N, H, O, B	FHW, PHW	Near Rapid Run Rd. DST. CSO 523
RR02	1.20	5.8	39.103000, -84.65300	C, D, N, H, O, B	FHW	Bender Road Crossing

***Table 12**. List of sampling locations and sample types for the 2014 Direct Tributaries and Taylor Creek watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites (QHEI). Regional reference sites that are sampled as part of the overall MSDGC four year monitoring plan are also included. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Drainage Area mi²	Latitude - Longitude	Chemistry Data Type[1]	Biological Data Type[2]	Location
***Rapid Run** (continued)*						
RR01	0.10	9	0.000000, 0.000000	C, D, N, H, O, B	FHW	Bender Road Crossing
Wulff Creek						
RR04	0.55	2.2	39.101000, -84.64000	C, D, N, H, B	FHW, PHW	Wulff Run Road
Unnamed Trib to Wulff Run @RM 0.77						
RR05	0.68	1.3	39.093950, -84.62820	C, D, N, H, B	FHW, PHW	near intersection of Oakwood & Delhi Rd.
WAU 02-05 – Indian Creek Watershed						
Indian Creek						
IC06	2.43	0.5	39.163000, -84.71400	C, D, N, H, O, B	FHW, PHW	Hampshire Road Crossing
IC05	2.08	1.1	39.158300, -84.71670	C, D, N, H, O, B	FHW, PHW	Near Hole #5 tee off
IC02	1.22	1.5	39.154000, -84.72756	C, D, N, H, O, B	FHW, PHW	Near Aston Oaks Golf Club
IC01	0.30	2.3	39.152000, -84.74200	C, D, N, H, O, B	FHW, PHW	Near Tisch Scientific Parking Lot
Unnamed Trib to Indian Creek						
IC07	0.13	0.4	39.152000, -84.73000	C, D, N, H, B	FHW, PHW	at Dead End of Stonehaven Dr.
Unnamed Trib to Indian Creek @RM 1.55						
IC08	1.50	0.1	39.159000, -84.72300	C, D, N, H, B	FHW, PHW	Cross roads Church lower parking lot
Reference Sites						
Mill Run						
RF11	0.90	7.8	39.546100, -84.06308	C, D, N, H, O, B, DS	HD, QL, FHW	off Route 42
Stonelick Creek						
RF14	3.10	73.5	39.139200, -84.18530	C, D, N, H, O, B, DS	HD, QL, FWD	5353 Stonelick Corners Rd.

***Table 12**. List of sampling locations and sample types for the 2014 Direct Tributaries and Taylor Creek watersheds bioassessment. The sample type is indicated (see footnotes) and habitat was recorded at all sites (QHEI). Regional reference sites that are sampled as part of the overall MSDGC four year monitoring plan are also included. (ust. – upstream; dst. – downstream)*

Site ID	River Mile	Drainage Area mi²	Latitude - Longitude	Chemistry Data Type[1]	Biological Data Type[2]	Location
***Stonelick Creek** (continued)*						
RF13	1.00	75.7	39.122500, -84.19920	C, D, N, H, O, B, DS	HD, QL, FWD	US RTE. 50 upstream
Fivemile Creek						
RF15	0.50	10.4	39.113600, -84.02030	C, D, N, H, O, B, DS	HD, QL, FHW	Bluesky Park Road Bridge
W. Fk. E. Fk. Little Miami River						
RF16	0.10	29.1	39.230080, -83.91476	C, D, N, H, O, B, DS	QL, FWD	State Route 123
Dodson Creek						
RF17	0.05/0.20	32.4	39.222200, -83.81140	C, D, N, H, O, B, DS	HD, QL, FWD	Ford near mouth

[1] C – conventional; D – demand; N – nutrients; H – heavy metals; O – organics; B – sediment chemistry.

[2] FHW – fish headwater; FWD – fish wadeable; HD – macroinvertebrate artificial substrates; QL – qualitative macroinvertebrates; PHW – Primary Headwater Habitat.

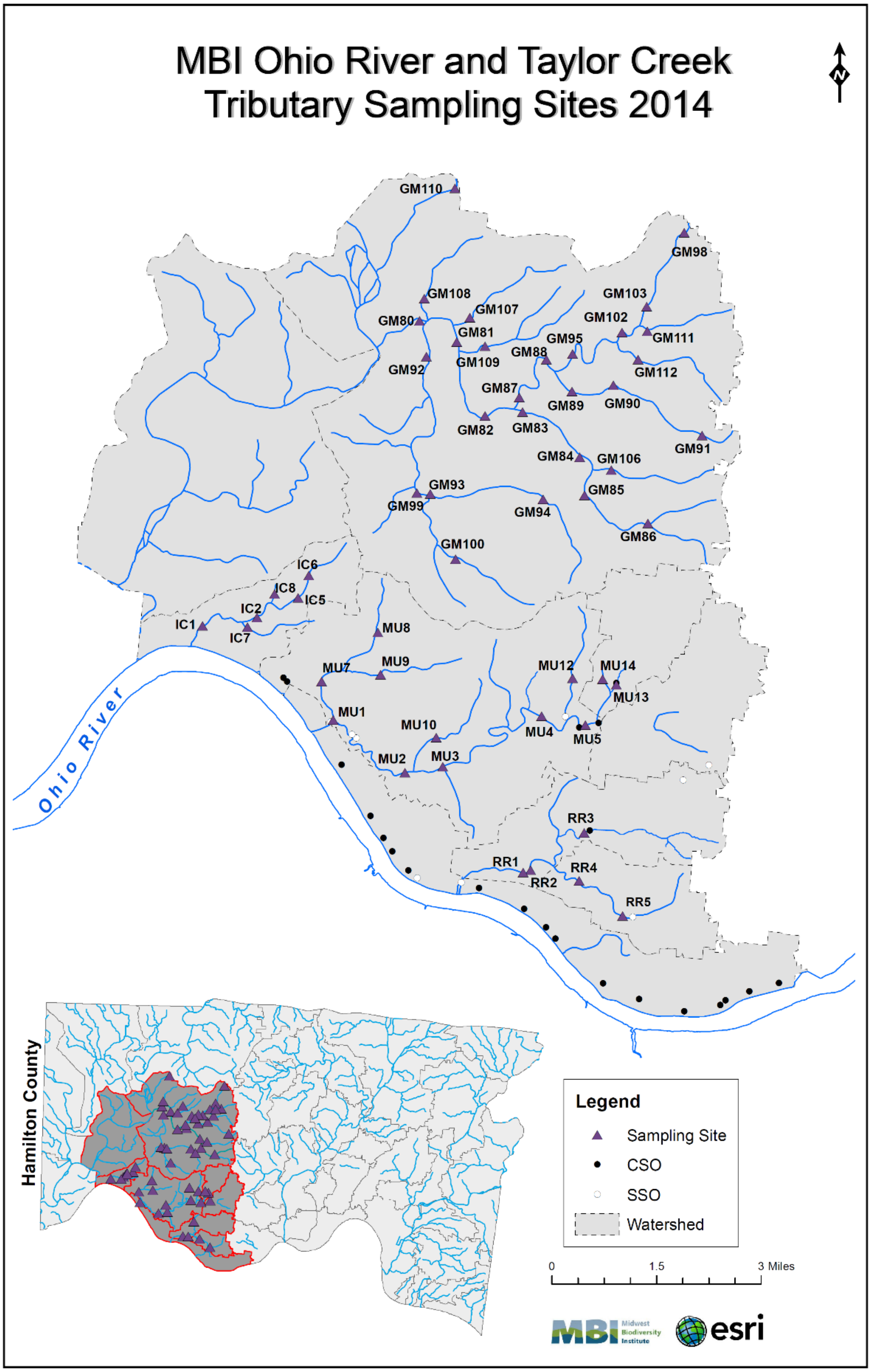

***Figure 7**. Map of the 2014 Direct Tributaries and the Taylor Creek watershed showing biological, chemical, and physical sampling locations (▲) with the site code and locations of wastewater discharges. MSDGC CSO locations appear as black circles. The MSDGC service area appears in the study area inset (lower right).*

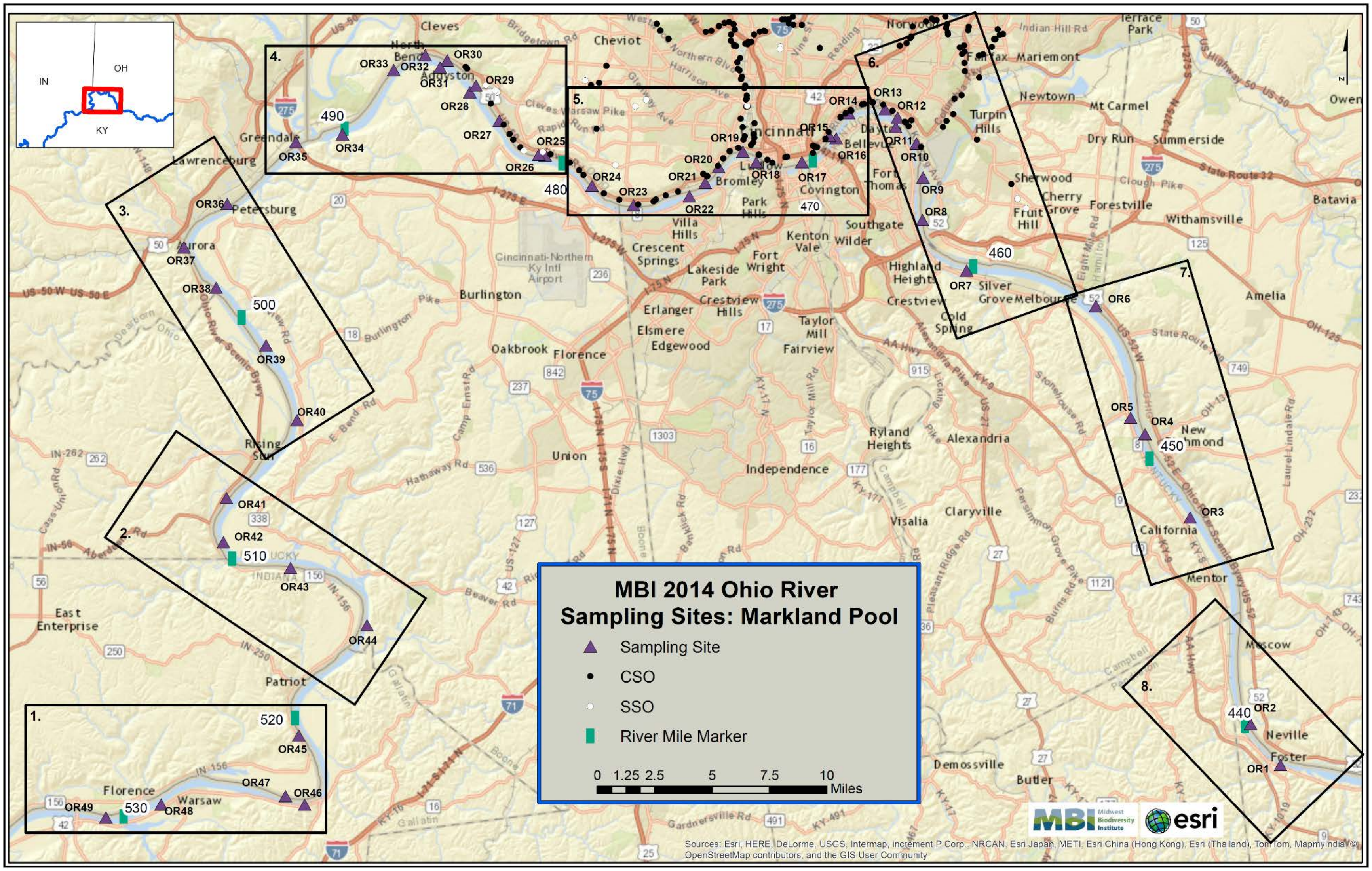

Figure 8. *Map of the 2014 Ohio River mainstem showing biological, chemical, and physical sampling locations (▲) with site codes and locations of MSDGC CSOs and SSOs (boxes are close-up maps in Appendix F). MSDGC CSO locations appear as black circles. CSOs along KY shoreline are not shown.*

Biological Methods

The 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 *two 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 biological 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 (1989a). 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 specified by Ohio EPA (1989a).

A three person crew carried out the sampling protocol for each type of wading equipment. Sampling effort was indexed to lineal distance and sites 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’ 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 each stream or river).

Sampling was conducted within a June 16-October 15 seasonal index period and twice at all wading sites and once at headwater 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. Fish measuring less than 15-20 mm in length were generally not included in the data as a matter of practice except for species that are juveniles and adults at these lengths.

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 flow velocities (generally $\geq$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 and by hand picking. 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 rendered 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 the Invertebrate Community Index (ICI; Ohio EPA 1987; DeShon 1995) score for the quantitative samples and a narrative assessment for the standalone qualitative samples (Ohio EPA 2013).

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 determined at a minimum. Methods for the collection of macroinvertebrates and salamanders at PHWH candidate sites followed the qualitative macroinvertebrate collection techniques used by the Ohio EPA for all stream types (Ohio EPA 1989a) 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 were preserved. Adult and juvenile salamanders were placed into plastic bags with moist leaf litter. The larva were transported in stream water and placed in a cooler and returned to the lab for preparation of voucher specimens and verifications.

Habitat Assessment

Physical habitat was evaluated using the QHEI developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995; Ohio EPA 2006). 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 sites throughout Ohio 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; Rankin 1989, 1995).

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. Bankfull 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 – Grab Sampling

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 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°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 2014 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 6) 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) and the ORSANCO WQS (ORSANCO 2013) 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 Hamilton County 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 2014 study area. The Ohio River is defined as a Primary Contact water and sub-categories have not been created.

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. ORSANCO is responsible for deriving recreation criteria in the Ohio River (ORSANCO 2013) and have set E. coli criteria that are no single sample should be greater than 240/100mL, and should not exceed 130/100mL as a monthly geometric mean (at least 5 samples required).

Determining Use Attainability

Use designation reviews and recommendations for revisions, if necessary, are a direct product of the 2014 Direct Tributaries and Taylor Creek watershed assessments. 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 9-11 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 9 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

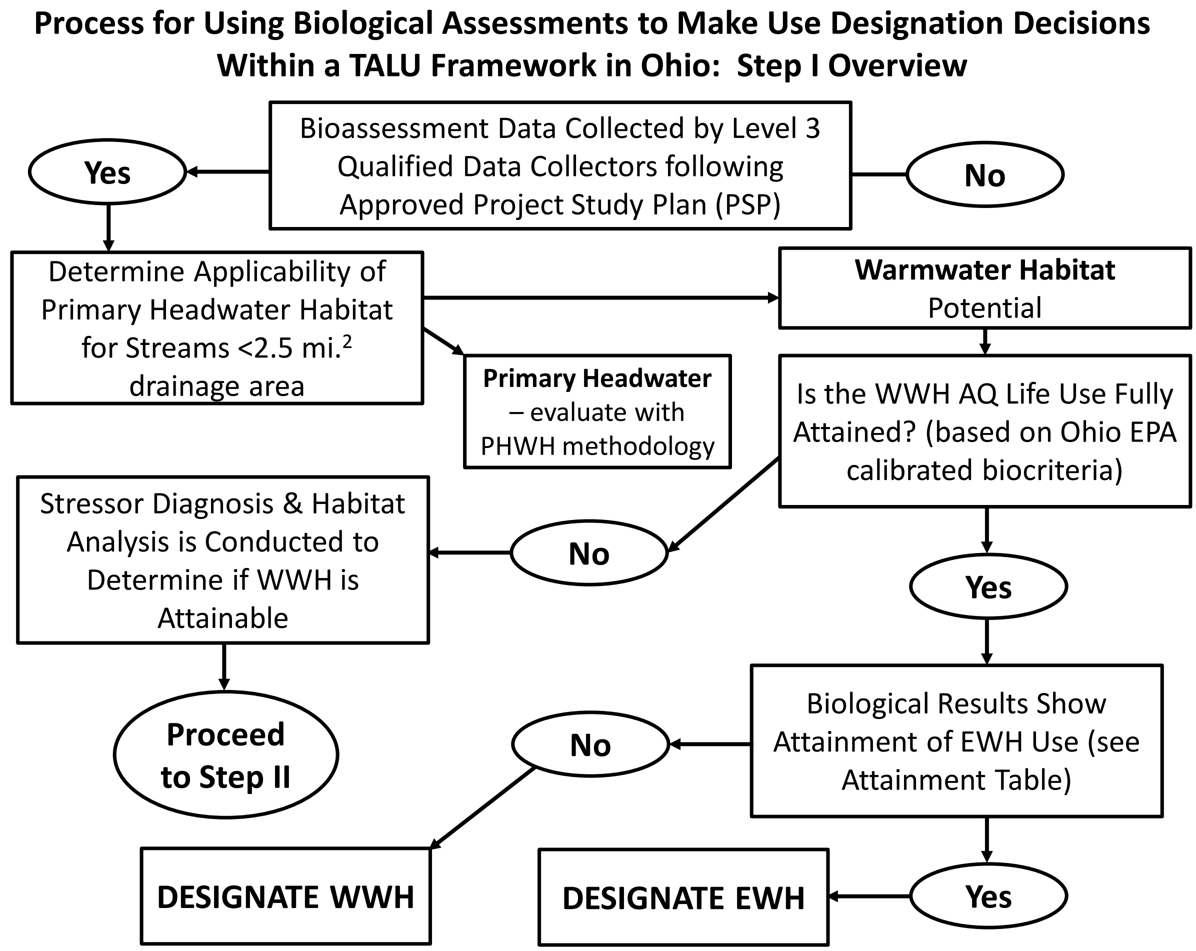

***Figure 9**. Step I: Overview of the process for using biological assessments to make use designation decisions in Ohio based on the tiered aquatic life uses framework.*

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 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 10).

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

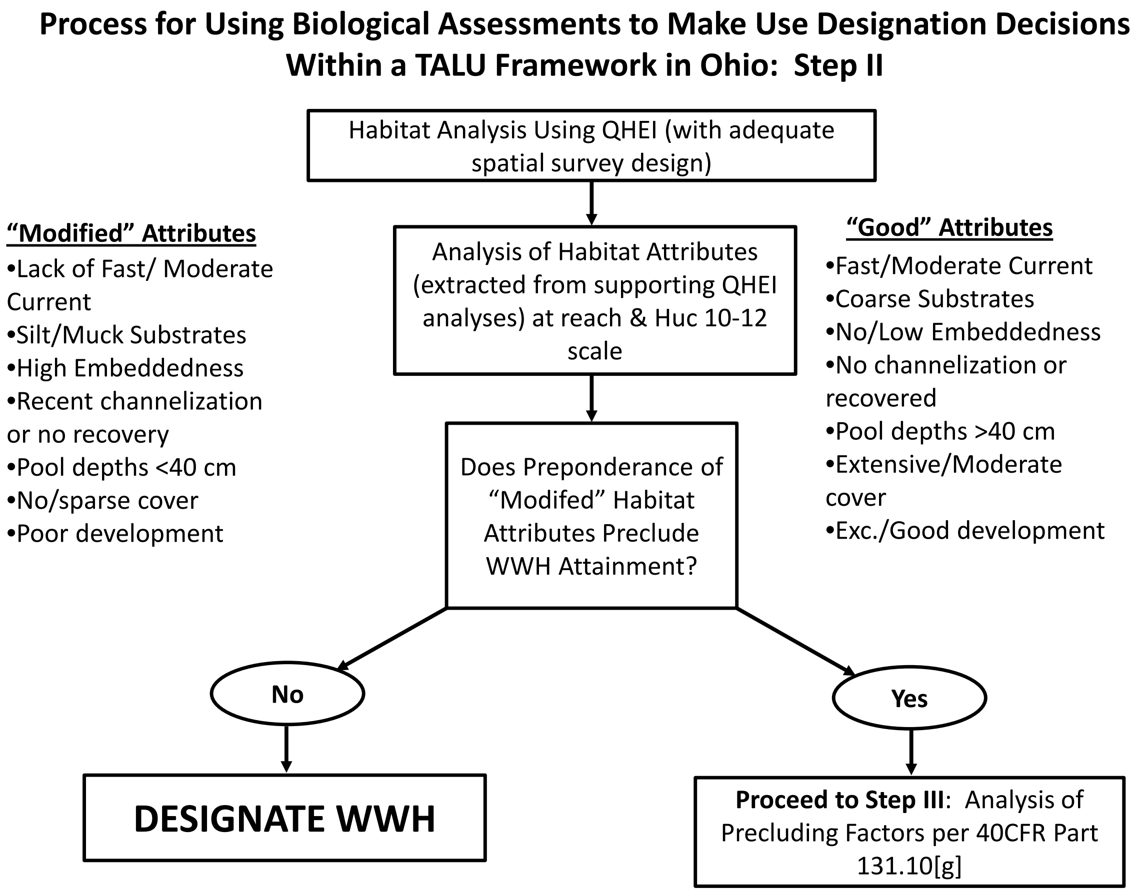

***Figure 10**. Step II: Using the analysis of habitat attributes to make decisions about WWH use attainability.*

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 are expressed as "good" and "poor" attributes (Figure 10) 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 10. For example, a QHEI score ≥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 11). 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:

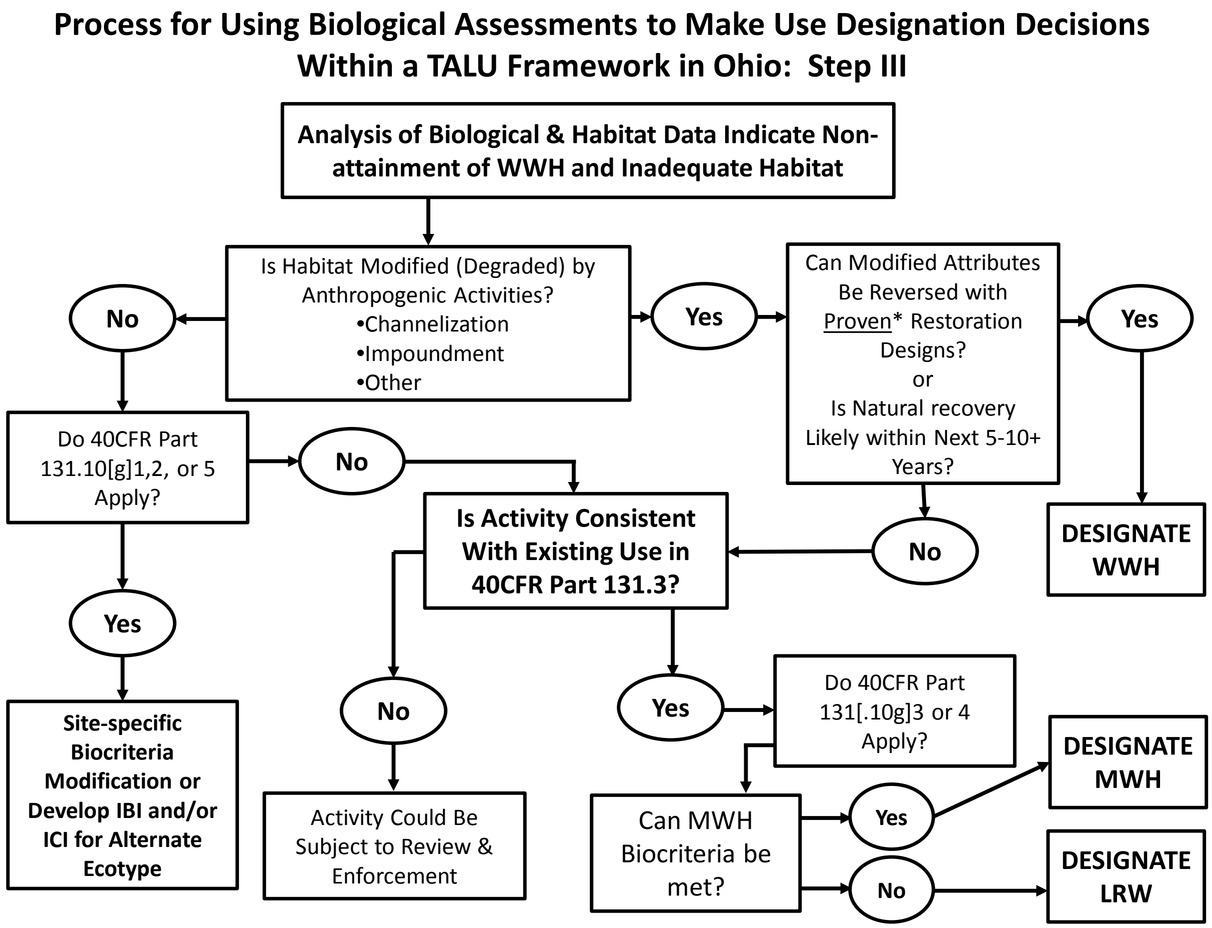

***Figure 11**. Step III: Overview of the use attainability analysis parts of the use designation process in Ohio.*

". . . 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.

Ohio River Mainstem

Aquatic life use attainment in the Ohio River is identified using biological assemblages as well as examining exceedances of water quality criteria. In their 2014 305(b) report, ORSANCO detailed data use to assess aquatic life use support in the Ohio River (ORSANCO 2014):

> *"The Ohio River warm water aquatic life use was assessed based on fish population surveys and water chemistry data collected through the Bimonthly and Clean Metals Monitoring Programs. These results were then compared to applicable criteria for the protection of aquatic life. Water quality criteria violations found in greater than ten percent of samples at a monitoring station would indicate impairment on their own. Aquatic life criteria for total iron are exceeded in greater than ten percent of samples in many segments of the river. Violations of aquatic life criteria were also observed for both dissolved oxygen and temperature in the lower river."*

Even though chemical exceedances were identified, ORSANCO relied on fish assemblage data as a more robust and direct measure of aquatic life use attainment and using a weight-of-evidence (WOE) approach to listing impaired segments of the Ohio River (ORSANCO 2014):

> *"Although physical and chemical criteria violations exist, the Commission utilized the WOE approach. Based on an assessment of fish population surveys from 2009-2013, which indicate full support for every pool, the entirety of the Ohio River is assessed as fully supporting the aquatic life use."*

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) and the Ohio WQS (OAC 3745-1-07). The rationale for using the biological results in the role as the principal arbiter within a weight of evidence framework has been extensively described 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 chemistry data, habitat data, effluent data, 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 12 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 product

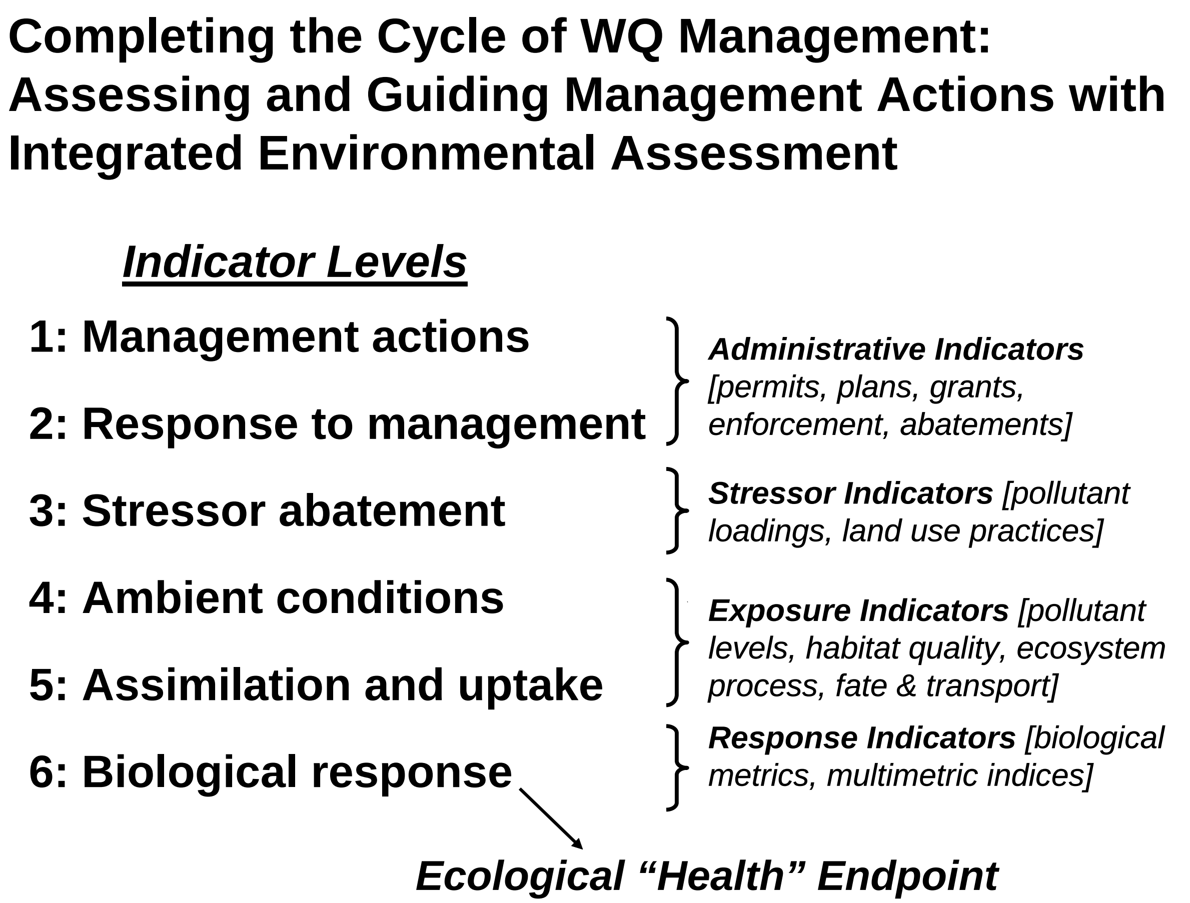

***Figure 12**. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995) and further enhanced by Karr and Yoder (2004).*

STUDY AREA DESCRIPTION

General Setting – Direct Ohio River Tributaries and Taylor Creek

The 2014 study area lies in southwest Ohio and is generally bounded by Mill Creek to the east and the Great Miami River to the west and northwest, and the Ohio River to the south. Major streams within the 2014 study area included Muddy Creek, Indian Creek, Rapid Run, and Taylor Creek and tributaries. The Direct Ohio River Tributaries are impacted by CSOs, SSOs, urban runoff, and the physical effects of instream sewer line construction. The tributaries are suburban to urban in nature being most developed in the upper portions of each watershed. Taylor Creek is not impacted by CSOs and largely avoided the impacts of instream sewer construction when interceptor sewers for the Taylor Creek Regional WWTP were installed in the mid to late 1990s. Land use ranges from suburban to almost rural.

Subecoregion Characteristics

The 2014 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 2014 study area lies almost entirely within the Northern Bluegrass subregion (71d) of the Interior Plateau. The characteristics of this subregion appear in Table 13.

Description of Pollution Sources and Other Stressors

Pollution sources and general stressors in the 2014 study area include permitted discharges of municipal process wastewater, 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 Tables 14 (Direct Ohio River tributaries) and 15 (Taylor Creek).

Point Sources

There are no major NPDES permitted discharges in the Direct Tributaries or Taylor Creek watersheds. There are 12 minor discharges most of which are small WWTPs serving businesses and or subdivisions (Table 15). Some areas in Taylor Creek are unsewered.

Wet Weather Sources

CSOs and SSOs are the major permitted sources of wet weather pollution in the Direct Tributaries study area (Table 14). Most discharge to Muddy Creek and a single CSO discharges to Rapid Run. No CSOs or SSOs discharge to Indian Creek.

Table 13*. Level IV subregions of the 2014 study area and their key attributes (from Woods et al. 1995).*

Level IV Subregion	Physiography	Geology	Soils	Potential Natural Vegetation	Land Use/Land Cover
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 mesophytic 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

Table 14. Major pollution sources in the 2014 Direct Ohio R. tributaries study area.

River Mile	NPDES Permit No.	MSDGC CSO#	MSDGC SSO#
Muddy Creek			
At headwaters	1PX00022	676	
At headwaters	1PX00022	520	
7.00	1PX00022		1025
7.00	1PX00022		641
6.53	1PX00022	520	
5.97	1PX00022		1061
5.97	1PX00022		1012
1.65	1PX00022		623
1.00	1PX00022		697
0.90	1PX00022		693
0.20	1PX00022		675A
0.10	1PX00022		701
Rapid Run			
2.8	1PX00022	223	

***Table 15**. Major pollution sources in the 2014 Taylor Creek study area.*

Facility	River Mile	NPDES Permit No.	Status
Taylor Creek			
Lil Goodie Shoppe	1.0	1PZ00104	Minor
Chateau Lakes Homeowners Assn	4.6	1PW00007	Minor
Wesselman Creek			
Home City Ice	6.0	1PX00035	Minor
Great Oaks Joint Vocational School District	4.2	1PT00050	Minor
Eagles Lake Condominium Association	3.4	1PW00029	Minor
Unnamed Tributaries to Taylor Creek			
Skyridge Condominiums	3.8*	1PW00016	Minor
Skyridge Northcrest Apts Treatment Plant	3.8*	1PW00032	Minor
Wullenweber Motors, Incorporated	4.5*	1PS00011	Minor
Canterbury Row Condo Assoc	5.5*	1PZ00008	Minor
Manchester Plaza Shopping Center	5.9*	1PX00002	Minor
Diane Sullivan Office Complex	6.5*	1PZ00110	Minor
Biederman Educational Ctr.	6.5*	1PZ00051	Minor

*RM at which an unnamed tributary enters Taylor Creek.

General Setting – Ohio River Mainstem

The 2014 Ohio River mainstem study area included the entirety of the Markland navigation pool (Figure 8) which extends 95.3 miles from the Markland dam near Warsaw, KY upstream to the Meldahl dam near Neville, OH. As with the near entirety of the Ohio River mainstem, the riverine habitat has been significantly altered by dams operated by the U.S. Army Corps of Engineers for barge navigation. A “pool” is formed behind each dam to maintain safe depths for barge traffic. The habitat within each pool can vary being more riverine immediately downstream from a dam and more lentic in closer proximity to the upstream side of a dam. The more natural riverine features of the historical Ohio River have been inundated by the impounding effect of each dam. The pool has a gradient of 0.4 feet per mile and averages 1,594 feet wide and 31 feet deep.

The Markland pool lies in a portion of the Ohio River heavily influenced by industry with a large amount of barge activity. Major tributaries include the Little Miami River (RM 463.5; drainage area = 1,750 mi.^{2}), the Licking River (RM 470.2; drainage area = 3,670 mi.^{2}), Mill Creek (RM 472.5; drainage area = 166 mi.^{2}), the Great Miami River (RM 491.1; drainage area = 5,400 mi.^{2}), Tanners Creek (RM 494.8; drainage area = 136 mi.^{2}), Hogan Creek (RM 496.7; drainage area = 130 mi.^{2}), and Laughery Creek (RM 498.7; drainage area = 350 mi.^{2}). These river basins and watersheds are primarily forested (54.7%), but also support row cropping (14.0%) and pasture land uses (13.2%).

Point Sources

There are 15 major and 10 minor permitted direct discharges to the Ohio River mainstem in the Markland pool (Table 16). Six of the major discharges are electric generating stations some of which discharge once-through cooling water, eight are municipal WWTPs, and one is an industrial source. The aggregate flow from the WWTPs is 280 MGD largest of which is the MSDGC Mill Creek WWTP at 120 MGD. The INEOS industrial facility discharges approximately 10 MGD pf process wastewater. Tributaries such as the Little and Great Miami Rivers carry treated wastewater discharged to their respective mainstems totaling more than 100 MGD each.

Wet Weather Discharges

Sixty-one (61) MSDGC CSOs discharge either directly or in close proximity to the Ohio River mainstem (Table 16). This total does not include the CSOs that discharge to Ohio River tributaries such as Duck Creek, Mill Creek, Muddy Creek, and Rapid Run and which likely influence water quality in the mainstem nor does it include those located along the Kentucky shoreline. The upstream most MSDGC CSO discharges at RM 465.1 just downstream from the Little Miami River. The downstream most CSO enters at RM 484.9 just downstream from Muddy Creek. Other wet weather sources include SSOs to tributaries and urban runoff from the Cincinnati metropolitan area. Wet weather discharges also originate on the Kentucky side of the mainstem from the Newport-Covington metro area and are under the jurisdiction of Northern Kentucky Sanitary District 1.

***Table 16**. Major pollution sources in the 2014 Ohio River mainstem study area. Figure references are used in subsequent graphs to depict locations of major discharges and tributaries. CSOs along KY shoreline are not listed. R – river right (OH/IN); L – river left (KY; looking dst.)*

Source (Flow in MGD)	River Mile (Bank)	NPDES Permit No.	Status	Figure Reference
Ohio River Mainstem (90-001)				
Duke Energy Ohio Inc-William H. Zimmer Station	443.4R	1IB00011	Major	1
Village of Moscow	444.0R	1PE00008	Minor	
Tate Monroe Water Association, Inc	440.5R	1IX00060	Minor	
Nine Mile Creek Wastewater Treatment Plant (3.0 MGD)	445.3R	1PK00008	Major	2
Village of New Richmond	450.9R	1PB00022	Minor	
Duke Energy Beckjord LLC	452.9R	1IB00000	Major	3
SD #1 Eastern Regional WWTP (KY; 4.0 MGD)			Major	
Greater Cincinnati Water Works Richard Miller WTP	463.0R	1IV00040	Minor	
Little Miami River	463.5R			A
CSO 669	465.1R	1PX00022		
Little Miami WWTP (MSDGC; 55 MGD)	465.2R	1PL00000	Major	4
CSO 468	466.0R	1PX00022		
CSO 467, 466, 469	466.1R	1PX00022		
CSO 657	466.6R	1PX00022		
CSO 667	467.0R	1PX00022		
CSOs 459, 460	467.2R	1PX00022		
CSO 458	467.4R	1PX00022		
CSOs 452, 453	467.5R	1PX00022		
CSOs 451, 658	467.9R	1PX00022		
CSO 450	468.1R	1PX00022		
CSO’s 448, 449	468.4R	1PX00022		
CSO 447	468.9R	1PX00022		
CSO 446	469.2R	1PX00022		
CSOs 461, 462, 463, 464, 465	469.6R	1PX00022		
CSO 444	469.9R	1PX00022		
Licking River	470.3L			B
CSOs 438, 439	471.0R	1PX00022		
CSO 436	471.6R	1PX00022		
CSO 435	471.8R	1PX00022		
CSO 433, 434	472.1R	1PX00022		
CSOs 430, 431, 432, 489	472.4R	1PX00022		
Mill Creek	472.5R			C
Mill Creek WWTP (MSDGC; 120 MGD)	472.7R	11PM00001	Major	5
CSO 427	472.8R	1PX00022		
CSOs 424, 425	473.0R	1PX00022		
CSOs 423	473.2R	1PX00022		
CSO 422	473.5R	1PX00022		
CSOs 419, 420, 421	474.1R	1PX00022		
Peter Cremer North America LP	474.5R	1IG00003	Minor	
CSO 416	475.3R	1PX00022		
CSO 415	475.7R	1PX00022		
CSO 414	476.1R	1PX00022		

***Table 16**. Major pollution sources in the 2014 Ohio River mainstem study area. Figure references are used in subsequent graphs to depict locations of major discharges and tributaries. CSOs along KY shoreline are not listed. R – river right (OH/IN); L – river left (KY; looking dst.)*

Source (Flow in MGD)	River Mile (Bank)	NPDES Permit No.	Status	Figure Reference
Ohio River Mainstem (90-001)				
CSO 413	476.2R	1PX00022		
CSO 412	476.8R	1PX00022		
Marathon Petroleum Co LP - Cincinnati Terminal	477.2R	1IN00025	Minor	
CSO 411	477.6R	1PX00022		
CSO 410	478.2R	1PX00022		
CSO 223	479.2R	1PX00022		
CSO 654	479.4R	1PX00022		
Kinder Morgan River Transportation	479.6R	1IN00169	Minor	
CSO 408	479.8R	1PX00022		
CSO 541	480.5R	1PX00022		
SD #1 Dry Creek (KY; 47.0 MGD)	480.5L	KY0021466	Major	
Rapid Run	480.8R			D
SSO 701	480.8R	1PX00022		
Muddy Creek WWTP (MSDGC; 15.0 MGD))	481.0R	1PK00006	Major	6
SSO 702	481.4R	1PX00022		
CSO 406	481.6R	1PX00022		
CSO 405	482.0R	1PX00022		
CSO 404	482.3R	1PX00022		
CSO 403	482.7R	1PX00022		
CSO 402	483.4R	1PX00022		
Muddy Creek	484.1R	1PX00022		E
INEOS ABS USA Corp. (≈10 MGD)	484.3R	1IF00001	Major	
CSOs 675, 676	484.9R	1PX00022		
Indian Creek	486.0R			F
Indian Creek WWTP	486.5R	1PK00020	Minor	
Agrium North Bend Nitrogen Operations	489.3R	1IE00009	Minor	
Marathon North Bend Terminal	489.7R	1IF00000	Minor	
Duke Energy Ohio Inc - CG&E Miami Fort Station	490.4R	1IB00001	Major	7
Great Miami River	491.1R			G
Tanners Creek EGS (IN)	494.2R	IN0002160	Major	8
PSEG-Lawrenceburg EGS (IN)	494.9R	IN0060950	Major	9
S. Dearborn WWTP (IN; 6.0 MGD)	494.9R	IN0024538	Major	10
SD #1 Western Regional WWTP (KY; 20.0 MGD))	503.9L	KY0107239	Major	11
Duke-East Bend EGS (KY)	511.0L	KY0208923	Major	12

RESULTS and DISCUSSION

Chemical/Physical Water Quality

Chemical/physical water quality in the Ohio River and the Taylor Creek and Direct Tributary study areas 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 tributary, and all reference sites once in October. The results were evaluated by assessing exceedances of criteria in the Ohio or ORSANCO 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 the Ohio River mainstem and separately by Ohio EPA Waterbody Assessment Units (WAU; Ohio EPA 2010) for the Direct Tributaries, Taylor Creek, and Reference Sites. Bacteria data were collected by grab samples at all sites and were used primarily to determine the status of recreational uses in accordance with either ORSANCO (Ohio R.) or the Ohio WQS (Taylor Cr., Direct Tribs., Reference sites). ORSANCO and Ohio EPA protocols for determining attainment of the applicable designated recreational use tier were generally followed. Water quality was assessed by grab samples collected at predetermined locations in the water column and at graduated frequencies at all sites in the 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 the Ohio River mainstem, the Direct Ohio River Tributaries, and Taylor Creek study area WAUs. Commonly collected chemical parameters were compared either to criteria in the Ohio WQS (Table 17) or to ecoregion-based benchmarks and biologically derived thresholds in Ohio EPA (1999) for chemical stressors that are commonly associated with urban runoff (Table 18) and for nutrient parameters (Table 19). The biologically derived thresholds relate concentrations to levels associated with attainment of fish IBIs and macroinvertebrate ICIs for the tiered aquatic life uses in the Interior Plateau (IP) or Eastern Corn Belt Plains (ECBP) ecoregions (Ohio EPA 1999). MBI also calculated the Ohio EPA Stream Nutrient Assessment Procedure (SNAP; Draft Ohio EPA 2015) to determine the risk to aquatic life from eutrophication effects.

WAU 09-05 – Taylor Creek

Only one site (GM108 with a PHW3A existing use) had a single grab sample excursion of the 4.0 mg/l minimum D.O. criterion for WWH during the 2014 survey (Table 17). Two of three sites in Taylor Creek with continuous data had single days with diel swings >6.5 which (Table Sonde) indicates the indirect effect of excessive nutrient enrichment. Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen and an indicator of organic enrichment. Most sites in the Taylor Creek watershed had median TKN values that slightly exceeded regional reference levels for headwater (0.5 mg/l) and wadeable (0.6 mg/l) streams (Table 19). At three Taylor Creek headwater sites (GM83, GM84, and GM85) nitrate-N (NO_3-N) concentrations were elevated in response to sewage inputs and urban runoff (Table 19).

Mean chloride levels were highly elevated compared to reference values (31-35 mg/l) throughout the Taylor Creek watershed with many values >100 mg/l (Figure 14). Values of chloride greater than 100-140 mg/l, where the sources are related to road salt runoff, are typically associated with acute late-winter, early-spring values exceeding the 250 mg/l chronic criterion (Kaushal et al. 2005; Trowbridge et al. 2010). Total chloride levels in the major tributaries of Taylor Creek (Figure 14) vs. river mile and from two sites collected in the 1970s were compared. It appears that chloride has increased from levels measured in the 1970s that were similar to current reference site concentrations at nearly all of the sites that now exceed 100 mg/l. This is a pattern that is similar to that observed in other urban areas where road salt is applied (e.g., Kaushal et al. 2005). Based on analyses done in the Chicago area (MBI 2010) benchmark values of 112 (fish) to 141 mg/l (macroinvertebrates) are associated with increasingly degraded biological conditions. The concern herein is that chloride levels are approaching concentrations where deleterious effects on fish and macroinvertebrate impacts begin to emerge. This is also consistent with the impairments observed in the smaller tributaries that are closer to the actual sources, e.g., chlorides in runoff from road salt.

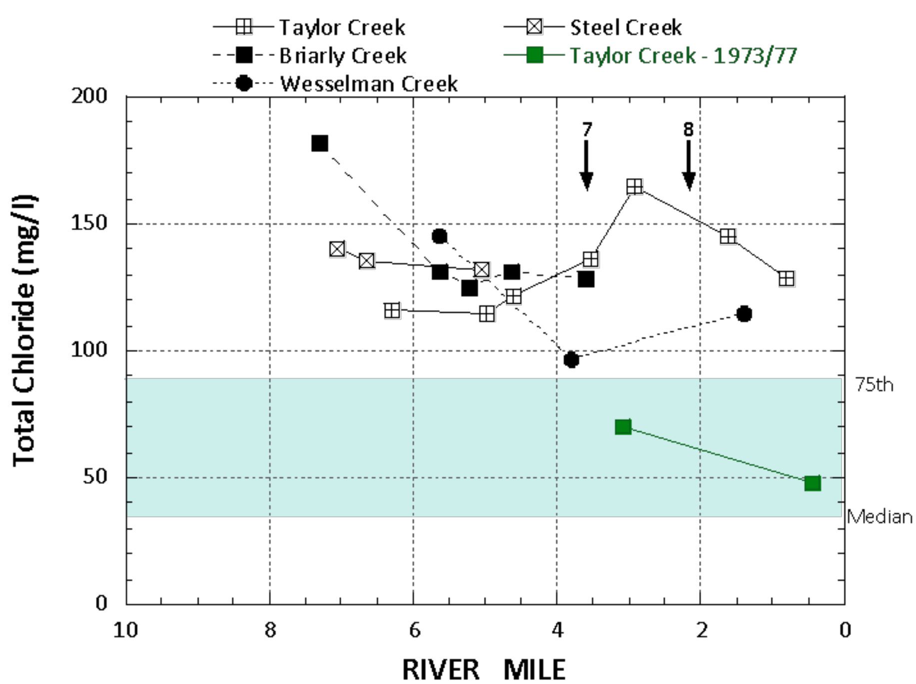

***Figure 14**. Plot of total chloride for Taylor Creek and larger tributaries. River miles of tributaries are in relationship to the mouth of Taylor Creek (i.e., Taylor Creek confluence RM + tributary RM). Blue shading represent the statewide range for headwater streams (median – 75th percentile) for chloride.*

WAU 02-03 – Muddy Creek

The Muddy Creek watershed had four sites that had significant excursions of the 4.0 mg/l minimum D.O. criterion for WWH streams in 2014 (Table 17). Two of these were in the Muddy Creek mainstem (MU04, MU05) and were in the closest proximity to major CSO discharge locations. Two unnamed tributaries (MU12 and MU13) had D.O. exceedances and were also downstream of CSO/SSO discharge points (CSOs 676, 520; SSOs 641, 1012, 1025, 1061). Ammonia-N (NH_3-N) was elevated at MU03 (1.95 mg/l), MU13 (1.55 mg/l), and MU14 (0.52 mg/l) and was associated with CSO/SSO locations (Table 19).

WAU 02-04 –Rapid Run

Site RR03 had a significant excursion of the 2 mg/l minimum D.O. criterion for the assigned LRW use designation in 2014 (Table 17). This site also had high total NH_3-N (1.67 mg/l). This site is just downstream of CSO 223 and also has sewer lines in the streambed. It also had an exceedance of the pH criterion which suggests high algal activity resulting from the nutrient enrichment from CSOs/SSOs and urban runoff.

Reference Sites

While all of the reference sites attained the WWH biological criteria, four sites had grab samples with values below the 4.0 mg/l WWH minimum criterion. Continuous monitoring at these sites confirmed the occurrence of diel excursions below the 4.0 mg/l minimum, although none of these sites had diel swings >6.5 mg/l. This result is consistent with modest nutrient enrichment in streams with good habitat and intact riparian zones that minimize the negative near-stream effects of nutrient enrichment.

Chemical Comparison of the Direct Tributaries, Taylor Creek, and Reference Sites

There were some distinct differences in the water chemistry between the Direct Tributaries, Taylor Creek, and the reference sites. In general the reference sites had D.O. regimes that reflect background conditions (i.e., smaller diel swings), but some had lower minimum values than observed in Taylor Creek and Muddy Creek (Figure 15). The severity of organic enrichment as indicated by wider D.O. swings, elevated NH_3-N, and elevated nutrients were greatest in Muddy Creek and its tributaries where CSOs/SSOs were the most prevalent (Figures 15-18). Conductivity levels and chloride concentrations were highest in Taylor Creek and Indian Creek, but less so in Muddy Creek. All were elevated compared to the reference sites. It may be that CSO effluents can act to dilute chlorides compared to streams in Taylor Creek and Indian Creek where flows are comprised of surface runoff and shallow groundwater (Figures 19-20). Total dissolved solids (Figure 18) were the lowest in Rapid Run.

The delivery and effects of pollutants in small headwater streams of the Direct Tributaries and Taylor Creek are rather complex. Streams with high CSO/SSO inputs (Muddy Creek) had more evidence of organic enrichment from these sources. The dilution from these sources also tended to result in lower chlorides compared to sites without CSOs/SSOs. Smaller tributaries were disproportionately impaired compared to mainstem sites which is a result of being closer to the sources of contamination and the larger sites having more dilution of those impacts.

Ohio River mainstem

Conventional water chemistry parameters showed little variation in median values along the length of the Markland pool (Figures 21-24). Total chloride (Figure 21) and conductivity (Figure 22, Table 20) showed little change or variation with river mile except for slight increases in their variability at the confluence of major tributaries. A long term trend analyses of chloride levels in the Ohio River basin (ORSANCO 2008) showed that chloride has increased over time at nearly all sites including major tributaries. The largest increase was in the Little Miami River where chloride concentrations are increasing at a rate of about 0.75 mg/l/yr and median values have increased from the high 30s to near 70 mg/l. Although elevated values of chloride seem the most problematic in tributaries, long-term increases could influence aquatic life in the mainstem.

TKN, a key measure of organic enrichment, was variable with many median values below detection (Table 21), but higher maximum values were associated with sources located between river miles 475 and 486 (Figure 23). D.O. values were all above the 5.0 mg/l average criterion for the Ohio River. There was perhaps a small downward trend from about 8.0 mg/l to 7.5 mg/l from upstream to downstream in the study area (Figure 24), but these values are not deleterious to aquatic life. BOD values (not plotted) were at or near detection in most samples indicating little excessive oxygen demand in the Markland pool water column during the sampling period. Median total NH_3-N values (mg/l) were mostly at detection levels (Table 21), but slight increases from background for maximum values occurred downstream of RM 485 and Ohio River tributaries with CSOs/SSOs including Rapid Run, Mill Creek and Muddy Creek. Median values of TSS (not plotted, Table 21) were all generally low (range: 7-16.5 mg/l) throughout the Markland pool, although maximum values were often higher downstream of the tributaries in Cincinnati, but still generally less than 60 mg/l. A similar pattern was observed for sulfate (Table 20) with generally low median values in the Markland pool (well below 100 mg/l; criterion = 250 mg/l). Comparatively high maximum values >100 mg/l (but <250 mg/l water quality criterion) occurred downstream from the tributaries in Cincinnati with CSOs/SSOs and urban runoff.

***Table 17**. Conventional pollutant parameters in Taylor Creek, Direct Tributaries, and Reference Sites sampled in 2014 (grab samples) that exceeded Ohio water quality criteria for aquatic life.*

Site ID	River Mile	Location	Aquatic Life Use	Exceedances of Aq. Life Criteria
WAU 09-05 – Taylor Creek Watershed				
Eagle Creek (Trib. to Taylor Cr. at RM 0.91)				
GM108	0.28	Pull-off near 7430 Eagle Creek Rd.	PHW3A	D.O. (3.60)
WAU 02-03 – Muddy Creek Watershed				
Muddy Creek				
MU05	6.35	Sidney & Muddy Creek Pull-Off	WWH	D.O. (1.96), (1.14)
MU04	5.40	Beneath Ebenezer Road bridge	WWH	D.O. (3.60), (3.60)
Unnamed Trib. to Muddy Creek @RM 5.97				
MU12	0.65	Gloria Dell Lutheran Church	WWH	D.O. (3.06)
Unnamed Trib. to Muddy Creek @RM 6.53				
MU13	0.60	Intersection of Werk Rd & Westborne Dr.	WWH	D.O. (1.38)
WAU 02-04 –Rapid Run Watershed				
Rapid Run				
RR03	2.70	Near Rapid Run Rd. DST. CSO 523	MWH	D.O. (0.58); pH (6.05)
Reference Sites				
Mill Run				
RF11	0.90	off U.S. Route 42	WWH	D.O. (2.76)
Fivemile Creek				
RF15	0.50	Bluesky Park Road Bridge	WWH	D.O. (3.94), (3.09), (3.04), (0.50)
W. Fk. E. Fk. Little Miami River				
RF16	0.10	State Route 123	WWH	D.O. (3.88), (3.40), (3.74), (3.08)
Dodson Creek				
RF17	0.05	Ford near mouth	EWH	D.O. (3.67)

***Table 18**. Urban parameter results in the Taylor Creek and Ohio River direct tributary study area in 2014. Values >reference targets are highlighted in yellow.*

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target[1]	Median	Target	Median	Target	Median	Target	Median	Target
Taylor Creek												
GM86	6.3	WWH	907	600	120	35	71	119	400	443	48	16
GM85	4.98	WWH	1156	600	136	35	65	119	630	443	24	16
GM84	4.6	WWH	961	600	139	35	72	119	520	443	15	16
GM83	3.53	WWH	946	600	140	35	83	119	540	443	5	16
GM82	2.93	WWH	911	600	169	35	77	119	530	443	4	16
GM81	1.62	WWH	900	600	150	35	70	119	510	443	6	16
GM80	0.8	WWH	796	610	130	31	62	120	470	464	15	25
Unnamed Trib. to Taylor Creek @RM 4.9												
GM106	0.28	WWH	702	600	111	35	64	119	350	443	32	16
Unnamed Trib. to Taylor Creek @RM1.74												
GM109	0.45	WWH	779	600	101	35	65	119	445	443	58	16
Forfeit Run (Trib. to Taylor Cr. @RM1.42)												
GM107	0.3	WWH	1018	600	192	35	105	119	625	443	71	16
Eagle Creek (Trib. to Taylor Cr. @RM0.91)												
GM108	0.28	WWH	773	600	81	35	54	119	420	443	76	16
Steel Creek												
GM111	2.16	WWH	940	600	138	35	56	119	560	443	2	16
GM102	1.79	WWH	931	600	137	35	66	119	540	443	9	16
GM95	0.3	WWH	897	600	132	35	62	119	550	443	9	16
Trib. to Steel Creek (Oakview Estates)												
GM98	2.3	WWH	NC	600	NC	35	NC	119	NC	443	NC	16
Unnamed Trib. to Steel Creek @RM												
GM103	0.3	WWH	819	600	125	35	87	119	460	443	64	16
Briarly Creek												
GM91	3.9	WWH	933	600	195	35	93	119	590	443	8	16
GM90	2.45	WWH	923	600	129	35	80	119	520	443	48	16
GM89	1.82	WWH	852	600	129	35	71	119	530	443	9	16
GM88	1.22	WWH	853	600	132	35	65	119	540	443	12	16
GM87	0.2	WWH	840	600	133	35	62	119	460	443	8	16

***Table 18**. Urban parameter results in the Taylor Creek and Ohio River direct tributary study area in 2014. Values >reference targets are highlighted in yellow.*

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target[1]	Median	Target	Median	Target	Median	Target	Median	Target
Unnamed Trib. to Briarly Creek @RM1.44												
GM112	0.46	WWH	715	600	109	35	86	119	385	443	11	16
Wesselman Creek												
GM94	4.72	WWH	1102	600	192	35	31	119	680	443	20	16
GM93	3	WWH	884	600	103	35	46	119	480	443	34	16
GM99	2.9	WWH	893	600	116	35	58	119	480	443	7	16
GM92	0.5	WWH	788	600	122	35	79	119	480	443	12	16
Unnamed Trib. to Wesselman Creek @RM 2.59												
GM100	2.95	WWH	578	600	70	35	46	119	280	443	24	16
Unnamed Trib. to GMR @RM 16.3												
GM110	1.75	WWH	NC	600	NC	35	NC	119	NC	443	NC	16
Muddy Creek												
MU05	6.35	WWH	458	600	61	35	22	119	150	443	7	16
MU04	5.4	WWH	469	600	51	35	31	119	215	443	4	16
MU03	2.72	WWH	700	600	66	35	44	119	390	443	4	16
MU02	2.25	WWH	634	600	74	35	47	119	390	443	4	16
MU01	0.17	WWH	432	600	33	35	62	119	210	443	34	16
Unnamed Trib. to Muddy Creek @RM 6.53												
MU13	0.6	WWH	481	600	84	35	33	119	260	443	29	16
Unnamed Trib. to Muddy Creek @RM 5.97												
MU12	5.97	WWH	324	600	44	35	24	119	110	443	6	16
Unnamed Trib. to Muddy Creek @RM 2.37												
MU10	0.6	WWH	717	600	90	35	65	119	360	443	26	16
Unnamed Trib. to Muddy Creek @RM 0.3												
MU08	1.8	WWH	760	600	64	35	82	119	360	443	36	16
MU07	0.6	WWH	657	600	76	35	64	119	340	443	3	16
Unnamed Trib. @0.45 to Unnamed Trib. to Muddy Creek @RM 5.97												
MU14	0.2	WWH	1063	600	192	35	64	119	600	443	6	16
Unnamed Trib. @0.95 to Unnamed Trib. to Muddy Creek @RM 0.3												
MU09	0.6	WWH	677	600	83	35	66	119	320	443	11	16

***Table 18**. Urban parameter results in the Taylor Creek and Ohio River direct tributary study area in 2014. Values >reference targets are highlighted in yellow.*

Site ID	River Mile	Aq. Life Use	Conductivity		Chloride		Sulfate		TDS		TSS	
			Median	Target[1]	Median	Target	Median	Target	Median	Target	Median	Target
Rapid Run												
RR03	2.7	LRW	539	600	15	35	20	119	130	443	19	16
RR02	1.2	LRW	522	600	93	35	59	119	510	443	2	16
RR01	0.1	LRW	738	600	111	35	88	119	450	443	2	16
Wulff Creek												
RR04	0.55	LRW	898	600	130	35	48	119	490	443	5	16
Unnamed Trib. to Wulff Run @RM 0.77												
RR05	0.68	WWH	740	600	111	35	37	119	560	443	1	16
Indian Creek												
IC06	2.43	WWH	770	600	84	35	60	119	470	443	16	16
IC05	2.08	WWH	731	600	69	35	56	119	155	443	34	16
IC02	1.22	WWH	662	600	82	35	48	119	405	443	12	16
IC01	0.3	WWH	663	600	64	35	93	119	435	443	20	16
Unnamed Trib. to Indian Creek @RM												
IC07	0.13	WWH	888	600	108	35	48	119	530	443	4	16
Unnamed Trib. to Indian Creek @RM 1.55												
IC08	1.5	WWH	1279	600	159	35	106	119	640	443	4	16
Reference Sites												
Mill Run												
RF11	0.9	WWH	668	600	39	35	23	119	360	443	7	16
Stonelick Creek												
RF14	3.1	WWH	514	610	31	31	32	119	290	443	15	16
RF13	1	WWH	544	610	34	31	32	119	270	443	10	16
Fivemile Creek												
RF15	0.5	WWH	420	600	39	35	21	119	240	443	5	16
W. Fk. E. Fk. Little Miami River												
RF16	0.1	WWH	480	600	37	35	23	119	240	443	3	16
Dodson Creek												
RF17	0.05	WWH	579	600	27	35	56	119	300	443	4	16

[1] Target concentrations represent the 75th percentile of reference sites statewide in Ohio for wadeable or headwater streams.

***Table 19**. Nutrient parameter results in the results in the Taylor Creek and direct Ohio River tributaries study area during 2014. Values >reference targets or other benchmarks are shaded in yellow.*

Site ID	River Mile	Aquatic Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m3) +		Benthic Chlorophyll (mg/m3) ++	
			Median	Target[1]	Median	Target[1]	Median	Target[1]	Median	Target[1]	Median	Target[2]	Median	Target[3]
Taylor Creek														
GM86	6.3	WWH	ND	0.05	0.431	1.1	0.600	0.50	0.250	0.08	1.000	30	83.3	182
GM85	4.98	WWH	ND	0.05	8.382	1.1	0.787	0.50	0.792	0.08	1.000	30	14.7	182
GM84	4.6	WWH	ND	0.05	1.482	1.1	0.666	0.50	0.250	0.08	1.600	30	41	182
GM83	3.53	WWH	ND	0.05	2.622	1.1	0.667	0.50	0.250	0.08	1.605	30	136	182
GM82	2.93	WWH	ND	0.05	0.607	1.1	0.528	0.50	0.250	0.08	3.740	30	85.3	182
GM81	1.62	WWH	ND	0.05	0.878	1.1	0.623	0.50	0.250	0.08	3.740	30	72.7	182
GM80	0.8	WWH	ND	0.05	0.567	1.2	0.650	0.60	0.250	0.10	5.340	30	73.3	182
Unnamed Trib. to Taylor Creek @RM 4.9														
GM106	0.28	WWH	ND	0.05	0.497	1.1	0.628	0.50	0.255	0.08	1.600	30	NC	182
Unnamed Trib. to Taylor Creek @RM 1.74														
GM109	0.45	WWH	ND	0.05	0.443	1.1	ND	0.50	0.265	0.08	1.300	30	NC	182
Forfeit Run (Trib. to Taylor Cr. @RM 1.42)														
GM107	0.3	WWH	ND	0.05	0.716	1.1	0.652	0.50	0.250	0.08	1.835	30	NC	182
Eagle Creek (Trib. to Taylor Cr. @RM 0.91)														
GM108	0.28	WWH	ND	0.05	0.269	1.1	0.544	0.50	0.200	0.08	5.900	30	NC	182
Steel Creek														
GM111	2.16	WWH	ND	0.05	0.025	1.1	0.626	0.50	0.250	0.08	1.000	30	108	182
GM102	1.79	WWH	ND	0.05	0.569	1.1	0.613	0.50	0.250	0.08	1.000	30	159	182
GM95	0.3	WWH	ND	0.05	0.628	1.1	0.656	0.50	0.250	0.08	1.000	30	71	182
Unnamed Trib. to Steel Creek (Oakview Estates)														
GM98	2.3	WWH	NC	0.05	NC	1.1	NC	0.50	NC	0.08	NC	30	NC	182
Unnamed Trib. to Steel Creek @RM														
GM103	0.3	WWH	ND	0.05	6.564	1.1	0.696	0.50	0.418	0.08	3.170	30	NC	182
Briarly Creek														
GM91	3.9	WWH	ND	0.05	0.668	1.1	ND	0.50	0.250	0.08	1.000	30	65.8	182
GM90	2.45	WWH	ND	0.05	0.937	1.1	0.648	0.50	0.250	0.08	1.000	30	83.1	182
GM89	1.82	WWH	ND	0.05	1.822	1.1	ND	0.50	0.250	0.08	1.000	30	152	182
GM88	1.22	WWH	ND	0.05	2.685	1.1	0.547	0.50	0.250	0.08	1.600	30	75.6	182
GM87	0.2	WWH	ND	0.05	0.411	1.1	ND	0.50	0.250	0.08	1.070	30	44	182

***Table 19**. Nutrient parameter results in the results in the Taylor Creek and direct Ohio River tributaries study area during 2014. Values >reference targets or other benchmarks are shaded in yellow.*

Site ID	River Mile	Aquatic Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m3) +		Benthic Chlorophyll (mg/m3) ++	
			Median	Target[1]	Median	Target[1]	Median	Target[1]	Median	Target[1]	Median	Target[2]	Median	Target[3]
Unnamed Trib. to Briarly Creek @RM 1.44														
GM112	0.46	WWH	ND	0.05	6.307	1.1	0.781	0.50	0.410	0.08	1.035	30	NC	182
Wesselman Creek														
GM94	4.72	WWH	ND	0.05	1.004	1.1	0.638	0.50	0.250	0.08	1.000	30	41	182
GM93	3	WWH	ND	0.05	0.465	1.1	ND	0.50	0.250	0.08	3.740	30	49	182
GM99	2.9	WWH	ND	0.05	0.453	1.1	0.562	0.50	0.250	0.08	1.000	30	34	182
GM92	0.5	WWH	ND	0.05	0.033	1.1	0.526	0.50	0.250	0.08	1.000	30	48.8	182
Unnamed Trib. to Wesselman Creek @RM 2.59														
GM100	2.95	WWH	ND	0.05	1.622	1.1	0.891	0.50	0.480	0.08	4.360	30	NC	182
Unnamed Trib. to Great Miami R. @RM 16.3														
GM110	1.75	WWH	NC	0.05	NC	1.1	NC	0.50	NC	0.08	NC	30	NC	182
Muddy Creek														
MU05	6.35	WWH	1.948	0.05	0.020	1.1	3.093	0.50	0.545	0.08	1.835	30	111	182
MU04	5.4	WWH	ND	0.05	1.051	1.1	0.671	0.50	0.225	0.08	1.035	30	121	182
MU03	2.72	WWH	ND	0.05	0.372	1.1	ND	0.50	0.250	0.08	1.335	30	153	182
MU02	2.25	WWH	ND	0.05	0.064	1.1	ND	0.50	0.250	0.08	1.600	30	120	182
MU01	0.17	WWH	ND	0.05	1.755	1.1	1.000	0.50	0.250	0.08	17.905	30	26.3	182
Unnamed Trib. to Muddy Creek @RM 6.53														
MU13	0.6	WWH	1.545	0.05	0.130	1.1	3.084	0.50	0.250	0.08	1.000	30	NC	182
Unnamed Trib. to Muddy Creek @RM 5.97														
MU12	5.97	WWH	0.278	0.05	0.328	1.1	0.950	0.50	0.250	0.08	1.070	30	NC	182
Unnamed Trib. to Muddy Creek @RM 2.37														
MU10	0.6	WWH	ND	0.05	0.546	1.1	ND	0.50	0.250	0.08	1.070	30	NC	182
Unnamed Trib. to Muddy Creek @RM 0.3														
MU08	1.8	WWH	ND	0.05	0.657	1.1	0.668	0.50	0.250	0.08	2.140	30	NC	182
MU07	0.6	WWH	ND	0.05	0.507	1.1	0.629	0.50	0.250	0.08	1.070	30	NC	182
Unnamed Trib. @0.45 to Unnamed Trib. to Muddy Creek @RM 5.97														
MU14	0.2	WWH	0.520	0.05	1.217	1.1	1.283	0.50	0.250	0.08	1.000	30	NC	182
Unnamed Trib. @ 0.95 to Unnamed Trib. to Muddy Creek @RM 0.3														
MU09	0.6	WWH	ND	0.05	0.812	1.1	ND	0.50	0.250	0.08	4.270	30	NC	182

***Table 19**. Nutrient parameter results in the results in the Taylor Creek and direct Ohio River tributaries study area during 2014. Values >reference targets or other benchmarks are shaded in yellow.*

Site ID	River Mile	Aquatic Life Use	Total Ammonia (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Total Phosphorus (mg/l)		Sestonic Chlorophyll (mg/m3) +		Benthic Chlorophyll (mg/m3) ++	
			Median	Target[1]	Median	Target[1]	Median	Target[1]	Median	Target[1]	Median	Target[2]	Median	Target[3]
Rapid Run														
RR03	2.7	LRW	1.669	0.05	0.050	1.1	5.490	0.50	0.970	0.08	2.670	30	154	182
RR02	1.2	LRW	ND	0.05	0.345	1.1	ND	0.50	0.164	0.08	1.000	30	101	182
RR01	0.1	LRW	ND	0.05	0.000	1.1	ND	0.50	0.082	0.08	1.000	30	99.1	182
Wulff Creek														
RR04	0.55	LRW	ND	0.05	4.485	1.1	ND	0.50	0.187	0.08	1.600	30	NC	182
Unnamed Trib. to Wulff Run @RM 0.77														
RR05	0.68	WWH	ND	0.05	1.846	1.1	0.580	0.50	0.138	0.08	1.070	30	NC	182
Indian Creek														
IC06	2.43	WWH	ND	0.05	0.575	1.1	0.625	0.50	0.278	0.08	6.935	30	28	182
IC05	2.08	WWH	ND	0.05	0.793	1.1	0.690	0.50	0.276	0.08	7.300	30	67.9	182
IC02	1.22	WWH	ND	0.05	0.050	1.1	0.578	0.50	0.250	0.08	14.305	30	19.4	182
IC01	0.3	WWH	ND	0.05	0.278	1.1	0.830	0.50	0.222	0.08	5.340	30	30.1	182
Unnamed Trib. to Indian Creek @RM														
IC07	0.13	WWH	ND	0.05	0.297	1.1	0.531	0.50	0.250	0.08	1.000	30	NC	182
Unnamed Trib. to Indian Creek @RM 1.55														
IC08	1.5	WWH	ND	0.05	2.266	1.1	ND	0.50	0.250	0.08	1.000	30	NC	182
Reference Sites														
Mill Run														
RF11	0.9	WWH	ND	0.05	0.445	1.1	ND	0.50	0.250	0.08	1.000	30	30	182
Stonelick Creek														
RF14	3.1	WWH	ND	0.05	0.181	1.1	ND	0.50	0.250	0.08	2.670	30	136	182
RF13	1	WWH	ND	0.05	0.271	1.1	ND	0.50	0.250	0.08	2.140	30	19.2	182
Fivemile Creek														
RF15	0.5	WWH	ND	0.05	0.425	1.1	0.781	0.50	0.250	0.08	1.600	30	26.2	182
W. Fk. E. Fk. Little Miami River														
RF16	0.1	WWH	ND	0.05	2.225	1.1	0.772	0.50	0.250	0.08	1.600	30	66	182
Dodson Creek														
RF17	0.05	WWH	ND	0.05	0.376	1.1	0.657	0.50	0.250	0.08	1.300	30	100	182

[1]Target concentrations represent the 75th percentile of reference sites statewide in Ohio for wadeable or headwater streams

[2]Mesotrophic-eutrophic boundary from data from Van Nieuwenhuyse and Jones (1996); not applicable to small streams, but provided for context.

[3]Benthic chlorophyll cutoffs: Low - < 182 mg/m^2; High > 320 mg/m^2

***Table 20**. Urban parameter results in the Ohio River in 2014. The data were evaluated against reference targets that are based on inland large rivers in Ohio (75th percentile values).*

Site ID	River Mile	Bank	Specific Conductivity (µS/cm) [1]	Chloride[2]	Sulfate[3]	TDS[4]	TSS[5]
Ohio River							
OR01	438.2	KY	404	29	67	230	13
OR02	440.0	OH	406	28	78	240	11
OR03	447.5	KY	402	29	67	225	12
OR04	450.8	OH	407	30	69	230	11
OR05	451.4	KY	405	30	67	215	13
OR06	455.5	OH	407	31	80	240	10
OR07	460.1	KY	410	31	91	225	14
OR08	462.6	OH	411	32	91	230	8
OR09	464.1	OH	420	33	84	225	12
OR10	465.3	OH	423	33	86	225	10
OR11	466.0	KY	415	32	69	220	12
OR12	466.2	OH	419	33	67	205	12
OR13	466.7	OH	418	33	92	210	10
OR14	468.0	OH	419	32	65	210	8
OR15	468.9	KY	417	32	93	215	10
OR16	468.9	OH	418	33	62	205	7
OR17	470.3	KY	412	32	74	215	10
OR18	472.0	KY	399	32	72	215	12
OR19	472.5	OH	406	32	93	220	12
OR20	473.5	OH	417	32	109	210	10
OR21	474.2	OH	418	32	76	220	12
OR22	474.9	KY	398	31	68	245	12
OR23	477.0	OH	421	31	79	230	10
OR24	478.7	OH	428	32	78	215	11
OR25	480.6	OH	423	31	89	235	12
OR26	480.8	OH	423	29	64	215	13
OR27	482.7	OH	416	31	84	210	11
OR28	484.1	KY	413	31	80	220	14
OR29	484.2	OH	412	31	71	210	10
OR30	485.4	OH	425	31	84	205	10
OR31	485.5	KY	357	30	73	185	13
OR32	486.2	OH	362	31	85	210	9
OR33	487.3	KY	358	31	79	215	9
OR34	490.1	KY	357	29	87	220	15

***Table 20**. Urban parameter results in the Ohio River in 2014. The data were evaluated against reference targets that are based on inland large rivers in Ohio (75th percentile values).*

Site ID	River Mile	Bank	Specific Conductivity (µS/cm) [1]	Chloride[2]	Sulfate[3]	TDS[4]	TSS[5]
OR35	491.7	IN	423	33	90	205	15
OR36	494.9	IN	436	35	93	215	17
OR37	496.9	IN	370	32	72	205	10
OR38	498.6	KY	364	31	100	225	16
OR39	501.2	KY	373	31	82	200	16
OR40	504.0	IN	392	32	88	215	11
OR41	507.6	KY	416	31	66	220	11
OR42	509.2	IN	414	31	80	220	16
OR43	511.9	KY	415	30	74	225	10
OR44	515.7	IN	423	30	84	220	10
OR45	520.5	KY	423	31	79	210	10
OR46	523.4	IN	423	30	75	220	12
OR47	524.1	KY	422	31	73	230	14
OR48	528.6	KY	424	31	88	235	16
OR49	530.5	IN	424	31	69	245	13

[1]Conductivity 75th percentile at Ohio Inland Rivers: **837 µS/cm**
[2]Chloride 75th percentile at Ohio Inland Rivers: **82 mg/l**
[3] Sulfate 75th percentile at Ohio Inland Rivers: **170 mg/l**
[4]TDS 75th percentile at Ohio Inland Rivers: **520 mg/l**
[5]TSS 75th percentile at Ohio Inland Rivers: **50 mg/l**

***Table 21**. Nutrient parameter results in the Ohio River in 2014. Values >reference targets are highlighted in yellow and are based on inland large rivers in Ohio (75th percentile values) or literature values for sestonic chlorphyll.*

Site ID	River Mile	Bank	Total Ammonia[1] (mg/l)	Nitrate[2] (mg/l)	TKN[3] (mg/l)	Total Phosphorus[4] (mg/l)	Sestonic Chlorophyll[5] (µg/l)
				Ohio River			
OR01	438.2	KY	ND	3.392	ND	0.194	1.335
OR02	440.0	OH	ND	1.533	0.592	0.212	1.600
OR03	447.5	KY	ND	2.521	ND	0.205	1.335
OR04	450.8	OH	ND	1.088	ND	0.201	1.070
OR05	451.4	KY	ND	1.093	ND	0.201	1.870
OR06	455.5	OH	ND	1.276	ND	0.250	1.600
OR07	460.1	KY	ND	1.128	ND	0.250	3.200
OR08	462.6	OH	ND	1.175	ND	0.250	2.935
OR09	464.1	OH	ND	1.130	ND	0.250	4.005
OR10	465.3	OH	ND	2.804	ND	0.250	3.470
OR11	466.0	KY	ND	0.850	ND	0.250	3.470
OR12	466.2	OH	ND	0.976	0.530	0.250	4.005
OR13	466.7	OH	ND	2.300	ND	0.250	3.740
OR14	468.0	OH	ND	1.311	ND	0.250	2.670
OR15	468.9	KY	ND	1.600	ND	0.250	3.470
OR16	468.9	OH	ND	1.733	ND	0.202	2.005
OR17	470.3	KY	ND	1.013	ND	0.250	2.935
OR18	472.0	KY	ND	1.355	ND	0.250	4.540
OR19	472.5	OH	ND	2.056	ND	0.250	2.405
OR20	473.5	OH	ND	1.928	ND	0.250	2.140
OR21	474.2	OH	ND	3.334	0.666	0.250	3.205
OR22	474.9	KY	ND	1.317	ND	0.250	3.740
OR23	477.0	OH	ND	3.779	ND	0.250	2.670
OR24	478.7	OH	ND	3.450	ND	0.250	2.935
OR25	480.6	OH	ND	0.939	ND	0.250	3.335
OR26	480.8	OH	ND	1.286	0.532	0.250	2.670
OR27	482.7	OH	ND	1.268	ND	0.250	2.135
OR28	484.1	KY	ND	2.025	ND	0.250	2.670
OR29	484.2	OH	ND	1.080	0.598	0.250	1.605
OR30	485.4	OH	ND	0.718	0.609	0.250	2.070
OR31	485.5	KY	ND	1.034	ND	0.250	1.000
OR32	486.2	OH	ND	1.120	ND	0.250	1.600
OR33	487.3	KY	ND	1.946	ND	0.250	1.570
OR34	490.1	KY	ND	1.670	ND	0.250	1.605

***Table 21**. Nutrient parameter results in the Ohio River in 2014. Values >reference targets are highlighted in yellow and are based on inland large rivers in Ohio (75th percentile values) or literature values for sestonic chlorphyll.*

Site ID	River Mile	Bank	Total Ammonia[1] (mg/l)	Nitrate[2] (mg/l)	TKN[3] (mg/l)	Total Phosphorus[4] (mg/l)	Sestonic Chlorophyll[5] (µg/l)
OR35	491.7	IN	ND	1.326	ND	0.250	9.890
OR36	494.9	IN	ND	1.095	ND	0.250	6.410
OR37	496.9	IN	ND	1.953	ND	0.170	6.940
OR38	498.6	KY	ND	1.592	ND	0.235	5.600
OR39	501.2	KY	ND	1.225	ND	0.190	7.470
OR40	504.0	IN	ND	1.265	0.611	0.233	4.005
OR41	507.6	KY	ND	0.853	0.541	0.234	4.805
OR42	509.2	IN	ND	1.654	0.578	0.250	3.475
OR43	511.9	KY	ND	0.748	0.561	0.250	3.205
OR44	515.7	IN	ND	1.216	ND	0.250	3.735
OR45	520.5	KY	ND	1.246	ND	0.250	2.670
OR46	523.4	IN	ND	2.700	ND	0.250	2.405
OR47	524.1	KY	ND	1.345	0.538	0.250	2.135
OR48	528.6	KY	ND	2.030	ND	0.250	3.470
OR49	530.5	IN	ND	2.485	ND	0.250	4.005

[1]Total ammonia 75th percentile at Ohio Inland Rivers: **0.08 µS/cm**
[2]Nitrate 75th percentile at Ohio Inland Rivers: **3.26 mg/l**
[3] TKN 75th percentile at Ohio Inland Rivers: **1.10 mg/l**
[4]Total phosphorus 75th percentile at Ohio Inland Rivers: **0.41 mg/l**
[5]Sestonic chlorophyll: the range is defined by literature sources, especially Van Nieuwenhuyse and Jones (1996) and Heiskary et al. (2010): **20-45 µg/l**.

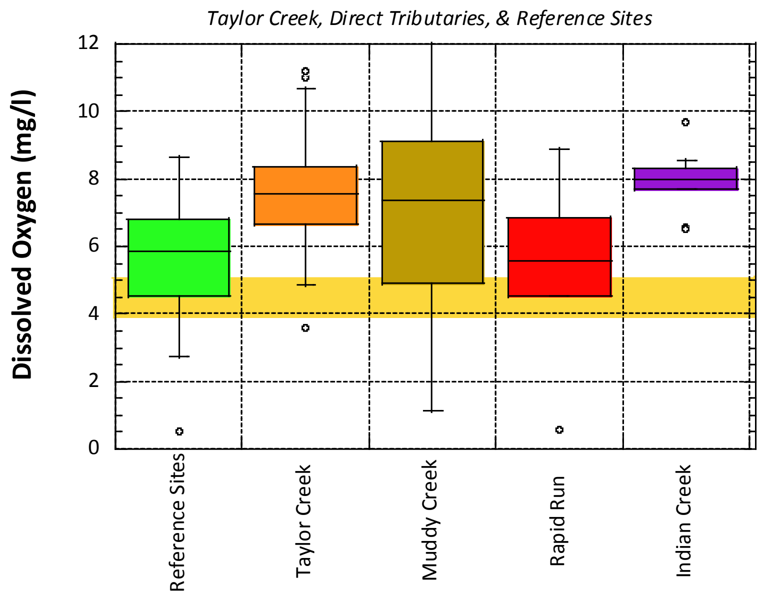

Figure 15. *Box plot of D.O. levels for streams in Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek) and year 4 Reference Sites. Orange shaded bar represents the 4.0 mg/l minimum/5.0 mg/l 24 hr. average WWH D.O. criteria.*

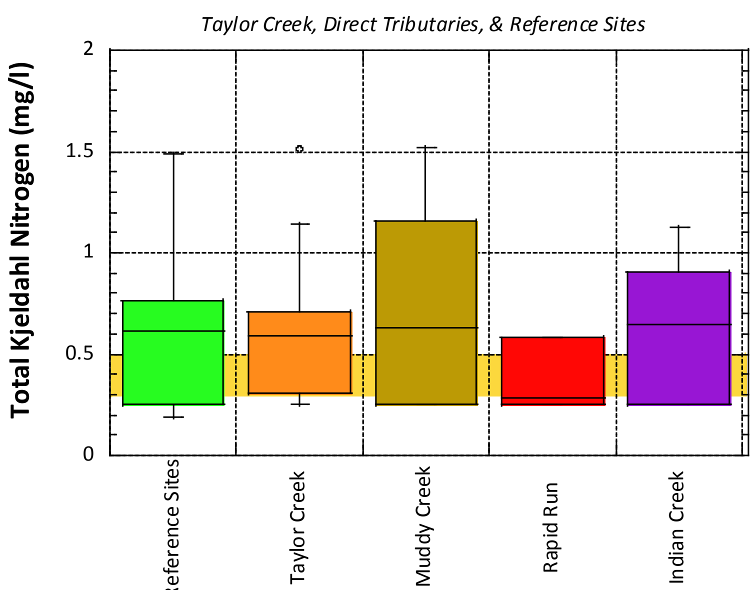

Figure 16. *Box plot of TKN for streams in Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek) and year 4 Reference Sites. Orange shaded bar represents the median and 75th percentile of Ohio statewide headwater reference sites.*

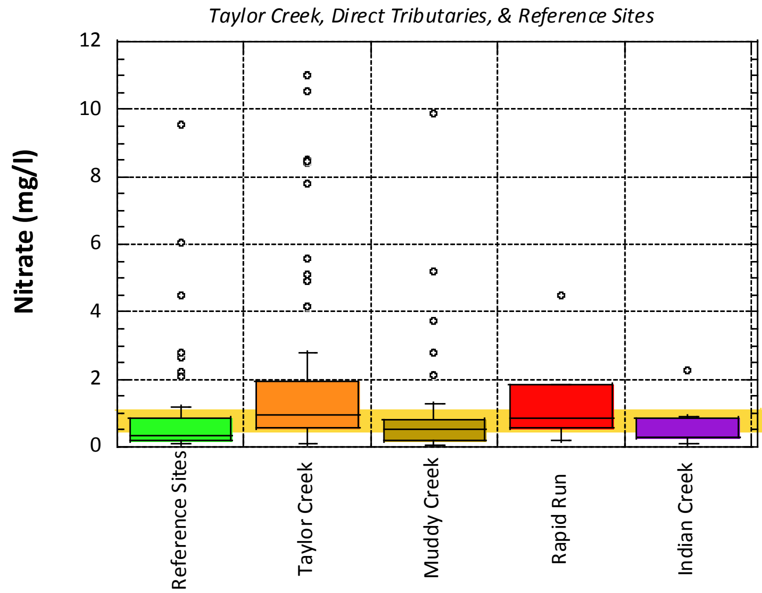

Figure 17. *Box plot of total nitrate-N for streams in Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek) and year 4 Reference Sites. Orange shaded bar represents the median and 75th percentile of Ohio statewide headwater reference sites.*

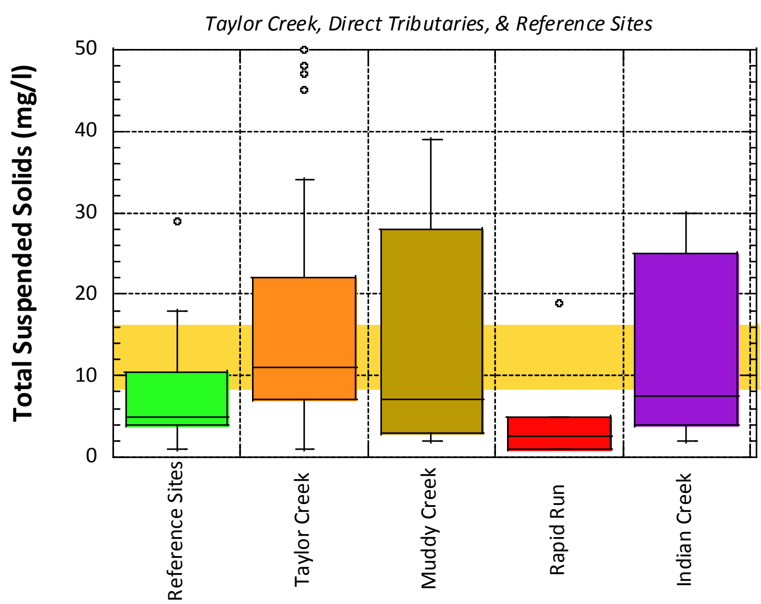

Figure 18. *Box plot of TSS for streams in Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek) and year 4 Reference Sites. Orange shaded bar represents the median and 75th percentile of Ohio statewide headwater reference sites.*

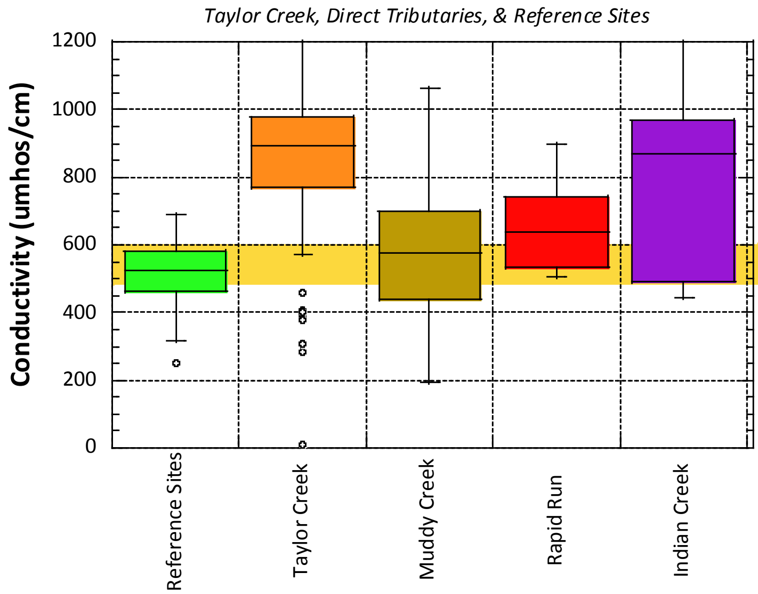

Figure 19. *Box plot of Conductivity for streams in Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek) and year 4 Reference Sites. Orange shaded bar represents the median and 75th percentile of Ohio statewide headwater reference sites.*

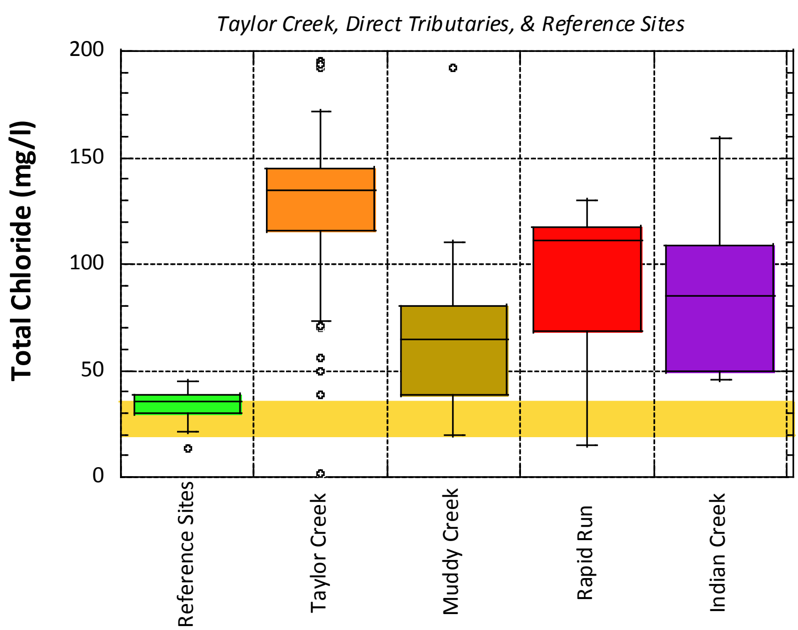

Figure 20. *Box plot of Total Chloride for streams in Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek) and year 4 Reference Sites. Orange shaded bar represents the median and 75th percentile of Ohio statewide headwater reference sites.*

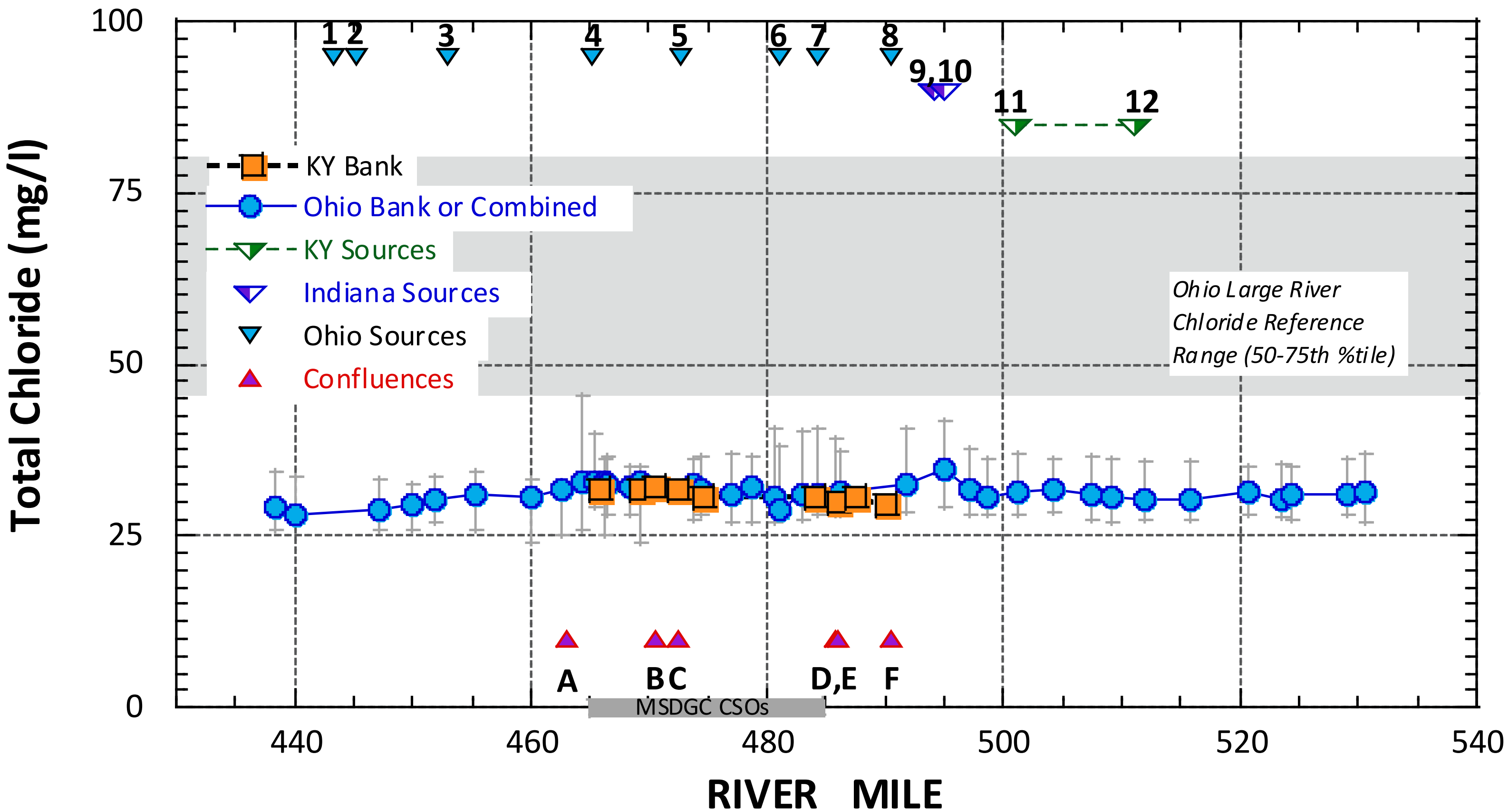

***Figure 21**. Total chloride (mg/l) vs. river mile for sites sampled in the Ohio River Markland navigation pool during 2014. Shaded area represents Ohio inland large river reference sites range (median-75th percentile values). Numbers at top represent key pollution sources and letters at bottom are major tributary confluences depicted in Table 16. Right bank sites (Ohio shoreline) are blue circles and left bank sites (KY shoreline) are orange squares.*

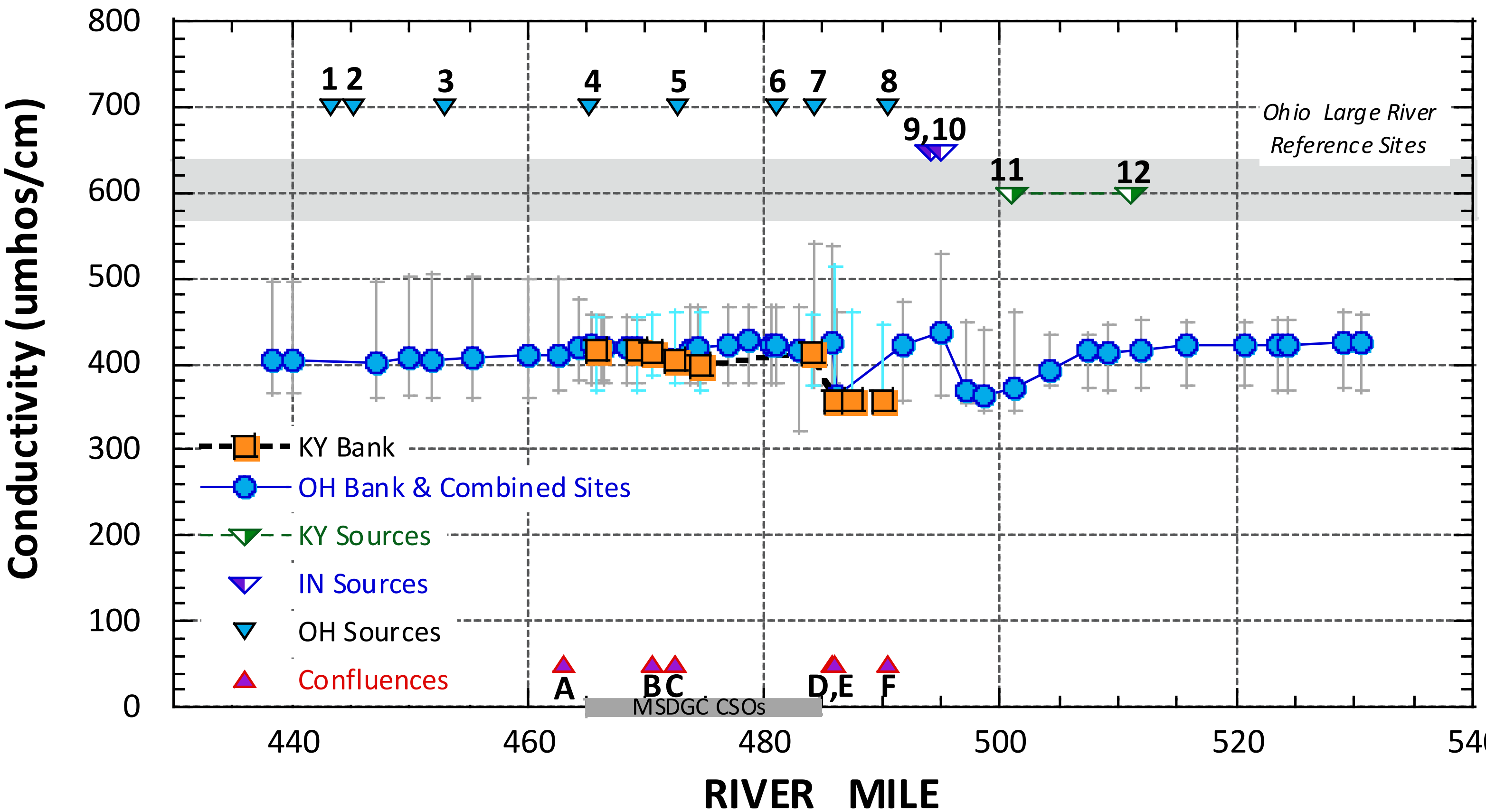

Figure 22*. Conductivity (µS/cm) vs. river mile for sites sampled in the Ohio River Markland navigation pool during 2014. Shaded area represents Ohio inland large river reference sites range (median-75th percentile values). Numbers at top represent key pollution sources and letters at bottom major tributary confluences depicted in Table 16. Right bank sites (Ohio shoreline) are blue circles and left bank sites (KY shoreline) are orange squares.*

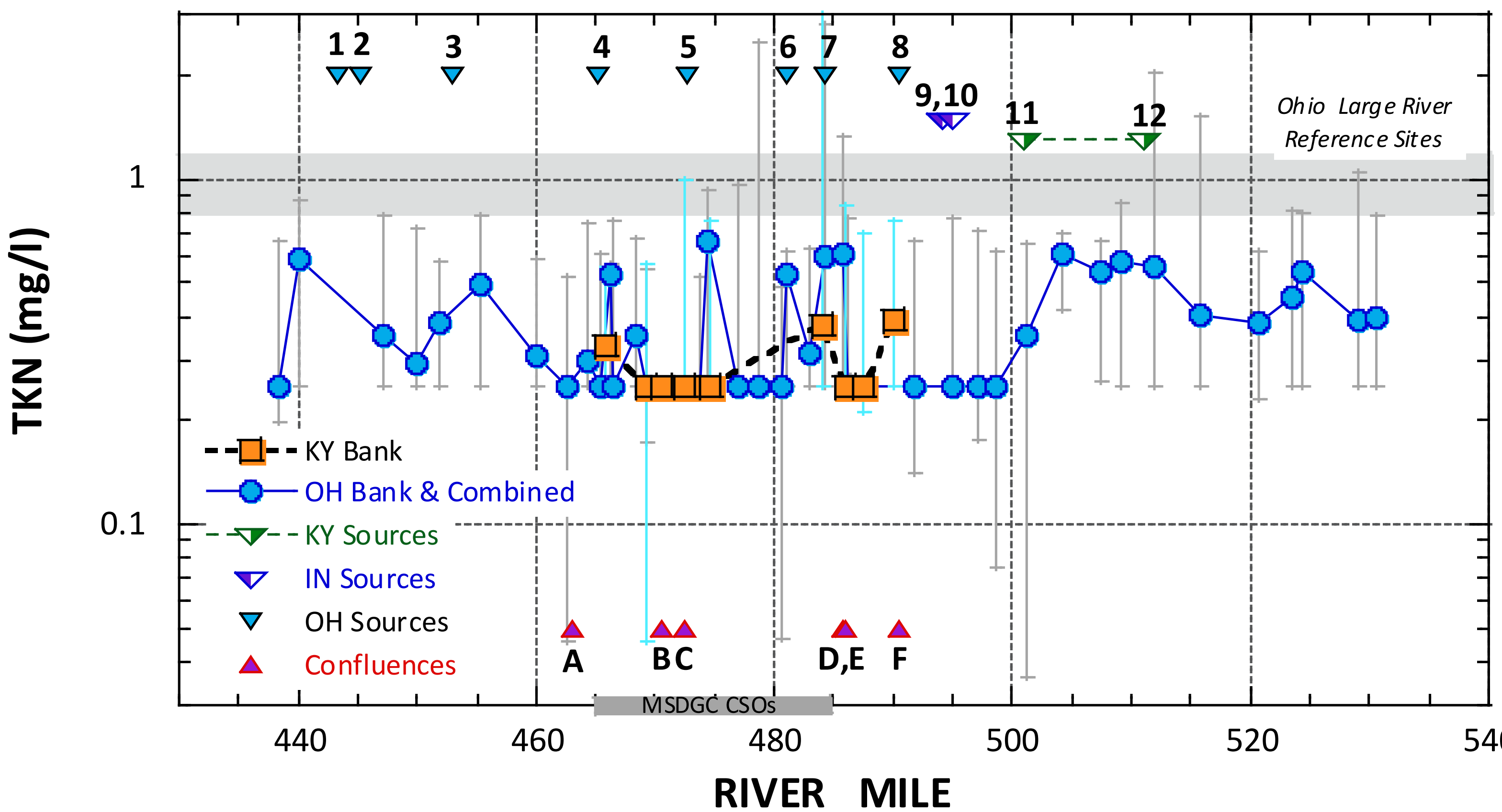

***Figure 23**. Total TKN (mg/l) vs. river mile for sites sampled in the Ohio River Markland navigation pool during 2014. Shaded area represents Ohio inland large river reference sites range (median-75th percentile values). Numbers at top represent key potential pollution sources and letters at bottom major tributary confluences depicted in Table 16. Right bank sites (Ohio shoreline) are blue circles and left bank sites (KY shoreline) are orange squares.*

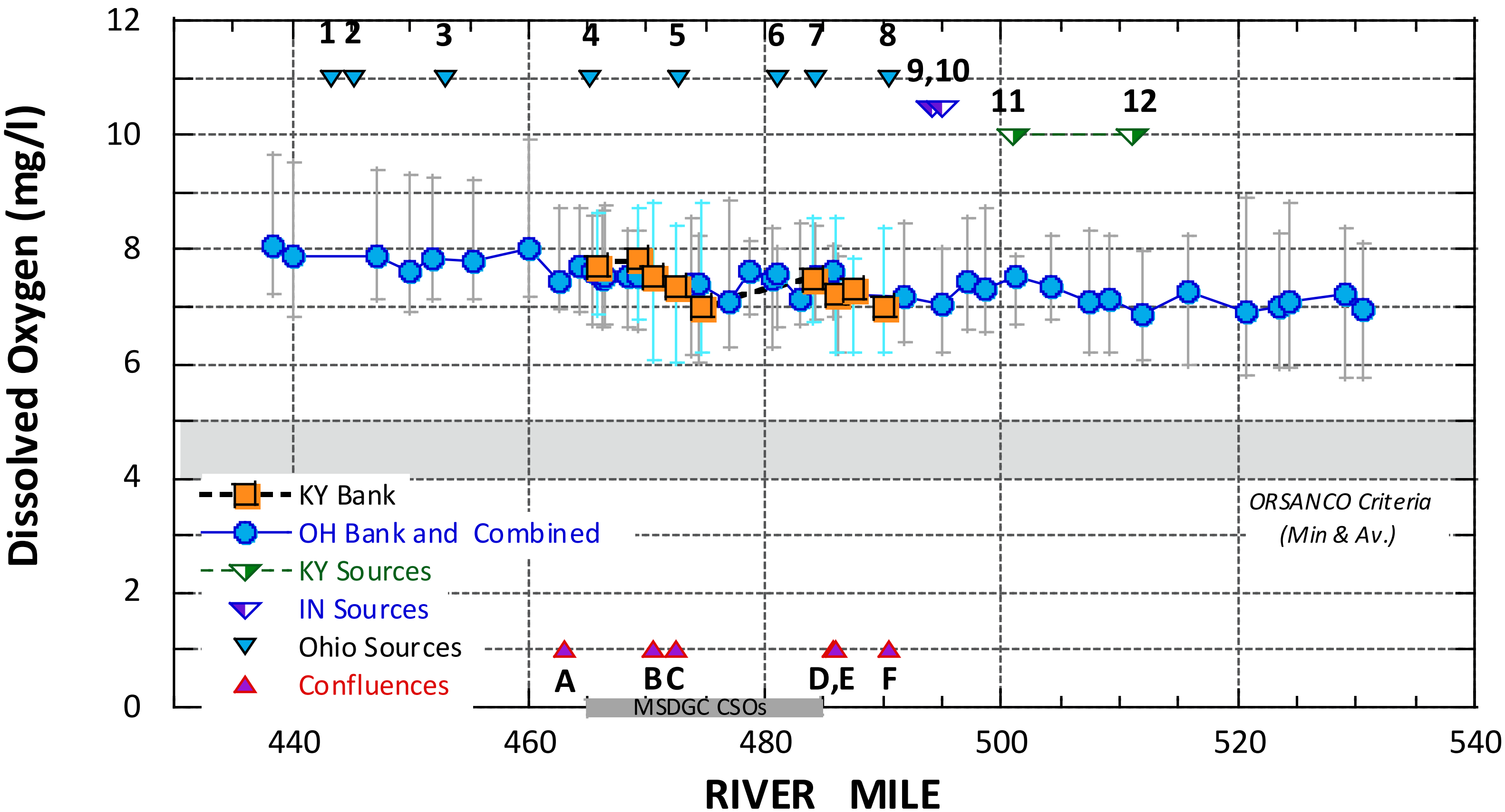

***Figure 24**. D.O. (mg/l) vs. river mile for sites sampled in the Ohio River Markland navigation pool during 2014. Shaded area represents the D.O. minimum (4.0 mg/l) and 24 hr. average (5.0 mg/l) water quality criteria. Numbers at top represent key potential pollution sources and letters at bottom major tributary confluences depicted in Table 16. Right bank sites (Ohio shoreline) are blue circles and left bank sites (KY shoreline) are orange squares.*

Continuous Monitoring

D.O. (mg/l), temperature (◦C), conductivity (µS/cm), and pH (S.U.) were monitored continuously over 3-4 consecutive day periods at five selected mainstem Ohio River sites during early September and at selected locations in Taylor Creek and Direct Tributaries during July, August, and early September. The Ohio River results were very different from the inland streams and largely related to the greater dilution available. An initial inspection of the results in the Taylor Creek and the Direct Tributaries showed patterns and exceedances of criteria and thresholds for D.O., temperature, and conductivity.

Ohio River Mainstem

Continuous monitoring data from the Ohio River mainstem generally varied little between stations which can be attributed to the greater dilution from the upstream watershed (Figure 25). Sites were set at five different locations in the Cincinnati area during early September 2014. For the four parameters (temperature, pH, D.O., conductivity) there was little effect if any from the tributaries or CSOs to the mainstem, at least during the period of sampling which was conducted during late summer base flow conditions (Figure 25).

WAU 09-05 – Taylor Creek

The sites with continuous monitors were in full attainment of the aquatic use criteria and the only major issue identified in the continuous monitoring data was elevated conductivity (Figure 26) that was also evident in grab samples. Elevated conductivity is related to the same issues as the observed increases in chlorides. As was previously discussed, grab samples indicate increasing chloride values compared to results obtained on the 1970s. The values observed in Taylor Creek are nearing the range (100-140 mg/l) where adverse effects on aquatic life become evident.

WAU 02-03 – Muddy Creek Watershed

Two sites in Muddy Creek (MU02 and MU03) exhibited wide diel swings in D.O. and instantaneous values below the minimum criteria (Figure 26). Site MU03 also had elevated pH which is indicative of increased algal respiration. These results coupled with elevated ammonia values at sites downstream of CSOs/SSOs are evidence of excessive organic enrichment from these sources.

Reference Sites

Several of the reference sites (RF11, RF15, RF16, RF17) had instantaneous D.O. values below the WWH minimum criterion (Figure 26, upper left). However, pH, temperature, and conductivity values were within criteria and reference ranges.

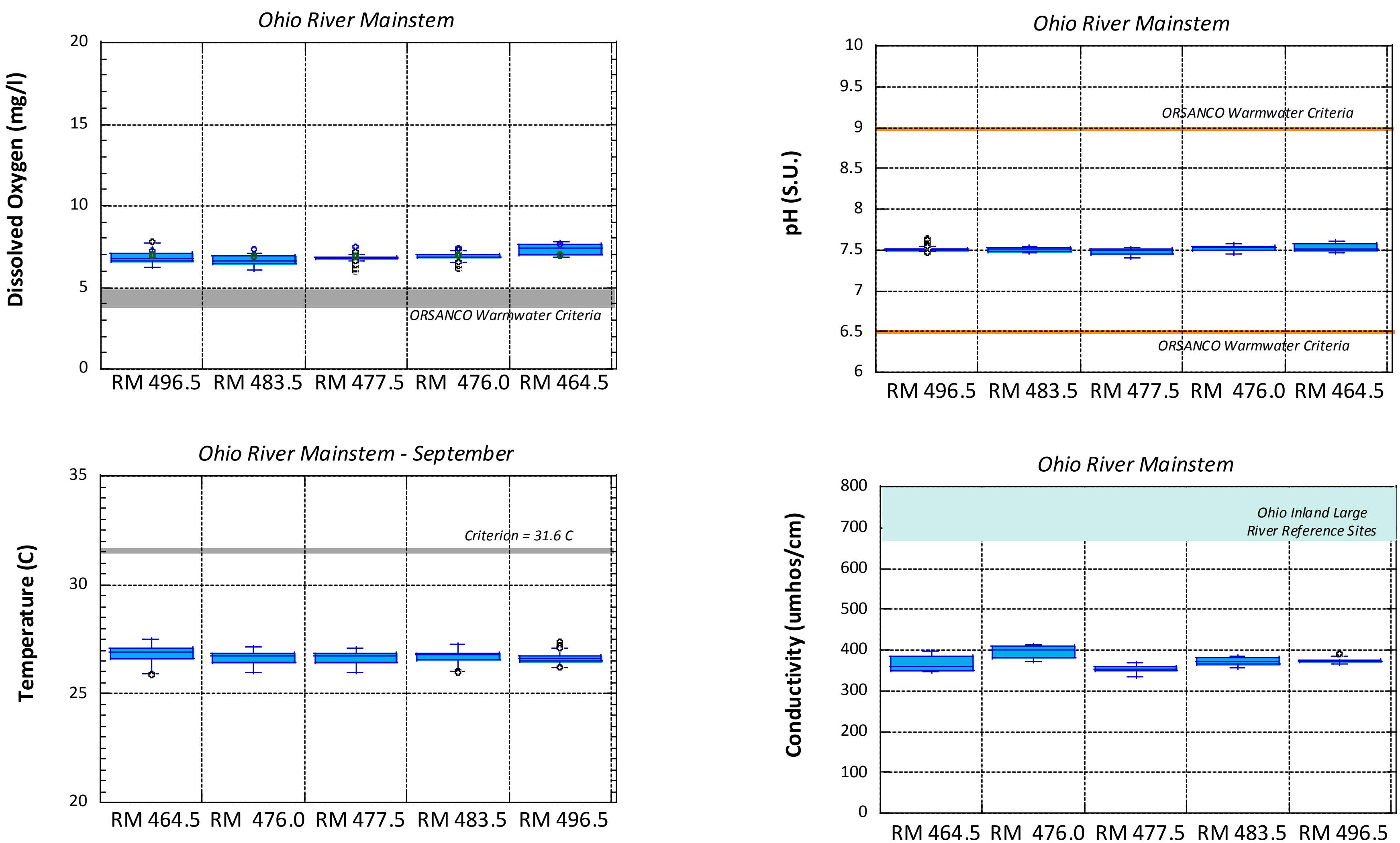

***Figure 25**. Continuous D.O. (upper left), temperature (lower left), pH (upper right) and conductivity (lower right) results in the mainstem of the Ohio River during September 2014. The shaded bars are water quality criteria (D.O., pH, temperature) or the median-75th percentile range of inland Ohio large river reference sites (conductivity).*

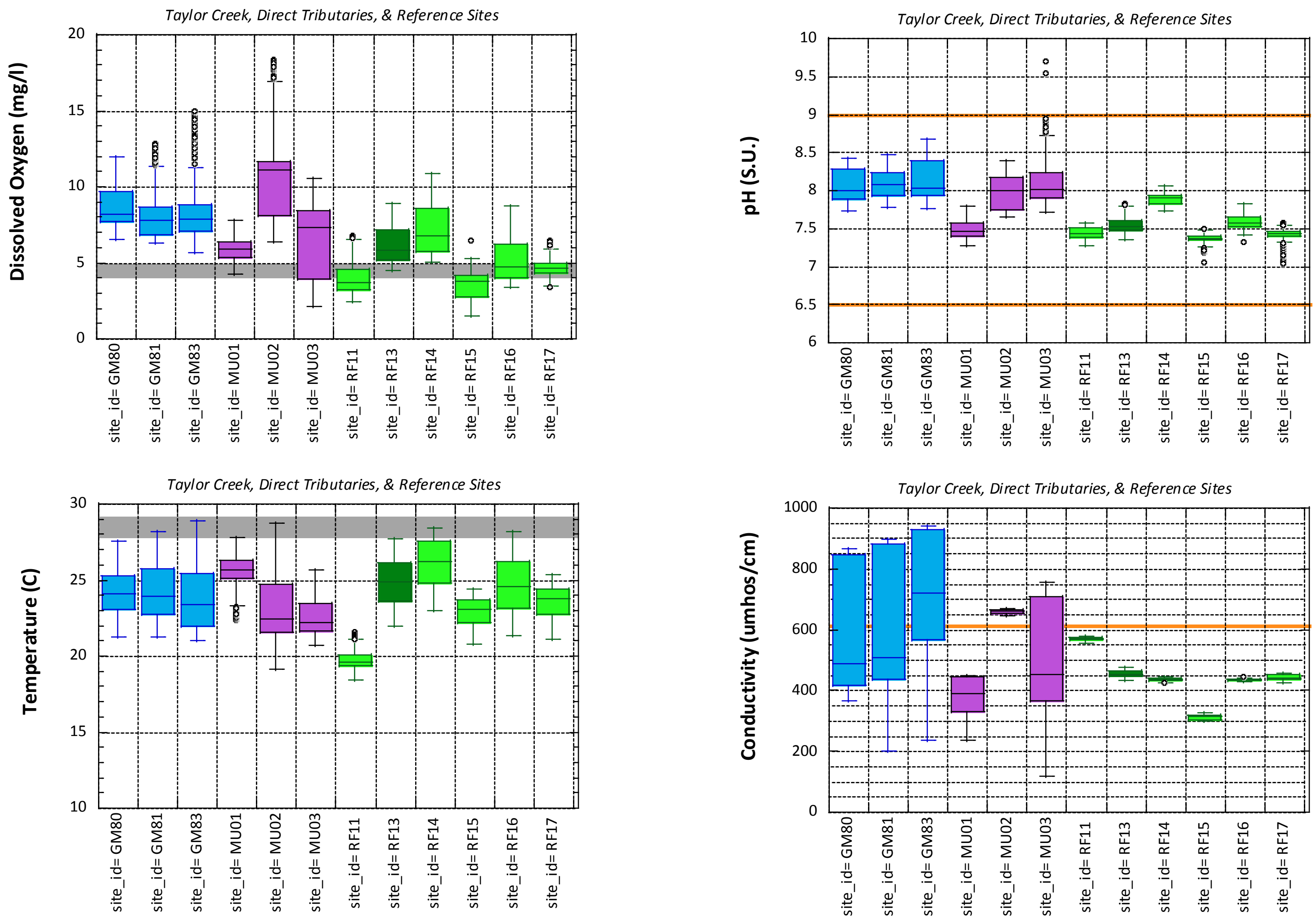

***Figure 26**. Continuous D.O. (upper left), temperature (lower left), pH (upper right) and conductivity (lower right) results in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites during 2014. The shaded bars are water quality criteria (D.O., pH, temperature) or the 75th percentile of statewide headwater reference sites (conductivity).*

Sediment Chemistry

Sediment samples were collected from 24 sites in Taylor Creek and the Direct Ohio River Tributaries (Tables 22 and 23) and at 48 sites in the Ohio River mainstem (Tables 24 and 25). 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 Interior Plateau 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 to aquatic life.

None of the 24 Taylor Creek or Direct Ohio River Tributaries sites had sediment metal concentrations greater than the PEC (probable effect level) and only one site in the Ohio River mainstem (OR3, RM 447.2) had a value for lead above the PEC. In the inland tributaries, three sites had sediment metal concentrations greater than the threshold effects levels, and four sites with concentrations greater than the Ohio SRVs (Table 22). Of these four sites that exceeded the TEC levels, one was in Taylor Creek, and two were in Muddy Creek. The only parameters that exceeded TEC or PEC organic compound benchmarks were PAH compounds (Table 23 and 25). PAHs originate from oil-based compounds (e.g., tars, motor oils, etc.) and are typically associated with runoff from highways and other paved surfaces.

Ohio River Mainstem

In the Ohio River mainstem four of 48 sites had values for metals above the TEC levels scattered along the length of the Markland pool (Table 24). For organic compounds there were six of 48 sites that had values above the TEC or PEC thresholds (Table 25). These occurred primarily within the segment of the mainstem that is impacted by CSOs/SSOs and urban runoff in the Cincinnati area. Three pesticides, two of which exceeded the PEC (chlordane and toxaphene), were detected at OR18. Toluene >PEC was found at OR21 which is in the vicinity of the Ohio R. tributaries and CSO/SSO locations.

WAU 09-05 – Taylor Creek

In Taylor Creek (Table 22) there was a minor exceedance of the TEC threshold for arsenic at GM80 which is the most downstream site. A minor exceedance of the TEC threshold occurred for lead at the upstream-most site in Briarly Creek (GM91). Six or seven metal compounds were detected at each site in Taylor Creek and the sampled tributaries. The source of metals is likely related to urban runoff. There were a number of PAH compounds above the TEC (Table 23), but not above the PEC level in Taylor Creek, Briarly Creek, and Wesselman Creek particularly at the downstream-most sites. PAH compounds included chrysene, fluoranthene, phenanthrene, and pyrene, which are commonly observed in urbanized areas. Urban runoff is the likely source of these compounds.

WAU 02-03 – Muddy Creek

In the Muddy Creek watershed there was minor exceedance of the TEC threshold for lead at MU05 in Muddy Creek which is downstream of a CSO (Table 22). Five to nine metal compounds were detected at each site in Muddy Creek and the sampled tributaries. The source of metals is likely related to a combination of CSOs/SSOs and urban runoff.

At sites MU03 and MU05 in Muddy Creek PAHs exceeding the PEC concentration were observed and it is associated with the aquatic impairment measured at these sites (Table 23). In Muddy Creek the PAHs are likely contributed by CSOs/SSOs and urban runoff.

Reference Sites

The Reference sites had no exceedances of the TEC or PEC thresholds for sediment metals, but between six to eight metals were detected at each site (Table 22). All organic compounds were below detection at each of the sampled reference sites (Table 23).

Aquatic Habitat in the Lower Great Miami River Study Area

This section focuses on key habitat stressors in Taylor Creek and the Direct Ohio River tributaries. The assessment is based on the QHEI and its metrics, submetrics, and individual attributes. A QHEI matrix consisting of good and poor habitat attributes (after Rankin 1995) was developed for each site in the Taylor Creek and Direct Ohio River Tributary study areas (Table 26).

WAU 09-05 – Taylor Creek Watershed

QHEI scores in the Taylor Creek watershed in 2014 and the results of prior Ohio EPA surveys in 1988 and 1990-1992 are illustrated on Figure 27. With minor exceptions, QHEI scores in the Taylor Creek watershed were generally good-excellent (Table 26). Poor habitat attributes in streams of the Taylor Creek watershed are largely related to flow issues and a lack of instream cover which can be reduced by excessively flashy flows from urban runoff. In general habitat conditions in these streams should be capable of supporting assemblages of fish and macroinvertebrates consistent with the WWH use designation. There was no clear differences in QHEI scores between the 1988 or 1990-1992 scores and 2014, with perhaps Steel Creek scoring slightly lower in 2014 (Figure 27). Stream channel responses to impacts such as increased flashiness from stormwater flows may be occurring and it would be prudent to track changes in habitat and channel features in the future.

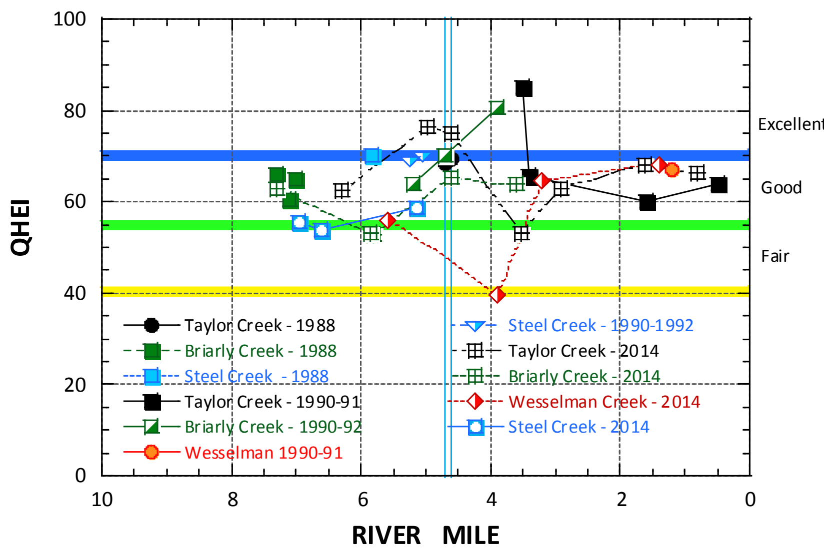

***Figure 27**. QHEI scores vs. river mile for larger streams in the Taylor Creek watershed from 1988-2014.*

***Table 22**. Sediment metal concentrations in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites that were detected and >Ohio sediment reference values (SRV), >Threshold Effect Concentration (TEC), or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values.*

Site ID	River Mile	Collection Date	Aq. Life	Tested	Detected	>Ohio SRV Guidelines	>TEC and < PEC	>PEC
WAU 09-05 – Taylor Creek								
Taylor Creek								
GM86	6.3	29-Oct-14	WWH	11	6			
GM84	4.6	30-Oct-14	WWH	11	7			
GM83	3.53	29-Oct-14	WWH	11	6			
GM82	2.93	15-Oct-14	WWH	9	6			
GM81	1.62	15-Oct-14	WWH	9	7			
GM80	0.8	15-Oct-14	WWH	9	7	As_S (12.00); Mg_S (36000.00)	As_S (12.00)	
Briarly Creek								
GM91	3.9	29-Oct-14	PHW3A	11	7	Pb_S (52.00)	Pb_S (52.00)	
GM89	1.82	29-Oct-14	WWH	11	7			
GM87	0.2	29-Oct-14	WWH	11	6			
Wesselman Creek								
GM94	4.72	29-Oct-14	WWH	11	7			
GM93	2.9	27-Oct-14		11	9			
GM92	0.5	28-Oct-14	WWH	11	6			
Steel Creek								
GM111	2.16	28-Oct-14	WWH	11	6			
GM102	1.79	28-Oct-14	WWH	11	6			
GM95	0.3	28-Oct-14	WWH	11	6			
WAU 02-03 – Muddy Creek								
Muddy Creek								
MU05	6.35	27-Oct-14	WWH	11	8	Cu_S (27.00)	Pb_S (40.00)	
MU04	5.4	27-Oct-14	WWH	11	5	Ca_S (210000.0)		
MU03	2.72	27-Oct-14	WWH	11	9			
MU01	0.17	22-Oct-14	WWH	11	8			
Unnamed Trib. to Muddy Creek @RM 0.3								
MU08	1.8	27-Oct-14	PHW3A	11	9			
Reference Sites								
Stonelick Creek								
RF13	1	28-Oct-14	WWH	11	6			
Fivemile Creek								
RF15	0.5	28-Oct-14	WWH	11	8			
W. Fk. E. Fk. Little Miami River								
RF16	0.1	28-Oct-14	WWH	11	7			
Dodson Creek								
RF17	0.05	28-Oct-14	WWH	11	8			

***Table 23**. Sediment organic compound concentrations in Taylor Creek, Direct Ohio River Tributaries, Reference Sites that were detected and >Threshold Effect Concentration (TEC) or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values.*

Site ID	River Mile	Collection Date	Aquatic Life Use	Parameters Tested	Parameters Detected	>TEC and < PEC	>PEC
WAU 09-05 – Taylor Creek							
Taylor Creek							
GM86	6.3	29-Oct-14	WWH	104	0		
GM84	4.6	30-Oct-14	WWH	104	2	Fluoranthene (730.00); Pyrene (580.00)	
GM83	3.53	29-Oct-14	WWH	104	0		
GM82	2.93	15-Oct-14	WWH	104	3	Chrysene (570.00); Fluoranthene (650.00); Pyrene (510.00)	
GM81	1.62	15-Oct-14	WWH	104	4	Chrysene (500.00); Fluoranthene (720.00); Phenanthrene (410.00); Pyrene (560.00)	
GM80	0.80	15-Oct-14	WWH	104	5	Chrysene (490.00); Fluoranthene (670.00); Phenanthrene (460.00); Pyrene (540.00)	
Briarly Creek							
GM91	3.9	29-Oct-14	PHW3A	104	7	Benzo(b)fluoranthene (520.00); Benzo(a)pyrene (360.00); Chrysene (830.00); Fluoranthene (1200.00); Indeno(1,2,3-cd)pyrene (300.00); Phenanthrene (610.00); Pyrene (1000.00)	
GM89	1.82	29-Oct-14	WWH	104	3	Chrysene (390.00); Fluoranthene (500.00); Pyrene (410.00)	
GM87	0.2	29-Oct-14	WWH	104	0		
GM94	4.72	29-Oct-14	WWH	97	3	Fluoranthene (1400.00); Phenanthrene (700.00); Pyrene (1100.00)	
Wesselman Creek							
GM93	2.9	27-Oct-14	WWH	104	0		
GM92	0.5	28-Oct-14	WWH	104	2	Phenanthrene (430.00); Pyrene (400.00)	
Steel Creek							
GM111	2.16	28-Oct-14	WWH	104	0		
GM102	1.79	28-Oct-14	WWH	104	1	Pyrene (350.00)	
GM95	0.30	28-Oct-14	WWH	104	0		

***Table 23**. Sediment organic compound concentrations in Taylor Creek, Direct Ohio River Tributaries, Reference Sites that were detected and >Threshold Effect Concentration (TEC) or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values.*

Site ID	River Mile	Collection Date	Aquatic Life Use	Parameters Tested	Parameters Detected	>TEC and < PEC	>PEC
WAU 02-03 – Muddy Creek							
Muddy Creek							
MU05	6.35	27-Oct-14	WWH	104	15		Anthracene (1200000); Benzo(b)fluoranthene (6900000); Benzo(k)fluoranthene (2700000); Benzo(a)pyrene (4500000); Chrysene (7800000); Fluoranthene (13000000); Fluorene (600000.0); Indeno(1,2,3-cd)pyrene (2700000); Phenanthrene (8300000); Pyrene (930000
MU04	5.4	27-Oct-14	WWH	104	0		
MU03	2.72	27-Oct-14	WWH	104	5		Benzo(b)fluoranthene (350000.0); Fluoranthene (790000.0); Indeno(1,2,3-cd)pyrene (150000.0); Phenanthrene (450000.0); Pyrene (640000.0)
MU01	0.17	22-Oct-14	WWH	104	5	Benzo(b)fluoranthene (560.00); Benzo(a)pyrene (390.00); Indeno(1,2,3-cd)pyrene (270.00); Phenanthrene (510.00); Pyrene (1000.00)	
Reference Sites							
Stonelick Creek							
RF13	1.0	28-Oct-14	WWH	104	0		
Fivemile Creek							
RF15	0.5	28-Oct-14	WWH	104	0		
W. Fk. E. Fk. Little Miami River							
RF16	0.1	28-Oct-14	WWH	104	0		
Dodson Creek							
RF17	0.05	28-Oct-14	WWH	104	0		

***Table 24**. Sediment metal concentrations in the Ohio River mainstem that were >Ohio sediment reference values (SRV), >Threshold Effect Concentration (TEC), or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values.*

Site ID	River Mile	Collection Date	Tested	Detect-ed	>Ohio SRV Guidelines	>TEC and <PEC	>PEC
Ohio River							
OR01	438.3	20-Oct-14	9	7			
OR02	440.0	20-Oct-14	9	6			
OR03	447.2	20-Oct-14	9	7	Cu (58.00); Pb (1300.00)	Cu (58.00)	Pb (1300.00)
OR04	450.0	20-Oct-14	9	7			
OR05	451.8	20-Oct-14	9	7			
OR06	455.4	20-Oct-14	9	7			
OR07	460.0	20-Oct-14	9	6			
OR08	462.6	21-Oct-14	11	9			
OR09	464.3	21-Oct-14	11	9			
OR10	465.3	21-Oct-14	11	8			
OR11	465.8	21-Oct-14	11	10	Cd (1.20); Cu (35.00); Zn (200.00)	As (11.00); Cd (1.20); Cu (35.00); Pb (44.00); Zn (200.00)	
OR12	466.2	21-Oct-14	11	8			
OR13	466.5	21-Oct-14	11	8			
OR14	468.4	21-Oct-14	11	8			
OR15	469.2	21-Oct-14	11	9			
OR16	469.3	21-Oct-14	11	8	Pb (110.00)	Pb (110.00)	
OR17	470.5	21-Oct-14	11	8			
OR18	472.5	21-Oct-14	11	9			
OR19	472.5	21-Oct-14	11	8			
OR20	473.8	21-Oct-14	11	8			
OR21	474.3	21-Oct-14	11	9			
OR22	474.6	21-Oct-14	11	8			
OR23	477.0	22-Oct-14	11	9			
OR24	478.7	22-Oct-14	11	9			
OR25	480.6	22-Oct-14	11	8			
OR26	481.1	22-Oct-14	11	8			
OR27	483.0	22-Oct-14	11	9			
OR28	484.1	22-Oct-14	11	8			
OR29	484.2	22-Oct-14	11	8			
OR30	485.7	22-Oct-14	11	9			
OR31	485.9	22-Oct-14	11	8	Cu (78.30)	Cu (78.30)	
OR32	486.2	22-Oct-14	11	8			
OR33	487.5	22-Oct-14	11	8			

***Table 24**. Sediment metal concentrations in the Ohio River mainstem that were >Ohio sediment reference values (SRV), >Threshold Effect Concentration (TEC), or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values.*

Site ID	River Mile	Collection Date	Tested	Detect-ed	>Ohio SRV Guidelines	>TEC and <PEC	>PEC
OR34	490.1	22-Oct-14	11	8			
OR35	491.8	22-Oct-14	11	6			
OR36	495.0	23-Oct-14	11	8			
OR37	497.2	23-Oct-14	11	8			
OR38	498.6	23-Oct-14	11	10	Cd (1.60); Cu (29.00); Zn (150.00)	Cd (1.60); Pb (39.00); Zn (150.00)	
OR39	501.3	23-Oct-14	11	8			
OR40	504.1	23-Oct-14	11	7			
OR41	507.5	23-Oct-14	11	8			
OR42	509.2	23-Oct-14	11	9			
OR43	511.9	23-Oct-14	11	8			
OR44	515.8	23-Oct-14	11	7			
OR45	520.8	23-Oct-14	11	7			
OR46	523.6	23-Oct-14	11	8			
OR47	524.3	23-Oct-14	11	7			
OR48	529.0	24-Oct-14	11	7			
OR49	530.5	24-Oct-14	11	8			

WAU 02-03 – Muddy Creek

QHEI scores ranged from poor to good in streams of the Muddy Creek watershed (Table 26). Two sites in Muddy Creek (MU01, MU03) and a tributary (MU14) showed evidence of channel modifications and the site at the mouth of Muddy Creek (MU01) is also influenced by the Ohio River. An examination of poor habitat attributes in Muddy Creek (e.g., poor cover scores, lack of fast current, silt and embeddedness) indicates that conditions are consistent with flashy flows and urban runoff.

WAU 02-04 –Rapid Run

Portions of Rapid Run and Wulff Run have been altered in the past by extreme habitat disturbances (Table 26) related to the placement of sewer lines directly in the stream channel (Ohio EPA 1992). In 1992 these streams were recommended to be assigned the LRW aquatic life use because the initial alterations resulted in a near dewatering of the stream channel resulting in very poor fish and macroinvertebrate assemblages (Ohio EPA 1992; Table 27). Streams in the Rapid Run watershed are very susceptible to this type of damage because the streams are perched on limestone bedrock layers above layers of softer blue-grey shales that are more erodible. Destruction of the limestone bedrock layers by trenching for installation of sewer lines destabilized the substrate and created "debris torrents" consisting of large

***Table 25**. Sediment organic concentrations in the Ohio River mainstem that were >Threshold Effect Concentration (TEC) or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values*

Site ID	River Mile	Collection Date	Tested	Detect-ed	>TEC and <PEC	>PEC
Ohio River						
OR01	438.3	20-Oct-14	104	0		
OR02	440.0	20-Oct-14	104	0		
OR03	447.2	20-Oct-14	104	0		
OR04	450.0	20-Oct-14	104	0		
OR05	451.8	20-Oct-14	104	0		
OR06	455.4	20-Oct-14	104	0		
OR07	460.0	20-Oct-14	104	0		
OR08	462.6	21-Oct-14	104	0		
OR09	464.3	21-Oct-14	104	0		
OR10	465.3	21-Oct-14	104	0		
OR11	465.8	21-Oct-14	104	0		
OR12	466.2	21-Oct-14	104	0		
OR13	466.5	21-Oct-14	104	0		
OR14	468.4	21-Oct-14	104	5		Chrysene (720000.0); Fluoranthene (1000000); Indeno(1,2,3-cd)pyrene (200000.0); Phenanthrene (380000.0); Pyrene (830000.0)
OR15	469.2	21-Oct-14	104	0		
OR16	469.3	21-Oct-14	104	0		
OR17	470.5	21-Oct-14	104	0		
OR18	472.5	21-Oct-14	104	14	Endrin (100.00)	Gamma-BHC (50.00); Chlordane (1000.00); Toxaphene (2000.00)
OR19	472.5	21-Oct-14	104	0		
OR20	473.8	21-Oct-14	104	0		
OR21	474.3	21-Oct-14	104	1		Toluene (98700.00)
OR22	474.6	21-Oct-14	104	0		
OR23	477.0	22-Oct-14	104	0		
OR24	478.7	22-Oct-14	104	0		
OR25	480.6	22-Oct-14	104	0		

***Table 25**. Sediment organic concentrations in the Ohio River mainstem that were >Threshold Effect Concentration (TEC) or >Probable Effect Concentration (PEC). Numbers in parentheses are measured values*

Site ID	River Mile	Collection Date	Tested	Detect-ed	>TEC and <PEC	>PEC
OR26	481.1	22-Oct-14	104	0		
OR27	483.0	22-Oct-14	104	0		
OR28	484.1	22-Oct-14	104	0		
OR29	484.2	22-Oct-14	104	0		
OR30	485.7	22-Oct-14	104	0		
OR31	485.9	22-Oct-14	104	0		
OR32	486.2	22-Oct-14	104	1		Fluoranthene (370000.0)
OR33	487.5	22-Oct-14	104	0		
OR34	490.1	22-Oct-14	104	0		
OR35	491.8	22-Oct-14	104	0		
OR36	495.0	23-Oct-14	104	0		
OR37	497.2	23-Oct-14	104	0		
OR38	498.6	23-Oct-14	104	2		Chrysene (350000.0); Fluoranthene (360000.0)
OR39	501.3	23-Oct-14	104	0		
OR40	504.1	23-Oct-14	104	0		
OR41	507.5	23-Oct-14	104	0		
OR42	509.2	23-Oct-14	104	0		
OR43	511.9	23-Oct-14	104	0		
OR44	515.8	23-Oct-14	104	1		
OR45	520.8	23-Oct-14	104	1		
OR46	523.6	23-Oct-14	104	1		
OR47	524.3	23-Oct-14	104	0		
OR48	529.0	24-Oct-14	104	0		
OR49	530.5	24-Oct-14	104	0		

limestone slabs and unconsolidated shale materials. Because of the size and volume of this material and the small size of the streams it was concluded at that time that recovery would be unlikely and LRW would be the attainable near-term condition. Indeed, the streams were not able to readily move or export this unconsolidated material. However, in the intervening 20+ years the streams responded in a different manner that has resulted in incremental physical and biological improvements. Rather than exporting this material downstream, the interstitial gaps in the debris torrent has been filled by sand, gravel, and other fines (see photos in Figure 28). In essence, the wetted channel now flows on top of these materials such that pools and riffles have regained some functions and now offer useable habitat. However, at this time the

***Table 26**. Summary of biological and habitat trends at station RR02 (RM 1.2) in Rapid Run between 1991 and 2014.*

Year	IBI	Species	ICI	Qual. EPT Taxa	QHEI
1991	12*	2	P*	4	36.5
2014	24	6	F	7	56.5

channel does not approximate the pre-disturbance conditions where QHEI scores were good to excellent, but conditions have improved to the extent that biological index scores are consistent with fair quality compared to the very poor and poor results in 1991 (Table 27). We recommend that Ohio EPA conduct a more extensive sampling in Rapid Run and other similarly affected streams affected by sewer line construction in southwest Ohio to support new use attainability analyses.

Reference Sites

The reference sites all had good-excellent QHEI scores (Table 26) and all attained the WWH biocriteria for fish and macroinvertebrates. Even though conditions were good, some of these sites had poor attributes for silt cover and embeddedness indicating that watershed practices could be improved and current attainment could be threatened if such conditions persist or increase. The siltation and fine sediments are consistent with agricultural runoff and with the enriched conditions that were reflected in some of the low D.O. levels in the grab sample and continuous results.

Ohio River Mainstem

ORSANCO collects habitat data in the Ohio River mainstem which forms the basis for interpreting the appropriate fish and macroinvertebrate thresholds which vary with habitat type. ORSANCO has identified five different habitat types that represent the coarseness of the river bottom and depth along the shoreline where sampling takes place. Sites with poorer habitat (e.g., finer substrates) are expected to have a less diverse assemblage and site with coarse substrate (e.g., boulder, cobble, gravel) are expected to be more diverse. QHEI assessments were also accomplished to provide a general narrative assessment of habitat quality. Figure 29 and Table 28 illustrate the QHEI results for the Ohio River. Because the Ohio River shoreline reflects littoral and pool type habitats QHEI scores were lower than typical scores for inland free-flowing rivers. In addition, the Ohio River is modified by the navigational dams, thus it was expected to yield lower scores. Habitat changes along the mainstem were not extensive, but the diversity of QHEI attributes did decrease within the more urban or developed reaches (Figure 29). QHEI scores were typically in the mid-40s to low 50s which is consistent with scores in impounded reaches of inland rivers.

The five habitat types of ORSANO varied with the QHEI largely reflecting the differences in substrate conditions between sites (Figure 30). ORSANCO type A reaches generally had the highest QHEI scores. The ORSANCO habitat type is a key variable for adjusting the expected score of the ORFin for determining attainment or non-attainment. A more diverse and sensitive assemblage of fish species is expected where habitat, primarily related to substrate, is more diverse.

Figure 28*. Photos of Rapid Run at RM 1.2 in 1991 (upper; Ohio EPA 1992) and in 2014 (lower). Although photos were taken from a different vantage point it is clear that large gaps in the debris torrent in the 1991 (upper) photo have since been filled by fine sands and gravels evident in the 2014 photo (lower). The result is an incremental improvement in habitat quality that supports fair biological assemblages.*

***Table 27**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites sampled in 2014. (■- 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
WAU 09-05 – Taylor Creek																																		
Taylor Creek																																		
GM86	6.3	62.5	■	■		■		■		■	■	■	7						0						●			●				2	2.67	0.38
GM85	4.98	76.5	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
GM84	4.6	75.0	■	■		■	■	■	■	■	■		8						0											●		1	4.5	0.22
GM83	3.53	53.0	■			■				■	■	■	5		●		●		2						●			●				2	2	0.5
GM82	2.93	63.0	■	■		■		■		■	■	■	7						0						●			●				2	2.67	0.38
GM81	1.62	68.0	■	■		■	■	■		■	■	■	8						0		●							●	●			3	2.25	0.44
GM80	0.8	66.5	■	■		■	■	■		■	■		7						0									●		●		2	2.67	0.38
Unnamed Trib. to Taylor Creek @RM 4.9																																		
GM106	0.28	73.5	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
GM107	0.3	61.8	■	■		■	■	■			■	■	7						0		●							●	●			3	2	0.5
GM108	0.28	68.5	■	■		■	■	■		■	■	■	8						0		●							●				2	3	0.33
GM109	0.45	59.5	■	■		■	■	■		■		■	7					●	1		●							●				1	4	0.25

***Table 27**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites sampled in 2014. (■- 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
Briarly Creek																																		
GM91	3.9	63.0	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
GM90	2.45	53.3	■	■		■				■		■	5				●	●	2						●			●				2	2	0.5
GM89	1.82	52.8	■	■		■	■			■		■	6				●	●	2									●				1	3.5	0.29
GM88	1.22	65.3	■	■		■	■	■		■	■	■	8						0				●					●				2	3	0.33
GM87	0.2	64.0	■	■					■	■	■	■	6				●		1					●	●							2	2.33	0.43
Unnamed Trib. to Briarly Creek @RM 1.44																																		
GM112	0.46	67.8	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
Wesselman Creek																																		
GM94	4.72	56.0	■	■		■				■		■	5				●	●	2						●			●				2	2	0.5
GM93	3	39.5		■						■	■	■	4				●		1					●	●	●		●				4	1	1
GM99	2.9	64.5	■	■		■		■		■	■	■	7						0				●		●			●				3	2	0.5
GM92	0.5	68.0	■	■		■	■	■	■	■	■	■	9						0													0	10	0.1
Unnamed Trib. to Wesselman Creek @RM 2.59																																		
GM100	1.21	37.0		■						■		■	3	●			●	●	3					●	●			●				3	1	1

***Table 27**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites sampled in 2014. (■- 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
Steel Creek																																		
GM111	2.16	55.5	■	■		■	■			■	■	■	7				●		1									●				1	4	0.25
GM102	1.79	54.0	■	■						■		■	4				●	●	2					●	●			●				3	1.25	0.8
GM95	0.3	58.8	■	■			■	■		■	■	■	7						0					●		●		●				3	2	0.5
Unnamed Trib. to Steel Creek @RM																																		
GM103	0.31	59.5	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
WAU 02-03 – Muddy Creek																																		
Muddy Creek																																		
MU05	6.35	62.0	■	■						■	■	■	5				●		1					●	●			●				3	1.5	0.67
MU04	5.4	63.3	■	■		■				■	■	■	6				●		1						●			●				2	2.33	0.43
MU03	2.72	46.0		■			■			■	■	■	5				●		1	●				●		●		●				4	1.2	0.83
MU02	2.25	63.5	■	■		■	■	■			■	■	7						0									●	●			2	2.67	0.38
MU01	0.17	38.0		■							■		2	●	●		●		3		●			●	●			●	●		●	6	0.43	2.33
Unnamed Trib. to Muddy Creek @RM 2.37																																		
MU10	0.6	57.3	■	■						■	■	■	5				●		1					●	●			●				3	1.5	0.67

***Table 27**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites sampled in 2014. (■- 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 Muddy Creek @RM 5.97																																		
MU12	0.65	61.5	■	■						■	■	■	5				🔴		1					🟡	🟡			🟡				3	1.5	0.67
Unnamed Trib. @RM 0.45 to Unnamed Trib. to Muddy Cr @RM 5.97																																		
MU14	0.2	44.0		■				■			■	■	4						0					🟡	🟡			🟡	🟡			4	1	1
Unnamed Trib. to Muddy Creek @RM 0.3																																		
MU08	1.8	68.3	■	■				■					3				🔴	🔴	2		🟡			🟡	🟡			🟡	🟡		🟡	6	0.57	1.75
Unnamed Trib. to Muddy Creek @RM 0.3																																		
MU07	0.6	53.3	■	■		■	■	■		■	■	■	8						0									🟡				1	4.5	0.22
Unnamed Trib. @0.95 to Unnamed Trib. to Muddy Creek @RM 0.3																																		
MU09	0.6	57.0	■	■							■	■	4				🔴		1		🟡			🟡	🟡			🟡	🟡			5	0.83	1.2
WAU 02-04 –Rapid Run																																		
Rapid Run																																		
RR03	2.7	39.8	■	■							■		3		🔴		🔴		2		🟡			🟡	🟡			🟡	🟡		🟡	6	0.57	1.75
RR02	1.2	56.5		■		■	■			■	■	■	7				🔴		1									🟡				1	4	0.25
Wulff Creek																																		
RR04	0.55	67.0	■	■				■		■	■	■	6						0					🟡	🟡			🟡				3	1.75	0.57

***Table 27**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites sampled in 2014. (■- 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 Wulff Run @RM 0.77																																		
RR05	0.68	59.0	■	■			■			■	■	■	6				🔴		1					🟡				🟡				2	2.33	0.43
WAU 02-05 – Indian Creek Watershed																																		
Indian Creek																																		
IC06	2.43	72.0	■	■			■	■		■	■	■	7						0		🟡			🟡				🟡				3	2	0.5
IC05	2.08	52.5		■			■	■				■	4					🔴	1		🟡			🟡				🟡	🟡			4	1	1
IC02	1.22	62.0	■	■		■	■	■					5					🔴	1		🟡							🟡	🟡	🟡		4	1.2	0.83
IC01	0.3	58.5	■					■		■	■	■	5		🔴				1		🟡			🟡	🟡			🟡				4	1.2	0.83
Unnamed Trib. to Indian Creek																																		
IC07	0.13	62.0	■	■		■	■	■		■		■	7					🔴	1									🟡				1	4	0.25
Unnamed Trib. to Indian Creek @RM 1.55																																		
IC08	1.5	52.0	■				■			■		■	4				🔴	🔴	2					🟡				🟡				2	1.67	0.6
Reference Sites																																		
Mill Run																																		
RF11	0.9	70.5	■	■		■	■	■		■	■	■	8						0		🟡							🟡				2	3	0.33

***Table 27**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in Taylor Creek, Direct Ohio River Tributaries, and Reference Sites sampled in 2014. (■- 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**
Stonelick Creek																																		
RF14	3.1	74.5	■	■		■	■	■			■	■	7				●		1		●				●			●	●	●		5	1.33	0.75
RF14	3.1	66.5	■	■		■	■		■		■	■	7				●		1		●								●			2	2.67	0.38
RF13	1	72.0	■	■		■	■				■	■	6				●		1		●							●	●	●		4	1.4	0.71
RF13	1	70.5	■	■		■		■		■		■	6					●	1		●				●			●				3	1.75	0.57
Fivemile Creek																																		
RF15	0.5	67.5	■	■	■	■	■	■		■	■	■	9						0									●				1	5	0.2
W. Fk. E. Fk. Little Miami River																																		
RF16	0.1	71.0	■	■		■	■			■	■	■	7				●		1									●				1	4	0.25
Dodson Creek																																		
RF17	0.05	73.8	■	■		■	■	■		■	■	■	8						0									●				1	4.5	0.22
RF17	0.05	77.0	■	■		■	■	■		■	■	■	8						0		●							●				2	3	0.33

***Table 28**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River mainstem sampled in 2014. (■- 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
Ohio River (90-001)																																		
OR01	438.2	48.0		■						■	■	■	4			●	●		2			●		●		●		●				4	1	1
OR02	440.0	50.3		■						■	■		3				●		1			●		●	●			●			●	5	0.67	1.5
OR03	447.5	49.3		■						■	■		3				●		1			●		●	●			●			●	5	0.67	1.5
OR04	450.8	48.5		■						■	■		3				●		1			●		●	●			●			●	5	0.67	1.5
OR05	451.8	44.0								■	■		2				●		1		●	●		●	●			●			●	6	0.43	2.33
OR06	455.4	46.8		■							■		2				●		1			●		●	●			●	●		●	6	0.43	2.33
OR07	460.0	41.5		■							■		2				●		1		●	●		●	●	●		●	●		●	8	0.33	3
OR08	462.6	42.0								■	■		2				●		1			●		●	●	●		●			●	6	0.43	2.33
OR09	464.3	50.8		■						■	■		3				●		1			●		●	●			●			●	5	0.67	1.5
OR10	465.3	50.5		■						■	■		3				●		1			●		●	●			●			●	5	0.67	1.5
OR12	466.2	46.3		■						■	■		3			●	●		2			●		●	●	●		●			●	6	0.57	1.75
OR12	466.2	48.5		■						■	■		3			●	●		2			●		●	●			●			●	5	0.67	1.5
OR13	466.5	45.0		■						■	■		3			●	●		2			●		●				●			●	4	0.8	1.25
OR14	468.4	51.5		■						■	■		3			●	●		2					●				●			●	3	1	1
OR15	469.2	51.0		■					■	■	■		4			●	●		2					●							●	2	1.67	0.6
OR17	470.5	46.5		■						■	■		3			●	●		2					●	●			●			●	4	0.8	1.25

***Table 28**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River mainstem sampled in 2014. (■- 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
OR18	472.0	47.5		■						■	■		3			●	●		2			●		●	●			●			●	5	0.67	1.5
OR19	472.5	41.5		■							■		2			●	●		2		●	●		●	●	●		●	●		●	8	0.33	3
OR20	473.8	49.0		■						■	■		3			●	●		2					●				●			●	3	1	1
OR21	474.3	47.2		■						■	■		3			●	●		2					●				●			●	3	1	1
OR22	474.6	48.8		■						■	■		3			●	●		2					●	●			●			●	4	0.8	1.25
OR23	477.0	44.3		■						■	■		3			●	●		2			●		●				●			●	4	0.8	1.25
OR24	478.7	44.5									■		1			●	●		2			●		●				●	●		●	5	0.33	3
OR25	480.6	44.0		■							■		2			●	●		2			●		●				●	●		●	5	0.5	2
OR26	481.1	34.5									■		1		●	●	●		3		●	●		●	●			●	●		●	7	0.25	4
OR27	482.7	44.0									■		1			●	●		2			●		●				●	●		●	5	0.33	3
OR28	484.1	40.0									■		1			●	●		2		●	●		●		●		●	●		●	7	0.25	4
OR29	484.2	46.3		■						■	■		3			●	●		2			●		●				●			●	4	0.8	1.25
OR30	485.7	45.3		■							■		2			●	●		2			●		●				●	●		●	5	0.5	2
OR31	485.9	37.5									■		1			●	●		2		●	●		●	●			●	●		●	7	0.25	4
OR32	486.2	31.8									■		1		●	●	●		3		●	●		●		●		●	●		●	7	0.25	4
OR33	487.5	45.3		■						■	■		3			●	●		2		●			●				●	●		●	5	0.67	1.5
OR34	490.1	44.3		■							■		2			●	●		2			●		●				●	●		●	5	0.5	2

***Table 28**. Qualitative Habitat Evaluation Index (QHEI) scores showing good and modified habitat attributes at sites in the Ohio River mainstem sampled in 2014. (■- 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
OR35	491.8	41.3						■			■		2		●	●			2		●	●		●				●	●		●	6	0.43	2.33
OR36	495.0	36.5									■		1		●	●	●		3		●	●		●	●			●	●		●	7	0.25	4
OR37	497.2	46.3		■						■	■		3			●	●		2			●		●	●			●			●	5	0.67	1.5
OR38	498.6	43.5									■		1			●	●		2			●		●	●			●	●		●	6	0.29	3.5
OR39	501.3	47.8	■	■							■		3			●	●		2			●		●				●	●		●	5	0.67	1.5
OR40	504.1	42.5		■							■		2			●	●		2			●		●				●	●		●	5	0.5	2
OR41	507.5	43.5						■			■		2			●	●		2			●		●				●	●		●	5	0.5	2
OR42	509.5	41.3									■		1			●	●		2			●		●	●			●	●		●	6	0.29	3.5
OR43	511.9	43.3						■			■		2		●	●	●		3		●	●		●	●			●	●		●	7	0.38	2.67
OR44	515.8	48.0		■						■	■		3			●	●		2		●			●	●			●	●		●	6	0.57	1.75
OR45	520.8	47.5		■						■	■		3			●	●		2		●			●	●			●	●		●	6	0.57	1.75
OR46	523.6	48.8		■						■	■		3			●	●		2		●			●	●			●	●		●	6	0.57	1.75
OR47	524.3	40.0									■		1			●	●		2		●	●		●	●	●		●	●		●	8	0.22	4.5
OR48	529.0	33.3						■			■		2		●	●			2		●			●	●			●	●		●	6	0.43	2.33
OR49	530.5	42.0						■			■		2		●	●			2		●			●				●	●		●	5	0.5	2

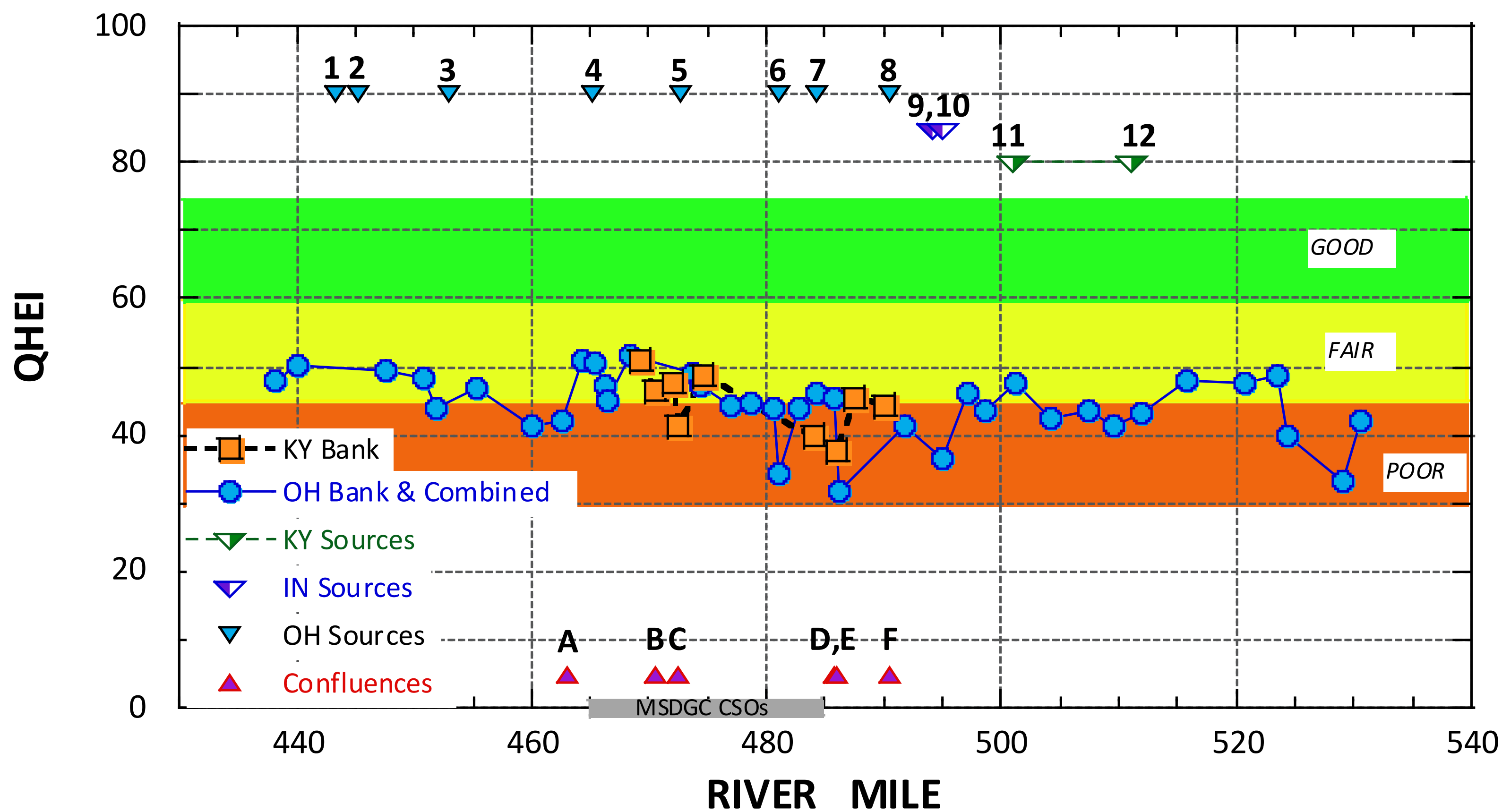

Figure 29. *Plot of QHEI vs. river mile at sites sampled in the Ohio River mainstem in 2014. The green shaded area represent thresholds generally indicative of good quality habitat in inland rivers. The numbers and letters are discharges and confluences depicted in Table 16.*

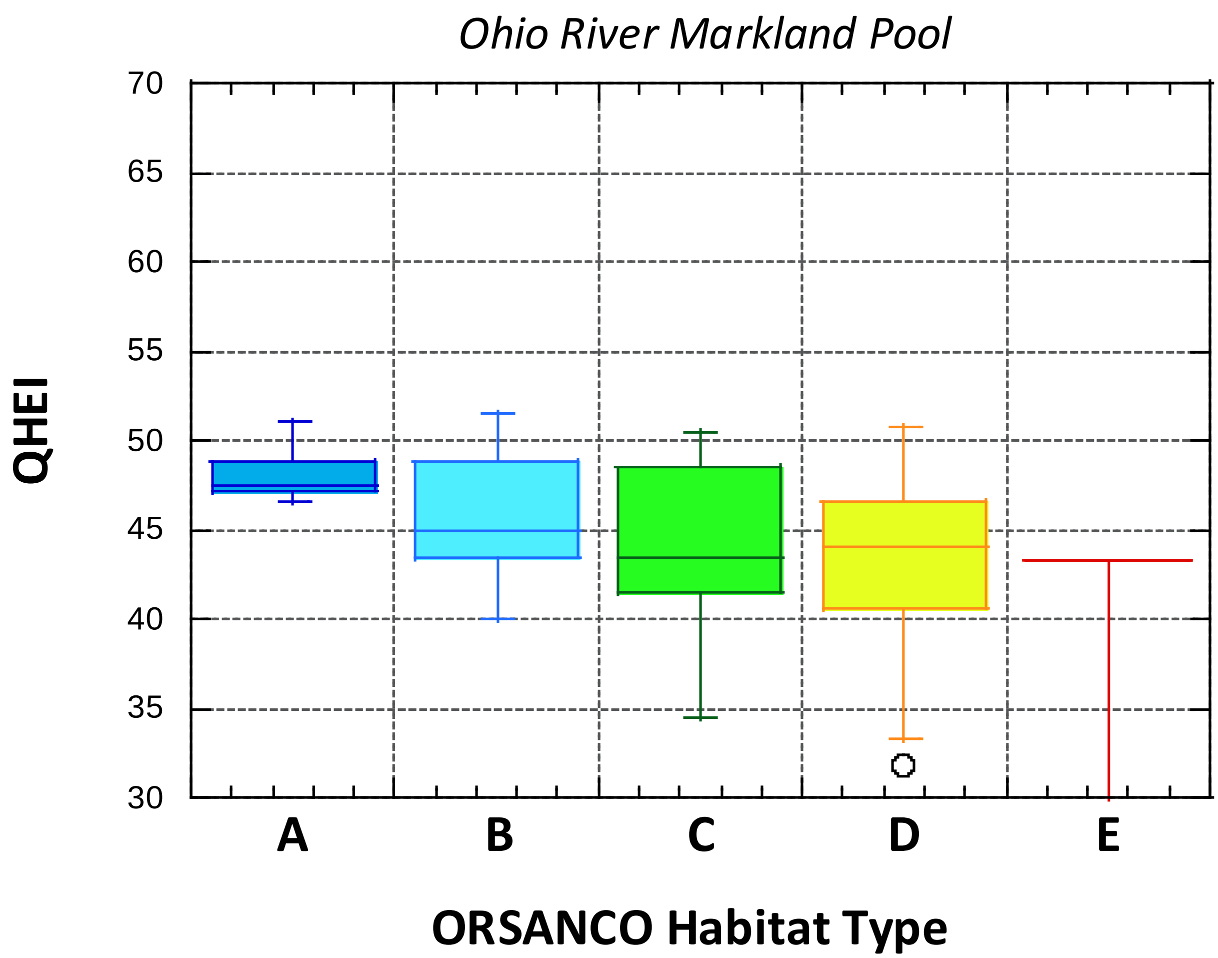

***Figure 30**. Box-and-whisker plots of QHEI by ORSACNO habitat type (A-E) in the Ohio River mainstem in 2014.*

Biological Assemblages

Direct Tributaries and Taylor Creek

Fish and macroinvertebrates were sampled at all wetted sites in 2014. These assemblages were used to assess 40 of the 51 sites in the Taylor Creek and Direct Ohio River Tributary study areas. The remaining 11 were assessed using the Primary Headwater Habitat methodology and two additional sites were dry and assessed with the HHEI only.

Fish Assemblages

This section focuses on the condition and status of fish assemblages in the Taylor Creek and Direct Ohio River Tributary study areas (Table 29). The assessment is based on the presence and relative abundance of key fish species and their respective traits or metrics that are expected in regional reference streams (Table 29).

Overall narrative fish assemblage condition ranged from fishless or very poor to excellent. Of the 40 sites with fish assemblage data that were not assessed as PHWH or were not dry, 13 sites (33.3%) fully attained the IBI biocriteria threshold for WWH or LRW as applicable, and 26 (66.7%) failed to attain these thresholds (Table 30). Two sites with an existing WWH use were dry when sampling was attempted, although macroinvertebrate assemblages were able to be assessed when the site had water.

Table 29*. Fish assemblage sites classified by aquatic life use and attainment or classification status (based on fish data only) during the 2014 survey.*

Aquatic Life Use	Fish Assemblage Attainment Status			
	N	**Full**	**Partial**	**Non**
MWH	3	1	0	2
WWH	36	12	0	24
WWH (dry)	2	-	-	-
	Primary Headwater Habitat Classification			
PHW3A	8			
PHW2	3			

WAU 09-05 – Taylor Creek

In Taylor Creek impairments were due to the failure of the IBI to attain the WWH criterion at the two most upstream sites (Figure 31) and the macroinvertebrates at the three most upstream sites (Table 29). The IBI scores in Taylor Creek were in most cases similar to or higher than the scores collected by Ohio EPA in 2010, and demonstrably better than scores from the 1988 and 1991 (Figure 31). When compared to all but the reference sites, Taylor Creek on average had higher IBI scores, more sensitive species, more darter species, and generally fewer tolerant individuals than the Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek; Figure 32). Downstream sites in Taylor Creek had more sensitive species than upstream sites or the small tributaries where they were largely absent. The loss of sensitive species is characteristic of streams influenced by urban development and subsequent runoff.

WAU 02-03 – Muddy Creek

Only two of the WWH sites attained the WWH fish IBI biocriterion in Muddy Creek (MU02) and the unnamed tributary at RM 0.3 (MU07). Fish assemblage condition elsewhere was poor and very poor (Table 29) and characteristic of severe enrichment from CSOs/SSOs and urban runoff. These streams typically had few sensitive species (0-3), few or no darters, and elevated percentage as tolerant individuals (Figure 32). Sites in closer proximity to CSOs were more affected than downstream sites. This provides additional evidence of a strong impact from the CSOs in the watershed.

WAU 02-04 – Rapid Run

Fish assemblages in streams in the Rapid Run watershed were impacted by CSOs, particularly in the headwaters and by extensive modifications of habitat alterations from instream sewer line construction in both Rapid Run and Wulff Run. The upstream-most site showed the strongest impact (nearest CSOs). Compared to the 1991 results (Ohio EPA 1992) fish assemblages have improved in the lower sites as habitat has partially recovered from the initial sewer line construction activities. As was discussed elsewhere, the severe dewatering of habitats in the late 1980s and early 1990s has lessened with gravels and fines filling interstitial spaces that raised the water level at some sites. The extent of such recovery remains unclear, but the partial recovery of the fish and macroinvertebrate assemblages is underway.

WAU 02-05 – Indian Creek

Indian Creek which discharges directly to the Ohio River had poor-fair fish assemblages and lacked sensitive fish species and darters that would be expected if conditions were closer to reference. Urban runoff and a golf course contributed silt and altered flow conditions that resulted in a lack of fluvial dependent species such as darters in this stream.

Ohio River Mainstem

MBI sampled fish at 49 sites in the Ohio River in 2014 collecting 24,687 individuals representing 64 species (of which 57 are native) and 3 hybrids. The fish assemblage attained the ORSANCO expectations for the ORFIn based on habitat types at all sites (Figure 33). It is clear from examining the plot of ORFIN values along with the expected values based on habitat that the habitat type is a key variable in the variation of the fish assemblages that were observed.

The Modified Index of Well-being (MIwb) which measures abundance (numbers and biomass less tolerant species) and diversity was also evaluated (Figure 34). There were several small declines in MIwb scores, but all scored within the good-excellent narrative range (which was derived for inland Ohio Rivers). This indicates there is are good numbers of fish species across non-tolerant species. The number of sensitive fish species (after Ohio EPA 1987) vs. river mile for the Ohio River (Figure 35) showed a response to the habitat type, but also declines downstream from the Little Miami and Great Miami River confluences.

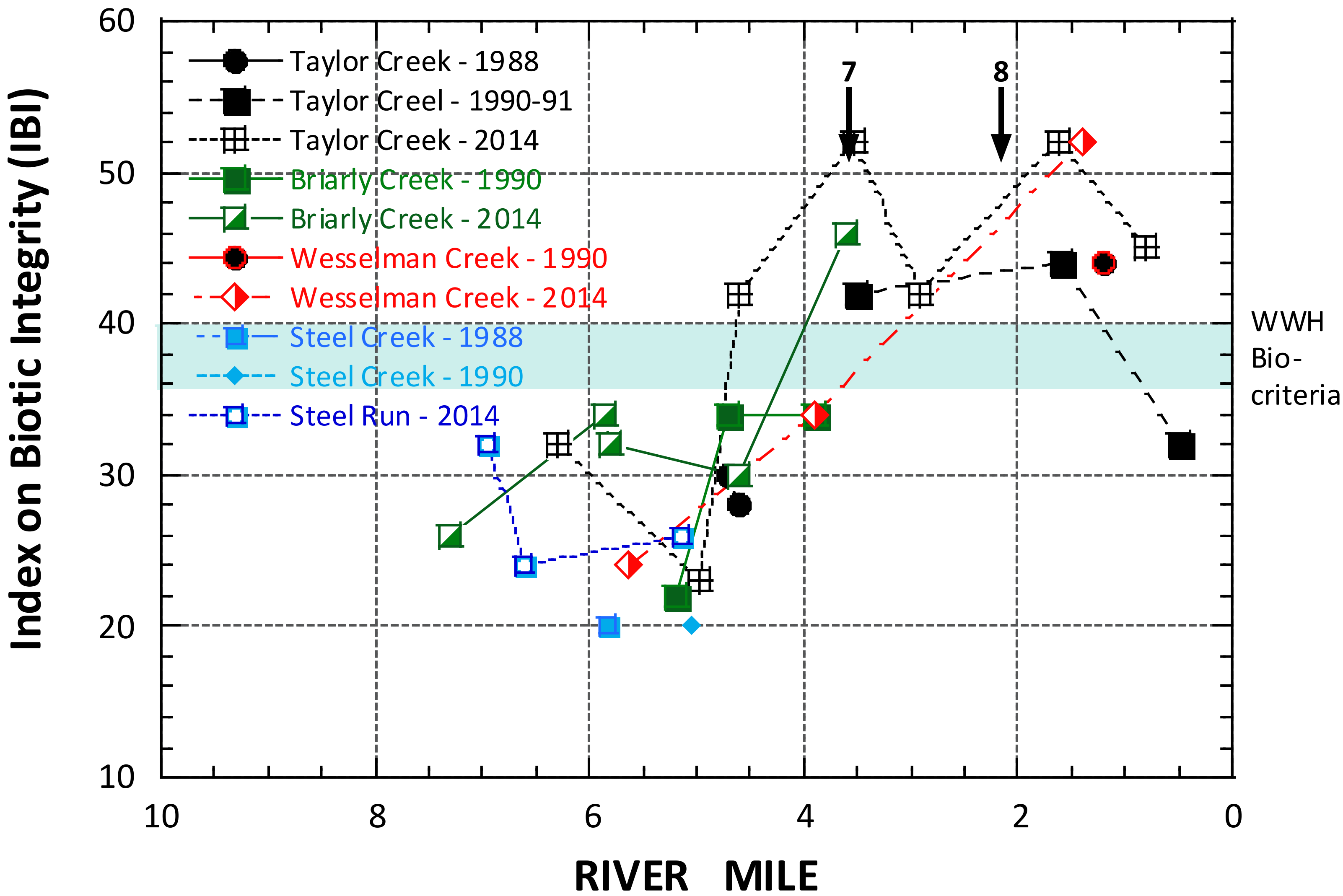

Figure 31. *Plot of the Index of Biotic Integrity (IBI) vs. river mile for larger streams in the Taylor Creek watershed from 1988 to 2014. The shaded bar represents the appropriate biocriteria range for the WWH aquatic life use that is applicable to headwater and wadeable streams in the Interior Plateau ecoregion.*

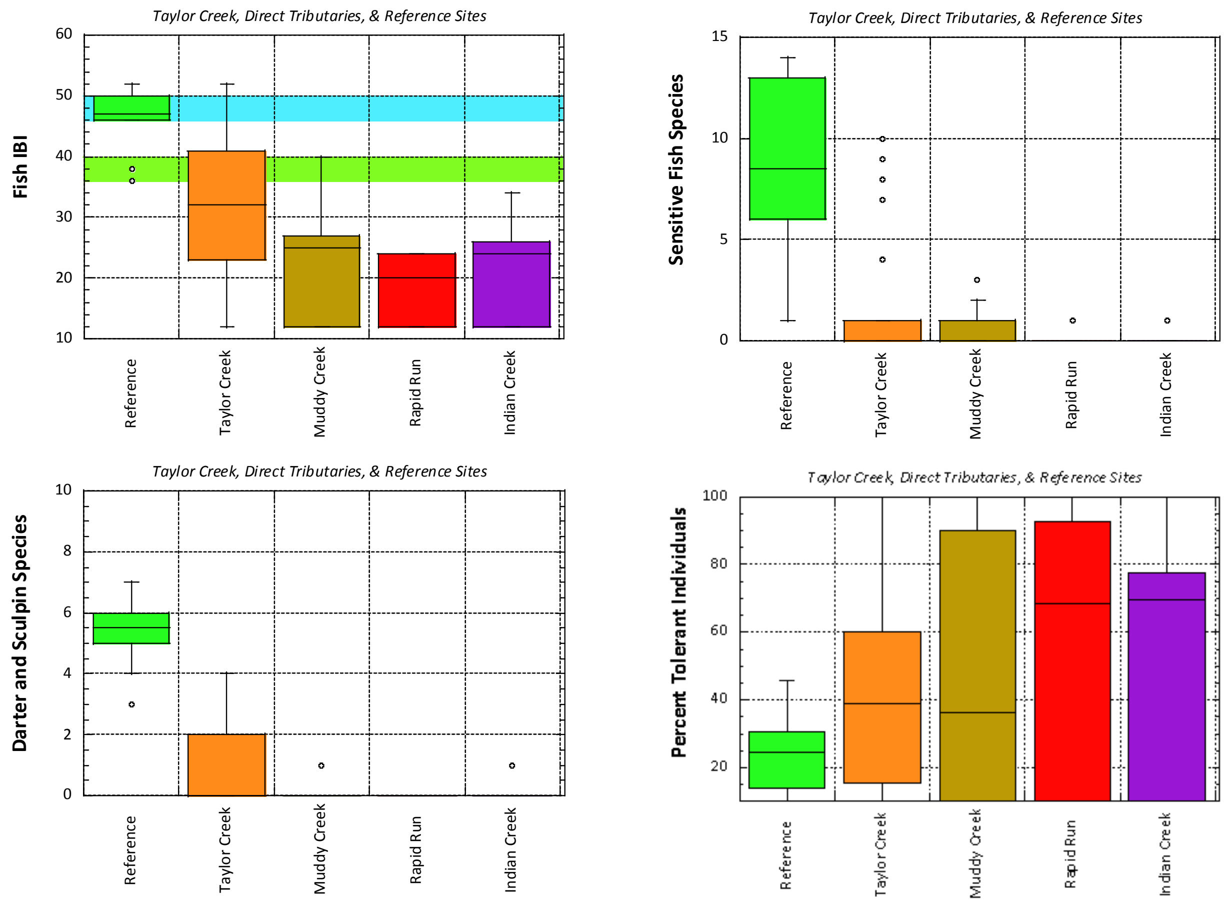

***Figure 32**. Box-and-whisker plots of key fish metrics by subwatershed for Taylor Creek, Direct Ohio River Tributaries (Muddy Creek, Rapid Run, Indian Creek), and Reference Sites sampled in 2014.*

Macroinvertebrate Assemblage Results 2014

Macroinvertebrate assemblages in the Taylor Creek and Direct Ohio River Tributaries study area were indicative of very poor to very good water quality. Impairments were typically related to urban runoff and sewage (Taylor Creek) or CSOs/SSOs and urban runoff (Direct Ohio River Tributaries). Macroinvertebrate monitoring in the Ohio River mainstem followed ORSANCO protocols and calculation of the ORMIn. This had not yet been incorporated into ORSANCO assessments at the time thus our primary use of this data was to examine longitudinal trends in metrics in relation to potential sources of stress from WWTPs, other discharges, CSOs/SSOs, and major tributary confluences.

WAU 09-05 – Taylor Creek

In Taylor Creek, the macroinvertebrates met the WWH biological criteria at the four downstream sites, but were rated as fair (non-attaining) for the three upstream sites (Table 28). The upstream sites had fewer sensitive taxa than the downstream sites and had large populations of *Turbellaria* which indicates organic enrichment. The upstream sites on Briarly Creek (GM90), Wesselman Creek (GM94), and Steel Creek (GM111, GM102) were all rated fair

***Table 30**. Key biological and habitat attributes for fish and macroinvertebrates in the Taylor Creek, Direct Ohio River Tributaries, and Reference Sites, 2014.*

				Fish Assemblage Statistics									Macroinvertebrate Assemblage Statistics				
Site ID	River Mile Range	Drainage Area mi.²	QHEI	# Fish Species	# Sens. Fish Sp.	# Head-water Sp.	% Pioneer-ing	% Tol.	Rel. No.	DELT Anom.	MIwb	IBI	ICI	Narr. Rat-ing	Qual. EPT Taxa	# Cold water Taxa	Aquatic Life Use
WAU 09-05 – Taylor Creek Watershed																	
Taylor Creek																	
GM86	6.30	1.2	62.5	3	0	0	31.44	31.44	388	0	na	32	-	F	7	1	WWH
GM85	4.98	2.2	76.5	4	0	0.5	15.57	22.91	334	0	na	23	-	F	6	1	WWH
GM84	4.60	3.9	75	9	1	1	11.28	16.17	532	0	na	42	-	F	7	0	WWH
GM83	3.53	5	53	15	4	2	8.14	10.18	786	0	na	52	-	G	12	1	WWH
GM82	2.93	12.6	63	16	4	1	5.99	6.3	1302	0	na	42	52	-	13	0	WWH
GM81	1.62	14.3	68	23	8	1	15.58	14.49	1104	0	na	52	54	-	9	0	WWH
GM80	0.80	26.5	66.5	21.5	8	1	30.69	27.16	1345	0	9.0	45	48	-	14	0	WWH
Unnamed Trib. to Taylor Creek @RM 4.9																	
GM106	0.28	0.9	73.5	8	0	1	90.16	93.37	2052	0	na	38	-	F	3	0	WWH
Forfeit Run (Trib. to Taylor Cr. @RM 1.42)																	
GM107	0.30	1.4	61.8	4	0	0	94.55	94.55	110	0	na	26	-	F	9	0	WWH
Eagle Creek (Trib. to Taylor Cr. @RM 0.91)																	
GM108	0.28	0.7	68.5	0	0	0	0	0	0	0	na	12	-	-	1	0	PHW3A
Unnamed Trib. to Taylor Creek @RM 1.74																	
GM109	0.45	0.9	59.5	0	0	0	0	0	0	0	na	12	-	-	8	1	PHW3A
Unnamed Trib. to the Great Miami R. @RM 16.3																	
GM110	1.75	0.1	0	1	0	0	0	0	0	0	na	12	-	-	0	0	PHW2
Briarly Creek																	
GM91	3.90	0.3	63	2	0	0	68.1	68.1	326	0	na	26	-	-	4	1	PHW3A
GM90	2.45	1.3	53.3	2	0	0	27.62	27.62	724	0	na	34	-	F	6	0	WWH
GM89	1.82	2.1	52.8	6	0	0	42.94	49.86	694	0	na	32	-	MG	8	0	WWH
GM88	1.22	6.6	65.3	7	0	1	36.93	41.99	2372	0	na	30	-	MG	8	0	WWH
GM87	0.20	7.1	64	15	4	1	26.04	30.2	914	0	na	46	-	G	10	0	WWH
Unnamed Trib. to Briarly Creek @RM 1.44																	
GM112	0.46	1.2	67.8	5	0	0	39.25	42.5	800	0	na	32	-	F	7	0	WWH

***Table 30**. Key biological and habitat attributes for fish and macroinvertebrates in the Taylor Creek, Direct Ohio River Tributaries, and Reference Sites, 2014.*

Site ID	River Mile Range	Drainage Area mi.²	QHEI	Fish Assemblage Statistics									Macroinvertebrate Assemblage Statistics				Aquatic Life Use
				# Fish Species	# Sens. Fish Sp.	# Head-water Sp.	% Pioneer-ing	% Tol.	Rel. No.	DELT Anom.	MIwb	IBI	ICI	Narr. Rat-ing	Qual. EPT Taxa	# Cold water Taxa	
Wesselman Creek																	
GM94	4.72	1.1	56	3	0	0	83.67	83.67	196	0	na	24	-	F	5	0	WWH
GM93	3.00	2.6	39.5	6	0	2	37.97	54.01	474	0	na	34	-	G	11	0	WWH
GM99	2.90	5.7	64.5	10	1	2	11.26	38.57	586	0	na	40	-	G	11	0	WWH
GM92	0.50	7.6	68	22	10	1	26.74	24.49	890	0	na	52	-	G	12	0	WWH
Unnamed Trib. to Wesselman Creek @RM 2.59																	
GM100	1.21	1.4	37	1	0	0	100	100	46	0	na	20	-	-	2	0	PHW3A
Steel Creek																	
GM111	2.16	0.8	55.5	3	0	1	44.95	54.7	574	0	na	32	-	F	7	0	WWH
GM102	1.79	2.6	54	5	0	0	53.13	78.13	384	0	na	24	-	F	7	0	WWH
GM95	0.30	4.4	58.8	7	0	1	48.07	59.5	1506	0	na	26	-	MG	8	0	WWH
Unnamed Trib. to Steel Creek @RM																	
GM98	2.30	0.1	Dry	-	-	-	-	-	-	-	na	-	-		0	0	PHW2
Unnamed Trib. to Steel Creek @RM																	
GM103	0.31	1.2	59.5	6	0	0	49.26	61.03	272	0	na	22	-	F	5	1	WWH
WAU 02-03 – Muddy Creek Watershed																	
Muddy Creek																	
MU05	6.35	5.4	62	0	0	0	0	0	0	0	na	12	-	VP	0	0	WWH
MU04	5.40	5.4	63.3	1	0	0	100	100	14	0	na	12	-	VP	0	0	WWH
MU03	2.72	12.3	46	4	0	1	13.21	40.57	212	0	na	26	-	F	4	0	WWH
MU02	2.25	12.1	63.5	12	3	1	22.51	31.64	4096	0	na	40	48		8	1	WWH
MU01	0.17	16.6	0	23	2	0	1.73	1.88	1386	0	na	28	-	-	-	-	WWH
Unnamed Trib. to Muddy Creek @RM 2.37																	
MU10	0.60	0.7	57.3	1	0	0	0	0	2	0	na	12	-	VP	0	0	WWH
Unnamed Trib. to Muddy Creek @RM 5.97																	
MU12	0.65	1	61.5	2	0	0	79.75	79.75	158	0	na	26	-	VP	0	1	WWH
Unnamed Trib. to Muddy Creek @RM 6.53																	
MU13	0.60	1.9	-	1	0	0	0	0	0	0	na	12	-	VP	0	0	WWH

***Table 30**. Key biological and habitat attributes for fish and macroinvertebrates in the Taylor Creek, Direct Ohio River Tributaries, and Reference Sites, 2014.*

Site ID	River Mile Range	Drainage Area mi.²	QHEI	Fish Assemblage Statistics: # Fish Species	# Sens. Fish Sp.	# Head-water Sp.	% Pioneer-ing	% Tol.	Rel. No.	DELT Anom.	MIwb	IBI	Macroinvertebrate Assemblage Statistics: ICI	Narr. Rat-ing	Qual. EPT Taxa	# Cold water Taxa	Aquatic Life Use
Unnamed Trib. @RM 0.45 to Unnamed Trib. to Muddy Cr @RM 5.97																	
MU14	0.20	0.1	44	0	0	0	0	0	0	0	na	12	-	-	0	1	PHW2
Unnamed Trib. to Muddy Creek @RM 0.3																	
MU08	1.80	0.7	68.3	2	0	1	93.57	100	280	0	na	24	-	-	6	2	PHW3A
Unnamed Trib. to Muddy Creek @RM 0.3																	
MU07	0.60	2.8	53.3	12	3	1	25.16	80.22	1264	0	na	36	-	G	10	0	WWH
Unnamed Trib. @0.95 to Unnamed Trib. to Muddy Creek @RM 0.3																	
MU09	0.60	1	57	2	0	1	45.16	100	434	0	na	26	-	VP	7	1	PHW3A
WAU 02-04 –Rapid Run Watershed																	
Rapid Run																	
RR03	2.70	2.2	39.8	0	0	0	0	0	0	0	na	12	-	VP	0	0	MWH
RR02	1.20	5.8	56.5	6	1	1	61.04	68.56	1304	0	na	24	-	F	7	2	MWH
RR01	0.10	9	0	1	0	0	0	0	0	0	na	12	-	MG	10	0	MWH
Wulff Creek																	
RR04	0.55	2.2	67	2	0	0	93.02	93.02	86	0	na	20	-	P	4	0	WWH
Unnamed Trib. to Wulff Run @RM 0.77																	
RR05	0.68	1.3	59	2	0	0	100	100	558	0	na	24	-	VP	1	0	WWH
WAU 02-05 Indian Creek Watershed																	
Indian Creek																	
IC06	2.43	0.5	72	2	0	1	86.72	100	1310	0	na	24	-	MG	8	1	WWH
IC05	2.08	1.1	52.5	4	0	1	30.34	64.47	1002	0.2	na	34	-	MG	8	1	WWH
IC02	1.22	1.5	62	4	0	1	77.16	77.78	324	0	na	26	-	MG	8	0	WWH
IC01	0.30	2.3	58.5	7	1	0	74.81	74.81	1334	0	na	24	-	F	6	0	WWH
Unnamed Trib. to Indian Creek @RM																	
IC07	0.13	0.4	62	0	0	0	0	0	0	0	na	12	-	-	5	1	PHW3A

***Table 30**. Key biological and habitat attributes for fish and macroinvertebrates in the Taylor Creek, Direct Ohio River Tributaries, and Reference Sites, 2014.*

				Fish Assemblage Statistics									Macroinvertebrate Assemblage Statistics				
Site ID	**River Mile Range**	**Drainage Area mi.^{2}**	**QHEI**	**# Fish Species**	**# Sens. Fish Sp.**	**# Head-water Sp.**	**% Pioneer-ing**	**% Tol.**	**Rel. No.**	**DELT Anom.**	**MIwb**	**IBI**	**ICI**	**Narr. Rat-ing**	**Qual. EPT Taxa**	**# Cold water Taxa**	**Aquatic Life Use**
								Unnamed Trib. to Indian Creek @RM 1.55									
IC08	1.50	0.1	52	0	0	0	0	0	0	0	na	12	-	-	2	1	PHW3A
								Reference Sites									
								Mill Run									
RF11	0.90	7.8	70.5	17	4	3	29.74	38.09	982	0	na	52	40	MG	13	1	WWH
								Stonelick Creek									
RF14	3.10	73.5	70.5	24	12	1	18.92	16.54	885	0.11	9.12	51	50		15	0	WWH
RF13	1.00	75.7	71.3	28	13.5	1	12.73	10.86	1167	0.06	9.23	49	-	VG	15	0	WWH
								Fivemile Creek									
RF15	0.50	10.4	67.5	9	1	1	66.46	20.5	322	0	na	36	-	G	12	1	WWH
								W. Fk. E. Fk. Little Miami River									
RF16	0.1-0.2	29.1	71	24	7.5	1	33	28.98	856	0.17	8.72	46	-	MG	9	1	WWH
								Dodson Creek									
RF17	0.05-0.2	32.4	75.4	20	7.5	0.5	24.12	38.06	357	0.36	7.21	42	42		12	1	WWH

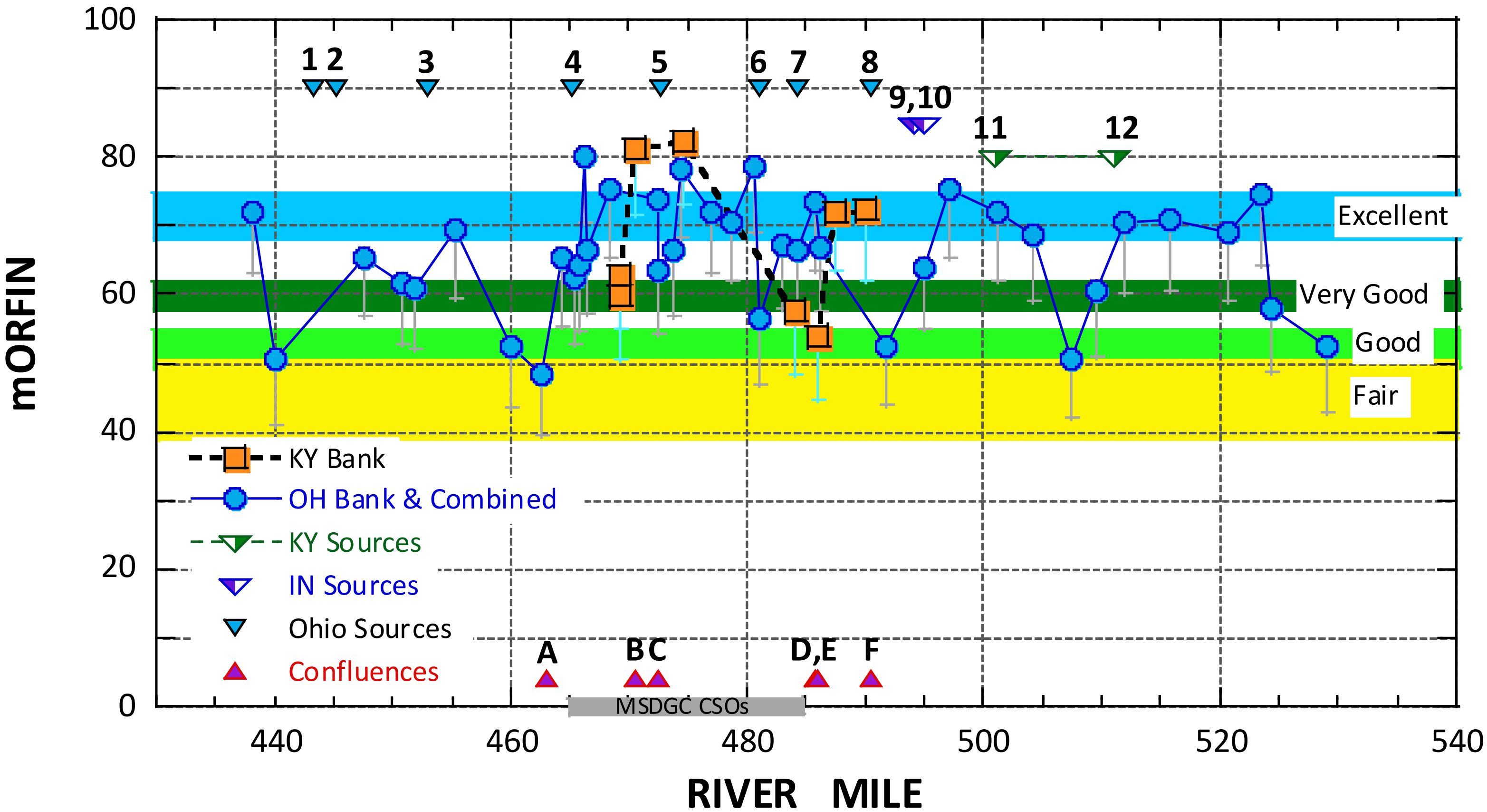

***Figure 33**. Plot of ORFIN vs. river mile in the Ohio River mainstem, 2014. The shaded bars represent ORSANCO narrative ranges for adjusted ORFIN scores (dependent on habitat type). The lower tails represent adjusted ORFIn scores based on habitat type. The numbers and letters are discharges and confluences depicted in Table 16.*

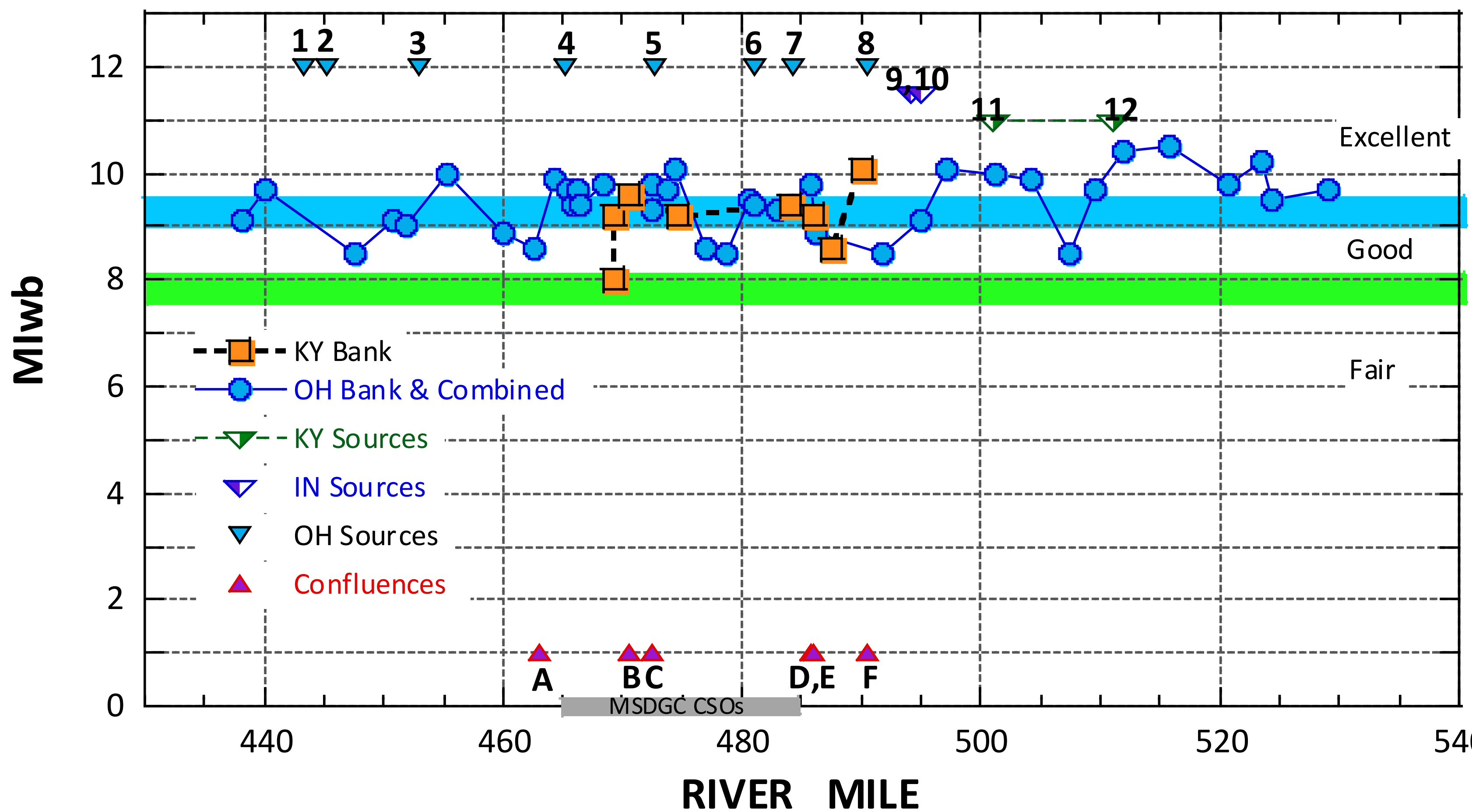

Figure 34. *Plot of the MIwb vs. river mile in the Ohio River mainstem, 2014. The shaded bars represent Ohio EPA narrative ranges for the MIwb in large inland Ohio rivers. The numbers and letters are discharges and confluences depicted in Table 16.*

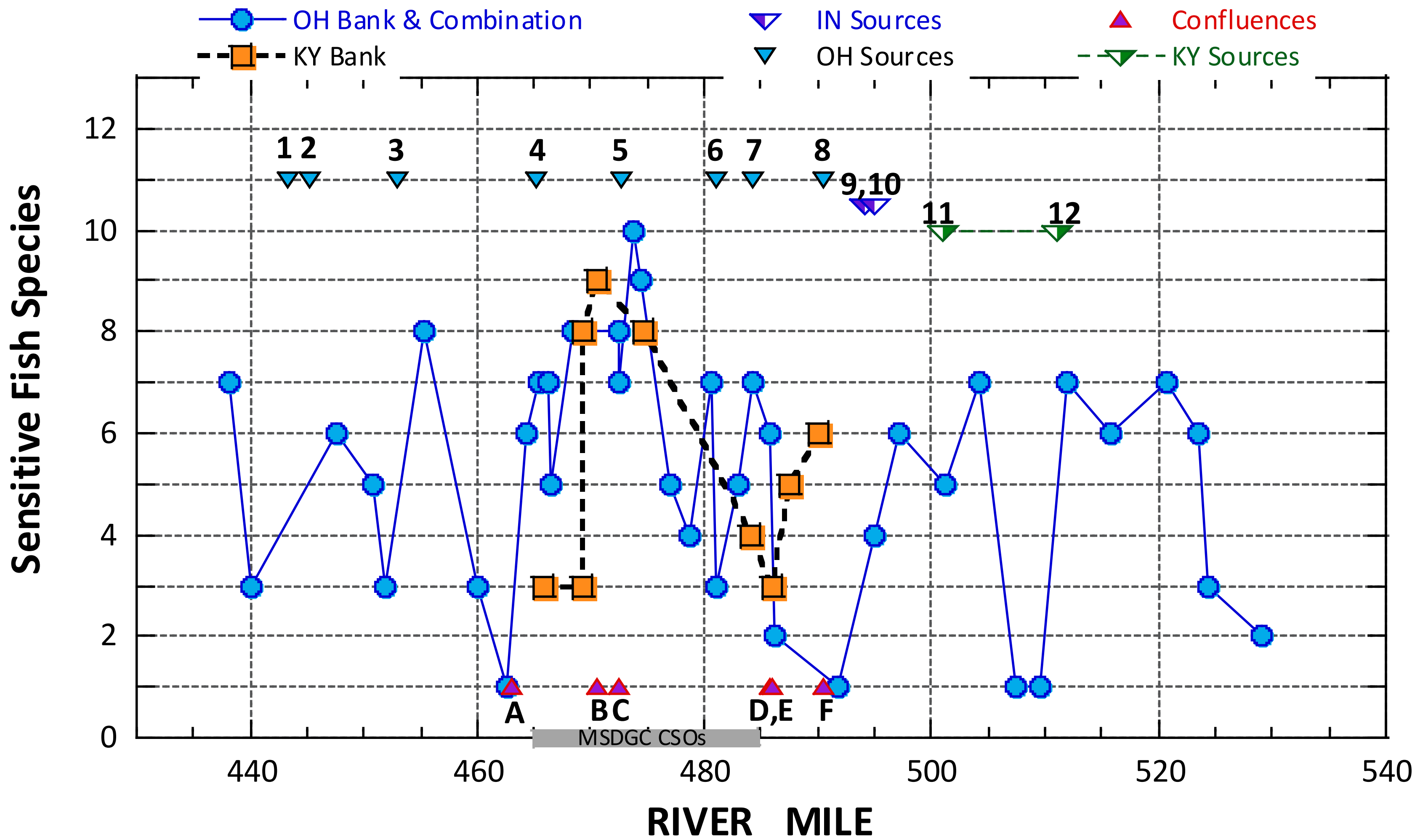

***Figure 35**. Plot of Sensitive (Ohio EPA 1987) fish species vs. river mile in the Ohio River mainstem, 2014. The numbers and letters are discharges and confluences depicted in Table 16.*

and all increased with distance downstream. It is likely that the effects of urban runoff are more pronounced in the smaller streams where flashy flows from urban runoff and summer low flow periods render the assemblage at these sites more susceptible to impacts. The trend of increasing chloride concentrations over time (~1 mg/l/yr) is a potential threat to these streams in the future - as stated earlier impaired macroinvertebrate assemblages have been associated with chloride concentrations above ~100-140 mg/l.

WAU 02-03 – Muddy Creek

The macroinvertebrate assemblage condition in the Muddy Creek watershed ranged from very poor to excellent. In the vicinity of CSO discharge points (e.g., MU04, MU05, MU13) the assemblages were very poor and there was often physical evidence of CSO/SSO discharges in the form of sewage solids, diapers, and other sewage debris. Such sites typically lacked any sensitive taxa and were predominated by tolerant taxa such as oligochaetes and red midges. With distance downstream the results often showed recovery with the addition of sensitive taxa. Muddy Creek at sites MU04 and MU05 had multiple PAH compounds in the sediments exceeding probable-effect levels which could also contribute to macroinvertebrate impairments.

WAU 02-04 –Rapid Run

Rapid Run is a LRW stream based on extreme habitat alteration related to the instream construction of sewer lines. The site closest to a major CSO (RR03) was in very poor condition and had only tolerant taxa. Further downstream (RR2 - fair, RR1 – marginally good) the results showed incremental recovery away from upstream CSO discharges that contributed organic enrichment excessive nutrients. As discussed previously, sands and fines have filled the previous gaps in the debris torrent resulting from the instream sewer line construction which has allowed the water level to remain on the surface. Wulff Creek, which was sampled in a reach that was not directly affected by sewer line construction in 2014, was limited by organic enrichment from an upstream CSO. The tributary to Wulff Creek was also limited by organic enrichment from urban runoff and instream sewer lines.

WAU 02-05 –*Indian Creek*

The macroinvertebrates in Indian Creek were marginally good at the upper three sites (IC02, IC05, IC06), but fair at the mouth (Table 28) primarily because of silts and impoundment by a beaver dam. The excessive siltation originated from urban runoff and a golf course in Indian Creek which was readily deposited in the impoundment formed by the beaver dam.

Reference Sites

The condition of the macroinvertebrate assemblage at reference sites ranged from good to excellent and all sites attained the WWH aquatic life biological criteria. Fivemile Creek (RF15) had nearly interstitial flows and the resulting low flows could explain some of the low D.O. values observed at this site.

Ohio River Mainstem

Longitudinal patterns of the macroinvertebrate assemblages in the Ohio River were somewhat variable, but seemed to reflect impacts from the Ohio tributaries where CSOs are prevalent. In contrast to the fish assemblage ORFIN scores where sites ranged from fair to excellent quality, the majority of ORMIn scores (25 of 39 sites ~64%) were rated as poor or very poor quality (Table 30). No sites were rated as excellent, only two of 39 (5.1%) were rated as very good, and 6 of 39 (15.4%) were rated as good. In contrast to fish, which can move between shallows and deeper water, macroinvertebrates are less mobile over short time periods making them more susceptible to variations in river flow or periodic changes in chemical water quality. As discussed in earlier sections, many of the water chemistry parameters, at least during normal summer-fall river flows, were not found at concentrations considered harmful to macro-invertebrate assemblages. One possible exception was with the sediment chemistry results where concentrations of PAHs were above the Probable Effect Concentration (PEC), although such values were not widespread enough to explain the range of variation in ORMIn scores in the Markland pool. Although there was some association with habitat type and ORMIn score it was not as strong as observed with the fish assemblage results which may be related to the influence of the Hester-Dendy component of the index which can provide some control for local scale habitat influences.

A plot of qualitative EPT taxa for MBI sites (Figure 37) were generally low compared to inland rivers in Ohio and fluctuations seemed to reflect an influence by major tributaries. EPT values were low upstream of Cincinnati, increased downstream from the Little Miami River (A), and then declined sharply downstream from Mill Creek (C). The number of EPT taxa remained low downstream from Rapid Run (D), Muddy Creek (E), and Indian Creek and the presence of direct CSO discharges to the mainstem. An increase in EPT taxa was observed at the lower three sites in the Markland pool.

Overall, the ORMIn scores indicate that the macroinvertebrate assemblages were potentially more impaired than the fish assemblages in the Markland Pool. It should be noted here that ORSANCO has not yet established impairment thresholds for ORMIn in the Ohio River mainstem. More detailed analyses would be needed to ascertain the causes of this difference. However, macroinvertebrates in the Ohio River may be more susceptible to variations in river flow and episodic impacts given their lower mobility compared to the fish assemblages.

Table 31. *Summary of narrative ranges of the ORMIn in the Markland Pool collected by MBI and ORSANCO and by bank of the mainstem (OH vs KY).*

Locations	N	Very Poor	Poor	Fair	Good	Very Good	Excellent
MBI Data (OH bank)	16	2	10	3	1	-	-
MBI Data (KY bank)	10	1	6	2	1	-	-
ORSANCO (OH bank)	4	1	0	1	1	1	-
ORSANCO (KY bank)	9	1	2	2	3	1	-
Total	**39**	**5**	**18**	**8**	**6**	**2**	**0**

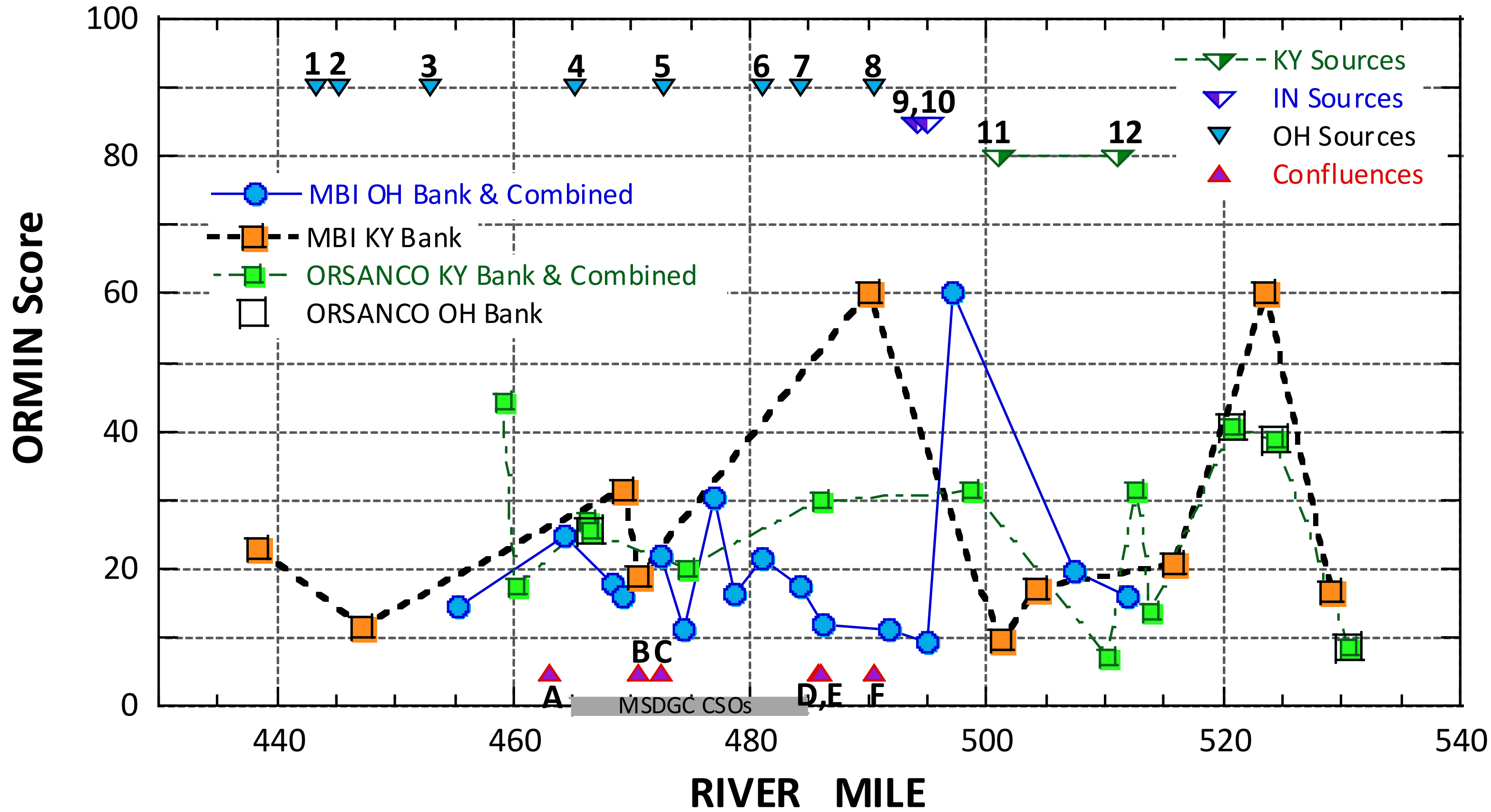

Figure 36. *Plot of the ORMIn vs. river mile in the Ohio River mainstem during 2014. Blue circles (OH Bank or combined banks outside of MSDGC area) and orange squares (KY bank) represent data collected by MBI and small green squares (KY bank) or larger open squares (OH bank) represent data collected by ORSANCO. The numbers and letters are discharges and dams depicted in Table 16.*

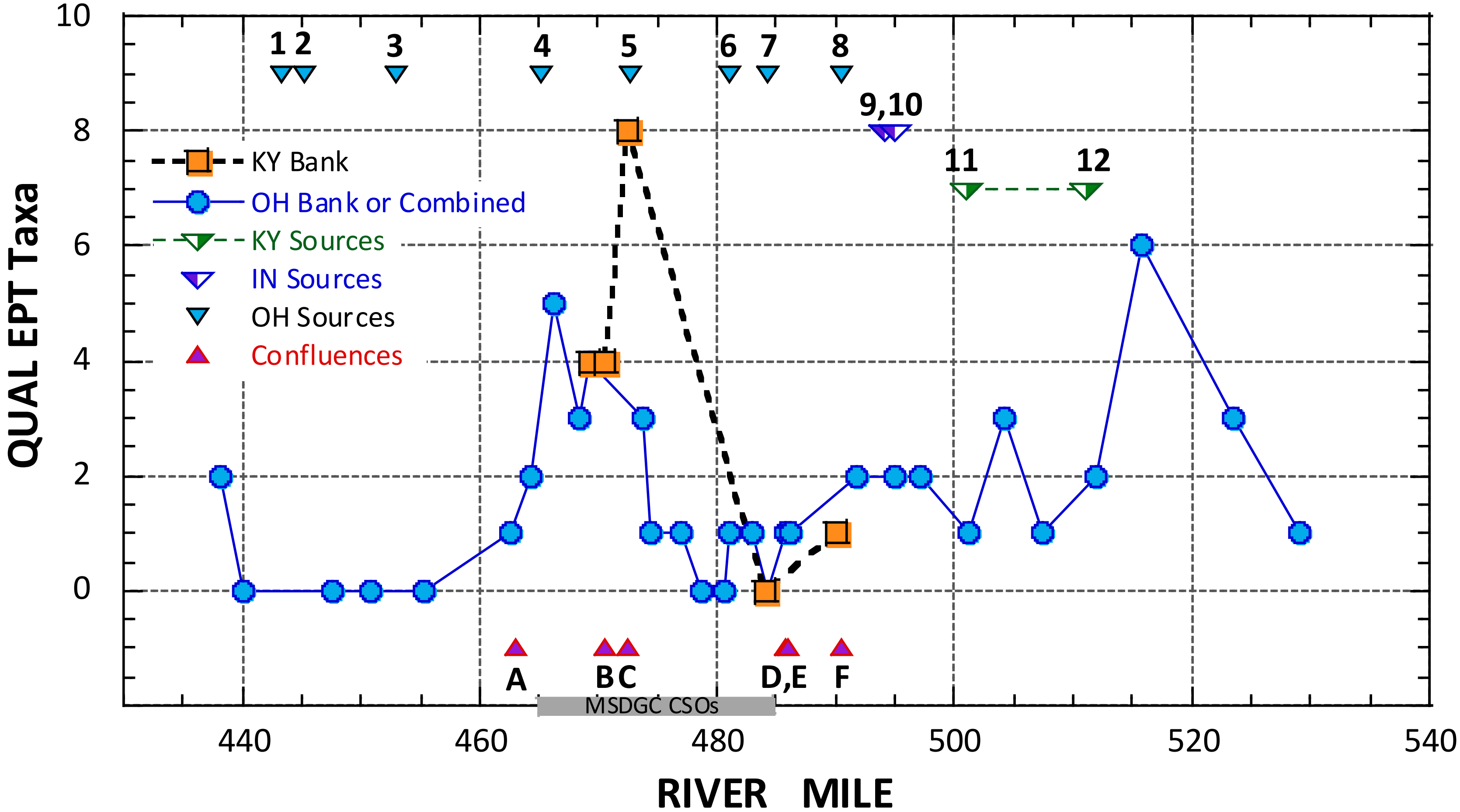

***Figure 37**. Plot of qualitative EPT taxa vs. river mile in the Ohio River during 2014. The numbers and letters are discharges and dams depicted in Table 16.*

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Appendix A

2014 Ohio River, Direct Ohio River Tributaries, and Taylor Creek Fish Assemblage Data:
Index of Biotic Integrity
Modified Index of Well-Being
Species by Sampling Site

[Submitted as Excel files]

Appendix B

2014 Ohio River, Direct Ohio River Tributaries, and Taylor Creek Macroinvertebrate Assemblage Data: Invertebrate Community Index Macroinvertebrate Taxa by Sampling Site

[Submitted as Excel files]

Appendix C

2014 Ohio River, Direct Ohio River Tributaries, and Taylor Creek Primary Headwaters Data

[Submitted as Excel files]

Appendix D

2014 Ohio River, Direct Ohio River Tributaries, and Taylor Creek QHEI by Sampling Site

[Submitted as Excel files]

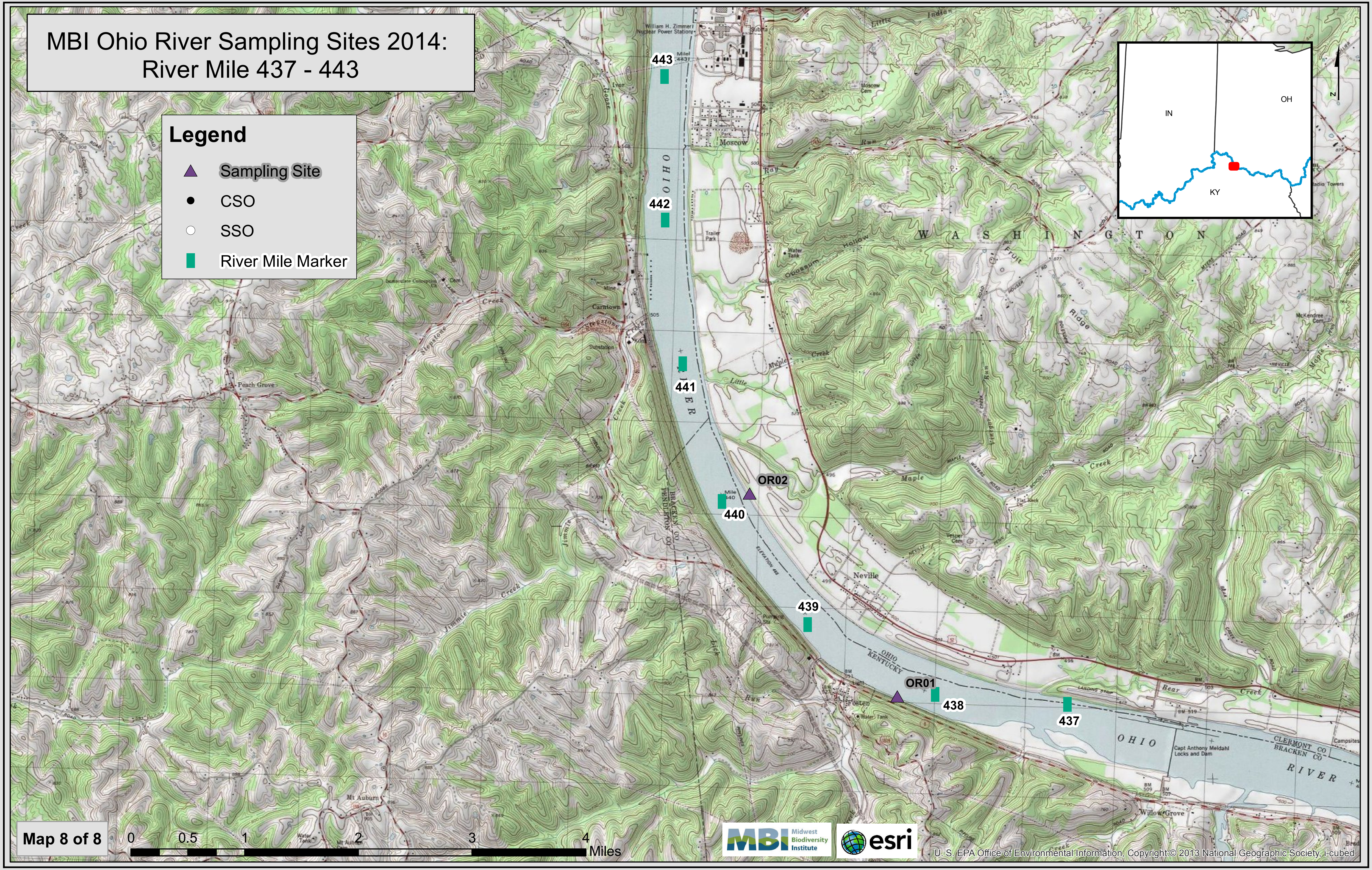
Appendix E

2014 Ohio River, Direct Ohio River Tributaries, and Taylor Creek Water Quality Data:
Grab Sampling Data
Sediment Chemistry Data

[Submitted as Excel files]

Appendix F

2014 Ohio River Sampling Sites by Segment


MBI Ohio River Sampling Sites 2014:
River Mile 437 - 443
Legend
Sampling Site
CSO
SSO
River Mile Marker
443
442
441
440
OR02
439
OR01
438
437
IN
OH
KY
Map 8 of 8
0
0.5
1
2
3
4
Miles
MBI Midwest Biodiversity Institute
esri
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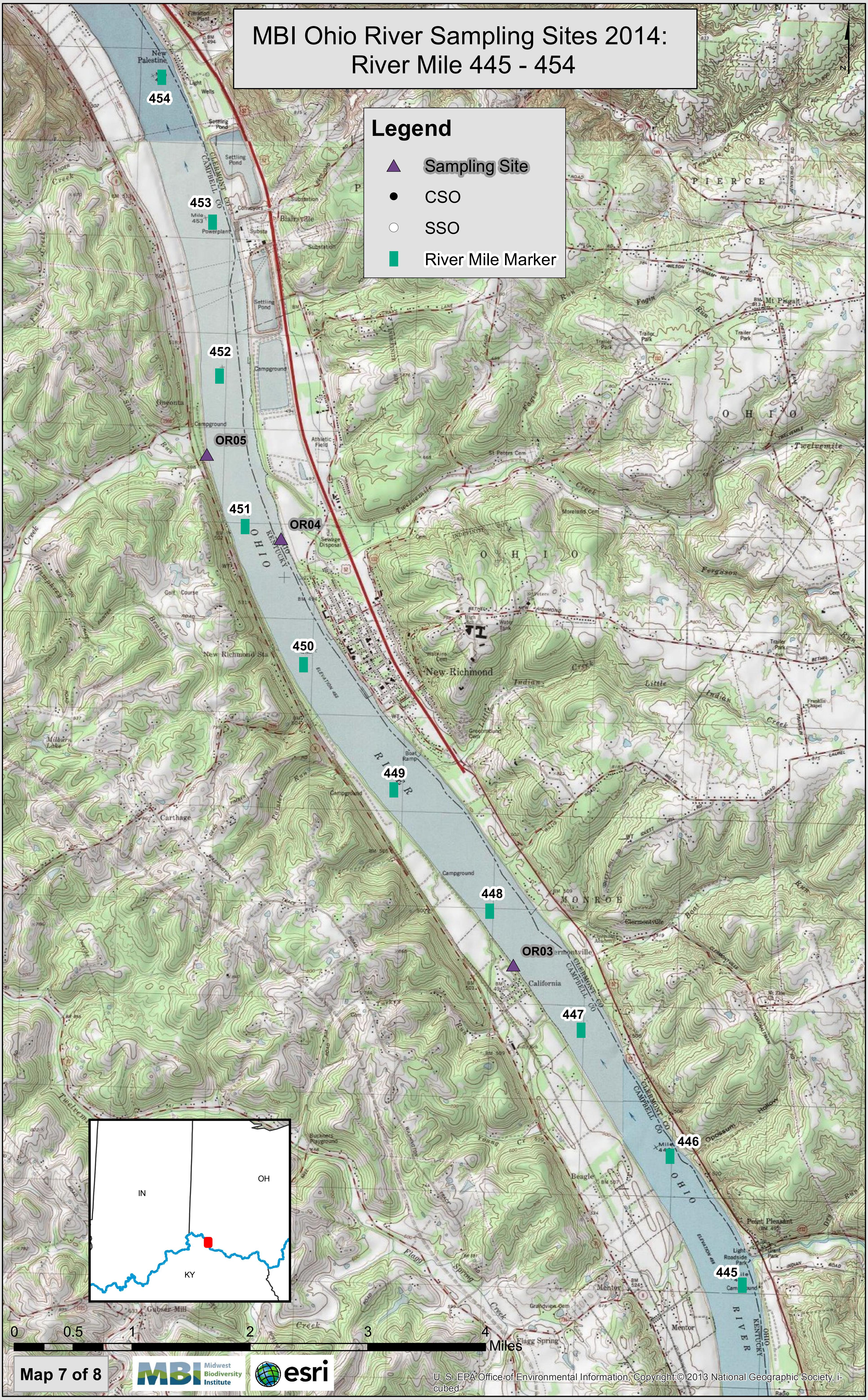
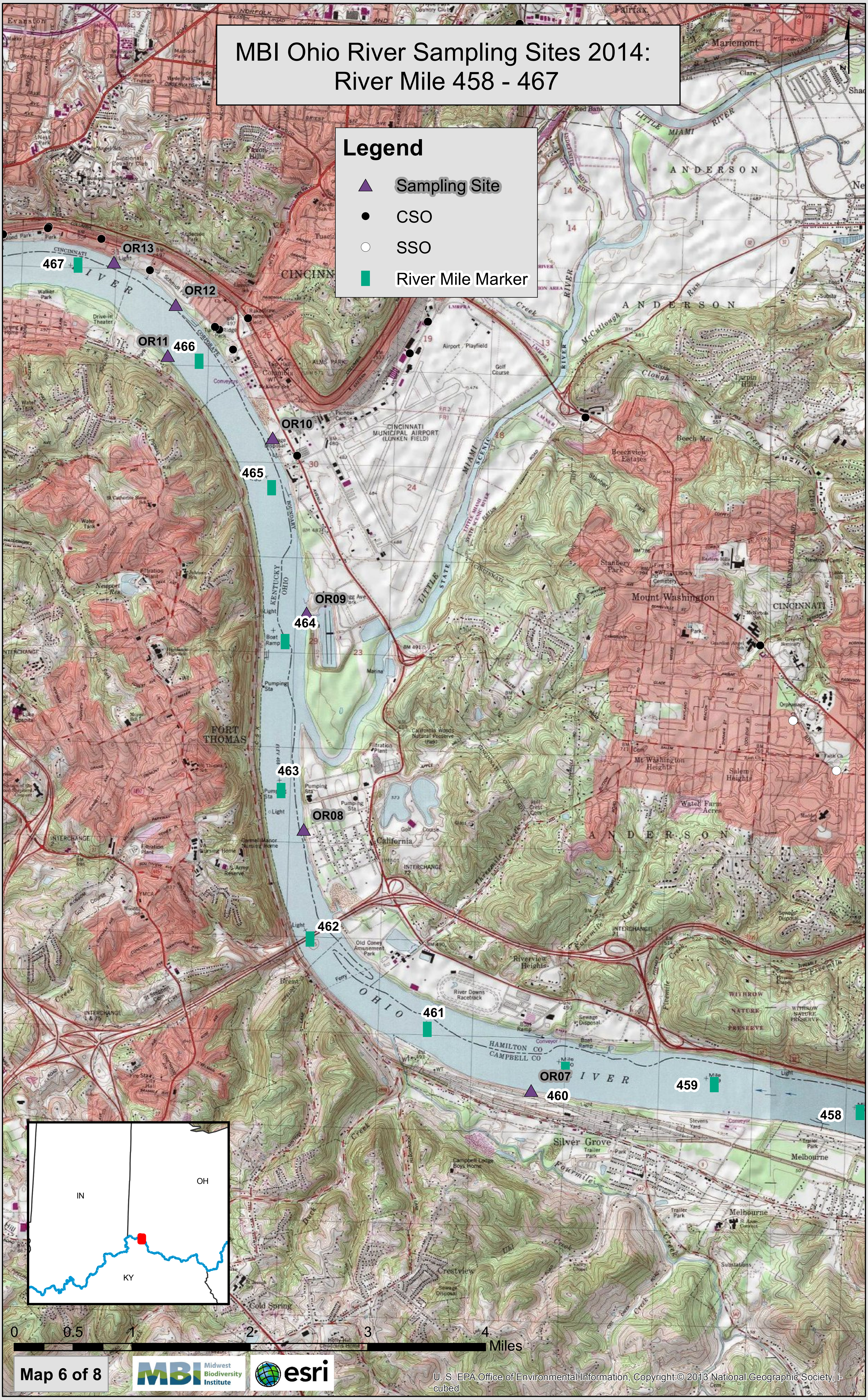
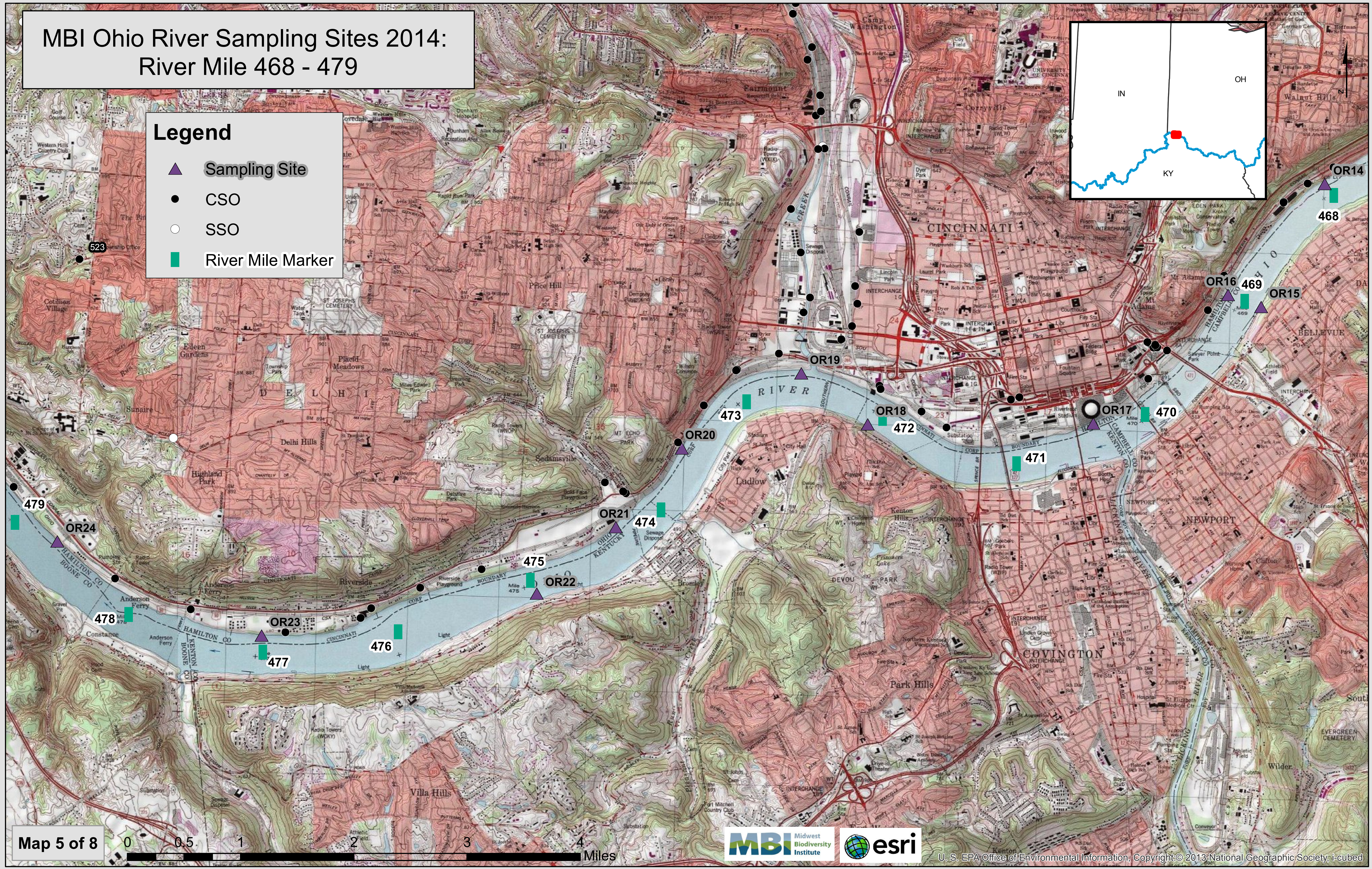
MBI Ohio River Sampling Sites 2014:
River Mile 445 - 454

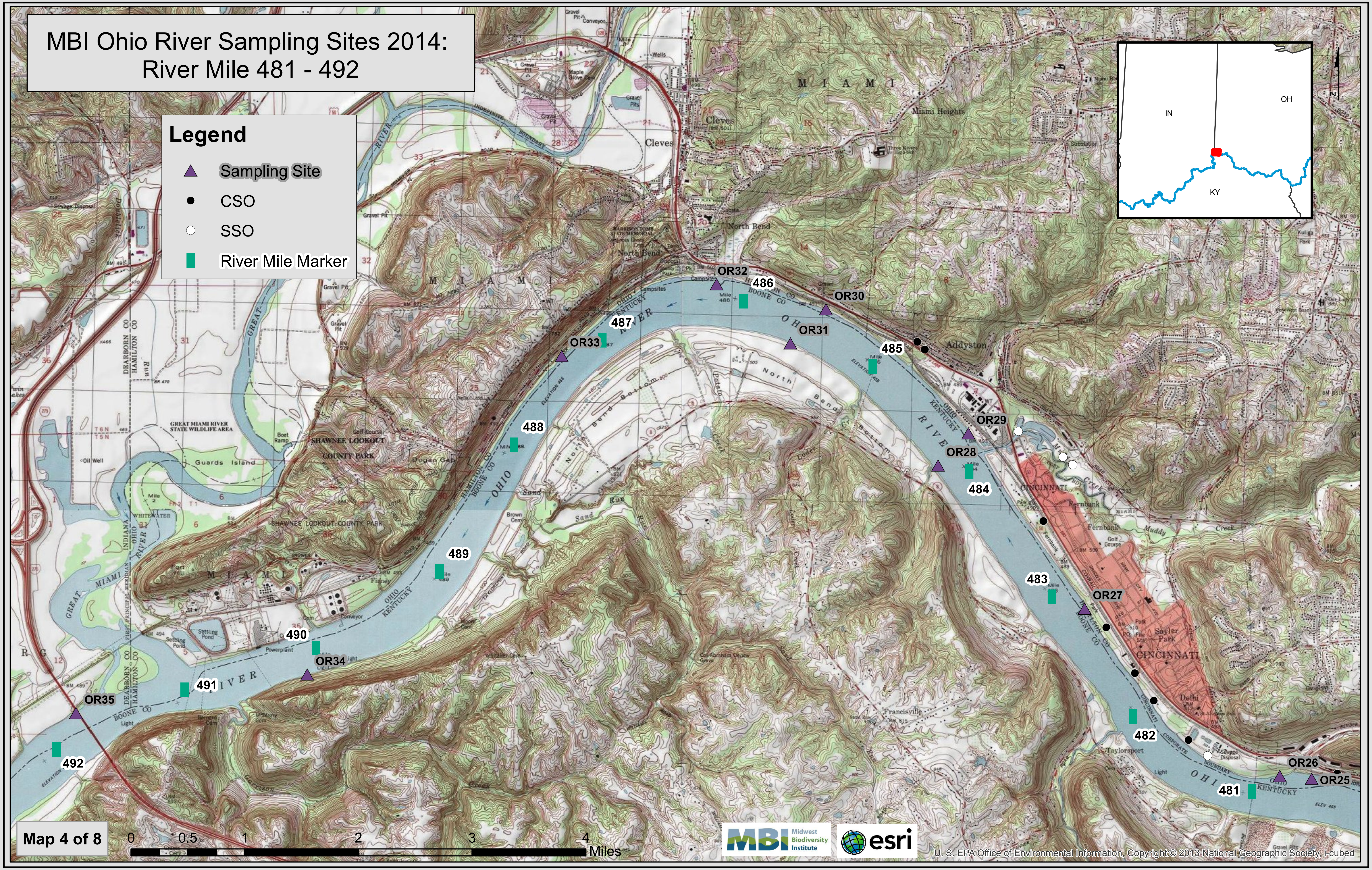


MBI Ohio River Sampling Sites 2014: River Mile 458 - 467



MBI Ohio River Sampling Sites 2014: River Mile 468 - 479




MBI Ohio River Sampling Sites 2014:
River Mile 481 - 492
Legend
Sampling Site
CSO
SSO
River Mile Marker
IN
OH
KY
OR25
OR26
OR27
OR28
OR29
OR30
OR31
OR32
OR33
OR34
OR35
481
482
483
484
485
486
487
488
489
490
491
492
Cleves
North Bend
Addyston
Miami Heights
CINCINNATI
Sayler Park
Delhi
Francisville
Taylorsport
GREAT MIAMI RIVER STATE WILDLIFE AREA
SHAWNEE LOOKOUT COUNTY PARK
Guards Island
Map 4 of 8
0 0.5 1 2 3 4
Miles
MBI Midwest Biodiversity Institute
esri
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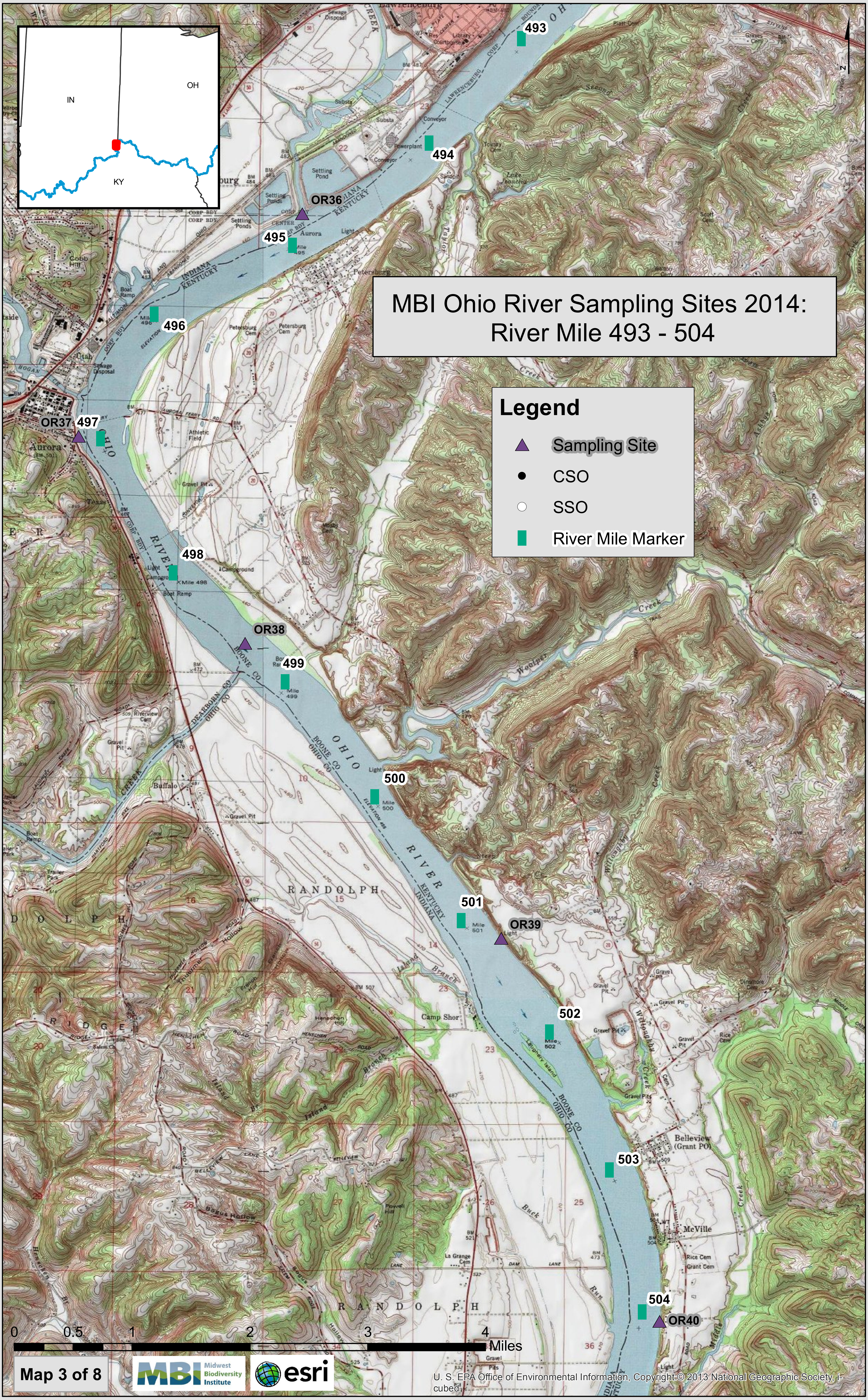
MBI Ohio River Sampling Sites 2014:
River Mile 493 - 504
Legend
Sampling Site
CSO
SSO
River Mile Marker
IN
OH
KY
493
494
495
496
497
498
499
500
501
502
503
504
OR36
OR37
OR38
OR39
OR40
0
0.5
1
2
3
4
Miles
Map 3 of 8
MBI Midwest Biodiversity Institute
esri
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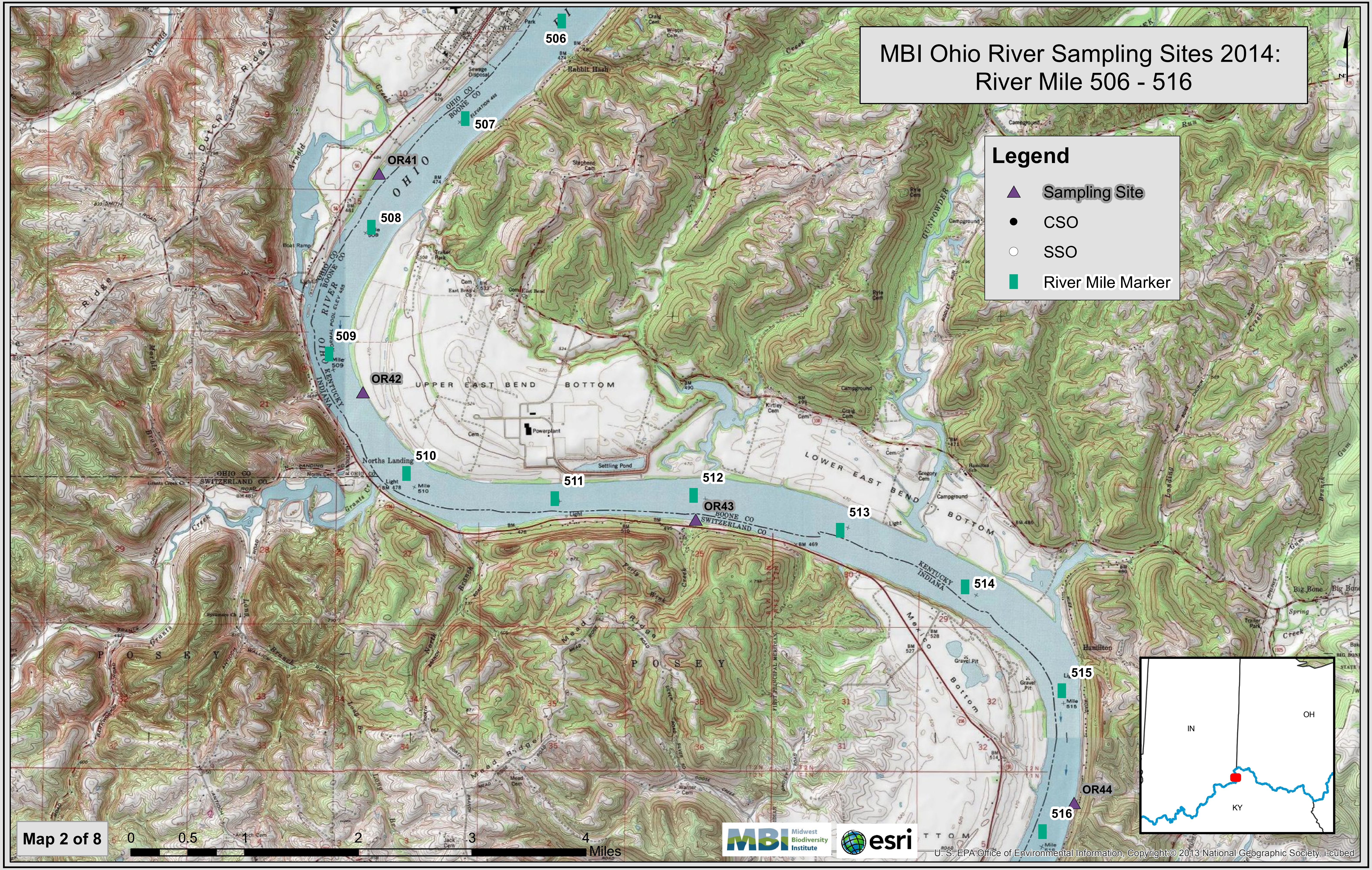
MBI Ohio River Sampling Sites 2014:
River Mile 506 - 516
Legend
Sampling Site
CSO
SSO
River Mile Marker
506
507
508
509
510
511
512
513
514
515
516
OR41
OR42
OR43
OR44
UPPER EAST BEND BOTTOM
LOWER EAST BEND BOTTOM
Powerplant
Settling Pond
Norths Landing
OHIO RIVER
KENTUCKY
INDIANA
BOONE CO
SWITZERLAND CO
POSEY
Hamilton
IN
OH
KY
Map 2 of 8
0
0.5
1
2
3
4
Miles
MBI Midwest Biodiversity Institute
esri
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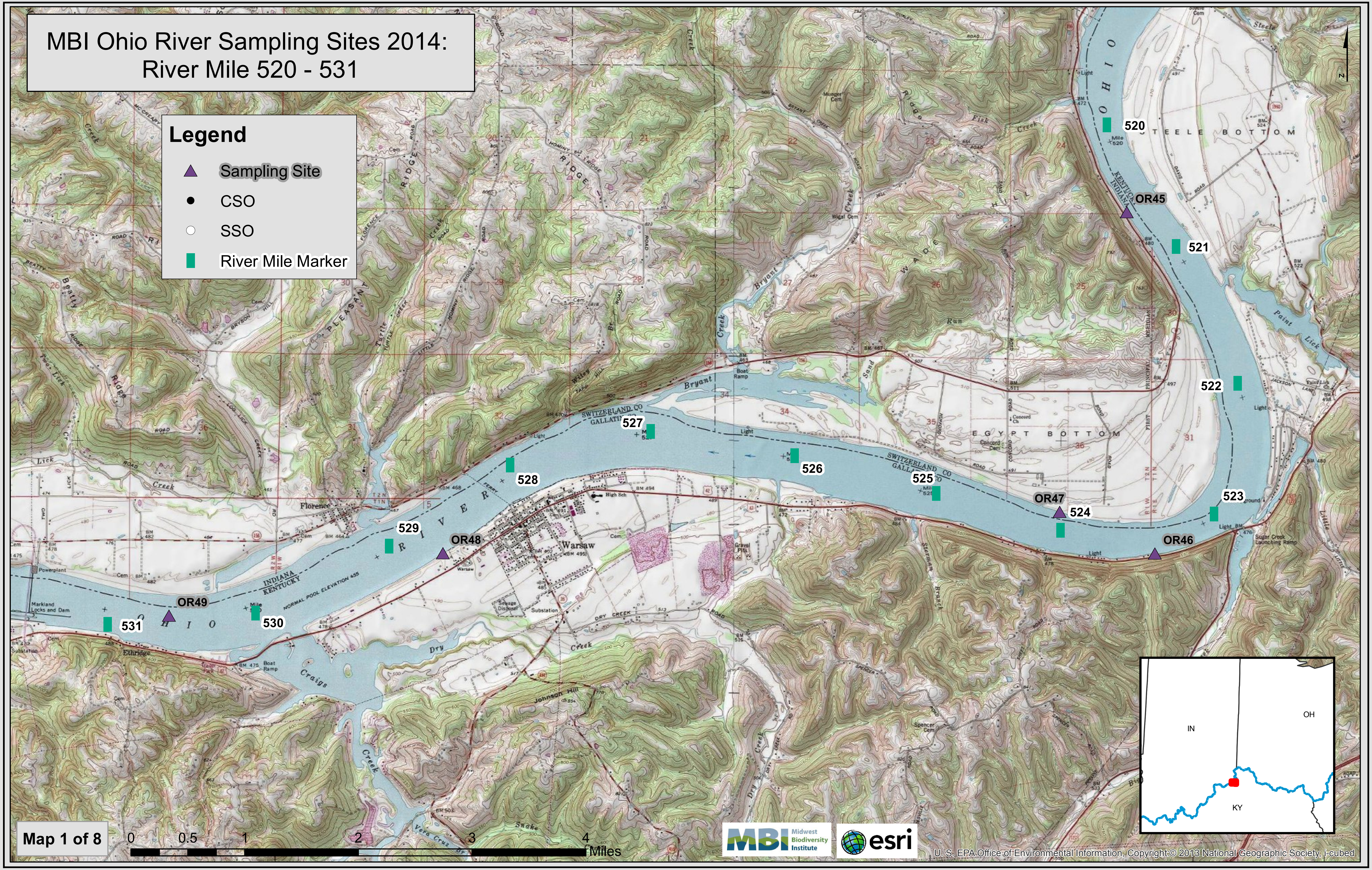
MBI Ohio River Sampling Sites 2014:
River Mile 520 - 531
Legend
Sampling Site
CSO
SSO
River Mile Marker
OR45
OR46
OR47
OR48
OR49
520
521
522
523
524
525
526
527
528
529
530
531
STEELE BOTTOM
EGYPT BOTTOM
OHIO
RIVER
INDIANA
KENTUCKY
SWITZERLAND CO
GALLATIN
Florence
Warsaw
Markland Locks and Dam
Ethridge
NORMAL POOL ELEVATION 455
IN
OH
KY
Map 1 of 8
0
0.5
1
2
3
4
Miles
MBI Midwest Biodiversity Institute
esri
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